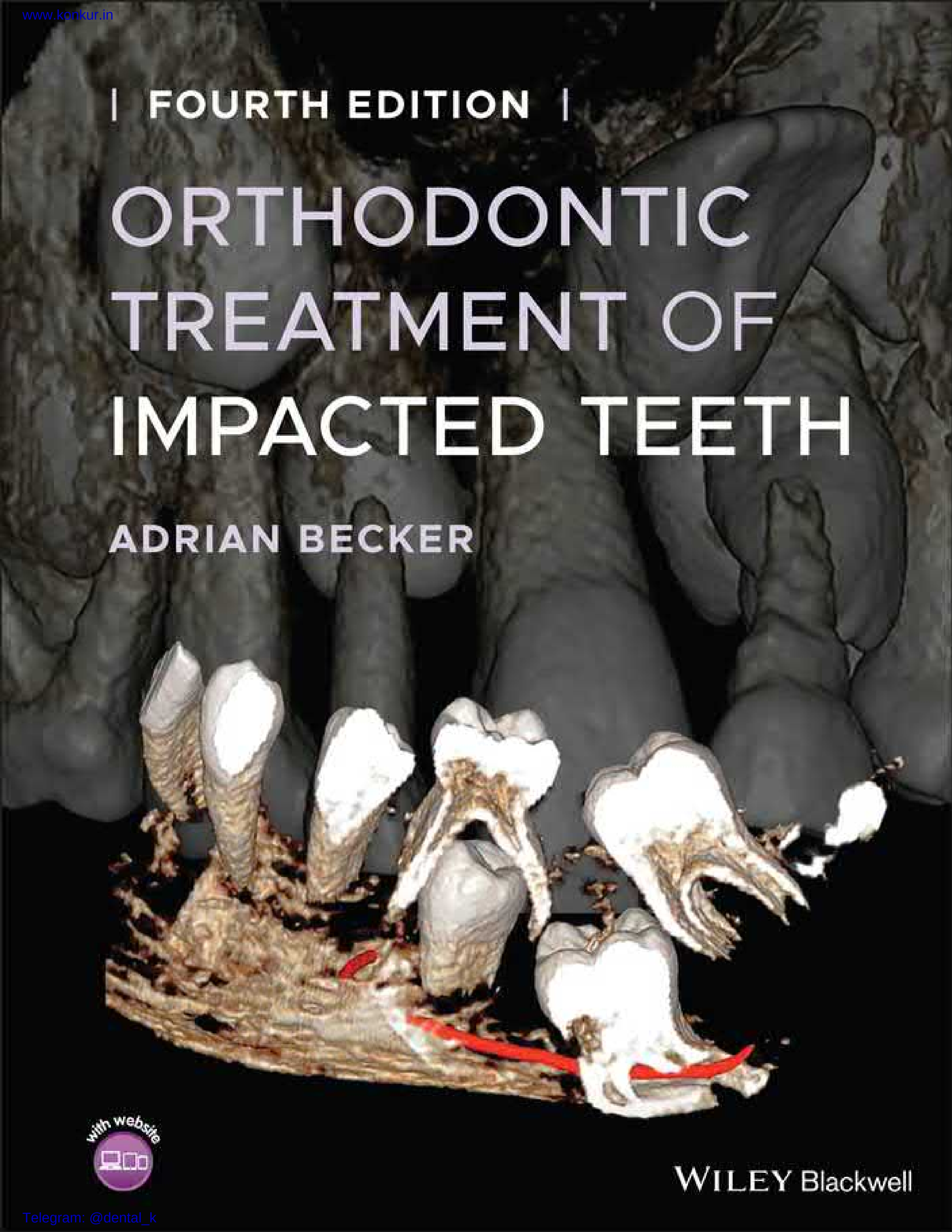

FOURTH EDITION

ORTHODONTIC TREATMENT OF IMPACTED TEETH

ADRIAN BECKER

with website

WILEY Blackwell

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To my wife Sheila, to our children, to our grand and great grandchildren and to the memories of our parents and my sister.

Orthodontic Treatment of Impacted Teeth

Fourth Edition

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WILEY Blackwell

This edition first published 2022

Edition History
Martin Dunitz (1e, 1998), Informa UK Ltd (2e, 2007) and John Wiley & Sons Ltd (3e, 2012)

Registered Offices
John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA
John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial Office
9600 Garsington Road, Oxford, OX4 2DQ, UK

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Wiley also publishes its books in a variety of electronic formats and by print-on-demand. Some content that appears in standard print versions of this book may not be available in other formats.

Library of Congress Cataloging-in-Publication Data

Names: Becker, Adrian, author.
Title: Orthodontic treatment of impacted teeth / Adrian Becker.
Description: Fourth edition. | Hoboken, NJ : Wiley-Blackwell, 2022.
Identifiers: LCCN 2021043991 (print) | LCCN 2021043992 (ebook) | ISBN 9781119565376 (cloth) | ISBN 9781119565390 (adobe pdf) | ISBN 9781119565383 (epub)
Subjects: MESH: Tooth, Impacted | Orthodontics, Corrective–methods
Classification: LCC RK527 (print) | LCC RK527 (ebook) | NLM WU 101.5 | DDC 617.6/43–dc23
LC record available at https://lccn.loc.gov/2021043991
LC ebook record available at https://lccn.loc.gov/2021043992

Cover Design: Wiley
Cover Images: Courtesy of Adrian Becker

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Preface to the First Edition

There can be little question that the treatment of impacted teeth has caught the imagination of many in the dental profession. The challenge has, over the years, been taken up by the general practitioner and by a number of dental specialists, including the paedodontist, the periodontist, the orthodontist and, most of all, the oral and maxillofacial surgeon. Each of these professionals has much 'input' to offer in the resolution of the immediate problem and each is able to show some fine results. However, no single individual on this specialist list can completely and successfully treat more than a few of these cases without the assistance of one or more of others of his/her colleagues on that list. Thus, the type of treatment prescribed may depend upon which of these dental specialists sees the patient first and the level of his/her experience with the problem in his/her field. Such treatment may involve surgical exposure and packing, orthodontic space opening, perhaps autotransplantation, or a surgical dento-alveolar set-down procedure, or even just an abnormally angulated prosthetic crown reconstruction.

Experience has come to show that the orthodontic/surgical modality has the potential to achieve the most satisfactory results in the long term. Despite this, many orthodontists have ignored or abrogated their responsibility towards the subject of impacted teeth to others, accounting for the popularity of other modalities of treatment. The subject has become something of a Cinderella of dentistry.

Within the orthodontic/surgical modality, much room exists for debate as to what should be done first and to what lengths each of the two specialties represented should go in the zealous pursuit of its allotted portion of the procedure. The literature offers scant information and guidance to resolve these issues, leaving the practitioner to fend for him/herself, with a problem that has ramifications in several different specialist realms.

This book discusses the many aspects of impacted teeth, including their prevalence, aetiology, diagnosis, treatment timing, treatment and prognosis. Since these aspects differ between incisors and canines, and between these and the other teeth, a separate chapter is devoted to each. The material presented is based on the findings of clinical research that has been carried out in Jerusalem by a small group of clinicians over the past 15 years or so, at the Hebrew University – Hadassah School of Dental Medicine, founded by the Alpha Omega Fraternity and from the gleanings of clinical experience in the treatment of many hundreds of my patients, young and old.

An overall and recommended approach to the treatment of impacted teeth is presented and emphasis is placed on the periodontal prognosis of the results. Among the many other aspects of this book, the intention has been to propose ideas and principles that may be used to resolve even the most difficult impaction, employing orthodontic auxiliaries of many different types and designs. None of these is specific to any particular orthodontic appliance system or treatment 'philosophy', notwithstanding the author's own personal preferences, which will become obvious from many of the illustrations. These auxiliaries may be used with equal facility in virtually any appliance system with which the reader may be fluent. The only limitation in the use of these ideas and principles are those imposed on the reader by his/her own imagination and willingness to adapt.

The orthodontic manufacturers' catalogues are replete with the more commonly and routinely used attachments, archwires and auxiliaries, which are offered to the profession with the aim of streamlining the busy practice. These items have not been tailored to the demands of the clinical issues that are raised in this book. These issues, by their very nature, are exceptional, problematic and often unique, while occurring alongside and in addition to the routine. Among the more common limitations self-imposed by many orthodontists has been the disturbing trend to rely so completely upon the use of preformed and pre-welded attachments that they have forgotten the arts of welding and soldering and no longer carry the necessary modest equipment. This then restricts one's practice to using only what is available and sufficiently commonly used to make it commercially worthwhile for the manufacturer to produce. By consenting to this unhealthy situation, the orthodontist is agreeing to work with 'one hand tied behind his/her back' and treatment results with inevitably suffer.

I acknowledge and am grateful for the help given me by several colleagues in the preparation of this book. An excellent professional relationship has been established, and has withstood the test of time, with two senior members of the Department of Oral and Maxillofacial Surgery at Hadassah, with whom a *modus operandi* has been developed, in the treatment of our patients. Professor Arye Shteyer, Head of the Department, and, subsequently, Professor Joshua Lustmann have educated me in the finer points of surgical procedure and care while, at the same time, have demonstrated a respect and understanding of the needs of the orthodontist at the time of surgery. I am grateful to them for their collaboration in the writing of Chapter 3.

Dr Ilana Brin read the original manuscript and made some useful suggestions, which have been included in the text. I am grateful to Dr Alexander Vardimon for his comments regarding the use of magnets and to Dr Tom Weinberger for the discussions that we have had regarding several issues realised in the book. My wife, Sheila, read the earlier drafts and made many important recommendations and corrections. More than anyone else, she encouraged me to keep writing during the many months when other and more pressing responsibilities could have been used as justifiable excuses for putting the project aside.

My colleagues Dr Monica Barzel, Dr Yocheved ben Bassat, Dr Gabi Engel, Dr Doron Harary, Dr Tom Weinberger and Professor Yerucham Zilberman, and my former graduate students Dr Yossi Abed, Dr Dror Eisenbud, Dr Sylvia Geron, Dr Immanuel Gillis, Dr Raffi Romano and Dr Nir Shpack, have provided me with several of the illustrations included here and I am indebted to them.

I am grateful, too, to Ms Alison Campbell, Commissioning Editor at Martin Dunitz Publishers and to Dr Joanna Battagel, Technical Editor, for their constructive and professional critique of the manuscript, which contributed so much to its ultimate format. I also thank Naomi and Dudley Rogg, of the British Hernia Centre, for the computer and office facilities that they placed at my disposal during my short sabbatical in London in the latter stages of the preparation of the work for publication.

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I am very thankful for their cooperation and for their agreement.

Adrian Becker
Jerusalem

Preface to the Second Edition

In the nine years that have elapsed since the publication of the first edition of this book, much has changed in the field of orthodontics in general and, perhaps even more so, as it relates to the treatment of impacted teeth. The advances in imaging, particularly cone beam computerized tomography, have made accurate positional diagnosis of an impacted tooth virtually foolproof, enabling the application of appropriately directed traction to resolve even the most difficult cases. Temporary orthodontic implants have provided the opportunity to resolve the impaction, in many cases without the need for an orthodontic appliance and before orthopaedic treatment *per se* is begun. They have opened up a whole new area to exploit for mechanotherapeutic solutions to many of the problems we face.

The first edition was based on the findings of clinical research that was carried out over a long period of time in Jerusalem during the 1980s and 1990s. In much the same way, this second edition documents the findings of ongoing and evidence-based studies carried out by largely the same small group of clinical investigators, since then. Most of these published articles were the product of an excellent working collaboration with Dr Stella Chaushu, a former student of mine and now Senior Lecturer in the Department of Orthodontics. Her industrious and intellectual qualities have contributed to the output of a large number of valuable published studies in just a few short years.

Under the leadership of Professor Refael Zeltser, chairperson of the Department of Oral and Maxillo-facial Surgery at the Hebrew University – Hadassah School of Dental Medicine in Jerusalem, a whole generation of young surgeons has grown up who exhibit the ability to appreciate and value the finer points of cooperation with the orthodontist. Dr Eran Regev and Dr Nardi Casap in Jerusalem, Dr Gavriel Chaushu, the chairperson at the parallel department of the Sourasky Hospital in Tel Aviv, and Dr Harvey Samen in private practice, have worked closely with me in the treatment of our patients. Many of these cases are illustrated in the pages of this book. I derive considerable satisfaction from seeing the surgical expertise learned from and handed down by Professors Arye Shteyer and Joshua Lustmann being practised by these highly professional colleagues, on a day-by-day basis. Their awareness and perception of the significance of their work in determining the long-term outcome have helped me to aim for the highest quality results and the well-being of the patient. They deserve my gratitude.

In the preparation of this book, I have called upon and am grateful for the expertise of a small number of people, who have provided me with authoritative and essential information that has permitted me to make the text more comprehensive and more complete. In particular, I mention Dr James Mah and Dr David Hatcher in California, with regard to cone beam CT imaging and Dr Joe Noar in London, with regard to the use of magnets.

I have given and continue to give courses and lectures on the subject of impacted teeth in many places all over the world which, in the past few years, have been presented in collaboration with Dr Stella Chaushu. It is at these meetings that I come across some of the most interesting and rare material. I am indebted to several individual members of these audiences who frequently approach us during a coffee break, radiograph in hand, with some truly remarkable conditions, several of which have been included in this book, together with appropriate recognition.

My colleagues in the Orthodontic Department in Jerusalem have often become the sounding board for many of the ideas that are presented herein and I am thankful to them for the discussions that we have had. I appreciate their taking the stand of devil’s advocate in these situations, forcing me to justify or to discard. Nevertheless, none of this would ever have been published had I not spent so many years teaching the students on our postgraduate orthodontics specialty course. These future orthodontic standard bearers are privileged to learn from the various individual teaching preferences of mentors who rely on years of experience in practice, particularly when it comes to this bracket or that, this treatment philosophy or that and this orthodontic guru or that. Additionally, they have learned to look for and even demand clinical ideas and treatment policies that have a proven evidence-based, track record to commend them and to justify their use. I know of no other postgraduate orthodontic course, worldwide, in which the subject of impacted teeth is explicitly taught in a comprehensive and integrative manner, including a designated weekly clinical session. It was this more than any other factor which encouraged me to embark on this mammoth task.

The future of our profession and the long-term superior care of the even younger generation of our patients is in the hands of these aspiring orthodontists. I am grateful to them for having, perhaps unwittingly, cajoled me into writing this text. I hope that it will be a source of information for them as they undertake the challenge of some of the more difficult, unconventional and unusual cases that they will inevitably come across in practice and for which they will be expected to find appropriate therapeutic answers.

I wish to thank the following publishers of two articles, as follows:Several of the illustrations comprising Figure 7.8 were reprinted from the *World Journal of Orthodontics. Vol. 5. The Role of Digital Volume Tomography in the Imaging of Impacted Teeth,* by Adrian Becker and Stella Chaushu. 2004. with permission from Quintessence Publishing Co, Inc.

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Adrian Becker
Jerusalem, Israel

Preface to the Third Edition

Only 14 years have passed since the publication of the first edition of this book and much has changed in orthodontics, in general and in the context of the treatment of impacted teeth, in particular. The subject material that appeared in that small monograph has developed several fold, in the light of research and the advent of new technology. These two factors have encouraged the orthodontic specialist to be more discerning in the diagnosis of pathology and more innovative and resourceful in the application of directional traction. Mistaken positional diagnosis and surgical blunders have become less common and consequent failure to resolve the impaction less frequent. At the same time, they have permitted the orthodontist to become more adventurous and to successfully apply his/her knowledge and experience to the treatment of cases where previously the tooth would have been scheduled for extraction. If this third edition may yet contribute to the furtherance of this favorable trend in any way, I will consider that my mission will have been accomplished.

It was the aim in each of the earlier editions of this book to present reasoned principles of treatment for tooth impaction, illustrated by examples from real life. Following these principles to their logical conclusion, Chapter 15 has been added in the present edition to illustrate how some extreme examples or cases with concurrent complicating factors may be resolved, several of which involve the expertise of colleagues in our sister specialties. Oddities, such as the "banana" third molar, with its impacting influence on its immediate neighbor, are also new to this edition.

Failure has intrigued me for a long time and, while Chapter 12 was new to the second edition, it has been enlarged now in the third. The recognition and importance of invasive cervical root resorption (ICRR) as a cause of failure to resolve an affected impacted tooth seems to be hardly known within the profession. There is a section added herein which discusses the etiology of this pathological entity, its disease process, its potency as a factor for failure and speculates on accepted standard procedures that may predispose to its occurrence.

To write a textbook or to update an edition may take several years. Once it is finished, it has to go through the many months of the publishing process, with questions and corrections, proofreading and amendments. In the meantime, what was written becomes progressively obsolete – new ideas are put forward in the journals, some are disciplined studies and others just innovative clinical methods learned in the very singular one-on-one situation in the orthodontic operatory between orthodontist and patient. In order to provide at least a partial answer to this, I have set up an internet website at www.dr-adrianbecker. com, in which regular updates on clinical research and technique, vignettes describing individual conditions or just a customized approach to the treatment of a specific case, are published with the aim of complementing the book. The site also features a "troubleshooting impacted teeth" page for individual clinical consultations – open to anyone, whether orthodontist, patient or concerned parent. Details of the patient and his/her condition will need to be filled in and existing radiographs, CBCT and other relevant information uploaded. A report is returned to the sender within a few days with suggestions and recommendations for treatment.

The clinical research on which this text is largely based has been the product of long-term cooperation with Professor Stella Chaushu, PhD, DMD, MSc, Chairperson of the Orthodontic Department in Jerusalem, to whom are due my special thanks. I am grateful to my co-authors who have advised me in my writing of several of the chapters herein and to a number of my colleagues who have sent me illustrative material which I have included, with their permission. I would also like to recognize Mr. Israel Vider, director of the Dent-Or Imaging Center in Jerusalem, for his CT imaging expertise, his assistance in granting me access to his technical laboratory and for his work on several of the illustrations that are published in this edition.

Adrian Becker
Jerusalem, October 2011

Preface to the Fourth Edition

As the fourth edition of this book goes to print, I am happy to present a much-enhanced text, both in terms of the verbal discussion and the illustrated figures, which is offered in a similar pattern to its predecessors. The third edition of *Orthodontic Treatment of Impacted Teeth*, published in 2012, had 15 chapters. This new edition comprises 21 chapters, of which several are completely new and, together with the significant additions and improvements, the overall content is now approximately 60% larger.

Video clips and other 3D illustrations cannot be published in book form, thus preventing the printed literature from matching the advances in the recording of radiographic imaging that is now commonplace in dental schools, in radiographic imaging centres and in private dental offices. This is particularly so in relation to orthodontics, in general and to accurate positional and pathological diagnosis, that are so essential in the resolution of tooth impaction, in particular. In order to overcome these serious illustrative limitations, I have included a Companion website adjacent to the text, to enhance the orthodontist's ability to use the existing presentation modes (secondary reconstructions), to extract the maximum information that is available in a cone beam CT scan. A number of 3D video clips are presented, to illustrate how to refine the diagnostic know-how, which can only be to the benefit of the patient. These are embedded in PowerPoint presentations, with concise accompanying comment to highlight the salient points at issue. This should assist those who still have 3D comprehension difficulty in accurately locating the impacted tooth.

There are many new areas in the present text that feature aspects that have not been fully described in the literature to date. There are also a number of supposed truths that are shown to be spurious and contrary to our understanding of the biological process.

Just to mention a few of the many examples that the reader will find in this edition:

- Did you know that hooked roots are not a reason that teeth do not erupt (see Chapter 13)?
- Unerupted incisor teeth that have been severely damaged by trauma inflicted in infancy remain high in the maxilla adjacent to the nasal floor, neither growing their roots nor showing any signs of ever erupting into the mouth. Can these teeth be mechanically erupted? Will they develop roots of a sufficient length that will contribute to the tooth surviving into adulthood? Will the eruption of these teeth generate new bone that could naturally rehabilitate the formerly deficient alveolar ridge (see Chapter 6)?
- Instead of developing a long straight root, the severely traumatized central incisor in a 2-year-old child may develop a root that continues to grow at an acute angle to the calcified portion of the tooth, to form a tightly curved or angled dilaceration. The root continues to grow in the wrong direction, necessitating root canal treatment and root amputation to enable the orthodontist to re-align the majority portion of the tooth. Perhaps there is a way to correct the direction of the further root growth and thereby achieve a normally apexified vital tooth with a perfect crown, indistinguishable from and aligned with its beautiful adjacent counterpart (see Chapter 6).
- There appears to be a cut-off age of 9 years for the maxillary lateral incisor to develop at least half its normal root length. If there is less than a half root at this age, as seen in a small or peg-shaped tooth, the chances that the unerupted canine will become the victim of eruption disturbance become notably exaggerated (see Chapter 6).

- Conventional wisdom has it that mandibular second and third molars are sometimes impacted because their roots are being 'held down' by entanglement with the inferior alveolar canal (mandibular branch of the trigeminal nerve). We maintain that this view is unfounded (see Chapter 13). It is more likely that another factor, such as invasive cervical root resorption (ICRR), enlarged dental follicle, crowding of adjacent teeth and even possibly pre-eruption intra-coronal resorption, represents the primary aetiology that prevents eruption (the 'cause'). With the root apices then growing in cramped circumstances, in close proximity to pathological entities or anatomical limits, the further erratic development of the root ends inevitably results in entanglement with the nerve and vascular bundle (the 'effect').
- You have just finished the phase 1 treatment of a child, for the treatment of a cross-bite or an impacted incisor or for maxillary anterior crowding, and he is now 8 years old. As the final flourish, you have aligned the incisors and paralleled their roots into their final adult orientation. The four incisors look beautiful and the parents are happy. In order to hold on to this delightful result, a fixed or removable retainer will need to be placed, until the child is ready for phase 2 treatment in 3–4 years' time. The question that needs to be asked is: Will the 'attention to detail' at this early stage and the apparently laudable 'intention to fully exploit the capabilities of an existing orthodontic appliance' be to the patient's overall benefit, or will they raise the spectre of iatrogenic damage in the long term, by potentially disturbing the eruption of the canine (see Chapters 6, 7 and 18)?

A word about the tooth-numbering convention used in this book. For the most part, the narrative in this volume refers to the individual teeth by their full descriptive title. Thus, we may refer to an impacted maxillary left permanent canine tooth or an infra-occluded deciduous mandibular second molar tooth – a six-word definition for a very small entity. However, for the sake of brevity and particularly for the annotation of teeth in an illustration, an author will prefer to use a shortened code for each tooth. The numbering system we have used here is the Fédération Dentaire Internationale (FDI) numbering system. This system has been widely accepted in many parts of the world, being easy to understand, logical and adaptable to the various tooth groups. It is compatible with computerized representation and uses the same description of the teeth on either side and in either jaw in a symmetrical and rapidly recognizable manner.

The method assigns a two-number code to each tooth. The first number defines the quadrant in which the tooth is found. Thus, the right maxillary quadrant, from midline to last molar, is given the number 1. The left maxillary quadrant is number 2; the left mandibular quadrant number 3; and the right mandibular quadrant number 4. The individual teeth are then numbered from 1 to 8, beginning from the midline and proceeding to the last molar. In this manner, all impacted canines will be recognized by the second number 3: a right maxillary canine would be denoted 13; a left mandibular second molar would be assigned 37; and a mandibular right lateral incisor 42. All four canines are rarely impacted in the same individual, but when this occurs, it will be appreciated that 13, 23, 33 and 43 will be more easily recognizable than the 6, 11, 22 and 27 of the so-called 'universal' numbering system, which seems to have achieved acceptance largely in the USA. (We have occasionally used the hash sign # in front of the number, in order to clearly differentiate the tooth number from other numbers in the text.)

Similarly, numbering the deciduous teeth employs the quadrant system in the same order, labelled from 5 to 8 and the teeth numbered 1 to 5. Thus, the maxillary deciduous right central incisor is defined as 51 and an infra-occluded mandibular right deciduous second molar is numbered 85.

I am grateful to each of my co-authors for having enthusiastically responded to my invitation to write a specific chapter in this volume and for having submitted their finished manuscripts ahead of the deadline I set for them. The chapter on biomechanics as it relates to impacted teeth was written and illustrated by Dr Ulrich Kritzler, who is in private practice in Warendorf, Germany and a regular contributor to the international orthodontic literature. The rapidly expanding popularity of clear aligners in orthodontics prompted me to invite a discussion of their use, suitability and the limitations of their application to the treatment of cases with impacted teeth. This has been authored by Prof. Dror Aizenbud, Chair of the Unit for Orthodontics and Craniofacial Anomalies in Haifa, Israel.

For the past several years, I have availed myself of the expert services of Mr Amnon Leitner, perhaps the most knowledgeable and skilled master radiographic imaging technician I have ever had the good fortune to meet and to work with. I invited him to enlarge and update the chapter on diagnostic imaging, specifically with regard to cone beam computerized tomography. Several of his highly informative secondary reconstructions, 3D screenshots and video clips appear in that chapter and additional examples of his work may be seen in a number of other chapters.

I am grateful to Dr Athina-Maria Mavridou of KU Leuven (University of Leuven) in Belgium, a trained endodontist and an accomplished research scientist, who provided helpful comment on the histopathological aspect of my description of invasive cervical root resorption. ICRR is a specific pathological entity in its own right and is discussed in Chapter 10. The positive diagnosis of ICRR has serious repercussions in relation to the treatment of impacted teeth, yet it is substantially uncharted territory and rarely recognized by orthodontists.

As in the second and third editions, I acknowledge the contribution to several chapters in the book, of Prof. Stella Chaushu, Chair of the Department of Orthodontics at the Hebrew University–Hadassah School of Dental Medicine, Jerusalem, Israel. For the past 25 years, our academic collaboration has achieved much in terms of basic and clinical research, particularly in the area of eruption disturbance. Tooth impaction has also been the subject of the many invited lectures and courses that we have conducted together internationally and this book largely represents the culmination of those years of endeavour, even from as early as 1964. It reflects many of the fruits of our joint academic collaboration.

Writing a text on the subject of impacted teeth involves filtering out the relevant and appropriate conclusions of published studies from the mass of orthodontic literature in general, and specifically honing in on those evidence-based investigations published in the leading international, peer-reviewed orthodontic journals. The treatment decisions made in individual cases or in small case series of the treatment of rare conditions cannot, by virtue of their small numbers, be founded on evidence that is other than anecdotal. This does not necessarily negate the validity of the decision to treat the next patient with the same condition in a similar manner. However, it must be understood that the decision can be justified on an empirical basis only and is likely to be dependent on careful patient selection; and it does obligate this and any other author to report the possibility of bias. I have tried to comply with this and hope that I have been successful in my diligence in the examples of treatments elaborated in the text.

In my efforts to produce a readable and understandable narrative, I managed to persuade my brother Laurence (Shmuel) Becker to be responsible for the editing and proofreading of this work. He is a lawyer and is the first to admit that he knows absolutely nothing about orthodontics. His theory was that if he could understand what I have written in this volume and could follow the ideas and the logical sequence, then any orthodontist should be able to read, follow and understand the text and the ideas that I have tried to portray easily and painlessly. And so he has corrected, amended, shuffled words around, relocated sections and substituted my words for others that only a lawyer can produce. (He is probably the only other person who will have read the entire book at least five times over.) For all this, I am greatly in his debt.

The wondrous workings of today's desktop computers have provided me with the means to write this text, which would never have been possible using the steam-propelled typewriter. However, my computer has also given me a false sense of security, learned from bitter experience. Many times in the past three years I lost material that I had spent days writing, either because I had failed to save it or because I had 'copy-pasted' these sections into other files, which I promptly and unintentionally deleted. I cannot count the number of times that I called my son-in-law, Asher Cohen (also a lawyer), setting him the task of rediscovering them and putting me back into the business of writing. He found them every time, at break-neck speed. I salute his alacrity and his digital skills!

I closely identify with the legendary Danish pianist and comedian who, at the same advanced age as I am now, was still appearing on stage before large live audiences. At the end of one of his solo performances, Victor Borge acknowledged: 'I wish to thank my parents for having made this possible and I wish to thank my children for having made it necessary.'

Adrian Becker
Jerusalem, Israel
June 2021

About the Companion Website

This book is accompanied by a companion website.

www.wiley.com/go/becker/orthodontic_treatment_impacted_teeth

The website includes a series of Power Point presentations mainly of CBCT interpretation work-ups and particularly in relation to diagnosis of impacted teeth. They contain embedded video clips illustrating methods for refining accurate positional identification or analysis of the teeth in 3D and in improving the qualitative recognition of pathologic entities.

Each online resource is called out in the text by number for ease of location.

View all animations in full screen by clicking the square button under the bar at the bottom right of the animation window.

1
General Principles Related to the Diagnosis and Treatment of Impacted Teeth

Adrian Becker

[Dental age]
[Assessing dental age in the clinical setting – the Jerusalem method]
[When is a tooth considered to be impacted?]
[Impacted teeth and local space loss]
[Whose problem?]
[The timing of the surgical intervention]
[Patient motivation and the orthodontic option]

In order for us to understand what an impacted tooth is and whether and when it should be treated, we must first define our perception of normal development of the dentition as a whole and the time-frame within which it operates.

The development of a child has many components. In assessing the developmental age of a child, it is necessary to consider and correlate these components and there is a hypothetical mean for each, though the overall development rate rarely falls exactly on this mean. A child's growth and development rate may also be different for each of the developmental components.

- *Somatic age*: A child may be tall for his or her age, so that his or her somatic age may be considered to be advanced.
- *Skeletal age*: By studying radiographs of the progress of ossification of the epiphyseal cartilages of the bones in the hands of a young patient (the carpal index) and comparing this with average data values for children of his or her age, we are in a position to assess the child's skeletal age.
- *Sexual maturation age*: The sexual age of a child is related to the appearance of primary and secondary sexual features.
- *Mental age*: This is assessed by intelligence quotient (IQ) tests.
- *Behavioural age*: This is an assessment of a child's behaviour and his or her self-concept.

These are among the indices complementing the *chronological age*, which is calculated directly from the date registered on the child's birth certificate. All these parameters are essential in the comprehensive assessment of a child's developmental progress.

Dental age

Dental age is another of these parameters and is a particularly relevant and important assessment used in advising as to the timing of proper orthodontic treatment. The tables and diagrammatic charts presented by Schour and Massler [1], Moorrees et al. [2, 3], Nolla [4], Demirjian et al. [5], Koyoumdjisky-Kaye et al. [6], Willems et al. [7] and Liversidge et al. [8] demonstrate the stages of development of the teeth, from initiation of the calcification process through to the completion of the root apex and the average chronological ages at which each stage occurs. Normal and healthy tooth buds develop from initial calcification to root apex closure at a given rate for each of the teeth groupings. That is to say that incisors, canines, premolars, first, second and third molars, in the mandible and in the maxilla, differentiated between males and females, all have their individual specific time at which they reach the various developmental stages. These stages are empirically defined in the above classic works. Schour and Massler [1] produced an atlas from *intra utero* to adulthood, consisting of 21 consecutive drawings, which feature annual development schemes up to age 12 as well as 3 more schemes up to age 35 years. Nolla [4], on the other hand, used a radiographic assessment of tooth development at 10 different developmental stages, starting from the presence of the crypt through to root apex closure (apexification).

Estimating the stage of development based on the eruption time of teeth is an unreliable method of assessing dental age. Although eruption of each of the various groups of teeth normally occurs at a particular time (when there is half to two-thirds of the final root length), nevertheless this may be influenced by local factors, which may cause premature or delayed eruption with a wide time-span discrepancy. This may be true even when root development may be proceeding unhindered.

In contrast, examination of periapical or panoramic X-rays is a far more accurate tool for dental age assessment. With few exceptions, mainly related to frank pathology, root development proceeds in a fairly constant manner and usually regardless of tooth eruption or the fate of the deciduous predecessor.

Let us take the case of a child of 11–12 years of age who has four erupted first permanent molars and only the permanent incisors, with deciduous canines and molars completing the erupted dentition. If practitioners were to refer only to the eruption chart, they would note that at this age *all* the permanent canines and premolars should have erupted. They may then conclude that the 12 deciduous teeth had been retained beyond their due time. The treatment that would appear to be the logical sequel to this observation would be the elective extraction of all the deciduous teeth!

This, however, is an overly simplistic diagnosis, since indeed there are two possible conclusions to the practitioner's observations. It is of paramount importance to carefully study the radiographs in order to distinguish between these two possibilities and thereby avoid unnecessary harm being inflicted on the child and the parents.

The initial conclusion to which the practitioner came would indeed be correct if the radiographs were to show that the unerupted permanent canines and premolars had completed most of their expected root length, showing that the child's dental age corresponded with his chronological age. In the present case (Figure 1.1), the deciduous teeth had not shed naturally, presumably due to insufficient resorption of their roots constituting an impediment to the normal eruption of the permanent teeth. Their permanent successors must then strictly be defined as having delayed eruption. The logical line of treatment would be to extract the deciduous teeth on the grounds that their continued presence defines them as over-retained.

However, there is a second possibility, where the radiographs reveal relatively little root development, more closely corresponding on the tooth development chart (Figure 1.2) to the picture of a 9-year-old child. The child's birth certificate has indicated the age of 12 years and this may well be corroborated by body size and development and even by intelligence level. Nevertheless, her dentition is that of a child three years younger, thus determining *dental age* as 9 years. Extraction of deciduous teeth in these circumstances would be the wrong line of treatment, since it is to be expected that these teeth will shed normally at the appropriate *dental* age. Early extraction may lead to the undesired characteristic consequences of early extraction, performed for a completely different reason.

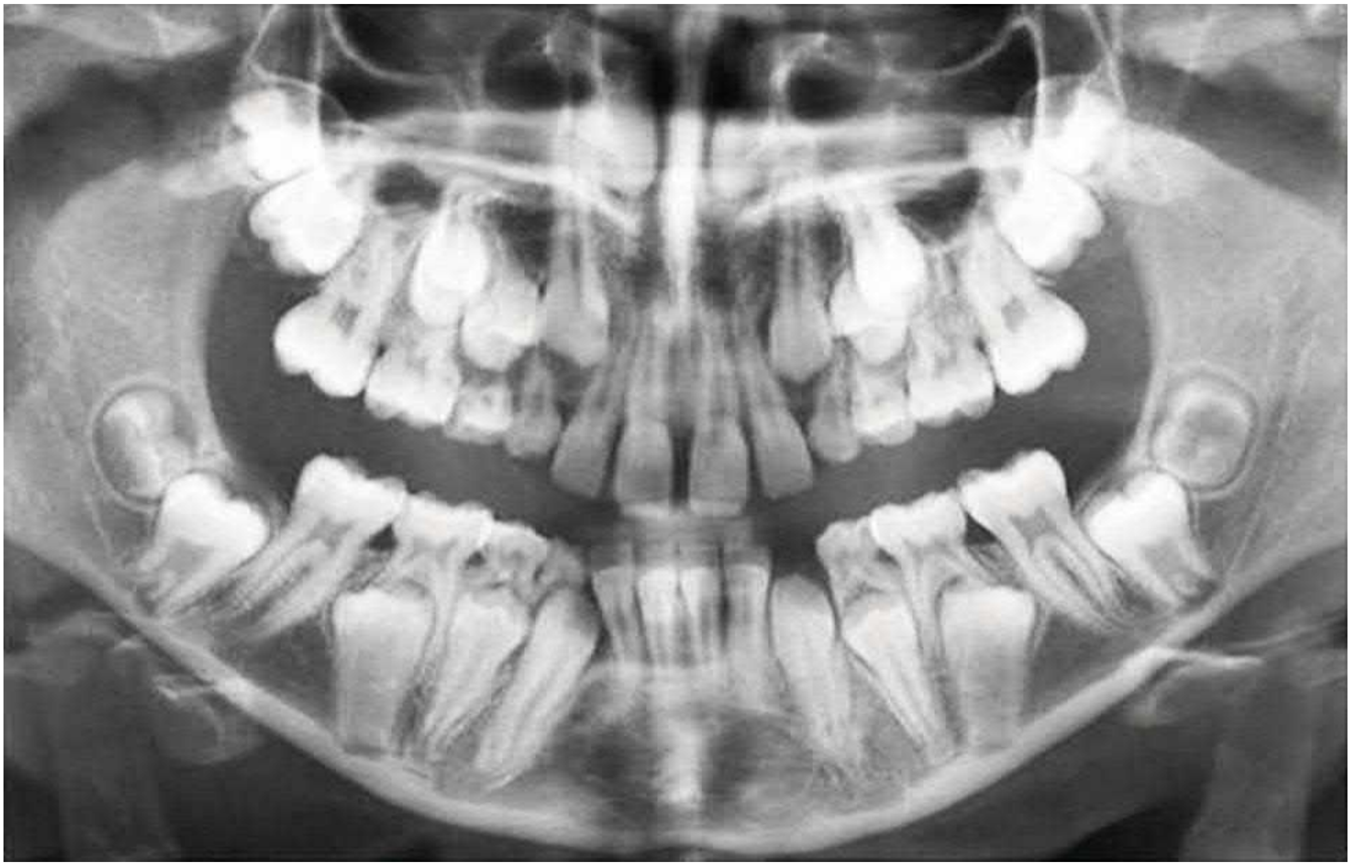

Fig. 1.1 The advanced root development of the canines and premolars indicates a dental age of 12–13 years, despite the presence of 11 deciduous teeth in this 10-year-old child. This defines the deciduous teeth as over-retained and extraction is their appropriate treatment. A note should be made and follow-up is needed regarding the relatively slow eruptive progress of the second permanent molars.

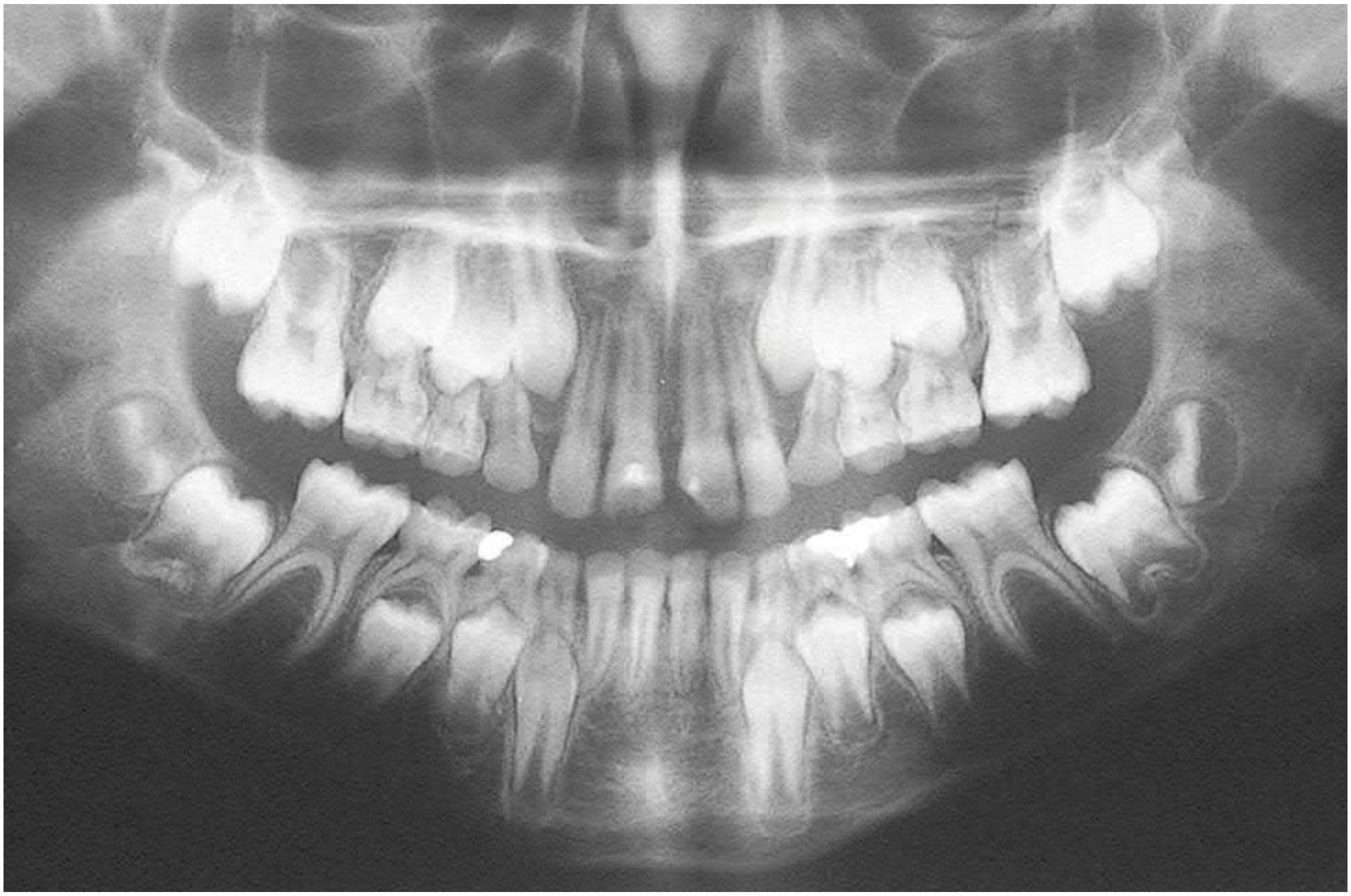

Fig. 1.2 A 12-year-old patient with root development indicating the late dental age of 9 years. Extraction of deciduous teeth is contraindicated

An additional parameter of teeth development must also be considered. Although on average, central incisors, canines and first and second molars in the maxilla show identical rates of development of one side of the mouth compared to the other, this may not be true for certain specific teeth. There may be a marked variation between right and left sides in the development rate of maxillary lateral incisors and mandibular second premolars and, less commonly, of maxillary second premolars.

In the same way that we may determine the patient's overall dental age, these identical principles also serve to enable us to diagnose the dental age of the patient's individual unerupted permanent teeth. However, because developmental variation is found within these different groups of teeth, the developmental stage of a single tooth cannot be used as an indicator for overall dental development and dental age must be evaluated employing a comprehensive, all-round assessment. Only then can a definitive determination be offered.

Accurate assessment of dental age is critical in deciding when to treat a patient in general and in regard to the treatment of impacted teeth in particular.

We are now in a position to define the terms that we shall use throughout this text, as follows:

- *Retained deciduous tooth*: This term has a positive connotation and refers to a tooth that remains in place beyond its normal, chronological shedding time due to the absence, or retarded development, of the permanent successor. A radiograph of the permanent successor is required in order to determine the presence and developmental status of the unerupted permanent tooth.

- *Over-retained deciduous tooth*: In contrast, this term has a negative connotation and refers to a tooth whose unerupted permanent successor exhibits root development in excess of two-thirds of its expected final length (Figure 1.3). Here too, a radiograph of the permanent successor is required in order to determine the status of the deciduous tooth and its implied treatment.

Fig. 1.3 The mandibular left second deciduous molar is retained (extraction contraindicated), since the root development of its successor is inadequate for normal eruption. The right maxillary deciduous canine, in contrast, is over-retained (extraction advised), since the long root of its successor illustrates delayed eruption.

- *Permanent tooth with delayed eruption*: This term refers to an unerupted tooth whose root is developed in excess of two-thirds of its expected final length and whose spontaneous eruption may nevertheless be expected within a reasonable time.
- *Impacted tooth*: This refers to a tooth whose root is developed in excess of two-thirds of its expected final length, but which is not expected to erupt in a reasonable time.

When assessing the dental age of the patient, it is important to emphasize that one should not include the maxillary lateral incisors, the mandibular second premolars and the third molars in this calculation. The development timetable of these teeth is not always in line with that of the patient’s other, ontologically more stable teeth [9, 10]. These are the same teeth that are most frequently congenitally missing in cases of partial anodontia (hypodontia) or oligodontia. Indeed, reduced size, poorly contoured crown form and late development of these teeth are all considered microforms of congenital absence [9–12]. The variation in their timing is, however, always expressed as *lateness* and they are never seen in a chronologically more *advanced* state of development than the other teeth. If the individual dental age of any of these variable groups of teeth is advanced, then so too is the dental age of the entire dentition in which they are to be found.

In summary, therefore, we may assert as follows:

- All orthodontists must have at their fingertips the ages at which the permanent teeth normally erupt.
- Permanent teeth normally erupt when approximately two-thirds of their final root length has developed.
- The remainder of the root reaches apexification approximately 2½–3 years after eruption.
- Determining the closed apex of the tooth on a radiograph is usually an easy and accurate parameter to establish.
- Determining the completed proportion of the root of a tooth, whose final completed length is unknown, is not an assessment that can be performed accurately. It rather falls into the realm of informed guesswork.

Having now set out the principles upon which dental age may be assessed, we must turn to the practical side of translating these principles into clinical terms in a logical, systematic and didactic manner. The simplistic way of adopting the above principles would be to take the panoramic radiograph or full-mouth periapical survey and then work around each dental arch from one tooth to the next, individually and from left to right, upper to lower, evaluating each tooth in turn. This would then require coordinating all the individual results and computing a final figure that is the dental age of the patient. The resulting conclusion would have to be compared against the values seen on an idealized chart of the norms for a given population [1, 4, 13]. Although this method delivers accuracy, it requires a considerable time and it is likely to take an hour or so to reach the final conclusion. It is an arduous and tedious endeavour, which does not lend itself to the conditions that are present in a busy clinical orthodontic practice.

What is recommended is a simple, logical but systematic approach that can be employed chairside to reach a similar conclusion in just a few minutes, even at the initial orthodontic consultation visit. This method will rely on the same criteria of establishing the development of crown and root, but must do so in a step-by-step manner, starting from a different point of departure. The ‘starting point’ of this systematic approach has, for reasons that will be explained in the following paragraphs, been set at the cut-off dental age of 9 years.

Assessing dental age in the clinical setting – the Jerusalem method

There are several criteria that are appropriate to the appraisal of tooth development when using full-mouth periapical radiographs or a panoramic film. The information that is available regarding the ages at which the various stages of dental development occur is based on the classic random studies that have been carried out over many decades of the local populations of the researchers involved. The figures for the mean ages at which these stages occur, in the hypothetical child, are as follows:

1. The first signs of the presence of a tooth are discernible radiographically with the initiation of calcification of incisal edges and cusp tips. Thereafter, one may observe the formation of the completed crown as well as progressive degrees of root formation (usually expressed in fractions), and thence the fully closed root apex. Since orthodontic treatment is largely performed on a relatively older section of the child population, the stages of actual formation of the root become the only relevant factors.
2. The accuracy with which one may assess fractions of an incomplete, immeasurable and

merely 'expected' final root length is not reliable and is very much a matter of individual observer variation.

3. The stage of tooth development that is easiest to define with confidence and with accuracy is that which relates to the closure of the root apex. So long as the dental papilla at the root end remains discernible, the apex is open and Hertwig's root-forming, epithelial sheath is in an active stage of increasing root length. However, once fully closed, the papilla disappears and a continuous lamina dura will be seen on a periapical radiograph, closely following the root outline. These are the specific diagnostic signs of that landmark event. Apexification is therefore the most important single factor upon which a system of assessment may be faithfully and easily made of the dental age of a given patient in the clinical environment.
4. From population studies, we learn that the first permanent tooth to erupt in the mouth is the mandibular central incisor, closely followed by the first permanent molars, and this occurs at the age of 6 years.
5. Root development of the permanent teeth is completed approximately 2.5–3 years after their normal eruption [4]. This allows us to conclude that, at the age of 8.5–9 years, the child's mandibular incisors will be the first teeth to exhibit closed apices and will usually be closely followed by the four first permanent molars. This being the case, it is clear that the age of 9 years must be the basic starting point from which to commence the evaluation of the child's dental age. If mandibular incisors or molars demonstrate root closure, then the tentative diagnosis would be that the patient has a dental age of *at least* 9 years. If the apices are still open, then the conclusion would be that the child has a lower dental age.

It should be emphasized, however, that the exercise is aimed at ranking a specific child's dental development vis-à-vis the above hypothetical mean. Whether or not the evaluated tooth has actually erupted is entirely irrelevant to this equation.

Let us examine the progressive diagnostic path in its correct order (see also Table 1.1):

1. If the mandibular central incisor roots are complete, we may presume that the patient is at least 9 years old (dental age), i.e. this figure is derived from 6 years (the normal age of eruption as determined by two-thirds root length development), with the addition of 2.5–3 years to apexification.
2. We may then proceed and check for closed apices of the first molars (9–9.5 years).
3. At 9.5 years, the mandibular lateral incisors roots will have completely developed.
4. The next teeth in the expected eruption series are the maxillary central incisors, whose closed apices would indicate a dental age of 10 years.
5. Because their rate of development is variable, it would be wise to bypass the assessment of the maxillary lateral incisors at this point in the diagnostic process and move on to examine the later teeth.
6. Apexification of the mandibular canines and first premolars (12–13 years).
7. Thereafter, the maxillary first premolars (13–14 years).
8. In common with the maxillary lateral incisors, the mandibular second premolars are also developmentally variable teeth and their assessment should also be bypassed for the present calculation.
9. Next there are the maxillary canines (14–15 years).

10. The final stage of development relates to the four second molars (15 years).

Table 1.1 Apexification age of individual tooth types.

9 years	Mandibular central incisors
9–9.5 years	First molars and mandibular lateral incisors
10 years	Maxillary central incisors
11 years	Maxillary lateral incisors
12–13 years	Mandibular canines
13–14 years	Maxillary first premolars
14–15 years	Second premolars and maxillary canines
15 years	Second molars

This stage-by-stage apexification determination will lead us to the last tooth in this sequence with a closed apex (Figure 1.4), which indicates the dental age of the patient. Once the determination is completed, it is valuable to return to the maxillary lateral incisor and the mandibular second premolar. If these are developing normally, then their age of eruption would be 8 years and 11 years, respectively, with an apexification date of 11 and 14 years, respectively. Retarded development of these individual teeth may be age assessed according to the above criteria for calcification. An illustration of this situation would be where the overall dental age assessment is diagnosed as 12 years, yet the right maxillary lateral incisor might match a 9-year-old child and the left mandibular second premolar might even be characteristic of someone 8 years of age.

In contrast to the above process of examination and assessment and in the case of a dental age less than 9 years, none of the permanent teeth will have completed their root development. Here clinicians will have no choice but to rely on their own estimation of the degree of root development, of the degree of crown completion and, in the very young, of the stage of initiation of crown calcification (Figure 1.5). This is most conveniently carried out by working backwards from the expected development at age 9 years and, with this as a base, comparing the dental development status of the patient, beginning with the mandibular central incisors and the first permanent molars.

Fig. 1.4 Root apices are closed in all first molars, all mandibular and three of the maxillary incisors, excluding the left lateral incisor. Canine and premolar apices are open.

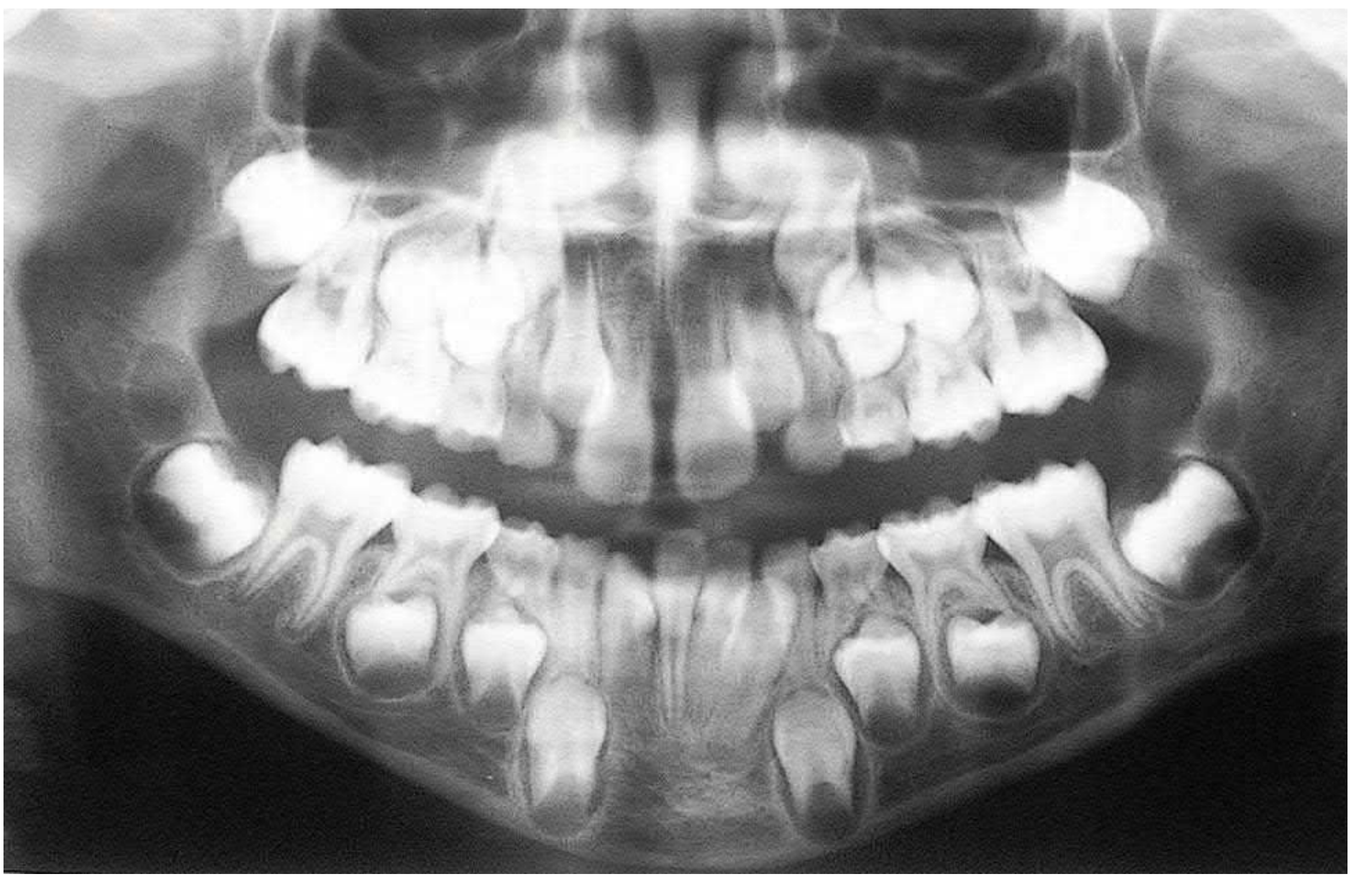

Fig. 1.5 No closed apices. Dental age assessment 7–7.5 years.

By way of illustration, at a dental age of 6 years the length of the roots of the mandibular central incisors and the first permanent molars will be seen to be one-half to two-thirds developed. Confirmation of this will come from a comparison, which may be made with the development stage reached by the other teeth, where one would anticipate that unerupted maxillary central incisors will have reached one-half root length, mandibular canines one-third root length, first premolars one-quarter root length, and so on.

As already noted, however, variations do occur, particularly with maxillary lateral incisors, mandibular second premolars or third molars. This may lead to certain apparent contradictions. It is therefore recommended to exclude consideration of these teeth when making the relevant assessments and thereby not only simplifying the process, but also contributing to the accuracy of the resulting assessment.

In addition, as stated above, *early* development of these teeth in relation to the development of the remainder of the dentition does not appear to occur. Indeed, individual variability is expressed only in terms of degrees of *lateness*. Accordingly, the developmental status of these teeth is available as corroborative evidence for the determination of dental age, but only if their own developmental stage is shown to be in line with the remainder of the dentition.

In a similar way, one should not incorporate abnormal features in the calculation process of the assessment of dental age. Unusually small teeth, coniform premolars, mandibular incisors and peg-shaped lateral incisors are all wont to develop very much later than normally shaped and sized teeth of the same series; indeed, sometimes as much as three or four years later. Thus, in diagnosing dental age for a patient with an abnormality of this nature, a general determination of the dentition should point out that this abnormal tooth may display a much lower dental age. A 14-year-old patient who has a complete permanent dentition, including the second molars, may yet exhibit a mandibular second deciduous molar. The radiographs (Figure 1.6) show the apices of the first molars, central and lateral incisors, mandibular canines and premolars to be closed, while the maxillary canines and the second molars are almost closed. However, the unerupted mandibular second premolar has an open root apex and presents a development stage equivalent to about a quarter of its expected eventual length, or even less. Correspondingly, although we may assess the dental age of the dentition as a whole to be 11-12 years, we would have to point out that the dental age of the unerupted second premolar is approximately 7 years. The conclusion here, in the context of this terminology, is clearly that the second premolar, *individually*, does not exhibit delayed eruption and the deciduous second molar is not over-retained. Thus, it would not be appropriate to extract the deciduous tooth at this point, but rather to wait for at least a few years, during which time the tooth may be expected to shed normally.

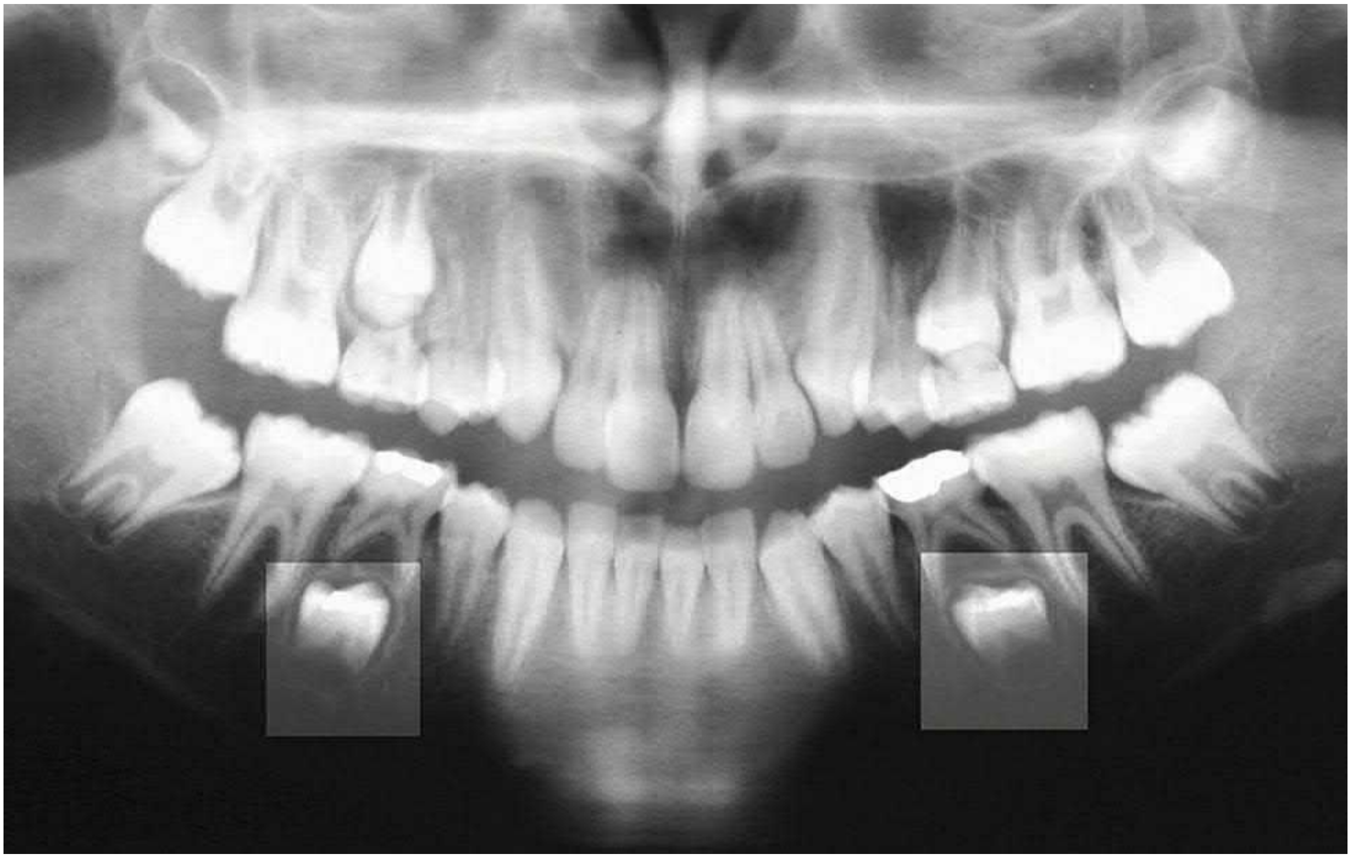

Fig. 1.6 Late-developing second mandibular premolars with retained (*not* over-retained) deciduous second molars in a child with a dental age of 11–12 years. The contrast and brightness of this poorly contrasted picture have been adjusted in the relevant areas to clearly show the stage of development of these tooth buds.

In summary, there are four different parameters that can explain the existence of certain deciduous teeth that are inconsistent with the chronological age of the patient. Each of these parameters has clinical repercussions and labelling a patient as one particular grouping will in fact dictate the nature of the treatment required:

1. *A late-developing dentition*: In this condition the dental age of the patient has developed slower than his chronological age. This is evident radiographically by a lesser root formation in the entire dentition than that which is expected at the chronological age. Typically, this is accompanied clinically by the continued and symmetrical presence of all the deciduous molars and canines on both sides of the jaw. Here, the extraction of deciduous teeth is contraindicated, since the teeth are expected to exfoliate normally when the appropriate *dental* age is reached.

2. *A normally developing dentition with over-retained deciduous teeth*: In this condition and despite the fact that the dental age of the patient correlates with her chronological age, the radiograph demonstrates one or more permanent teeth, which show well-developed roots but have remained unerupted, i.e. beyond their due eruption time. In most examples of this condition, the anomaly tends to be localized in a single section of the dentition. This may be due to an ectopic siting of the permanent tooth bud, which has stimulated the resorption of only a portion of the root of its deciduous predecessor. Shedding has not occurred due to the continued presence of the remaining part of the root or of another unresorbed root. Indeed, sometimes the condition may be found symmetrically in a single dental arch or even in both

arches. In this condition the recommended treatment is extraction of the over-retained tooth or teeth.

3. *A normally developing dentition with single or multiple late-developing permanent teeth*: This condition is commonly found in relation to the maxillary lateral incisor and the mandibular second premolar teeth. Normal shedding of the tooth is expected to occur when the root of the permanent tooth reaches two-thirds to three-quarters of its expected length. Accordingly, extraction of the deciduous predecessor is to be avoided.
4. *A combination of the above*: Sometimes one may see features of all of these three alternatives in a single dentition. In such a case the recommended treatment would need to be multiple and selective, each condition treated in its appropriate way.

The importance of a careful diagnosis and differentiation of the above conditions cannot be over-emphasized. All the aspects of planning and timing of treatment of the patient with impacted teeth depend entirely on a correct diagnosis.

When is a tooth considered to be impacted?

Based on the principles set out by Grøn [13], it has been widely accepted that, under normal circumstances, a tooth erupts with a developing root and with approximately three-quarters of its final root length. Typically, when they erupt the mandibular central incisors and first molars will have marginally less root development, whereas the mandibular canines and second molars will demonstrate slightly more root development. This is now generally accepted as a diagnostic baseline from which to evaluate the eruption of teeth in general.

Thus, where an erupted tooth shows less root development (Figure 1.7), it would be appropriate to label it as prematurely erupted. (This will usually be the consequence of the early loss of a deciduous tooth, particularly where extraction was dictated by the presence of periapical pathology, typically due to untreated caries.)

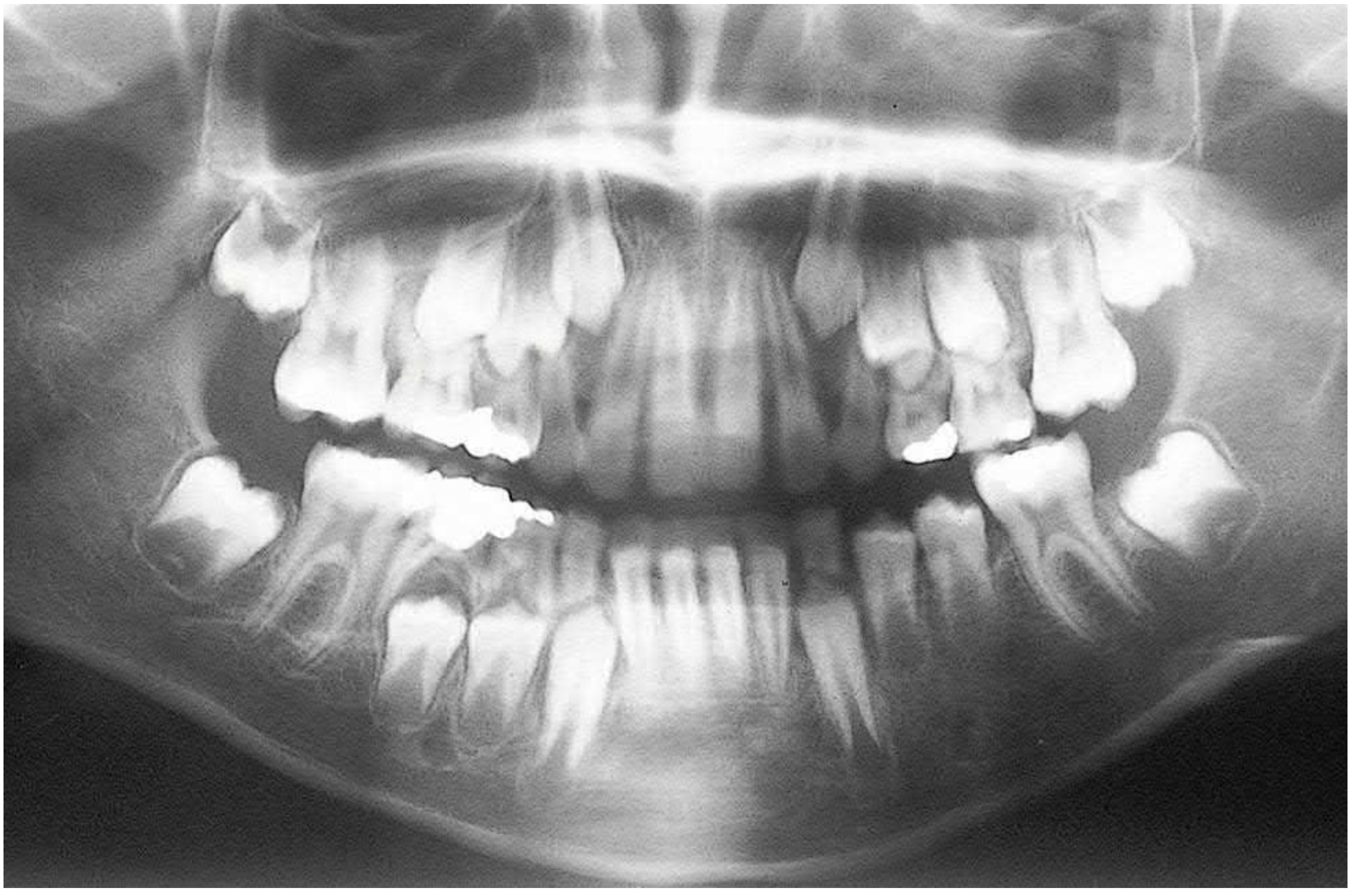

Fig. 1.7 The left mandibular premolars are prematurely erupted, with insufficient root development, due to premature extraction in a caries-prone dentition.

Conversely, where an unerupted tooth exhibits a more completely developed root, then the eruption process of this tooth must be presumed to have been impeded. (This may have been caused by any one of several aetiological possibilities, such as a failure of resorption of the roots of a deciduous tooth, or an abnormal eruptive path, the presence of a supernumerary tooth, or dental crowding, perhaps a much-enlarged dental follicle/dentigerous cyst, or indeed any other forms of soft tissue pathology or disturbance in the eruption mechanism of the tooth.) One should not overlook the possibility that the cause of the non-eruption may also be a thickened post-extraction or post-trauma repair of the mucosa.

It is to be noted that if there is a history of very early extraction of one or two deciduous molars, we may find that there will be a substantial delay in the eruption of the premolars, indeed, even complete non-eruption, caused by a thickened mucosa overlying the teeth. It is usually possible, for a period of a year or more, to palpate these teeth by virtue of their distinct outline being clearly visible and causing a bulging of the gum. However, eruption may not occur at all.

Impacted teeth and local space loss

Let us now look at the consequences of the inevitable time lapse between the performance of a surgical procedure to remove the cause of an impaction and the full eruption of the impacted tooth into the vacated space in the dental arch. The extent of this time-span is linked to several factors, specifically the initial distance between the tooth and the occlusal plane, the stage of development of the particular tooth, the age of the patient and the manner in which hard and soft tissue may be laid down in the healing wound. There are consequences to this time period, which need to be addressed. Local changes in the erupted dentition, such as space loss and tipping of the adjacent erupted teeth, may occur as a result of the break in integrity of the dental arch caused by the surgical procedure. The surgical intervention is no less likely to elicit the drifting of neighbouring teeth than is any other factor that may be caused by loss of dental tissue and interproximal contacts.

If an odontome or supernumerary tooth creates an obstacle to an unerupted permanent tooth, the result may be substantial vertical (and sometimes mesial, distal, buccal or lingual) displacement of the permanent tooth. In such a case, the ideal treatment would be to remove the obstructing body in order to leave the deciduous teeth intact, since the deciduous teeth would function to maintain arch integrity during the time lapse needed for the permanent tooth to erupt normally. However, in order to gain access to perform the necessary surgery, it is usually necessary to extract one or more deciduous teeth. This brings to the forefront the importance of interim space maintenance, particularly in the posterior area, during the lengthy time needed to allow for the long distance that a displaced permanent tooth may have to travel before it erupts into the mouth. Advance orthodontic planning is called for, preferably before or immediately subsequent to the surgical procedure. The interim space-holding device should be retained until full eruption of the permanent tooth has occurred.

The impaction of teeth is often associated with the lack of available space in the immediate area. This is frequently due to the drifting of adjacent teeth, as well as to crowding of the dentition in general. In these circumstances, the spontaneous eruption of an impacted tooth is unlikely to occur unless adequate or, preferably, excess space is available. It would be better to delay the excision of the associated pathological entity and permit this corrective treatment to be attempted, until the root development of the unerupted tooth is adequate to bring about the desired eruption. However, the surgeon may not give consideration to the orthodontic aspect and will probably insist on removing most forms of pathology as soon as a tentative diagnosis is reached, in order to obtain examinable biopsy material for the establishment of a definitive diagnosis. Nevertheless, the entirely benign nature of odontomes and supernumerary teeth causes these obstructions to be considered exceptions to this rule and the timing of their removal may be considered in a more leisurely fashion.

Whose problem?

Patients do not go to their dentist complaining of an impacted tooth. Indeed, they are frequently totally unaware that this abnormality exists. There is no pain, no discomfort and no swelling. The layperson would not see that there is a missing tooth, since the deciduous predecessor may not have shed naturally and no gap would be visible to the untrained eye. The vast majority of impacted teeth are discovered quite by chance, often in routine dental examination, and are not the result of a patient's direct complaint. As a general rule, it is the paediatric dentist or the general dental practitioner who, during a routine dental examination, may discover and record the existence of an over-retained deciduous tooth. A periapical radiograph will then confirm the diagnosis.

In the present context, there are two situations where abnormality in appearance can motivate a patient to seek professional advice.

The first typically occurs when the patient is 8–10 years old. A single maxillary central incisor has erupted a year or so previously and the discerning parent notices that the erupting lateral incisor on the opposite side has not left enough space for the anticipated eruption of the second central incisor (Figure 1.8). The deciduous central incisor may be present over-retained or it may have exfoliated. Although the parent has recognized the abnormality, he or she will not generally have the technical understanding to think of the possibility of impaction of the unerupted central incisor.

The second situation will occur with a 14–15-year-old patient who has become worried by an unsightly carious lesion in an over-retained maxillary deciduous canine. The patient will usually be unaware that this is not a permanent tooth. Appropriate professional advice will need to be given, explaining that the appropriate line of treatment is probably not restoration, but rather extraction and resolution of the impaction of the permanent canine.

In either of these two situations, because of symptoms related to relatively rare complications of impacted teeth, some patients in this category will have initially been seen by their general dental practitioner. The symptoms that may lead to this path are, *inter alia*, mobility or migration of adjacent teeth (due to extensive root resorption), painless bony expansion (dentigerous or radicular cyst) or perhaps pain and/or discharge caused by a non-vital over-retained deciduous tooth or an infected cyst, with communication to the oral cavity [14].

Fig. 1.8 Space loss in a 10-year-old child, due to an impacted maxillary right central incisor.

Initially, it will be necessary to ascertain whether there is a good chance that resolution will be spontaneous once the aetiological factor has been removed or whether active appliance therapy may be indicated. In order to do this, it is important to accurately and visually assess the exact position, long-axis angulation and rotational status of the tooth and make an assessment of space in the arch. Having done so, the paediatric dentist or general dental practitioner will now have to decide who should treat the problem.

Many dentists, believing that surgery will be required, will prefer not to accept responsibility for this type of situation and will refer the patient to an oral and maxillofacial surgeon. The surgeon may opine that the problem is essentially surgical in nature and will proceed to remove the over-retained deciduous teeth, clear away other possible aetiological factors, such as supernumerary teeth, odontomes, cysts and tumours, and also expose the impacted permanent tooth. If the impacted tooth is buccally located, the surgical flap may be apically repositioned to prevent primary closure and to maintain subsequent visual contact with the impacted tooth after healing has taken place. In many cases, this will have the effect of encouraging eruption. For the few weeks following, until healing (by 'secondary intention') has occurred, the wound will usually be packed with a proprietary zinc oxide/eugenol-based periodontal pack (e.g. CoePack®) or a gauze strip impregnated with Whitehead's varnish. The surgeon uses careful placement and wedging of the pack between an impacted tooth and its neighbour in order to help free the tooth and allow it to erupt naturally when the pack is removed.

In the more difficult impactions, wider surgical exposure may be undertaken, which would involve fairly radical bone resection, both around the crown and down to the cemento-enamel junction, with complete removal of the dental follicle. The principal aims of this procedure are to clear away all possible impediments to eruption and to ensure that subsequent healing of the soft tissues does not cover the tooth again.

Thereafter, for a period of several months or even years (for some of the more awkwardly positioned teeth), the surgeon, family dentist or children's dentist will usually follow up the spontaneous eruption of the impacted tooth until it reaches the occlusal level. Only then, if alignment is poor or the tooth still has not erupted, will the patient probably be referred to the orthodontist.

What is quite clear is that the patient should have been referred to the orthodontist directly in the first place. Although the orthodontist cannot directly influence the position of the impacted tooth until after the appropriate access has been provided surgically and until an attachment has been placed on the tooth, nevertheless, with proper planning and management, including referral for surgical exposure at the appropriate stage in the treatment, a much higher qualitative level of care would be provided and in a very much shorter time-frame.

This will be discussed in the ensuing chapters of this book.

The timing of the surgical intervention

From this discussion, it is clear that the timing and nature of the surgical procedure are determined at the time of the initial diagnosis, by the degree of development of the teeth concerned.

The first scenario occurs at an early stage, when a radiographic survey of a very young child may reveal pathology, such as a supernumerary tooth, an odontome, a cyst or a benign tumour, which appears likely to prevent the normal and spontaneous eruption of a neighbouring tooth. In such a case, it would be inappropriate to expose the crown of an immature tooth. One would not want to encourage the tooth to erupt before an adequate (half to two-thirds) root length has been produced. Secondly, at that early stage of its development, the tooth cannot yet be considered to be impacted. Given time and freedom to manoeuvre, the tooth will probably erupt by itself.

Early exposure risks the possibility of damage to the crown and to the subsequent root development of the tooth. On the other hand, however, it would not be wise to ignore the situation after the discovery of the pathological condition (Figure 1.9). The potential for impaction has been revealed and leaving the condition untreated may worsen the prognosis. Accordingly, the appropriate treatment at this stage might be the removal of the pathological entity, without disturbing the adjacent permanent teeth or their follicular crypts. It may then reasonably be expected that normal development and eruption will occur in due course. However, while this is clearly the desirable course of action, access to the targeted area may be impeded by the proximity of adjacent developing structures, so that delay may still be advisable. A competent oral and maxillofacial surgeon should be consulted.

The second scenario occurs when the discovery of the pathological condition is only made when the patient is much older. In this case (Figure 1.10), the superiorly displaced central incisor has a two-thirds root and is ready for eruption. The appropriate treatment here is to extract the deciduous and supernumerary teeth and hope that this will encourage eruption of the permanent incisor. In many scenarios, spontaneous eruption may be expected even with a closed apex, provided there is adequate space in the dental arch and little or no displacement of the impacted tooth [15, 16].

As we shall see in subsequent chapters, there are several situations and tooth types where spontaneous eruption may not occur, or may not occur in a reasonable time-frame. This will be so in the case of severe displacement of the affected tooth. In these instances, it may be necessary to supplement the natural eruptive potential of the tooth and divert it mechanically, with the use of an orthodontic appliance.

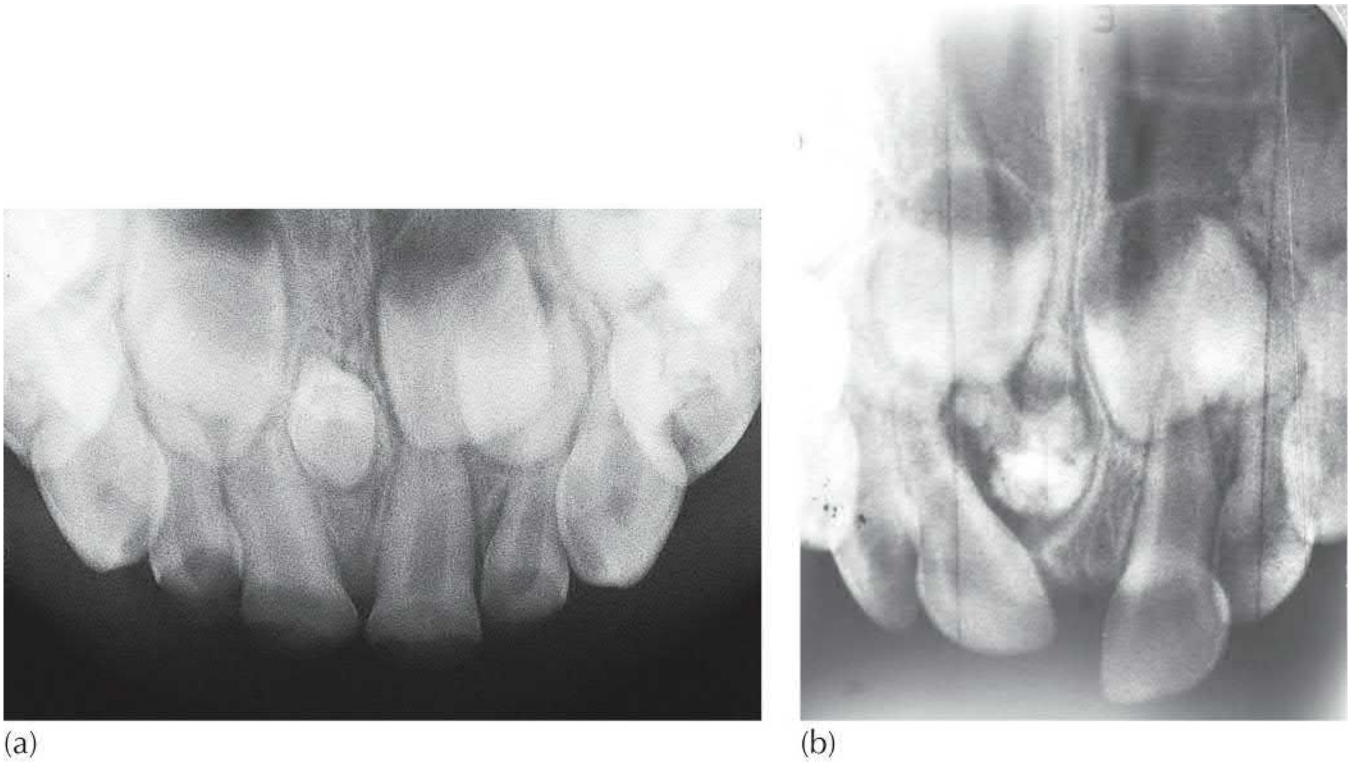

Fig. 1.9 (a) Chance finding of mesiodens in a 4-year-old child. (b) Chance finding of odontoma in a 1-year-old infant.

Fig. 1.10 An 8-year-old child exhibits an unerupted maxillary left central incisor with two supernumerary teeth superimposed, pointing in opposite directions. The permanent incisor is developed adequately for eruption (retarded eruption) and the deciduous incisor is over-retained.

Patient motivation and the orthodontic option

Angle's class II malocclusion is to be found in 20–25% of the child population in most countries of the Western world [17, 18]. However, this is not reflected in an orthodontic practitioner's office, where one finds that up to 75% of patients are being treated for this malocclusion. The reason for this incongruity in seeking treatment is entirely facial appearance, since the visible manifestation of the condition causes the patient's appearance to be adversely affected to a much greater extent than by most other conditions. In other words, appearance plays an extremely large part in the initiative and motivation of the parent to seek treatment for the child and for the child to be ready to be treated.

Most of the other patients on the orthodontist's roster are being treated for additional (though arguably less unsightly) conditions (such as crowding, single ectopic teeth, open bites or class III relationships). It follows that relatively few patients with acceptable appearance have been referred for strictly health reasons, which may not normally be apparent to the patient. This small number of patients will have agreed to orthodontic treatment only after being motivated by the careful and persuasive explanations of a general or paediatric dentist, orthodontist, periodontist, prosthodontist or oral surgeon, who will have warned them of the ills that are otherwise likely to befall them and their dentition.

Aside from maxillary central incisors, most impactions are symptomless and do not usually present an obviously abnormal appearance. The natural result is that motivation for treatment in symptom-less cases is minimal and much time has to be spent in explanations to patients before they accept that treatment is appropriate and before they are prepared to accept the constraints entailed in its execution.

However, the story does not end there, since most patients require periodic 'pep talks' to maintain their cooperation and their resolve to complete the treatment. Many patients may not maintain the required standard of oral hygiene, thus rendering the continuation of treatment difficult if not impossible. On the other hand, it is just as difficult to remove appliances from a patient in the middle of treatment, when impacted teeth have partially erupted and large spaces are already present in the dental arch. For these reasons, although ambitious and innovative treatment plans are in order, it is essential to take into account the aspect of motivation before advising lengthy and complicated treatment, since the risk of the treatment being prematurely aborted may be high.

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2
The Logistics of Orthodontic Treatment for Impacted Teeth

Adrian Becker

The anchor unit

Attachments

Intermediaries/connectors

Elastic ties and modules versus auxiliary springs

Temporary anchorage devices

Magnets

It is well known that movement of teeth adjacent to an impacted tooth will often have a positive effect on the eruptive behaviour of that tooth, particularly if the movement involves the opening of space in the dental arch [1]. By the time the space has increased to be of a suitable size and by the time the oral and maxillofacial surgeon is able to make appropriate arrangements for its surgical exposure in a busy schedule, a new periapical radiograph may indicate that the impacted tooth has significantly improved its position. In such a case, the surgery may become superfluous. Indeed, if the spontaneous eruption seems likely to occur imminently, or at least within a reasonable period, there is obvious merit in waiting for this to actually occur.

If, on the other hand, eruption looks as if it will take many months, then the orthodontist must weigh the benefits of avoiding surgery against the drawbacks involved in leaving orthodontic appliances in place for an extended period of time. As a general rule, orthodontic appliances increase the susceptibility of the teeth to caries, which is evident with the initial appearance of so-called white spot lesions [2]. In the case of long-term presence of appliances, there is a significant risk of proliferative inflammation of the gingivae and serious periodontal involvement. Indeed, the longer the appliances are in place, the greater the risk of damage.

There is, however, a further factor to be taken into account, because removing the appliances before treatment is completed brings with it the risk of having to replace the appliances. This may be necessitated in order to correct a malposition of the newly erupted (and erstwhile impacted) tooth. The flip side is to accept a compromised and inadequate outcome. To solve this dilemma, the clinician may elect to advise surgical exposure followed by orthodontic traction in order to expedite the eruption of the tooth and thus clear the way to complete the treatment within a very much shorter time.

A similar dilemma may arise when orthodontic treatment has provided space and surgery is undertaken to remove a physical obstacle. In such an event the elimination of the obstacle will have rendered the impaction potentially resolvable, without further treatment. However, the surgical intervention involved in removing the obstacle will offer the opportunity of anaesthetized access to the unerupted tooth. It would be a pity not to exploit that opportunity, since subsequent healing of the wound will deny that access. If that eruption does not then take place, a second surgical intervention in the same area will have been necessary and much time will have been wasted confirming that spontaneous eruption will not occur.

It is therefore quite clear that the time factor is most important. Orthodontic appliances are in place and there may be an unsightly space in the dental arch. Orthodontically aided eruption will unquestionably speed up the resolution enormously and, this being so, the patient's best interests are to be served by including exposing and bonding the impacted tooth among the factors to be considered at the planning stage.

When the existence of an impaction is only a small part of a complex overall malocclusion, the time factor becomes more critical. It would be a reasonable estimate that a given overall orthodontic problem, by itself, may require two years of treatment. In the case of an awkwardly placed impacted tooth, the resolution of the problem may take a further year or more [3–5]. To add the luxury of a wait-and-see period is to add yet more time to this already extended three-year plus period. During all this time, orthodontic appliances are being worn. The result of all this is that, while the orthodontist may well be rewarded by an improved position of the impacted tooth, a deteriorating state of oral health, due to poor oral hygiene, may deprive the achievement of all meaningful content.

Let us remind ourselves of the definitions set out in Chapter 1, in which it was noted that a 'permanent tooth with delayed eruption [is an] unerupted tooth whose root is developed in excess of two-thirds of its expected final length and whose spontaneous eruption may nevertheless be expected within a reasonable time'. A tooth that is not expected to erupt within a reasonable time in these circumstances is termed an impacted tooth. Thus, in the present context and despite the fact that the tooth may be expected to erupt spontaneously 'in time', this period may be considered 'unreasonable', when taking into account the likelihood of detrimental iatrogenic effects on the remainder of the dentition, engendered by this extra and often considerable waiting period. This then will reclassify the tooth (in clinical therapeutic terms) as an impacted tooth. As such, a proactive surgical exposure should be considered.

In this chapter we shall therefore discuss the manner in which the orthodontic treatment of impacted teeth needs to be modified to accommodate the special requirements of the orthodontic appliance, the specific components that may be usefully employed and the accompanying treatment strategy that will make its performance run smoothly. It is not the intention here to discuss the details of appliance therapy. These will be set out in later chapters, where we will discuss the different groups of impacted teeth that are seen in practice. However, some general principles are in order at this juncture.

The anchor unit

For most malocclusions, quality treatment is best provided by the use of one or other of the recognized fixed appliance treatment techniques. If the dental arches are correctly related and adequate space is present, then the teeth are initially 'levelled' to a labial archwire of standardized archform and a given coefficient of elasticity. Later, heavier round or rectangular steel archwires are substituted to activate root movements that will pave the way to achieving an optimal result. In cases of incorrectly related dental arches, the use of other appliances is recommended, such as headgear, functional appliances or intermaxillary means of traction, prior to or together with the fixed appliances. Here, space may be provided by the extraction of teeth or by lengthening the arches mesio-distally or expanding them laterally.

When dealing with a malocclusion that incorporates an impacted tooth, this procedure will need to be modified. Unlike other teeth in the mouth, the impacted tooth may be severely displaced from its normal position in all three planes of space, and much anchorage will be expended in bringing it into alignment. Accordingly, a rigid anchor base must be developed against which to pit the forces required to resolve the impaction.

At the age at which an impacted maxillary canine is treated, the full permanent dentition (with the exception of third molars) is usually present. Accordingly, a fully multibracketed appliance would normally be placed in position. With the use of light archwires, the entire dentition will be treated through the stages of levelling and the opening of adequate space in the arch for the impacted tooth. A heavy and more rigid archwire is then placed into the brackets on all the teeth of the fully aligned and complete dental arch. The aim of this is to provide a solid anchorage base [5, 6], which will not allow the distortion that may otherwise result from the forces that will eventually be applied to the impacted tooth after its exposure. One should not underestimate the demands made on the anchor unit by forces designed to resolve a grossly displaced canine, particularly if the forces are applied for an extended duration.

By contrast, at the age at which an impacted upper central incisor needs to be treated, only first permanent molars and three permanent incisor teeth are present in the maxillary arch. Accordingly, in order not to compromise the remainder of the dentition, it will be necessary to employ alternative means of making the appliance system rigid in order to oppose the light forces that will be applied to the impacted tooth. The anchorage value of the appliance may be enhanced by including a soldered transpalatal bar or by bonding brackets to the deciduous molars and canines.

Attachments

Some form of attachment must be placed on the tooth in order to be able to influence its positive resolution and to bring it into its place in the dental arch. These attachments have changed over the years, reflecting the advances made in the field of dental materials.

Lasso wires

In the years prior to the mid-1960s, a lasso wire (Figure 2.1), twisted tightly around the neck of the canine, was widely employed, and indeed was the type of attachment that we ourselves used in our very earliest cases. It will be readily appreciated that the shape of the crown of a normally shaped healthy tooth is such that its narrowest waist diameter is at the cemento-enamel junction (CEJ). This is where the lasso wire will inevitably settle. This undesirable consequence will unavoidably result in irritation and recession of the gingival and periodontal tissues and will actively prevent their reattachment in this vital area. There is also evidence that, as a consequence of employing this method, external resorption and ankylosis have been produced in the area of the CEJ [7]. The excellent alternatives that are available today have rendered the lasso wire obsolete.

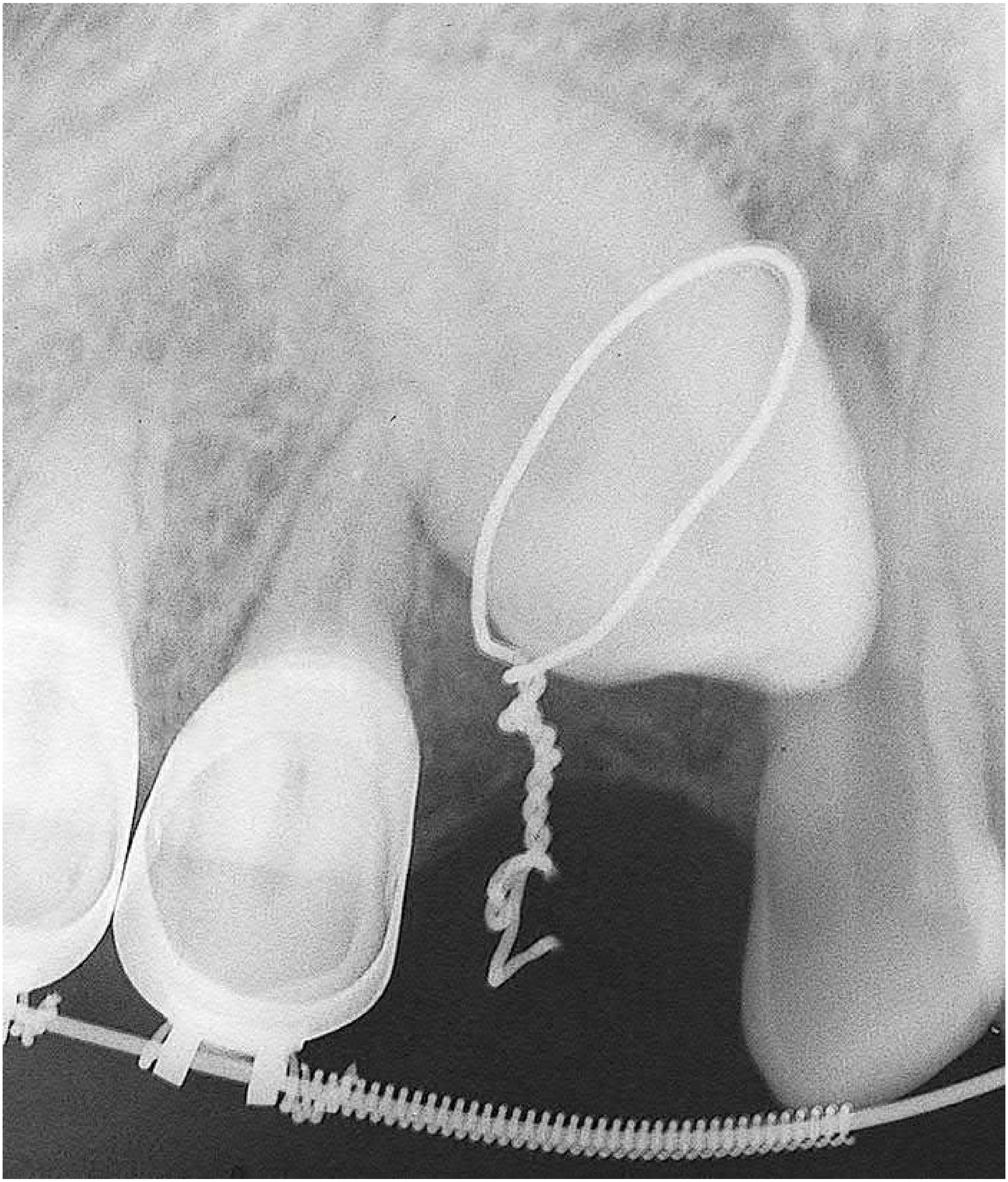


Fig. 2.1 Lasso wire encircling the neck of an impacted canine (circa 1971).

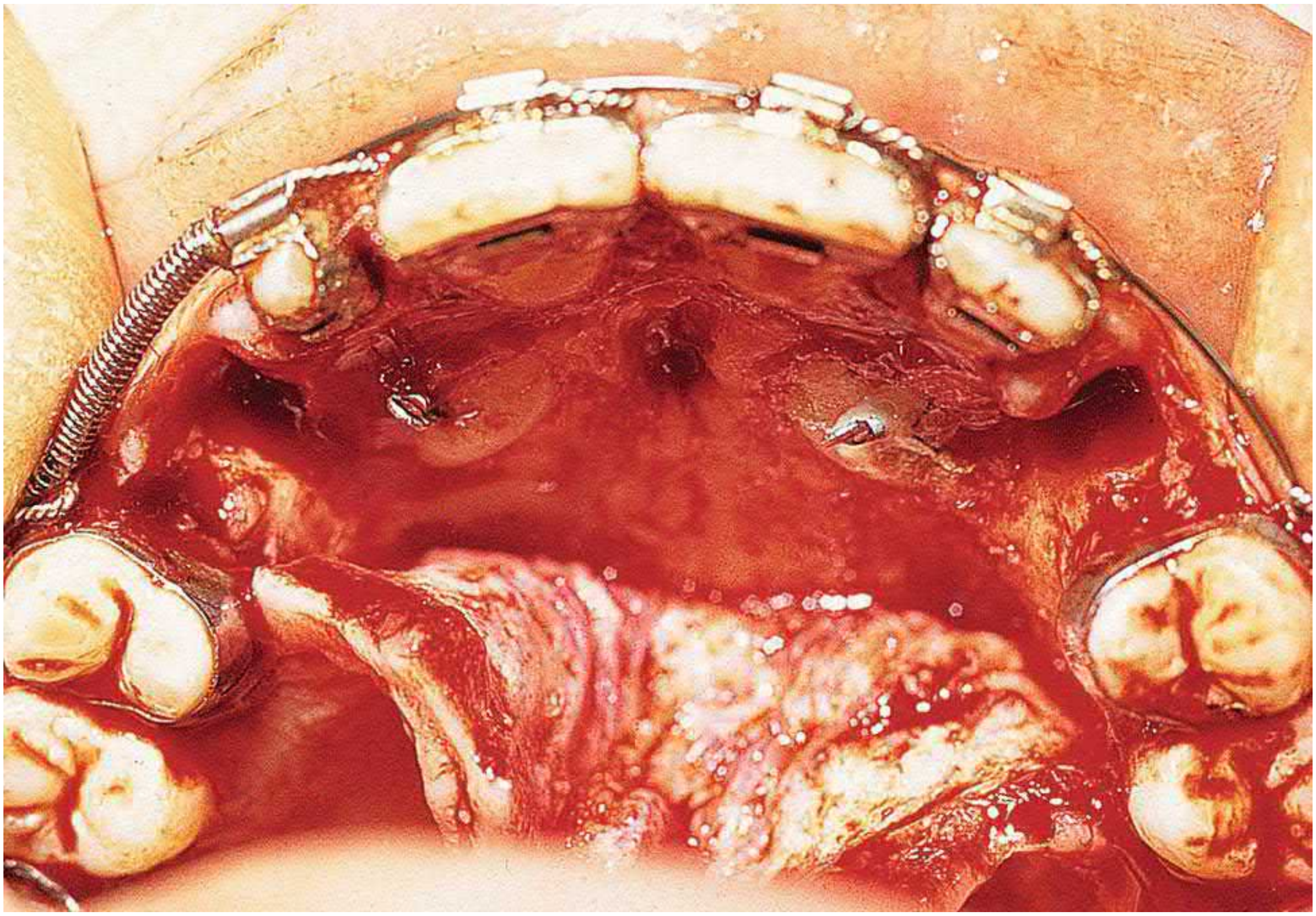


Fig. 2.2 Threaded pins set into prepared holes, drilled and tapped into the enamel and dentine of the surgically exposed canines (circa 1973).

Threaded pins

Several systems of threaded pins (Figure 2.2) have been available for many years. Their original specific purpose was to provide retention for an amalgam or composite core and to allow the provision of a cast crown in a severely broken-down tooth. However, these threaded pins have also been used in the past as the attachment for an impacted tooth [8, 9], although they have now been totally superseded by other methods of attachment. Some of the disadvantages of the threaded pins method include the fact that it is dentally invasive, necessitating subsequent restoration. Given the difficulties of access to many impacted teeth and the desirability of limiting surgical exposure as much as possible, it may be difficult to determine the orientation of the long axis of the tooth and the drilled hole may inadvertently enter the pulp. Moreover, unerupted and non-functional teeth often have large pulp chambers. Even in the most favourable of circumstances, it seems that this unnecessarily aggressive method actually causes damage to a virgin tooth, in light of the fact that there are eminently suitable, non-invasive methods and efficacious alternatives, as we shall discuss below. Nevertheless, the method was still in use and apparently recommended as late as 2004, which was, anachronistically, well into the present era of composite bonded attachments [8, 9].

Orthodontic bands

Preformed orthodontic bands with welded attachments [10] largely replaced both the lasso wire and the threaded pin in our protocol. Clinical experience with these bands showed them to be considerably more compatible with ensuring the health of the periodontal tissues. As with the lasso wire, the use of a band dictated a very wide surgical clearance of tissue on all sides of the tooth. However, in order to permit the introduction and cementation of the band, it was imperative, at the time of placement, to adequately control haemorrhage around the crown and to avoid contamination from oozing blood inside the cement-filled band.

Bonded attachments

With the introduction of acid-etch composite enamel bonding, all the above-mentioned methods became obsolete. The adoption of the acid-etch composite bonding technique to the crown of a tooth has many advantages [11–15], most notably in terms of simplicity and reliability of the bond [14]. However, its greatest advantage is that, to be successful, it requires relatively little exposed surface of enamel, a fact that has contributed much to the subsequent periodontal health of the treated result. It is presently without doubt the method of choice from almost every point of view, and is appropriate to replace other methods in virtually all circumstances.

Standard orthodontic brackets

The points to be considered when choosing the type of attachment to be placed on impacted teeth are different for the impacted tooth than those relating to an erupted tooth that needs to be brought into its position in the dental arch. The wide array of orthodontic brackets, advertised in the catalogues of the various orthodontic manufacturing companies, represents sophisticated designs of attachment, which will enable the orthodontist to perform any direction of movement on a tooth in all three planes of space. Since many, or perhaps most, impacted teeth require a wide variety of movements, it would seem logical to place a sophisticated orthodontic bracket on the affected tooth from the outset.

The particular stage of the initial movement of the impacted tooth, from its ectopic position until it reaches the main archwire, effectively represents the resolution of the impaction. This entire stage, until the bonded attachment arrives at and engages the main archwire, is the most difficult part of the treatment of the displaced tooth and it is not possible to achieve much more than tipping, extrusion and some rotation. In other words, the value of the bracket up to that point is no greater than that of a simple eyelet [14]. Indeed, on several counts, the potential of the eyelet outweighs that of the conventional bracket during the impaction resolution stage.

The base of a conventional bracket is wide and rigid and is manufactured so as to closely conform to the shape of the crown of the tooth in its mid-buccal location. It is impossible to adapt this preformed base to the shape of another part of the tooth's surface than that 'average, one-size-and-shape-fits-all' contour for which it has been designed. It follows that composite bonding on a different location on the tooth is very likely to lead to failure [14]. Orthodontic brackets are highly specialized, each having a slot milled to a very precise blueprint, specific to the particular tooth for which it is intended. The mesio-distal angulation differs between one tooth and another, the 'in–out' bucco-lingual depth of the slot will vary, the torque angulation will not be the same for all the individual teeth, and the height at which the bracket should be placed on an incisor will not be the same as that on the canine. These are the basic definitions on which the so-called straight-wire appliances are built. Accordingly, it is quite obvious that all this highly sophisticated programmed engineering is only meaningful if the bracket is bonded in its appropriate, predetermined mid-buccal location on the crown of the tooth. We shall see in later chapters that, at the time of the surgical exposure of an impacted tooth, it is very frequently logistically impossible or inadvisable to bond an attachment in the mid-buccal position on the crown. This site on the crown of the tooth may not be accessible due to its relationship to the root of an adjacent tooth. An excessive amount of soft and hard tissue might need to be surgically removed in order to provide access to achieve the ideal placement, thereby producing unnecessary surgical damage, which always has a price to pay in the form of appearance and long-term periodontal prognosis of the treated result [14].

The standard orthodontic bracket in any technique is relatively large, possesses a wide, high and sharp profile, and, even when placed in alternative positions on the tooth (by force of circumstance at the time of surgery), may find itself deeply sited within the surgical wound. The shear bulk of the bracket creates irritation as the tooth is later drawn through the soft tissues, particularly the mucosa (Figure 2.3). A ligature wire or elastic thread, which will have been tied to it, must also originate deep in the wound and will be stretched across the replaced flap tissue in the direction of the labial archwire. This will increase the possibility of impingement of the investing tissues and may lead to inflammation and even to permanent periodontal damage.

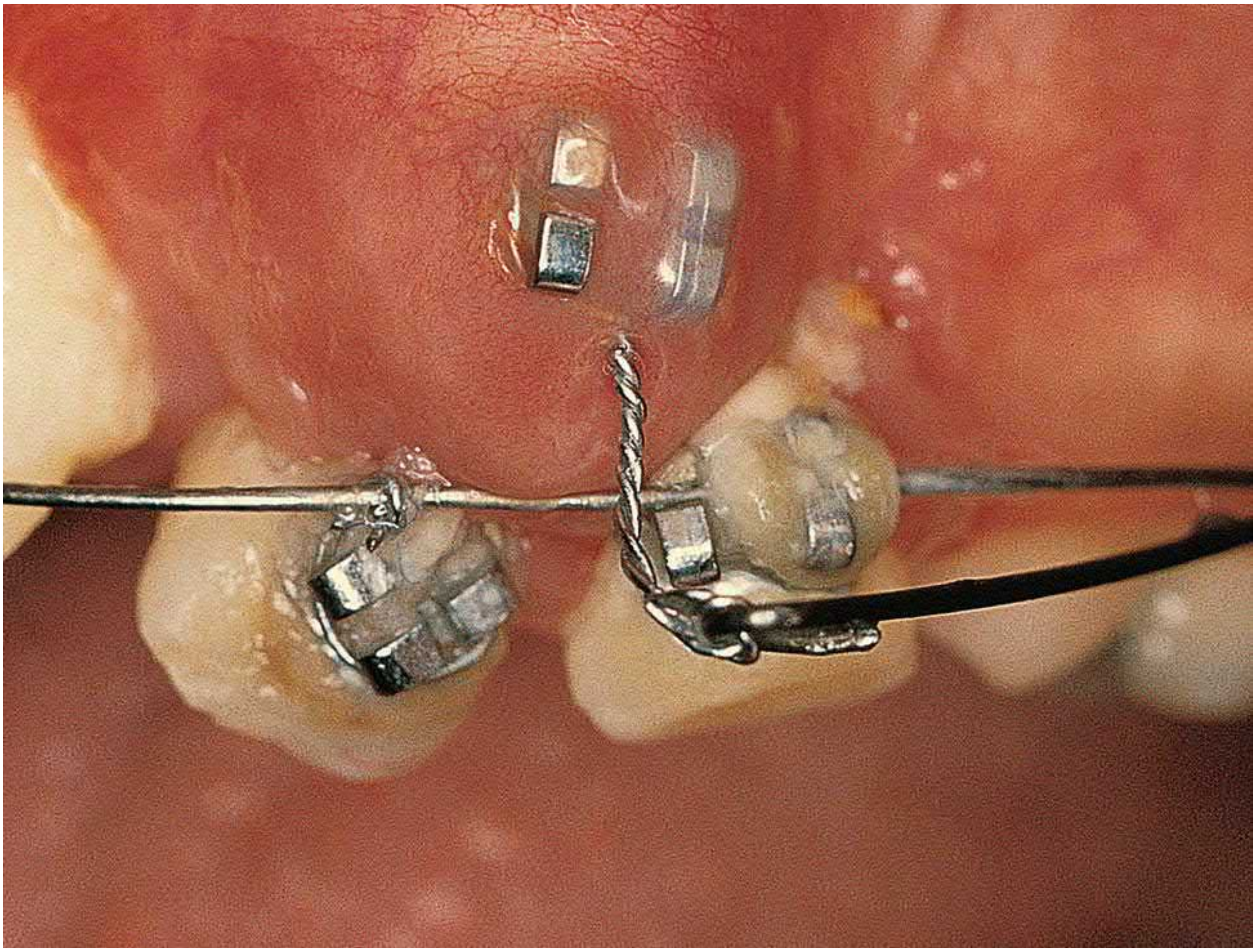


Fig. 2.3 As the impacted tooth is about to erupt, the high-profile Siamese edgewise bracket has fenestrated the swollen gingival tissue.

As the displaced tooth moves towards its place in the arch, exuberant gingival tissue bunches up in front of it, leading to a confrontation with a conventional orthodontic bracket. The existence of the exuberant gingival tissue in advance of the tooth can often cause ‘pinching’ between this tissue and the teeth in the arch immediately adjacent to it. This is less likely to occur if a deliberately generous space has been previously provided in the arch for the tooth. Such a precaution may avoid unnecessary periodontal damage.

A simple eyelet or button

An eyelet, welded to orthodontic bond material with a mesh backing (Figure 2.4), is soft and easy to contour, enabling its adaptation to the bonding surface to be more intimate and retentive. Its relatively small size and low profile make the mid-buccal position of several of the more awkwardly placed teeth considerably more accessible as compared with the placing of a conventional bracket. Its modest dimensions are also less of an irritant to the surrounding tissues, particularly during the critical phase as it breaks through gingival tissues in the final stages of its eruption into the oral cavity [15].

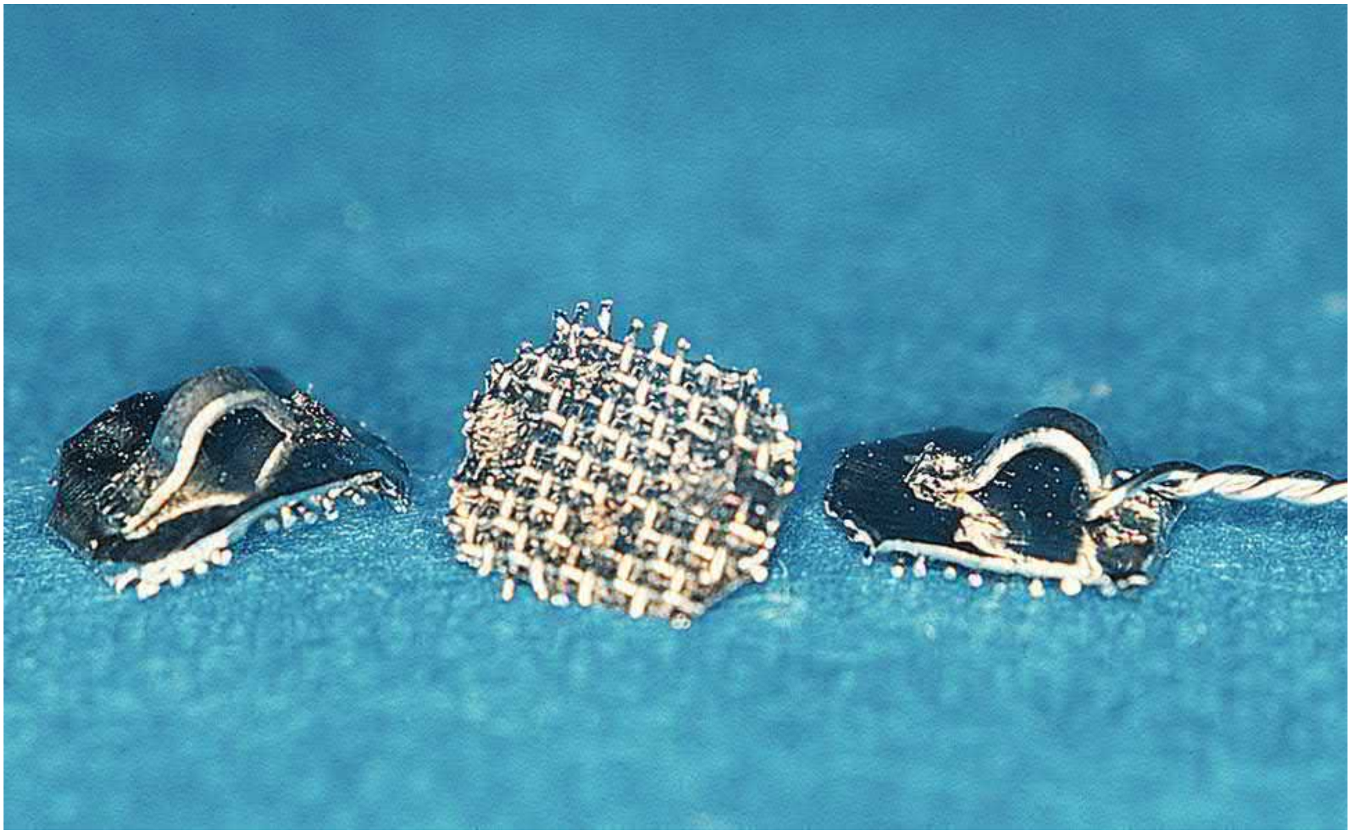


Fig. 2.4 Eyelets welded to a pliable band material base, backed by steel mesh.

The need to properly adapt the base of the attachment to the shape of the recipient surface of the crown of the tooth cannot be over-emphasized. Thus, the use of standard brackets with 'anatomic' bases, as supplied by the manufacturer, has been shown [14] to fare considerably better in the mid-buccal position of the impacted tooth (80.6%) than on any other surface, particularly the palatal surface. The chances of the survival on a palatal site were shown to be 58.3% – i.e. a failure rate of almost 1 in 2. By comparison, a small attachment (such as an eyelet) on a pliable base, properly and individually adapted to the form of the recipient site, which demonstrated a 96.7% level of reliability against detachment, will allow the orthodontist to work with the greatest degree of confidence.

A button is useful for engaging elastic chains and is usually placed on the lingual side of a tooth in circumstances where rotation of the tooth is required. However, it is also suitable in the present context.

For these reasons, small eyelets and buttons are recommended as the initial attachment, which is placed at the time of surgery and removed only when the tooth has progressed to the point where it is in close proximity to the archwire. At that point in time, they should be replaced by the same type of sophisticated bracket that is being used on the other teeth, thereby initiating the more intricate root manipulations of the tooth (rotating, uprighting and torqueing). Also at this point, the impaction will have been treated and there will be no ectopically displaced teeth. All the teeth will be located close to the line of the arches, forming what would otherwise constitute a typical pre-orthodontic scenario. Elsewhere in this book I have called this environment the 'orthodontic ballpark', because the case will have now become a routine orthodontic case.

Intermediaries/connectors

We shall see in Chapter 4 and again in Chapters 6 and 7 that there are important periodontal advantages to be gained by full closure of the surgical flap at the end of the visit at which the surgical exposure is performed [15]. The impacted tooth will have been re-covered by the surgical flap and will be lost from sight, unless the impacted tooth is fairly superficially placed. The only manner in which contact may be maintained with it is through some form of physical connection, such as a ligature wire, gold chain or elastic thread, which was attached to the eyelet before or immediately after it was bonded to the tooth. These may be termed intermediaries or connectors.

Since elastic thread can only be tied once, it is not recommended to be used as an intermediary. Gold chain has found a surprising degree of acclaim and acceptance worldwide because it is undoubtedly suitable and sufficiently strong to serve as an intermediary. However, it is unnecessarily sophisticated, expensive and not widely available. There is also one practical drawback to its use, which relates to its physical properties. If a closed surgical approach is used after bonding of its attachment base to a tooth, the end of the chain will need to be held in locking tweezers or artery forceps until it is ligated to its active traction element, be it a spring or elastic thread. If the gold chain is not thus held, then the fine-linked chain may collapse down and slip between the recently sutured edges of the flaps and be lost from sight. This may also happen when an open surgical approach is performed, where the collapsed chain may fall between the wound edges and into the cervical area of the newly exposed tooth. Indeed, this entire unfortunate series of events may also occur during later visits for re-ligation of the still only partially erupted tooth. In all the above cases, the subsequent search for the lost chain is very uncomfortable for the patient and may even require reopening of the healing soft tissue cover.

The use of a stainless steel ligature is far easier from every point of view. It is cheap, abundant and readily at hand in every orthodontic and surgical operatory. The ligature is passed through the eyelet and twisted into a long braid with an artery forceps before bonding is undertaken. The braided wire, or pigtail, hangs loosely in the eyelet until bonding and suturing have been completed. It should be of sufficient substance for it to be rolled up into a loop, which will not easily be unravelled by extrusive forces. On the other hand, it must not be so thick that the effort needed to twist the braid or bend into a hook will seriously test the bond strength of the newly placed attachment. In practice, the use of a soft stainless steel ligature wire of 0.012 in. or 0.014 in. gauge is generally the most suitable.

A popular and simple modification of the stainless steel ligature recommends that the pigtail be braided in such a way that each two or three turns of the braid is followed by a small loop, then two or three more turns, another loop and so on. In this way, the braid comprises a convenient chain of loops, which may be shortened as necessary by cutting off the excess, while exploiting the loop closest to the gingival tissue [16]. However, as the tooth progresses, 'rolling up' the terminal loop of a merely twisted stainless steel ligature (Figure 2.5) is simple and eminently 'user-friendly'.

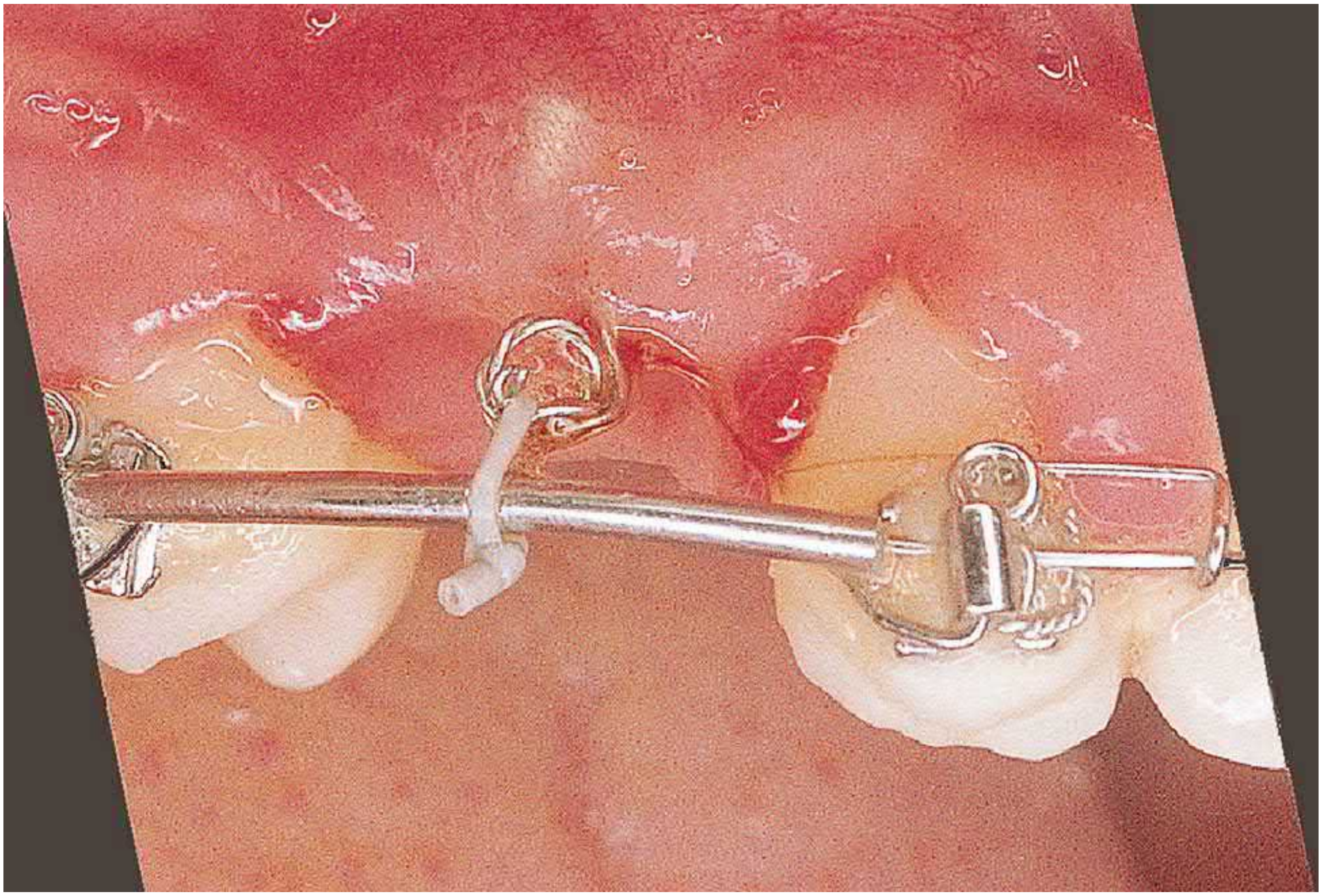


Fig. 2.5 A direct tie using a very short length of elastic thread.

Elastic ties and modules versus auxiliary springs

At first glance, elastic ties of one sort or another present the orthodontist with the most convenient means of applying light forces to a tooth, with a good range of action. However, their use is more disappointing than might initially be thought.

The manufacturer's spool of elastic thread usually comes in the form of fine hollow tubing, which is easier to tie than a solid elastic thread. Most orthodontists tie the thread with a simple knot that, when used to tie ordinary string, will not unravel. The stretch factor is set by trial and error, as there can be no accurate control on the amount of force applied. Unlike ordinary string, however, when tying elastomeric thread the knot tends to loosen and much of the original force of the connection will be lost. When subjected to tension, any of the materials that are used to make this elastic thread suffer very rapid and very significant force decay. Force levels of chains of various lengths are known to decay to below the force required for tooth movement. This takes place in a period of between one and three weeks, depending upon the amount of tension initially applied [17, 18].

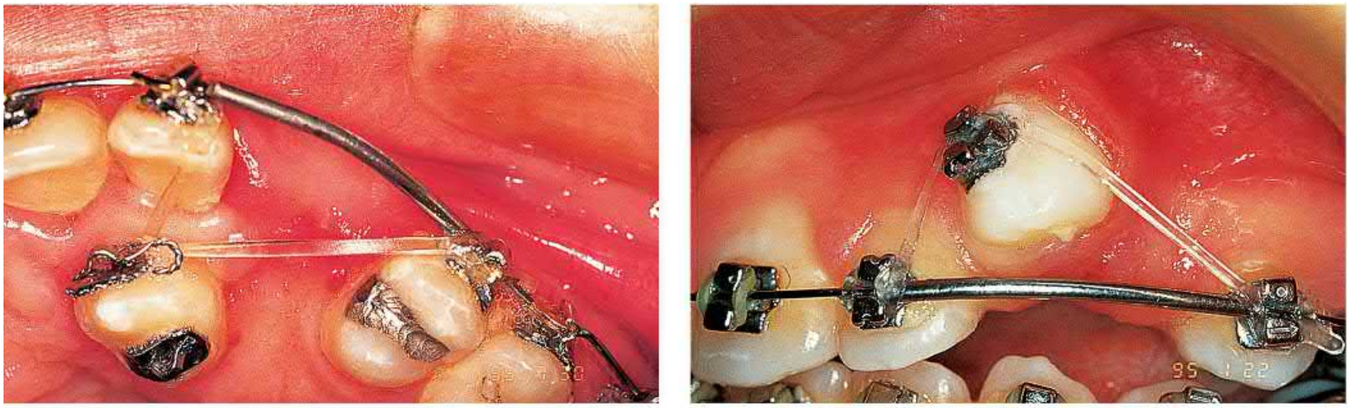
A shorter piece of stretched elastic (Figure 2.5) will have a very short range and run the risk of applying an initial excessive amount of force if the tie is good – or none at all, if the tie loosens. An excessive initial force could severely test the immature periodontal ligament (PDL) of the recently exposed tooth and the bond strength. In the case of an unerupted tooth close to the line of the arch, traction applied directly from its attachment to the archwire will generally be very inefficient, requiring frequent changes and producing a minimal response at each change. Moreover, for all practical purposes, it is impossible to measure or control such a force.

For these reasons, it is prudent to use more distant sites from which to apply traction to the unerupted tooth, where the greater length of stretched elastic thread serves to increase the range of the traction force and its effectiveness in moving the tooth over a longer period of time. To achieve this, the elastic thread needs to be drawn to the target area on the archwire, through the agency of a loop bent into the archwire at that point. The thread may then be tied back to the hook on the molar tube of the same side, with care being taken to insert a stop in the archwire, mesial to the tube, or indeed any other means that will prevent mesial movement of the molar.

The 'slingshot' elastic is an excellent alternative for the situation, in which space has been opened for an unerupted or partially erupted and buccally, palatally or superiorly displaced tooth. A cut piece of steel tubing or a closed coil spring may be fed onto the archwire between the brackets in order to maintain the space and an elastic chain or thread is stretched across the gap between the brackets on the two adjacent teeth. The middle of the chain is then gripped with an artery forceps or Howe plier and stretched over the attachment on the ectopic tooth (Figure 2.6a, b) or on the twisted steel ligature, coming through the sutured edge of a replaced surgical flap.

As a general rule, elastic thread should only be used as a link, connecting the non-elastic steel pigtail to a similarly non-elastic and heavy archwire. If a lighter flexible archwire is used, the tie should be made with a steel ligature – the archwire will then provide the elastic displacement. Nickel–titanium alloy wires may be used with great effect in this context, but the distortion of the archwire will bring about alteration in both the horizontal and vertical planes, to produce unwanted change in the form of the dental arch and an uneven occlusal plane, i.e. loss of anchorage. Therefore, if a single super-elastic archwire is tied into the brackets on each of the teeth in the levelled and aligned arch and then into an attachment bonded to a severely displaced impacted tooth, control of overall archform will be lost. This will be evident in the three planes of space, causing tipping movements of individual teeth, alterations in the occlusal plane, asymmetrical skewing of the shape of the arch and loss of occlusal contacts. The adjacent teeth will be relatively intruded and will be displaced buccally or palatally and tipped towards the space reserved for the impacted tooth. Super-elastic wires should not be used in circumstances of displacement without a heavy base arch in place capable of resisting these unwanted movements of the immediately adjacent anchor teeth. However, it should be clearly understood that for a nickel–titanium archwire to develop adequate vertically directed eruptive force, it must be free to slide in the bracket slots of the other teeth to which it is ligated (Figure 2.7a, b). The presence of a heavy base arch tied in with elastomeric ligatures will, however, considerably increase the friction and binding of the super-elastic archwire in the brackets. This may not be evident when the elastomeric is first placed and it is difficult to check. As a consequence, the pressure from the deflection, which was applied in order to fully engage the super-elastic wire in the slots, may be nullified by the inability of the wire to slide freely through the brackets.

The combined use of a flexible archwire and an elastic thread tie [7] will be counterproductive, since the elasticity of the one that exerts the stronger force will be effectively neutralized and offer no physical advantage over a steel ligature. At the same time, the displacement of the weaker element will be the only factor that will be active in moving the teeth.



(a) (b)

Fig. 2.6 (a) The slingshot elastic. A palatally impacted canine has erupted into the palate (see Chapter 7). The elastic chain module, placed between the bracket of lateral incisor and first premolar, is stretched towards the canine and ligated to the buccal eyelet. The steel tube on the archwire maintains the space. (b) The slingshot used on a buccal canine.

Orthodontists generally use elastic ligatures and chains to move teeth by tying the material in its stretched, elongated form, thereby drawing the dental elements towards one another. However, the range of elasticity in this longitudinal direction will be limited and, as pointed out above, will decay rapidly. Nevertheless, a lateral displacement of an elongated elastic thread produces a potentially greater range of movement, within suitable orthodontic force levels, than does a longitudinal displacement. This 'slingshot' principle may be more efficiently applied to move teeth that lie at a distance from the main arch, giving more controlled and measurable forces (Figure 2.7a, b).

(a) (b)

Fig. 2.7 (a, b) The use of nickel–titanium auxiliary wire as the active element in applying eruptive force to the unerupted canines, by being thread through the 'rolled-up' stainless steel pigtails that are ligated to the eyelets. There is a heavy 0.020 in. gauge base arch. The low-profile eyelets, which were bonded at exposure in a closed surgery procedure, can be seen through the translucency of the healthy and uninflamed gingiva.

Notwithstanding these comments and with the required careful consideration in the planning of their use, elastic ties, nickel–titanium auxiliary archwires, chains and modules are extremely helpful in many situations created by the presence of impacted teeth. However, properly designed springs, auxiliary to a heavy base arch, are usually more efficient: they are able to deliver a measured and controlled force, the force decay is lower, a variety of metallic alloys are available for spring fabrication, their range of action may be very broad and their direction is accurate. These will be illustrated in the succeeding chapters in the consideration of cases as they pertain to the individual groups of teeth.

Thus far, our discussion has centred on maintenance of a steady force through as wide a range as possible. Now we must address the force values that are appropriate for application to an impacted tooth.

When planning traction to a single-rooted tooth through its long axis, pure extrusion is produced with no resistance from the bone of the coronally divergent socket. Thus, the force is applied to the tooth and transferred directly to the supporting fibres of the PDL. As such it requires to be minimal – of the order of 10–15 g – because resistance is small. If a greater force is applied, the tooth may become excessively loose and the extrusion achieved will bring with it relatively little supporting alveolar bone.

If we then introduce a modicum of tip into this movement, then the tooth will be brought into close proximity with the bony socket walls, thus interjecting resistance. Compressing the fibres on the pressure side and stretching them on the tension side will generate hyalinization and cause undermining resorption of the alveolar bone. The force required to elicit eruption will be in the range of 20–40 g/cm^2 of root surface.

Soft tissue resistance must also be taken into consideration. With a simple window technique exposure, the crown of the tooth is free to erupt directly to its place, with little or no interference from the soft tissues. The full traction force is transmitted to the PDL at the cementum/alveolar bone interface. By contrast, a closed eruption technique will leave the tooth covered by a soft tissue flap, which will have been firmly sutured into its former place. Some of the applied traction will then be dissipated in overcoming the tension of this soft tissue flap and must therefore be increased to reach the threshold needed for tooth movement.

When traction is applied to a tooth following an apically repositioned flap procedure, tension is created in the tissues by virtue of the fact that the flap has been sutured superiorly to the labial side of the tooth. This tension is eruptively directed and may then cumulatively magnify the applied force. For this reason, it is sometimes advisable in the first instance to rely only on pressure from the sutured flap, leaving the application of biomechanical traction to a subsequent visit. This is particularly relevant in cases where the tooth is high and labially or buccally displaced.

Temporary anchorage devices

Bone anchor screw

Treating impacted teeth largely has to do with the facility to develop vertical eruptive forces and to bring them to bear on 'vertically challenged' teeth. At best, there is very little bone in the same jaw coronal to an impacted tooth at the outset, and certainly less or none after the tooth has been surgically exposed. This leaves precious little opportunity to establish an 'anchor' against which to tie elastic modules and chains for the horizontal movement of teeth in various directions [19, 20]. As a means of obtaining skeletal anchorage, a simple titanium screw temporary implant is often used in routine orthodontics. A screw device is placed as the base, to which traction may be applied from a small distance to attempt to obtain an appreciable range of action.

In this limited sense, therefore, using a temporary anchorage device (TAD) in the same jaw as the impacted tooth is largely inappropriate. Some of these screws are designed with two slots at right-angles to one another, which serve as the means for driving the screw into the bone, but may also be used as an orthodontic bracket slot into which a rectangular archwire may be ligated in the usual manner. Other designs include a slot for an orthodontic archwire in the neck of the screw, beneath the screw head. A short length of rectangular 0.019 in. × 0.025 in. wire may be fabricated into a custom-made, self-supported spring. This is then rigidly tied into the slot on the screw, which will have been placed at some distance and in a more convenient mesial, distal or apical location in relation to the impacted tooth. The screw (the anchor) may then be used as a platform from which to apply traction to the tooth and to erupt it vertically to a considerable degree.

Using a TAD as a direct anchor in the opposite jaw, in the absence of an orthodontic appliance, has the clear advantage that there can be no adverse (particularly intrusive) movement of the teeth adjacent to the impacted tooth, since these are not exploited as anchor units. Nevertheless, this method demands the cooperation of the patient in the placement of intermaxillary elastics, stretching from the device to the pigtail ligature hook, which itself extends from the bonded orthodontic bracket/button/eyelet on the impacted tooth. These two rigid extremities on which to place the elastic are not always easily accessible for the patient or even for a dedicated parent, and may accordingly prove to be impractical in some cases. To circumvent this problem, it will be necessary to place a full orthodontic appliance, which is stabilized by ligation to a TAD on the affected side in the opposing dental arch. This provides an implant-supported anchor arch configuration. Intermaxillary traction from any conveniently located hook or bracket on that appliance may then be applied directly to the attachment on the impacted tooth, without fear that the teeth in the anchor arch will over-erupt. This will also assume that the attachment hook on the impacted tooth is accessible for the patient and is not painful to manipulate.

Impacted second molars, which are largely inaccessible for the patient, require a more circuitous approach. This approach dictates setting up the same implant-supported configuration in the opposing anchor arch, but in this case a full appliance also needs to be placed in the affected arch.

The logistics are as follows:

- An accessory archwire, custom-designed eruption spring or elastic chain is ligated in active mode between a convenient location on the main arch and the attachment on the impacted tooth, the aim being to erupt the tooth.
- In order to overcome the tendency of the reactive force to intrude the teeth on that side of the dental arch of that jaw, vertical elastics are prescribed to be placed by the patient between convenient and easily accessible hooks or buttons between upper and lower appliances.

An indirect anchorage system is thus created in which active extrusive forces are applied and controlled by the orthodontist. Loss of anchorage in the same jaw (intrusion of the teeth) is combatted by the patient placing intermaxillary vertical elastics. Loss of anchorage in the opposite jaw (extrusion of the teeth) is prevented by ligation to a TAD in that jaw (Figure 2.8a–c).

When a maxillary impacted canine does not respond to extrusive forces that are applied from a molar-to-molar, fully bracketed orthodontic set-up, it may be due to ankylosis or to invasive cervical root resorption (ICRR). As the result, a distinct cant of the occlusal plane is produced, due to intrusion of all the teeth ligated to the archwire, but mostly of the immediately adjacent teeth (Figure 2.8), illustrating severe loss of anchorage. If the orthodontist then looks to include the mandibular dental arch to increase the anchorage, while maintaining the extrusive force on the canine, there will be no improvement, but the teeth in the lower jaw will begin to over-erupt and a cant will develop in that jaw.

Once the diagnosis has been made, the canine needs to be disconnected from the extrusive element and the cant must be corrected. In order to achieve this, a TAD screw should be placed in the lower jaw and linked by an elastic chain to the full lower archwire. This indirect anchorage system guarantees the anchorage potential of the mandibular dentition. The over-eruption and asymmetry may be corrected by vertical intrusion in the mandible and, with intermaxillary up-and-down elastics, vertical extrusion in the maxilla, to restore the occlusal plane and the occlusion to normal. Only if the ICRR or ankylosis of the canine can be treated successfully can vertical forces then be reapplied, with the expectation of a positive outcome.

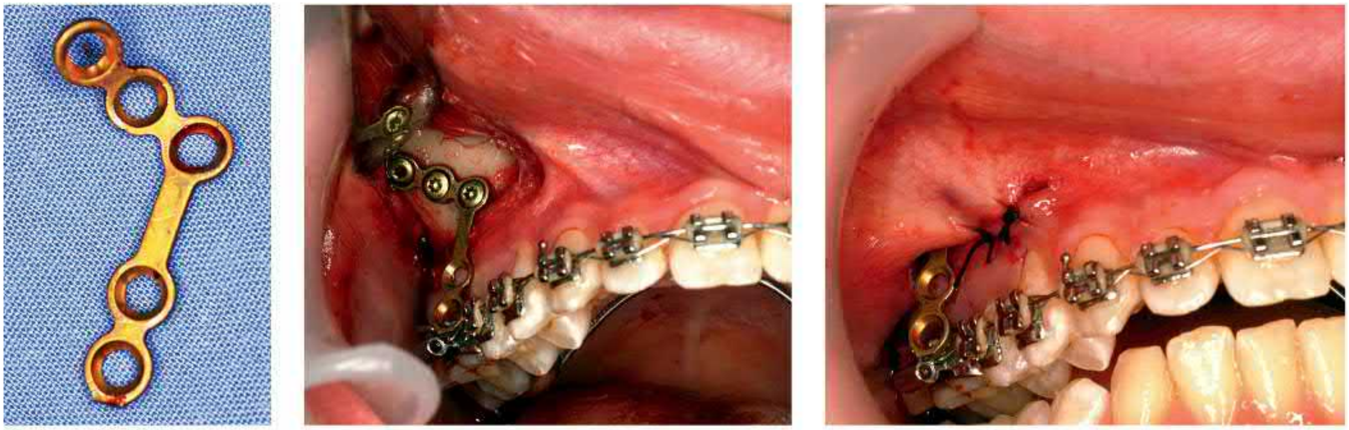
The phenomenon of non-eruption of a tooth in one jaw is often accompanied by over-eruption of its antagonist, particularly in the molar region. The ostensibly successful resolution of an impacted mandibular second molar may actually be prejudiced by being prevented from reaching the occlusal plane, due to its elongated opposite number. To treat the over-erupted tooth, a simple titanium screw implant may be inserted on the palatal side of the alveolus adjacent to the second molar and an elastic chain stretched from this TAD to the zygomatic plate, across the occlusal surface of the tooth. In this manner, intrusive force is applied by the chain and a rapid reduction in the height of the tooth may be achieved. This reduction in height will then permit the vertical elastic from the plate to the mandibular second molar to erupt the tooth to its ideal height in relation to the occlusal plane, without the need to involve conventional multibracketed orthodontics in the eruption process.

It has been shown that titanium screws have a success rate in excess of 80% [20], although this author is unable to reach that level of success. Notwithstanding the fact that the screws are easily and rapidly replaced in the event of failure, the very failure itself creates a nuisance in the smooth running of the treatment. Accordingly, in cases where considerable movement is needed on a fairly long-term basis, a good alternative is the use of a malleable titanium plate onlay. This may be adapted to the shape of an area of bone surface, such as in the palate or the inferior surface of the zygomatic process of the maxilla [21]. Titanium screws are then used to secure the plate to the strategically selected area, and the flap sutured to leave only the extremity of the plate exposed at one end, for use as an elastic attachment device. The zygomatic plate TAD appears to be much more successful in terms of its reasonably long-term usefulness and has been shown to have a much lower failure rate than screws [22].

Fig. 2.8 An indirect anchorage system. (a) Extra-oral view to show tipped occlusal plane due to anchorage loss during the attempted active eruption of the non-responsive left maxillary canine. (b) Intra-oral view of the same case shows the exposed canine ligated with elastic ligature to the first premolar. The space was held open by a steel tube tied between the incisor and premolar brackets. The extrusive force had resulted in the lateral open bite and cant of the occlusal plane. (c) Vertical intermaxillary bite-closing (blue) elastics were used to support the anchorage of the maxillary arch. The mandibular canine bracket was ligated to a titanium screw temporary anchorage device with an elastic chain, to prevent unwanted reactive eruption of the lower teeth.

Zygomatic plate

Zygomatic plates (Figure 2.9a–c) may be used as the direct source of anchorage for intermaxillary and intramaxillary elastic attachment. Their placement is surgically more demanding than the bone anchor screw and they are generally inserted by an oral and maxillofacial surgeon. Notwithstanding this disadvantage, the zygomatic plate has several inherent advantages over screw TADs. In the first place, since it is not placed on the alveolar ridge, it can be used as the base from which to apply traction to move teeth in the mesio-distal plane over long distances, without impediment and without the need to alter their positions in the light of progress. Thus, if placed bilaterally in a young adult patient, they may be employed in place of the much-hated, user-contentious and under-worn extra-oral headgear for efficient horizontal distal movement of all the posterior teeth, *en bloc*, in the treatment of a class II case.



(a) (b) (c)

Fig. 2.9 Zygomatic plate. (a) An onplant plate. (b) The plate is held in place by three screws into the inferior surface of the zygomatic arch. (c) The extension portion is drawn through the edges of the fully replaced and resutured surgical flap.

Zygomatic plates also have excellent application in the vertical plane, as in the treatment of open bite cases that are due to or in association with forward tongue posture and abnormal swallowing behaviour. In these patients there is an increase in the height of the lower third of the face and the maxillary posterior teeth are over-erupted, with elongated alveolar processes. To close the anterior open bite by extrusion of the incisor teeth is both counterproductive in terms of the face height and highly unstable. On the other hand, it is easy to apply vertically intrusive force to the posterior teeth and achieve a significant reduction in the lower facial height. It should be remembered that 1 mm of molar intrusion is reflected as 3 mm of anterior open bite closure, simply because the incisors are that much further away from the temporomandibular joint centre of the mandibular rotation. The plate should be supported by placing a transpalatal bar between the molars, to prevent buccal 'rolling' of these teeth that would occur by applying the intrusive force from the zygomatic onplant plate to an unsupported single molar. The intrusively directed force is then distributed to the bracketed posterior teeth through the agency of an archwire that must reach all the way to the last erupted molar on each side. Intrusion of posterior teeth, rather than extrusion of anterior teeth, may produce more stable results in what seems to offer a greater chance for correction of the abnormal tongue and swallowing anomalies. It should be understood that the prognosis is still in doubt but, if considerable clinical experience (in the declared absence of solid evidence) is anything to go by, probably improved.

In the immediate context of the treatment of impacted teeth, however, this procedure offers advantages for problems that are difficult to overcome by other means, and nowhere is its efficacy easier to demonstrate than in relation to the resolution of an impacted second mandibular molar. If an attempt is made to elevate an impacted mandibular molar, particular one with a distinct mesial inclination beneath the distal bulbosity of the first molar, a great deal of anchorage potential may be expended in its alignment. To use the remaining teeth as the base from which the extrusive force is to be applied will rapidly cause marked intrusion of these teeth and a strong cant in the occlusal plane. In time, this may then secondarily cause an asymmetrical deterioration in the maxillary occlusal plane.

Had the opposing teeth been used as the anchorage base, rapid extrusion of these teeth and a cant in the upper occlusal plane would be generated. Furthermore, the maxillary second molar may already have over-erupted *a priori*, in the absence of the unerupted mandibular second molar, and may even be impinging on the soft tissue overlying this impacted tooth. Clearly, therefore, intra-arch or inter-arch tooth-borne mechanics are completely inappropriate unless backed up by some form of skeletal anchorage.

The over-eruption of an unopposed maxillary second molar is usually recognized by its vertically prominent mesial marginal ridge in relation to the occlusal plane, as represented by the distal marginal ridge of the first molar. This needs to be corrected concurrently with orthodontic eruption of an impacted mandibular molar, to bring it into occlusion at the level of the occlusal plane. To this end, an elastic chain may be drawn across the occlusal surface of the over-erupted maxillary molar from a palatal screw TAD to the intra-oral extremity of the zygomatic plate implant.

At the same time, a vertical intermaxillary elastic may be placed by the patient from the same intra-oral extremity of the zygomatic plate, to an attachment on the impacted tooth in the mandible. In this manner, it is easy to balance the degree of extrusion of the one with the degree of intrusion of the other, in relation to the occlusal plane. For these movements to be completed, no brackets or other appliances need to be placed on any of the other teeth. Furthermore, no retainer appliances need to be placed at the end of this phase of the treatment.

It will be appreciated that the zygomatic plate is an important device that may be used as a support to move a tooth mesially or distally and to extrude or to intrude a tooth. It may also be employed as an anchor base to safeguard against movement of a block of teeth and to move a large number of teeth at one and the same time. It may be used for intermaxillary up-and-down stability in the correction of vertical discrepancies and, antero-posteriorly, for class II or class III correction.

Ankylotic, infra-occluded, implanted or otherwise non-movable teeth as bone anchors

There are several situations where an erupted or partially erupted deciduous or permanent tooth cannot be moved. Ankylosis is usually the term given to these teeth, although infra-occlusion of deciduous or permanent teeth may not necessarily be due to ankylosis. Successfully replanted teeth that have been avulsed as the result of trauma are usually ankylotic. These teeth may often be included in an orthodontic appliance to act as bone anchors, in much the same way as described above regarding the zygomatic plates and screw TADs. Accordingly, they may be used as the base against which orthodontic forces may be applied to other teeth.

Magnets

One possible source for the application of suitable forces is the rare earth magnet. These magnets were developed more than 60 years ago, and it has more recently become possible to reduce them in size with the introduction of lanthanide alloys, so that now they may be exploited in the present context. The professional literature has presented successful clinical results of the treatment of impacted teeth in humans [23–26] using magnetic forces. The 'pull' of the rare earth magnet is generated along the line of the magnetic plane and in consequence it is possible to prescribe tooth movement in all three planes [27, 28]. However, these magnets corrode significantly in the intra-oral environment and have to be carefully coated in order to render them safe. A parylene coating has been shown to seal them successfully and, when embedded in acrylic appliances, these magnets can be isolated from the intra-oral environment and protected from heavy biting forces [28].

There are a number of other significant problems with the use of the rare magnet. The attracting forces that exist between the two magnets are in inverse proportion to the square of the distance between them. This means that when employed in order to move displaced or ectopically positioned teeth, the magnet that is sited on the appliance must be placed close to the magnet that has been bonded to the displaced tooth, otherwise the force between them will be too low. Furthermore, if the magnets are not ideally sited one on top of the other, there will be a dramatic drop in force level [28, 29].

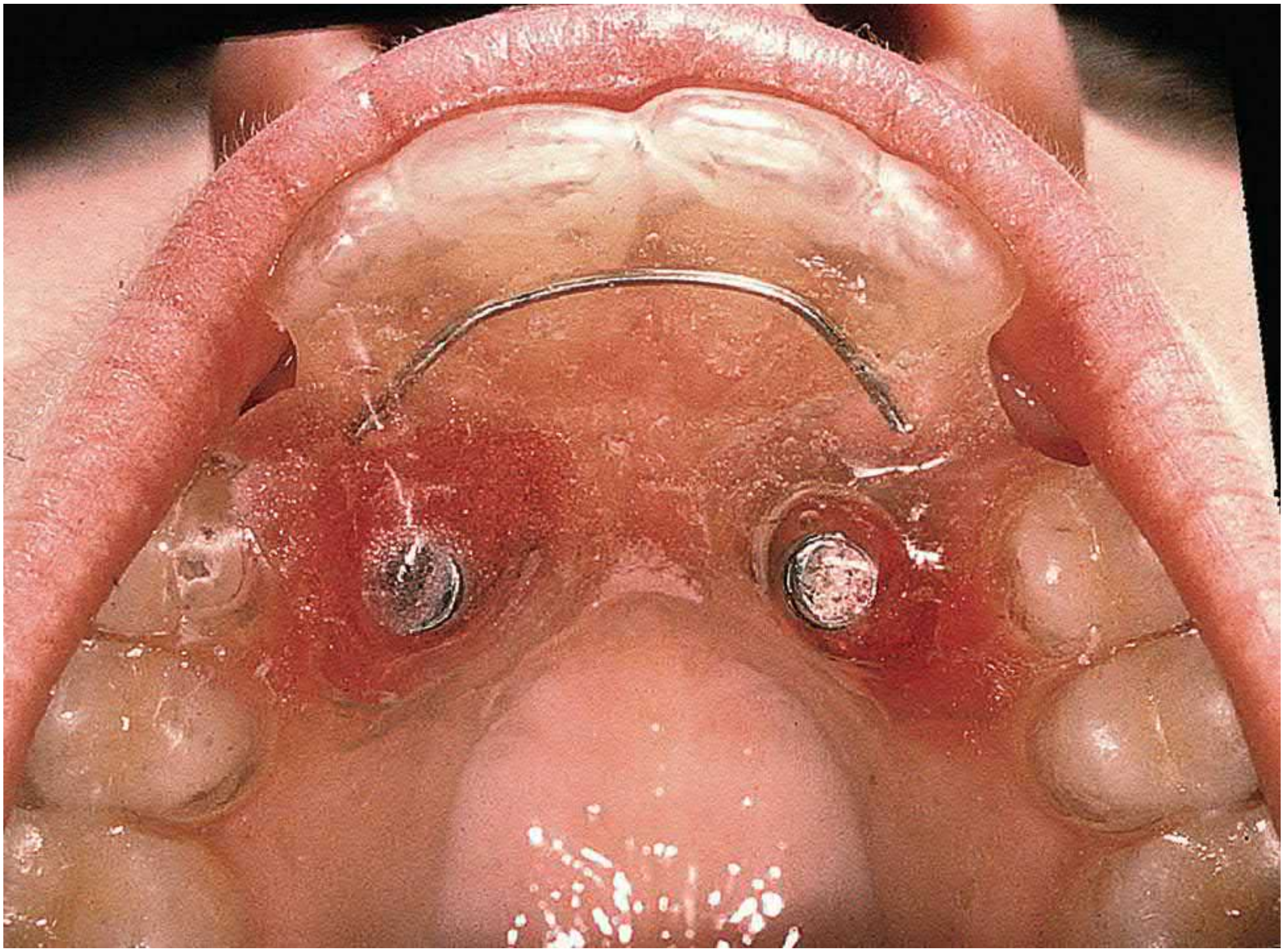


Fig. 2.10 The bonded magnet 'backpack'.

Courtesy of Professor A. D. Vardimon.

The notion that traction may be applied without the need to trail a wire or a chain through the soft tissues of the palate has a definite appeal to professional authors. They speculate that this will improve the ultimate periodontal condition of the teeth, since 'eruption simulates a normal eruption process'. However, the following points should be remembered:

- The tooth must in any event initially be surgically exposed.
- The magnet must be bonded to it.
- An open exposure will be indicated for a very superficial and mildly displaced tooth.
- For a deeper and markedly displaced tooth, the flap must be partially or fully replaced and healing must occur.
- The tooth must then travel through the tissues with this relatively large magnetic 'backpack' (Figure 2.10).

Each of these caveats will present an obstacle that signifies a departure from the similarity to a tooth that has erupted normally. Even if the idea is 'attractive' [30], the use of magnets for impacted teeth is still in its early developmental stages and seems to have been largely lying dormant since the mid-1990s. The methods that have been described still demonstrate a number of technological disadvantages, the size of the magnets and the inverse square rule of their force of attraction being the most pertinent. At the present time, this method cannot yet be seen as an unequivocal substitute for the more traditional and conventional methods described above [31–34] and has largely been sidelined.

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3
Biomechanics for Aligning Ectopic Teeth

Ulrich Kritzler and Katja Chromy

Basic principles

Statically determinate and statically indeterminate systems

Consistent and inconsistent systems

Appliances

Useful adjuncts

Appendix: Colour code convention for moments and forces

Basic principles

In orthodontics the application of appropriate forces and moments is necessary for full control during tooth movement. The chosen appliance will influence the rates of tooth movement, potential tissue damage and pain response [1, 2]. However, this is only one side of the equation, because there is a consequential and equivalent opposite reaction to these forces and moments, which will act on the anchor teeth and must be resisted [1, 2].

An understanding of applied biomechanics guides the orthodontist to determine how to maximize the former (the application of appropriate forces) and control the latter (the opposite reaction). When the clinician has determined the treatment goals and has established a sequence of treatment, the force systems needed for reaching those goals can be developed by optimally selecting and combining forces [1–3].

In order to succeed, the orthodontist must have a clear strategy to promote the desired tooth movement. Well-defined treatment goals described in all three planes of space, followed by the application of a goal-oriented appliance, are key to the solution of most problems encountered when aligning impacted teeth. Only an appropriate application of force can efficiently generate this displacement [4].

We are often presented with facile solutions to our mechanical problems utilizing brackets and wires, but these are mostly inappropriate. While they represent efficient marketing, and serve the interests of the supply company, they are not a panacea for all biomechanical obstacles.

So long as biological and mechanical principles and experience in manual skills are ignored, the orthodontist will inevitably encounter the same problems with every kind of appliance. These principles and skills are the very foundations upon which the profession is built and must be employed if the ectopic tooth is to be moved into the arch and aligned efficiently [3].

In order to achieve this, the first step is to determine the exact 3D location of the ectopic tooth to be moved, its shape and its proximity to the adjacent teeth.

In the nature of things, the individual tooth will likely be displaced at a distance from and essentially outside its normal location area, where all methods of movement may be conveniently applied. Accordingly, initial single-point forces will be generally employed for the purpose of bringing these teeth into a more convenient and accessible location, from where sophisticated orthodontic 3D control of movement will be feasible, referred to elsewhere in this volume as the ‘orthodontic ballpark’. A single-point force has both magnitude and direction. When a force does not act through the centre of resistance (CR) of a tooth, the tooth will rotate, the CR will move in the direction of the line of that force, and the tooth will simultaneously rotate around the CR [5].

It is important that the point of force application on the ectopic tooth be as near as possible to the tip of its cusp, thus enabling the formation of a mental picture of the tooth in relation to its immediate vicinity and assisting in planning its projected movement.

Force application to a single point of contact is restricted to producing extrusive and tipping forces and should be used for as long as the ectopic tooth has not been brought close to its desired place in the arch.

Current literature supplies no evidence regarding the relation between force magnitude and rate of tooth movement and there is no evidence-based force level that can be recommended for the optimal efficiency in clinical orthodontics [6]. However, the available evidence from animal experimental studies indicates that the optimal range is 25–35 cN [7, 8]. It is these light forces that should be used to bring the tooth into the arch [1, 2, 8].

Forces act in a straight line [4, 9]. Accordingly, if there is an obstacle in the direct path to the target site, the tooth must initially be moved in a different direction, in order to avoid the obstacle and bring it to a location from where a straight line may then be achieved.

If resorption of the roots of adjacent teeth is evident or appears likely to occur, it will be essential to undertake treatment at the earliest opportunity in order to distance the offending tooth from those roots [10].

Statically determinate and statically indeterminate systems

When a force is acting on a single-point contact on the ectopic tooth, i.e. there is no wire that is fully engaged into a bracket slot, such systems are defined as statically determinate [2]. The biomechanical systems that are statically determinate are simple and efficient because the forces and moments to be applied are easy to calculate, using simple measurements of appliance forces and distances [2].

In statically indeterminate systems the wire is engaged in the brackets of all teeth, including both the active and the reactive (anchor) units of the system. The extent of the forces and the moments developed in relation to the brackets are determined by the wire deflection. When the wire is inserted into two bracket slots, the force systems that are developed in the two units interact and consequently cannot be measured directly. A continuous arch can be considered as a long series of statically indeterminate systems [2].

Consistent and inconsistent systems

When an archwire is inserted into a series of malaligned brackets, it will produce both forces and couples at each bracket. When both the force and the moment at the bracket are in the correct direction in relation to their suitability to produce the desired tooth movement, the force system is termed consistent [1, 2]. If only some forces or moments are in the required direction, the force system is considered inconsistent [1, 2]. Consistency, therefore, usually refers to a force system where both forces and couples are needed.

Sometimes, however, either the applied force or the couple may not be required or they may produce an undesired side effect. In addition, if a side effect force or couple is present, the force system will also be considered inconsistent [1, 2]. Inconsistency is often the reason why a straight-wire appliance may encounter a poor response [1, 2].

Appliances

Orthodontic forces are obtained by deflection or torsion of flexible wires and cantilevers, and by activation of springs and elastics.

An important characteristic of the force systems generated by a cantilever or by well-maintained up-and-down elastics is their high degree of constancy over time and deactivation (qualitative constancy).

In direct contrast, the force system generated by a straight-wire appliance is only determined by the mutual relationship between the brackets and the wire [3]. Placing straight wires into badly placed brackets may or may not result in favourable tooth movement, depending on the geometric relationships between the brackets [11].

It will become apparent that these limitations in the straight-wire approach can unmistakably influence orthodontic outcomes [3]. Using a so-called customized straight-wire approach with predetermined prescription brackets and utilizing robot-formed wires cannot replace the manual skill of the orthodontist, neither can it render the biological and mechanical basis upon which the profession is built redundant [3, 4].

Ideal orthodontic care achieves individualized, predetermined treatment objectives. The selected course of action should address the patient's problems and meet the individualized goals. These components imply that different patients require different treatments, which means that one appliance design (brackets prescription, archwire sequence, etc.) will not be capable of solving the problems of all patients [1–3].

In a continuous arch technique, where the number of variables is unknown or not measurable, the system becomes statically indeterminate and orthodontic prediction becomes impossible.

It is therefore clear that a purely straight-wire approach cannot replace the custom-made appliances needed to accomplish the specific goal of aligning an ectopic tooth efficiently.

The orthodontic tooth movement can generate bone and it is important to recognize that teeth can be moved 'with bone' or 'through bone'. The tissue reaction that determines whether the movement is with bone or through bone depends on the stress/strain distribution in the periodontium surrounding the loaded teeth [3]. The displacement of teeth into edentulous areas or outside the initially given envelope without loss of attachment has demonstrated that teeth can be displaced with bone if the stress/strain distribution can be controlled [3].

No standard bracket design can deliver individualized treatment objectives. Only the orthodontist can control the specific characteristics of the force system to be used in treatment. The optimal alignment of ectopic teeth can only be resolved by the application of a custom-made appliance, using a force system generated by wire bending [3].

Treatments should be performed with individualized appliances that adapt the force system to the patient and not the patient to the force system.

The active units

There are six basic elements employed in the treatment mechanics, specifically for the alignment of ectopic teeth. They are:

- The cantilever.
- The torsion/ballista spring.
- Elastics or closed-coil springs.
- Piggyback arch wire.
- The V bend/root spring (alpha–beta spring).
- Torqueing auxiliaries.

Preference depends entirely on the directional requirement of the movement needed and the proximity of the ectopic tooth to the continuous archwire.

Cantilevers

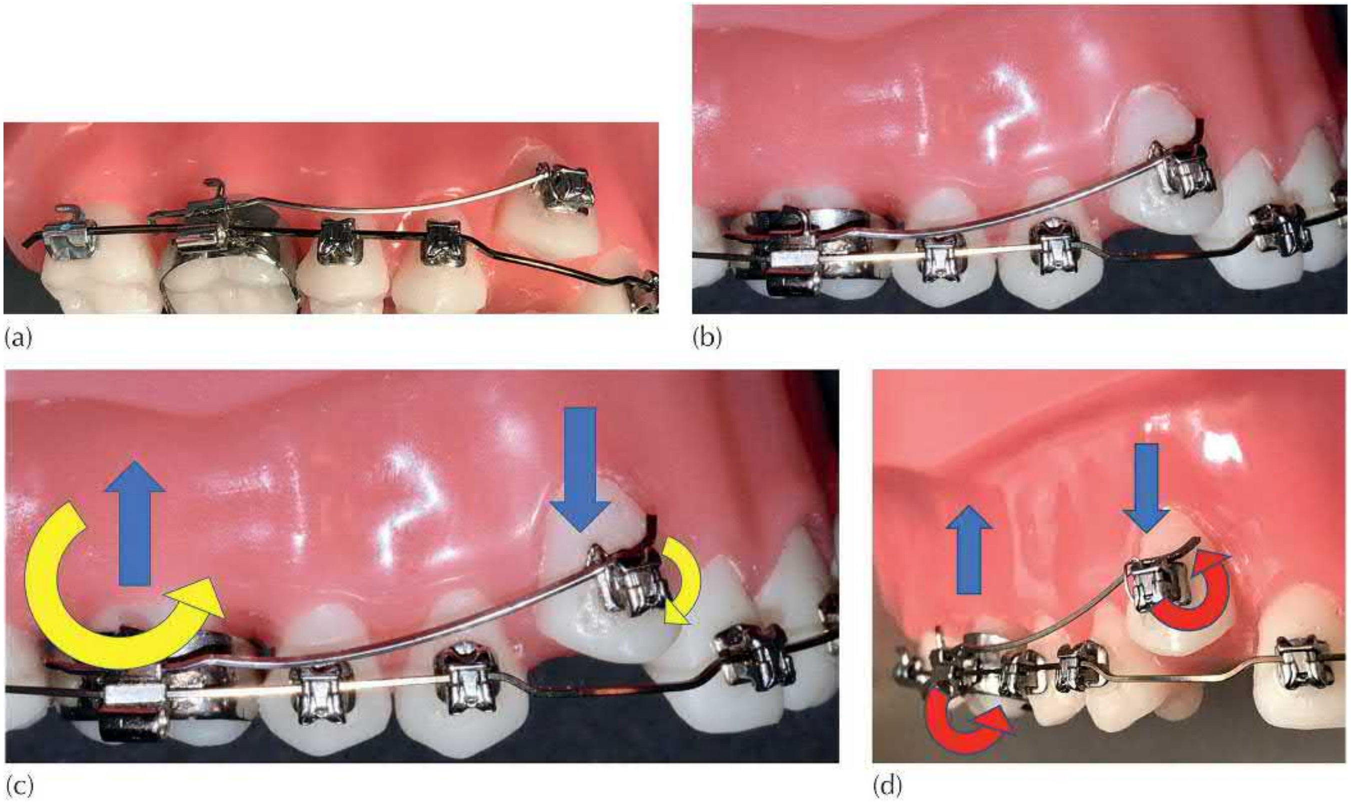
Cantilevers are useful in the delivery of a single extrusive and/or lateral force. A cantilever system is characterized by a pure force acting at its extremity (the free end) with single-tooth contact. Its other end is engaged in a bracket, slot or tube, where it exerts an equal and opposite force and a moment [12, 13]. The cantilever system may be used in many modifications. As a rule, the cantilever should be as long as possible in order to decrease the force and increase the deflection (activation distance or range). The auxiliary tube of the first molar bands is most suited for engaging the cantilever, since it prevents excess play in the tube. It will accept a 0.016 in. × 0.022 in. cantilever wire in a 0.018 in. or a 0.017 in. × 0.025 in. cantilever wire in a 0.022 in. strap-up.

With a statically determinate force system, where forces and moments are either known or measurable, the behaviour of the impacted tooth is mostly predictable. Impacted teeth need movement in two directions. An eruptive force is needed to bring the tooth to the level of the occlusal plane and a horizontal (buccal or mesio-distal) force to bring the tooth into alignment in the arch. This may be achieved using a cantilever. However, it may also be achieved using a triangular elastic (1/4 in., 6 mm/70 cN) to the two opposing teeth, provided that they are engaged in a rigid continuous archwire in the opposing arch.

Cantilevers are made either of beta-titanium (TMA) wires, Connecticut New Archwires or nickel–titanium (NiTi) wires. When using NiTi wires, bends should ideally be made with a hammerhead plier, or the Sander Memory Maker, to maintain the desired cantilever shape. Using a range of different types of wire for cantilever construction allows the orthodontist to use light forces, which can easily and usefully be measured with a gauge, in combination with long ranges of activation.

Cantilever for extrusion of buccal displaced canines

The force system is acting on the canine and first molar (see Figure 3.1a–d). The cantilever will produce forces and moments in different planes of space. In the sagittal plane (Figure 3.1c), note the stepped bypass created in the otherwise continuous archwire. The vertical plane is shown in Figure 3.1d. Forces and moments are shown 2 dimensional for simplicity's sake. The plane of space they are acting in is indicated by their colour. A colour code convention table (Table 3.1) is annexed.



(a) (b) (c) (d)

Fig. 3.1 (a) Buccal cantilever for extruding a canine. In practice, an eyelet is often to be preferred in the early stages of the canine eruption. (b) The whole arch comprising rectangular wire is used as an anchorage unit. Cantilevers are inserted in the utility tube and tied with a one-point contact to the displaced tooth. (c) Activation of the spring by tying it to the impacted canine creates an extrusive force on the canine, an intrusive force and a tipping moment on the molar in a crown mesial root distal direction (sagittal plane). The moment in the auxiliary tube is equal to the product of the applied force and the distance between the centre of resistance (CR) of the molar and the point of force application on the canine. If the extrusive force does not pass through the CR of the canine, an additional but small moment will be generated on the canine in the sagittal plane. (d) Activation of the spring by tying it to the impacted canine creates a third-order couple at the molar, an intrusive force at the molar and an extrusive force at the canine. If the point of force application at the canine is lingual to the CR of the molar, buccal root torque will be generated at the molar tube instead of lingual root torque.

Cantilever for extrusion and buccal movement of palatally displaced canines

The cantilever configuration is shown in Figure 3.2a–d. The force system is acting on the canine and first molar, and moments and forces are generated in the horizontal and sagittal planes.

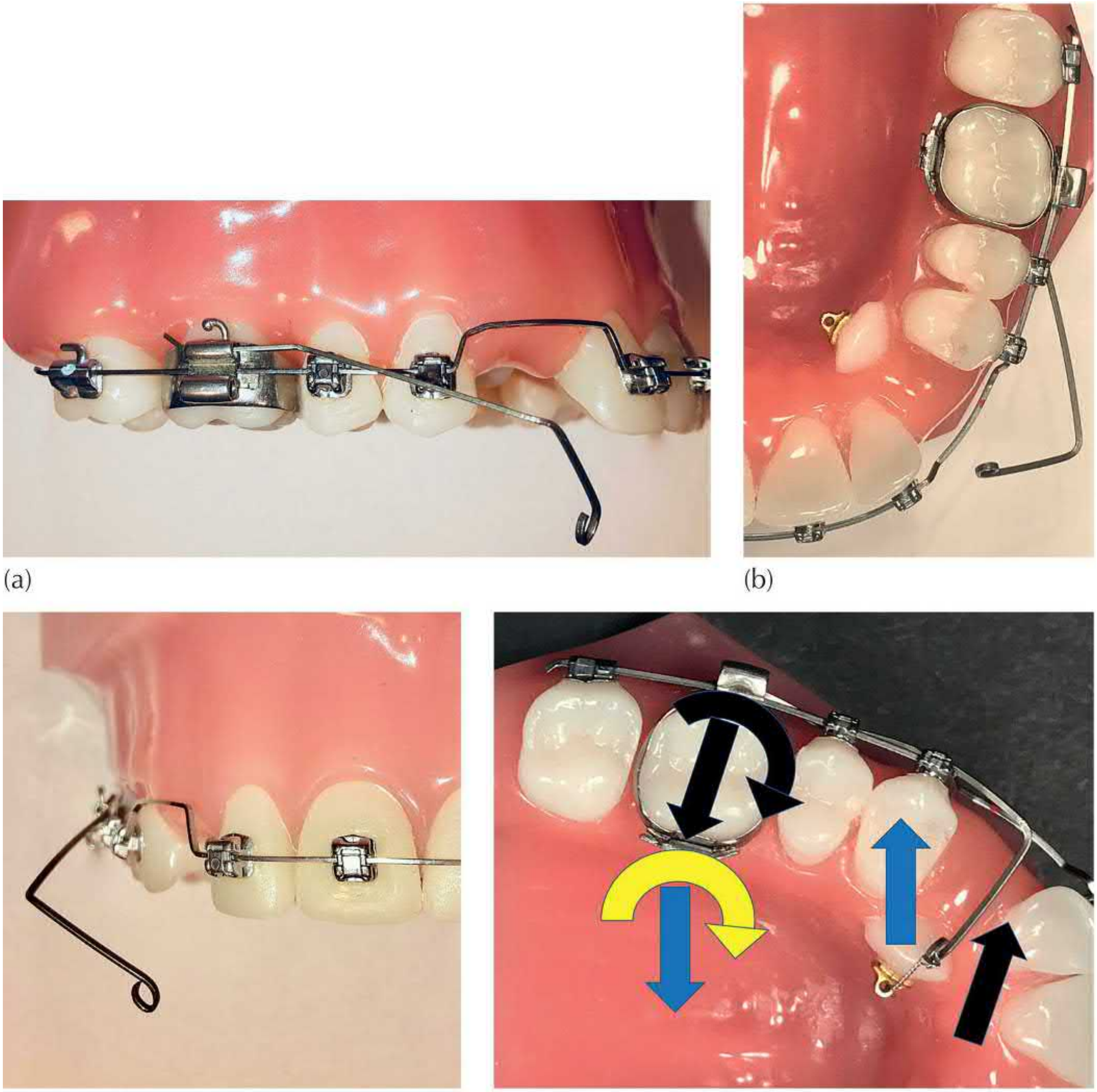
In cases of palatally displaced canines, the force system for the extrusion of the canine is different regarding the third-order displacement of the molar, because the applied force is acting palatal to the CR.

For buccally engaged cantilever systems in 0.018 in. strap-ups, a transpalatal arch (TPA) would be preferred for stabilization of the buccal segments.

All buccal cantilever systems should be used with a bypassing but rigid base arch.

Composite TPA TMA cantilever

TMA cantilevers (0.018 in. TMA) can be welded to a TMA TPA (0.032 in. × 0.032 in. or 0.032 in. round) and used for erupting palatally displaced canines (Figure 3.3a, b). Possible side effects resemble those created by buccally engaged cantilevers and should be countered with a stiff rectangular continuous bypass archwire.



(a) (b) (c) (d)

Fig. 3.2 (a) The passive cantilever, made of rectangular wire, extends from the molar auxiliary tube and crosses to the lingual through the space in the canine site. The anterior end is occlusal to the canine. N.B. A stepped bypass is introduced into the continuous main arch. (b, c) The base arch is stepped upwards to permit unobstructed extrusion and to allow the cantilever to cross to the lingual. (d) Activation of the cantilever creates two moments at the molar to rotate it mesio-lingually and in a crown mesial and root distal direction (in the sagittal plane).

This is arguably the best method for extrusion and distalization of palatally impacted canines that can be accomplished.

Stainless steel TPA cantilever combination

A stainless steel 0.016 in. torsion spring can be welded to a stainless steel TPA (Figure 3.3c–e). These cantilevers can easily produce force vectors, which may be difficult to generate by other means [2].

It is emphasized that the cantilever should not be ligated directly into a canine bracket, but tied to the eyelet/bracket/ligature wire on the canine to create a one-point contact. A rigid continuous canine bypass archwire will minimize undesirable side effects by distributing them to a larger number of teeth. Nevertheless, a flattening of the posterior occlusal plane resulting from the forward tip moment on the first molar should be monitored at every appointment and adjusted as necessary.

When using light forces of the order of 25–35 cN, adverse effects should not occur.

Cantilevers used as uprighting springs

Ectopic lower second molars often need uprighting before they can be aligned. The magnitude of the moment necessary for a molar uprighting has been suggested – on an empirical basis – to be at least 1000 cN-mm [2]. Depending on the cant of the occlusal plane, uprighting may be combined with an antero-posterior or vertical displacement, i.e. intrusion or extrusion (Figure 3.4a).

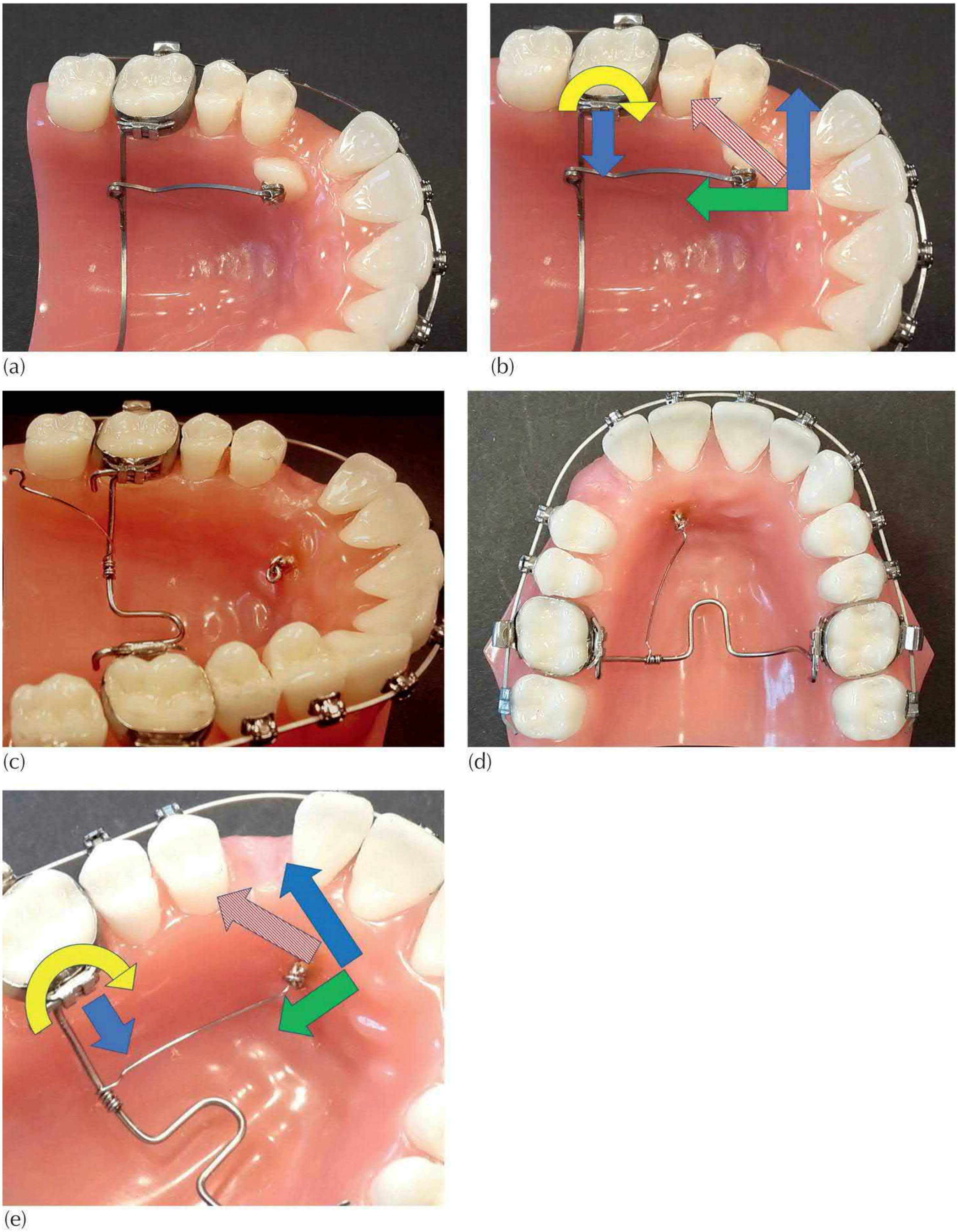
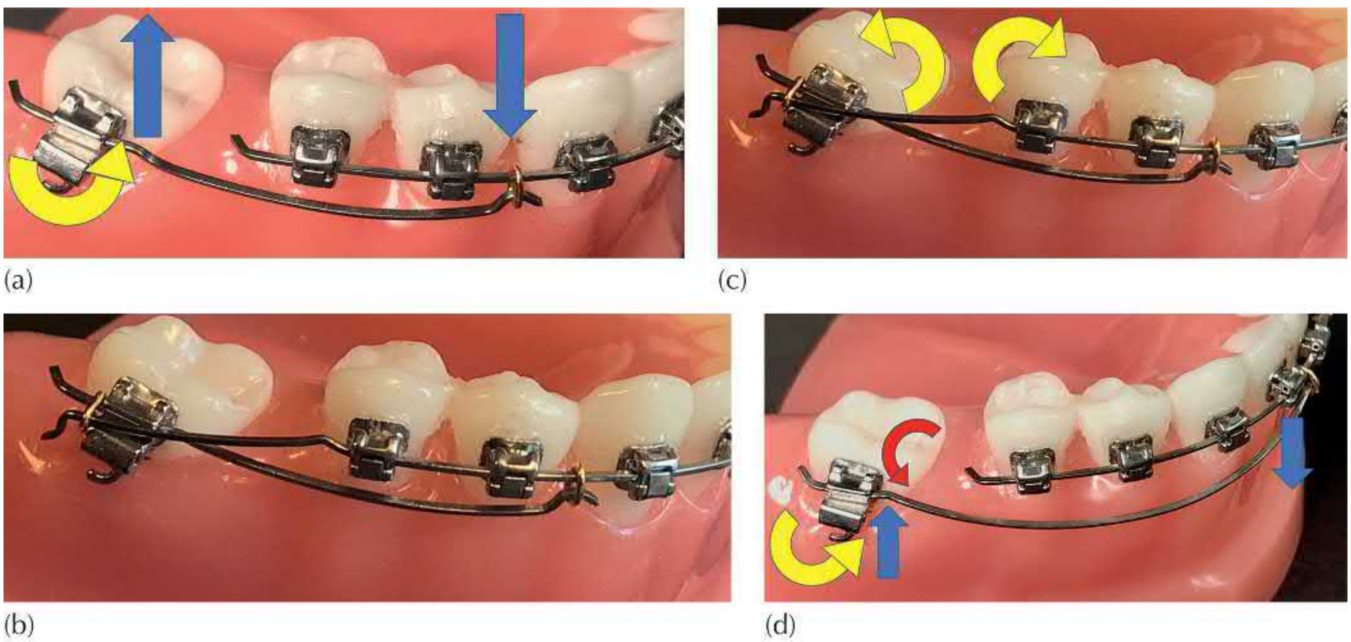


Fig. 3.3 (a) For illustration purposes only, a combination of the beta-titanium (TMA) transpalatal arch (TPA) with a rectangular TMA cantilever has been used, which may generate excessive forces. The recommendation is to weld a 0.018 in. round TMA cantilever to the TMA TPA for clinical

applications. The activated spring may be welded directly to the TPA, with or without including the 360° helix. (b) The canine will be extruded and moved posteriorly away from the roots of the incisors. (c) A 0.016 in. stainless steel torsion spring is here welded to a stainless steel TPA in its passive mode. (d, e) Using the same configuration with a 0.016 in. stainless steel spring and stainless steel TPA. The helical torsion spring should be welded halfway towards the midline and four or five loops wound clockwise (viewed from above) around the TPA close to the palatal mucosa. The number of loops is crucial for force reduction. The spring should be kept in the horizontal part of the TPA to ensure a linear vertical line of action. A stiff continuous base arch made of 0.017 in. × 0.025 in. or 0.019 in. × 0.025 in. stainless steel serves admirably as an anchorage.

For the adjustment of the appropriate cantilever length in the sagittal plane, the necessary case-based combination of vertical movement and uprighting has to be determined. If a significant extrusion of the molar is needed, the cantilever should be short in order to produce a high force delivered to the molar tube/bracket. If little or no extrusion is desired, a low force should be combined with a large moment. In these cases the cantilever has to be as long as possible. The moment is calculated as the product of the length of the cantilever and the force, which can be measured by a digital push–pull force gauge or a Correx tension gauge: moment = force × distance or $M = F \times d$.



(a) (c) (b) (d)

Fig. 3.4 (a) The biomechanical force system generated by a cantilever is a combination of a moment and a force generated at the unit into which the cantilever is inserted. With a one-point ligation on the other end, only a single force is developed. (b) Base arch extension with V bend placed mesial off centre. The extension and the cantilever have a one-point ligation using chain links. (c) If extrusion of the molar is contraindicated, the cantilever for uprighting should be counteracted by a second cantilever; alternatively, the base arch should be extended to the second molar with a one-point ligation at the second molar and configured with an mesial off-centre V bend as shown above. (d) The force system using a long cantilever.

Molar uprighting, as a pure rotation, where the centre of rotation coincides with the tooth CR, can be produced with two cantilevers by means of a statically determinate force system [2, 14, 15]. Alternatively it may be achieved with a root spring (alpha–beta spring) activated in Burstone geometry VI using a statically non-determinate force system [2]. As a third option, the base arch may be extended to the second molar with an off-centre V bend placed mesially (Figure 3.4b). Because the vertical forces generated cancel each other out, the base arch can be made using 0.019 in. × 0.025 in. NiTi wire. The V bend has to be placed outside the mouth with a hammerhead plier or Sander Memory Maker.

In a statically determinate force system the two cantilevers generate equal and opposite moments and forces to the molar and the anchorage unit. The developed forces thereby become neutralized (Figure 3.4c) [2].

In brachycephalic patients with good musculature, a long cantilever to the front teeth can be used as an alternative [2, 16]. Instead of 50 cN, which is produced by a medium-length cantilever, this approach will produce only 30–35 cN of vertical force, which may be controlled by occlusal forces [2, 16]. The force acts lingually, as opposed to both the root spring and the V bend, which act parallel to the dental arch and in close proximity to the CR. Accordingly the points of application of the cantilevers are not necessarily parallel to the alveolar process. Instead, they will be on either side of the CR. This will generate an additional tipping in either the buccal or the lingual directions to the CR of the molar. Using short or medium cantilevers with the point of force application buccal to the CR, the molar is tipped lingually during uprighting. With a long cantilever from the molar to the incisors, the point of force application is lingual to the CR, and the molar is tipped buccally (Figure 3.4d).

If the second molar needs to be intruded, a second cantilever may be inserted into a vertical tube and welded to the continuous arch between the first and second premolar teeth. It must be tied in a one-point contact to a short distal extension from the auxiliary tube of the second molar [16].

An increase in cantilever length reduces the load deflection ratio [16]. However, long cantilevers will generate high moments and a permanent deformation of the wire may occur. For this reason, if small forces are needed (50 cN and below), 0.017 in. × 0.025 in. TMA wires have been recommended. Even lower forces may be generated by using cantilevers made of Connecticut New Archwire or NiTi wire. When permanent bends are required to be introduced into NiTi wires, these should be made using hammerhead pliers or the Sander Memory Maker.

If larger forces are needed, wires of the same gauge should be of stainless steel. When using stainless steel cantilevers, an unacceptably high load deflection rate may often be generated. This may be reduced by adding loops to the stainless steel appliance. Moreover, a permanent deformation of the incorporated tip-back bend may be caused when the cantilever is activated. This may be prevented using a ‘safety pin configuration’ with a 360° helix/coil placed in front of the molar tube, which will be closed when activated [2].

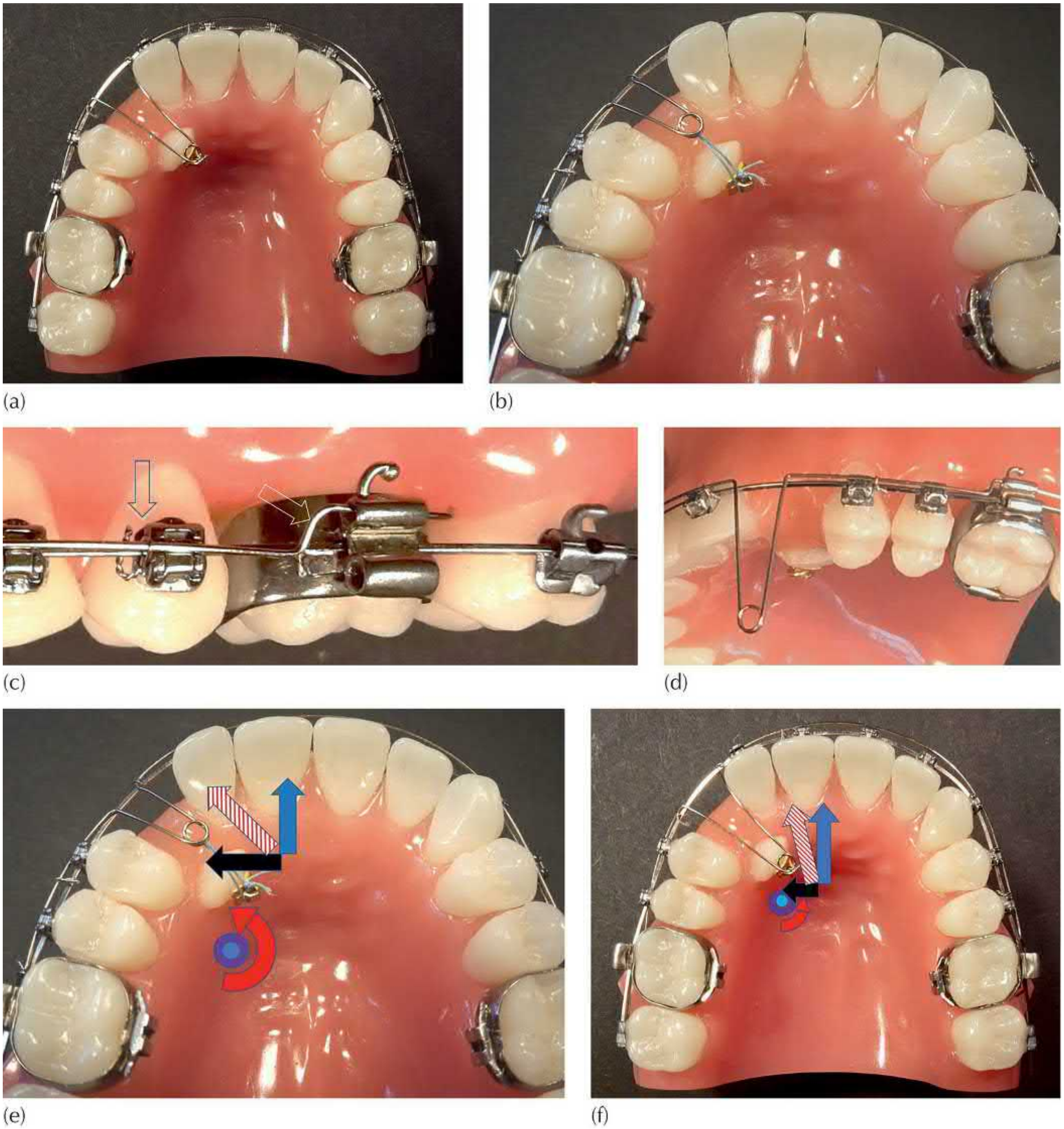


Fig. 3.5 (a, b) Ballista spring. The active configuration may differ in vertical loop length for applying different force values and vectors. The ballista spring may be tied to the eyelet with suture material to prevent soft tissue irritation caused by the cut end of the ligature wire. Patient comfort may also be enhanced by masking the cut end with a light-cured droplet of 'flow' composite material. (c) In some self-ligating brackets, the light auxiliary labial arch may have stepped ends for better torque generation, but in general the curvature of the arch dictates the extrusive force, whether there is a stepped end or not. (d) Passive shape. In (c) and (d) a continuous archwire is serving as anchorage. Using self-ligating brackets, the circumferential light auxiliary labial arch is stepped on both ends and engaged in the utility tubes. Using conventional brackets, the arch is ligated 'piggyback' to the brackets on the other teeth, over the passive base arch. This is impossible with Damon or any other self-ligating bracket, which cannot accept two

archwires. In anticipation of the arrival of the displaced tooth, the space may be maintained by threading a closed-coil spring onto the archwire. An additional tie mesial to the molar bands may sometimes be necessary. (e, f) Force direction: vertical force with an oblique transverse force direction in (e) and mainly vertical force in (f).

Ballista springs/torsion springs

The ballista spring (Figure 3.5a–f) was introduced by Jacoby in 1978 [17]. A cantilever made of round stainless steel wire of varied gauges (0.014–0.018 in.) engages both the headgear and the buccal tube to prevent rotation in the slot. The cantilever arm is extended to the canine area incorporating a 90° bend towards the lower arch. Attaching this arm to the palatally displaced canine by turning it upwards produces the torsion required to provide extrusive force on the canine.

A modification of this concept was introduced by Caprioglio [18, 19]. There are, however, some reservations about this concept, since the resultant extrusive force of 3–4 oz is too high to be physiologically appropriate. In a similar fashion, there are doubts regarding the auxiliaries using reversed mousetrap spring mechanisms introduced by Bowman (Kilroy Spring I for palatally impacted and Kilroy Spring II for buccally impacted canines), both of which develop excessive forces, thereby causing undesired intrusive and transverse side effects on the adjacent teeth [20].

By contrast, more appropriate physiological forces will be applied when using the ballista spring modification of Kornhauser et al., known as the light auxiliary labial arch [21]. A vertical loop pointing downwards in the canine area is fashioned into a preformed circumferential arch of 0.016 in. stainless steel. This full arch auxiliary should always be used as a piggyback wire on a stiff continuous base arch, with both ends being inserted into the auxiliary tubes on the first molars or, occasionally, into the second premolar brackets. Displacing the loop upwards towards a palatally displaced canine produces a twist (torsion) that creates the light extrusive force of 25–35 cN on the canine, with a low deflection rate.

The force delivered to the impacted tooth by this mechanism is derived from the horizontal and upwards deflection of the vertical loop as it deforms the circumferential archform. The force may be reduced by using a finer-gauge archwire or a lesser deflection. It may be increased by including an offset mesial to the molar band, inserted into an auxiliary tube. Alternatively, an elongated end of the wire, exiting the distal end of the molar tube, may be bent occlusally and in contact with the buccal surface of the molar, prior to engagement of the loop with the canine. Engaging the loop in the canine attachment will then activate the extrusive force. It should be noted here that force measurement of the loaded spring is very simple to adjust and regulate.

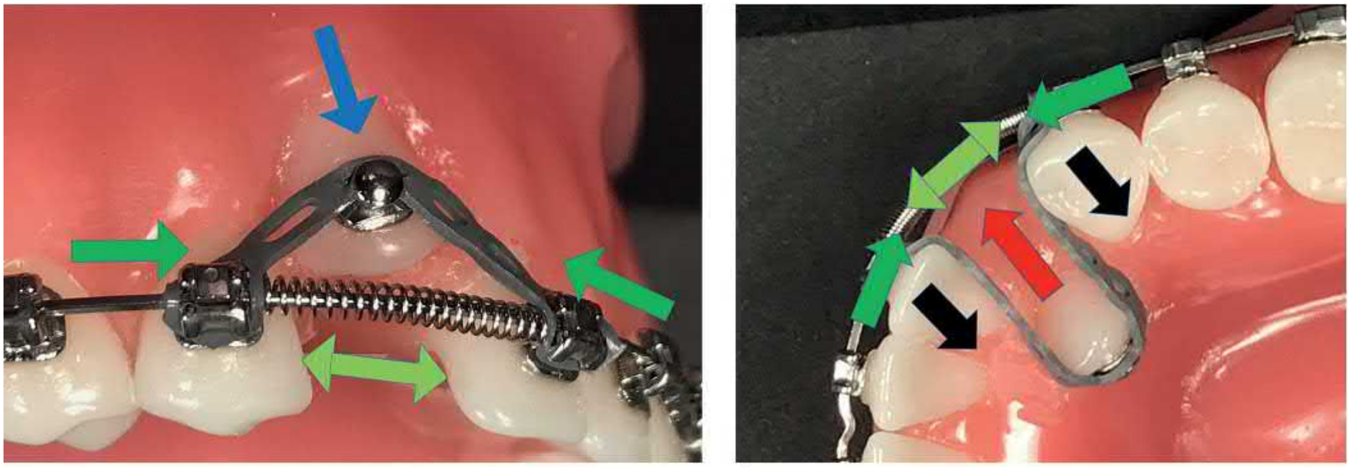
This method may also be used for a labial canine by constructing the loop to lie horizontally in its passive state and turned upwards in the vestibulum to be activated by ensnaring its terminal helix in the twisted ligature from the canine.

Elastics

As impacted teeth require to be moved in two directions, an eruptive force is needed to bring the tooth to the level of the occlusal plane and a horizontal (buccal or distal) force to bring the tooth into alignment in the arch. Palatally impacted teeth are generally moved into the arch using elastic chains or elastic threads extending from the canine to a main continuous buccal archwire, provided there is a free direct path, without the interference with a lateral incisor root (Figure 3.6a, b).

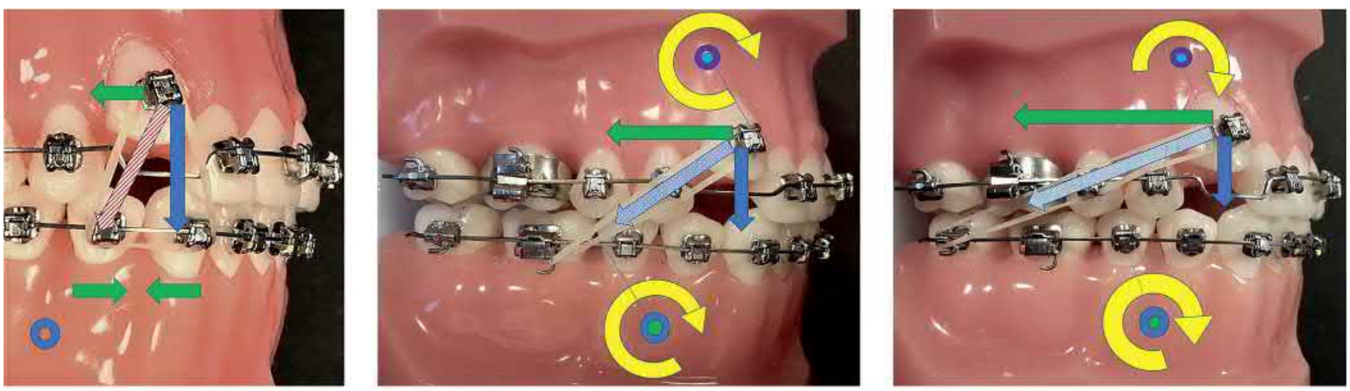
The conventional use of elastics to archwires for the purpose of completing this task successfully can still be accompanied by the appearance of undesirable movements of the adjacent teeth, such as displacement or rotations, indicating that anchorage is not sufficient. The need for a rigid base arch in this context is elementary.

Unwanted side effects, produced by intramaxillary elastics to the continuous archwire, are common. Intramaxillary elastic traction should not be used with non-rigid archwires, except when applying palatal elastic traction to a transpalatal arch or in the presence of intermaxillary traction.



(a) (b)

Fig. 3.6 (a, b) Using an elastomeric chain is relatively simple and cost-effective in terms of time and materials. In order to achieve a good treatment outcome, it is crucial to control the direction of force application in the interests of avoiding unwanted side effects.



(a) (b) (c)

Fig. 3.7 (a) Short vertical elastics exhibit a greater vertical component of force compared to a horizontal force. (b, c) Long class II elastics to the lower first or second molars may rotate the mandibular arch in a clockwise direction, with extrusion of the mandibular posterior teeth. The occlusal plane of the mandibular arch will rotate clockwise (steepen), which will influence the degree of vertical overlap. The equivalent moments, operating at the centre of rotation of the mandibular arch, are determined by the points of force application of the elastic and the lines of action of the forces.

Vertical elastics (Figure 3.7a) may be very helpful in these cases, but these must be used carefully since they may unintentionally cant an occlusal plane. Their rotational effect should be monitored in all three dimensions at each appointment.

When using triangular elastics from the maxillary canine to the mandibular first premolar and canine, vertical forces will be acting approximately through the CR of the mandibular dentition and, therefore, no tipping will occur in the sagittal plane.

When using unilateral triangular or long class II elastics to extrude and distalize an ectopic buccal canine, only light forces should be exerted (80 cN), using larger or thinner-gauge elastics.

Long class II elastics can produce a large moment at the CR of the mandibular arch. This may steepen the mandibular occlusal plane (Figure 3.7b, c).

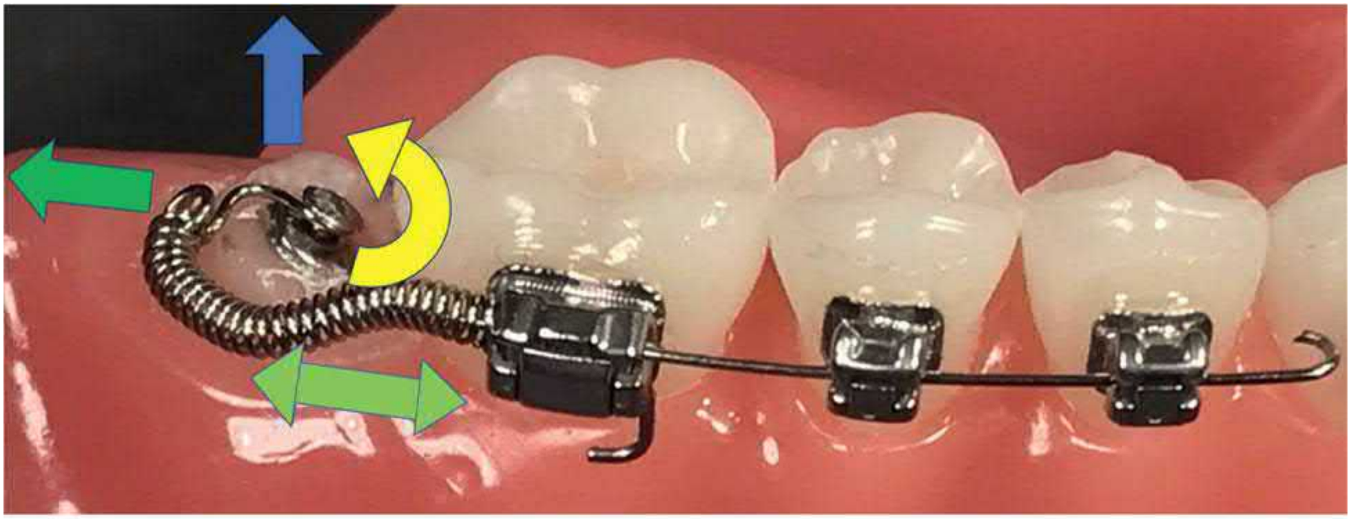
When using higher forces, a rotation of the entire mandibular arch can be produced in the sagittal and frontal planes of space.

NiTi closed-coil springs

NiTi springs generate approximately the same force system as elastics. They have a favourable load deflection rate and do not require cooperation of the patient. NiTi springs can be recommended in order to attain adequate traction and the force level will be adjusted to the required low forces [22–24]. They may also be used with patients whose compliance may be suspect.

NiTi open-coil springs

Most impacted lower second molars are tipped mesially and therefore need to be tipped distally in order to clear the distal aspect of the first molar. Only the occlusal surface of the second molar need be exposed; a button can be bonded in the second molar's central groove and a sectional equipped with a compressed NiTi super-elastic open-coil spring (Figure 3.8a, b). This is hooked onto the button and placed in the slots of the self-ligating Snaplink™ tube on the first molar and the premolar brackets. As the spring expands, the sectional wire will slide distally taking the second molar with it, to clear the first molar. If there is not sufficient wire remaining mesial to the first premolar to enable complete alignment of the second molar, the first premolar bracket can be debonded.



(a)

(b)

Fig. 3.8 (a) Sliding mechanics with a NiTi open-coil spring threaded over a 0.016 in. stainless steel sectional for freeing a mesially tipped lower second molar. (b) The hook on the distal end of the sectional is fixed to the button. A 360° helix is used as a stop for the NiTi spring.

Using continuous NiTi wires

Tying a 'light' NiTi wire to an ectopic canine may produce adverse effects. The arbitrary levelling of a high canine, without the simultaneous use of a stabilizing rigid base arch, can produce significant side effects. Although the moments on the canine and the horizontal forces produced cancel each other out, the extrusive forces will be doubled and the desired space-opening effect will be accompanied by intrusion and tipping on the adjacent teeth (Figure 3.9a–c).

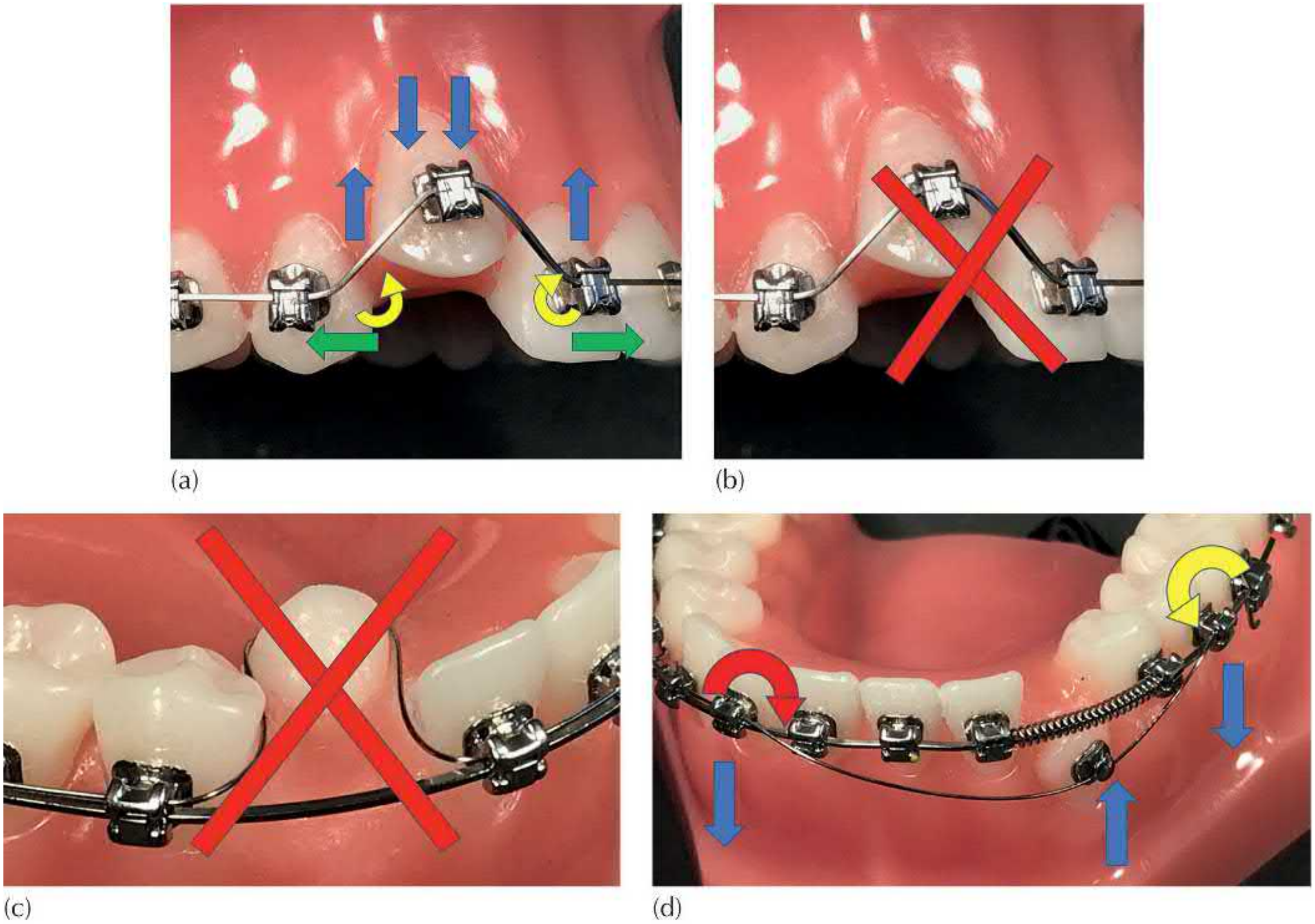


Fig. 3.9 (a) When aligning a high canine using a continuous and fully engaged NiTi wire, forces and moments would normally be generated. However, a deflection of more than 3 mm will produce binding in the brackets and the vertical forces on the canine will be nullified. (b, c) If the deflection of the NiTi wire is more than 3 mm, the angulation may exceed the clearance of the bracket slot. Under such circumstances the frictional effects are rapidly exceeded by the binding effects, and motion may cease altogether. (d) For the super-elastic wire to perform to best advantage, it should only be tied to a more distant tooth three or four teeth along in the arch. When the ectopic tooth is gradually brought into the arch, the tying position can be moved up incrementally until the ectopic tooth is fully aligned.

The average forces and moments produced by super-elastic NiTi archwires are reported to be high. Large deflections will generate maximum force levels, which are greater than the recommended values found in the literature and are generally accepted as being excessive. At an interbracket distance of 7 mm, wire deflections of more than 3 mm in the vertical or horizontal plane will create maximum binding. Disturbances to the system such as mastication may cause sporadic release of the binding of the wire in the brackets of the adjacent teeth as well as the release of traction to the canine.

Below the critical angle for binding, the wire can slide freely through the bracket slots. It has been reported that in cases where the impacted canines are high in the maxilla that are treated with continuous NiTi wires ligated in the slots, there is a rapid initial reduction in vertical forces. This occurs at the same time that sagittal forces are rapidly increasing from zero, due to binding. The presence of binding on the adjacent teeth reduces the magnitude of vertical forces on the canine. With sufficiently high binding forces on the adjacent teeth, the vertical force on the displaced canine may be reduced to zero, thereby creating a total lock. It has been shown that vertical forces on the canine are greatest at 3 mm wire deflection [25]. Binding in adjacent brackets will cause excess wire length to build up between adjacent teeth as the canine descends, thereby generating mesio-distal forces acting on the adjacent teeth [25]. Because the critical angle for binding is difficult to measure in the clinical setting, it may be assumed, as a rule of thumb, that binding in adjacent teeth in the canine area reaches its maximum at about >+3 mm of wire deflection [25, 26].

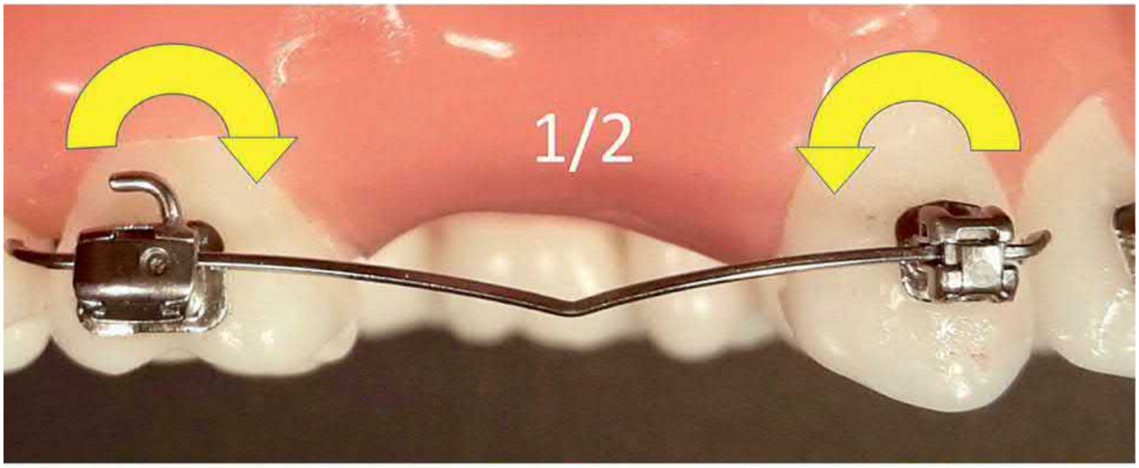
It should be stressed that levelling and aligning mechanics performed recklessly and irresponsibly, involving large deflections of the NiTi wire in the vertical and/or horizontal planes of space, may generate forces that are far too high and unphysiological [25, 27–28]. When binding occurs, the applied forces become pathogenic and it must then be assumed that the danger of root resorption of the adjacent teeth increases. An additional adverse effect of binding is a resultant decrease in the extrusive force on the canine down to values close to zero, which will be reflected in a much increased treatment time.

Super-elastic wires should only be applied when overlaid on the main archwire and tied directly to the attachment of the canine with a single-point contact (Figure 3.9d). A deflection of the piggyback wire of more than 3 mm should be avoided, as emphasized above, and the piggyback wire should not be attached to all the brackets along the way on the base arch. Ligation of the super-elastic spring should only be tied closer to the ectopic canine when the tooth is near to its final place.

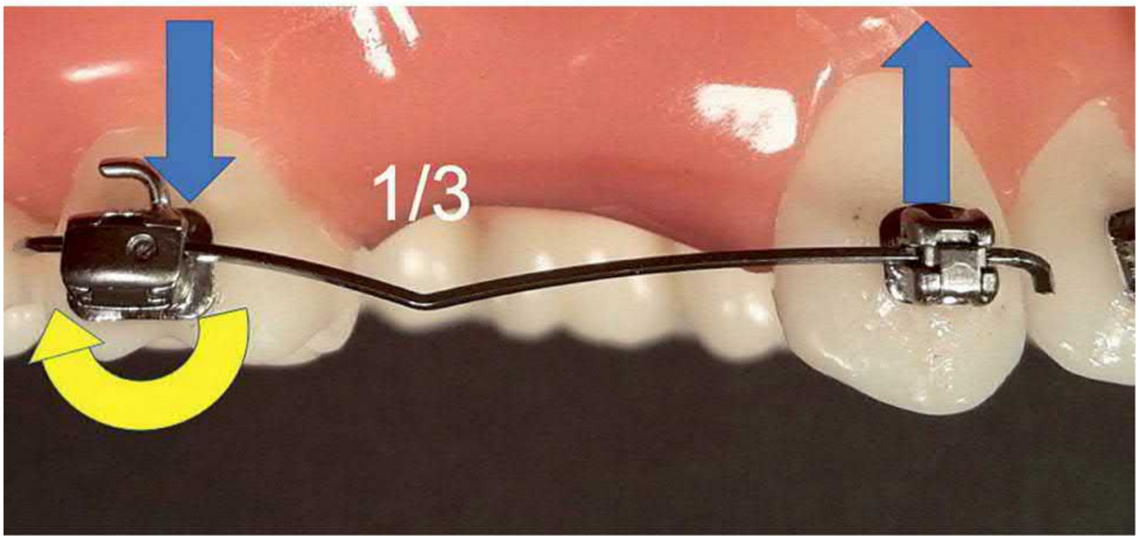
Creative wire bending using V bends between anchorage unit and ectopic tooth

The V bend delivers a force system that is highly dependent on its position [2, 3]. Placed exactly in the middle of the interbracket distance, it will always deliver two equal and opposite couples and no forces. This is independent of whether it is placed as a second- or a first-order bend [1–3]. This situation simulates a Burstone geometry VI. The two teeth will be subject to a pure rotation with neither extrusive nor intrusive forces. It is essential that the wire first be checked outside the mouth for total passivity, before the bend is placed midway between the two bracket units [2].

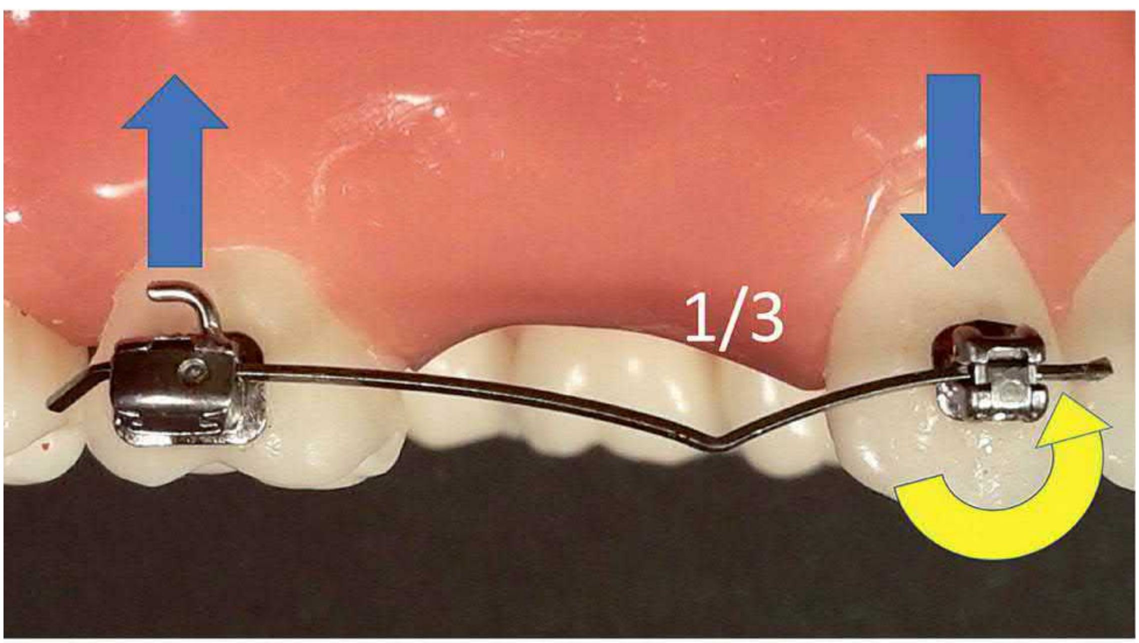
The force system produced by an alpha/beta spring or by a V bend varies during the tooth movement and is defined as ‘fluctuating’ (Figure 3.10a–c). The configuration changes between Burstone geometry VI and geometry IV, which only delivers an extrusive force to the canine. Friction and the resistance to movement of the reactive unit are factors that may influence the force system and the clinical effects. Thus, uprighting a canine by pure rotation is not easy to achieve unless distally uprighting the molar is needed as the reactive force vector. The uprighting of the canine can therefore be very slow compared to the action of a cantilever [2].



(a)



(b)



(c)

Fig. 3.10 (a–c) Changing the position of the V bend will create totally different force systems. To show the influence of the interbracket position of a V bend, the force systems (forces and moments) generated are indicated by arrows. Note how a displacement can alter the distribution and direction of forces and moments completely.

The activation of a statically indeterminate system includes two angles, with two brackets. The measurement of the angular values in the clinic is difficult to assess, and has little significance. The wire activation with respect to the two brackets, however, is important information and may be assessed by other means [2].

The angular activation corresponds to a linear activation, namely the distance between the wire end and one bracket when the wire has been inserted in the other. This can be measured by means of a caliper [2].

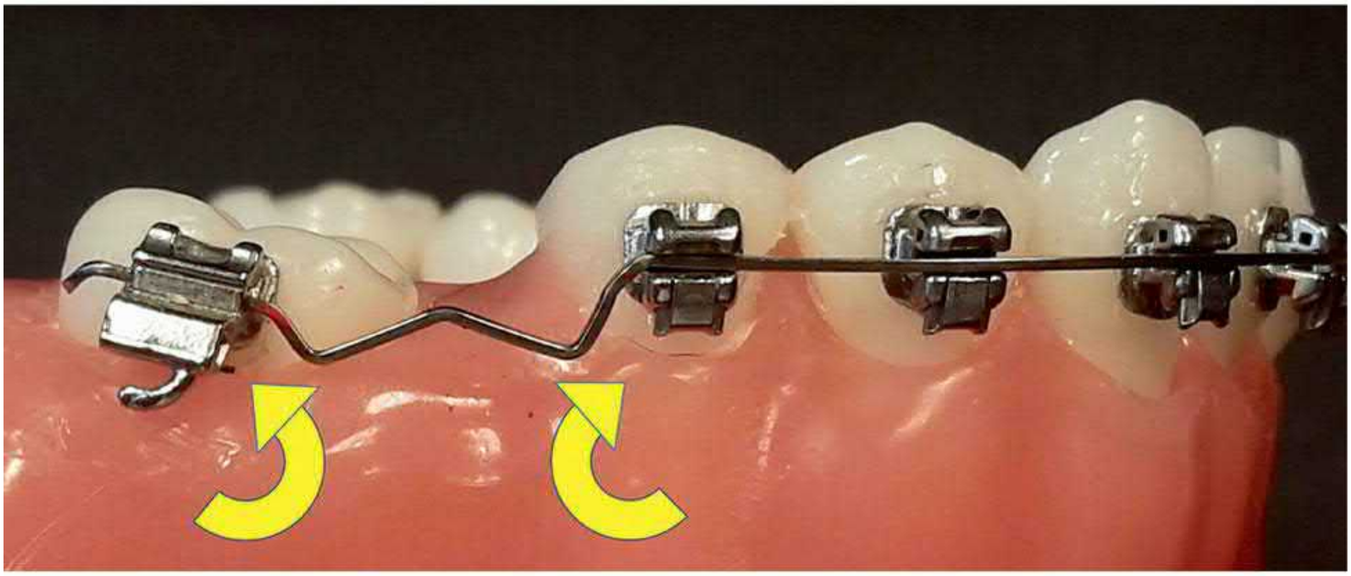
Root springs (alpha–beta springs)

Root springs (also called alpha–beta springs) can be made from 0.017 in. × 0.025 in. TMA wire. In most cases a truncated V design corresponding to a centred V bend is used.

If the interbracket distance between the displaced tooth and the adjacent tooth is sufficient (>10 mm), intra-segmental mechanics may also be incorporated in a continuous arch. In order to reduce the load deflection rate, the continuous arch should be made of a rectangular Connecticut New Archwire or NiTi wire. (Note: bends have to be made with a hammerhead plier or the Sander Memory Maker.) A V bend activated in geometry VI will produce molar uprighting by pure rotation. If both units are displaced at the same time, no vertical forces will be generated on either side.

Many other configurations of the root spring/centred V bend are possible. It delivers two equal and opposite moments and no forces. When using a V bend, it is important that the wire has been initially adjusted so that it is completely passive before the V bend is placed (Figure 3.11a, b).

(a)



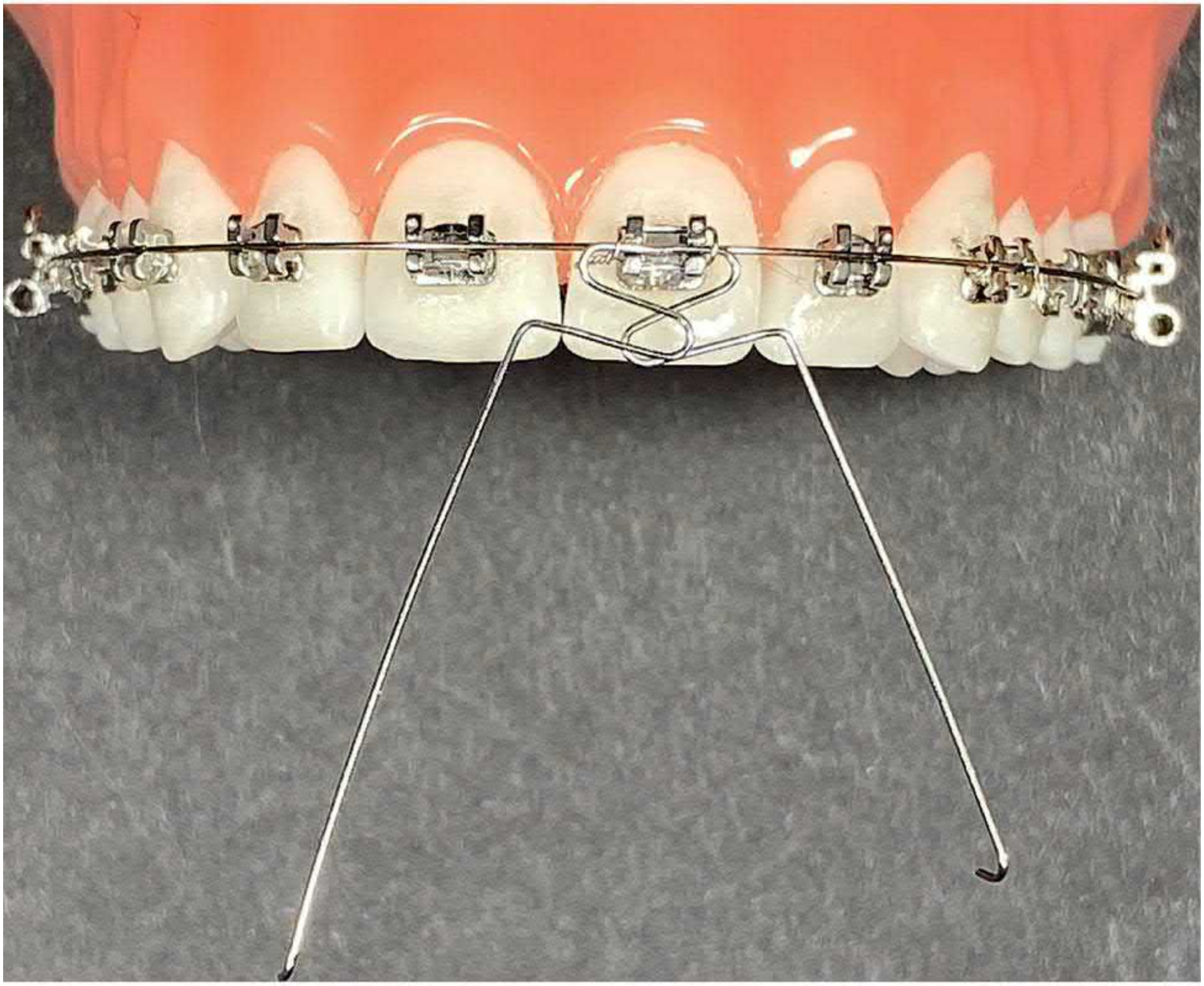
(b)

Fig. 3.11 (a) The passive configuration of the alpha–beta spring has to be made and first tested in the mouth. (b) It is recommended to make the V bend activation bend outside the mouth to ensure the geometry corresponds to a geometry VI. The root spring has been activated outside the mouth and reinserted, which produced moments.

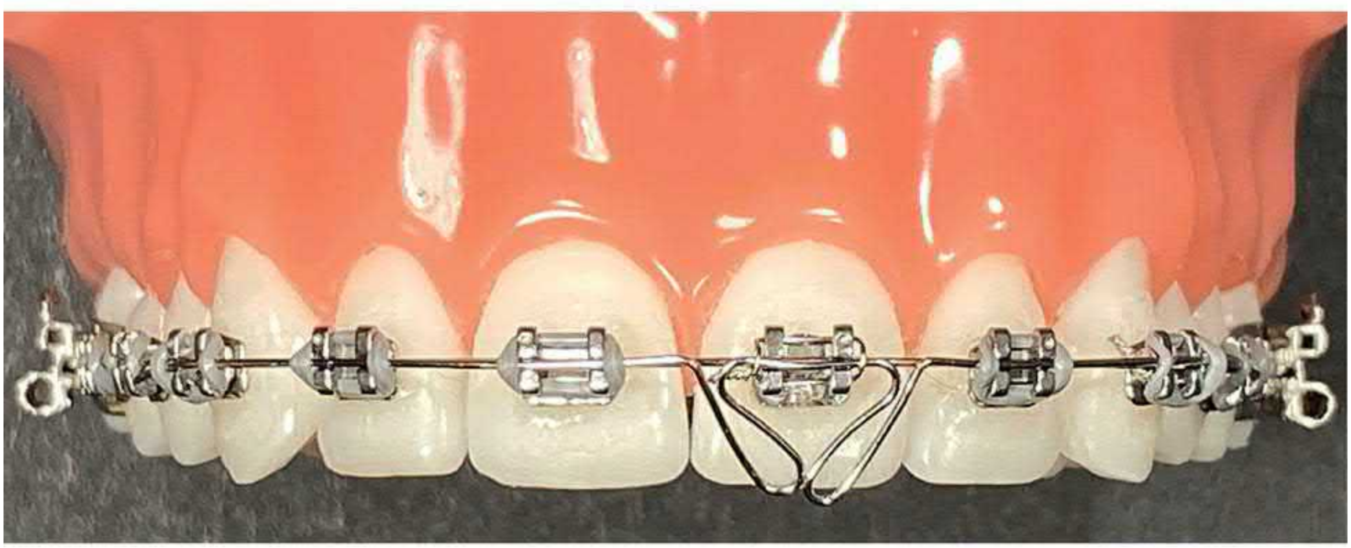
Torqueing auxiliaries/torque application

Ectopic teeth brought into the arch may require torque application. For torqueing a single tooth the use of auxiliary springs may be the preferred solution. Warren spring auxiliaries can torque the canine independently [29]. When an archwire–Warren spring combination for palatal crown torque is used with a full-size archwire, the spring is bent to push against the incisal part of the crown, but no torque movement will occur because the edgewise wire will twist to produce lingual root torque, thereby making this appliance inappropriate [1]. This auxiliary must be placed on a round or undersized rectangular wire in order to make the mechanism a valid one [1]. Wires adjusted to torque individual teeth should be sufficiently undersized to allow the wire to rotate in the slot of the adjacent tooth with no reciprocal torque reaction on that tooth. This precaution is more easily observed with a 0.022 in. slot than with a 0.018 in. bracket slot [30].

A good alternative is the von der Heydt torqueing auxiliary on a heavy passive round arch. This auxiliary is formed from 0.014 in. or 0.016 in. hard stainless steel wire and placed under a passive base arch of 0.018 in. or 0.020 in. round stainless steel. Simply by tying the two arms of the auxiliary into the brackets, piggyback style down to the main arch, torque is introduced to rotate the long axis of the tooth around the main arch (Figure 3.12a, b). It may incorporate two spurs for torqueing both central incisors or four spurs for all four incisors concurrently. It may be used for labial root torque by pointing the spurs above the brackets. For lingual root torque, the auxiliary is inverted, with the spurs point inferiorly to the brackets. Since it is it is supported by a round base arch, this mechanism cannot cause reactive lingual root torque on the adjacent incisors – no ‘round-tripping’.



(a)



(b)

Fig. 3.12 (a, b) A 0.016 in. main arch is combined with a 0.016 in. von der Heydt torqueing auxiliary engaged in 0.018 in. × 0.025 in. brackets.

The von der Heydt auxiliary is routinely used in the Begg technique, has a very long range of action and a single activation is often adequate to complete a significant degree of torque. However, should the patient not attend for routine observation and adjustment, a few extra weeks can sometimes find the root apex bulging the oral mucosa.

A 0.016 in. main arch will need reinforcement if it is to supply the needed anchorage. The possible reinforcements would need to include one or both of a more substantial compensatory curve of the main arch or a Goshgarian or soldered transpalatal arch.

Furthermore, the use of available variable torque options may help to achieve the required root torque. In more demanding cases, reverse torque can be employed by inverting the bracket to change the torque value from positive to negative or vice versa (Figure 3.13).

The effective torque of inverted brackets is dependent on the preferred bracket prescription. For instance, an inverted upper canine bracket of the McLaughlin-Bennett prescription will not deliver buccal root torque, but will deliver an increased inclination of 14° (from –7° palatal root torque to 7°).

Anchorage

A bypass archwire can be used to connect all teeth on the arch with the exception of the ectopic tooth, to form a rigid stabilizing anchorage unit. It requires a heavy archwire that, for maximum anchorage value, needs to be of rectangular stainless steel wire, which ideally will fill the slots of the brackets. Bypasses are stepped out, with either first- or second-order bends, in order to avoid any interference with the erupting ectopic tooth.

Using a bypassing arch wire, it is possible to distribute the undesired forces and moments over a larger number of teeth and therefore minimize clinical side effects.

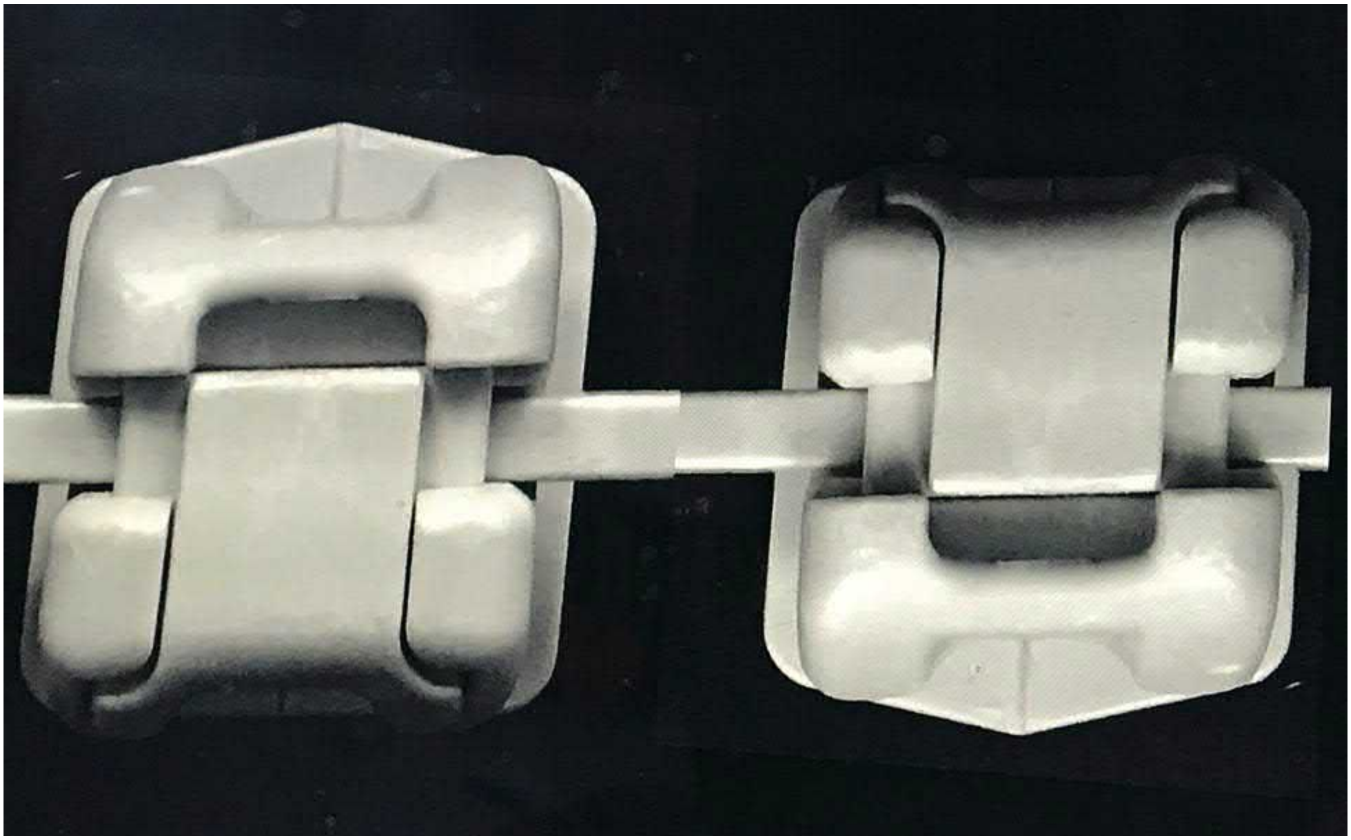


Fig. 3.13 When inverting a left upper canine bracket, it has to be kept in the same side of the arch in order to retain the same distal root tip.

Because of the low forces engaged in orthodontic treatment in general, the reinforcement of anchorage by using mini-screws is not usually necessary. Nevertheless, the introduction of skeletal anchorage has potentially widened the spectrum of orthodontics, allowing for treatments that could not previously be done solely with conventional appliances. Biomechanical knowledge is, however, mandatory, in order to ensure that the system is not abused [3].

Useful adjuncts

Efficient biomechanics are not dependent on additional gadgets. The active, tooth-moving unit solely concerns the ectopic tooth or teeth. In order to have the facility to apply a cantilever, there need to be auxiliary tubes on the first molars. As the ectopic tooth is brought into the proximity of the arch with traction applied to an eyelet, a bracket has to be substituted to enable controlled alignment. If the tooth is severely rotated and/or tipped, the replacement of the eyelet by bonding a bracket, which carries an additional vertical slot incorporated in the bracket base, will be advised. It should be noted that uprighting and de-rotation of the canine may be accomplished simultaneously, using a cantilever. Since light forces are used, sufficient anchorage is available with the use of a rigid base arch connecting all the other teeth and consolidating them into a single anchor unit.

If a lingual arch or transpalatal arch is necessary, Goshgarian tubes, Burstone lingual brackets or hinge cap attachments on the first molars will permit simultaneous multitasking.

In order to use only light forces, composite cantilevers may be prepared, using a stiffer section in TMA 0.017 in. × 0.025 in. and a more elastic section in TMA round 0.018 in. wire. The stiffer part will secure a tight seat in the auxiliary tube, while the elastic part delivers the needed low force.

Forces applied with a cantilever tied to the eyelet/bracket/ligature wire of the tooth to be moved creating a one-point contact can be controlled using a Correx tension gauge (Figure 3.14).

Fig. 3.14 The use of a Correx tension gauge is recommended to measure/control the level of the applied forces with cantilevers.

Straight lengths of new materials, such as the Connecticut New Arch Wire, are bendable and produce lower forces than TMA wire [31].

Super-elastic Nitinol wire may be used for cantilevers, when bended with the Sander Memory Maker, Khouri Bendistal pliers (Figure 3.15) or hammerhead pliers. Third-order bends cannot conventionally be bent into super-elastic wires without destroying the structure of the wire. With the help of the Memory Maker (Figure 3.16), it is possible to programme bends of each order into the NiTi wires, as well as torque [32].

Fig. 3.15 Khouri Bendistal pliers are reliable tools for bending wire ends and V bends.

Fig. 3.16 The Sander Memory Maker allows NiTi wire adjustments in all planes of space and torque application.

Appendix: Colour code convention for moments and forces

Forces and moments in the three planes of space are depicted as follows:

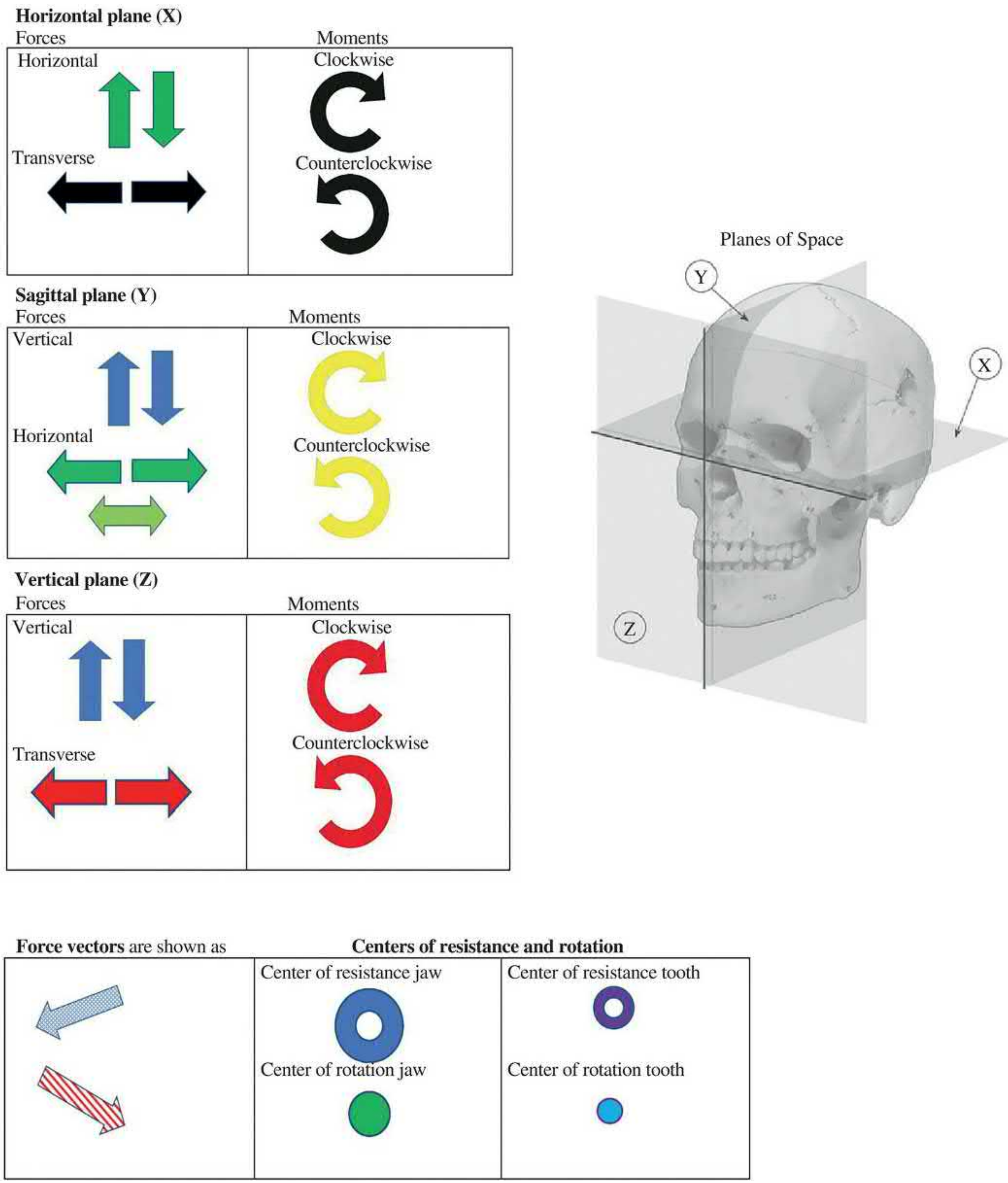


Table 3.1 Colour code convention.

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4
Diagnostic Imaging for Impacted Teeth

Adrian Becker, Amnon Leitner and Stella Chaushu

Planar radiography

Computerized tomography

Cone beam computerized tomography

It is not the purpose of this chapter to present a complete manual on dental radiography, but rather to highlight concisely those techniques and methods that are useful in the clinical setting, as they pertain to impacted teeth.

The methods offered have two main aims [1, 2]. The first relates to the furnishing of qualitative information regarding normal and abnormal conditions that may be associated with unerupted teeth. Thus, we will discuss and compare the different ways of radiologically displaying and recognizing pathological entities, including supernumerary teeth, enlarged eruption follicles, odontomes and root resorption. The second aim is to describe the various radiological techniques that the clinician may find helpful in accurately pinpointing the position of a clinically invisible, unerupted tooth in the three planes of space. The relative merits of these techniques are discussed and indications for their use are suggested in relation to the different groups of teeth concerned.

Planar radiography

Periapical radiographs

The first, simplest and most informative radiograph is the periapical view. This view is oriented to pass through the minimum of surrounding tissue, in order to give accuracy and quality of resolution. There are two techniques to review: the paralleling technique and the bisecting technique. In the paralleling technique, the receptor, which is a sensor or phosphor storage plate (PSP), is placed as close to the tooth as possible, but parallel to its long axis, with the X-ray beam directed perpendicular to it. In areas where the parallel technique is impossible due to poor access, the bisecting angle technique is used, in which the receptor is placed as close to the tooth as possible, but not parallel to its long axis. The X-ray beam is aimed perpendicular to an imaginary plane, which bisects the angle between the long axis of an erupted tooth and the plane of the receptor, thus ensuring a minimum of distortion. The periapical radiograph is designed to view the tooth itself from the angle of best advantage, unrelated to its position in space.

From the periapical view, it will be immediately obvious if there is an impacted tooth and if its stage of development is similar to that of its erupted antimere, with at least two-thirds of its root length. The presence and size of a follicle will be obvious and crown or root resorption, root pattern and integrity will be possible to ascertain. The presence and description of hard tissue obstruction will be evident, allowing the observer to distinguish connate, incisiform and barrel-shaped supernumeraries, as well as odontomes of the complex or compound composite type. Similarly, this view will show soft tissue lesions, such as cysts. The great clarity that the view offers is superior to other views and should always be used as the initial radiograph of a suspected impacted tooth in a radiographic examination. The periapical view is two-dimensional, and thus can give no information in the bucco-lingual plane. Overlapping structures cannot be differentiated on a single radiograph as to which is lingual and which buccal.

For this radiograph to give the most advantageous view of the teeth in the maxillary arch and in the mandibular anterior segment, the central ray of the periapical view must be oblique and vary between 20° and 55° to the occlusal plane [3] (depending on the region to be X-rayed), while attempting to be as true to the paralleling technique as possible. Given this oblique direction, any attempt to estimate the height of an impacted tooth or its bucco-lingual location, *without additional information*, must fail.

When performing periapical radiography on the posterior teeth in the mandibular arch, however, the most advantageous direction has the central ray very close to the horizontal and, as such, also offers a true lateral view of these teeth. Thus, except for the bucco-lingual situation details, the observer will see the most precise detail of the tooth and its surrounding tissues; it will also be possible to accurately assess its height in the jaw.

Occlusal radiographs

Mandibular arch

Occlusal radiographs in the mandibular arch are properly executed by tipping the patient's head backwards and pointing the X-ray tube at right angles to a receptor held between the teeth in the occlusal plane (Figure 4.1). The head will need to be tipped back to permit the positioning of the X-ray tube under the chin. In the lower canine/premolar region, the occlusal view is a 'true' occlusal view and should depict all the posterior standing teeth in cross-section, thereby providing bucco-lingual positional information on the tooth and any associated structures in a plane at right angles to that seen on the periapical radiograph. Due to the thickness of bone traversed, detail is much poorer, unless there is expansion owing to a large cyst or a bucco-lingually displaced tooth.

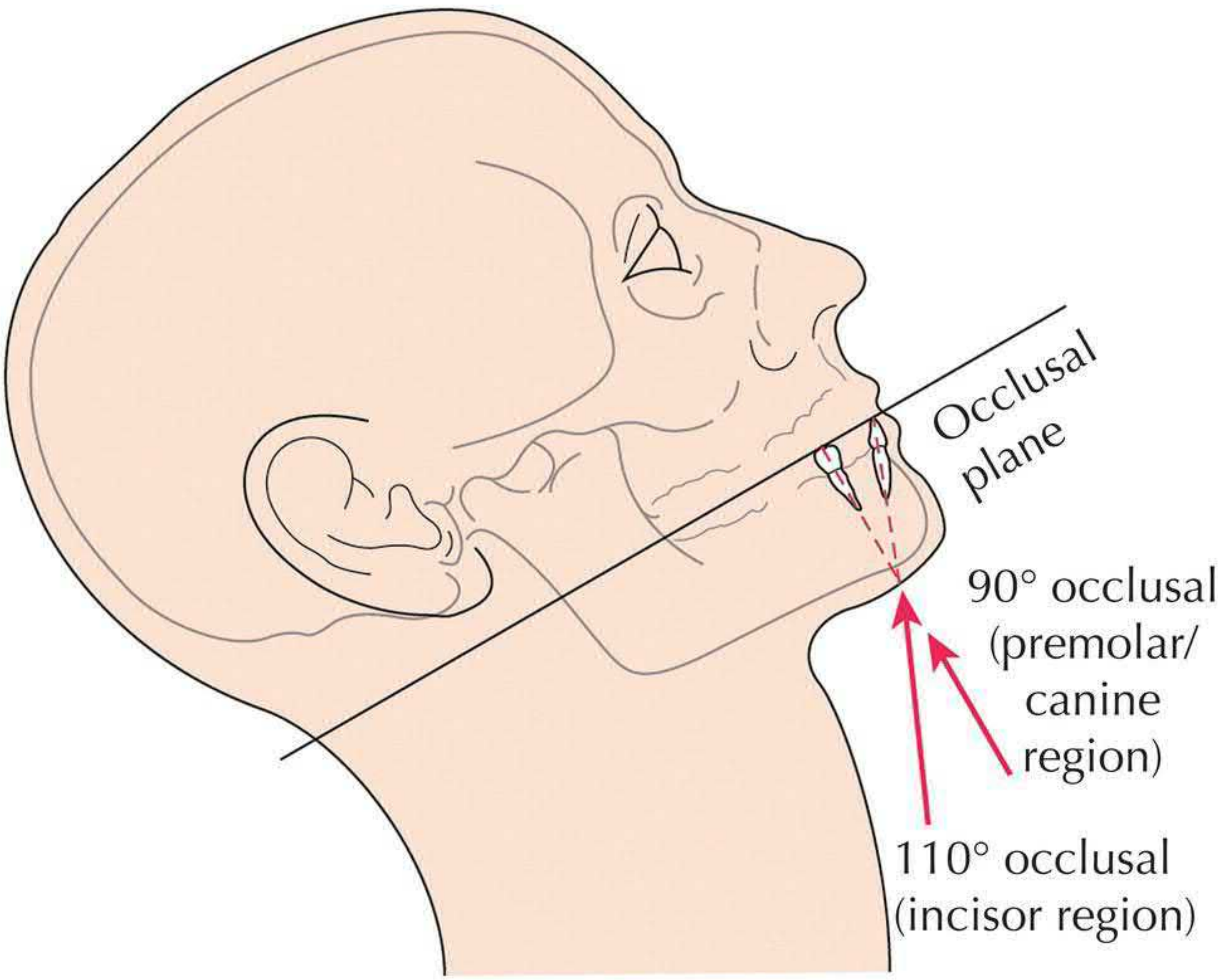


Fig. 4.1 The angle of the central ray in a true occlusal view of the lower jaw depends on the area of interest.

Source: Reproduced from previous edition. Adrian Becker, *The Orthodontic Treatment of Impacted Teeth*, 2nd ed., 2007 with the kind permission of Informa Healthcare – Books.

In order to produce a true occlusal view in the anterior region of the mandibular arch (Figure 4.1), the head will need to be tipped back further and the tube pointed at the symphysis menti, at an angle of 110° to the occlusal plane, in line with the long axes of the incisor teeth. To achieve the same for the molar teeth, the 90° angle to the occlusal plane will need to be augmented by a 15° medial tilt of the tube, to compensate for the characteristic slight lingual tipping of these teeth [3]. This means that, ideally, the radiograph should be performed individually for each side, in order to capture each molar in its long axis and its true occlusal view.

Maxillary arch

Maxillary anterior occlusal

In the maxillary arch, the nose and forehead interfere with the positioning of the X-ray tube close to the area to be viewed. The best that can be achieved by positioning the tube close to the face is an oblique, anterior, maxillary occlusal view of the teeth, which is perhaps better described as a high or steeply angled periapical view (Figure 4.2). This view will shorten the apparent length of the roots and will be a far cry from the cross-sectional view that is so easy to achieve in the mandibular arch. The central ray passes through cancellous bone rather than the compact bone that is found in the mandible, so detail is usually good, although not as clear as with the periapical view.

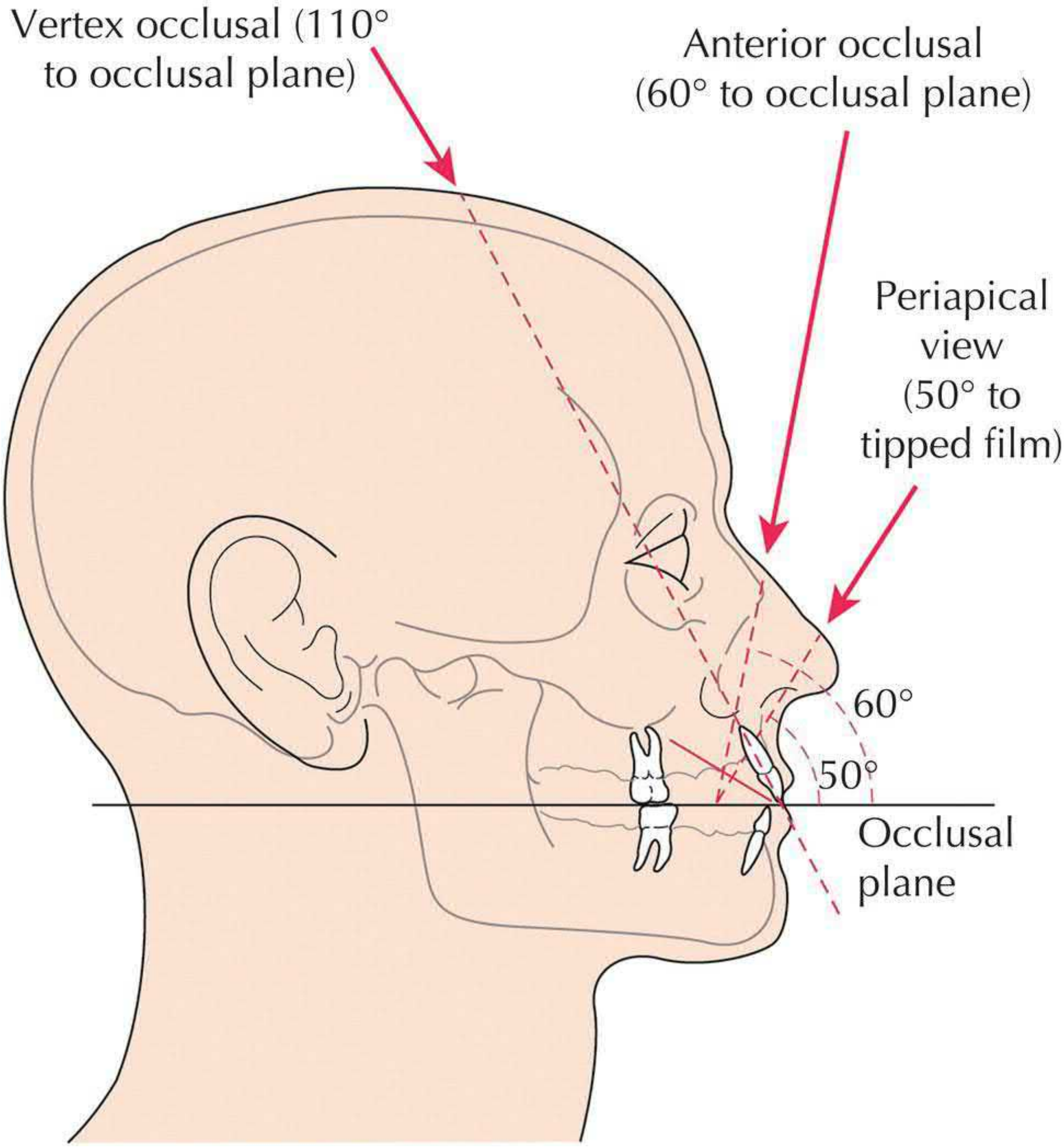


Fig. 4.2 A diagram showing incisor inclination, receptor position and central X-ray beam, differentiating the periapical view, the anterior (oblique) occlusal view and the true vertex occlusal view.

Source: Reproduced from previous edition. Adrian Becker, *The Orthodontic Treatment of Impacted Teeth*, 2nd ed., 2007 with the kind permission of Informa Healthcare – Books.

True (vertex) occlusal

A true (vertex) occlusal 2D view of the anterior maxilla [4] needs a very long exposure time and it is for this reason that the method has never been popular. It is therefore almost with a collective sigh of relief among professionals that the method has been totally superseded by the introduction of volumetric cone beam computerized tomography (CBCT) scanning. The CBCT imaging modality, which can give much more information with little or no increase in radiation dosage, is discussed towards the end of this chapter.

Extra-oral radiographs

The panoramic view, while not showing detail to the same degree as a periapical radiograph, has the advantage of simply and quickly offering a good scan of teeth and jaws, from the temporo-mandibular (TM) joint on one side to the TM joint on the other. It is probably true to say that today orthodontists are in general agreement that this radiograph gives the most qualitative information to act as a starting point from which to proceed to other forms of radiography, in line with the demands of the particular situation in any given case.

True and oblique extra-oral views (Figure 4.3a–c) and the variously angulated oblique occlusal radiographs all provide information that may be used to complement the periapical radiograph, particularly when tooth displacement is severe. However, the use of any oblique radiograph, be it a single periapical, an occlusal or a lateral jaw radiograph, for the accurate localization of a buried tooth may frequently be misleading. This being so, two incipient dangers exist. First, a surgical procedure may be misdirected and a flap opened on the wrong side of the alveolar process. Second, misinterpretation of the tooth's position may lead the operator to consider there to be a very favourable prognosis for biomechanical resolution when in fact the tooth may be in a completely intractable position. In such circumstances, therefore, the choice of treatment will be inappropriate.

In view of these and other shortcomings, these cases are now diagnosed and treatment planned using CBCT imaging and the only extra-oral radiographs still in use, to complement panoramic radiographs, are the lateral and PA cephalometric projections.

Three-dimensional diagnosis of tooth position

As dentists, we are used to seeing periapical radiographs of individual teeth and, provided that the teeth concerned are erupted and in the line of the arch, these radiographs have many advantages. However, in this view the X-ray tube is not directed in either the true horizontal, true vertical or true lateral plane. Aside from radiography of the mandibular posterior teeth, the tube is always tipped at an angle to one or more of these planes. For an erupted tooth this is unimportant, since the third dimension is supplied by direct vision within the mouth. However, while it gives a good 2D representation of the tooth, this view has limited value when visualization of an unerupted tooth is required in the three planes of space.

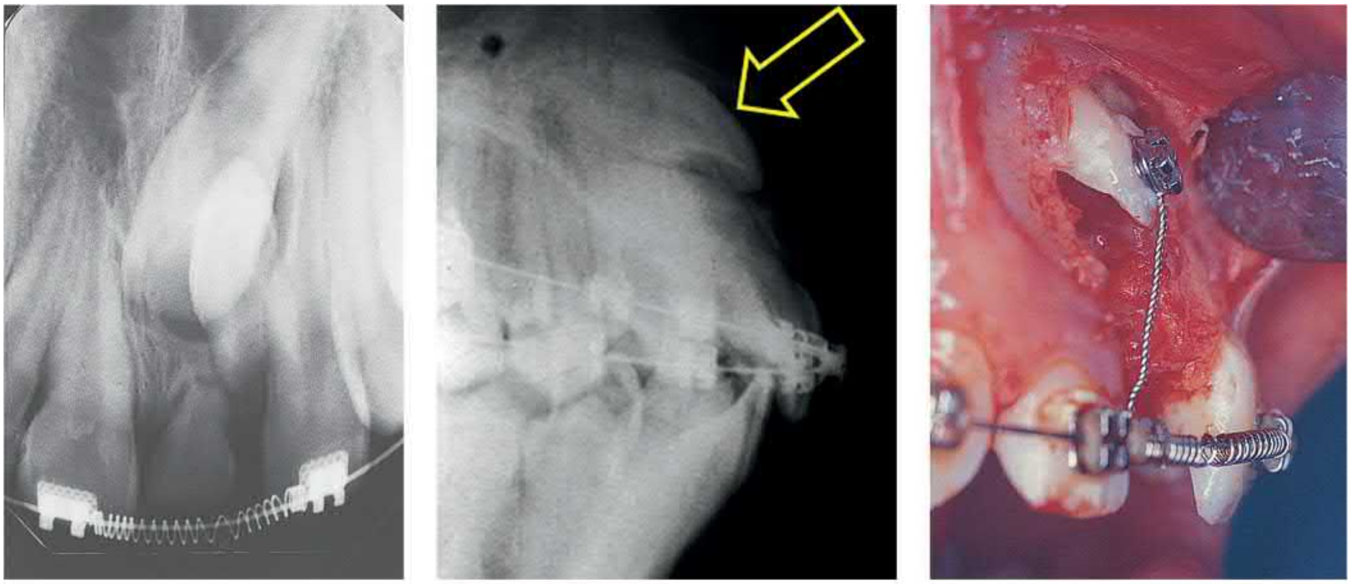

(a) (b) (c)

Fig. 4.3 (a) The periapical view shows an impacted left maxillary central incisor, due to an inverted, unerupted, supernumerary tooth. The deciduous tooth is over-retained. Accurate diagnosis of the height of the impacted tooth in the alveolus is not possible to determine from this view. (b) The anterior maxilla seen on a lateral cephalometric radiograph shows the high impacted central incisor (arrow) and its bucco-lingual location, facing the labial vestibular sulcus. (c) The parallel intra-oral photographic view at surgical exposure. The radiograph has been laterally inverted to simplify comparison.

Courtesy of Dr D. Harary.

Parallax method

By following the principles involved in binocular vision, two periapical views of the same object, taken from slightly different angles, can provide depth to the flat, 2D picture presented by each of the radiographs individually (Figure 4.4) [5–7]. This is of considerable help in distinguishing the buccal or lingual displacement of the canine, which is low down and fairly close to the line of the arch, and is performed in the following manner (Figure 4.5):

1. A periapical-sized receptor is placed in the mouth, preferably using the bisecting angle technique, placing it against the palatal aspect of the area where the tooth would normally be situated. The X-ray tube is directed at right angles (ortho-radial) to the tangent to the line of the arch at this point, as for any periapical view, and at the appropriate angle to the horizontal plane for the tooth in question (50° for the central incisor, etc.).
2. A second receptor is placed in the mouth in the identical position but, on this occasion, the X-ray tube is shifted (rotated) mesially or distally round the arch, although held at the same angle to the horizontal plane and directed at the mesially or distally adjacent tooth. To achieve this, the tube should describe an arc of between 30° and 45° of a circle whose centre is somewhere in the middle of the palate.

There should be no problem identifying which of the two radiographs is the ortho-radial view and which was taken from the distally deviated aspect, simply by comparing the relative distortion of the erupted teeth on the two radiographs. However, by radiographically ‘labelling’ the deviated receptor with the placement of a paper clip in one corner or by using a different receptor size for the deviated view, such as an occlusal-sized receptor, this distinction will be simplified.

Let us assume that a right unerupted canine is palatally placed (Figure 4.5), so that this tooth will be close to the middle of the picture obtained in both radiographs. In the first picture (direction B), where the tube is directed over the designated canine area of the ridge, the lateral incisor root will be on the right of the picture. If the canine is also mesially displaced, there will be some overlap of the canine crown and the lateral incisor root. On the second picture, taken from the front (direction A), the right lateral incisor root and the crown of the palatal canine will be in the middle of the picture, superimposed on one another, to a much greater degree.

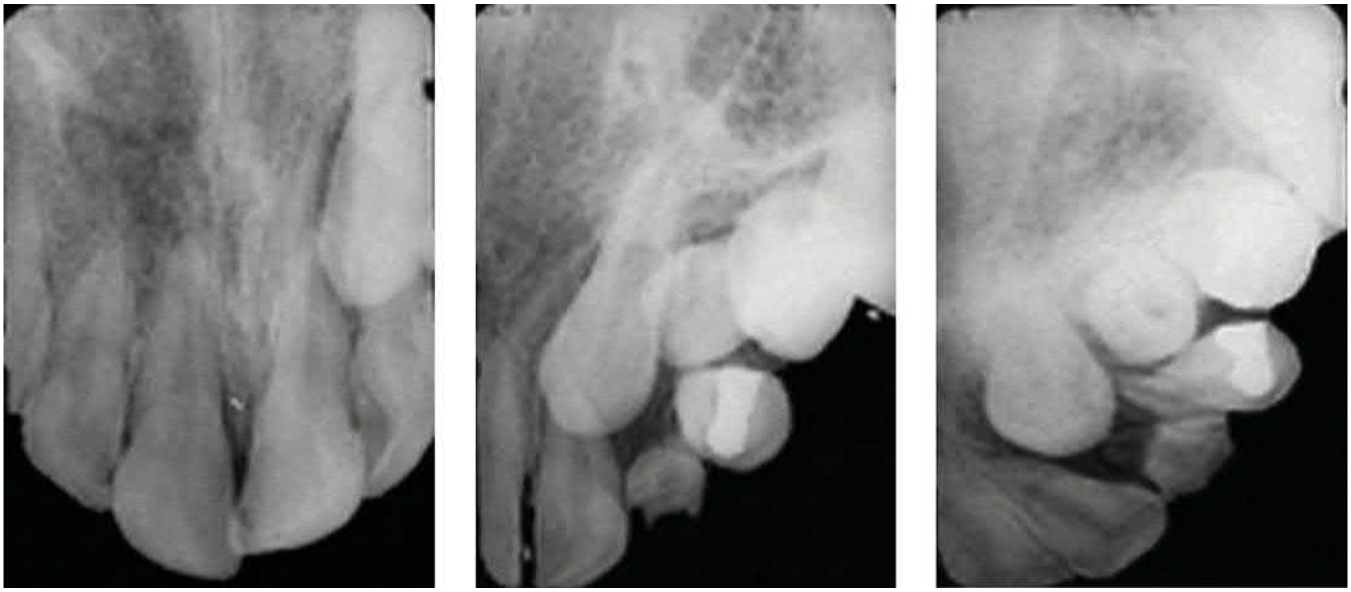
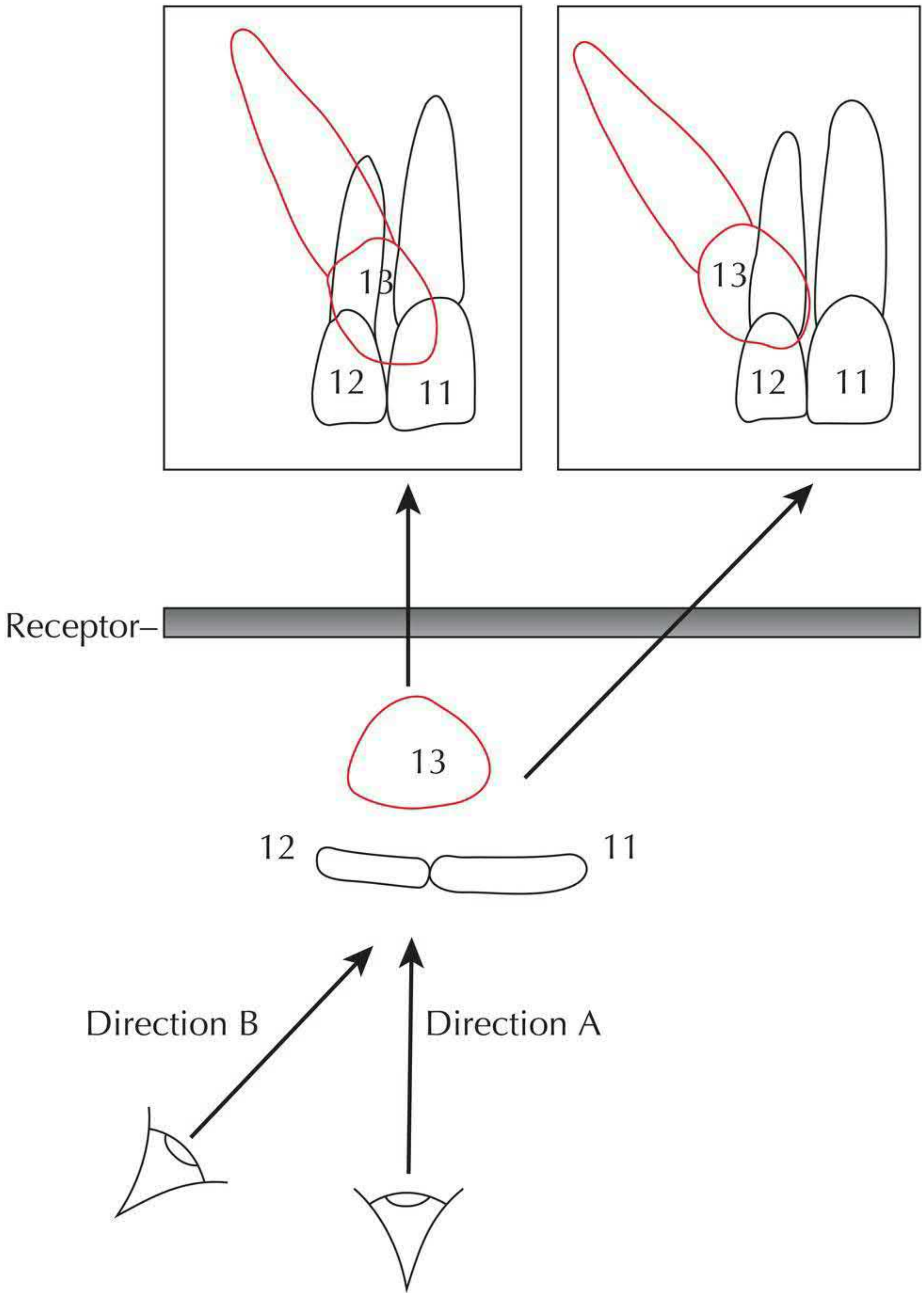


Fig. 4.4 The left periapical view, oriented for the central incisors, shows the crown of the canine superimposed on the distal half of the central incisor root. The middle radiograph, rotated 30° to the left, shows the canine overlapping only the lateral incisor root. By rotating the central beam a further 30°, superimposition of the canine over the lateral incisor root has been eliminated. The canine is palatally displaced.



13
12
11
13
12
11
Receptor
13
12
11
Direction B
Direction A

Fig. 4.5 A diagrammatic representation of the parallax method. If the observer's eye peers along the axis of the X-ray beam in each case, the image on the radiograph will be easy to reconstruct.

Source: Reproduced from previous edition. Adrian Becker, *The Orthodontic Treatment of Impacted Teeth*, 2nd ed., 2007 with the kind permission of Informa Healthcare – Books.

Jacobs [7, 8] enjoins the observer to demonstrate this principle by the simple act of using the right eye, purporting to be the X-ray tube, and holding up two fingers vertically, at eye level, with one finger obscuring the other. If the observer now closes this eye and opens the other, without moving the head and fingers, the new vantage point for inspection will have resulted in a visual separation of the two fingers. Through the left eye, the obscured finger will have 'moved' to the left of the forward finger, to become partially visible. Transferring this to the radiographic context, in the second picture, the tooth furthest from the tube (i.e. the palatal tooth) will 'move' in the same direction that the X-ray tube has travelled from the first exposure.

This parallax method has its limitations, although it is very useful in cases where there is a minimal height discrepancy between the erupted and unerupted adjacent teeth. However, when the canine is high and the periapical view shows no superimposition of the canine over the roots of the erupted teeth, or where the superimposition is only in the apical area, then the overall picture may be very misleading. Accordingly, a different method of localization should be used, as follows: the periapical view is directed from above the occlusal plane and in an oblique downward and medial direction, which distances the palatal canine from the roots of the other teeth and makes it appear higher than the anatomy of the maxilla would allow. While it may prove useful in locating the position of the crown of the impacted tooth, it is not adequate to the task of accurately placing the root apex and thereby defining the orientation of its long axis. These are important parameters when assessing treatment difficulty and prognosis during the treatment planning stage and are absolutely critical for the successful resolution of an impacted tooth, as we shall see in the following chapters.

A useful variant of the same technique is the vertical parallax, in which two radiographs are taken of the area, with the central ray of one periapical radiograph being more steeply angled in the vertical plane than the other. In this manner, the separation of the images in the more steeply angled (above the occlusal plane) radiograph will result in a palatal tooth being more superiorly related vis-à-vis the target tooth than in the regular radiograph.

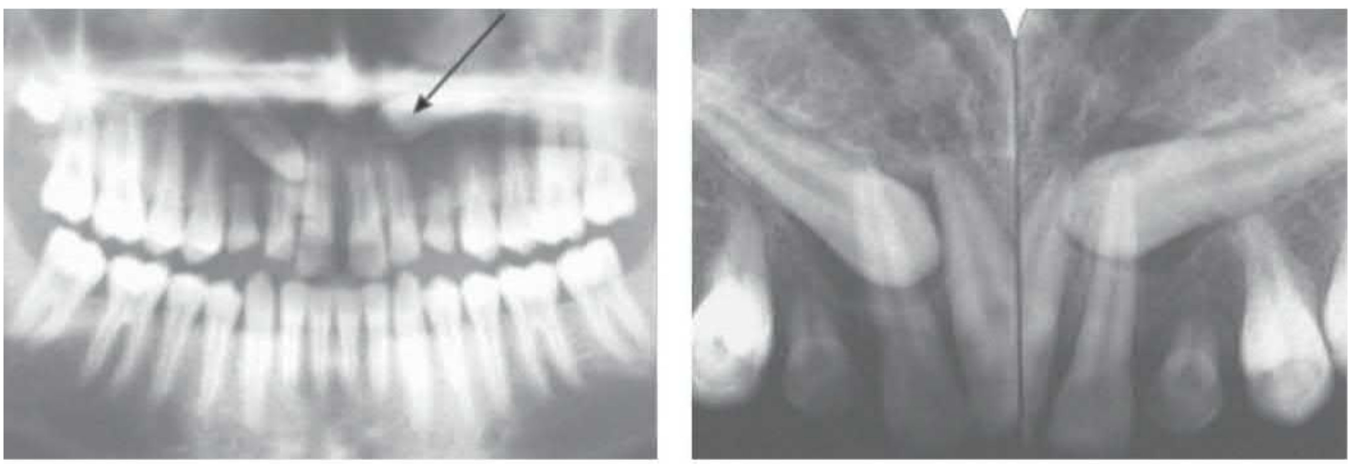
Unfortunately, the parallax method in general offers a relatively low degree of reliability. In a study to evaluate the usefulness of its two variants [6], six experienced orthodontists were given the case records of 39 patients with ectopic canines. The cases were evaluated twice, once using radiographs that showed vertical parallax and once with radiographs that featured horizontal parallax, although the parallax pairs were not revealed to the examiners as being of the same individual. In 83% of cases the correct positional diagnosis was made with the horizontal method, while only 68% of cases were correctly diagnosed with the vertical method. These results expose the method as being too crude, or the experts insufficiently discerning, for it to be relied upon with any degree of confidence. Thus, while often useful to obtain an initial overall impression, the method should certainly be backed up by more reliable diagnostic radiographic methods before a final treatment plan is presented to the patient.

In the incisor region, an unerupted permanent incisor may be associated with one or two supernumerary teeth (mesiodentes). The parallax method is insufficiently clear in these cases due to the presence of two or three hard tissue entities in the bone, superimposed on the outline of the roots of the deciduous teeth and at varying heights in the alveolus.

The question arises as to whether the parallax principles may be applied to other types of receptor combinations, possibly with a greater degree of reliability. A vertical imaging discrepancy between teeth in the line of the arch and those that are buccally or palatally displaced can be created between the panoramic view and the periapical/anterior occlusal views (Figure 4.6). The panoramic view is a rotational tomograph, with the cone of the machine pointing upwards with a very small 7° tilt from below the occlusal plane, as it circles around the head of the patient. Because this view is recorded when the receptor is on the buccal side of the teeth and the cone directed from the palatal aspect, this is equivalent to a 7° tilt of the X-ray cone, when translated into a buccal-to-palatal direction.

By contrast, the direction of the central ray in an anterior occlusal view (60–65°) or periapical view (50–55°) is angulated much more steeply to the receptor. These will both show superimposition of an ectopic tooth over the tooth in the line of the arch, but it is the degree of vertical discrepancy between these radiographs and the panoramic view that will reveal the position of the displaced tooth.

The same panoramic view, with the X-ray beam hitting this area when the cone is at the back of the patient's head, will project the anterior midline area in its postero-anterior aspect. The canine and premolar regions will be projected from an increasingly angulated viewpoint, as the X-ray cone moves from the back to the side of the head. The molar and retromolar areas will be projected from the side, on the same revolving receptor, as a consequence of the further rotation of the X-ray beam.



(a) (b)

Fig. 4.6 The vertical tube shift method using a panoramic radiograph and periapical views. (a) The panoramic radiograph shows the left canine very high and above the root apices of the incisors (arrow). The right canine superimposes on the apical third of the adjacent incisor. (b) The periapical views show the left and right canines overlapping one-third and two-thirds of the incisor roots, respectively. Both canines are labial.

If all the teeth are in the same approximate semi-circular line of the arch, then their mesio-distal relationships will be fairly accurately represented on the radiograph. However, a palatally displaced canine or premolar tooth is imaged when the X-ray cone is at a point, in its arc of circle, just behind the ear on the opposite side. Viewed from this position, the palatally placed tooth will be 'thrown' mesial to its true mesio-distal position and will be shown superimposed more mesially on other structures than would be evident from its appearance on a lateral cephalogram [9]. Accordingly, a panoramic radiograph (an oblique lateral view) and a lateral cephalogram (a true lateral view) may be coordinated to determine the bucco-lingual location in the canine or premolar regions, in a similar manner to the use of two periapical views in Clark's parallax method

[5]. Obviously, this is dependent on the individual teeth being clearly discernible on the cephalogram, bearing in mind that sometimes unavoidable superimposition in the anterior region may invalidate the method (Figure 4.7).

The panoramic X-ray machine is normally adjusted so that its circling of the jaws maintains a fixed distance from the focal spot to the dental arch (for a patient with the ideal jaw shape). The perimeter of the arch falls within the centre of the focal trough that the machine produces. Teeth that are palatal to the line of the dental arch are displayed as enlarged horizontally and those that are buccally displaced are shown reduced horizontally.

The mesio-distal width of a maxillary permanent canine is approximately 90% of the width of the maxillary central incisors. With a normally located canine, the distance between it and the receptor may be slightly larger than that of the central incisor, due to the form of the arch in that area. Thus, in these cases it is common to see, on the panoramic radiograph, similar mesio-distal widths of these two teeth. A buccally displaced canine, on the other hand, will generally reflect the true width difference between the two teeth, because its distance from the receptor is similar to that of the central incisor (Figure 4.8, left canine).

This principle was used in an investigation of this phenomenon, which revealed that when the mesio-distal width of the crown of an unerupted canine (as it appears and is measured directly on the panoramic radiograph) is 1.15 times larger (i.e. 15% greater) than that of the adjacent central incisor (the canine-to-incisor index), then the canine will be palatally displaced [10, 11]. This was found to be reliable in 100% of cases in which the canine was seen on the radiograph to be superimposed on the coronal or middle portions of the root of the adjacent incisor.

As can be seen in this illustration (Figure 4.8), by direct measurement of the crown of the patient's right canine, the mesio-distal width of the crown appears considerably more than 15% larger than that of the right central incisor, while the left incisor is approximately the same width as the left central incisor. Each of them is superimposed on the middle portion of the root of its immediate neighbour, validating the conclusion that the right canine is palatal and the left buccal.

Earlier studies that had attempted to diagnose canine position on a panoramic radiograph using the principle of differential enlargement revealed only an 80–89% degree of reliability of diagnosis [12, 13]. This was due to the inclusion of cases where the image of the canine was superimposed on the apical portion of the root of the incisor. The anatomy of the anterior portion of the maxilla is responsible for this aberration. Erupted permanent incisor teeth do not stand vertically upright, but their roots tip palatally at a significant angle to the vertical (Figure 4.9). This means that the root apices are considerably more distant from the panoramic machine receptor than are the crowns. If a canine is located high up on the labial side of the root apices (in the labial alveolar depression in the incisor region inferior to the nose), the tooth may still be considerably more distant from the receptor than are the crowns of the incisors. Thus, the image of the canine crown will be enlarged to a greater extent than that of the incisor crowns and will appear disproportionately large on the radiograph.

(a) (b)

Fig. 4.7 The lateral tube shift method using a panoramic radiograph and a lateral cephalogram. (a) In the panoramic view, the X-ray cone projects this image in the premolar area when it is behind the ear of the opposite side and therefore provides an oblique lateral view. This gives the misleading impression that the unerupted right second premolar (arrow) is rotated. (b) The lateral cephalometric view of the same patient shows only a very mild mesial displacement of the second premolar (arrow), with a minimal rotation of its palatal cusp in a mesial direction. Since this projection is a true lateral view, this is the true mesio-distal position of the tooth. The imaging of the second premolar for a panoramic view is made when the X-ray cone is behind the ear on the other side. This means that the apparent mesial displacement and apparent rotation of the tooth, seen here, confirm that it is also palatally displaced. Its size relative to the first premolar also confirms its palatal displacement. A tooth placed palatally vis-à-vis the focal trough appears wider than the same tooth in a buccal position.

Fig. 4.8 The enlarged premaxillary segment of a panoramic radiograph showing two unerupted maxillary canines. Note the inequality of image size of the two canines.

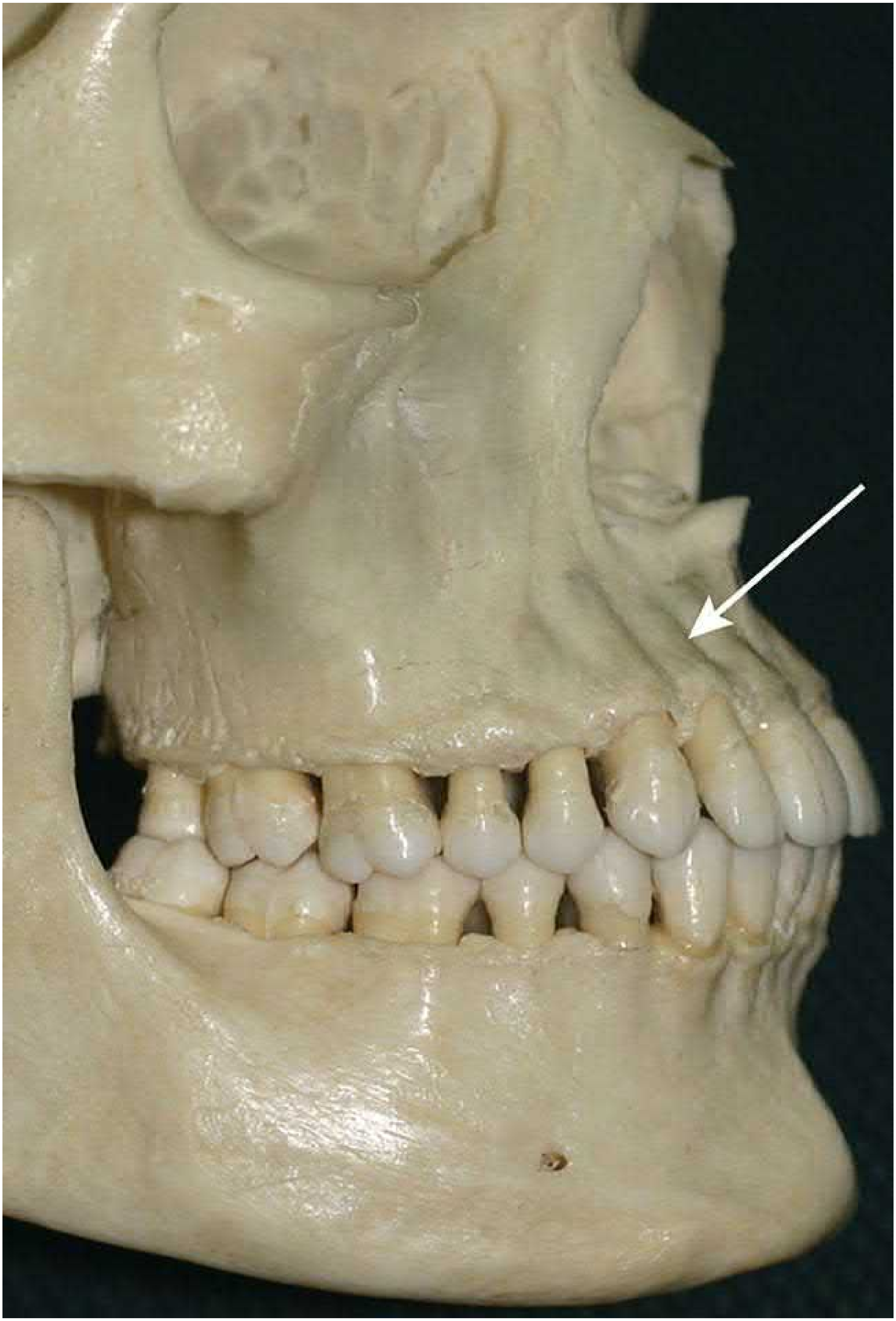


Fig. 4.9 On the dry skull, the roots of the maxillary incisor teeth can be seen to tip palatally at a significant angle to the vertical, creating a depression in the bone (arrow) at the level of their apices. A canine impacted labially in this depression will be more distant from the panoramic receptor than the incisor crowns and will therefore cast a much enlarged image on the radiograph. The use of the panoramic view for positional diagnosis at this relative height would therefore be incorrect.

Accordingly, the 1.15 canine-to-incisor index formula excludes all canines whose superimposition on the incisor root is high in the apical area. If the method is restricted to those cases in which the canine traverses the root of the incisor inferior to its apical third, then its use in determining the bucco-lingual positioning of the crown of an impacted tooth is valid, without the need to resort to other views.

It is very important to clarify that panoramic radiography is extremely sensitive to deviations in patient positioning. The patient is positioned with the jaws placed exactly in the middle (in the bucco-lingual aspect) of the focal trough. Any deviation from the middle of the focal trough will cause distortion, especially in the horizontal magnification. In such cases the apparent mesio-distal dimension of the teeth is unreliable.

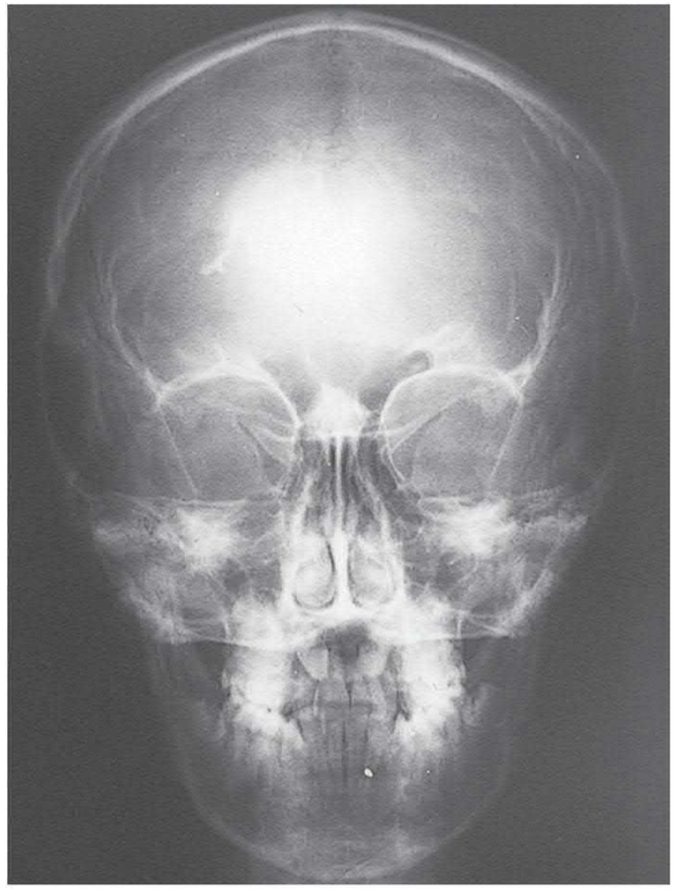
Radiographic views at right angles

Radiographic views may be taken at right angles to one another in various ways but, for the method to be of value, it must be possible to determine the exact orientation in space of both the receptor and the central ray [1, 2]. The observer must be in a position to deduce these from observation of other structures on the radiograph whose locations are known. Thus, if one begins with a periapical view, it becomes necessary to provide another view that is at 90° to it, in order to satisfy the minimum geometric conditions. However, having done this, it must be possible to mentally reconstruct the exact orientation of this second view at a later date, by looking at the radiograph alone and without necessarily having prior knowledge of exactly how the tube and receptor were placed. This is obviously very confusing and completely impractical.

Standardization

Standardization of views is required within the confines of strict adherence to the planes of space. Any 2D view, carried out in meticulous accordance with the standards, becomes simple for the observer to appreciate and when information from the other views at right angles to it is merged with it, the composite 3D picture is easy to reconstruct mentally. A true lateral view (Figure 4.10a) will give exact information regarding both the antero-posterior and vertical location of an object, relative to other structures that may be seen both on that radiograph and clinically. It will provide bucco-lingual (transverse) plane information for the incisors, but not for the posterior teeth. A true occlusal view will offer positional information in both the antero-posterior and the transverse planes, but not in the vertical plane. Thirdly, there is the true antero-posterior view (Figure 4.10b), which defines the height (vertical plane) of a tooth as well as providing bucco-lingual information for the area of the premolars and molars, but not the incisor area. By combining the information provided by any two of these three radiographs, three-dimensional localization may be determined.

(a)



(b)

(c)

Fig. 4.10 (a) The true lateral cephalometric radiograph shows both canines superimposed at a higher level than the other teeth. Their axial inclination on the antero-posterior plane is favourable, with the crowns and apices apparently normally located. (b) The postero-anterior cephalometric radiograph shows the two canines similarly angulated, with their apices in the line of the arch and their crowns close to the midline. From these two radiographs, we may conclude that the apices are ideally placed and that the long axes of the teeth have a downward, mesial and palatal inclination. (c) The panoramic view of the same patient. The appearance of canines close to the midline is very similar to that seen on the posterior-anterior cephalometric radiograph.

Translating these principles into radiographic practice demands repeatability of patient positioning standards for each radiograph. This might present some difficulties when these radiographs are not consistently executed by the same person, since they have to deal with different and many times challenging jaw structures. However, the problems are not insurmountable and, insofar as the radiographs provide the clinician with accurate positional visualization of the unerupted tooth, doing so may be entirely worthwhile.

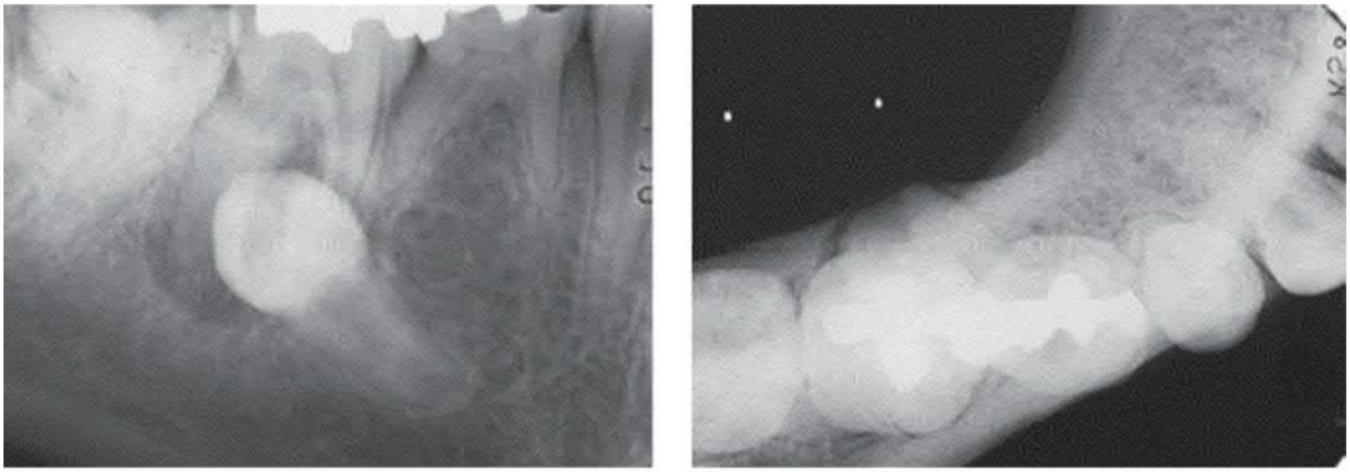
For most orthodontic cases, a lateral cephalometric radiograph (a cephalogram) is an essential initial step, whose primary purpose is the routine measurement of angles and planes. On the other hand, this radiograph potentially contains much useful information regarding the location and angulation of unerupted teeth. The radiograph represents a true lateral view of the skull and, for the present purposes, of the jaws and the anterior maxilla in particular (Figure 4.10a). Although there are many superimposed structures in this area, the outline of a canine may be clearly seen. The direction of the long axis of the tooth in the anterior–posterior and vertical planes may be clearly defined, together with the mesio-distal position of both crown and apex.

With regard to the mandibular posterior area, we have pointed out that the routine periapical radiograph produces a true lateral view, with the X-ray tube pointing at right angles across the body of the mandible and in the horizontal plane. The height and mesio-distal position of a buried tooth may then be accurately defined. The occlusal radiograph of this area is directed perpendicular to the occlusal plane and adds the bucco-lingual dimension, thereby completing the 3D picture. Accordingly, these two views will provide a good assessment of the position of unerupted teeth in this area (Figure 4.11).

If a cephalometric radiograph is not available, the same view of the anterior maxilla may be obtained on a small, occlusal-sized receptor. The receptor is held vertically against the cheek and parallel to the sagittal plane of the skull. The X-ray tube is directed horizontally above and parallel to the occlusal plane from the opposite side of the face and at right angles to the receptor. The result is called the tangential view and has the advantage of simplicity. This view is particularly useful in monitoring progress in the resolution of impacted incisors during active treatment.

At the age that most patients first present with an impacted central incisor, around 8–10 years, the permanent canine teeth are unerupted and are located both well forward and high in the anterior maxilla. Thus, on the lateral cephalometric or tangential view, right and left canines will be impossible to distinguish from one another. The roots of the incisors, at the same height as the canines, as well as the superimposed images of the more inferiorly placed crowns of the erupted incisors and deciduous canines, will all be impossible to differentiate from one another and from any supernumerary teeth that may also be present. For this reason, the lateral view may be of limited value in cases where there is obstructive impaction, with minimal displacement. When gross displacement is present, however, the outlines of the altered axial inclination and height of the tooth are usually possible to delineate, despite the considerable superimposition of other teeth.

Nowhere is this view a greater asset than when a dilacerate central incisor is present, since, because of its relative height, it separates out this malformed tooth superiorly from the root apices of the other teeth and from the permanent canines (Figure 4.12). Furthermore, the morphology may be seen to best advantage from this aspect, which allows definitive and accurate diagnosis to be made of the condition, together with its precise relation to surrounding structures. The lateral cephalogram/tangential view should be considered an essential requirement in the radiographic recording of a dilacerated central incisor.



(a) (b)

Fig. 4.11 The true lateral and true occlusal views, taken together, provide all the information needed for a good positional assessment of crown and root in the three planes of space. (a) The periapical view (a true lateral in this case) of an impacted mandibular right second premolar shows the tooth to be tipped 60° distally from the vertical, with its incomplete apex at the correct height and mesio-distal location. (b) The true occlusal view shows the crown of the tooth to be lingual to the molar and the apex to be in the bucco-lingual line of the arch. The long axis of the tooth, proceeding from its ideally sited apex, can be described as rising at a 30° angle in a distal and lingual direction, to overlap the molar roots on the lingual side.

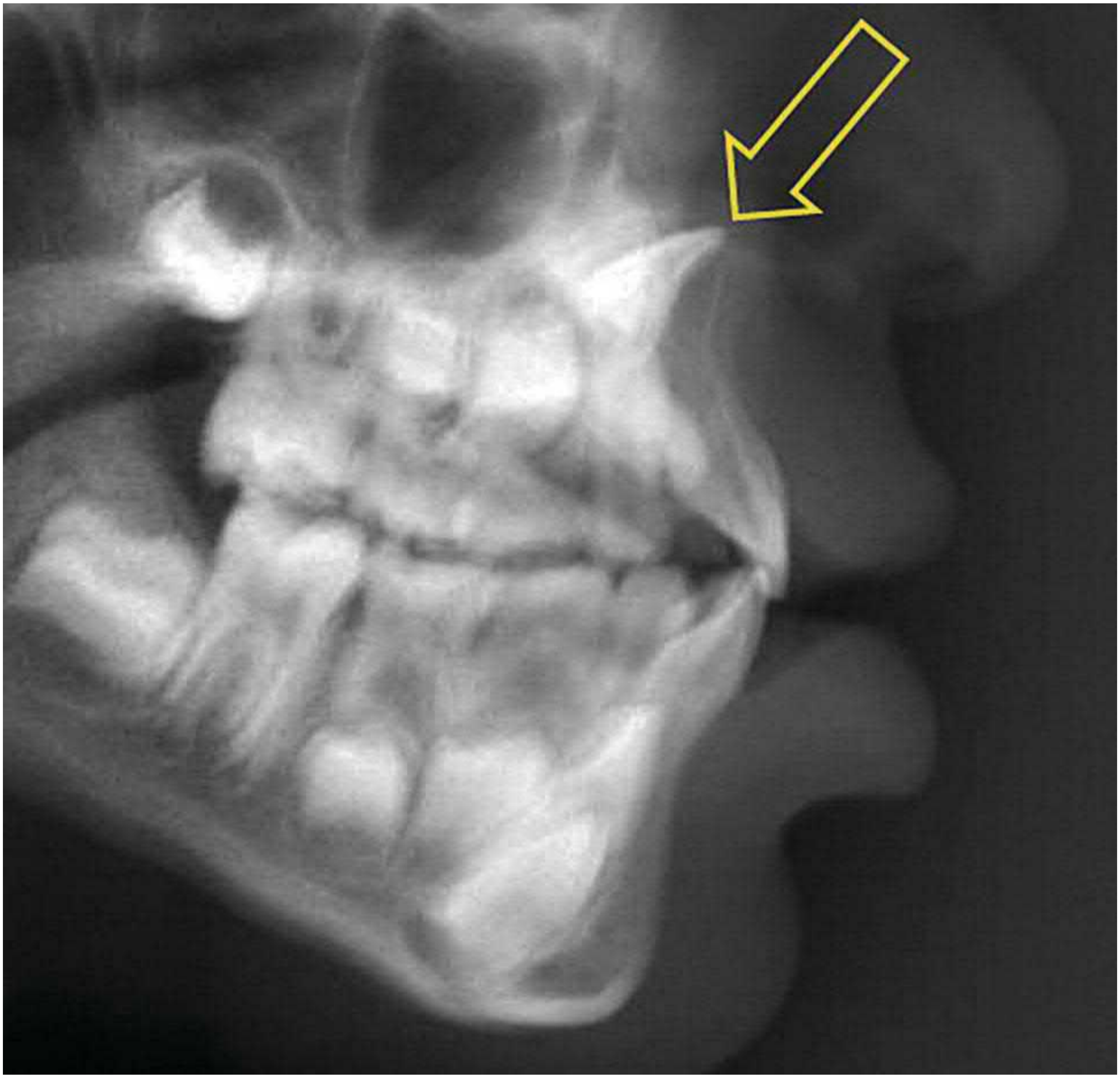


Fig. 4.12 A dilacerated central incisor (arrow) seen in a lateral cephalometric radiograph.

For maxillary canines, the lateral view is extremely useful. It should be remembered that most impacted maxillary canines are diagnosed in the full permanent dentition, when all the other teeth have erupted. This permits clear radiographic imaging of the canine when it is sited at a higher level than the other teeth.

A postero-anterior cephalometric radiograph is used less routinely in orthodontics, but it does offer the clinician the opportunity to view the maxilla in a different plane, the true postero-anterior view (Figure 4.10b), which is at right angles to the lateral cephalogram. The overlap of structures of the base of the skull and the maxilla renders detail of individual teeth less clear, but a good postero-anterior radiograph will show the height of both the crown and the root of a significantly displaced tooth, as with the lateral radiograph. This view also shows whether the root apex of an ectopic posterior tooth is in the line of the arch and how far the crown is deflected in the palatal direction. The bucco-lingual tilt of the long axis of the tooth will be plainly visible

(Figure 4.10b). However, the view is less practical in the mandible, where the left and right sides of its V-shaped body converge, as they proceed forward towards the anterior midline and are thus oblique to the central ray. There is usually excessive overlap, more radio-opaque bone and difficulty in discerning even markedly bucco-lingually displaced teeth. For structures close to the midline, the panoramic view offers a very similar representation (Figure 4.10c) and a much clearer picture. Since this view is a rotational tomograph, it eliminates all structures that are either lingually or buccally outside the narrow focal trough at which it is aimed.

An occlusal projection of the anterior maxilla (Figure 4.2) offers the possibility of viewing in the third plane of space, at right angles to each of the two earlier radiographs, and recording the position of the displaced incisor or canine without overlap. However, for maximum effect it is important to project the X-ray beam through the long axis of the maxillary teeth, as we have just described.

Any two of these three views (the lateral cephalogram or tangential view, the postero-anterior cephalogram view and the true occlusal view) will provide complete information regarding every aspect of the height, bucco-lingual and mesio-distal location of the crown and the root, and the degree of tilt of the long axis of the impacted tooth and its relation to neighbouring teeth. The postero-anterior cephalogram and the occlusal views, however, are not always as clear as is desirable, and they may need to be repeated or discarded. In a case of bilateral canine impaction, the lateral cephalometric or the tangential view may create confusion, since one canine will be superimposed on the other and distinguishing them may be a problem, whereas other views will usually facilitate differentiation. Two identically oriented and superimposed canines (Figure 4.10) will obviously not need to be differentiated.

It is essential to be aware that many of the radiographs that we take for other reasons should always be scrutinized for useful information regarding positions of unerupted teeth. This is particularly so regarding cephalograms, whose principal aim is to measure and compare angles and distances on tracings of specific landmarks on the radiograph. Sadly, these potentially valuable views are often filed away without sufficient thought.

From these projections, it is very easy to build up a 3D picture of the exact position and angulation of the impacted tooth and to define the type of movement that will be necessary to bring the tooth into alignment. When a composite mental reconstruction is made of the position of the unerupted tooth in space, the design of the appliance needed to resolve the impaction is simplified and fewer surprises are likely to be encountered. It is, however, a *sine qua non* in all these cases to examine a periapical view of the tooth in order to eliminate the possibility of local pathology, which is much more likely to be missed on the extra-oral views.

The foregoing description has covered the various methods available for envisioning the anatomical form and 3D location of unerupted teeth, using plain film radiography. We have seen that, in order to achieve an adequate picture of the relationships between the crowns of these teeth and the surrounding anatomical structures, including adjacent teeth, information gleaned from several different types of view needs to be put together to make up the complex picture. Nevertheless, even when enough information is available, mistakes and misdiagnoses are sometimes made by experienced orthodontists [6], occasionally with serious repercussions for the patient.

It would be appropriate now to consider the question of whether the same degree of precision in root apex location and 3D root orientation is essential for both the orthodontist and the surgeon. From the point of view of the oral surgeon, diagnosis of the position of the crown, buccal or palatal to the line of the arch, is generally all that is needed, regardless of whether the tooth is to be exposed for orthodontic alignment or extracted. The position of the root apex and the orientation of the long axis of the tooth are irrelevant for surgical exposure. If the tooth is to be extracted in one piece, careful dissection of the tissue surrounding the crown and dislodging it with an elevator or extraction forceps will deliver the tooth, together with its root. Even if the root portion is sectioned and scheduled for extraction, after removal of the crown portion, its general orientation and apex position can be determined by the anatomy and general orientation of the crown. For these reasons and until CBCT became first choice, many surgeons have had to rely solely on the tube shift parallax method of positional diagnosis for exposure or extraction of impacted teeth, and have done so with a degree of exaggerated confidence. However, today the majority will overwhelmingly prefer cross-sectional slices reconstructed from a CBCT series.

From the point of view of the orthodontist, however, while the position of the crown is important, the position of the apex and the orientation of the long axis of the tooth are crucial. When the root apex of the impacted tooth is displaced, re-siting it in its correct position is fraught with technical difficulty and can only be done once the crown has been brought into its place in the arch and ligated into the main archwire. As we shall discuss in Chapter 7, root movement is the most damaging movement to the root itself and to the supporting tissues. It has been shown to be one of the factors that most undermine the periodontal prognosis of the treated result [14–16]. Orthodontists cannot be expected to be confident in their ability to bring a tooth into full alignment if an accurate 3D diagnosis of its position is not available. In the event, a surgical exposure may be attempted from the wrong side of the alveolus and unnecessary damage will ensue. Alternatively, the impacted tooth may be drawn in the wrong direction and will be brought into contact with the root of an adjacent tooth, which may lead to resorption of that root or to the blocking of further progress. The reader is referred to Chapter 18 for an illustrated description of failures and how most of these were due to positional misdiagnosis.

Unfortunately, the above-mentioned plane radiograph methods exhibit many shortcomings. This is particularly true in relation to the bucco-lingual plane. Undoubtedly, the most difficult aspect to define is the relative proximity of the impacted tooth to the root of an adjacent tooth on which its image is superimposed in the bucco-lingual plane, as seen on a periapical, anterior occlusal, panoramic or cephalometric radiographs. Whether there is a small distance between them or whether the crown of the impacted tooth lies in a resorption crater on the palatal or labial aspect of the root of an incisor may be impossible to determine using plane 2D radiography. As a result, an undiagnosed and severely resorbed tooth, with a poor long-term prognosis, may be mistakenly included as an integral but ‘weak link’ in the final scheme of the dentition in a projected treatment plan [17].

The relative accuracy of positional diagnosis using planar radiography is, therefore, inadequate in many instances. While this is so, there can be no question that a good number of cases continue to be successfully treated, despite a lack of adequate imaging documentation that would be needed to make even an approximate positional diagnosis. In some cases, no serious attempt at definitive diagnosis of the position of the impacted tooth is made until the unsuspecting and potentially unfortunate patient is on the operating table.

Computerized tomography

It was in the late 1980s [18, 19] that the use of computerized tomography (CT) scanning was first proposed as a tool for the identification of the exact position of the palatally impacted canine, particularly when root resorption of the lateral incisor is suspected [20]. At that time, while its excellent potential was recognized for diagnosis of the position of impacted and supernumerary teeth, the large dosage of radiation that routine CT imaging required was difficult to justify for all but the most complex and exceptional cases. The previously common use of plain 2D radiography often failed to disclose the exceptional and difficult nature of the particular case – a matter that would later be abundantly clear on a CT scan.

In the years following the first edition of this book, CT has found and established an important place in planning the treatment of impacted teeth. Accurate 3D localization of the impacted tooth is immediately available. In this way, the exact relationships between the impacted teeth and their adjacent teeth could be seen along the entire lengths of the crowns and roots of each.

Using this modality, it has become possible to improve the overall assessment of cases in which the impaction could best be resolved with orthodontic treatment and to sufficiently separate them from those where the tooth was in an intractable position. Trial and error slowly became a practice of the past [21, 22], since it became possible to present a 3D radiographic image of what the surgical field would look like when an impacted tooth was uncovered by the oral surgeon. This helped to eliminate positional misdiagnosis and the consequent undertaking of treatment for those relatively few cases in which the position and proximity of other teeth made it impossible to arrive at a successful conclusion to the treatment.

Similarly, the axial (horizontal) and cross-sectional (vertical) 'slices' as selected provided information in the bucco-lingual plane, which had been generally impossible to discern with routine plane radiography. These views contributed materially to the evaluation of the prognosis of the intended treatment. Thus, the bucco-lingual proximity of teeth and the existence and extent of oblique root resorption all become assessable, and these were and are important factors in determining choice of teeth for extraction or indeed whether to undertake treatment at all.

In a study performed in 1988 [19], the prevalence of resorption of the roots of incisor teeth, as associated with an impacted canine, was investigated by plain 2D radiography and found to affect 12% of the individuals in the sample. When the same investigators repeated their study 12 years later using spiral CT scanning [23], the number of affected individuals increased to 48%! There can be little doubt that this was due to this vastly improved diagnostic tool and to the fact that resorption of the buccal or palatal aspects of the roots of the incisor teeth cannot be seen on regular radiograph. It is only when the buccal or palatal resorption has become sufficiently extensive to cause a change in the shape of the mesio-distal profile of the root that it may be identified by plain 2D radiography and this type of resorption would go undiagnosed.

CT offers advantages in assessing the proximity of the impacted tooth to an adjacent pathological entity. It also provides valuable assistance in evaluating aberration in the shape and appearance of the crowns and roots of teeth that were suspected of having been damaged or have suffered from abnormal development due to past trauma [24].

Conventional spiral CT machines, as used in routine hospital practice for imaging various parts of the body, expose the body to an X-ray beam in the form of a progressive spiral, encircling the body over a specific, defined area, with continuous radiation during the whole scanning time. This submits the patient to a high dose of ionizing radiation and has been a subject of concern when considering its use in the dental context. The dosage was evaluated by Dula et al. [25, 26] using what they called a 'hypothetical mortality risk'. In this assessment, the mortality risk associated with routine dental radiographs ranged between 0.05 and 0.3×10^{-6} units, depending on the type and number of radiographs performed, while a CT scan of the dental area alone was assessed at 28.2×10^{-6} for the maxilla and 18.2×10^{-6} for the mandible.

Cone beam computerized tomography

Hounsfield conceived the idea of CT in 1967 and, together with Cormack, invented the first commercially viable CT scanner in 1972. He and Cormack were later awarded the Nobel Prize for their contributions to physiology and medicine. However, the use of CT in dentistry only lasted 24 years until, in 1996, the QRsrl Company from Verona, Italy introduced CBCT with the 'NewTom 9000'. Radiation was 90% less than for a routine medical CT. This new technology was referred to as digital volume tomography (DVT) and it has revolutionized the world of dental and maxillofacial imaging. In comparison with CT, CBCT has made imaging simpler, more accessible and cheaper. The NewTom 9000 and its successor the NewTom 3G, which was launched in 2004, employed an image intensifier connected to a charge-coupled device (CCD) camera-type detector. This was not new technology and other manufacturers, such as Morita (3D Accuitomo), Hitachi (CB MercuRay) and Sirona (Galileos), chose similar technology. All machines employed an image intensifier-type detector, reconstructed to a sphere-shaped volume.

In the first years of the new millennium, the newer and superior flat panel detector (FPD) technology was introduced to the dental market by Imaging Sciences International, with its first CBCT machine, the iCAT, employing an amorphous silicon FPD. Within a short time thereafter, all new CBCT machines were fitted with an FPD and today there are over 20 CBCT manufacturers worldwide.

The FPD is superior to its predecessors in all characteristics including its size and weight, but also because it prevents information loss due to the peripheral truncation from which image intensifiers suffer, with their spherically shaped volume. The FPD used in CBCT machines employs indirect conversion, in which the X-ray energy is converted first into light energy and from there into a signal. The amplitude of the signal from each pixel in the detector is dependent on the amount of illumination indirectly converted. Indirect conversion FPDs have become standard detectors in all CBCT machines. Direct conversion technology from X-ray energy straight to a signal is (at the time of writing this chapter) the latest expected CBCT developmental stage, which has so far only reached panoramic radiography. It produces high-resolution quality images with better signal-to-noise ratios and dose efficiency.

The detailed workings of a CBCT machine are beyond the scope of this book and will only be discussed here insofar as they relate directly to the context of impacted teeth. For a comprehensive description of the manner in which CBCT works, the reader is referred to a supplement article that appeared in the *Australian Dental Journal* in 2017 [27].

Cone beam computed tomography technology

The X-ray source, emitting a pyramidal-shaped beam, is mounted on a gantry facing a detector. Unlike the rotation centre in a panoramic machine, which slides during its rotation, the CBCT gantry axis is fixed. The patient is positioned with the centre of the region of interest (ROI) in close proximity to the gantry's rotation axis. The gantry performs 180–360° rotation around the patient's head, during which, in most machines, multiple exposures (150 to about 1000) are taken. The number of exposures taken depends on the protocol chosen in the specific machine, but certain machines radiate continuously during the exposure. The 2D images taken in this single rotation of the patient during the scan are collectively known as *raw data*, which is then reconstructed into a 3D volume. This procedure is called a *primary reconstruction* and is carried out by a software algorithm. The algorithm will calculate and create the volume according to the protocol chosen and is depicted in the form of a cylindrical stack of axial slices, reminiscent of thin slices of salami, one on top of the other.

Processing the scanned information

When the orthodontist's CBCT machine is 'in-house', the imaging process is initiated with the software supplied by the machine manufacturer, or with third-party software. When the patient is referred to an imaging centre, the imaging technician will produce a DICOM (Digital Imaging and Communications in Medicine) set, representing the international standard for image format and file structure for communication, handling, storing, and printing of medical and dental imaging and image-related information. It will be handed over together with a viewer program supplied by the CBCT unit manufacturer, or with a third-party software viewer preferred by the imaging centre. Often, however, more digitally savvy orthodontists may decide to use their own third-party software to achieve the same ends. In this case only, the DICOM set is handed over and the orthodontists employ their own software.

Many orthodontists will prefer to patronize a professional imaging centre, who may offer a service to perform a work-up of the case. The technicians at the centre are experts in specifically providing an accurate positional diagnosis of the tooth/teeth in the three planes of space and in relation to the adjacent teeth and other anatomical structures. The work-up should be adequate to the task of analysing and discovering the existence of pathological entities, leading to the diagnosis of the cause of the impaction, a task for which this modality is second to none.

Secondary and online reconstructions can alter the patient position by tilting in any desired axis in space and slicing it in any direction and in any chosen slice thickness. The slices are not limited to straight cuts, with the panoramic view being the most popular curved cut. A thick panoramic view looks similar to the traditionally irradiated 2D panoramic view and it has the advantage that its form is without horizontal or vertical magnification and, therefore, without distortion. It is possible to avoid overlapping of individual teeth, especially in the premolar area, and there is no projection of other structures, such as the hyoid bone on the mandible or spinal vertebrae on the anterior region. The only information presented on the images is precisely what exists in the focal trough. The disadvantage of the reconstructed panoramic view is that artifacts found in the focal trough will be seen in the reconstructed panoramic view even if their source is outside the focal trough or even the FOV. If an extra-large FOV is chosen, 3D orthodontic software has the capacity to produce standardized cephalometric views and the many other views needed for an orthodontic portfolio. A handful of devices have this capability. It is very important to note that all devices that enable this extra-large FOV will perform this scan using half-beam scan technology (up to 40% less radiation). The result is a normal- to low-resolution scan, which in most cases will be sufficient for all the reconstructed views needed for the orthodontic portfolio. When zooming in on an impacted tooth and its surroundings, one might find it difficult to go into delicate details, like minor resorption, early-stage invasive cervical root resorption (ICRR), etc.

3D module

A majority of dental CBCT software will have some kind of 3D volume-rendering module, which is a very valuable tool for the accurate positional diagnosis and treatment planning of impacted teeth. The 3D volume-rendering module depicts the individual teeth in their exact spatial arrangements and proximity to one another, from root apices to crown tips and viewable from every angle. The capabilities of this module vary between software programs and normally include several viewing modes. A logical examination sequence would start with the 3D rendering module, during which the ROI is identified, before moving on to slicing these areas.

It is possible to move and rotate the volume, to 'sculpt' away areas that interfere or obstruct, to clip in a given axis and to peel away bone. In relation to impacted teeth, the most popular viewing modes in the orthodontic context are the transparent mode and the opaque bony appearance. The 3D module is good for a general, overall survey and will help clarify the crown and root relationships of impacted and supernumerary teeth with adjacent structures. Unfortunately, 3D portrayal cannot be trusted to discern tooth contact or minor resorption, not even using ideal viewing angles. Bone peeling, relevant to the opaque bony viewing mode, is not a tooth segmentation procedure, because this will peel off visual information with a density below the set threshold. When cortical bone areas have a similar density to that of dentine, the software is unable to distinguish between the two and will peel both. When the 3D threshold control is altered, the visible tooth volume changes. Thus, when thicker cortical bone needs to be peeled off, more dentine will be peeled off with it and a smaller tooth volume will result.

Case 1: Ways of imaging and their effect on tooth size

Figure 4.13 represents six different ways to image the area of the dentition immediately surrounding the maxillary right permanent canine. The clinical aim was to determine if the space between the lateral incisor and first premolar, which was partially filled by the retained deciduous canine, offered sufficient mesio-distal width to accommodate the permanent canine in its trajectory down to the occlusal level. The 3D opaque bony view needs to be peeled in order to clarify this point. This is presented with progressively more aggressive peeling from parts 4.13(a) to 4.13(d). Part 4.13(a) appears to have peeled off only the soft tissue. However, the alveolar bone covering the labial side of the canine is extremely thin and, because of its low density, will ‘disappear’ along with the soft tissues. Reducing the peeling would cause ‘reappearance’ of the soft tissue and obscure the thin bone covering. Proceeding from part 4.13(a) through to part 4.13(d), actual tooth volume begins to be peeled away. Thus, while there is visible interproximal solid contact in parts 4.13(a) and 4.13(b), there is also the suspicion of minor root resorption at the distal of the incisor. In part 4.13(c) the solid contact transmutes into a lighter contact and in part 4.13(d) into an apparent open contact, as the peeling process depletes the tooth volume. When rendering the volume in the 3D transparent mode, as depicted in part 4.13(f), there is no interproximal contact with the lateral incisor and, therefore, it may be assumed (wrongly) that there is a clear path to accommodate the unerupted canine. Since valid accurate information is an obvious clinical requirement, it is essential to understand how minor errors such as this may creep into the assessment of space by this method.

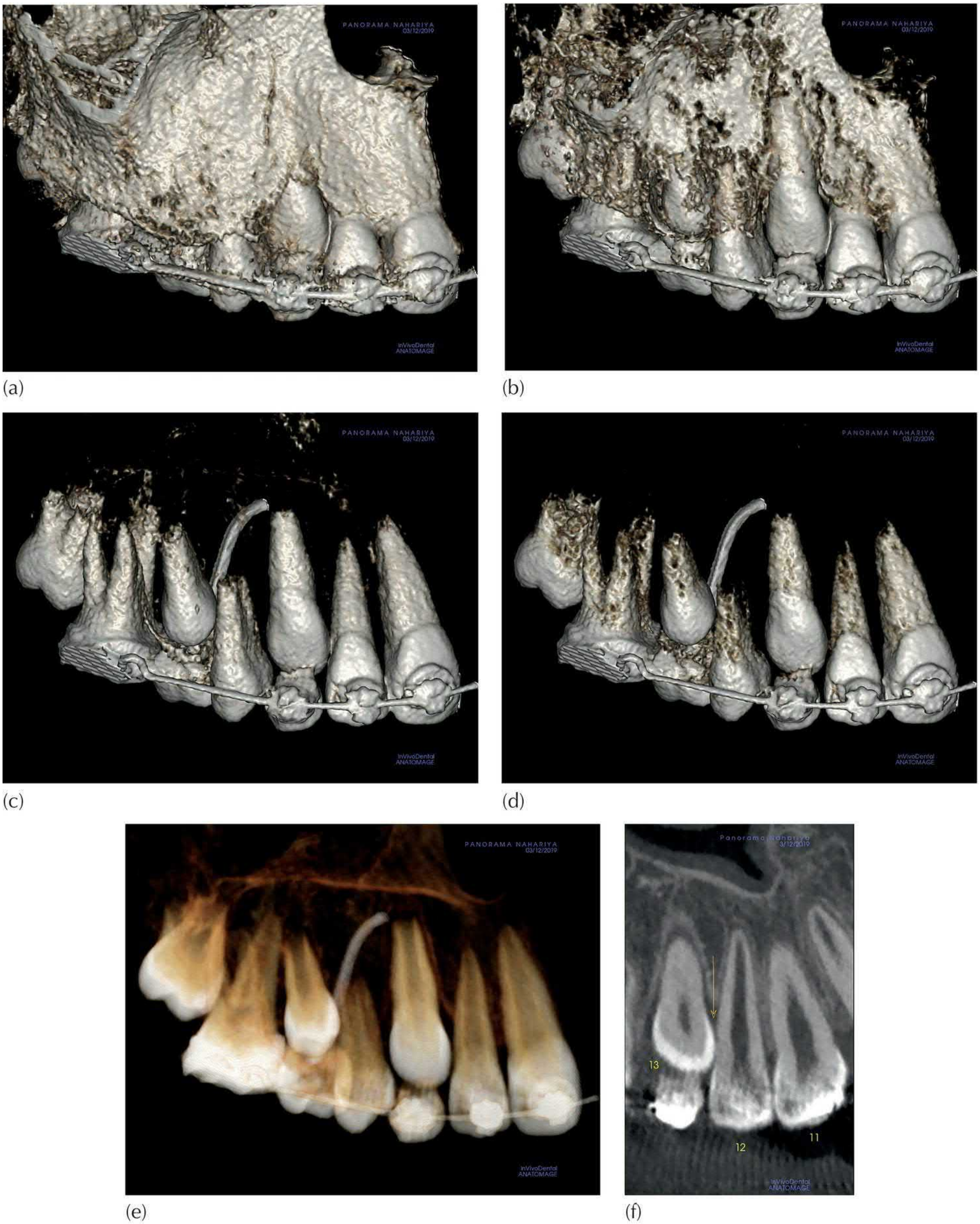


Fig. 4.13 Bone peeling in 3D. (a–d) Progressive bone peeling and how it may mislead by altering the teeth volume and interproximal contact. (e) Volume rendering in the 3D transparent mode. (f) Longitudinal slice cropped from the multi-planar reconstruction screen (Figure 4.14) showing the deepest point of interproximal contact (see text).

The multi-planar reconstruction (MPR) screen presentation in Figure 4.14 is a typical example. In order to define the exact mesio-distal contact area between the lateral incisor and canine on the right side, the sagittal (Figure 4.14b) and coronal (Figure 4.14c) planes are tilted until the long axis of the incisor is brought exactly vertical. Once the tooth is vertically positioned, it may be rotated on its axis. The yellow line with arrows at both ends is a custom section tool, which has the ability to rotate around an axis marked at its centre. It is placed on the axial (Figure 4.14a) view with its centre at the point at which it meets the tooth axis, on which rotation may be made. The window in Figure 4.14(d) displays the cut produced by the rotation tool. By rotating the tool, the tooth outline may be depicted at any point on the 360° circle. The deepest point of contact is illustrated in the window in Figure 4.14(d) and enlarged separately in Figure 4.13(f).

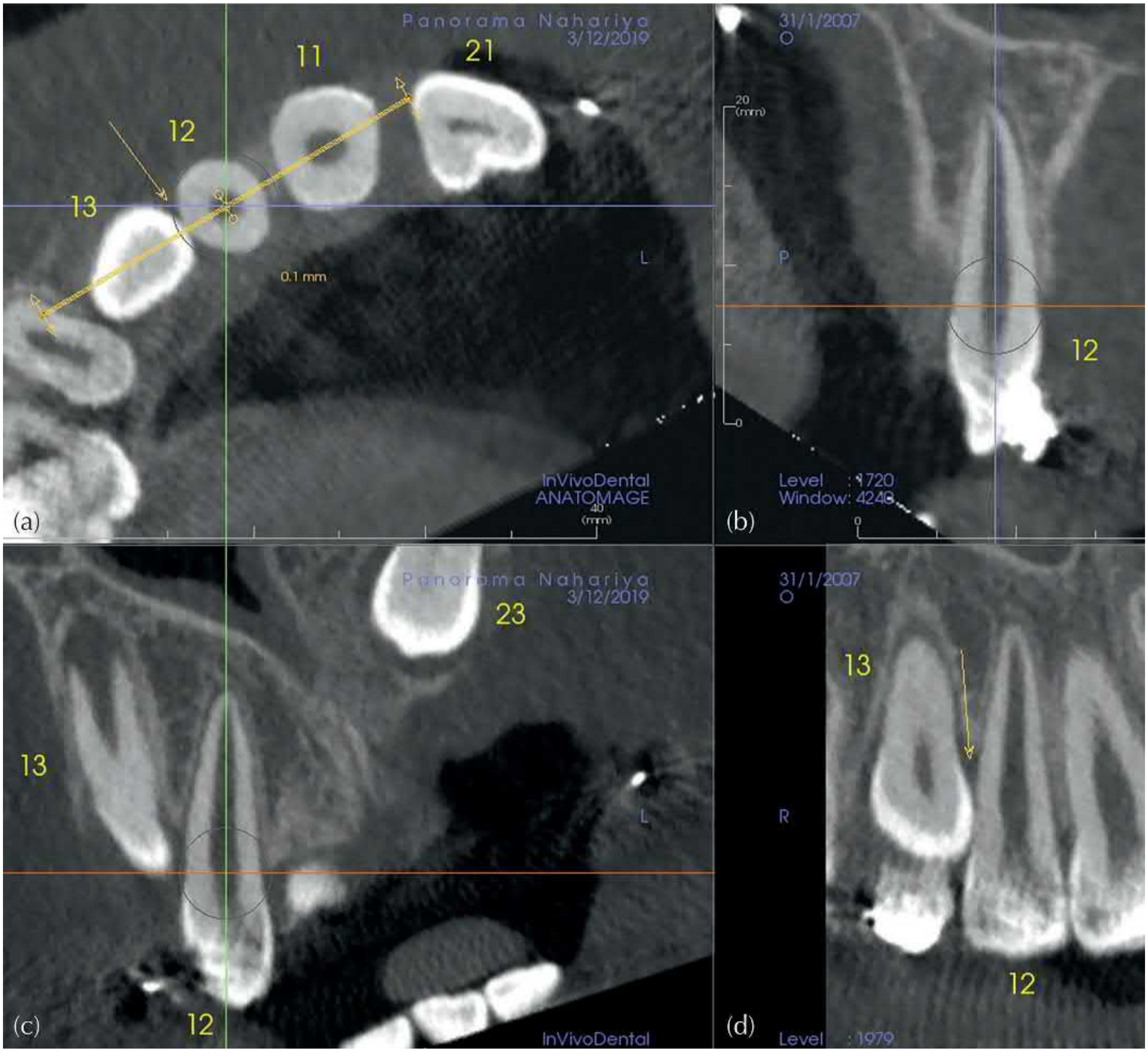


Fig. 4.14 A view of the multi-planar reconstruction screen for Case 1, as presented in InVivoDental software (see text).

Peeling the 3D opaque bony mode and exploiting the 3D transparent mode offer many advantages in appreciating the inter-relations of the teeth and the surrounding structures. Understanding of the process by which they are produced and their reducing effect on tooth volume are factors that often need to be taken into account.

In light of the foregoing discussion, it will not come as a surprise to learn that peeling of bone in the body of the mandible will result in much loss of teeth volume, particularly the thick bone of the buccal side of the mandible. In practice, because the densities of the teeth and the surrounding compact bone are of a similar order, it is largely impossible to peel this thick buccal bone without excessively reducing tooth volume and it becomes necessary to combine clipping and, in some cases, sculpting to achieve the desired results (as demonstrated in Case 2).

Case 2: Peeling, clipping and sculpting

In this case the clinical aim was to find aetiological evidence for the failure to erupt of the first mandibular molar on the right side. In order to enhance the 3D view, a combination of mild bone peeling, clipping and sculpting away part of the lingual cortical bone was executed (Animation 4.1 on this book's website). Two additional animations (Animation 4.2 and Animation 4.3) will enhance the perception of the case. The latter animation shows how, by tilting the chin upwards (in the SW) and thereby placing the molar in a vertical position, animation becomes more informative (orthodontic treatment by Dr Ronen Zoizner).

The lesser density of the bone in the upper jaw makes the situation there much more favourable for obtaining good-quality imaging of the impacted teeth, while maintaining tooth volume.

It is important to note that the 3D transparent view tends to deceptively show tooth volumes to be smaller than they are and, as such, should be treated with caution.

Automatic tooth segmentation

This procedure, based on artificial intelligence (AI), is already in use (Figure 4.15). At the time of writing it is a third-party service, which will undoubtedly be added to the CBCT software by the manufacturers. This is an excellent feature because it saves time and effort, but should only be used to obtain a general impression. Presently it is not accurate enough in relation to tooth volume. In the not too distant future, however, it is expected to improve, as with most applications that depend on AI. Tooth contact or minor resorption will need to be confirmed, preferably in the MPR screen.

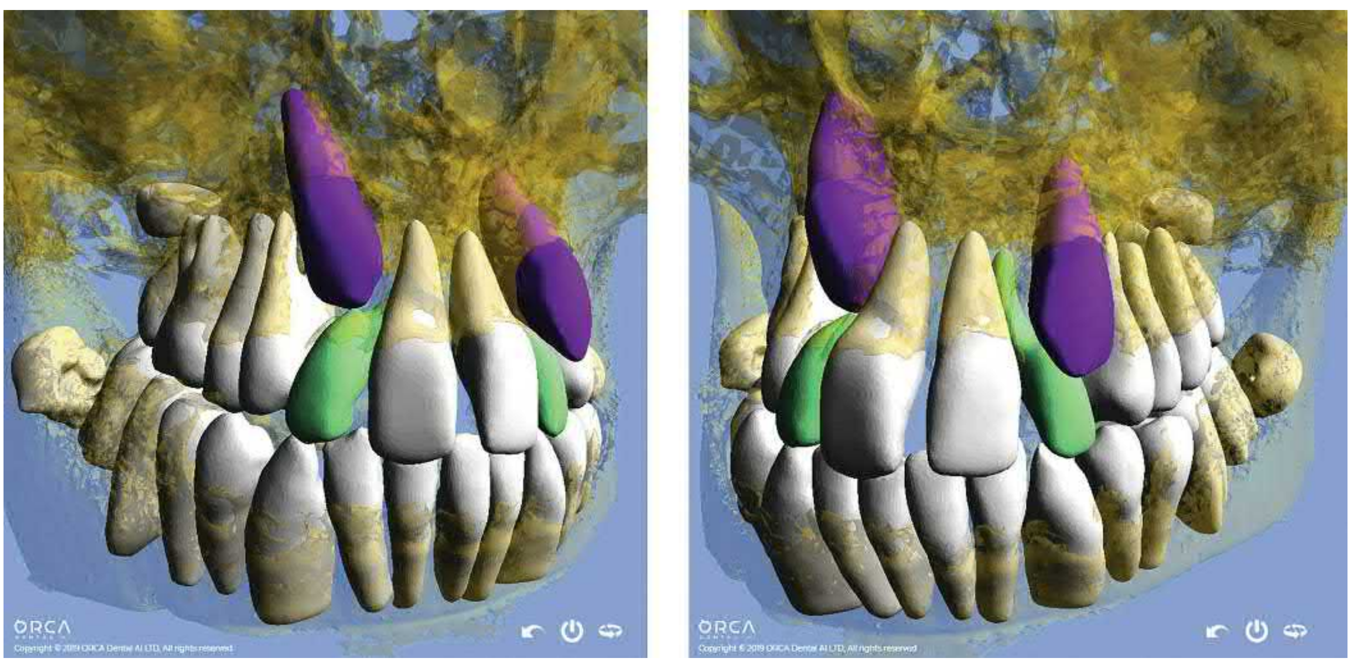


Fig. 4.15 Automatic segmentation, artificial intelligence (AI) driven. The software algorithm automatically segments the teeth and bone for each jaw separately and the inferior alveolar canal. A viewer that can run on a PC or a smartphone will allow each entity to be coloured, rotated in all axes and moved separately, as well as being removed and much more.

Courtesy of ORCA Dental AI.

Multi-planar reconstruction

This is the basic screen in all CT software and displays the three anatomical planes: axial, coronal and sagittal. The initial display is dictated by the orientation in space in which the patient was positioned during the scan. The operator may then tilt the volume in all three axes and reach any desired position in space, i.e. the position of the patient's head may be virtually altered after the scan was taken. An initial overall impression of the situation may be gained by exploring the scanned volume, using the 3D volume-rendering module. At the outset, however, in order to discover if there are any relevant and unexpected details in the general area, a careful examination of each of the three planes for incidental findings is essential.

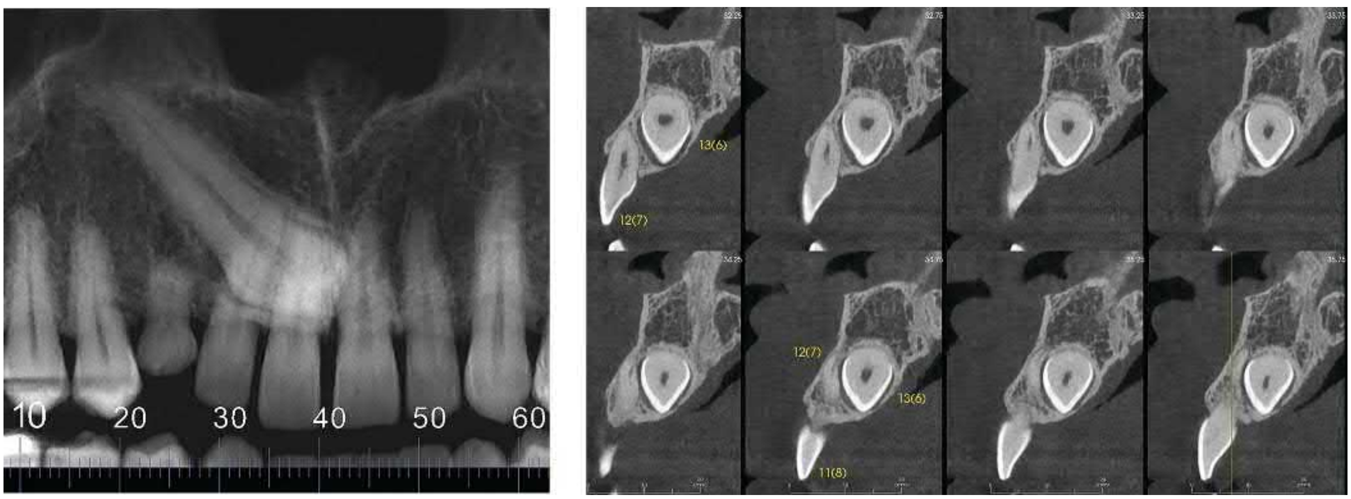


Fig. 4.16 Diagnosing resorption, cross-sections. The lateral incisor #12(7) is tipped mesially. Cross-sections are vertical cuts. Therefore in this case the cross-sections cannot reveal the resorption to its full extent.

From this point on, the focus of the investigation is directed specifically to the impacted tooth/teeth. Many orthodontists will rely on the bucco-lingual information, gleaned from a series of cross-sectional cuts that are perpendicular to the curved panoramic cut. It is a common misconception that all the information in the bucco-lingual plane should lie in these cross-sections, which may often be 1 mm thick with 1 mm spacing from each other. In fact, this concept is a clear recipe for negligently failing to identify important information, because the angle of these sections cannot reveal all the relevant data (Case 3, Figures 4.16–4.18).

The MPR screen contains all the information and it is a very important tool. The first step to be taken is a thorough three-plane scrolling of the ROI, with slice thickness set to a minimum (the voxel size), in the absence of sharpening filters. The ability to tilt one or more planes is an advantage in achieving the appropriate and more diagnostic cutting/slicing angle for visualization. The action that adds the ultimate level of diagnosis is viewing each involved tooth separately. It is necessary to tilt each tooth to a vertical position and to examine it while rotating it through 360° and covering every possible angle (Figures 4.14 and 4.17). Additional scrolling through the axials along the vertical tooth will complete the process. Similarly, if the impacted tooth is located at an almost horizontal angle, it is tilted so that its long axis is exactly oriented in the horizontal and sagittal posture. Using the same rotating tool, on this occasion the tool should be placed on the tooth axis in the coronal plane window (Figure 4.19c). After rotating the tool through 360°, additional scrolling through coronals along the tooth will complete the diagnostic information.

Case 3: Diagnosing Resorption

The left-hand image in Figure 4.16 represents the anterior portion of a reconstructed panoramic view, depicting a typical, palatally impacted and strongly tipped canine. At the same time, the root of the lateral incisor is tipped mesially. The right-hand image in Figure 4.16 shows a row of eight serial cross-sectional cuts across the root of the lateral incisor, presenting a suspicion of root resorption, due to the proximity of the canine crown. Because the cross-sectional cuts are always vertical on a reconstructed panoramic view, the tipped root of the lateral incisor cannot be sectioned to reveal the resorption to its full extent. The MPR screen (Figure 4.17) is the place to look for the extent of the resorption. The coronal (Figure 4.17c) and sagittal (Figure 4.17b) planes are tilted to bring the lateral incisor long axis to a perfect vertical posture. The rotating tool is placed on the tooth axis in the axial (Figure 4.17a) plane. The tool is then rotated 360°, thus depicting its outline at every possible angle. The window in Figure 4.17d is recording the resorption in the disto-palatal aspect. The tool continues on its way around the tooth axis and in Figure 4.18 a resorption in the palatal aspect is recorded, indicating the breadth of the resorption lesion. There is, indeed, no substitute for this diagnostic ability in the aspect of the tooth long axis (orthodontic treatment by Dr Ronen Zoizner).

Case 4: Multi-planar reconstruction for an incisor that is almost horizontal

The clinical aim was to learn why the right central incisor had refused to erupt, and to establish its exact location and anatomy and assess its proximity to other teeth and structures. The right central incisor was horizontally and sagitally re-aligned in the axial (Figure 4.19a) and sagittal (Figure 4.19b) planes and the centre of the rotating tool was placed on its long axis in the coronal window (Figure 4.19c). Rotating the tool has revealed the tooth anatomy and interproximal contact areas. Figure 4.19(d) represents the cut produced by the rotating tool. In this case it demonstrates the point of contact with the lateral incisor (Animation 4.4) (orthodontic treatment by Dr Morris Strauss).

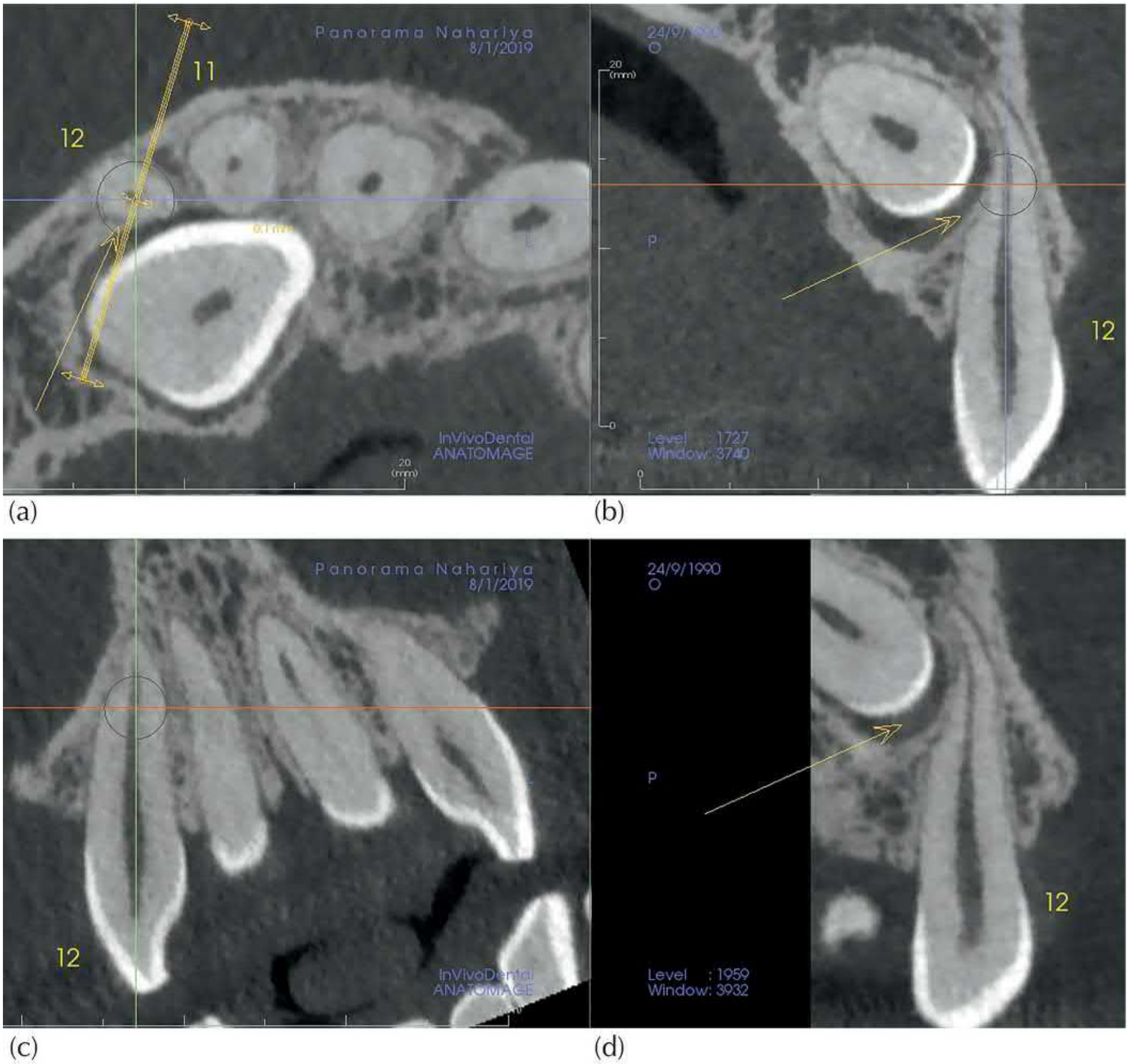
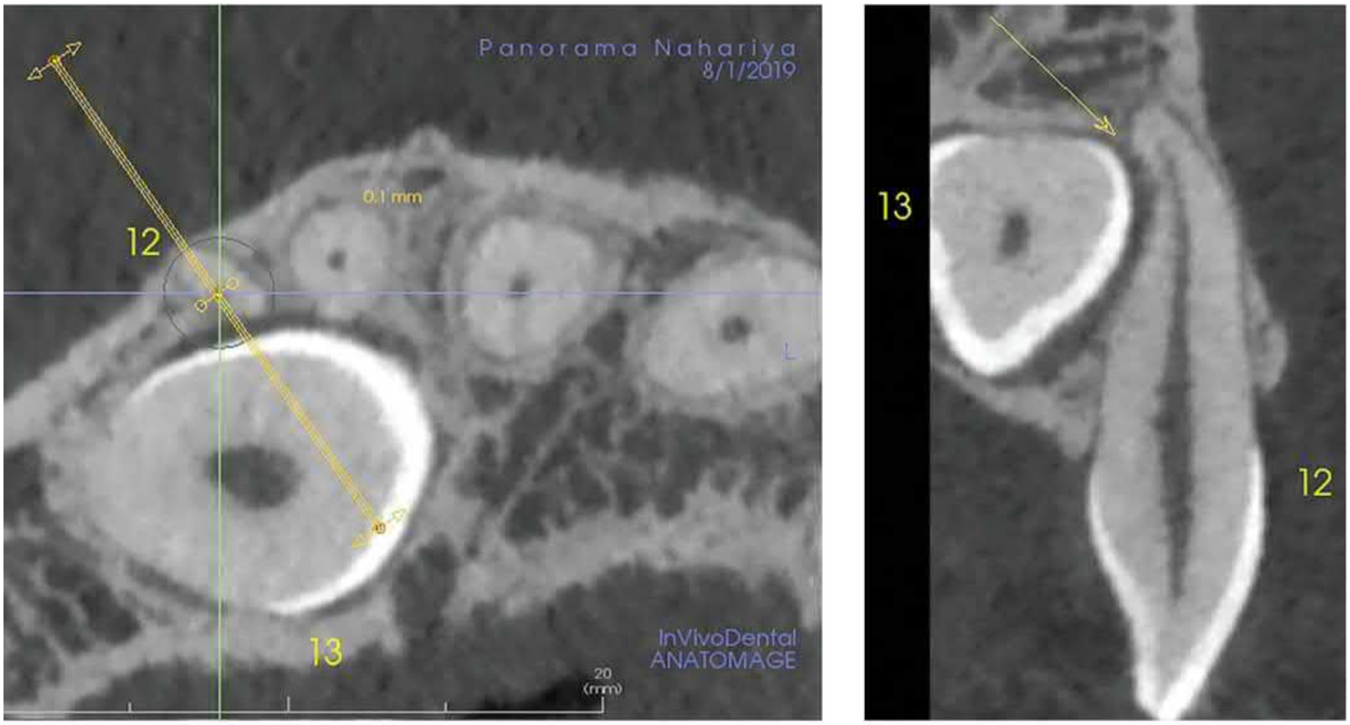


Fig. 4.17 Diagnosing resorption with multi-planar reconstruction. The long axis of the lateral incisor from Figure 4.16 has been tilted to a vertical position in the coronal (c) and sagittal (b) planes. The rotating tool is placed on the tooth axis in the axial (a) plane. Window (d) shows the resorption in the disto-palatal aspect.



(a) (b)

Fig. 4.18 Diagnosing resorption with multi-planar reconstruction (MPR). The axial (a) and the special tool window (b) are cropped from the MPR screen. The appearance in (b) reveals the resorption in the palatal aspect.

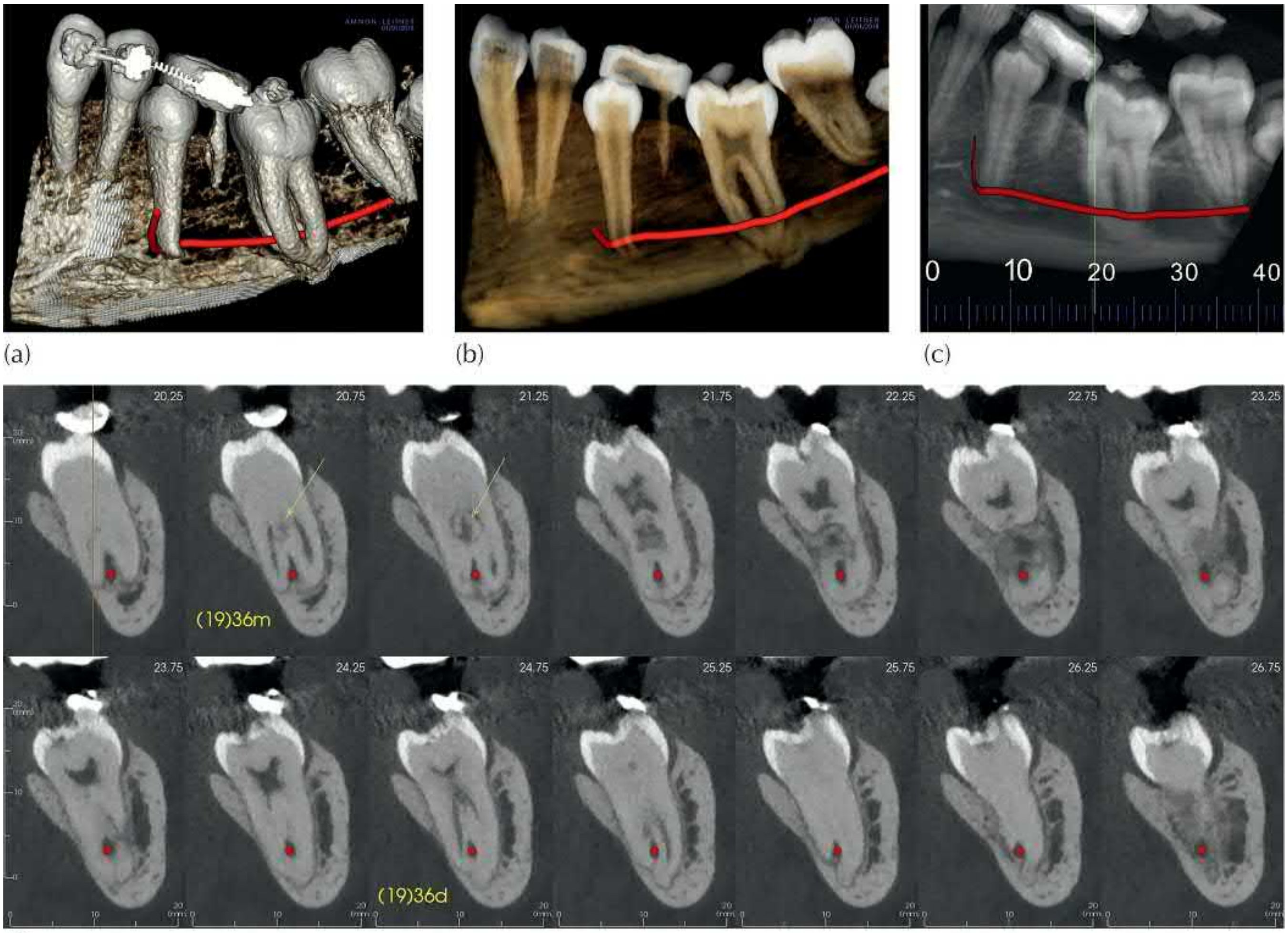
Inferior dental canal marking

Tracing the inferior alveolar and marking it in red is a helpful feature. Once marked, it is embedded in the volume and will show as a red dot or line in any cut that crosses its path. This method is used principally in planning the placement of dental implants. However, for much the same reason, it has value in respect of the inter-relations between the inferior dental (ID) canal and a severely and deeply infra-occluded/impacted molar or premolar, whose roots are developing in close proximity to it (Figure 4.20 and Case 5).

Fig. 4.19 Multi-planar reconstruction for an incisor that is almost horizontal. The right central incisor was horizontally and sagitally re-aligned in the axial (a) and sagittal (b) planes and the centre of the rotating tool is placed on its long axis in the coronal window (c). Window (d) represents the cut produced by the rotating tool, in which the contact point with the lateral incisor is demonstrated.

Case 5: Inter-relations between the inferior dental canal and the first molar

The clinical aim was to find aetiological evidence for the failure to erupt of the first mandibular molar on the left side. The first impression from looking into the 3D bony view (Figure 4.20a) was that the ID canal was embraced by both distal and mesial roots (Animation 4.5). Such a condition is usually caused by some obstruction in the way of the eruption path of the tooth, as a result of which the roots continue to develop and, in this case, to embrace the canal. The obstruction can be caused by a physical blockage or by ankylosis preventing the natural eruption of the tooth. While exploring the 3D view, a resorption lesion was observed in the mesial root next to the furcation. Figure 4.20(b) shows clipping of the buccal side all the way to the furcation, leaving the volume with only the lingual side of #36 (19), thereby enhancing the lesion area view (Animation 4.6). The 3D module is a wonderful tool for gaining a general impression, but the investigation is actually carried out on the MPR screen. Figure 4.21 is a cropped MPR screen where the arrows indicate the ICRR lesion. A scroll through all three planes of the MPR screen can be viewed in Animation 4.7.



(a) (b) (c)

(d)

Fig. 4.20 First mandibular molar embracing inferior dental canal. (a) 3D bony view using bone peeling, sculpting and clipping. (b) 3D transparent view, buccal side clipped up to molar furcation, leaving only the lingual side for visualization. (c) Panoramic view with defining cross-sectional grid. (d) A series of cross-sectional slices showing the neurovascular bundle on each slice.

It is important to note that the majority of ICRR lesions originate at the cemento-enamel junction (CEJ). When searching for aetiological evidence for an impacted tooth eruption failure, it is important to check the CEJ carefully, while rotating the tooth 360° as explained in Case 3, for an early-stage ICRR.

With the earlier introduction of spiral CT and subsequently of CBCT, much debate was generated in relation to the justification for their use in orthodontics in general, and their value in the diagnosis and treatment planning of impacted teeth in particular. For planar radiography to provide a comparable level of positional information, a number of different views of the impacted tooth would need to be taken and the accumulated level of radiation that these would generate is of the same order as that emitted by the new CBCT machines.

The many studies that have been undertaken, for patients with an impacted tooth, to compare the advantages of using CBCT over plain 2D radiography have not provided the conclusive evidence that one would expect. It is clearly an indisputable fact that 3D imaging has, at least in theory, provided an infinite number of possible angles from which to view the tooth, as compared with a 2D radiological representation. So why was there no conclusive result? Could it be that the range and depth of CBCT post-processing techniques that were performed were not as sophisticated as they should have been? Or perhaps only a minimum/standard orthodontic service was offered by the imaging technicians for the individuals comprising the patient samples. It is our opinion that the technicians in many of the radiological institutes in most of the Westernized countries we have visited or with whom we have had professional communication have not succeeded in mastering the complexities involved in the sophisticated interpretation of the CBCT imaging modality.

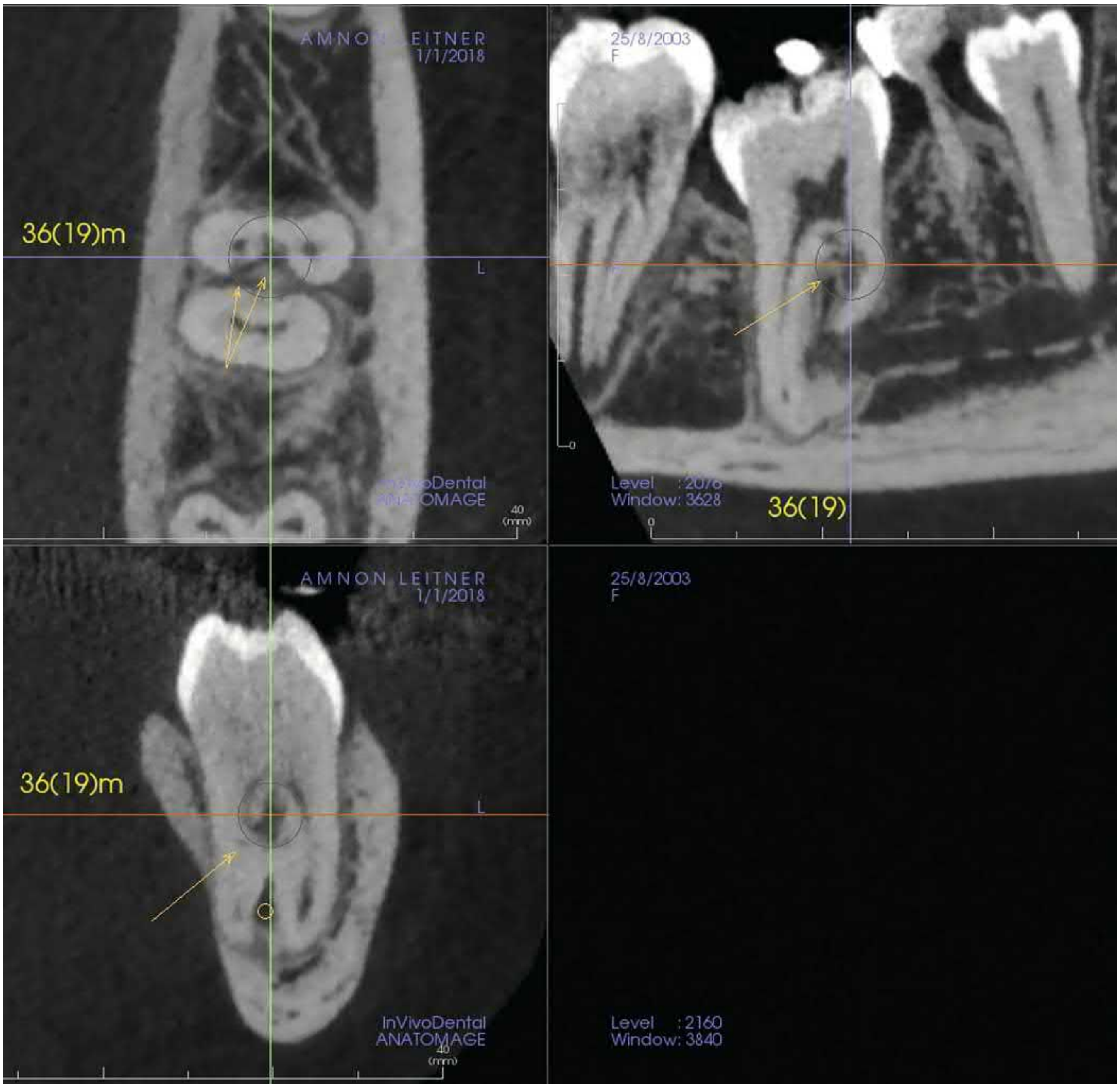


Fig. 4.21 Multi-planar reconstruction view. Arrows indicate the invasive cervical root resorption lesion in the first molar mesial root.

The greatest advantage that the cone beam volumetric machine has over conventional CT machines is that its radiation dosage is only a fraction of that emitted by the medical machine. As shown in Table 4.1, the CBCT machine irradiates the patient at approximately 8–23% of the regular CT machine, when 8% is compared to small FOV and 23% compared to craniofacial (extra-large) FOV.

Table 4.1 is based on typical exposure protocols and is calculated from data collated from multiple published studies. The levels of standard 2D dental radiography, CT and CBCT patients' median effective dose are compared and are shown as equivalent to daily background radiation. An average small FOV effective dose is 50 μSv, while that of a dental panoramic is about 20 μSv. A complete mouth series done with a round collimator ranges from 100 (CCD) to 200 (photostimulable phosphor plate, PSP) μSv.

What do these figures mean to the lay public? With our responsibility as dentists to convey information in a manner understandable to those seeking our treatment and in order to obtain informed consent, it is imperative to present the issue in its context, without blinding the patient with scientific data. Thus, it may be more pertinent to use the comparison that (a) the average person receives a dose of about 8 μSv per day or 2700 μSv per year from the environment [28]; and (b) flying from New York to Tokyo by the transpolar route exposes the passenger to ionizing (cosmic) X-rays of approximately 150 μSv and from New York to Seattle approximately 60 μSv [29].CBCT represents state-of-the-art technology, with direct relevance to the determination of macroscopic anatomy and accurate positional diagnosis of impacted teeth. The machinery is not beyond the financial means of most hospitals, radiology institutes, imaging centres, dental clinics and dental school radiology departments. Its advantages to the orthodontist and surgeon are manifest. Its level of emitted ionizing radiation is low and the cost to the patient affordable. It is a recommended procedure for many of the cases discussed within the context of this book.

Table 4.1 Typical effective dose from radiographic examination.

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Examination	Median Effective Dose	Equivalent Background Exposure[a]
Intra-oral [b]		
Rectangular collimation		
Posterior bite-wings: PSP or F-speed film	5 μSv	0.6 day
Full-mouth: PSP or F-speed film	40 μSv	5 days
Full-mouth: CCD sensor (estimated)	20 μSv	2.5 days
Round collimation		
Full-mouth: D-speed film	400 μSv	48 days
Full-mouth: PSP or F-speed film	200 μSv	24 days
Full-mouth: CCD sensor (estimated)	100 μSv	12 days
Extra-oral		
Panoramic[b]	20 μSv	2.5 days
Cephalometric[b]	5 μSv	0.6 day
Chest[c]	100 μSv	12 days

Cone beam CT[b]		
Small field of view (<6 cm)	50 μSv	6 days
Medium field of view (dentoalveolar, full arch)	100 μSv	12 days
Large field of view (craniofacial)	120 μSv	15 days
Multidetector CT		
Maxillofacial[b]	650 μSv	2 months
Head[c]	2 mSv	8 months
Chest[c]	7 mSv	2 years
Abdomen and pelvis, with and without contrast[c]	20 mSv	7 years

[a] Approximate equivalent background exposure is calculated based on an estimated background radiation dose of 3.1 mSv/year. Exposures more than the equivalent of 3 days are rounded off to the nearest day, month or year.

[b] Median dose from dento-maxillofacial radiography with typical exposure protocols is calculated from data collated from multiple published studies. Doses in the range of 10–1000 μSv are rounded off to the nearest multiple of 10.

[c] American College of Radiology, https://www.acr.org/Clinical-Resources/Radiology-Safety/Radiation-Safety.

CCD, charge-coupled device; CT, computed tomography; PSP, photostimulable phosphor.

Having said that, however, there is an inherent danger with this type of comprehensive imaging. The means of presentation of the results of the CBCT scan are very attractive to the layperson and several of the animations may be undertaken to impress the orthodontic patient, who may request a copy of the 'before and after' portfolio as a souvenir of the orthodontic treatment and outcome. In today's world, this can easily become part of the 'hard sell' and a means of attracting new patients. Consequently, the danger is that the stage may be set for the production of animations for the sake of 'completeness', much of which may be superfluous to the clinical needs of the patient, resulting in excess exposure of the patient to a large overdose of ionizing radiation.

ALARA

This leads us to explain the term ALARA – and what it means in practice [30].

It is only many years after treatment with any form of radiation that we see the stochastic effects, which include a higher susceptibility of the individual to various forms of cancer. It is known that these effects are amplified with increased exposure and that children are more susceptible than adults. Yet it is children and young adults who are the main patient population for orthodontic treatment. It is therefore incumbent on the practitioner to reduce this exposure to the minimum, while deriving a maximum of information adequate to the problem in hand. This is what ALARA signifies – As Low As Reasonably Achievable.

As we have already noted, there is a selection of scanning protocols and a low-dose feature in every machine. It stands to reason, therefore, that when a CBCT scan is justified, it is because plane 2D radiography cannot maximize the information needed for that patient, or that dose risk/benefit weighs in favour of CBCT. CBCT should be performed using the scanning protocol with the most efficacious risk/benefit and the smallest FOV possible.

Unfortunately, most orthodontists are not exploiting all the benefits of the CBCT scan, despite the fact that they tend either to scan patients in-house or refer them to an imaging centre, or to a colleague who has the facilities and the know-how available. It is of paramount importance that this wanton and cavalier attitude to CBCT scans should be disparaged and be replaced by orthodontists themselves becoming familiar with the important advantages offered by these machines.

In order to fulfil optimal scanning requirements for accurate diagnosis, orthodontists must be involved, proactive and specific regarding FOV and all other scanning parameters, including for such simple and apparently trivial instructions as scanning a seated patient, even with machines designed for erect subjects. All video animations prepared and produced by Amnon Leitner (panorama@inter.net.il).

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5
Surgical Exposure of Impacted Teeth

Adrian Becker

A brief history of surgery in relation to the treatment of impacted teeth
Aims of surgery for impacted teeth
Surgical intervention without orthodontic treatment
The surgical elimination of pathology
The principles of the surgical exposure of impacted teeth
Partial and full-flap closure on the palatal side
A conservative attitude to the dental follicle
Pathological pressure necrosis
Quality-of-life issues following surgical exposure
Cooperation between surgeon and orthodontist
The team approach to attachment bonding

A brief history of surgery in relation to the treatment of impacted teeth

Prior to the 1950s, few orthodontists were prepared to adapt their skills and their ingenuity to the task of resolving the impaction of maxillary canines and incisors, many preferring to refer these patients to the oral surgeon. The decision regarding the method of treatment of a particular impacted tooth was usually made by the oral and maxillofacial surgeon (OMFS). It was OMFSs who considered the options, chose the one they felt was appropriate and stage-managed the treatment process.

Surgeons would raise a flap, expose the tooth widely and only then make the decision whether to save the tooth or extract it. If, in their opinion, the impacted tooth could be brought into the dental arch, it would be left open to the oral environment with or without a surgical pack. If, in their judgement, this was unlikely to happen, they would extract the tooth on the spot and then write a note to that effect to the orthodontist. As can be imagined, many potentially retrievable, impacted teeth were thereby condemned to extraction.

The development of the role of the orthodontist in the rescue of impacted teeth was due to the realization that surgical treatment was just not enough. Whereas the elimination of the cause of the impaction and the provision of optimal space (by orthodontic means) did indeed provide a favourable environment to encourage autonomous eruption, it was clear that this alone was far from being universally successful. This led to the second realization: that orthodontic treatment alone was also not enough. It was acknowledged that, in order to achieve a more affirmative and quality result, with greater predictability, surgically afforded access would be required, together with the application of active and positive forces of traction/extrusion directly to the tooth.

From the early 1970s in the Hebrew University-Hadassah School of Dental Medicine in Jerusalem, Israel, orthodontists joined forces with the OMFS at the chairside and in the operating theatre, to adapt and cement preformed canine orthodontic bands during the surgical procedure itself. This had been the procedure prior to the era of acid-etching enamel and direct bonding of brackets. As a result, many more of these teeth were reclaimed and, in time, took their rightful place in the dental arch. However, in order to place a band, the entire crown needed to be dissected free of its dental follicle and clear of adjacent bleeding surfaces. This demanded radical surgery and efficient isolation of the tooth during the cementation process. Not every surgeon was willing to cooperate, thereby making the orthodontist much more selective in the choice of surgeon, particularly for difficult cases [1, 2].

Although it had been proposed for use in dentistry in the mid-1970s, direct composite bonding at the time of surgery was not adopted for use with impacted teeth until quite late after its introduction to clinical dentistry. Initially, many opinion leaders in the profession were not prepared to recommend the method, because of the inability to employ rubber dam isolation. They felt that it was not possible to achieve appropriate conditions for acid-etch bonding in the surgical field.

Nevertheless, in 1996, the efficacy and reliability of the more modest surgical requirement of merely exposing a small area of crown enamel were investigated, recognized and finally reported in the literature [3]. Many of the cases comprising the investigated sample in that study involved impacted teeth that would earlier have been regarded as intractable and no doubt would have been extracted.

This development had a very positive effect on the role, ability and expertise of the orthodontist to treat impacted teeth. We now had a more user-friendly method of bonding attachments, which encouraged the involvement of the surgeon in creating a more easily isolated and contamination-free area of crown enamel. There can be no doubt that the use of composite bonding made the work of the orthodontist much simpler to perform. In addition, the more modest scope of the surgical exposure that was now required immeasurably improved the quality of the results achieved.

A half-century has passed since the time when we, like every other orthodontist, would *send* patients to the surgeon to expose the tooth. Since that time, our contrasting protocol in Jerusalem has been to *accompany* the patient to the surgeon. Following the actual exposure of the tooth, the surgeon assumes the task of control of bleeding. The OMFS will also establish and maintain the moisture-free area to provide the orthodontist with access to the tooth and optimum conditions for cementation. No longer does the surgeon go off to drink coffee and leave the orthodontist to struggle in the attempt to bond an attachment with inadequate moisture control! So much so, that today's orthodontist who works in conjunction with the surgeon, has become more and more adventurous and prepared to tackle some of the most inaccessible impacted teeth [3]. This, together with the blessing of cone beam computed tomography (CBCT) imaging as a convenient tool for accurate positional diagnosis, has materially reduced the frequency of failure in the treatment of impacted teeth [4].

This subject was discussed at length in the article 'Surgical treatment of impacted canines: what the orthodontist would like the surgeon to know', which appeared in the August 2015 issue of *Oral and Maxillofacial Surgical Clinics of North America* [5]. The main thrust of the article was that it is in the interests not only of the patient, but also of the surgeon and the orthodontist, that both specialists be present and actively involved at the surgical procedure. Initially, the guest editor of that specific issue expressed concerns that the realities of practice in North America may make this impossible on a routine basis. In response, we pointed out that certain operative decisions, which are not always foreseeable until the surgical field is opened up, often need to be made chairside. Such decisions might include most or all of the following:

- Whether to place an attachment.
- Where to place it on the crown.
- In which direction to draw the gold chain or twisted steel ligature connector.
- Where it should exit the surgical area.
- Whether the surgically exposed area should remain open or closed.
- Whether to apply traction force to the orthodontic appliance at the time or at a subsequent appointment.

There are many ways available to the surgeon or periodontist to expose a tooth, any of which could be successfully performed in most cases. However, it is the orthodontist who should choose the most advantageous method [6–8] in order to identify the optimum attachment bonding site and the location of surgical entry to it, and to determine the type of exposure to be performed; all of the above, in order to be in a position to direct and apply the appropriate biomechanical force. Choice of surgical technique must aim to produce the healthiest and most aesthetic soft tissue architecture, which will be present *after* the tooth is brought into alignment. The absence of on-the-spot input may compromise one or more of the many aspects of the treatment, leading to a poorer periodontal prognosis and an inferior appearance of the treated result. The fact that the patient, the surgeon or the orthodontist may find the arrangement inconvenient might mean that the orthodontist cannot be present, but that must be recognized as a less than ideal situation. Not only does the presence of the orthodontist at the surgical episode serve the patient's best interests, it also speeds up the procedure, reduces discomfort and eliminates legally vulnerable misunderstandings and mistakes. The presence of the orthodontist is comforting and highly appreciated by the patient/parent and goes a long way to encourage confidence and trust.

Bonding an attachment during surgical exposure is not a function that a surgeon is adept at performing. It represents a highly technique-sensitive succession of tasks, which involve the following actions, all of which must be done simultaneously: lengthy flap and tissue retraction, and establishing and maintaining a completely dry, clean and blood-free surface of enamel while etching, rinsing, drying, painting with resin, light-curing, loading composite on the attachment, placing and curing. This delicate string of functions is not routinely performed by surgeons. Orthodontists, on the other hand, often successfully bond hundreds (literally!) of attachments every week.

The desirable location of the bonded attachment is strictly in the orthodontist's realm and it is not always possible to determine the location before surgery. Furthermore, when the exposed tooth comes into view, a decision may have to be made that may dictate the need to draw the tooth in a direction that had not previously been contemplated. This, in itself, may require an on-the-spot change in the predetermined bonding site. The luxury of being able to have 'second thoughts' at this crucial point in the treatment should not be surrendered lightly.

In a similar vein, the application of accurate directional traction from a customized spring mechanism is of considerably greater value if it is performed by the orthodontist under the cover of the pervading anaesthetic.

Notwithstanding this discussion, in cases of extreme displacement of an impacted tooth, extraction may be the treatment of choice. This may be due to the difficulty in attachment bonding or the inadvisability of performing an open surgical exposure. There can be no doubt that teamwork, combining the skill of the surgeon in controlling bleeding and the parallel skill of the orthodontist in bonding attachments, offers superior assurance against bond failure and towards overall treatment success.

One must not lose sight of the fact that it is the orthodontist who must follow through the remaining many months of active treatment. Failure to deliver the desired result will often sour the patient–doctor relationship and, moreover, may lead a resentful patient to seek legal recourse.

Aims of surgery for impacted teeth

It must be recognized that, other than transplantation, there are no *surgical* methods by which an impacted tooth may be positively and actively aligned. The best that surgery can do is to provide the optimal environment for normal and unhindered eruption and then live in hope that the tooth will oblige. In consequence, the recommendation in the latter part of the twentieth century was that those teeth that the oral surgeon considered worth trying to recover were widely exposed and packed with some form of surgical or periodontal pack, in order to protect the wound during the healing phase and prevent re-healing of the tissues over the tooth. The expectation was that the tooth would erupt spontaneously and could then be aligned with orthodontic treatment. Several other steps were often taken, depending on the individual preferences and beliefs of the surgeon, with the aim of providing that 'extra something' that would further improve the chances of spontaneous eruption. These measures were frequently empirical in nature and would include one or more of the following:

- Eliminating the follicular sac completely, down to the cemento-enamel junction (CEJ) area.
- Removing all bone around the tooth, down to the CEJ area, in order to dissect out and free the entire crown up to the coronal portion of the root of the impacted tooth.
- 'Loosening' the tooth by luxating it with an elevator or extraction forceps.
- Bone channelling in the direction of the desired movement of the tooth.
- Packing gauze or heat-softened gutta percha into the area of the CEJ, under pressure, in order to apply force to deflect the eruption path of the tooth in the preferred direction.

Back in the early 1970s, it was rare that the general dentist referred such patients to the orthodontist, at least not before full eruption had been achieved and then only to assist in moving the tooth horizontally into line with its neighbours. Before full eruption took place, the problem was considered to be within the realm of the oral surgeon. In many cases, 'success' in achieving the eruption of the tooth was indeed pyrrhic and sometimes actually caused a greater problem, particularly in relation to the periodontal condition of the newly erupted tooth and its survival potential – namely, its prognosis. This most unfortunate consequence was the result of the aggressive and overenthusiastic surgical techniques that were then being used, most of which typically left the tooth with an unaesthetic and elongated clinical crown, a lack of attached gingiva and a reduced alveolar crest height [9–13]. Just occasionally, these damaging procedures initiated an invasive cervical root resorption lesion, which created a state of non-response to orthodontic traction and failure in generating its eruption.

Surgical intervention without orthodontic treatment

Notwithstanding my description in the first part of this chapter, there are situations and conditions in which surgical intervention without orthodontic treatment is called for and indeed appropriate. Thus, in cases in which the impacted tooth is the only clinical problem (the occlusion and alignment being otherwise acceptable), the question that needs to be addressed is: what surgical methods are available that may be expected to provide a more or less complete solution without orthodontic assistance? In order to discuss this question, it is necessary to provide a description of the position of the impacted tooth that is being encouraged to respond to this kind of treatment.

Exposure only

The most obvious example is a superficially placed tooth, palpable beneath the bulging gum. This type of impaction may be found in relation to the maxillary canine (Figure 5.1), or in the mandibular premolar area (see Figure 1.8) or even the maxillary central incisor. The usual cause of this condition is where very early extraction of the deciduous predecessor was performed while the immature permanent tooth bud was still deep in the bone, with as yet inadequate eruption potential. Healing then took place, the gum closed over and the permanent tooth was unable to penetrate the thickened mucosa. Removing the fibrous mucosal covering or incising and re-suturing it to leave the incisal edges exposed (Figure 5.2a–c) will generally lead to a fairly rapid eruption of the soft tissue impacted tooth, particularly in the maxillary incisor area. The more the tooth bulges the soft tissue, the less likely will be a re-burial of the tooth during healing of the soft tissue, with the consequent rapid eruption of the tooth.

(a) (b) (c)

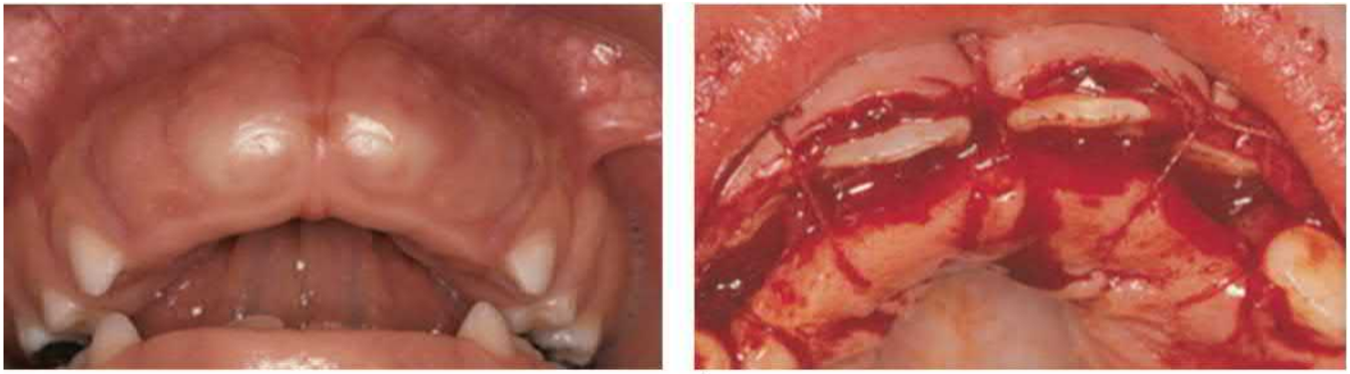
Fig. 5.1 (a) A 16-year-old female exhibits an unerupted maxillary left canine, which has been present in this position for two years and has not progressed. (b) The tooth was exposed and the flap, which consisted of attached gingiva, was apically repositioned. (c) At nine months post-surgery, the tooth has erupted normally, without orthodontic treatment.

Courtesy of Professor L. Shapira.

Exposure with pack

Taking this one step further, it is clear that an impacted tooth that is buried much deeper in the alveolus will be much more prone to being re-enveloped by its surrounding healing tissues. It will require a more radical exposure procedure to ensure its patency. In addition, it may need a pack to hold back the tissues during the post-surgical days and weeks, in order to ensure subsequent direct access to the tooth. While the surgeon may ultimately be rewarded with spontaneous eruption, this will inevitably take longer and the extent of the surgery may lead to a compromised periodontal result (Figure 5.3).

Over-retained deciduous teeth have been defined in Chapter 1 as teeth that are still present in the mouth when their permanent successors have reached a stage of root development that is compatible with their full eruption (two-thirds of expected root length). These deciduous teeth are to be considered as obstructing normal development. While it follows that they should be extracted, provision should be made at the same time to encourage the permanent teeth to erupt quickly.



(a) (b)

Fig. 5.2 (a) Soft tissue impaction of maxillary central incisors. (b) Apical repositioning of both labial and palatal flaps to leave the incisor edges exposed.

Courtesy of Professor J. Lustman.

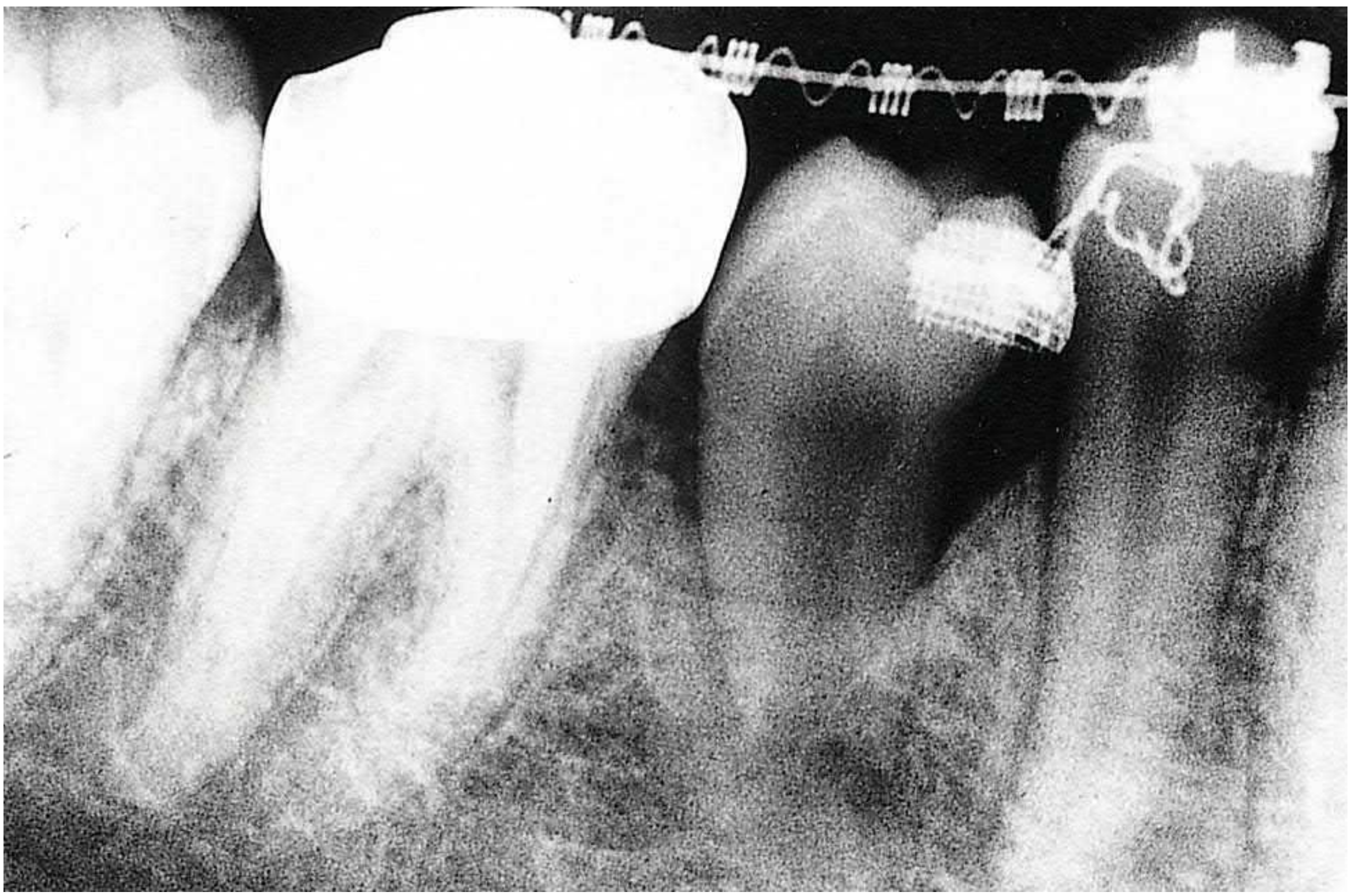


Fig. 5.3 Following exposure, attachment bonding and packing the unerupted tooth, it erupted spontaneously, but the bone level was compromised.

Permanent teeth whose eruption has been obstructed or delayed are abnormally situated deep in the alveolus and are in danger of becoming re-buried by the healing tissue of the evacuated socket of the extracted deciduous tooth. Accordingly, the crowns of the teeth should be exposed to their widest diameter and a surgical or periodontal pack placed over them and sutured in place for 2–3 weeks. This will encourage epithelialization down the sides of the socket and should prevent the re-formation of bone over the unerupted tooth.

In order to maintain the surgical opening, most surgeons and periodontists today will use a proprietary pack, such as CoePak™, which doubles as a dressing for the surgical wound. Alternatively, particularly with maxillary palatal canines, placement of a removable acrylic plate, which will have been prepared before surgery, can be employed in order to retain a small pack over the exposed tooth [14]. Regardless of the method, however, and parallel with the concern for maintaining the patency of the exposure, one must exercise appropriate concern to hold the space for the anticipated eruption of the impacted tooth. Space loss in the mixed dentition may often be very rapid and may result in halting the progress of the erupting tooth by its proximal contact with the adjacent teeth. It is essential that this aspect be considered and the appropriate provisions made and followed closely.

'Expose-and-pack' was revived and reintroduced as an approach and has been recommended for the treatment of severely palatally displaced maxillary canines [15]. This method has been recommended as being suitable for spontaneous resolution even in some cases of quite severe displacements. It creates the possibility of at least partial eruption through the surgically created and pack-maintained opening and permits relatively easy access for attachment bonding. Subsequent alignment of the tooth can then be beneficially undertaken, utilizing simplified appliance therapy. However, validation of the method by a disciplined clinical study has not been done and the evidence in its favour must therefore be considered anecdotal at present.

Notwithstanding its benefits, it must be noted that there are a large number of situations, particularly concerning maxillary canines, where this method is inappropriate. Examples of such situations include the following:

- Inadequate space in the dental arch to accommodate the tooth along any part of an intended path on the way to its normal location.
- The surgeon may realize at the time of surgery that spontaneous eruption appears unlikely to occur. Without the facilitating element of a traction appliance, he or she may be tempted to consider more radical surgical short-cuts, such as those listed above, despite the likelihood of thereby causing irreversible damage to the periodontium.
- Surgical exposure of a canine that is associated with severe resorption of the root of the adjacent incisor is difficult to accomplish without secondarily and inadvertently exposing the resorbed root apex. In this situation, leaving this highly sensitive area open will inevitably risk de-vitalization of the incisor.
- In a situation where an impacted tooth is in a grossly ectopic location, spontaneous eruption is unlikely to occur and assisted and directed traction is unavailable to bring about its resolution, unless suitable means were prepared ahead of time as a precautionary measure.
- With an unerupted canine that is located high on the labial side of the alveolar ridge, above the attached gingiva band, if a direct, window technique, open surgical exposure is performed, one would of necessity have to launch into a series of reparative periodontal tissue grafts at the conclusion of the orthodontic treatment. Such grafts would be needed to substitute for the thin and vulnerable oral mucosal attachment that would otherwise result.
- For an adult in the 40+ age group with an unerupted and untreated maxillary canine, the eruptive potential of the tooth is likely to have exhausted itself long ago and the tooth is unlikely to respond to the surgical exposure.

There are additional situations in which the use of open surgical exposures will be contraindicated, even when extrusive orthodontic traction is indeed available. Many of these situations will be discussed in the ensuing chapters of this book.

Exposure with pressure pack

It is common to find mesial impaction of a third molar, beneath the distal bulge of the second. It is less common to find a mesial impaction of a mandibular second permanent molar, beneath the distal bulbosity of the first permanent molar. The two situations, however, have similar characteristics. In their mildest form, they both present a condition that may sometimes respond merely to surgical intervention and packing. This is carried out by the exposure of the occlusal surface of the tooth and the deliberate and forceful wedging of a pack in the area between the two teeth and leaving it in place for 2–3 weeks. During this period, the pressure caused by the pack will often succeed in eliciting a small distal movement of the impacted molar, possibly causing it to erupt more freely when the pack is removed. The degree of control that is available to the operator in judging the amount of pressure to be applied is minimal and the extent to which the pack interferes periodontally is impossible to assess. Therefore, damage to the periodontium of the two adjacent teeth becomes a distinct possibility. Success in bringing about an improved position of the tooth may exact a cost in terms of the health of its supporting structures.

As an alternative to the use of a pressure pack, some orthodontists advocate the use of brass wire [16] or elastic separators, in order to apply a similar disimpacting force. Simple remedies of this kind may be effective in situations where the discrepancy is minor. However, in many of these types of cases the brass wire and the elastic separators will need frequent tightening, replacement and renewal. Briefly stated, the method is unreliable at best.

The surgical elimination of pathology

Soft tissue lesions

The subject of benign tumours and cysts is fully discussed in Chapter 14. For the aspect of surgical intervention, let it suffice to mention here that surgery is the first line of treatment that is indicated for these conditions. Immediately after the first tentative diagnosis, surgery is advised, if only for reasons of obtaining biopsy material to confirm the innocence of the diagnosis. Orthodontic treatment should also be considered at that time, although its application should be delayed until after healing of the surgical wound. In the case of cysts, orthodontic treatment should begin after the cyst has been eliminated and after a filling-in of bone has occurred around the involved teeth. The actual repair of the bony defect will itself improve the positions of grossly displaced teeth. This will be evident in follow-up radiographs and in the anatomical topography of the alveolar bone in the area. However, the surgical wound may take many months to heal completely. In the interim, supportive preliminary tasks (oral hygiene instruction, caries treatment, motivational education, etc.) may be undertaken, in preparation for the proposed orthodontic treatment. It is worthwhile to begin with achieving positive results from a preventive dental health programme aimed both at eliminating marginal gingival inflammation and at reduction of the incidence of caries.

Hard tissue obstruction

In the case of obstructive impaction, logic dictates the removal of the body that is obstructing the natural eruptive potential of the tooth. This is normally performed by the surgeon and often without recourse to adjunctive orthodontics. Although the procedure often succeeds, this course of action is far from foolproof.

In Chapter 6 we examine the reliability of spontaneous eruption, which results from the different surgical procedures involved in the treatment of impacted incisors. For the present discussion, we must recognize that there is a significant number of cases in which eruption does not occur within a reasonable time-frame.

Following the removal of the obstruction, be it a supernumerary tooth, an odontome, residual deciduous roots or even an infra-occluded primary tooth, the position of most unerupted teeth will eventually improve. However, many of these teeth may not erupt without assistance. The failure to erupt may be due to certain factors, including the extent of their displacement, the character of the healing tissues or other factors relating to the erstwhile obstruction.

A hard tissue body, such as a supernumerary tooth, occupies significant space in the alveolus. A compound odontoma will generally consist of a random mix of dental tissues and, together with its accompanying dental follicle, in many instances occupies even more space. The result is gross displacement of the developing bud of the normal tooth, both in terms of overall distance from its normal location and in the alteration of the orientation of its long axis. The root and/or crown of a tooth of the normal series will likely be deflected, whether mesially, distally, lingually or buccally. It may also be displaced superiorly (in the upper jaw) or inferiorly (in the lower). All these possible deflections will compromise its chances of spontaneous eruption. Cramped circumstances will have developed between the pathological entity and the adjacent teeth and between (a) the entity and the floor of the nose or (b) the lower border of the mandible (see Chapter 13). A further developmental risk is the forming of abnormally shaped roots on otherwise normal teeth. Such an abnormal consequence will itself cause deviated eruption paths and even prevent spontaneous eruption altogether. However, provided that the integrity of their periodontal ligament (PDL) is not compromised and the odontoma extracted, they may be successfully erupted with orthodontic appliances.

The failure of an impacted tooth to erupt will inevitably disturb the eruption patterns of the adjacent teeth, which, as a result, will then assume abnormal relationships to one another. Such relationships are usually characterized by tipping and space loss. The overall result of this is that this situation creates a secondary physical impediment to the eruption of the impacted tooth.

Infra-occlusion

In Chapter 11 we shall demonstrate in greater detail that infra-occluded permanent teeth are sometimes ankylosed to the surrounding bone and will consequently not respond to orthodontic traction. For the purposes of this present chapter, it should be briefly noted that the ankylosed area of the root is often minimal and may easily be detached by deliberate, but gentle, luxation of the tooth. This will normally be carried out using an elevator or extraction forceps and is done in such a way as to release the rigid and inflexible connection of the bony union. The aim is neither to remove the tooth from its socket nor even to tear the periodontal fibres (which is inevitable). The purpose is to bring the tooth to a greater than normal degree of mobility.

A frequent and undesired consequence of this procedure is a re-healing and re-attachment of the tooth to its former ankylotic connection. Accordingly, this approach can only be successful if the traction force is applied to the tooth immediately upon luxation and maintained continuously active. The re-healing of the bone will be modified by a localized microcosm of distraction osteogenesis [17, 18] created by the traction process. It follows that if the traction force is allowed to decay to ineffectiveness (between patients' visits for adjustments), re-ankylosis will result and the tooth will stop moving. Accordingly, in order to be effective, the traction must be of sufficient magnitude and range to cause distraction and to remain active between one visit for adjustment and the next.

The principles of the surgical exposure of impacted teeth

In general, there are two basic approaches to the surgical exposure of impacted teeth: the open eruption technique and the closed eruption technique [19]. A description and comparison of each of these approaches is set out below.

The open eruption technique

Historically, this was the first method used to expose impacted teeth. The tooth was exposed and remained open to the oral environment [20]. Following the removal of the soft tissue and of the bone that covered it, the newly exposed tooth was surrounded by freshly trimmed thick mucosa of the palate or the raw cut edge of the labial/buccal oral mucosa.

The open eruption technique may be performed in several ways but, essentially, these fall into two categories: the window technique and the apically repositioned flap technique.

The *window technique* involves the surgical excision of a circular section of the overlying mucosa and the thin bony covering. This method is illustrated in the advertising fliers that are distributed widely by companies to market soft tissue laser units. The method has the advantage that it is the simplest, most conservative and most direct method of exposing a tooth, which is palpable immediately under the oral mucosa. It may often be performed using only surface anaesthetic spray or gel. An attachment is immediately bonded to the tooth, enabling orthodontically encouraged eruption to proceed and facilitating complete alignment within a very short time. While this method obviously represents a significant advantage in the treatment of a young patient, the long-term outcome of the procedure may be characterized by loose oral mucosa on the labial side of the tooth. This is not of attached gustatory epithelium, but rather a mobile, thin, oral mucosa, which does not function well as gingival margin tissue. This situation has been widely documented in the periodontal literature.

It is therefore clear that, in the majority of cases of labially displaced teeth (due to their relative height), this entire surgical procedure is usually inappropriate and contraindicated in relation to the mobile area of the oral mucosa, above the level of attached gingiva. However, if the patient has a very wide band of attached gingiva (Figure 5.4) and a labially impacted tooth is situated well down in this band, a simple removal of the tissue overlying the crown could satisfactorily still leave 1–2 mm of bound epithelial attachment inferior to the free, movable, oral mucosal lining of the sulcus [7].

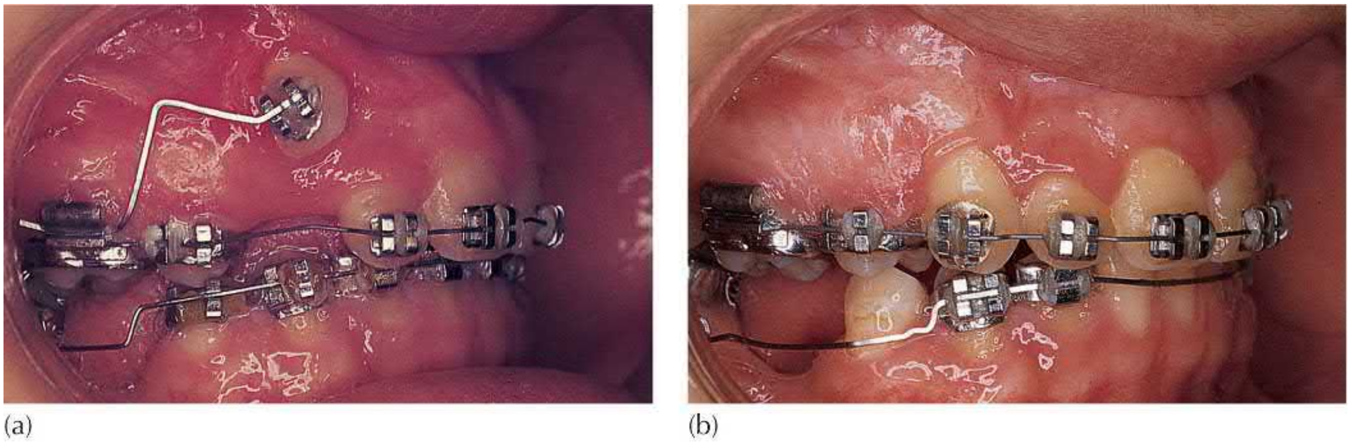


Fig. 5.4 (a) A high buccal canine exposed by circular incision in the very wide band of attached gingiva in this patient. (b) The tooth has been brought down together with attached gingiva on its

labial side.

Courtesy of Dr G. Engel.

By contrast, the palatal mucosa is very thick and securely bound down to the underlying bone. In consequence, following its eruption into the palate of a palatally impacted tooth, no parallel precautions need be taken in order to ensure a good attachment for its final periodontal status [5–7].

When the window technique is used on the palatal side, the cut edges of the wound need to be substantially trimmed back and the dental follicle usually needs to be removed in its entirety. The aim of this is to prevent re-closure of the very considerable thickness of palatal soft tissue over the exposed tooth. Additionally, where there is a deeply buried palatal canine, the patency of the exposure will need to be maintained with the aid of a surgical pack.

The *apically repositioned flap technique* for performing open exposure is with an apically repositioned flap on the labial/buccal side. This method is designed to improve the periodontal outcome by ensuring, in the final instance, that attached gingiva covers the labial aspect of the erupted tooth. This is achieved by raising a labial flap, taken from the crest of the ridge, and relocating it higher up on the crown of the newly exposed tooth. The method is a recognized and accepted procedure in periodontics and was first described by Vanarsdall and Corn [21, 22] in the context of surgical and orthodontic treatment of unerupted labially displaced teeth. According to these researchers, in the absence of the deciduous canine, a muco-gingival flap, which incorporates attached gingiva, is raised from the crest of the ridge (Figure 5.1). If a deciduous canine is present, the flap will be designed to include the entire area of buccal gingiva that invests it and the deciduous tooth itself will be extracted. In either case, the canine is exposed by detaching a flap from the underlying hard tissue, some way up into the vestibulum. The flap is then sutured to the labial side of the exposed crown of the permanent canine and will overlie its cervical area and cover the denuded periosteum. The remainder of the crown will be exposed. Subsequent eruption of the tooth will be accompanied by the healing of the gingival tissue. When the tooth takes up its final position in the arch, it will be found to be invested with a good width of attached gingiva.

The apically repositioned flap method of exposure is best suited to labially/buccally impacted teeth, which are situated above the band of attached gingiva and are not displaced mesially or distally from their place in the dental arch. However, if the case presents with more than a minor degree of mesial or distal displacement, a raised and full-thickness, soft tissue flap will result in unacceptable denuding of the alveolar bone covering the adjacent tooth and will contraindicate the use of this surgical modality. In order to overcome this, a partial-thickness surgical flap may be raised, which will then leave the donor area invested with a connective tissue cover [23] to heal over by epithelial proliferation.

This method of open exposure surgery will cause the tooth to acquire a new gingival margin, originating from the healed, cut edge of gingival tissue, which will move with the tooth as it is drawn down into its place in the arch. However, while the periodontal parameters may be very satisfactory, at the end of treatment the physical appearance of the tissues surrounding the aligned tooth will not have a completely natural look and it will usually be possible, even several years later, to identify the previously affected tooth with ease.

On the basis of the results of the study of Kokich's group from the University of Washington, relating to exposure on the buccal side of the ridge, the group questioned the justification for continued use of the apically repositioned flap method [24]. Indeed, it is clear that there are grounds for their scepticism, particularly in relation to canines that are more severely displaced.

On the other hand, it should be realized that, for the more trivial cases where the tooth is fairly close to its final mesio-distal position and is bulging the oral mucosa at its junction with the attached gingiva, the application of the apically repositioned flap method may actually eliminate the need for subsequent orthodontic treatment, while producing a good periodontal result.

Experience has shown that many of these teeth never fully come down to the occlusal level and those that do erupt well may take many months, sometimes stretching to a year or more. This appears to be due to the tendency to relapse, which is engendered by a surgically caused distortion of the mucosal lines in the muco-gingival area [24]. The overall, final result of this form of surgical exposure may display an unaesthetic gingival contour, requiring remedial grafting [21–25]. If left untreated, buccally palpable unerupted teeth may take many months to break through the mucosa and reach their final positions. The process may be speeded up by performing an apically repositioned flap.

If the unerupted tooth is very high, an apically repositioned surgical flap would need to be larger than usual, since it will need to involve attached gingiva from the crest of the ridge or the free gingiva of the deciduous tooth, to the height of the labial vestibular sulcus. In such circumstances the procedure is not recommended, since the flap would leave a wide area of periosteum of the labial bony plate unnecessarily exposed to the oral environment. This would result in the need to cover this area with grafts harvested from elsewhere in the oral cavity.

One convenient, alternative procedure for these very high teeth that we have described is to use the two separate techniques in sequence [26]. This would also be appropriate for conditions such as the labial dilacerated central incisor. The first stage is to use the closed eruption exposure procedure, including attachment bonding, to bring the tooth down until it is well above the attached gingiva, bulging the labial mucosa. Only at that point will the apically repositioned flap be used, with the flap being taken over the incisal edge/occlusal tip of the tooth and sutured on its labial side. The tooth will continue to be drawn occlusally, completely encompassed by firm gingival tissue. In addition, a well-sutured flap will apply pressure on the labial side of the buccally/labially displaced tooth, which will become a positive influence in moving it lingually towards the general line of the dental arch (see Chapter 15).

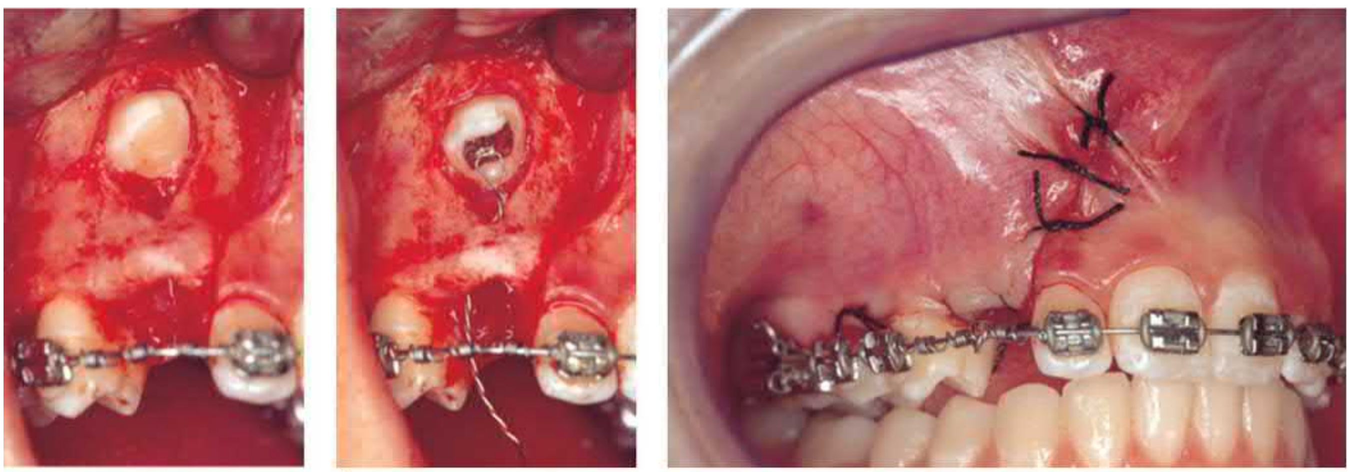
An important advantage of the apically repositioned flap method is that the buccally impacted canine is exposed to the oral environment and remains accessible for attachment bonding. Sometimes the progress of the tooth may be monitored for many months, without orthodontic assistance or appliances, until full eruption has occurred (Figure 5.1). At an appropriate later date, an attachment may be bonded by the orthodontist and active extrusion may subsequently be undertaken.

The closed eruption technique

The contrasting approach to surgical exposure is the closed eruption technique. This technique involves an orthodontic attachment bonded at the time of the exposure, with the tissues being fully re-sutured back to their former place, thereby re-covering the impacted tooth. The technique was first described by Hunt [27] and McBride [4, 5, 28] and is a procedure that may be used regardless of the height or mesiodistal displacement of the tooth.

In the case of a buccally impacted tooth, a surgical flap is raised from the attached gingiva at the crest of the ridge, with appropriate vertical releasing cuts, and is elevated as high as is necessary to expose the unerupted tooth. An eyelet or button attachment is then bonded and the flap fully sutured back to its former place [7]. The twisted stainless steel ligature wire (or gold chain, as preferred by some clinicians), which has been tied or linked to the attachment, is then drawn inferiorly through the sutured edges of the fully replaced flap. The surgical wound is thereby completely closed and the impacted tooth with its new bonded attachment is sealed off from the oral environment. Because it is fully closed, spontaneous eruption will not occur. Accordingly, active orthodontic force will need to be applied to the tooth to bring about its eruption [29]. In the following period of several weeks or months and after complete healing of the repositioned surgical flap has occurred, the tooth will progress towards and through the area of the attached gingiva and will create its own portal, through which it will exit the tissues and erupt into the mouth. In so behaving, it very closely simulates normal eruption and results in a similar clinical outcome in terms of its clinical appearance and objective periodontal parameters. It will usually be difficult to distinguish from any normally and spontaneously erupting tooth.

Crescini et al. [30] described a modification of the closed eruption technique, which they called the 'tunnel' technique, specifically relating to maxillary permanent canines. The aim of this aptly named method is even further to mimic the natural eruption process by applying extrusive force to move the impacted canine directly through the socket of the recently extracted deciduous canine (Figure 5.5). In this procedure, a full buccal flap is raised from the attached gingiva at the neck of the deciduous canine and adjacent teeth, in order to expose the surface of alveolar bone, and the deciduous canine is extracted. The twisted steel ligature or gold chain, which is linked to the bonded eyelet, is then threaded into the apical area of the newly vacated socket of the deciduous canine and drawn downwards to exit through its coronal end. No buccal bone need be removed beyond that immediately overlying the crown of the exposed canine. The flap is then sutured back to its former position, leaving only the end of the ligature/gold chain visible through the socket of the deciduous canine.



(a) (b) (c)

Fig. 5.5 Crescini's tunnel variation of the closed eruption technique. (a) A very high labial canine was exposed with a full-flap exposure, which included the gingival margin of the extracted deciduous canine. The canine was exposed and, below it, a bridge of buccal bone was left intact. (b) An attachment was bonded to the palatal aspect of the permanent canine and its pigtail ligature directed through the socket vacated by the extracted deciduous tooth. (c) The flap was sutured to its former place and vertical traction drew the tooth down, retaining the alveolar bone on its labial side.

Courtesy of Dr E Ketzhandler.

It will, however, be quite clear that this method is only indicated when the crown of the permanent canine is at a significant distance above and directly superior to the apex of the deciduous canine and when its orientation is close to the vertical. It cannot be employed when there is mesial or distal displacement of the impacted canine, overlapping the adjacent lateral incisor or the first premolar. Neither is it appropriate when the tooth is more than slightly palatal to the line of the arch.

It will be appreciated, too, that the socket of the *deciduous* canine is much narrower than the broad *permanent* canine crown. Moreover, normal healing of most of the more occlusal portion of the socket will have occurred and bone regenerated, much before the canine even reaches its more occlusal lower levels. One must assume, therefore, that the tooth will meet with resistance not only from the mature peripheral alveolar socket bone in the apical areas of the socket wall, but also from the more recently infiltrated young alveolar bone, which must be resorbed to make way for the eruption of the tooth. By retaining the buccal bridge of bone during surgery (given the conservative attitude to bone removal in general), the tooth will come down through an uncompromised bony matrix. The final outcome will show the aligned tooth to have excellent bony support, in terms of both its width and the level of the alveolar crest.

In considering the location and orientation of most impacted maxillary canines, each method of surgical exposure has its advantages and its drawbacks. These are apparent in relation to efficacy of treatment and post-surgical recovery, as well as regarding the overall treatment outcome in relation to aesthetics, periodontal prognosis and stability of the final result. An 'aggressive' canine that is located within the resorption crater that it has carved into the root of the adjacent incisor is a case in point. It is almost certain that an open surgical exposure would cause the loss of vitality of that incisor. However, a carefully performed *closed* exposure can usually be expected to enable the incisor to maintain its vitality. Similarly, the open surgical exposure method is not advised for severely ectopic canines, canines that are found in the more difficult sites, such as high above the apices of the other teeth, or those in locations where open surgery would involve leaving denuded root surfaces of adjacent teeth exposed to the oral environment. The deeper and more distant the impacted tooth is located within the jaw bone, the more radical is the bone resection that is required in order to ensure that the exposed crown of the tooth will not heal over in the weeks that follow. Open exposures in these more difficult situations are also more likely to adversely affect the patient's quality of life in the immediate post-surgical weeks, in terms of pain, recurrent bleeding, taste, halitosis and general function [20].

Initiation of traction

Even though the orthodontist may or may not be present during a closed surgical technique procedure, it is nevertheless imperative that an attachment be bonded at that time. It is obviously propitious to apply the eruptive force to the impacted tooth immediately, taking full advantage of the prevailing anaesthesia. The absence of the orthodontist will place the onus to do this, squarely but unfairly, on the shoulders of the surgeon.

In contrast, when open surgery is performed, the presence of the orthodontist is unnecessary, since the aim of the surgery is merely to prepare the stage for the future placement of an attachment by the orthodontist in his or her office. Accordingly, the surgeon must complete the exposure in such a manner as to be sure that the tissues will not heal over and make the tooth inaccessible in the few post-surgical weeks, until an attachment is bonded in the orthodontist's office and traction begins. Since orthodontic procedures in general do not require local anaesthesia, the orthodontist is unlikely to offer it to the patient at the next orthodontic appointment, even though there is a general sensitivity of the area, even to gentle manipulation. Inevitably, because the anaesthetic will not be given *and* because the orthodontist is not present at the surgical procedure *and* because the surgeon will not apply traction at the time, there is a loss of momentum in the progress of treatment. The first visit to the orthodontist will not be for quite a long time and it is inevitable that there will be an additional delay in the commencement of traction. It is therefore beneficial, even for the open procedures, that an attachment be placed at the time of surgery and to apply traction, in order to maintain the treatment momentum.

CBCT imaging of the impacted canine, in the case shown above, pinpointed the exact location of the canine (Figure 5.6a–c) and this enabled the direction of traction to be determined. The other serial slices and 3D reconstructions performed on the material have illustrated the level of technical difficulty of resolution of the impaction and subsequent alignment of the tooth. They have, however, also shown an apparently healthy PDL and an absence of signs of resorption and other pathology, both of the canine itself and of the roots of the adjacent teeth, which would determine whether or not the tooth would respond to orthodontic forces.

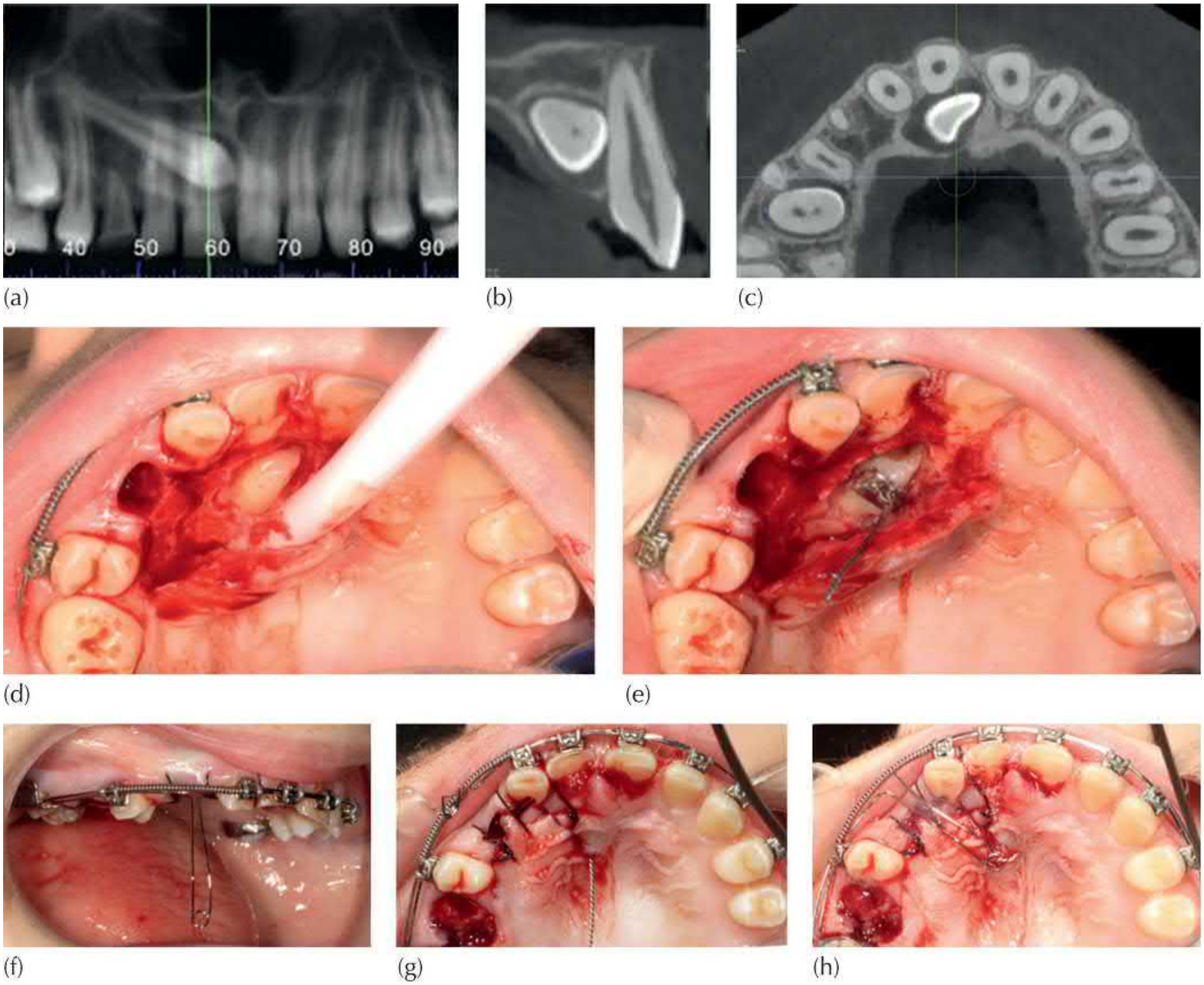


Fig. 5.6 Cone beam computed tomography (CBCT) imaging slices of a palatally impacted canine that has crossed the midline, as seen on (a) a panoramic curved slice (b) a cross-sectional slice and (c) an axial slice. The long axis of the canine is oriented approximately 10° to the horizontal. (d) A wide flap has been reflected, the deciduous canine extracted and the canine exposed. (e) An eyelet has been bonded to the most accessible location on the crown of the canine, with the twisted wire connector hanging loosely. (f) The surgical flap was re-sutured back to its former place, the loop of the auxiliary archwire in its passive (vertical) mode, after ligation over the main archwire. (g) The twisted ligature connector from the eyelet has been drawn through a small piercing in the flap,

located immediately opposite the eyelet above it. (h) The vertical loop of the auxiliary archwire is turned inwards and latched by the shortened connector, in contact with the palatal mucosa.

The crown of the impacted canine was exposed using a wide flap, but with minimal removal of bone. The deciduous canine was extracted. The unexposed crown lay between the root apices of the central incisors. Due to the obstruction caused by the roots of both the central and lateral incisors of the right side, it had traversed the anatomical midline, from where it had no available direct route to its appropriate place in the dental arch.

An attachment was bonded by the orthodontist, while haemostasis was maintained by the surgeon. The location for the bonding, chosen by the orthodontist, was the anatomically distal aspect of the rotated crown of the canine. This was also the most superficial and accessible site. A twisted steel ligature pigtail had been tied into the eyelet prior to its placement and was intended as the means of transferring extrusive force to the tooth.

The flap was pierced at the point where the flap covered the eyelet, to accommodate the ligature pigtail in its desired position, close to the midline. The pigtail was pushed through the pierced hole, before the flap was fully replaced and re-sutured.

An auxiliary labial archwire, with a vertical loop, was ligated at this point in piggyback fashion over the heavier base arch and its loop turned inwards and upwards. It was securely latched, in light horizontal contact, to the palatal mucosa, by the shortened and bent-over twisted ligature. Active vertical extrusive force would now erupt the tooth vertically downward, towards the tongue. From that point, a direct approach to the archwire could then be made, without interference by the incisor root.

In a situation where a palatal canine is located very high up in the maxilla, at the level of and close to the midline and to the incisor apices, an open exposure is contraindicated. There is every likelihood that the exposure will close over in the immediate post-surgical period, together with the possibility of loss of vitality of one or more of the incisors. The canine seen in Figure 5.6 was located across the midline and between the central incisor apices. The tooth was subsequently drawn posteriorly and vertically downwards, exiting in the mid-palate and thereby avoiding damaging the incisor apices and permitting lateral movement to its place in the arch. The initial activation was performed at the surgeon's chairside, immediately following completion of the exposure procedure.

Speed of eruption

When traction is applied to a palatally impacted canine in the closed eruption technique, the tooth may move rapidly, sometimes from a considerable distance, deep in the bone. As it exits the bone, it causes the very palpable bulge beneath the thick mucosa of the palate to increase in size. The thick mucosa will, in turn, create difficulty for the tooth to erupt through it. In such a circumstance, it is recommended that a small circular incision be made around the crown tip of the impacted tooth and the tissue removed to an extent that will re-expose the tooth with an aperture not exceeding the circumference of its crown. Further traction will then erupt the tooth very rapidly. Delay in performing this simple procedure will over-tax the anchorage unit and simply cause the anchor teeth to intrude and the overall archform to become disrupted.

The final treatment outcome

Several research groups, from various countries, have conducted studies on the effect of the open exposure technique on the post-treatment pulpal and periodontal status of maxillary canines, following the orthodontic resolution of impacted teeth. A Norwegian group [31] identified an increased depth of periodontal pockets on the distal side of the impacted teeth as well as bone loss on the mesial side. The group from the University of Washington [32] examined patients with impacted canines that had been treated by undefined ‘conservative’ surgical procedures. They identified attachment loss, reduced alveolar bone height and frequent instances of pulp obliteration, discoloration and misalignment. They also found that the previously impacted canines were quite discernible and conspicuous in 75% of the treated cases, which was presumably associated with marred external appearance.

In our own study, our Jerusalem group of researchers examined the results of the treatment, by the closed eruption technique, of palatal canines and found an excellent appearance, with slightly deeper pockets and a 4% loss of alveolar bone support [8]. In addition, in relation to buccally ectopic maxillary canines, we found a minor reduction in the width of the attached gingiva, but otherwise a good general periodontal result [9].

Studies carried out by others have further corroborated the good clinical periodontal results of the use of the closed eruption technique, in both buccal and palatal canine cases [33].

Using a mixed sample of cases of impacted incisors and canines in their study [32], the Washington group carried out a comparison of the open (specifically the apically repositioned flap exposure) and closed procedures. With regard to those treated with the open surgical approach, they found poorer results in both periodontic measurement and aesthetic assessment and, with regard to buccal canines, they identified an increase in clinical crown length and a deterioration and unevenness in the gingival margins (Figure 5.7). They also noted loss of attachment and alveolar bone, frequently accompanied by vertical positional relapse of the erupted tooth, after the completion of treatment. They reasoned that during the tissue healing that occurs after the surgical repositioning, the horizontal mucosal lines undergo stretching and distortion during the incisal movement of the tooth. Once orthodontic control is released, vertical relapse occurs due to a contraction of these extended mucosal lines. By contrast, in the closed eruption cases, they found that clinical crown length and gingival appearance in the closed eruption group were similar to those of the unaffected (control) side, with a completely normal periodontal attachment and no evidence of post-treatment relapse in incisor position.


(a) (b)

Fig. 5.7 Treatment for the right buccally impacted maxillary canine was performed using an open exposure, apically repositioned flap technique. (a) The post-treatment outcome shows a thick band of attached gingiva, but a long clinical crown with an unaesthetic lumpy appearance of the gingival margin. (b) The normally erupted canine of the left side is shown for comparison.

Impacted incisors are seen less frequently in the orthodontic office than are impacted canines. This accounts for the relative absence of studies of the results obtained from treatment of impacted incisors. However, based on the differences in the aetiologies of impaction in canines and incisors, it would be reasonable to assume that there could also be differences in the results achieved at the end of treatment.

It was with this in mind that the Jerusalem group [34, 35] undertook a study exclusively relating to maxillary incisors. The findings of the study in the open eruption group showed poor periodontal and aesthetic results, with increased pocket depth and a 10% loss of alveolar bone height. The clinical crowns were elongated and the band of attached gingiva reduced. On the other hand, those treated by the closed surgical procedure showed only minimal changes, with greater bone support, a lesser increase in clinical crown length and better external appearance than in the open surgery group. Crown length and attached gingiva were closely similar to those of the unaffected side, while the bone support level was reduced by between 5% and 6%.

In a later comparative study of open versus closed exposure, similar impacted incisor cases were matched for age, aetiology and location. The overall results favoured the closed surgical exposure method. The open exposure cases showed statistically poorer outcomes, characterized by increased crown length and more significant loss of bone support [9].

A recent split-mouth investigation of labially impacted maxillary canines was carried out in order to compare the results of a closed eruption surgical exposure of the affected canine with those of the normally erupting antimere. The conclusions were that, at the completion of orthodontic treatment, the previously impacted canines exhibited slight and clinically insignificant periodontal recession, compared with the contralateral normal tooth [33].

It will be clear from the summary of the evidence presented here that a closed surgical exposure approach produces good, predictable, long-term periodontal and aesthetic results and has advantages over the apically repositioned flap method [34, 35]. It might be appropriate to attribute these advantages to the closer similarity of the full-flap closed exposure procedure to the natural eruption process.

A Cochrane Collaboration systematic review

The Cochrane Collaboration offers systematic reviews of primary research in human health care and health policy, as well as clinical research in the effects of interventions, for the purposes of prevention, treatment and rehabilitation, in various fields. Existing primary research on a particular topic is collated and, using stringent guidelines, is assessed in order to establish whether or not there is conclusive evidence about a specific treatment. The reviews are updated regularly, ensuring that treatment decisions can be based on the most current and reliable evidence. In this way, these reviews provide us with the ideal framework to objectively adjudicate, without regard to personal subjective preference or bias, the rival claims of those advocating open exposure as opposed to those who advocate closed exposure.

These conflicting opinions were the subject of a Cochrane review that was undertaken in 2008 in the UK [36] and thereafter updated periodically [37–40]. The review only referred to those factors directly related to the surgical aspect and no regard was paid to the age of the patient, the presenting malocclusion or the type of active orthodontic treatment undertaken. The aim was specifically to search the literature for studies involving open and closed surgical exposure of impacted maxillary canines and to compare the outcomes of the two techniques in relation to the claims made by both surgeons and orthodontists. In the 2008 study, however, none of the 191 retrieved studies fulfilled the criteria to be included [36].

An update of the review was undertaken in 2017 [40], in which the researchers found only three studies in the literature that fulfilled their criteria to be included. However, in their assessment the authors stated that they 'considered the evidence to be of low quality, with two of the three included studies being at high risk of bias' and that 'the evidence suggests that neither the open nor closed surgical technique for exposing palatally displaced maxillary canine teeth is superior for any of the outcomes included in this review'. The authors were at pains to point out that their search through the literature had failed to disclose published studies suitable to be included in the review and that therefore evidence of a statistical or clinical difference between the two surgical techniques is lacking, and furthermore that currently the method of exposing a palatally displaced canine may be left to the personal preference and choice of the surgeon and orthodontist.

The UK research group stressed that there are impacted canines whose location and relationship to the roots of the adjacent teeth could render one of these two techniques of exposure impossible, impractical, ill-advised or potentially harmful. This means that the randomization of patients for the purpose of the study of open versus closed surgical exposure was not valid and the composition of the two sample groups of patients could no longer be considered comparable. It is therefore quite clear that the authenticity of the study is both directly and indirectly compromised. To overcome this unfortunate conclusion, the route taken by the UK group was to eliminate/disqualify difficult cases from the study, in order to achieve the parity needed for proper analysis.

Let us examine whether this corrective step can achieve valid parity of the samples:

- In the case of an impacted canine that is associated with severe resorption of the root of the adjacent incisor, 'open' surgical exposure is contraindicated, as it would seriously endanger the vitality of the affected incisor and, often, its very existence. Using the 'closed' eruption technique would offer the opportunity to salvage both teeth, while maintaining their vitality.
- Similarly, consider the case of palatal canines that are severely vertically displaced in the height of the maxilla, above the incisor apices, or those whose roots bucco-lingually straddle the ridge between the lateral and central incisors. An 'open' exposure procedure is highly unsuited to these clinical situations. The necessary broad exposure would place the vitality of the adjacent teeth at risk and, unless the exposure was extremely wide, it would rapidly close over and deny subsequent clinical access.

Accordingly, such cases (i.e. the more difficult cases) cannot be included in the random allocation for a fair comparison of open or closed surgical exposure and would need to be eliminated from the study sample. The very act of excluding these and other more difficult cases creates a heavy bias to the survey and is tantamount to limiting the findings of the study to being valid solely for simple or superficial cases.

Regardless of the method used, it is quite clear that the overall aim of the treatment must include the ability to employ the highest clinical standards of treatment and to produce the ideal outcome (i.e. where it is impossible to recognize which tooth had been impacted). The successfully treated impacted tooth must be identical in its form, its orientation, its colour, its gingival contour and its crown height to its antimere and in harmony with its neighbours. This ideal is achievable in a high proportion of cases when the 'closed' eruption technique is used, in combination with properly executed directional orthodontic traction and alignment. It is pertinent here to refer to the pre-orthodontic open exposure method espoused by Schmidt and Kokich, who, in their study of the method, found that *only 19%* of the previously impacted canines would escape detection by a panel of experts [41].

It is clear from what has been described here and what will be discussed in later chapters that the quality of the outcome is only partly due to the type of surgical procedure employed. Indeed, there are many other factors that are intimately involved in the final outcome, some of which may be just as influential in dictating the result. A number of these factors may be neutralized in a very large sample, if the randomization has distributed them equally between the two groups. Nevertheless, there are several others that cannot be discounted. It is imperative to recognize four distinct groups of such factors: namely, those related to the patient, those related to the radiologist, those related to the oral surgeon and those related to the orthodontist.

- *The patient*: Patients present a wide variety of positional diagnoses, both of the tooth and of its proximity to adjacent teeth. Some of these positional diagnoses are not amenable to open surgery procedures, as already noted. There is great variety of oral hygiene levels among patients and poor oral hygiene has a direct and negative influence on the quality of the periodontal outcome, even in the best treatment plan.
- *The radiologist*: Imaging today is far superior to that of yesteryear. A competent dental radiologist should be the person to offer a report of both planar and 3D imaging in a particular case, although many orthodontists and surgeons are also very adept. Nevertheless, mistakes are made in accurate positional diagnosis and in the search for pathological entities. Such mistakes are a frequent cause of treatment failure.
- *The surgeon*: No two oral surgeons work in the same manner. They will often exhibit differing preferences in relation to subjects such as flap design, amount of bone and soft tissue removal, whether or not to remove the follicle in its entirety, or pack size and the amount of pressure to be exerted via the pack. Some surgeons (particularly when the orthodontist is not watching!) are known to ‘assist’ in the eruption by radical exposure and by pushing an elevator down the PDL of the tooth in order to be sure that the tooth is mobilized. Additionally, when the surgeon is called upon to place the attachment, his or her bonding skill and knowledge of the most advantageous bonding location cannot match those of the orthodontist. This increases the risk of subsequent bracket detachment, repeat surgery and inappropriate traction direction. Any one of these factors may compromise periodontal health and gingival architecture.
- *The orthodontist*: Orthodontists also work in different ways, with widely differing appliance methods and customized traction device designs. There will be a periodontal price to pay for inappropriate directional traction, excessive traction forces and treatment inefficiency, not to mention varying quality standards of case completion.

These three professionals and the patient are four individuals, each of whom has an influence, for better or for worse, on the desired treatment result in the present context. The number of factors that exist within the area of responsibility of each one is both infinite and diverse, making it impossible to arrive at a definitive sample that will enable a comprehensive scientific comparison to be formed between the two surgical approaches. As if that were not enough, enlarging the sample, by including meta-analyses of different sub-populations and different practitioners from different centres and using differing techniques, only increases this diversity.

In summary, therefore, it can be stated that clear and authoritative answers to the question of surgical exposure preference are impossible to determine with any degree of validity. And this brings us back to outmoded, individual, surgeon-orthodontist experience and opinion, with the dubious reliance on such literary guidance as may be available – namely, a large body of published studies based on retrospectively chosen samples – from which to attempt to draw some appropriate, if empirical, conclusions. In view of the fact that the Cochrane Collaboration arrived at identical conclusions, it is postulated that, at this time, a comprehensive, evidence-based directive remains elusive.

Partial and full-flap closure on the palatal side

Impacted canines that are located on the palatal side are often palpable immediately beneath the palatal mucosa, which is itself firmly bound down to the underlying bone. In this situation, it is tempting to carry out the surgical removal of a circular section of the overlying mucosa and of the thin bony covering, in order to leave the tooth exposed. This has obvious advantages. In particular, the newly exposed tooth, when it finally erupts, will be favourably invested with attached gingiva. However, the palatal mucosal covering is very thick and the surgery will leave a broad cut surface, which will tend to close over unless its edges are substantially trimmed back and the dental follicle removed. Additionally, the exposure will need to be maintained using a surgical pack.

The result will be that, at the completion of the orthodontic alignment of the canine, this type of surgical approach will inevitably leave the palatal side of the tooth with a soft tissue deficiency and a long clinical crown. This is so even though, in the long term, the surrounding tissue will show the desired attached gingiva (Figure 5.8). This method has been favoured and promoted by Schmidt and Kokich in relation to palatally impacted canines. Their rationale is based on the assumption that the canines will, in many instances, improve their position and, in the course of time, erupt autonomously in the palate [41].

(a) (b)

Fig. 5.8 Treatment for the right palatally impacted canine was performed with an open exposure technique. (a) The post-treatment result shows attached gingiva of the palatal tissues covering most of the root, although the clinical crown length extends well down on the palatal side of the tooth, leaving several millimetres of root exposed on that side. The bone level is expected to be 8–10% defective compared to the untreated side. (b) The normally erupted left canine is shown for comparison.

Their descriptive study offered a retrospective evaluation of the post-treatment periodontal status of a group of patients who had been successfully treated by this method. However, their study was not based on a control group. Additionally, there appears to be no published controlled study that investigates the reliability and predictability of this treatment protocol.

As described above in relation to labial/buccal exposure surgery, so too on the palatal side, where full-flap closure allows the tooth to be exposed with the minimum of tissue removal and consequent reduction of surgical trauma. In addition, similar to the situation with the buccal side, it also requires the bonding of an attachment on the exposed tooth prior to suturing. When this is done and subjected to appropriate orthodontic mechanics, the final result will show that the bone support for the tooth, as well as the health and appearance of the muco-gingival tissues, is very satisfactory, as will be demonstrated in the following chapters.

In cases where there is a deeply located impacted tooth high in the palate, there is an accumulated body of evidence supporting a full-flap closure approach [8–12, 26–28, 30–35]. The advantages of this recommended method are both qualitative and quantitative: the excellent clinical appearance of the crown length and gingival architecture and the number of objective parameters considered in a periodontal examination. In addition, there will be a reduction in post-surgical pain and discomfort during the healing process [42–44].

The relief of crowding to reduce canine displacement

In cases where displacement of the canine has been caused by crowding or space loss (following early extraction of deciduous teeth), it is clear that relief of the crowding will facilitate spontaneous improvement in the position of the canine. However, time may not be on the side of the clinician who opts for this approach, since if there is too much delay the tooth may erupt through the oral mucosa. Nevertheless, if it is decided to proceed with this approach, a full case analysis should be prepared, leading to a diagnosis and treatment plan for the overall malocclusion. If, while the treatment is proceeding, the crowding is to be dispersed by distal movement of the molars, it will take longer to achieve the requisite available space in the canine region to permit the spontaneous improvement of the canine position. On the other hand, a premolar extraction will provide immediate relief of the crowding and an excellent opportunity for a self-correction of the buccal displacement, and with it the disappearance of the potential periodontal hazard.

In the treatment of a palatally impacted maxillary canine, a buccal approach to solving the crowding may sometimes be preferred, provided that its palatal displacement from the line of the arch is fairly minimal. Where the impacted tooth is vertically close to the CEJs of the adjacent teeth, the buccal approach may present a risk that interproximal bone may thereby disappear. Indeed, the greater the palatal displacement of the tooth, the greater will be the bony defect caused. Nevertheless, the buccal approach may be appropriate in cases where the teeth are marginally palatally displaced and situated higher in the maxilla. This will afford the opportunity for traction of the tooth by a more direct route to the labial archwire.

Impaction of the maxillary canine, close to the line of the dental arch, may have been caused by the mesially tipped long axis that it presents, and by the consequent direct contact of the mesial crown incline with the distal side of the root of the lateral incisor. This type of impaction is relatively simple to treat. Indeed, it should correct itself if the crown of the lateral incisor is tipped mesially, thereby closing the anterior spacing and providing room for the canine within the arch. The process will automatically cause the root apex of the incisor to move distally, coordinating the orientation of its long axis with that of the canine. If, however, the tooth maintains its stubbornness and shows no sign of erupting, then a labial surgical approach to the very mildly palatally displaced canine will often be the most suitable and, in terms of the traction, the most direct treatment.

A conservative attitude to the dental follicle

The dental sac or follicle is a fibrovascular capsule that has developed from a mesodermal condensation of cells on the outer surface of the external enamel epithelium of the enamel organ of a forming tooth. The follicle has an inner vascular plexus, through which the enamel organ is supplied with nutrients during growth and an outer vascular plexus, whose function is enlarging the bony crypt in which the tooth germ lies. This enlargement is achieved by its inherent capability to resorb the alveolar bone, notably as it begins to erupt. The follicle encompasses the entire crown of the tooth. Later, the outer surface of this sheath eventually develops into the periodontal membrane, which will connect the cementum covering of the developing root to the developing alveolar bone.

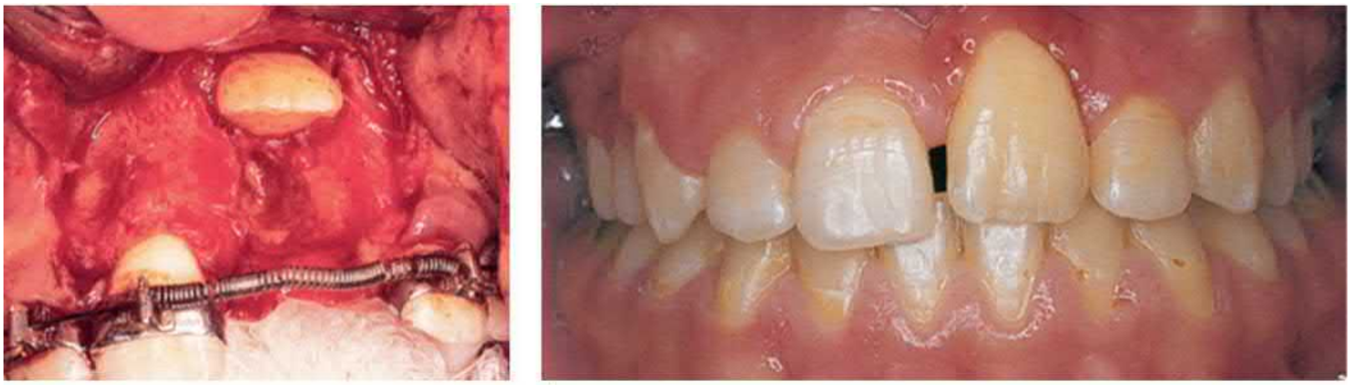
The enamel cuticle covering the crown is made up of a keratinous deposit from the ameloblasts and reduced enamel epithelium, and is contiguous with Hertwig's epithelial root sheath. This cuticle separates the crown of the tooth from the follicle, from which the root develops and cementum forms. It is this separation that is responsible for cementum not forming on the crown of the tooth.

The resorption process of the bony crypt is accompanied by eruptive movements, which, in turn, bring the tooth follicle into close proximity to the oral mucosa. The follicular epithelium fuses with the epithelium of the oral mucosa and allows the tooth to break through an epithelium-lined opening, with no associated bleeding. As eruption proceeds, the remainder of the follicle everts – indeed, it is turned 'inside out' – with the reduced enamel epithelium becoming the gingival cuff and presenting the most superficial point of attachment. When the tooth erupts in this normal manner, it is accompanied by a relatively generous band of gingival tissue, which is rounded and initially appears a little swollen. The most coronal portion of this gingival tissue is the free gingiva, which enables the attachment at its base to be direct to the cervical area of the enamel of the crown of the tooth, several millimetres coronal to the CEJ. An attachment of this nature is unusual, in the sense that the gingival band, immediately adjacent to the crown, adheres directly to the enamel through the agency of hemidesmosomes (cells that originate in the reduced enamel epithelium). Over the subsequent period of 3–4 years, this free gingival area of direct adherence to the enamel transforms into the junctional epithelium, thus providing the initial form of attachment of the gingiva to the tooth, on the cervical enamel area [45, 46].

It is the orthodontist's main duty to try to create conditions that will replicate this natural eruption process as closely as possible. Accordingly, the practitioner will need to treat the follicle conservatively. If the follicular tissue is totally removed, a gingival attachment direct to the enamel of the crown of the tooth can no longer be expected to succeed. Indeed, the attachment that will result will be on cementum, at the root surface or somewhere below and beyond the CEJ. The unfortunate result will then be an elongated clinical crown and a compromised periodontal result (Figure 5.9).

In the case of the surgical extraction of an impacted wisdom tooth, it is essential to carefully dissect out the dental follicle. This will prevent the possible later occurrence of cysts that may form from residual follicle epithelium. It follows that, in the absence of the wisdom tooth, the residual follicle has no function, other than its potential nuisance value. This, however, is not the case when the wisdom tooth is exposed and not extracted. In this latter situation, the surrounding follicle has an important function to fulfil – a function that is identical to the function of a normally erupting tooth and is integral to the establishment of a normal biological support system. It is important to understand this essential difference between *extraction* and *exposure* of the wisdom tooth.

It has been demonstrated in regard to teeth that have been buried for a long period that pathological changes occur in the follicle surrounding the crown (see Figure 6.13). These changes will have brought the enamel surface into direct contact with the surrounding tissues [47]. It is easy to draw a parallel between this condition and the artificial environment produced by an impacted tooth, which has been surgically exposed and which, in the absence of extrusive force being applied, has subsequently become re-buried in the tissues. If, for whatever reason, the tooth does not erupt spontaneously, a long-term direct contact between the tissues and the enamel of the tooth will occur.



(a) (b)

Fig. 5.9 A case treated by the author in the mid-1970s, before the era of the acid-etch technique. (a) A left impacted maxillary central incisor had been exposed and the entire follicular sac removed, prior to cementing a band. (b) At two years post treatment, the gingival contour is poor, the clinical crown is long and there has been positional relapse of the previously aligned tooth.

The surgeon will need to make an opening, adequate in size and one that will not eventually close over, and will therefore work to clear the tissues surrounding an impacted tooth. In doing so, in general, the surgeon will deliberately and completely remove the follicle surrounding the tooth (Figure 5.9). The oral epithelium will grow down the sides of the opening and into the area that has been surgically cleared of follicular tissue. It will grow down as far as the deepest point where instrumentation has occurred, which in this case will be at least to the CEJ or possibly a little way down the root surface. The depth of its descent will be entirely dependent on how carefully the surgery was performed. Such a depth is considerably more apical than one would expect to find in a tooth whose recent eruption has occurred spontaneously. A compromised gingival attachment will result. The subsequently erupted tooth will have a longer clinical crown and reduced alveolar crest height, in sharp contrast to a tooth that has erupted normally.

A new look must be taken at the surgical plan for the exposure of unerupted teeth. If bonding will not take place during the surgical procedure, then, in order to prevent the re-closing of the wound, a wider exposure must be performed and a surgical pack may need to be placed. Despite the importance of avoiding over-zealous surgical removal of the follicle and of damaging the CEJ area by the forceful placement of the pack, a poorer periodontal result is to be expected. Attachment bonding will need to be performed as soon as convenient, subsequent to the removal of the pack. However, at such a later date, the healing and swollen gingival tissue surrounding the exposed tooth will be tender and will be covered with plaque that will have accumulated since the procedure. It will also bleed with minimum provocation, since effective tooth brushing in this delicate and sensitive area is unlikely to have been possible. These are not conditions that are conducive to reliable attachment bonding, despite the ease of access.

A wide flap design has the advantage of exposing the area of bone covering the tooth, and this will be helpful in identification of the exact site of the tooth. A canine tooth, buried in a bony crypt in the palate, will alter the shape of the palate inferiorly, by creating a distinct bulge of thinned bone that will be all the more obvious if a larger area of the surrounding bone is visible. The creation of a similar bulge is also the case in both the labial plate of the maxilla and in the buccal or lingual plate of the mandible. In order to avoid contamination with blood during bonding, distancing of the edges and underside of the flap from the field of operation is most important and is most easily performed when the flap design is generous.

Once the bony surface has been exposed and the location of the buried tooth identified, the thin overlying bone may be lifted off very easily. The surgeon will generally use a sharp chisel with light hand pressure to cut open the bony crypt and remove the superficial part of its wall. In some cases the bone may be paper thin and can be cut with a sharp scalpel. Immediately beneath the bone, the dental follicle will appear to glisten in the beam of the operating lamp. A window should be cut in the follicle to match the full extent of the very minimal bony opening that has already been achieved. This will enable a view of the orientation of the tooth as it lies in its crypt.

As we shall describe in later chapters, it is of utmost importance to place the orthodontic attachment as close as possible both to the mid-buccal position of the crown of the tooth and to the incisal edge or cusp tip. This will ensure that the traction towards its place in the arch will tend to reduce any existing rotation and will reduce the amount of mechano-therapy to which the tooth will need to be subjected. For this reason, where a rotated tooth is exposed, the bony opening should be extended around the crown of the tooth, towards the mid-buccal area of the crown (provided that this can be done easily), while limiting further surgical damage. In this example, flap replacement may be completed and the pigtail ligature may be tied onto the newly placed attachment and drawn in the direction of the target site in the dental arch.

During exposure of the crown of a tooth, instrumentation of the enamel surface will hamper neither the eruption process nor the quality of the treated result. On the other hand, exposure and instrumentation of the root surface are potentially damaging. Exposing root surface presupposes that the natural attachment of the tooth at the CEJ will have been ruptured and, in consequence, renewed attachment will probably only be able to be established more apically. Indeed, there are yet more undesirable results of exposing root surface: periodontal fibres are severed and cementum exposed and subjected to drying (from the suction and air syringe) and contact with foreign substances (etchant, bonding materials). This can in due course lead to the initiation of a resorption process on the root surface, as well as to ankylosis and to total failure of eruption, as we shall read in Chapter 10. Even more common possible consequences include seriously reduced bone support, long clinical crowns and poor gingival attachment and quality.

Pathological pressure necrosis

Kokich advised against the use of the closed eruption technique for the exposure of canines that are deeply impacted in the palate, preferring an open surgical approach. The method he described [15] demands the removal of sufficient bone to create an opening whose diameter is larger than the crown of the tooth. The cavity is extended from crown tip to CEJ and concurrently the follicle is removed in its entirety. Kokich's rationale for this procedure was that contact made between the follicle of an advancing unerupted tooth and the alveolar bone causes the same resorption of the bone as is seen in the normal, unaided eruption process of teeth. He claimed that the proximity of bare enamel to alveolar bone does not physiologically initiate resorption, 'since there are no cells in the enamel to resorb the bone'. His contention was that 'resorption will eventually occur through pathological pressure necrosis, but it will occur slowly'. Accordingly, when an impacted tooth is located in mid-palate, the advice given was to perform an open exposure and maintain its patency, pending natural, spontaneous eruption, which may or may not occur. The confident but unsupported claim was that 'these palatally displaced canines will erupt on their own … in about 6 to 8 months' [15]. This is an interesting theory, except that this hypothesis has not been tested on a random sample of impacted canine cases and, more importantly, neither has there been an evaluation of the periodontal outcome nor the orthodontic success of such a sample.

Reparatory bone deposition begins in the organizing blood clot, soon after the surgical exposure. It therefore follows that, unless the widest part of the crown of the impacted tooth has been drawn fully outside the bony plate during a very short time period, it must be expected that bone will re-form over and around areas of the crown of the tooth. According to Kokich's hypothesis, this will cause the natural movement of the tooth to slow down or perhaps even stop, due to the 'pathological pressure necrosis' that will have occurred. One may be permitted to enquire what 'pathological pressure necrosis' is if not the undermining resorption and hyalinization of the alveolar bone that occur in every orthodontic tooth movement. However, there are no studies or case presentations reported in the literature, nor are there any clinically or histologically detectable post-treatment signs of pathology, which may give credence to the existence of a different and histopathological phenomenon. Notwithstanding this, its manifestation would obviously not augur well, either for patients whose teeth are deeply impacted in bone, or for others for whom several weeks or months may elapse after the surgical exposure and before orthodontic traction is applied.

In Chapter 18 we describe many of the more common reasons for failure to resolve the impactions and how these may be avoided. There are illustrations of cases of successful resolution of impaction as much as a year or more after the surgical exposure had been performed; cases where success was achieved after a significant gap in the treatment following an initially failed treatment by another practitioner. In these cases, before treatment was started, much mature bone had been laid down, providing an impediment in the path of the impacted tooth, and yet the second attempt at treatment was both successful and rapid and did not need re-exposure of the tooth.

Four decades ago, it was shown that the presence of an intact follicle was a prerequisite for the process of normal *unassisted* eruption [48]. Experience with routine biomechanical traction of impacted teeth has taught us, however, that even in the absence of a follicle, light orthodontic traction is capable of encouraging the resorption of bone that is needed for the *assisted* eruption of an exposed tooth.

In Chapter 10 we have pointed to anecdotal clinical evidence that contradicts Kokich's view. The chapter deals in detail with impacted maxillary canines that are associated with root resorption of their immediate neighbours. In the more extreme examples of this anomaly, the canine crown and the resorbed incisor root are intimately related and are situated in the middle of the ridge, surrounded by bone on all sides. Here the exposure has to be carefully planned to avoid surgical trauma to the incisor root area. It is clearly out of the question to carry out broad clearance of bone and of dental follicle to the full width and length of the crown of the canine and down to the CEJ. Nevertheless, these teeth can routinely be drawn through the surrounding bone and the impaction resolved, as with any other impacted tooth, with the application of light forces suitably directed, and in most cases with considerable speed.

Similarly, in Chapter 21 we describe the treatment of patients with cleidocranial dysplasia (CCD). Here surgical exposure is required on multiple impacted teeth, deeply displaced low down in the basal bone. For reasons outlined in that chapter, exposure of the canine and premolar teeth will typically be aimed at the buccal aspect of the teeth. It will avoid both the deliberate broad removal of bone surrounding the remainder of the crown of the tooth and exposing of the occlusal surface of the crown of the tooth superiorly. This method seems not to have any retarding effect on the eruptive response of the tooth to occlusally directed light forces, despite the fact that it may often have to resorb a thick layer of bone in the process. This is even the case where alveolar bone in CCD patients is considered to be particularly dense and the largely acellular cementum on the roots of their teeth is associated with slower resorption [49].

Bone graft and the impacted canine

A 9-year-old female patient was accepted for treatment by an orthodontic resident in the cleft palate unit of the Hebrew University-Hadassah School of Dental Medicine in Jerusalem. The patient, who was in the middle period of the mixed dentition, had a unilateral cleft lip and palate of the left side (Figure 5.10a). The palate was very narrow and V-shaped and she had a bilateral and anterior crossbite.

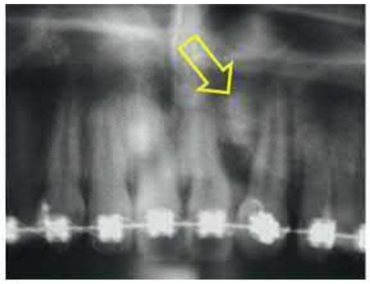
When the patient was admitted for the autogenous bone graft that would close off the cleft (Figure 5.10c, d), the lateral incisor on the distal side of the cleft was transposed with the unerupted maxillary canine (Figure 5.10b). These two anterior occlusal radiographs were recorded the day before and the day after the placement of the graft, for the purpose of checking the outcome of the procedure.

A rehabilitation treatment plan was established for the orthodontic part of the overall correction. The plan was to align the two teeth in their transposed relationship, rather than attempt to correct it. This was based on the periodontal assessment of the long-term relative merits of the two therapeutic possibilities. It was considered that moving the lateral incisor bodily into the area of the former cleft, where there was a glaring deficiency of alveolar bone, would seriously undermine this tooth’s prognosis. On the other hand, the former bone graft had largely resorbed and had undergone replacement by the normal bone turnover process. This presented a more favourable matrix through which the canine could be drawn and which would increase the volume of accompanying alveolar bone.

The lateral incisor was erupted, aligned and its long axis paralleled to those of the adjacent teeth, with space provided for the canine, mesial to this incisor. The canine was exposed and bonded with an eyelet attachment in a closed exposure procedure. It was then drawn mesially and vertically through the former bone graft into the lateral incisor location, where it was uprighted until parallel to the adjacent teeth.

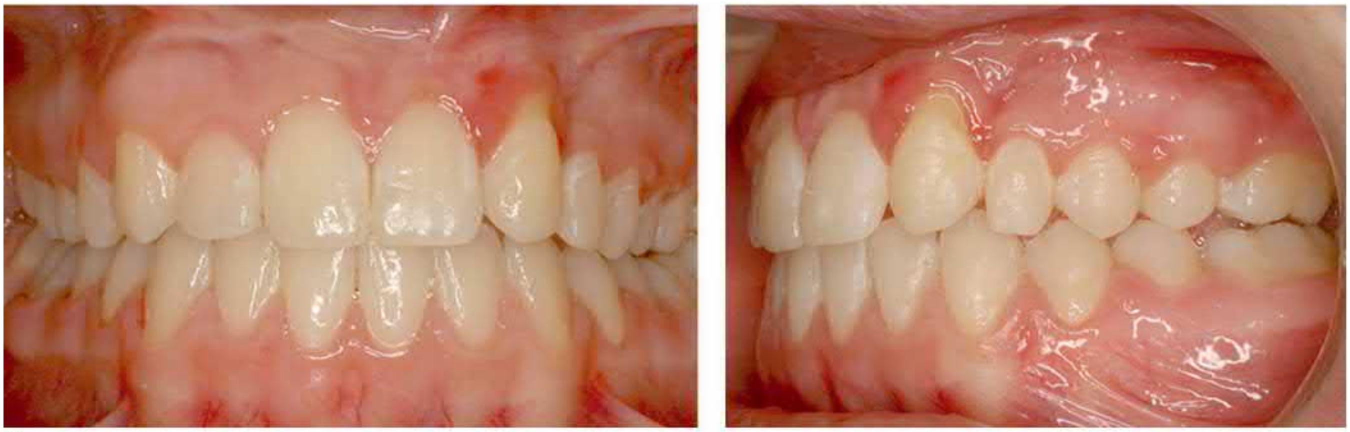
(a) (b) (c) (d) (e) (f)

(g)



(h)

(i)



(j)

Fig. 5.10 (a) The initial records of the dentition showing the narrowed V-shaped maxilla. (b) The oblique anterior occlusal view of the anterior maxilla shows the untreated cleft (yellow arrow) and the adjacent transposed lateral incisor (#22) and unerupted canine (#23). (c, d) Two identical anterior occlusal radiographs taken two days apart, immediately prior to and following the bone graft (green arrow) in place. (e) Alignment of the lateral incisor in the canine location and some spontaneous horizontal movement of the unerupted canine. (f) Following surgery and orthodontic traction, the canine has been aligned in the transposed order. The bony support of the canine and the lateral incisor is less than ideal for a good long-term prognosis. (g) The broadened and aligned maxillary dental arch with space provided for the canine in the incisor location. Note the significant alveolar bony defect in the incisor area. (h) The anterior portion of the panoramic view, showing the canine in the transposed location and the unresorbed remnant of the bone graft (arrow). (i) The final arch shape and dental alignment. (j) The final transposed alignment following removal of appliances.

In the final analysis and following removal of the orthodontic appliances, the aligned canine and lateral incisor, in their transposed locations, were both invested in a good width of alveolar bone and the surface architecture was excellent. The canine exhibited a long crown with gingival recession and it is expected that, in time, the red and swollen gingivae will improve as keratinization of the mucosa occurs, depending, of course, upon appropriate oral hygiene and normal function. The appearance of these teeth may be further improved by judicial grinding of the point of the canine cusp and flattening of the labial prominence [50].

In the literature, from time to time we come across individual clinical case reports illustrating the eruption of teeth through bone grafts. In one such report [51], the patient had been treated for a large composite odontoma, which comprised a myriad of small denticles. The odontoma occupied much of the anterior maxilla, replacing bone and displacing the unerupted maxillary canine. When all the individual denticles of the odontogenic hard tissue tumour were surgically excised, a very large cavity in the bone remained. The presence of the space-occupying benign entity had prevented the development of a significant potential volume of cortical bone. The authors had placed a graft of a synthetic bone substitute and subsequently erupted the impacted canine through it, in much the same way as was done in the last case (Figure 5.10).

In each of these difficult and extreme scenarios, a successful result of the treatment will almost always show good clinical and radiographic features. This is despite the necessity of having, post-exposure, to erupt the teeth through surrounding alveolar bone, taking care to limit the removal of follicular tissue.

The deliberate aim of the tunnel method [30], mentioned above, is to bring a large canine down through the much narrower socket that was recently vacated by the extraction of its deciduous predecessor. This cannot be achieved without the resorption of bone lining the socket. Furthermore, in view of the lengthy time involved in bringing a severely displaced canine into its place in the arch, however rapidly this may be achieved, the lower part of the socket will surely have undergone osseous healing. The eruptive progress of this tooth cannot proceed in the direction of this vacated socket before physiological healing has deposited new bone directly in its path.

The aim of the treatment must, therefore, be to make the final realignment of the teeth as close as possible to the normal condition, regarding an attractive dental display, normal appearance of the gingival environment, healthy supporting alveolar bone and periodontal attachment. The following two anecdotal cases show that these treatment goals are achievable if, during the exposure of the impacted teeth, care is taken in the surgical handling of the dental follicle.

In the closed eruption approach, which we described earlier in this chapter, we recommended reflecting a wide soft tissue flap, while only opening the dental follicle itself to a very minimal degree – just enough to permit the maintenance of haemostasis while the bonding of a small attachment is performed. The remainder of the follicle survives intact, which means that all other parts of the crown of the tooth are invested in follicular tissue that, when traction is applied, will presumably initiate bone resorption in the normal way. The break in the integrity of the follicle occurs solely at the site of the attachment, where only a minimum of bone will have been removed. It is open to speculation whether repair of the follicular tissue may occur over a bonded attachment and whether its integrity will be fully restored around the steel ligature to which traction is applied.

This idyllic scenario would appear to be most unlikely to occur in practice. Let us set aside for a moment the reasons why a conservative attitude to the dental follicle works so well, because the fact remains that, in these cases, post-orthodontic corrective periodontal flap and graft procedures are almost entirely superfluous in both the short and the long term. For the most part, the previously impacted teeth are impossible to distinguish, periodontally, radiographically and aesthetically, from their unaided neighbours and antimeres (Figures 5.11 and 5.12).

Quality-of-life issues following surgical exposure

Young patients who are about to undergo surgical exposure of an impacted tooth need to be informed how the procedure may affect their daily life in terms of pain, function, speech and the several other aspects that involve the oral cavity. The risks and benefits of the intended treatment must be clearly set out. Patients are often apprehensive at the thought of surgery, particularly if they are young and healthy with little or no previous experience of surgical procedures. The incidence and magnitude of these challenges are all part of the post-surgical follow-up, of which patients and their parents must be apprised. These aspects of the procedures constitute information that the law requires to be explained to them, in order for them to sign a statement of informed consent. While this is true of all types of orthodontic treatment, it is particularly so where surgery is involved.

A number of articles have recently appeared in oral surgery journals regarding these parameters within the context of the extraction of third molars. However, it is a matter of surprise that there is a significant paucity of published works that relate to quality-of-life (QoL) issues in the context of the surgical exposure of impacted teeth. The result has been that the information available to both clinicians and patients is often based on a single anecdotal episode or on the biased reports of individuals who have themselves experienced some form of oral surgery. Information thus gleaned is notoriously unreliable and will rarely have any application to the particular surgical exposure then planned.

This lack of professional information was the motivating factor for the prospective clinical studies that were undertaken in Jerusalem, to quantitatively assess the various aspects of QoL consequential to the performance of both open and closed surgery [42–44].

For the purpose of the QoL study, two groups of patients were assembled. One group included young patients who were scheduled for open surgery and the second group for closed surgery. On the day the exposure was performed, each patient was presented with seven identical questionnaires and was instructed to complete one of the questionnaires on each post-treatment day, for each of the following seven days. Information was then collected from the answers regarding pain, oral function, general disability, limitation in eating, absence from school and related parameters. The results for the group of patients who had had open exposure were then analysed and compared with those for the patients who had undergone closed exposure.

In general, it was found that full recovery from an open eruption exposure required five days, whereas only three days were required for a closed procedure. It was particularly observed that, in the case of the longer recovery period (the open technique), there was a higher level of pain, greater difficulty in eating and swallowing and an increased need for analgesics. More specifically, it was found that there was much greater discomfort with the open exposure in the case of a palatally impacted canine, especially if bone removal had been performed. However, it is noteworthy that exposure of impacted teeth with a buccal approach resulted in a high level of discomfort, regardless of the surgical method that had been employed. It may be speculated that this was due to the fact that paranasal and oral musculature is severed during buccal procedures and the surgical flap is sited in highly mobile oral mucosa.

Table 5.1 summarizes the effects on QoL issues immediately post treatment. We can see the advantages and disadvantages of complete flap closure (healing by primary intention) compared with the alternative open exposure techniques, in which the opening in the tissue over the impacted tooth is maintained by reducing the size of the flap and packing the wound or by repositioning the flap more apically (healing by secondary intention).

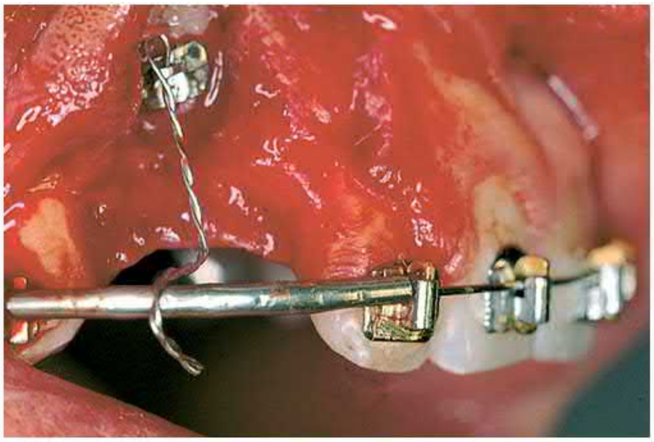
Cooperation between surgeon and orthodontist

From the discussion in this chapter so far, it will have become quite clear that there are severe limitations in the ability of the surgeon to single-handedly treat the cases discussed. We have sought to demonstrate that, in most situations, the inclusion of orthodontic procedures offers a better chance of success. Indeed, today orthodontists are playing an increasingly important role in the initial stages of the treatment of impacted teeth, in particular by providing the traction that is necessary to encourage eruption. In many of the cases where teeth were previously felt to have poor prospects for eruption, the contribution of the orthodontist to the ultimate successful result has been the ‘game changer’.

Once the oral surgeon has made the impacted tooth accessible, its destiny is largely dependent on the ability and the ingenuity of the orthodontist, to apply light traction in an appropriate direction, efficiently and with the appropriate means. If orthodontic treatment is available to the patient, the other highly empirical and suspect procedures listed at the beginning of this chapter, which may otherwise be suggested by the surgeon, become superfluous. There is no evidence that suggests that these procedures may improve the opportunity for orthodontic resolution, without thereby causing consequential harm.

(a) (b) (c) (d) (e) (f)

Fig. 5.11 A case of bilateral palatal impaction of maxillary canine treatment with the closed eruption surgical technique. (a) Anterior section of the pre-treatment panoramic view to show canines almost contacting in the midline. (b) Panoramic view of the post-treatment result. (c) The treated result seen 14 years post treatment with relapsed incisor overjet and overbite. (d) Close-up intra-oral view of the teeth from the labial side, showing the canines to be indistinguishable from their neighbouring teeth in terms of their crown length, gingival contour and excellent appearance. (e) Clinical view of the palatal sides of the two canines, 14 years post treatment, to show normal gingival contour, normal crown length and no recession. No reparative periodontal procedures were performed after the original closed surgical exposure. (f) Periapical radiographs of the teeth showing excellent bone support and pattern.



(a)

(b)

(c)

Fig. 5.12 (a) Mild palatal displacement of the right maxillary canine located very high in the line of the arch (Group 3 canine) and treated with full-flap closure on the buccal side (closed eruption technique). (b, c) The right and left sides are indistinguishable at the completion of treatment.

It may therefore be concluded that, with respect to the treatment of impacted teeth, the aims of the oral surgeon should be limited to:

- Provision of access to the buried tooth.
- Elimination of any obstruction from the tooth's eruptive path, such as supernumerary teeth, odontomes or thickened overlying mucosa.
- Maintaining haemostasis, thereby enabling active participation of the orthodontist at surgery in bonding an attachment to the exposed teeth, which is so critical in ensuring success.

In summary, it is our contention that the single most important aim of surgical involvement is to provide access to a tooth that is otherwise buried. This will enable the orthodontist to provide the means, in as simple a manner as possible, by which force may be applied to the tooth in question, through several subsequent visits over a longish time-span. For this to happen, an attachment has to be securely bonded and a firm ligature, or other form of intermediary, drawn to the exterior, to which steel wires, super-elastic nickel–titanium wires, elastic ligatures or an auxiliary spring may be tied. The responsibility for the successful execution of this procedure is shared between the oral surgeon and the orthodontist, each complementing the other in applying their very special and different skills to the resolution of the immediate task. Together they possess all the tools that are needed to complete the job, which neither is equipped to do alone.

If bonding an attachment to the tooth is to be carried out a few weeks after the surgery has been performed, then the presence of the orthodontist at the surgeon's side will be superfluous. However, the reliability of the bonding at this later date will be much poorer [3]. The surgeon will need to expose the tooth much more widely, place surgical packs and aim for healing 'by secondary intention'. This has been pointed out above and will be explained in greater detail in later chapters.

Table 5.1 Immediate effects of closed and open exposure treatments on quality of life.

Primary full-flap closure (closed exposure)
Advantages
• Rapid healing
• Less discomfort
• Good post-operative haemostasis
• Less impediment to function
• Conservative bone removal
• Immediate traction possible
• High degree of reliability of bonding possible in close proximity to resorbing root area
Disadvantages
• Presence of orthodontist needed
• Bond failure dictates re-exposure
Open exposure
Advantages
• Orthodontist's presence unnecessary
• Bond failure – needs no surgery
Disadvantages
• Greater risk of infection
• Greater discomfort

• Interference with functions of eating, chewing, talking
• Wider bone exposure
• Bad taste and smell in mouth
• Possibility of re-closure of exposure – dictates re-exposure
• Bonding reliability poorer
• Delayed initiation of traction
• Poorer periodontal condition
• Extra visits to change packs

The team approach to attachment bonding

It is appropriate to note that the development of the team approach to the bonding of an attachment was exemplified in the cooperation, expertise and forbearance of two (now retired) senior oral and maxillofacial surgeons in Jerusalem, Professors Arye Shteyer and Joshua Lustmann. The approach primarily represents an adjunctive surgical procedure, whose aim is to provide a small area of exposed enamel of the impacted tooth for the application of an orthodontic force-delivery system. Accordingly, it should be carried out on the surgeon's territory, rather than in the orthodontic clinic.

Before the surgical exposure is attempted, orthodontic treatment will have been initiated and, in most cases, will have reached the stage where levelling and alignment will have been prepared. More substantial steel archwires will have been used during space preparation and a heavier base arch will usually be in place to combine all the teeth into a composite anchor unit.

Those orthodontic procedures that remain to be carried out *during* the surgical episode are few and relatively simple and can all be performed in the oral surgeon's operatory. If they are properly prepared in advance, these procedures will not be time-consuming and will not disturb the surgeon's patient flow. Practical experience will dictate that the orthodontist should prepare a small tray of instruments and materials that are not normally available in the operating room. In addition, the orthodontist will have prepared an auxiliary device, which will have been chosen or customized at a previous visit, for the purpose of applying a directional force to the impacted tooth. This may take the form of a prepared and individualized ballista spring, or a flexible palatal arch or an auxiliary labial arch (see Chapter 7). The instrument tray should contain the items listed in Table 5.2.

In the treatment of an impacted palatal canine or of almost any other impacted tooth and immediately prior to the surgical exposure, it has been the author's practice to tie the labial auxiliary arch or other auxiliary into the orthodontic brackets. In its passive mode, the active loop will stand well away from the immediate surgical field and will not interfere with the work of the surgeon. As a poorer alternative, these auxiliaries may be placed on the instrument tray, in readiness for placement at the end of the surgical procedure.

Table 5.2 An instrument tray for a team approach.

Instruments
• Fine wire bending plier (e.g. Begg plier)
• Fine wire cutter
• Reverse-action bracket-holding tweezers, which are closed when not held and release when handles lightly squeezed
• Ligature director
• Mosquito or Matthieu forceps
• Fine scaler
Materials
• Etching gel
• Composite bonding material, preferably a light-curing material
• Applicators (sponge buds, fine brushes, etc.)
Attachments
• Eyelets welded to thin band material, backed with stainless steel mesh; these should be cut and trimmed into patches of various sizes, but no larger than the base of a small bracket
• Cut lengths of dead soft stainless steel ligature wire of gauge 0.012 in. or 0.014 in.
• Elastic thread and elastic chain

In the first stage of the treatment, the surgeon reflects the palatal soft tissue flap over the impacted tooth and removes the intervening bone, which is usually very thin and easy to peel with a scalpel blade. If a supernumerary tooth or odontome is present, this will be removed first. The dental follicle is then cut open in the target area, immediately overlying the crown, and the resultant exposure is widened. The increase of the width of the exposure should not be more than is necessary to satisfy two basic requirements: (a) to provide enough enamel surface to accept a small attachment; and (b) to do so in an area wide enough for adequate haemostasis to enable the bonding procedure to take place, without fear of contamination.

The next stage requires the surgeon to move to the other side of the operating table in order to be positioned to concentrate on maintaining the enamel surface, free of blood and saliva, throughout the critical bonding phase. In this function, and under these conditions of exposed and oozing soft tissue and bone surfaces, the surgeon will generally need to use a regular suction tip and a second and very fine tip in the form of a canula no. 14 or 16, in order to maintain a blood-free field of operation for the bonding procedure. Occasionally, the surgeon may be required to attend to a persistent bleeding point from the bone surface and may apply pressure from a blunt instrument or use bone wax to occlude the tiny vessel. In the case of soft tissue bleeding, electro-cautery may be employed, or a hot burnisher or even ligation of the vessel. Bleeding does not occur in the follicular space, but seepage from adjacent areas may happen and is best arrested with the use of light pressure from a strip of gauze, which may be left in place until suturing is ready to begin – *but it must not be forgotten*! Then, holding a retractor in one hand and alternating the suction tips as necessary with the other, the surgeon will be able to maintain the access and haemostasis to the immediate area of the newly exposed and impacted tooth.

The orthodontist, who has been waiting patiently for the surgeon to achieve the required state, will now step in and proceed directly to rinse the tooth surface with atomized water spray. This will be done from a standard triple syringe (or, if preferred, with sterile saline from a large syringe) through a wide-bore needle, in order to disperse any blood from the tooth surface. The saline is evacuated through the broad suction tip, operated by the surgeon. The fine suction tip then takes over and is made to hover over the entire exposed crown, close to the tooth surface, with the aim of achieving an air flow over the clean enamel. This produces and maintains effective drying, while the use of sterile saline as a rinsing agent does not appear to undermine the reliability of the bonded union.

Liquid etchants should not be used in the exposed surgical field [5, 25, 45], since it is difficult to limit their spillage and dispersal onto the exposed soft tissues and bone surfaces and, even more important, to prevent their spreading to the area of the CEJ, the PDL and cementum. There is mounting clinical evidence that excessive orthophosphoric acid etchant, which seeps onto the exposed root areas, will damage the cementum cover of the root. It may also enable the osteoclasts of the PDL to attack the naked dentinal root surface and thereby create a focus of invasive cervical root resorption. The etchant should be applied by the orthodontist in gel form on the end of a fine sponge bud or fine instrument. It should be left in place for 15 seconds and thereafter drawn off by the surgeon through the fine suction tip, *before* the surface is rinsed again with saline to remove the last traces of acid.

Continued use of the fine tip for a few more seconds will draw air over the surface of the crown of the tooth, until it is dry and the typical white matt appearance of the etched surface becomes apparent. The surface is now ready for bonding. Many practitioners may feel concern about the adequacy of the desiccation and may also prefer to be sure that no salt crystals remain from the dried saline. Experience shows that this concern is without foundation. Nevertheless, to allay these doubts, a final rinse with atomized water from the triple syringe may be carried out and followed by a fine compressed air stream, thereby doubly ensuring the appropriate degree of dryness of the enamel surface. Care must be taken that the compressed air stream be very gentle, in order to avoid splashing up blood from the surgical area, contaminating the enamel and causing bond failure. Oddly enough, the use of a suitably adapted electric hair dryer has the advantage of providing a gentle and waterless stream of warm air, which may be more effective in drying the etched enamel surface and is a method favoured by some clinicians.

The prepared eyelet attachment has a pliable base. An attachment of appropriate size should be selected and manually adapted by the orthodontist with pliers to conform to the target bonding site. A cut length of 0.012 in. (0.3 mm) or 0.014 in. (0.35 mm) soft stainless steel ligature wire is threaded through the eyelet and, with the use of mosquito or Matthieu forceps, is twisted into a medium-tight and firm pigtail, which should swing freely in the eyelet. Although any type of bonding agent may be used, we have found that light-activated systems are easier to handle in these circumstances than chemically activated systems.

The subject of attachments is discussed in more detail in Chapter 2. Nevertheless, one or two points are pertinent in the present context regarding bonding under conditions of surgical exposure.

The choice of the appropriate implement to be used, to carry the attachment to its place and to hold it there until setting has occurred, is also important. Many operators prefer to use mosquito or Matthieu forceps; however, freeing the instruments from the attachments is only possible to achieve by changing the hand grip and unlocking the ratchet that holds the beaks closed. These manoeuvres produce considerable jolting and jarring of the attachment and could cause loss of the delicate control needed for successful, accurate placement. Experience has shown that it is better to use reverse-action bonding tweezers, which, once the attachment has been placed, may be much more gently disengaged, to be left unsupported during the curing process.

The viscosity of the bonding paste should be adequate to prevent any 'floating' movement. However, if continuous pressure is desired during the setting period, one may place a ligature director, with its notch engaged, astride the eyelet loop and under light pressure. The freeing of the ligature director, once setting is complete, is achieved simply by merely withdrawing the instrument in the direction of its long axis, without generating any undue lateral jarring. It is always advisable, before requesting the surgeon to re-suture the flap, to test the strength of the newly bonded attachment by giving the pigtail ligature a firm tug.

As part of the original orthodontic treatment plan, an accurate radiographic assessment of the position of the impacted tooth will have been made and an approach to its orthodontic resolution formulated. With the impacted tooth in full view during the exposure procedure, the orthodontist must re-evaluate the earlier assessment and confirm or revise the traction direction accordingly. If the traction is to be directed in line with the prepared place in the dental arch, then the pigtail ligature will be swivelled on the eyelet until it points in that direction. The surgeon will then suture the flap back over the wire, leaving its end freely protruding through the cut and sutured edges.

As will be discussed in Chapter 7 with regard to a palatally impacted maxillary canine, sometimes the direction of the traction cannot be pointed straight to the labial archwire, due to the proximity of the roots of adjacent teeth. In such a case, the wire may initially need to be drawn vertically downwards towards the tongue, or posteriorly towards the molars. To achieve this, the pigtail, which cannot be drawn through the sutured edges of the flap, will rather be taken through the middle of the palatal area. This means that the reflected flap will need to be divided into two, one on each side of the pigtail (Figure 5.6g). A better alternative, prior to the replacement and suturing of the flap, is to pass the pigtail through a small pierced pinhole in the palatal flap mucosa. When suturing is finished and the palatal area completely closed off, the orthodontist should shorten the pigtail and turn it up into a hook or a circle, to be attached to an active palatal arch, ballista, auxiliary archwire or elastomeric chain, according to preference and suitability.

The replacement of the flap will once again conceal the impacted tooth. However, before it is hidden by the closure, it is prudent to photograph the tooth and its attachment (Figure 5.6d, e). This will be appreciated at a later stage, when the patient returns for routine orthodontic adjustment and further activation of the traction mechanism. It will enable subsequent decisions related to the direction of orthodontic traction to be made with greater reliability.

Traction should be applied immediately after the closure has been achieved and regardless of which traction method is used. This will help to reduce later manipulation of the ligature pigtail, which is very helpful, particularly during the first couple of post-surgical months. Such manipulation is unpleasant and even painful for the patient as the pigtail passes through the soft tissues.

There is much to be said for the first adjustment being fully exploited, with the application of appropriate traction while a local anaesthetic is still operational, i.e. at the time of surgical exposure. Subsequent manipulation may then only be necessary for two or three additional adjustment visits, before the tooth is erupted and before the pigtail becomes free from the soft tissue. If, prior to the surgery, an auxiliary labial archwire or a 'ballista' spring in its passive mode has been tied into the arch, as already recommended, then lightly pushing the loop from its vertical, inactive position towards the mid-palate and turning the pigtail ligature around it will provide appropriate light and continuous extrusive force. This will be active over a wide range of movement and will remain active for many weeks. Similarly, an auxiliary palatal arch may be slotted into the palatal horizontal molar tubes then raised, to be held by the pigtail ligature. Whichever of these devices is used, this orthodontic manoeuvre should take no more than a minute or two and can be done while the surgical instruments are being cleared away.

With the procedure described, and attachment placement performed by the orthodontist and with moisture control under the care of the surgeon, the bonding has been shown to be very reliable [3]. However, this has not always been the prevailing opinion. In the past, bonding in the presence of an open and bleeding wound, involving both soft and hard tissues, was strenuously resisted, since it was thought to be inconsistent with the attainment of a dry and uncontaminated field. This mistaken opinion on the part of the orthodontist was probably born more out of a reluctance to be present at the surgical episode than out of any experience of a high incidence of failure in attachment bonding in these circumstances.

From the discussion here, it will be abundantly clear that the presence of the orthodontist at the surgical intervention has multiple positive aspects:

- The orthodontist is able to see the exact position of the crown, the direction of the long axis and the deduced location of the root apex.
- The height of the tooth and its relation to adjacent roots may be noted and the orthodontist will be able to confirm the strategic plan for its resolution by direct visualization.
- The orthodontist will be in a position to decide, from the mechano-therapeutic aspect, exactly where he or she would like to see the attachment placed and will bond it there.
- The orthodontist is also the best person to fabricate, place and activate a suitable and efficient auxiliary to apply a directional force of optimal magnitude and range of movement and to do so at the time of actual surgery.

It is not fair to expect oral surgeons to be aware of how the different attachment locations may affect the orthodontic or periodontic prognosis; nor should they be expected to be sufficiently experienced with the bonding technique to do it themselves. Bonding is not a procedure that oral surgeons routinely carry out. The presence of the orthodontist allows for bonding to be performed efficiently, while the surgeon and the nursing attendant maintain haemostasis and the necessary dry field.

Some surgeons may take exception to the presence of the orthodontist at the exposure and may even use expressions like 'even the lowliest oral surgeon can place a bracket' or that it is 'a waste of time' [52]. It will then be quite apparent that the oral surgeon had sorely missed the point and had not understood the wider context of ensuring quality care and overall treatment success.

The ultimate responsibility for the success of the case rests firmly on the shoulders of the orthodontist, from the initiation of orthodontic treatment up to the point where the impacted tooth is brought into full alignment and, almost invariably, until the overall malocclusion is resolved. It would be irresponsible to abrogate the management of this crucial stage of the treatment to another party, when there is force to be applied to the newly exposed impacted tooth and where so much is at stake that will affect the future of the case. If, as has been advocated by many orthodontists and surgeons alike, orthodontists absent themselves and leave surgeons to make orthodontic decisions for which they are not equipped, they will be endangering the outcome and inviting legal proceedings, from which the orthodontist involved will not be immune.

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6
Impacted Maxillary Central Incisors

Adrian Becker

Aetiology

Attitudes to treatment of obstructed central incisors

Phase 1 treatment considerations

Traumatic causes

Aetiology

At the age of about 6 years, most children will experience a sudden and dramatic change in the anterior part of the dentition, with the shedding of the deciduous incisor teeth and the appearance of the permanent incisor teeth. As has been described in Chapter 1, the first teeth to erupt in the young child are usually the mandibular central incisors, although the first permanent molars may sometimes precede them. The mandibular lateral and maxillary central incisors erupt shortly afterwards, at 6.5–7 years. Under normal circumstances, the maxillary lateral incisors are the last of the incisors to erupt and, with their appearance about a year after the eruption of the adjacent central incisors, will complete the anterior dentition. Further changes in the dentition, in terms of shedding of deciduous teeth and eruption of their permanent successors, do not occur until approximately the age of 9.5–10 years. This means that there is a two-year period of relative stability, which is known as the mixed-dentition stage.

The spectacle of erupted lateral incisors, associated with the non-appearance of one or both of the central incisors, should always be deemed abnormal, whether or not a deciduous central incisor is still present. Further investigation should be undertaken to ascertain the reason for the aberration.

Congenital absence of a maxillary permanent central incisor, given the presence of permanent lateral incisors, is exceptionally rare, although it has been reported. In this situation, the shape of the single central incisor makes it impossible to distinguish whether it belongs to the right or left side. The patient's appearance is abnormal (Figure 6.1a–c) and rather reminiscent of a 'dental cyclops'. However, the abnormality in the appearance will also be due to other clinical features and malformation of other elements of the craniofacial complex, in a rare condition known as holoprosencephaly. The patient will have other midline anomalies, which may include an indistinct philtrum of the upper lip, an absence of the typical Cupid's bow, no midline frenum, a mid-palatal ridge and nasal obstruction or septum deviation. These patients will also exhibit a short anterior cranial base and maxilla, together with retrognathic and posteriorly inclined maxilla and mandible. The sella turcica will have an abnormal shape. The patient described here exhibits a mild form of holoprosencephaly [1] (Figure 6.1). The total picture presented dictates that the condition should not be treated as a simple, local and isolated congenital absence, as would be the case in relation to a missing maxillary lateral incisor or mandibular second premolar.

The most frequently seen presenting symptom in the framework of holoprosencephaly is the presence of a single midline central incisor. Let us turn our attention for a moment to what holoprosencephaly is and how its development goes astray, in comparison to the norm. At 5–6 weeks of human embryonic development, the forebrain is formed and the face begins to take shape. In cases of holoprosencephaly, the forebrain fails to develop into two cerebral hemispheres and the structures that are normally paired into identical right and left units remain as one. This condition expresses itself *inter alia* in defects in the development of the face and defects in brain structure and function. In most cases of holoprosencephaly, the malformations are so severe that the foetus dies i*n utero*. In less severe cases, many of these defects may not be obvious. The facial deformities usually seen in the eyes, nose and upper lip may be very mild and inconsequential and they may be easily missed in the physical examination. The child may have normal or near-normal psychological and intellectual development and no apparent mental impairment. Nevertheless, a very mildly affected child may be brought by a parent to the orthodontist because of the absence of one incisor, without any other obvious physical signs. The condition is therefore mentioned in this chapter on impacted incisors to bring it to the attention of an orthodontist who, having mistakenly decided that the tooth had been lost due to violence in the home environment, becomes suspicious of the parent's answer to directed questions regarding physical abuse.

(a) (b) (c)

Fig. 6.1 (a) Abnormal lip morphology, absence of philtrum and midline position of single central incisor, in a case of holoprosencephaly. (b) A view of the palate to show bilateral submucous clefting. (c) Intra-oral view of the same patient to show 'square' anatomy of incisor and indeterminate right/left designation. The lateral incisors are laterally flared as part of an otherwise normal 'ugly duckling' stage of development.

Courtesy of Dr S. Geron.

Trauma to the anterior maxilla in a young patient is probably an almost daily occurrence in many schools, playgrounds and during sports activities. Trauma at home should not be forgotten and may occasionally be the first clue to child abuse. By and large, the incidents are trivial and characterized by much bleeding from lacerations of the lip and gingivae, which may occasionally divert attention from underlying damage to the incisor teeth. These may have been traumatically intruded and lost from sight or even completely avulsed.

A careful history should be elicited to eliminate the remote possibility of avulsion of the permanent central incisor, which may have been overlooked. This may happen if the tooth had been in the very earliest stages of its eruption and therefore its absence went unnoticed at the time. A newly erupting central incisor is invested with a rudimentary, underdeveloped periodontal ligament (PDL), such that a relatively light and unfortunately well-directed blow may easily bring about its loss.

Obstructive causes

Supernumerary teeth

In a study of a sample of orthodontic patients [2] and an earlier study of school children [3], the incidence of supernumerary teeth in both investigations was found to be 1.2%. Several other studies have been undertaken over the years, with similar results [4–6]. In a further study of a sample of cases where supernumerary teeth were found [7], it was shown that a majority of these cases had associated eruption disturbances of the adjacent teeth.

When an existing permanent central incisor does not erupt and a diagnosis of impaction is made, the most common aetiological factor is the presence of one or more midline supernumerary teeth [2–6] (Figure 6.2 and in Figures 1.10 and Figures 1.10 and 1.11). For the most part, midline supernumerary teeth develop on the palatal side of the permanent incisors and as such occupy space within the bucco-lingually narrow alveolar ridge. This results in a labial and superior displacement of the permanent incisors.

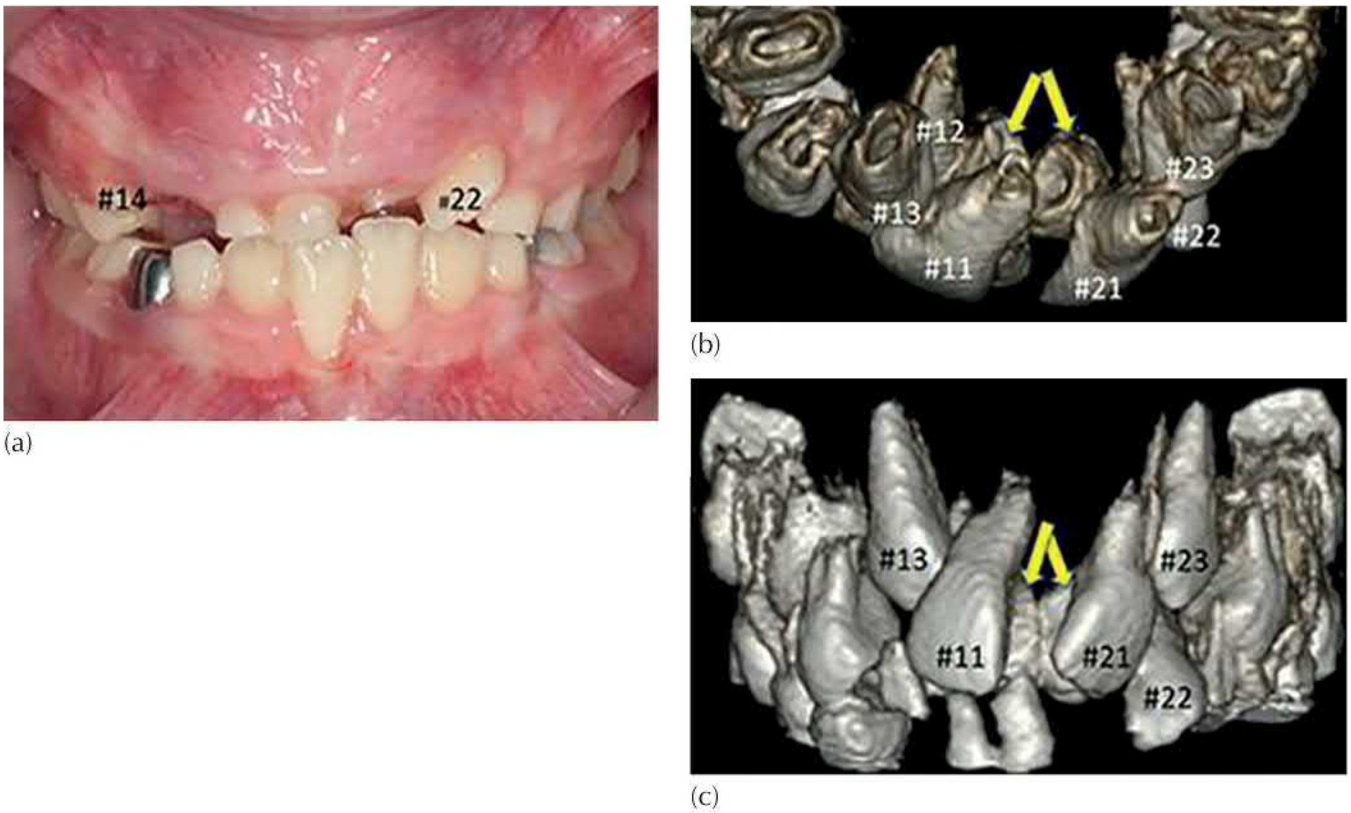


Fig. 6.2 (a) Clinical views of a 9-year-old boy with a bulging ridge form due to obstructive impaction of three incisors. Two deciduous incisors are over-retained and the left lateral incisor (#22) is erupting. (b, c) Two 3D views from the cone beam computed tomography (CBCT) images show the incisors (#11, #12 and #21) impacted due to the unerupted presence of two supernumerary teeth (yellow arrows). See Online PPT & video Fig. 6.2.

Odontomes

Odontomes are among the rarer causes of obstruction, resulting in the non-eruption of a normal central incisor. These are very variable in size and type but, whether they are of the complex or of the composite type, they will usually have a longer and wider cross-section and will therefore occupy more than the usual space in the alveolar ridge, often causing its expansion. Their presence will be highly likely to impede the eruption of an incisor.

In other cases, the central incisor is absent and a single odontoma has developed in its place (Figure 6.3). It is as if this single tooth has lost its genetically determined pattern and developed into a wildly disarranged amorphous mass of the dental tissues, i.e. enamel, dentin and cementum, which have grown in a wild and haphazard manner.

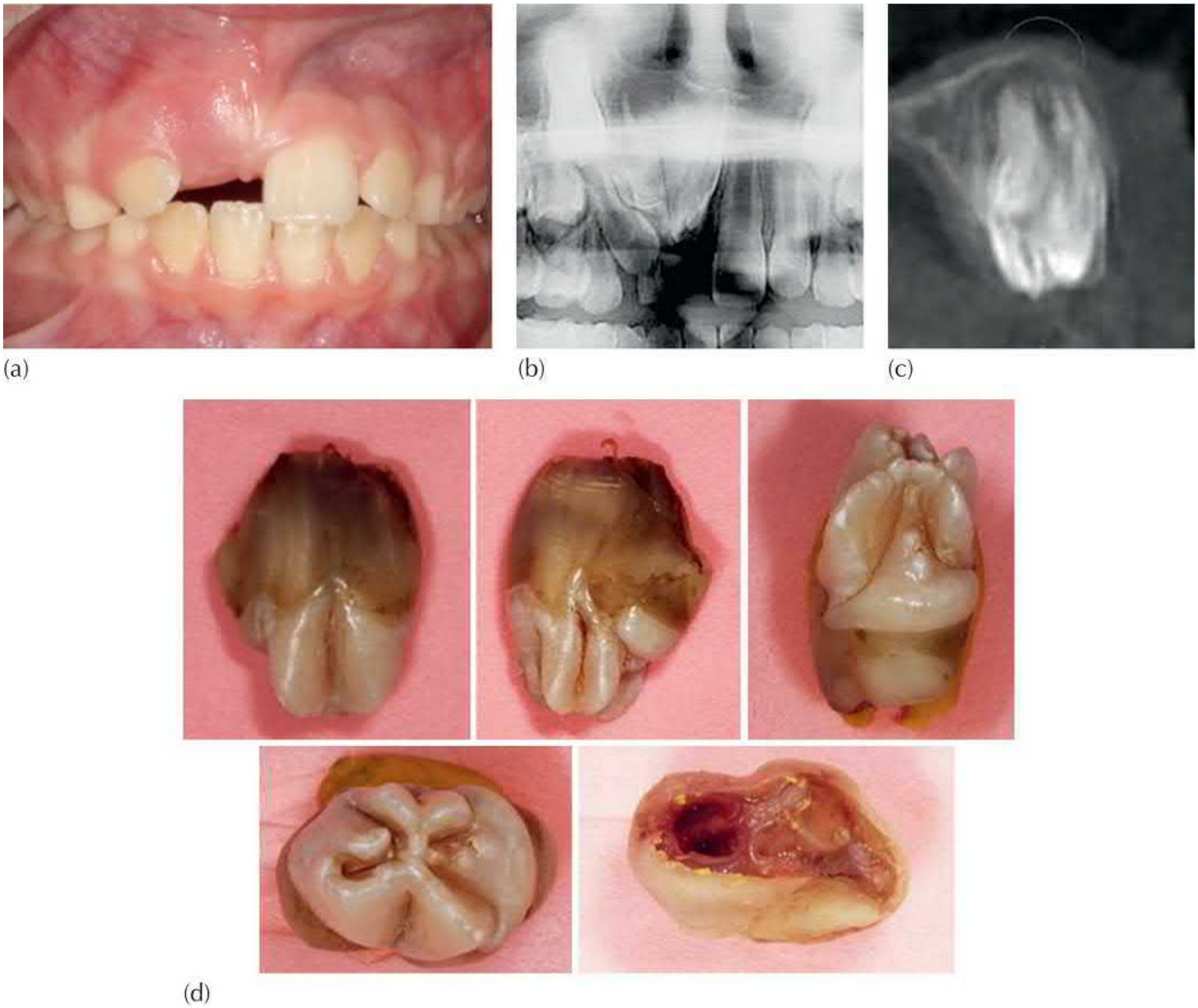


Fig. 6.3 (a) The anterior intra-oral view with teeth in occlusion and the unerupted odontoma bulging the alveolar ridge. (b) The panoramic view shows a single large odontoma, in place of the absent right incisor. (c) The cross-sectional cone beam computed tomography (CBCT) view to show undulating enamel-covered waves of dentinal and pulpal tissue. (d) The extracted odontoma viewed from different aspects, showing convoluted areas of enamel-covered dentine and the pulp chamber.

Ectopic position of the tooth bud

The development of a tooth bud in an abnormal location or at an abnormal angulation may have no apparent cause and may thus be attributed to traumatic or genetic factors (Figure 6.4). As a result of the displacement, normally placed adjacent teeth may consequently provide a physical obstacle to the normal eruption of that tooth. There may also be other physical obstacles, such as the above-mentioned supernumerary teeth or odontomes, which may be the reason for the secondary displacement of this tooth. While the early removal of this obvious aetiological factor may be strongly indicated, this does not necessarily affect the position of the tooth bud, which may continue to develop in its existing location, particularly if its root apex is closed.

Fig. 6.4 An abnormally sited central incisor, whose root apex is close to the canine area. The shape of the root also appears to be abnormal.

Any variation of position of a developing tooth will produce a concomitant variation in its eruption path. When the eruption path is very slightly deflected, the tooth will probably erupt, but it will display an abnormal angulation of its long axis, indicating the path along which it will have travelled. As its vertical development proceeds, its relationship to the deciduous predecessor will be more lateral, medial, palatal or labial. This will bring about a partial and oblique resorption along one side of the root of the deciduous incisor. In due time, the further progress of the permanent incisor and the oblique resorption pattern will guide it into contact with the crown of the adjacent deciduous tooth on that side.

The permanent tooth may remain impacted, if insufficient space exists to accommodate it. Alternatively, many months later than expected, the tooth may finally erupt adjacent to the over-retained deciduous tooth. This may develop into a cross-bite relationship, or it may be proclined labially, or a diastema may be produced in the midline. This situation may not correct itself after the belated shedding or extraction of the stubborn deciduous tooth [8–14].

Should the position of the developing tooth be more markedly displaced, which is unusual, its potential eruption path will be in a more obtuse direction and little or no resorption of the deciduous tooth will occur. In these circumstances, eruptive movements are minimal and the permanent tooth remains in a more or less unchanged position over a long period. Finally, when positive intervention is undertaken, removal of the cause will need to be supplemented with active appliance therapy for resolution of the impaction.

Attitudes to treatment of obstructed central incisors

For the last several decades in Europe, there has been a more or less standard protocol of orthodontic treatment of central incisors that, although normal in their anatomical development, are impacted and ectopic. In accordance with this protocol, the recommended advice is plain, clear and simplistic: (a) that adequate space be prepared for the tooth in the arch; and (b) that the obstructive cause of the non-eruption (such as a supernumerary tooth) be eliminated. The impacted central incisor teeth may then be expected to erupt spontaneously [7].

Studies that have been made of patients who have undergone this type of treatment have produced disappointing results in three important parameters:

- *Non-eruption*: Spontaneous eruption has been variously reported as occurring in only 54–78% of cases [7–10], which represents a low degree of reliability.
- *Time*: Even when eruption occurs, the average time for the affected tooth to make its appearance in the mouth is between 16 and 20 months [7, 9]. This is an unacceptably long period of time when one considers that the patient will be missing one or more front teeth for so many months. Additionally, 25% of patients require two surgical episodes, followed by a waiting period of 2.5–3 years before the tooth erupts [7]. Notwithstanding that, in a retrospective study of cases where space had been provided, the supernumerary tooth had been removed and a stainless steel crown had been cemented to the impacted tooth, eruption was found to have occurred in 96% of patients. However, this took on average three years [7].
- *Alignment*: The third parameter that displayed disappointing results relates to the adequacy of spontaneous alignment. Mitchell and Bennett [7] found that 36% of the teeth in their sample failed to erupt and 41% of the remainder required orthodontic assistance to rectify incomplete results. This means that 64% of the whole sample of cases ultimately needed mechano-therapy. Gardiner [11] also found that spontaneous alignment occurred in only a minority of patients. Obviously, the criteria for deciding what constitutes an ‘acceptable alignment’ vary from one clinician to another, and one may be permitted to speculate that it may also depend on whether the treatment is being carried out in a community health (managed care) clinic, a hospital orthodontic department (from which the material for these studies was collected) or a private orthodontic practice. In their more recent study, Ashkenazi et al. [9] found that in 64% of cases where supernumerary teeth had been removed without other forms of treatment, the impacted incisors failed to erupt, and in 9% there was only partial eruption. Accordingly, in only 17% of their cases was eruption successful, although into an unspecified location. Simple mathematics then shows that in about 90% of their cases, there was a need for active orthodontic treatment to erupt these teeth and to bring them into ‘acceptable alignment’.

There were, however, some clinical researchers [12–14] who recognized the need for affirmative action to control (or actively encourage) incisor eruption. In the era before the advent of acid-etch enamel bonding, they devised methods to overcome the inability to bond attachments to tooth enamel by using wire loops and invasive pinning, and even advocated passing a wire through a hole drilled in the incisal edge.

Mills warned against exposure of the crown of the permanent tooth during the procedure to remove the supernumerary tooth, pointing out that periodontal prognosis of the final result would be compromised [15]. He displayed a reticence to use mechano-therapy, beyond the use of a simple removable appliance to make space in the arch for the unerupted incisor. His approach seemed to have influenced opinion in Britain where, at the time, there was a wide consensus that the use of appliances in bringing down impacted central incisors was to be avoided. The reasons for his reticence were as follows:

- These teeth often erupt spontaneously, without outside assistance.
- Loss of labial bony plate.
- Poor gingival margin, with less attached gingiva.
- Gingival level discrepancy.

Mills offered little objective or evidence-based research to support these contentions. It may also be speculated that most or all of these shortcomings could be the result of the over-enthusiastic and outmoded surgical technique that was current at the time [15]. A full discussion of surgical exposure and periodontal prognosis will be found in Chapter 5.

As a rule, few children are brought to the orthodontist before 10 or 11 years of age. Nevertheless, the marred appearance of the child displaying a single erupted central incisor often motivates the parent to seek treatment much earlier. It would be callous and insensitive on the part of the orthodontist to show a lack of concern and unwillingness to offer a rapid solution, in the light of the parent's disquiet for the child's compromised appearance. This is particularly disturbing in the present context, since simple and effective means of improving the child's appearance are widely available.

The stereotypical patient would be a child of 7–8 years whose mother had brought him to the orthodontist because she had noticed that the left central incisor had erupted a year ago, but the right incisor still had not erupted. She had not brought him in earlier because she thought that it would erupt eventually and she had not been overly concerned. However, she was now worried because both lateral incisors had erupted and the space for the unerupted right central incisor had been partially closed off by the three erupted incisors, which had tipped mesially. The left central incisor will have typically moved 2 mm to the right and across the midline. This hypothetical scenario is not uncommon.

Your clinical examination reveals that the alveolus in the right central incisor region appears to be fairly broad or perhaps a little bulky (Figure 6.2a) and it certainly feels as though there is a tooth underneath the mucosa. You prescribe a periapical radiograph, which clearly shows a conical mesiodens, with little or no root development. It is located inferior to the image of a normal right central incisor. The root of this unerupted incisor is well over two-thirds of its final root length, its apex is still open and the tooth itself is located high in the alveolus.

Faced with this situation, many general practitioners (GPs) and paediatric dentists will refer the patient to an oral and maxillofacial surgeon (OMFS) to have the supernumerary tooth removed, on the assumption described that this abnormal tooth is the cause of the problem and that after its removal, the unerupted right central incisor can be expected to erupt spontaneously. Following the logical sequence, the OMFS would agree with the GP/paediatric dentist and would act accordingly. It is even likely that the OMFS would allay the mother's worry by radiating confidence that the tooth would erupt very quickly in the months that followed. However, OMFSs most probably do not have an efficient recall system to follow up a patient's progress and may never know if the incisor erupted – neither in this case, nor in previous ones. Sometimes the child may return three months later to check for progress, then six months later and then a year later and the OMFS will note that there is no right central incisor in sight. The logical sequence continues with the OMFS then recommending a second surgical procedure, to include surgical luxation of the tooth.

Unfortunately, let us be fair, many orthodontists would adopt the same treatment approach and would achieve the same disappointing results. Of all dental practitioners, orthodontists probably have the most reliable recall system enabling monitoring of the progress of eruption. Soon enough, they will notice the failure of the tooth to erupt and will realize that something must be done. By the time failure to erupt has been recognized and confirmed, the child will have reached the age of 9 or 10 years. He will have a seriously compromised dental alignment, he will be embarrassed to smile, his school friends will be making fun of him and his mother will be very concerned indeed. This is a condition that deserves immediate and efficient therapeutic attention and should not be taken lightly.

From as early as the mid-1950s, the orthodontic literature in Europe discussed these points at length and provided evidence that space opening is an important positive factor in improving the chance of autonomous eruption of the impacted incisor. Tipping the two adjacent teeth away from the intended central incisor site with a simple removable plate will increase the space at the crown level. However, it will cause their roots to move towards one another and directly into the expected path of eruption of the incisor. A consensus evolved that space should indeed be prepared by orthodontic movement of the adjacent teeth, to include the full length of the roots, i.e. bodily movement of these teeth, and that this should be done together with the extraction of the supernumerary tooth [12–15].

The statistics are remarkable and may be broadly summed up as follows. The success rate for achieving adequate eruption and acceptable alignment is only 10%. In one-third to one-half of the remaining cases, there is a total failure to erupt within a reasonable time-frame and, when eruption does occur, it characteristically takes over 1.5 years. About a quarter of the patients require a second surgical exposure procedure, followed by a further 2.5–3-year period of observation before the tooth erupts. When the teeth do finally erupt, nearly half of cases require orthodontic treatment to achieve some semblance of acceptable alignment; enough to reasonably justify a phase I orthodontic treatment [7–11].

So, questions need to be asked. Is this the best that the profession has to offer? Is this scenario regarding the attitudes of professional personnel still a common occurrence?

In view of the low level of success that simple obstruction removal can achieve, this begs the question of whether the impacted incisor should be exposed at the same time as the supernumerary tooth is removed. If the incisor has developed less than half of its expected root length, then the tooth should not be exposed at that seemingly opportune time. The incisor at this point in its developmental stage has yet to develop its eruptive potential. It may become re-enveloped with soft tissue or, if it erupts quickly, it may have too rudimentary a root for survival.

The problem with merely exposing a more mature tooth, however, is that the tooth will thereby be deprived of its follicle, and it is the follicle that is crucial for eruption through the bone and soft tissues [16, 17]. Should the tissues close again over the tooth, the absence of the follicle will be a hindrance. On the other hand, if the tooth is fairly superficially located, a wide exposure with pack may still be a good idea. However, this too presents a problem. In the presence of moderate to severe displacement of the tooth, the likelihood is very high of the tooth becoming re-covered with healing soft tissue and the deposition of new bone, even if a surgical or periodontal pack is placed for a few weeks.

It was noted earlier that the typical obstructed incisor may sometimes be markedly displaced from its intended position in the dental arch. If the surgeon chooses an open surgical procedure, then he or she must remove considerable quantities of bone and soft tissue around the tooth and place a surgical pack for several weeks, in order to maintain access to the tooth after healing has occurred. The effect of this procedure on the periodontal condition of the adjacent incisors will likely be very deleterious and the patient's gingival and periodontal health will be markedly compromised. What is more, the gingival architecture and appearance will also be very poor – a matter of no small significance when this will be at the front of the mouth, for all to see.

Performing a split pedicle graft, which is the modified form of open exposure as recommended by Vanarsdall [18, 19], will be kinder to the tissues, but the post-treatment appearance of the gingiva, even in a successfully resolved impaction, will leave much to be desired. Reparative periodontal surgery will be needed in later years to attempt to improve the appearance.

A successful open exposure procedure aims to leave the tooth accessible for future bracket bonding, if it should become necessary in the post-surgical period. In practice, this may be difficult to achieve in the long term and, in the event that the tooth does not erupt, soft tissue re-closure will often occur, necessitating renewed surgery. The inability of the patient, in the post-exposure weeks and months, to effectively clean this tender and haemorrhagic area makes attachment bonding at that time highly unreliable [20].

As an integral part of the surgical exposure procedure, consideration should be given to the placing of an attachment, with the ligature or chain exiting the healing wound. In this way, we may ensure later freedom of access for the application of extrusive traction. This would be extremely helpful in the event that the tooth were unable to erupt under its own steam. However, it is not recommended to leave this in a state of uncertainty for more than a few months while preparation is made for appropriate orthodontic treatment.

In a closed exposure procedure, it is imperative to bond an attachment at the time of surgery. A steel ligature or gold chain is usually drawn from the eyelet attachment (see Chapter 2), to exit the tissues through the sutured edge of the completely closed surgical flap. The chances of spontaneous eruption, however, would still be relatively low, for the reasons already noted. A fixed bracketed appliance would be needed to create adequate space between the roots of the adjacent teeth, along their full length and not merely between their crowns. The appliance will subsequently act as an anchorage base from which to apply extrusive forces to the impacted tooth, through the ligature or chain. The tooth will usually respond very quickly and, depending on the range of the light forces applied, will erupt into the mouth within three or four months. Once the tooth has erupted, the appliance will still be needed to align, rotate, upright and often lingually root torque the formerly impacted incisor. Root torque is frequently needed since the pre-extraction physical presence of the supernumerary tooth on the lingual of the incisor will have displaced the unerupted incisor labially. Closed exposure does not require the removal of more than a small section of bone and the dental follicle overlying the labial aspect of the crown of the tooth. In addition, it will not require bone, follicle or soft tissue removal elsewhere on the crown surface. It does not therefore compromise the periodontal condition of the adjacent teeth and, following eruption of the tooth, will usually produce superior gingival health, architecture and appearance.

From this discussion, it is clear that there is no preventive treatment programme that may, with any degree of reliability, be confidently recommended to produce a solution to the obstructed incisor. Space creation and surgical removal of the obstruction are essential elements of any treatment but, in the absence of orthodontic traction, one should anticipate a long period of patient expectation while hoping for spontaneous eruption, which may occur only in a small minority of cases.

While reading the following set of recommendations, it should be remembered that we are presently dealing specifically with the case of a 7–8-year-old child with an impacted incisor displaced high in the maxilla, associated with the presence of a supernumerary tooth. These recommendations do not necessarily apply to other forms of central incisor impaction nor to other age groups.

Phase 1 treatment considerations

Following determination of the overall orthodontic diagnosis of a child's malocclusion, a problem list should be drawn up, with the aim of opting for phase 1 early treatment. Occasionally there may be just one item on the list, namely the impacted tooth itself. More often, however, the presence of mandibular incisor crowding, posterior cross-bite or a class II relationship may also have been noted. The clinician must then decide which of these problems should be treated in this early treatment phase and which left until later. As a general rule, treatment priority should be given to the unerupted incisor. All other orthodontic procedures should be delayed until the incisor has been brought into alignment. A possible exception may be made if there is an anterior or posterior cross-bite and malalignment of the erupted adjacent incisors. In such a case their simultaneous resolution may sometimes be beneficial to the main purpose. This will be either because the treatment is simple or of short duration. Similarly, an exception can be considered for minor movement of adjacent teeth, in order to provide the needed space for the impacted incisor tooth. It is also generally believed that treatment of a cross-bite, which is associated with a functional deviation of the mandible into closure, should also be performed at this stage, in order to eliminate abnormal temporo-mandibular movement and dysfunction as early as possible. By and large, however, most other elements of an existing overall malocclusion would advisedly be left until the eruption of the full permanent dentition.

Trauma and dilaceration

It is often of great concern to a parent to note that a child displays a missing permanent central incisor, particularly when, concurrently, the contralateral central incisor has been present in the mouth for several months. Indeed, the urgency on the part of the parent to have this attended to may be sharpened when the lateral incisor of the same side erupts and clearly reduces the size of the space for the absent tooth. Ideally, many children will have been to the paediatric dentist for routine dental checks and will have been referred by the dentist for an orthodontic opinion. Often, however, the patient may be self-referred, directly to the orthodontist. With the notable exception of acute traumatic impaction cases, there really is no urgency in this context, unlike most other forms of presenting symptoms, such as pain and swelling.

On the first visit to the orthodontist of a patient who exhibits non-eruption of a permanent central incisor, a general medical history should be recorded carefully. It should be borne in mind that surgical intervention is very likely to be needed as an integral part of the treatment that is to be provided. Accordingly, such aspects as previous illnesses, particularly rheumatic heart disease, drugs being taken and bleeding tendencies, together with any other important and relevant items of information, require to be elicited at the outset.

The parent should be questioned carefully to discover whether there is a possibility that there had been a past episode of trauma and whether the child is generally accident prone. Targeted questions relating to bicycle accidents, falling from a chair, ladder or tree, or being hit in the mouth during play should be probed and all relevant answers carefully recorded, together with the approximate dates of their occurrence. The orthodontist must also bear in mind the possibility of well-hidden child abuse, and when there is suspicion of such, a report should be made to the local police.

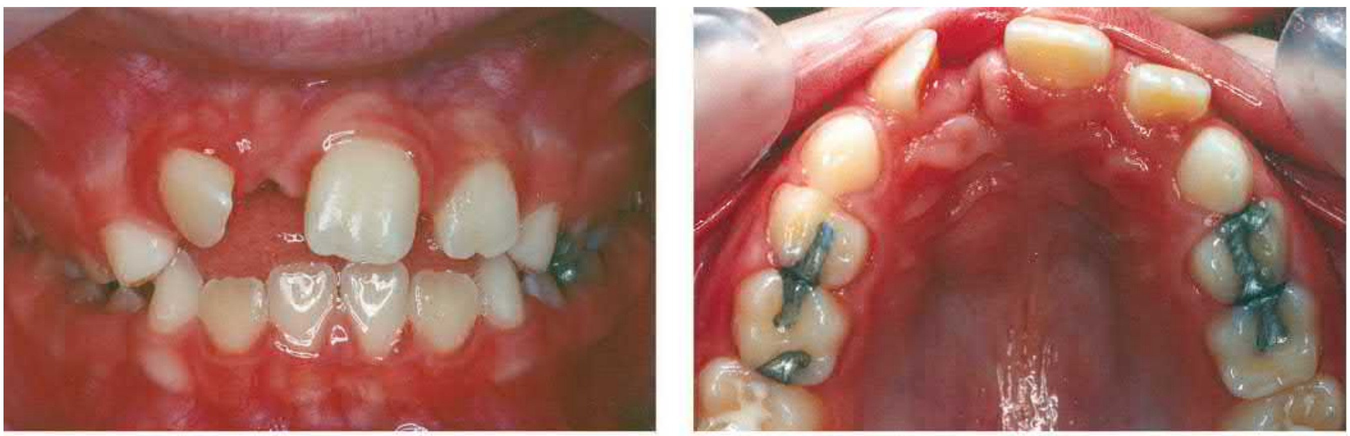
Diagnosis

Clinical examination

Without detracting from the importance of questioning the parents, much of the patient's dental experience and history is possible to ascertain from a glance at the dentition itself. The existence of sealants and restorations, the absence of teeth, gingival inflammation and the level of oral hygiene will often tell a great deal about the past attitudes of both the patient and the attending dentist, relating to preventive and restorative procedures. At the time the patient attends for treatment, the presence or absence of the *deciduous* incisor is generally irrelevant to the diagnosis. The central incisor of the opposite side and the lateral incisor of the same side will usually be seen to be tipped towards one another, and there will typically be insufficient space at the occlusal level for the appearance of the unerupted tooth. Wide, apically divergent, long axes of the two adjacent teeth will suggest the presence of an unseen and undiagnosed space-occupying physical obstruction, high up between their roots.

Palpation

In cases that indicate obstruction, the unerupted tooth itself is superiorly displaced on the labial side of the alveolar ridge and there may be additional and smaller irregularities bulging the alveolus more inferiorly. These are best identified by palpation. There will almost always be a labio-lingual widening of the ridge (Figure 6.2). If the ridge area is relatively thin inferiorly, this will indicate that teeth are not present at this level (Figure 6.5).



(a) (b)

Fig. 6.5 (a, b) Frontal and occlusal clinical views of a patient with a dilacerate central incisor, illustrating a bucco-lingually and vertically deficient ridge, due to the absence of teeth in the immediate area – the 'hourglass' ridge. See Online PPT & video Fig. 6.5 and 6.17.

The importance of palpation of the area is not to be underestimated, since if it is not performed sufficiently thoroughly an important diagnosis may be missed. The presence of a dilacerated central incisor will only be revealed by clinical examination if palpation is made very high in the labial vestibulum. Normally the superior midline area is delineated by the prominence of the anterior nasal spine, on each side of which a shallow depression will be felt. The palatal surface of a dilacerated incisor crown faces forwards and produces a hard swelling in the place where the shallow depression is expected. By superiorly retracting the upper lip, the oral mucosa may be found to move freely over the stretched area, which will emphasize the outline of the cingulum of the tooth.

Palpation of a dilacerated central incisor may also be made on the palatal side of the ridge. With the abnormal position of the coronal portion of the tooth, the further development of the root portion may be along an axis that is tipped more lingually. In the later stages of root closure, the apex may become palpable as a small, hard lump in the palate. This is a feature that unfortunately few clinicians seem to look for, even though it is a more reliable sign than may be realized. Mistaken diagnosis of crown location is an unusual event, since both the orthodontist and the oral surgeon need to undertake a clinical examination and review the radiographs before treatment and it is difficult to imagine that both could make the same mistake. Notwithstanding that, as we shall see in Chapter 18, such occurrences are seen from time to time.

Radiographic examination

In Chapter 4 we discussed in general terms the different methods of radiographically viewing unerupted teeth. There it was pointed out that the periapical view provides essential qualitative information in the simplest manner and, as such, should be the first step in an examination.

In the case of an unerupted central incisor, this view will generally highlight associated pathology, including hard tissue obstructions (supernumerary teeth of the various types, odontomes), soft tissue lesions (cysts, tumours) and abnormal root and crown morphology of the unerupted tooth. From this periapical view alone, it will usually be possible to establish the reason for the failure of the tooth to erupt.

If supernumerary teeth or odontomes are indeed visible on the film, information must be gathered relating to their size, number and mesio-distal relationship to the midline and the incisor teeth. This should all be discernible from the periapical view. On the other hand, the labio-lingual relationship to the adjacent erupted teeth cannot be diagnosed from this one film. Since the X-ray source for the periapical view is obliquely angled to the horizontal plane, a labial supernumerary tooth will appear lower in the vertical plane than a similar supernumerary located at the same height on the palatal side. Accordingly, the estimation of height is directly related to the labio-lingual position of the tooth, which provides the basis for the vertical tube-shift method of establishing the bucco-lingual relationship of an impacted tooth to an erupted tooth, described in Chapter 4.

A true lateral skull (tangential) view is not helpful in cases of patients in whom the aetiology for the impaction is the presence of unerupted supernumerary teeth, particularly at the age at which most patients will attend for treatment. This is due to the multiple superimpositions on the film of central and lateral incisors, deciduous and unerupted permanent canines, and the supernumerary teeth.

If a simple planar film is employed to decide whether the supernumerary teeth are labial or palatal to the unerupted incisors, then a second film will be needed in order to view the area from a different direction to assess the degree of separation of the teeth. This represents the essence of the parallax or tube-shift method, and may be achieved in several ways.

Utilizing the principles of parallax, a second periapical view, directed from a more distal vantage point, will usually help to localize the relative position of the unerupted teeth. Similarly, a routine anterior (oblique) occlusal film will help to separate out the images of the unerupted teeth in the vertical plane, using the same parallax principles. This will provide the information needed to compute the relative labio-lingual relationships of the individual structures.

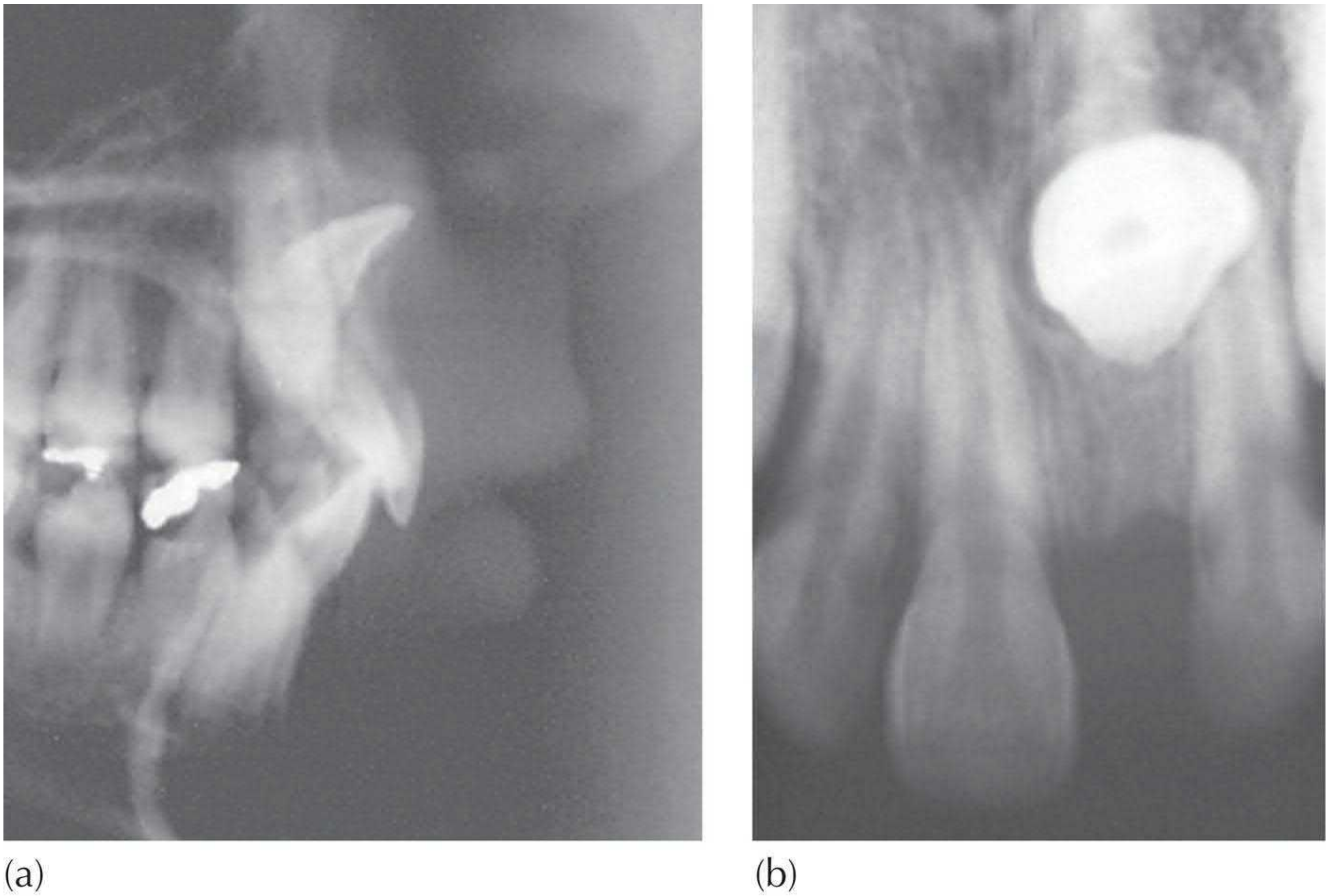


Fig. 6.6 (a) The anterior section of a lateral cephalogram shows the sagittal profile of a typical 'classic' dilacerate tooth, with its incisal edge at the level of the anterior nasal spine. The exact configuration of the obviously shortened root is obscured by the superimposition of adjacent teeth. (b) The periapical view of the same dilacerate central incisor typically shows the coronal portion to be viewed through its long axis, with the labial surface facing superiorly and cingulum area clearly depicted inferiorly. The pulp chamber is depicted in cross-section as a circle in the middle part of the root, while the apical portion points vertically upwards and is visible superior to the labial surface of the crown (the 'scorpion' appearance).

The initial periapical film may also be paired with a panoramic film, to achieve the same vertical tube-shift relationship between the films. The angulation of the central ray used to produce a panoramic film is from 7° below the horizontal, while that of the periapical view is 50° above. This wide difference between these two angulations presents different superimpositions on the film of the supernumerary teeth in the vertical plane, from which a simple assessment may be made.

Dilacerated central incisor teeth with labial displacement have a very special and characteristic appearance on a periapical radiograph. The long axis of the coronal (pre-trauma) part comes to lie in the direct line of the X-ray beam. This will portray the crown end on through its long axis, being superimposed on, and concentric with, a similar view of the widest part of the root. It will be readily understood, therefore, that the labial surface of the crown will be seen to face superiorly and the cingulum area will be clearly outlined inferiorly (Figure 6.6). The apical (i.e. post-trauma) portion of the root, on the other hand, progressively turns in the tight labial and vertical arc of a circle as development proceeds and will end up with 90° or more of angulation to the coronal portion. The root apex will appear as a very short 'tail' extending superiorly above the image of the tooth's labial surface. The picture is reminiscent of the upturned tail of a scorpion, viewed from the front (Figure 6.6).

Although this is clearly recognizable, the periapical film only gives an indication of the height of the tooth in the alveolus, while the detail of its curved axis and its general apico-incisal orientation will not be discernible. Confirmation of the 'classic' dilaceration diagnosis and the degree of its severity may thereafter be positively achieved using a tangential or lateral skull radiograph (Figure 6.6a). The information thus obtained will help to build up a more comprehensive picture of the tooth, particularly regarding details of its morphology, its height and the overall orientation of its dichotomous long axes.

In general in impacted incisor cases, computerized tomography (CT) is the ideal means of locating the exact 3D positions of these teeth, while eliminating the superimpositions inevitable in planar radiography [21]. It will also facilitate pinpointing the location of the initial curvature of the root of a dilacerate tooth, enabling the orthodontist to decide whether an apicoectomy will be necessary later, as root torque is nearing completion. It may also identify widely open apices, which may offer the possibility of pre-empting and correcting a worsening root curvature. Additionally, the relative position of the impacted tooth vis-à-vis supernumerary teeth will help the surgeon decide where to open the initial flap and more easily identify one supernumerary tooth from another and from the permanent incisors. It will also assist the orthodontist in assessing the relative difficult task of attempting to resolve the impaction and enable the design of appliance auxiliaries to suit the task. In cases of impacted incisors, whether due to obstruction or the consequences of trauma, cone beam computed tomography (CBCT) should be considered the ultimate diagnostic tool.

Collecting clinical and radiographic records in practice

As so often happens, the first visit of a patient is a result of either parent or patient having 'shopped around' in search of you or your nearest competitor, seeking to provide 'our sweet Janie' with 'a great smile'. However, this must in no way detract from the duty of the orthodontist to conduct a thorough and full clinical examination, including counting and identifying each of the teeth. This will often be followed by the revelation to the unsuspecting parent when you have discovered that a permanent tooth is absent or unerupted, and that a radiographic examination is required to both confirm this and check the existence of any other abnormalities.

The desirable and ethical approach in these situations is to proceed to request a panoramic radiograph, supplemented with one or two periapical views of the suspect area. A glance at the radiographs will confirm the existence of an impacted incisor. If the general permanent dentition is largely complete, with the exception of the area of the impaction, and if the timing is suitable for the commencement of orthodontic treatment, then other radiographs and intra-oral and extra-oral clinical photographs will also be included and a dental scan or dental impressions will be taken. At this early stage, it is important to exploit simple and inexpensive methods of maximizing the information available, before moving on to the possible need for CT imaging, which will involve a considerably larger dose of radiation and higher costs – not to mention the potential for its being superfluous.

If, on the other hand, the timing is not yet right and it is too early for treatment, then, on the condition that the location of the impacted tooth and its relationship with its neighbours are non-threatening, the patient should be placed on annual or semi-annual recall for reassessment. At a later stage, supplementary single radiographs may be needed in order to monitor the movements of the impacted tooth, until active treatment is indicated. In the meantime, during the long period for which the patient is under observation prior to treatment, it is incumbent on the orthodontist to gather as much information as possible from these planar radiographs.

In most countries, the population demanding orthodontic treatment is generally well educated with a measure of sophistication. They will have access to the internet and will be aware of the benefits and drawbacks of ionizing radiation. Accordingly, at a subsequent visit closer to the commencement of treatment, it is to be recommended to justify and explain to the parent the need for a CBCT evaluation. The consent of the informed parent must be obtained. If the impacted tooth is a maxillary central incisor, a phase 1 treatment is likely to be advised and, again, a CBCT evaluation is likely to be indicated.

Treatment timing

In Chapter 1 we discussed the incidence of unexpected pathological findings occurring during routine radiographic examination. In such an event, potential obstructions to eruption and any other form of pathology should, wherever possible, be eliminated before they have the chance to delay or impede eruption. Indeed this in itself may obviate the need for later orthodontic treatment.

Parents of very young children, as early as 3 years of age, are to be initially encouraged by the orthodontist to visit the paediatric dentist, in order to elicit compliance and cooperation with the simple and mainly prophylactic intra-oral procedures. The practitioner will likely perform a minimal radiological examination, which will include a pair of bite-wing radiographs to identify interproximal caries and often a maxillary anterior periapical view as part of an initial induction baseline protocol. The latter will typically show the developing central incisor teeth, separated by a small midline space, with the midline suture running between them and the lateral incisors, overlapping the distal third of the central incisor crowns, on either side. Occasionally, this view may reveal the existence of a midline supernumerary tooth (mesiodens). As pointed out at the beginning of this chapter, the presence of such an extra tooth in this position will not always cause an eruption disturbance, although the risk is high.

This whole procedure will undoubtedly trigger a round of consultations between the parents and the paediatric dentist on the one hand, and an orthodontist and an oral surgeon on the other. The subject of the consultations will be to search for an appropriate preventive treatment regimen to avoid subsequent eruption disturbances. The orthodontist will express the preference for removal of the mesiodens in order to permit the adjacent and unerupted permanent incisor teeth to develop normally and to erupt in their due time without assistance and into their ideal location. The oral surgeon, on the other hand, will caution against early surgery because of the possibility of collateral damage unintentionally inflicted on the dental follicles of the immature permanent incisors, due to the very constricted and dentally crowded anterior maxilla from which to excise the unwanted mesiodens. Additionally, this whole exercise cannot succeed without the simultaneous extraction of the deciduous incisors in order to gain access to the area. If the time is not yet appropriate for the permanent incisors to erupt, then the patient will be anteriorly edentulous for an extended period. Following the deciduous extractions, healing of the tissues will probably result in thickening of the mucosal tissue in the long term, which in turn is likely to obstruct the normal eruption of the permanent incisor teeth, when they are ultimately due.

By and large, it is the oral surgeon’s opinion that should take precedence in this scenario. There are, however, situations that will justify the timing of the extraction, in particular when the child reaches the age when the root development of the normal permanent tooth indicates the desirability of its imminent eruption.

It is to be pointed out that in a case where trauma has generated dilacerations, no preventive treatment is to be recommended. In this eventuality, every effort should be made to treat the child early in order to reduce the severity of the dilaceration in the non-calcified portion of the root end, as described in the study by Sun et al. [22].

When a patient presents with only a *single* central incisor but with *both* lateral incisors erupted, the normal eruption date of the other central incisor will have passed at least one year previously. The impacted tooth will be seen on the periapical radiograph to have at least two-thirds of its eventual root, this being the developmental landmark that indicates that a tooth should be erupted. Orthodontic and surgical treatment will then be indicated for both obstructed and dilacerate impaction cases.

Orthodontic appliances

An orthodontic appliance for use in the early mixed dentition

Opening the space for the unerupted tooth requires some form of orthodontic appliance and it has been established that a simple removable plate, with a couple of finger springs or a centre expansion screw, is manifestly unsuitable. Furthermore, vertical force control on the impacted tooth is difficult to achieve with a removable appliance, corrective rotatory movement of the finally erupted tooth is rarely adequate and uprighting and torqueing root movements are quite impossible. A practitioner using this method would essentially be placed in the position of an observer, unable to exercise control over eruption.

It is quite clear that if the tooth erupts (a) spontaneously, (b) into good alignment and (c) within a reasonably short period of time, then this relative inactivity will have been justified. However, an impacted tooth initially shares the limited labio-lingual width of the alveolar ridge with that very same supernumerary tooth that is likely to have been the cause of the non-eruption. Sharing this space usually causes the root of the central incisor to become displaced in either the labio-lingual or mesio-distal planes of space, or both. It is therefore likely that, in the final analysis, the successful autonomous erupting tooth will require root movement in a labio-lingual (torqueing) and/or a mesio-distal (uprighting) direction, not to mention significant rotational movement.

All of this points to the conclusion that a specific, purpose-designed type of appliance is indicated – an appliance that has the potential to deal efficiently with all these eventualities. Given the significantly wide spectrum of cases in which spontaneous eruption cannot be expected to result in a satisfactory alignment or where eruption has failed, it is essential to seek a biomechanical treatment modality, which will provide simple and rapid solutions to all the movements required. This would preferably include the ability to perform movements such as root torque, even though these are not often needed in phase 1 treatment.

A technique must be employed that provides satisfactory answers to *all* of the following aspects:

- The appliance should possess the capability to level and rotate the erupted incisor teeth rapidly and, with controlled crown and root movements, to open adequate space to accommodate the impacted tooth. This space is essential at both the occlusal level and for the entire length of the roots of the adjacent teeth.
- The surgical exposure of the crown of the impacted tooth, together with the bonding of an attachment, must be performed in a manner that will achieve a good periodontal prognosis, as described in Chapter 5. Therefore, the appliance must hold the space during and after the surgical procedure, while not hindering the surgeon’s access.
- Light and controlled extrusive forces must be generated from the appliance to be effective over a long range of movement, in order to bring the tooth down to the occlusal level, while

attention must be paid to providing anchorage that is adequate for the purpose.

- The potential must be created to accurately establish the position of the impacted tooth and that of its erupted neighbours, without changing to another appliance. This would include movement of the crowns and roots of each of these teeth in all three planes, whether or not these will be utilized.
- While it is important that the appliance has the potential to achieve a good finish, we have argued against aiming for the meticulous placement of teeth in the young child. As stated already, the pursuit of perfection and a 'fine-tuned' ideal alignment of the anterior dentition are to be strongly discouraged at such an early stage of dental development. This is particularly relevant when the unerupted permanent canines are very high and in close relation with the apical third of the lateral incisor roots.

Bonding brackets to the deciduous teeth

Typically, our young patient with a single impacted incisor tooth will only have two molars and three incisor teeth of the erupted maxillary permanent dentition. The principal problem that is then to be addressed is the need to eliminate the long and unsupported span between the permanent molars and lateral incisors. The question may be asked: is it possible and advantageous to include the deciduous canines and molars into a fully bonded appliance scheme with the use of regular brackets?

Due to the anatomy of the buccal surfaces of the deciduous teeth, this option presents several difficulties. In the first place, no dental manufacturing company presently produces bracket bases suitable for deciduous teeth. Bonding brackets designed for permanent premolars and canines, if employed with deciduous teeth, will leave large voids and ledges that will need to be filled with composite bonding material. In order to improve the fit of the bases, the natural buccal surfaces may be re-contoured by judicious grinding with a diamond bur. This would present a more accommodating shape that, given the short crown height characteristic of these deciduous teeth, would otherwise be challenging to achieve satisfactorily. Additionally, the diminutive crown height of the deciduous teeth virtually exhausts the options for determining bracket height.

Bond failure appears to be more common with deciduous teeth than one sees in routine orthodontic practice in the permanent dentition. This has repercussions for the design of archwires, which will need to incorporate bends and offsets in each of the series of archwires, copied from one to the next, in order to ensure passive ligation. There is rarely a need, nor an intention, to actually move the deciduous teeth. Moreover, the patient may present in the office, on an emergency visit, with the detached crown of a deciduous tooth hanging from the archwire by its ligated bracket, due to its having been shed before the limited treatment plan was completed.

In view of these potential complications, most practitioners will not even consider bonding the deciduous teeth. They will place bonded brackets only on the incisors, thus leaving a long span of unsupported flexible wire in the buccal region, where in fact a high degree of rigidity of the archwire is needed. A light flexible wire is completely unsuitable to bridge a long span. The reverse is true in the short inter-bracket distances of the incisor region, where a light flexible wire will be needed to perform the initial levelling, aligning and space adjustment. It would be impossible to avoid distortion and no vertically extrusive force could be directed from the molar tubes with such an archwire. This would still be true even if the archwire gauge were to be substantially increased.

Practitioners who are not prepared to exploit the deciduous teeth will have difficulty generating the extrusive movement needed for the impacted tooth. They will be limited to utilizing the adjacent incisors, which progressively intrude as extrusive traction of the vertically impacted incisor proceeds. Using a much heavier archwire in order to achieve an acceptable degree of support in the posterior region and an extrusive component anteriorly is not compatible with the very specific finer movements needed for the levelling, alignment, rotating, uprighting and torqueing that may be necessary for the initially malaligned incisor teeth.

The ideal solution would be to use an archwire that is flexible in the inter-bracket spans of the anterior teeth, yet rigid in the posterior long incisor–molar span. This is provided by the Johnson twin-wire appliance [23, 24], as described next.

Johnson twin-wire arch appliance

An updated version of the (obsolete and largely forgotten) Johnson twin-wire appliance presents certain unique features that make it especially suited and efficient to tackle the many treatment aspects of this specific problem in the early mixed-dentition (phase 1) stage. This is particularly so regarding anchorage in the vertical plane.

In 1929, Joseph E. Johnson first published his twin-wire technique as an appliance based on molar bands, interconnected by a soldered palatal arch (Figure 6.7). At the time, the novelty of the appliance was founded on the principle that *two* light (0.010 in.), tempered, stainless steel wires would align the short inter-bracket spans between the incisors more physiologically than *one* heavy (0.020 in.) wire. Johnson's wires, however, had a limited ability to resist a distorting influence and to return to the original form when the force was removed. Today, braided multi-strand and nickel–titanium (NiTi) wires will offer much improved qualities in this context.

(a) (b)

Fig. 6.7 (a) An occlusal view of Johnson's (modified) twin-wire arch, to show the soldered palatal arch. (b) 0.020 in. round tube sections are slotted into the 0.036 in. round molar tubes. The anterior sectional archwire in this case is a single 0.016 in. wire, since only one erupted permanent incisor is present and the usual multi-stranded wire is not needed. The alignment of the buccal tubes shows a downward tip as they proceed mesially, to encourage open bite closure and to aid the mechanically assisted eruption of the impacted tooth.

The modern application of Johnson's method uses long, narrow-gauge (0.020 in. internal diameter) tubes. These slide smoothly and accurately, without lateral or vertical 'play', in horizontally aligned, round molar buccal tubes (0.036 in.), which are soldered to the bands. The long, narrow tubes extend anteriorly to the deciduous canine area. An initial anterior, multi-strand steel or NiTi sectional wire is friction-fitted into the long 0.020 in. tubes and used to level and align the incisor. The friction fit is created by placing three or four bends in the multi-strand wire (more difficult to do effectively with the NiTi wire) and then drawing it through the tubes between two pliers, one of which should be grooved. The anterior sectional archwire, which is shown in Figure 6.7b), is a single 0.016 in. stainless steel wire. This is because only one erupted permanent incisor is present and the usual multi-strand wire is not needed. The alignment of the buccal tubes, as they proceed mesially, shows a downward tip to encourage open bite closure and to support the mechanically assisted eruption of the impacted tooth.

Typically, the appliance is prepared with a soldered palatal arch, on a plaster model and then transferred to the mouth. It is cemented in place, brackets are bonded to the anterior teeth and the prepared initial archwire is placed. The brackets may be of virtually any type, although there are several advantages to Begg brackets in this situation, since their vertical slot makes them particularly suited to the light vertical traction that is applied to encourage eruption of the impacted tooth.

By the second or third visit some weeks later, alignment of the three erupted incisor teeth will usually have been achieved and the multi-strand/NiTi flexible anterior sectional wire may be discarded and replaced by a plain round stainless steel 0.016 in., 0.018 in. or 0.020 in. wire. This is similarly inserted in the long narrow-gauge buccal tubes. In order to create space for the unerupted incisor, an expanded coil spring of appropriate length is threaded onto the main archwire and compressed between the brackets on the teeth on either side of the impacted tooth.

Space is gained very rapidly, with the movement being at least partly achieved by tipping, depending on which brackets are used. If Begg brackets are used, subsequent uprighting will need to be performed using auxiliary springs. Once there is adequate room to accommodate the unerupted tooth, a periapical radiograph should be taken to confirm that the desired amount of root uprighting has been achieved. A carefully measured piece of stainless steel tubing or closed-coil spring should be threaded onto the archwire and cut, so that it fits exactly between the brackets of the teeth adjacent to the impacted tooth. This ensures maintenance of the required space and contributes to the rigidity of the passive archwire. In addition, it will provide a firm platform from which light force may be applied to the unerupted tooth. Together with the rigid buccal tube arms and the soldered palatal arch, this will constitute a very significant anchorage unit in this biomechanical system.

The patient will now be ready for the surgical episode, at which an over-retained deciduous incisor and any buried supernumerary teeth are removed. The permanent incisor is surgically exposed and a bonded eyelet attachment placed, without requiring the removal of any part of the orthodontic appliance.

Erupting the impacted tooth requires relatively little force, merely a mechanism with a long range of action. As we have discussed in Chapter 2, directly ligating with elastic thread between the twisted pigtail ligature (which was tied into the eyelet at the time of surgery) and the main archwire is a very poor method. The force applied will be high and uncontrolled and its range will be minimal, particularly in the latter stages of extrusion. A more appropriate method is to stretch an elastic chain horizontally between the brackets on the teeth on either side of the affected tooth, raise the middle of the chain and ensnare it over the rolled-up pigtail ligature. This will require the achieved space to be maintained with a closed-coil spring or a measured and shaped length of oversized steel tubing between the two adjacent teeth, but the method will produce a much more controllable force and a good range of movement. Alternatively, an auxiliary light NiTi wire may be ligated over the steel main arch, and this too may be raised and ensnared over the rolled pigtail ligature.

If the patient is seen every 3–4 weeks and the appropriate adjustments are made, a previously obstructed tooth will usually erupt very rapidly and within a few months will be visible. This will help to provide the young patient with a more acceptable appearance and enhance self-confidence and self-image. The favourable time factor achieved by this approach should not be underestimated and should be taken into account, even when treating a younger patient. It is to be noted that an obstructed incisor will take less time to resolve than a dilacerate tooth, simply because it has a shorter distance to travel and considerably less root movement to experience, although the treatment principles are the same.

At the point when the tooth reaches the occlusal level, a reassessment will need to be made, to check whether uprighting, torqueing or rotation of the tooth is needed and, if so, whether or not it should be undertaken at this stage. If it is decided to proceed at this stage, then the eyelet is removed and a bracket, similar to that on the other teeth, is placed in its ideal position. Finishing is then achieved in the normal and appropriate manner.

In the dilacerate incisor case illustrated later in this chapter (Fig. 6.17), the final photographs were taken at the end of phase 2 of treatment, at age 13 years and after considerable labial root torque had been attained. Initial root torque was performed in the phase 1 stage and was completed at the conclusion of phase 2, together with an apicoectomy and root canal treatment.

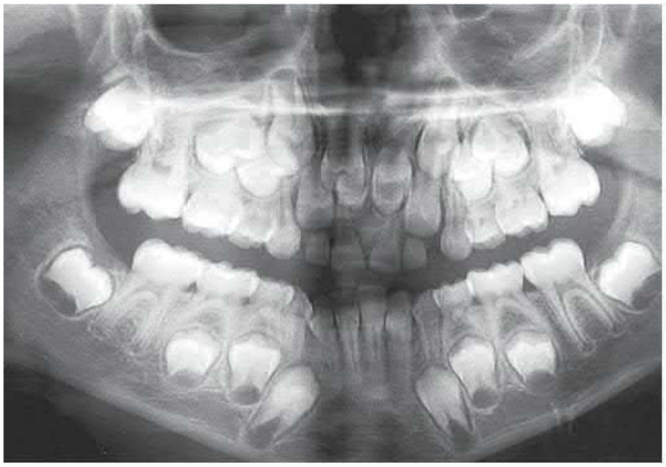
The construction, placement and activation of the orthodontic appliance are very simple and do not require a high level of expertise. The laboratory stage of appliance construction requires accurate soldering of the palatal arch and careful alignment of the buccal tubes, which a good orthodontic technician should master very quickly (although orthodontists may prefer to do this themselves). Cementation of the bands and bonding of the brackets in the mouth are routine, and the application of the prepared archwire produces a neat and robust appliance in the long span between the molar tubes and the incisor brackets. At the same time this will provide light and gentle, vertically directed forces of good range to the anterior teeth, leading to rapid results. The presence of the soldered palatal arch will ensure that undesired movement of the anchor molars cannot occur.

Rigid retention of the resulting incisor alignment, in the mixed dentition, will prevent the developmental movements that occur naturally under the influence of the eruptive movement of the canines, prior to their appearance in the mouth. At the end of phase 1, therefore, a bonded twistflex lingual retainer should not be placed.

Obstructive causes

Case 6.1: Bilaterally impacted central incisors due to obstruction by supernumerary teeth

An 8-year-old child was seen by a paediatric dentist for a routine dental examination, at the behest of the parents, who were concerned that the maxillary incisors had not erupted. The dentist noted that the erupted permanent dentition comprised the four first permanent molars and the mandibular four permanent incisors. All the other teeth in the mouth were deciduous, which, considering the child’s age, encouraged the dentist to investigate further. The panoramic film taken at the time (Figure 6.8a) and the periapical view (Figure 6.8b) confirmed a late dental age of approximately 7–7.5 years, as witnessed by the stage of development of the unerupted and erupted permanent teeth. The dentist noticed that the maxillary lateral incisors were more advanced in their eruption paths than the central incisors, although their root developments were similar. The reason for the lag on the part of the central incisors was the presence of two mesiodentes superimposed on the central incisors, which were already late and clearly destined for impaction.



(a)

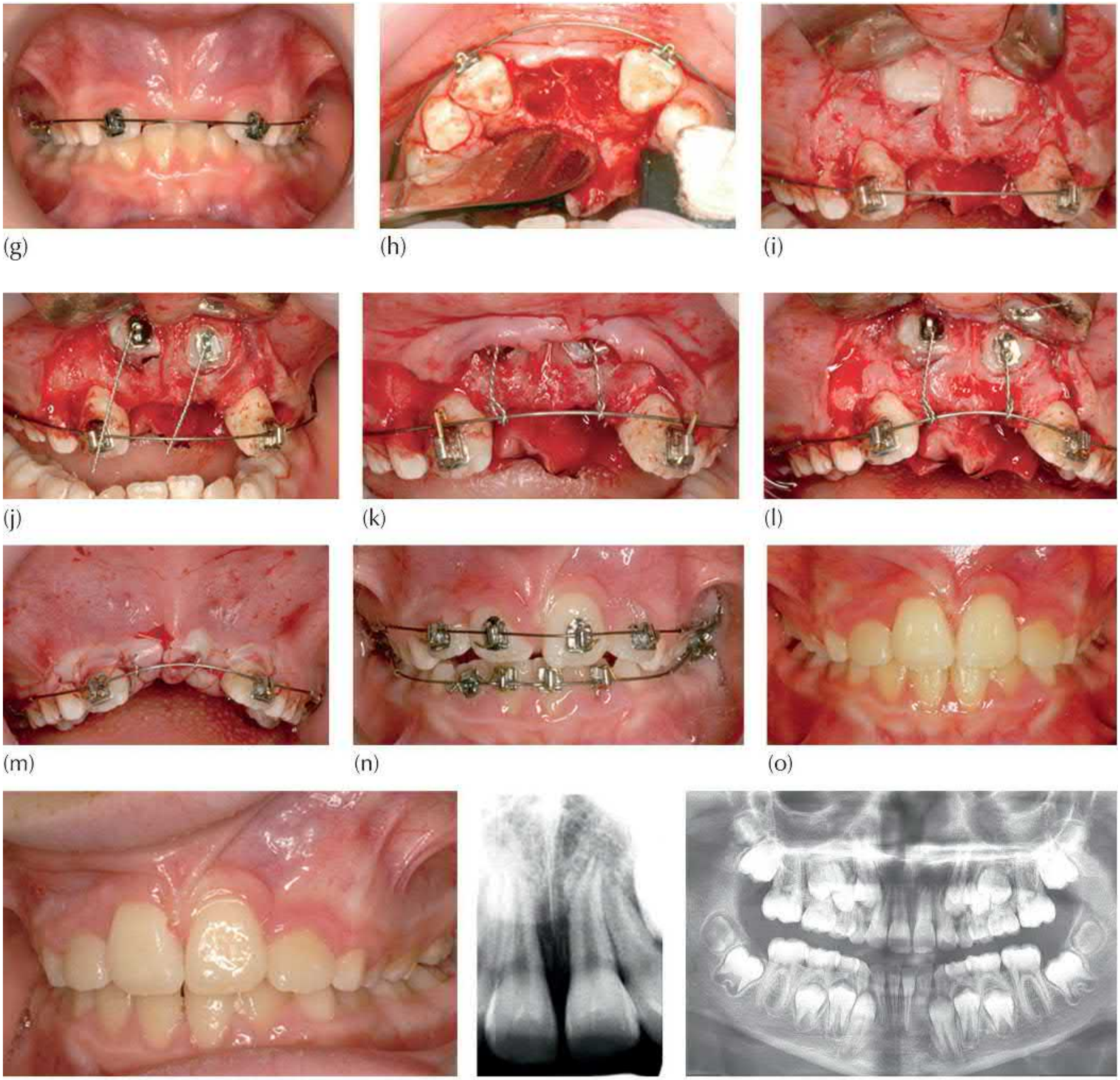
(b)

(c)

(d)

(e)

(f)



(g) (h) (i) (j) (k) (l) (m) (n) (o) (p) (q) (r)

Fig. 6.8 Impacted central incisors due to unerupted supernumerary teeth. (a) Panoramic view taken one year before treatment shows the permanent lateral incisors well advanced in their eruptive progress, two supernumerary teeth and over-retained deciduous incisors. (b) Periapical radiographic follow-up taken one year after extraction of the four deciduous incisors. (c) Intra-oral anterior view shows erupted lateral incisors and over-erupted mandibular incisors in contact with upper gingiva. The oral mucosa of the labial vestibule was enlarged with the palpable incisors. (d) With the teeth apart, the degree of mandibular incisor over-eruption is evident. The cone beam computed tomography (CBCT) was performed to locate the supernumerary teeth in relation to the central incisors, as seen (e) on the 3D screen shot and (f) on a cross-sectional slice across one of the central incisors and a palatally placed, rudimentarily developed mediodens. (g) The modified Johnson twin-arch 2 × 4 (2 × 2) appliance in place, using Begg brackets on the lateral incisors. A soldered palatal arch is present but unseen. (h) At surgery, the supernumerary teeth are identified on the palatal side. (i) A full labial soft tissue flap is raised from the crest of the ridge.

(j) Attachment bonding to exposed incisors. (k) The lock pins in the Begg brackets are released to permit the archwire to be raised. (l) The look pins are re-engaged to apply vertical traction to the incisor teeth. (m) The full flap is sutured back to its former place. (n) A Johnson 2 × 4 appliance is placed in the mandibular dentition to align and intrude the lower incisors. (o) Anterior intra-oral view, at the end of phase 1. (p) Note that the root of the left lateral incisor was displaced palatally and mesially by the labially palpable, unerupted canine. This, together with lingual root torque of the central incisors, was addressed in phase 2 of treatment. (q) Periapical view of the central incisors at the end of treatment. (r) Panoramic view at completion of phase 1.

The dentist extracted the maxillary deciduous incisors and placed the child on recall for a year later. She advised the parents that it was likely that the incisors will have erupted well before that time and without further help.

The child returned a year later with two erupted lateral incisors and still no sign of the central incisors. A new and follow-up periapical radiograph again revealed the unerupted mesiodentes superimposed on the impacted central incisors. In the meantime, the mandibular incisors had over-erupted and were occluding with the palatal gingiva (Figure 6.8c, d).

The patient was then referred for CBCT examination, from which the dentist considered that the two superimposed extra teeth were the reason for the failure to erupt. The 3D views seen on the CBCT image show the central incisor to be very high, with supernumeraries inferiorly and palatally situated. The cross-sectional (vertical) CBCT slice cuts through the central incisor, supernumerary, the lateral incisor and the mandibular lateral incisor in the superior–inferior direction (Figure 6.8e, f)

The patient was referred to an orthodontist. A modified maxillary Johnson's twin-wire arch was placed, involving two molar bands that were linked by a soldered transpalatal bar and an orthodontic (Begg) bracket on each of the two erupted lateral incisors, a 2 × 2 appliance (Figure 6.8g). The end-pieces of the composite labial archwire were made in 0.020 in. straight tubes that slotted into the 0.036 in. round buccal tubes on the molar bands. Having regard for the long spans between the molar tubes and the lateral incisor brackets and between the two lateral incisor brackets, the wire used for the anterior part of the labial arch was 0.016 in. round stainless steel. Virtually any brackets might have been used in this situation, but the Begg bracket was chosen because it has certain advantages in this specific phase 1 context.

At the surgical episode, the supernumerary teeth were identified and removed with access through a palatal flap (Figure 6.8h), followed by exposure of the labially displaced incisors through a full labial flap, raised from the crest of the ridge (Figure 6.8i). Bone was not removed in the surrounding area, except for the eggshell-thin bony covering of the follicles. Removal of bone inferior to the incisors would have left a deep defect by its interconnection with the vacated sockets of the extracted supernumerary teeth. Once again, the attachments were bonded by the orthodontist (Figure 6.8j), with the twisted pigtail ligature connectors drawn down directly to engage the archwire. The lock pins in the Begg brackets were initially released to permit raising the archwire to securely ensnare the twisted ligatures. The lock pins were then re-engaged, drawing the archwire down into the vertical bracket slots, thereby applying immediate extrusive traction to the two impacted incisors, before suturing the replaced flap (Figure 6.8m) and the patient leaving the operatory (Figure 6.8k, l).

At this point, a similar Johnson 2 × 4 appliance was placed in the mandibular dentition to align and intrude the over-erupted lower incisors, to permit full eruption of the maxillary incisors (Figure 6.8n). Other more minor features were not treated at this point, but left unaddressed until the time for phase 2 treatment (Figure 6.8o–r). Specifically, the left maxillary lateral incisor was in need of labial root torque and distal uprighting, which was left untreated at this time because the unerupted left canine was located against the disto-labial side of the incisor root and this would have created a disturbance in its subsequent eruption. Additionally, the central incisors were quite vertical and were scheduled for lingual root torque in phase 2.

What determines the end-point of a phase 1 treatment?

The results of evidence-based studies [25–28] have shown that a two-phase treatment of a class II malocclusion started in the mixed dentition, compared to a single treatment in the early permanent dentition, is unlikely to be more clinically effective, nor will it reduce overall treatment time. In addition, it is rare that the first phase of a two-phase treatment in the mixed dentition will simplify the second phase in the permanent dentition, which involves extractions or even orthognathic surgery. Nevertheless, there are exceptional situations where early treatment is to be advised. One such circumstance is where there is a danger of potential damage or deterioration occurring if early treatment is not administered. Another is when there is an urgent need to mitigate an unsightly appearance that may have severe psychological repercussions for the child.

Impacted central incisors are usually first diagnosed, and are best treated, at the age of 7–8 years, approximately four years before the maxillary canines are due to erupt. An impacted central incisor is one of the exceptions justifying early treatment. Treatment should not be delayed for a further three or four years merely in the interests of trying to achieve a single-phase orthodontic treatment plan in the full permanent dentition. Resolution of incisor tooth impaction should be considered the over-riding indication for a phase 1 orthodontic procedure. It should be executed efficiently, avoiding unnecessary attention to other peripheral details. Although root uprighting and torqueing should be performed as indicated, an ideal, final and artistic alignment of the adjacent teeth and intermaxillary relations is not the aim at this stage. Extending this first phase of treatment in order to achieve artistic alignment should be avoided, despite the temptation on the part of the orthodontist in the face of the remonstrations of a well-meaning parent.

Once appliances are removed, following the attainment of a fair degree of normality, there will be natural spontaneous changes in the alignment of these and adjacent teeth during the many months that follow and before the permanent canines come into their place. These changes are expected normal developmental changes, they are not a matter for concern and they should be allowed to occur unrestrained. This should be explained and emphasized to the parent and they must be made aware that these details will be addressed in the fully erupted dentition stage, together with the rest of the overall malocclusion.

Recommendations of the Jerusalem Group

Given this author’s interest in this subject, his private clinical orthodontic practice specifically encourages referrals of patients with impacted teeth, both self-referred and from colleague orthodontists. Cases involving impacted teeth comprise 30–40% of the office’s patient load. When treating a large number of patients with such a specific group of malocclusions, patterns emerge that would not normally be noticed under the more random population composition of the hypothetical ‘High Street’ orthodontic practice. Children with impacted central incisors, although often treated by a paediatric dentist, GP or oral surgeon, are rarely documented or followed up to the same degree as those treated by orthodontists.

Case 6.2: Maxillary incisor impaction and its relationship to canine displacement

An 8-year-old boy with special needs was diagnosed with an impacted maxillary left central incisor, due to the presence of an unerupted mesiodens (Figure 6.9a). The contralateral central incisor and both lateral incisors had erupted normally. The unerupted canines were both normally located. The four deciduous canines had been extracted earlier, apparently as the first step in a serial extraction protocol, but also to provide space for the impacted incisor.

He was seen by the orthodontist for the first time, without further treatment, at 9.7 years of age. The unerupted left central incisor had improved its position and was developing quite normally (Figure 6.9b). However, the left canine and lateral incisor appeared to be in the process of reversing (transposing) their order, with an emphatic mesial migration of the canine now superimposing on a lateral incisor root whose root apex had become strongly tipped distally.

In view of the management problems presented by the child, together with the degree of crowding and the continued presence of the mesiodens blocking the incisor, a surgical procedure was undertaken under general anaesthetic cover. In this single surgical procedure, the surgeon extracted the four deciduous first molars and also enucleated the four first premolars, to complete the serial extraction protocol. In addition, the surgeon extracted the over-retained deciduous left central incisor and exposed the left permanent central incisor. The orthodontist then bonded an eyelet attachment with the twisted steel ligature trailed through the sutured edge of the fully replaced flap, in a typical closed exposure manner. A short phase 1 orthodontic treatment was instituted solely to erupt the incisor, using the above-described modification of Johnson's twin-wire arch.

At 12.3 years and in common with successful serial extraction procedures, the crowding in three quadrants of the mouth had spontaneously resolved, with the normal eruption of the second premolars and three of the canines. On the side of the resolved incisor impaction, the canine and lateral incisor were now in an incomplete transposition relationship, with a strongly buccal and mesial displacement of the canine. At that stage, the boy had become much more amenable and a short phase 2 treatment was initiated, the principle aims of which were to align the buccally ectopic left maxillary canine and to upright and parallel the roots of the premolars and canines, with minor finishing procedures.

This case was treated 47 years before the publication of this edition and, for us, was one of the incisor impaction cases that were instrumental in raising our awareness of the possible existence of a distinct developmental pattern. It indicated the possibility that there was a connection with disturbance of eruption of the maxillary canine on the side of the formerly impacted central incisor and we decided to test this hypothesis. Incidentally, it was also instrumental in encouraging us to look more positively at the possibility of providing orthodontic treatment for this less fortunate section of the child population [29, 30].

The clinical study [31] of a consecutive sample of young children, who had received early mixed-dentition orthodontic and surgical treatment for an impacted central incisor, was initiated. Following this limited phase 1 treatment, the patients had been under follow-up observation and care, which had continued until the eruption time of the canines.

Since each participant in the experimental group had both a normal side and an affected side, a split-mouth comparison was carried out, in which each patient presented an impacted incisor on one side and a normally erupted incisor on the control side. On the unaffected side, where the maxillary incisor had erupted normally, 4.7% of the ipsilateral canines showed eruption disturbances or displacement. This figure is almost identical to that defining the prevalence of the lateral incisor anomaly (missing, peg-shaped and small) within a random young population [32–34]. This is significant insofar as there is a known connection between lateral incisor anomaly and canine impaction in the maxilla (as will be discussed in Chapter 7). On the side previously affected by, and treated for, impaction of the central incisor, 41.3% of the canines of the same side showed eruption disturbance. The canine disturbances took the form of 30.2% buccally displaced, 9.5% palatally displaced and 1.6% with complete canine–lateral incisor transposition. Additionally, half the buccally displaced canines were pseudo-transposed with the adjacent lateral incisor [31], i.e. they appeared to have changed places – the crowns had crossed over, but the invisible root was still in its correct place (Figure 6.9).

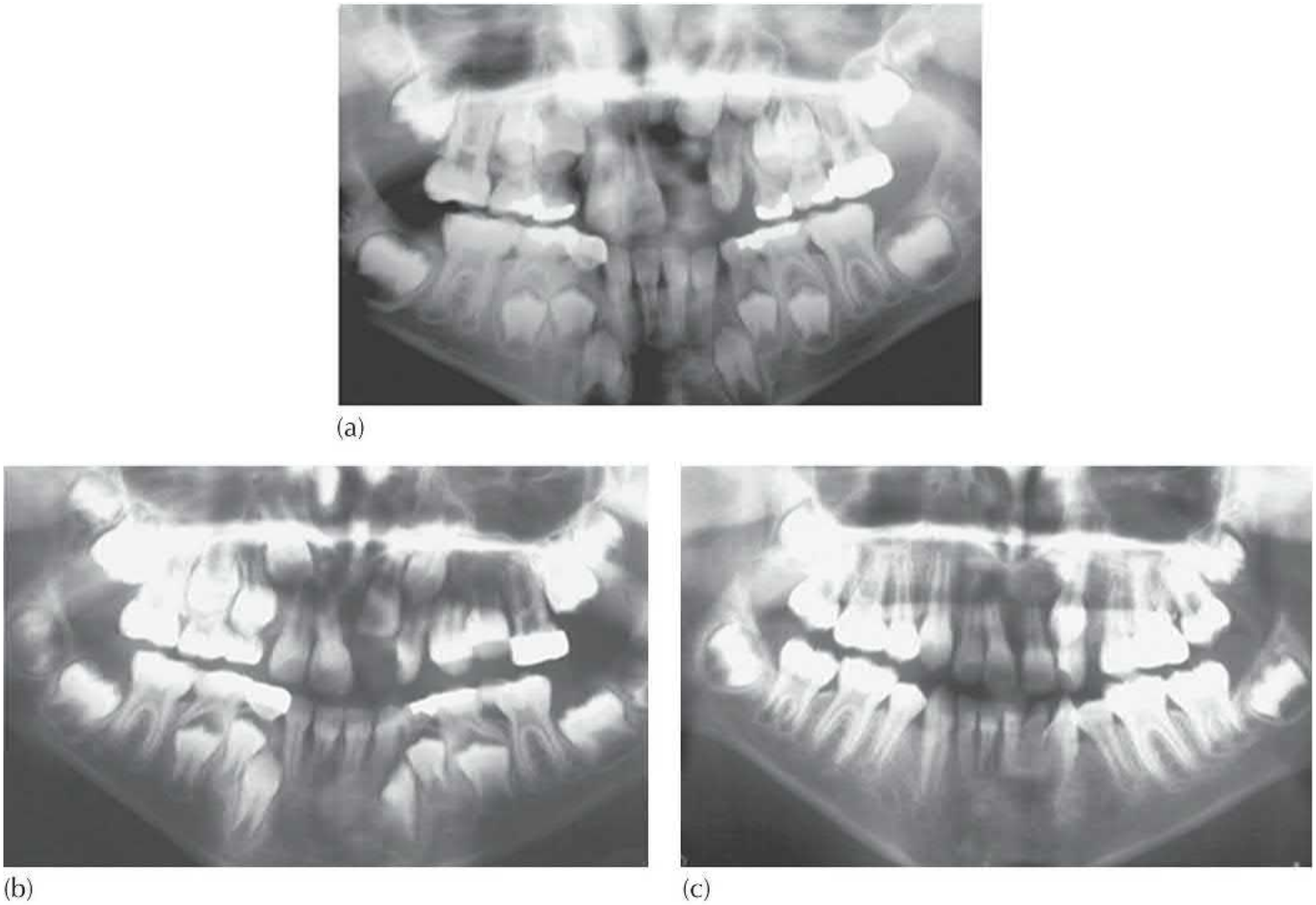


Fig. 6.9 The development of maxillary canine ectopia adjacent to an impacted central incisor. (a) A panoramic view at age 8 years. (b) A panoramic view at age 9.7 years. No active orthodontic treatment had been performed. (c) At 12.3 years of age after a successful serial extraction procedure. Active orthodontic treatment was commenced shortly thereafter.

This study emphasizes the need to thoroughly examine the positions of adjacent teeth, particularly canines, whenever an impacted incisor is present, and to prepare parents for the distinct possibility of future canine eruption disturbance. Equally important is that it should stress and encourage the orthodontist to make the phase 1 treatment as short as possible and not to pay unnecessary attention to meticulous alignment detail in the mixed-dentition stage of a child's development.

Traumatic causes

Earlier in this chapter, we referred to the fairly high prevalence of trauma to the anterior maxilla that occurs in the life of a child and to the importance that the practitioner should place on the need for eliciting a searching history.

Sudden, traumatic and very early loss of the deciduous incisor teeth may also be caused by a dental extraction, prompted by the presence of deep caries, or it may be a consequence of an earlier trauma. Typically, this will happen at the age of 3 or 4 years, at a time when the permanent incisor is not yet ready to erupt and a healing-over of the macerated gingival tissue occurs at this pre-eruption stage. In time, changes take place in the connective tissue overlying the developing permanent incisor, which prevent the tooth from penetrating the mucosa [35]. By the time the child is at the age of 7 or 8 years, one may see and be able to palpate the bulging profile of the central incisor (see Figure 5.2).

Dilaceration

In the early stages of their development high in the anterior part of the maxilla, the permanent central incisors are situated lingually and superiorly to the apices of the deciduous incisors. As part of their normal further development, their positions change as a result of their labially and inferiorly directed migration. This change will initiate an oblique resorption of the roots of their deciduous predecessors.

During this critical period, children are frequently involved in traumatic episodes of various degrees of intensity and a blow may be inflicted on the deciduous maxillary incisors from the front. A blow of sufficient magnitude will produce a lingual avulsion of the crowns of the permanent incisor teeth and a concomitant labial displacement of the roots. Such a severe blow may cause a fracture of the labial bony plate. In this latter situation, the roots of the teeth and the sharp edge of the fractured alveolar bone will be palpable in the labial sulcus, although the overlying mucosa will usually remain, stretched but intact. On occasion, this type of dislocation may occur with a deciduous incisor (Figure 6.10).

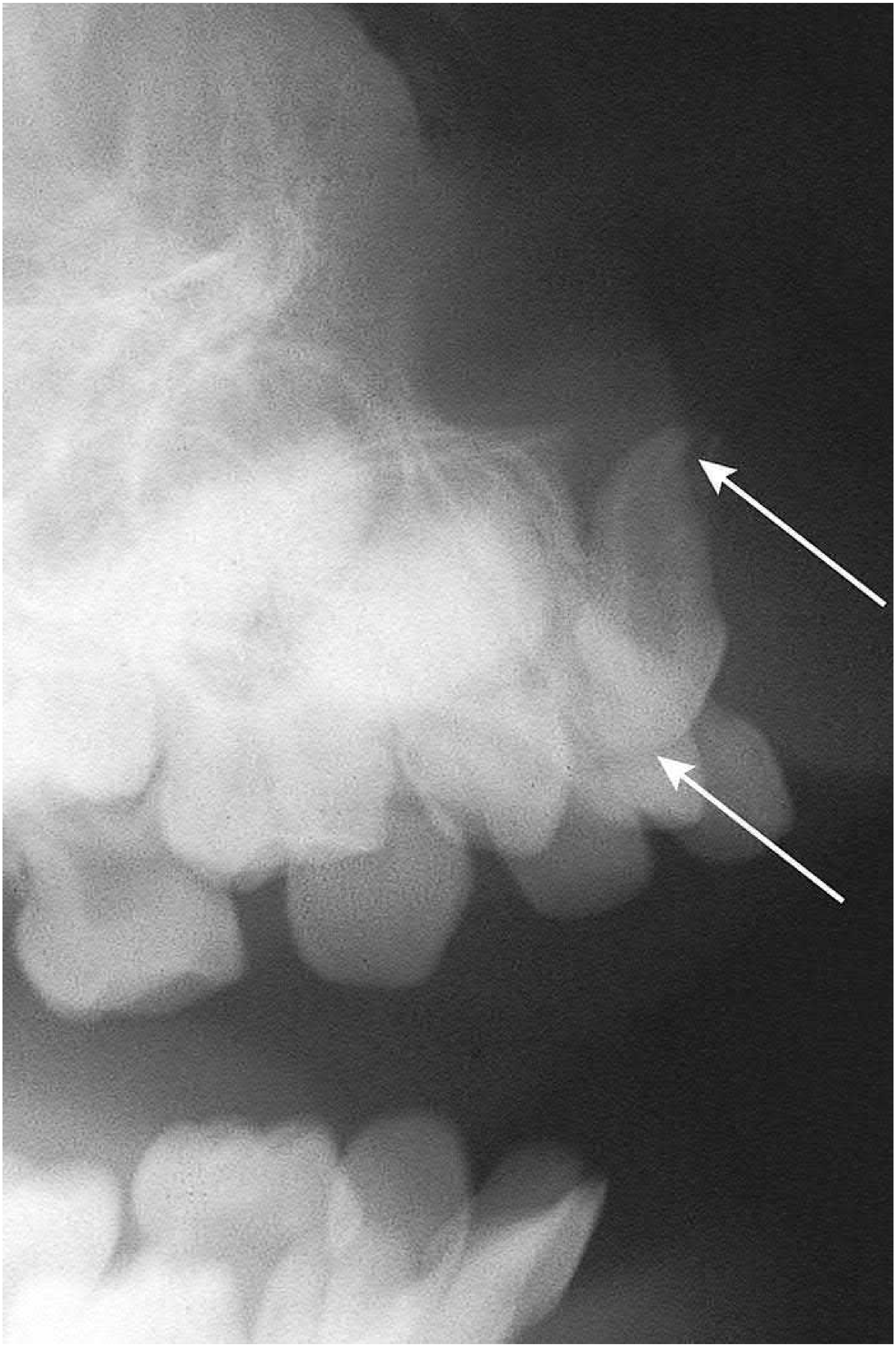


Fig. 6.10 The tangential view shows severe labial displacement of the root of the deciduous incisor (arrows).

Courtesy of Professor J. Lustmann.

The successional permanent incisor teeth, because of their locations in relation to the resorbing root ends of the deciduous incisors, will not usually be displaced and may continue unhindered in their normal developmental path.

The root of a deciduous incisor tooth is apically tapered, consequently a blow directed along its long axis from below will drive the tooth upwards into the sides of a similarly tapered socket. It follows that the alveolar process fracture that may occur will cause a part of the labial plate of bone to become displaced labially and the tooth to be relocated superiorly (intruded). Under these circumstances, trauma to the anterior part of the deciduous dentition may cause damage to the growing tooth buds of the permanent dentition and this may alter the further development of the permanent teeth in many ways.

The anomalies that may occur to the permanent incisors as the result of trauma range from a hypoplastic discoloration marking the enamel, through anatomical malformations of the crown or root, to non-proliferation of the root, to pulp death and to sequestration of the tooth bud [36]. The alterations in the form of the crown and the root of these teeth are collectively referred to as dilacerations. These are the result of the recovery process from the blow, which has disturbed the natural development, resulting in a variable combination of a hypocalcified, altered, attenuated or directionally reoriented form of the crown and/or root. The final shape and appearance of the injured tooth will be dictated by the direction and force of the blow and by the particular stage of development of the unerupted permanent tooth. Each of these anomalies will be unique in its form and no two traumatic incidents will produce the same result.

The traumatic blow will also cause damage to the specialized Hertwig's sheath epithelial layer, a layer of dentine-producing cells that is directly concerned with the normal development of the root of a growing tooth bud.

Since trauma, by its nature, affects the front of the mouth rather than other areas, the most common teeth to be adversely affected are the maxillary central incisors. As a general rule, we are not overly concerned with the actual damage that may be inflicted on the deciduous incisors, because they will not figure in the final long-term dental scheme planned for the patient. Clearly, fractured crowns may be repaired, but for more serious cases, the damaged tooth will need to be extracted, which, for a young child, rarely demands prosthodontic replacement.

'Classic' recurring dilaceration

There is, however, one exception. In direct contrast to the anomalies referred to above, there is one type of dilaceration that we shall call 'classic' dilaceration [35, 37–39]. It is classic because it is a recurring dilaceration, albeit not frequently, which consistently reproduces an almost identically shaped tooth (Figure 6.11), whose unerupted location and angulation are always the same. Given that its shape, location and infrequency are uniform, its causation has been the subject of much interest and discussion among paediatric dentists and orthodontists for over six decades. Several hypotheses have been suggested.

Fig. 6.11 A 'classic' dilacerated incisor.

The best-known and, probably, the majority opinion (indeed the consensus within the profession) postulates the following reconstructed scenario. When the trauma has been directed to the long axis of the deciduous tooth, the force of the blow may be transmitted superiorly to the developing permanent tooth. According to this hypothesis, the force delivered to the deciduous incisor is transmitted to the resorbing root apex, which momentarily establishes a sudden and sharp point of impact with the incisal edge or palatal aspect of the crown of the unerupted permanent incisor. It is opined that this will cause the partially developed permanent incisor tooth to undergo an immediate upward and labial rotation within its crypt. It is then assumed that any further root development that occurs in the post-trauma period will continue in the same direction as before, thereby producing a bizarre angle between the pre- and post-trauma portions of the tooth – the 'classic' dilacerated central incisor – with labial displacement of the crown portion. The location of this demarcation between the pre- and post-trauma portions of the tooth is assumed to relate to the stage of development of the root at the time of the trauma, thus determining the prognosis of any proposed orthodontic treatment for the tooth [40–45].

Before proceeding to the other hypotheses, let us just examine this majority opinion. In an attempt to determine whether there was any basis for this hypothesis, a protocol was established some years ago, in the emergency clinic of the Department of Pediatric Dentistry at the Hebrew University–Hadassah School of Dental Medicine, in Jerusalem, Israel. Children who attended the clinic having suffered trauma to their anterior deciduous teeth were subjected to routine clinical and radiographic examination, vitality testing and emergency pulpal and restorative treatments, as indicated. Prior to the new protocol being established, the routine radiographic examination had generally been limited to a periapical film of the area. However, it was obvious that this radiographic view was not appropriate to highlight any labial and superior displacement of the crown of the unerupted permanent central incisor within the crypt. Accordingly, the new protocol included a tangential radiographic view of the anterior maxilla (described in Chapter 4 as being a lateral view taken from the side, horizontally across the occlusal plane). This is in fact an identical view of the restricted anterior portion of a lateral cephalometric radiograph, except that in those days it was obtained on a small, occlusal-sized film by holding the film vertically and extra-orally against the cheek and parallel to the patient's mid-sagittal plane. Any alteration in the labio-lingual and vertical orientation of the crown of an incisor would then be immediately discernible on this film.

The protocol was run for several years and did not discover a single case where the crown of the tooth had been displaced, as widely believed, either at the time or in the immediate post-trauma period. However, in the succeeding years, a small but significant number of patients who had been seen in the emergency clinic of the Department of Pediatric Dentistry following trauma in their earlier years presented themselves in the Department of Orthodontics with a fully developed, classic, dilacerated central incisor. Since records existed from that previous time, the radiographs that had been taken when the protocol was in force were re-examined with specific regard to these patients. The absence of displacement of the crowns of the unerupted permanent central incisors on the immediate post-trauma films was re-confirmed. This survey effectively discredited the hypothesis according to which immediate tooth germ displacement is a cogent explanation for the aetiology of the phenomenon.

A second hypothesis was proposed by Howe, who suggested a developmental origin as an alternative cause for the classic dilacerations [46]. His contention was that the active process of the development of cysts, odontomes or supernumerary teeth may produce this phenomenon by displacement of the crown of the tooth or by interference and redirection of its root.

A third hypothesis emanated from Stewart's retrospective study [38] of the phenomenon of classic recurring dilaceration, occurring in cases in 70% of which there was no history of trauma in the patient sample. Nor was there macroscopic or microscopic evidence of trauma, nor the existence of a cyst, odontome or extra tooth. No case was found where both central incisors were affected and where there had been no damage to them or to neighbouring teeth, as would have been expected in at least a few instances had trauma been the cause. These cases also failed to show two distinct and angulated portions of the root, but rather a continuous and tight curve (Figure 6.12), quite different from those in which trauma, as an aetiological factor, had resulted in any of the other forms of dilaceration. The outcome of the study led Stuart to conclude that a fairly high proportion of dilacerations occur due to an ectopic siting of the tooth germ, whose root development is deformed by its proximity to and the anatomy of the palatal vault in the immediate vicinity.

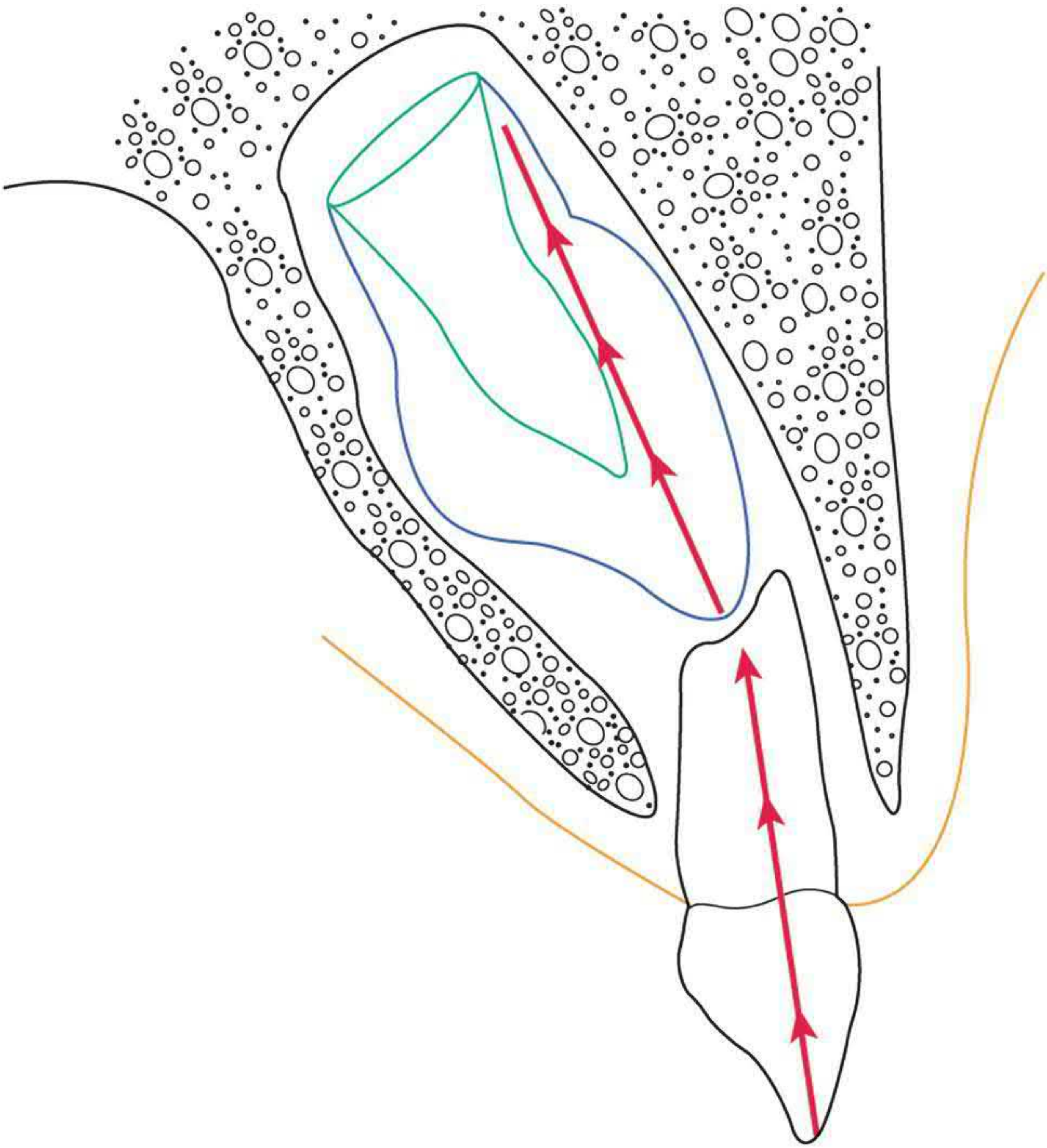


Fig. 6.12 A diagram to show how a vertically directed force through the deciduous incisor is transmitted to the labial aspect of the mineralizing root of the unerupted permanent incisor.

Source: Reproduced from previous edition. Adrian Becker, *The Orthodontic Treatment of Impacted Teeth*, 2nd ed., 2007 with the kind permission of Informa Healthcare – Books. See Online PPT & video 6.12 and 6.14.

However, these explanations are unsatisfactory on several counts. The affected cases show an almost identical and very typical anatomy of the tooth, which affects maxillary central incisors exclusively.

No case of bilateral occurrence or parallel incidence in lateral incisors has been reported in the literature. As if to illustrate the exception that proves the rule, the records of two isolated cases of bilateral occurrence (Figure 6.13) were sent to this author a few years ago and they remain the sole instances of this that he has hitherto seen.

Characteristically, the morphology of the crown of any classic dilacerate tooth is normal and is an exact mirror image of its unaffected antimere. The coronal portion of the root shows initial normal development. The remainder of the root develops strictly in the labio-lingual plane along a tight and continuous semi-circular path, rather than two straight portions of root at an angle to one another. The crown is grossly displaced in the bucco-lingual and vertical planes, while exhibiting minimal or no mesio-distal rotation around its long axis.

Not only is the anatomy typical, but the position and orientation of the tooth are also unique to this condition. The crown of the tooth is upturned and displaced high in the vestibulum on the labial side of the alveolus, with its palatal aspect palpable labially, and its incisal edge in close proximity to the root of the nose and the anterior nasal spine.

Andreasen and Andreasen suggested that the loss of a deciduous incisor may lead to scarring along the eruption path of the permanent incisor, which deflects the developing tooth labially [32]. It is to be noted that this runs counter to Stewart's observation that no history of early traumatic loss of the deciduous tooth had occurred in 70% of the cases in his series [38].

The Jerusalem hypothesis reads a completely different aetiological interpretation into these constantly recurring identical characteristics. The first step in the process of interpretation is to question the reliability of a child's or parent's memory regarding traumatic injury to the front teeth. Of course, if the trauma is severe, it will usually have resulted from one singular incident and will always be remembered. But this situation is rare. Much more frequent are cases of non-disfiguring trauma (i.e. trauma that causes no loss, fracture or displacement of the deciduous anterior teeth). In the course of play, this type of trauma occurs quite frequently in young children, is rarely noted and almost never remembered even as little as a week or two later, and certainly not in later years. Indeed, following a relatively minor blow, the child may have come home in tears, but the incident will often have been forgotten the next day, subject only to some minor, residual, temporary soreness or tenderness.

An abrupt and vertically directed blow through the long axis of the deciduous tooth will bring about transference of the impact to the intimately related, unerupted, permanent central incisor. Because the long axis of the permanent incisor has a more labially tipped orientation, the force will be transmitted in an oblique line, which runs through the incisal edge and the most superior point on the labial side of the newly forming root, close to or at the root-mineralization interface (Figure 6.12). This most recently formed extremity of the partially developed root has a circular knife edge of calcified dentine. Thus, the intrusive blow will be delivered directly to the sensitive cells of Hertwig's root sheath on the labial side of this narrow rim. The intrusive force is thereby concentrated along the knife-edge root extremity and will inflict considerable damage on cells of the formative root sheath, even though the actual force value was minimal. It will be appreciated that the concentration of a given pressure on a knife-edge surface will have far more impact than the same pressure on a broader surface.

It is entirely possible that the root sheath will never fully recover from the blow and this may result in an attenuated rate of production of dentine on the labial side of the tooth. Despite this incident, the remainder of the root-forming system will continue to produce dentine unscathed, undeterred and unabated. The result will be that the final shape of the root of this tooth will conform to a continuous labially directed curve (Figure 6.14) [36, 37, 39] until apexification is achieved. Furthermore, the dental papilla base of Hertwig's root sheath maintains its position fairly constantly within the alveolar process and against the eruptive force of the developing tooth.

It also provides the platform from which the downward development of the root is normally directed. Consequently, for as long as this unequal bucco-lingual mineralization gradient of the developing root continues, the crown of the incisor will continue to move labially and superiorly. In other words, dilaceration of this classic type is an anomaly that is traumatic in its origin (i.e. momentary) but developmental in its expression (i.e. protracted).

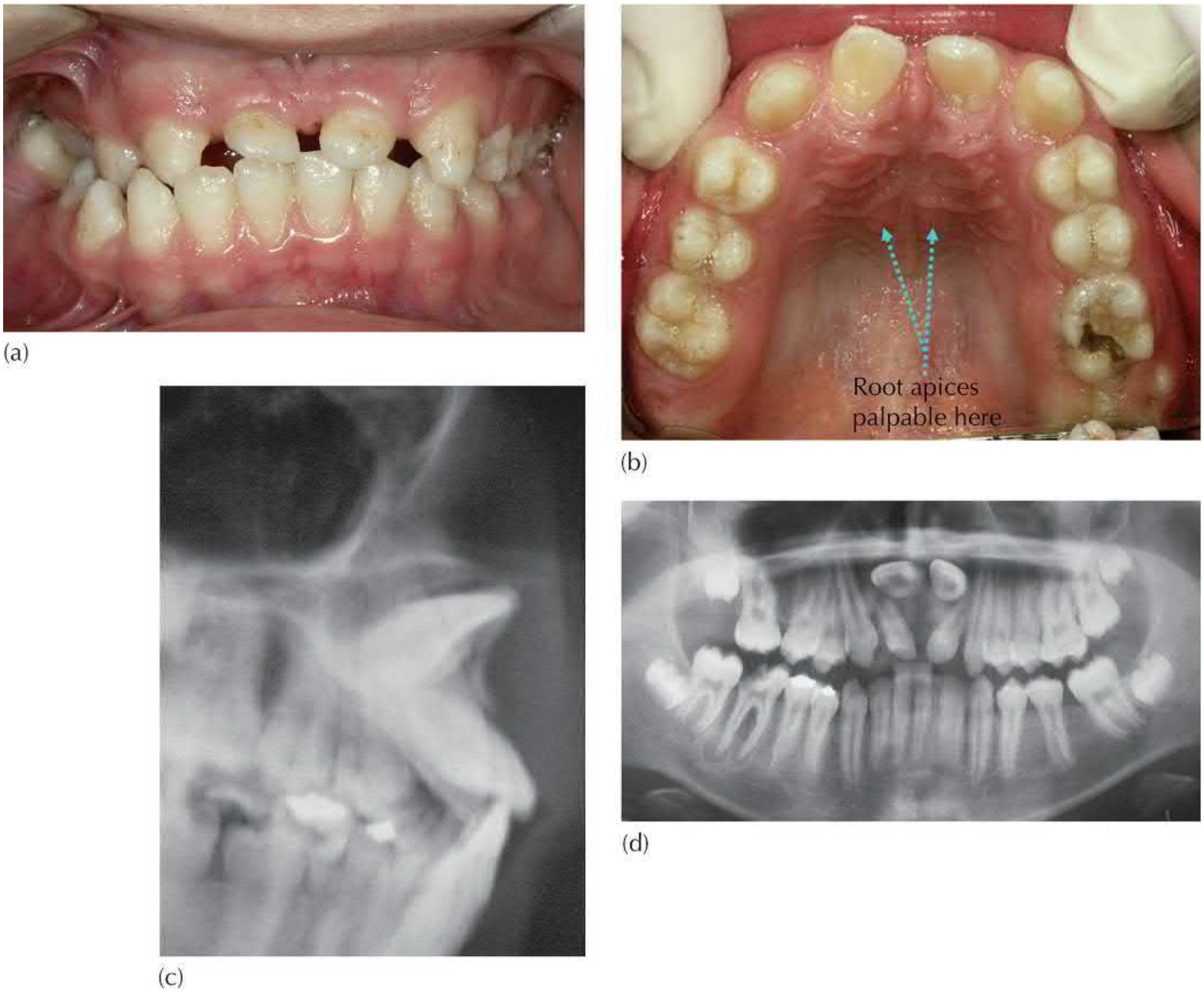


Fig. 6.13 (a) An extreme rarity: bilateral classic dilacerations of both central incisors, seen intra-orally from the front. (b) The occlusal view showing the palpable prominences of the apices of the two unerupted central incisors. (c) The anterior portion of a lateral cephalogram show the superimposed identical incisor crown adjacent to the anterior nasal spine. (d) The panoramic view of the location of the dilacerate central incisors.

Courtesy of Dr Srdan Marelic.

This hypothesis will also explain the typical appearance of the dilacerated tooth, as well as its final unerupted location under the nose. Furthermore, since it may occur as a result of a relatively minor trauma, this would account for the high proportion of cases with no apparent (remembered) history of trauma experience and no premature loss of or damage to the adjacent teeth. Its relative rarity may be due to the positional relationship between the deciduous and permanent incisor at the time of injury and a very specific directional relationship with the traumatic force vector. This may also account not only for an absence of bilaterally affected cases, but also for its non-occurrence among lateral incisors, as well as for lack of connection to any supernumerary teeth, cysts or odontomes. Furthermore, it will provide an explanation as to why there is no obvious displacement visible on the tangential radiographs that were taken immediately following the traumatic episode (Figure 6.14a, b) and as to why the tooth is never rotated in the horizontal plane, around its long axis.

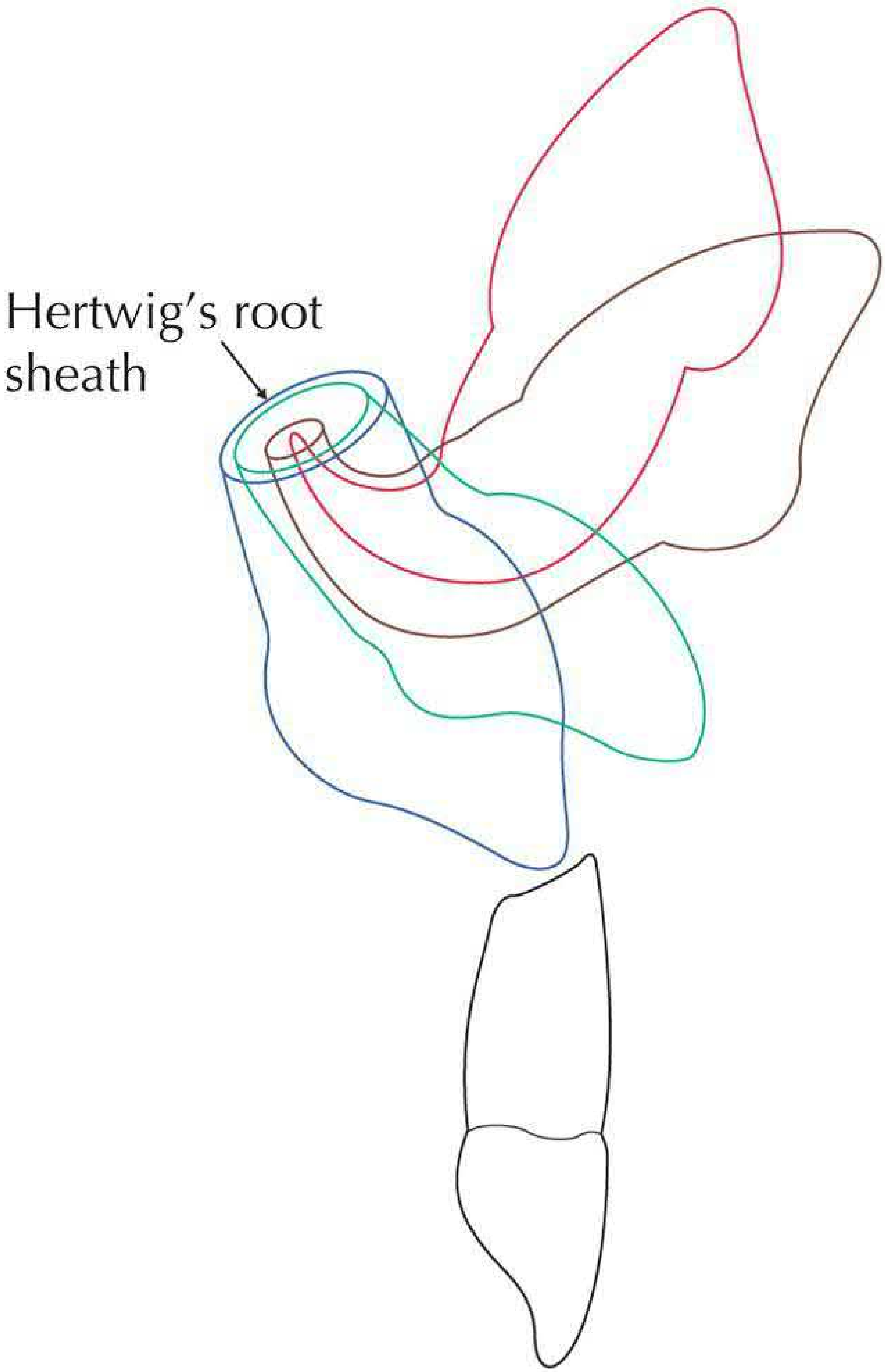

Hertwig's root sheath

Fig. 6.14 A diagrammatic illustration of the progressive alteration in the orientation of a dilacerated incisor, during the disturbed root formation. Note that the position of Hertwig's proliferating root sheath remains unaltered.

Source: Reproduced from previous edition. Adrian Becker, *The Orthodontic Treatment of Impacted Teeth*, 2nd ed., 2007 with the kind permission of Informa Healthcare – Books. See Online PPT & video 6.12 and 6.14.

The age at which the trauma occurs is therefore a critical factor in the exact location of initiation of the root bending and in the degree of distortion. The earlier the trauma, the greater the degree of dilaceration, simply because the younger the patient, the more dentino-generative potential will be realized post trauma. It would also seem that the force of the trauma is indeed a factor, insofar as it will cause a greater or lesser area of damaged dentine on the labial side, although this can only be conjectured.

From the clinical perspective, it seems probable that apexification of a trauma-affected incisor may be delayed because of the trauma and, at the age of 9–10 years, resolution of the impaction and the achievement of alignment are likely to be completed before the apex has closed. It follows, therefore, that the root will continue for many months thereafter to elongate along the same curved path towards the labial periosteum of the alveolar ridge. In practice, the orthodontist will be able to palpate this developing apex in the labial vestibular sulcus, because it will generally create a hard protrusion, disturbing the smooth continuity of its thin oral mucosa covering.

Case 6.3: A clinical view of the dynamic development of a 'classic' central incisor dilaceration

The records of a child who, at the age of 3.11 years, had suffered a blow to the front of his mouth clearly show the dynamic development of a 'classic' dilaceration (Figure 6.15a–d) over the succeeding period of six years until the age of 10. The primary intention of the subsequent series of films was initially to follow up the damage to the deciduous teeth, but it serendipitously showed the evolution of the classic dilacerate incisor. The first periapical film (Figure 6.15a) was taken at the emergency visit that the child attended on the day of the traumatic incident. Both deciduous central incisors had suffered the blow and the film was designed to assess the damage to these two teeth. The film shows a degree of widening of the PDL, which was reported in the notes of the case. The two unerupted permanent central incisors may be seen immediately above the apices of their deciduous predecessors and appeared to be unaffected.

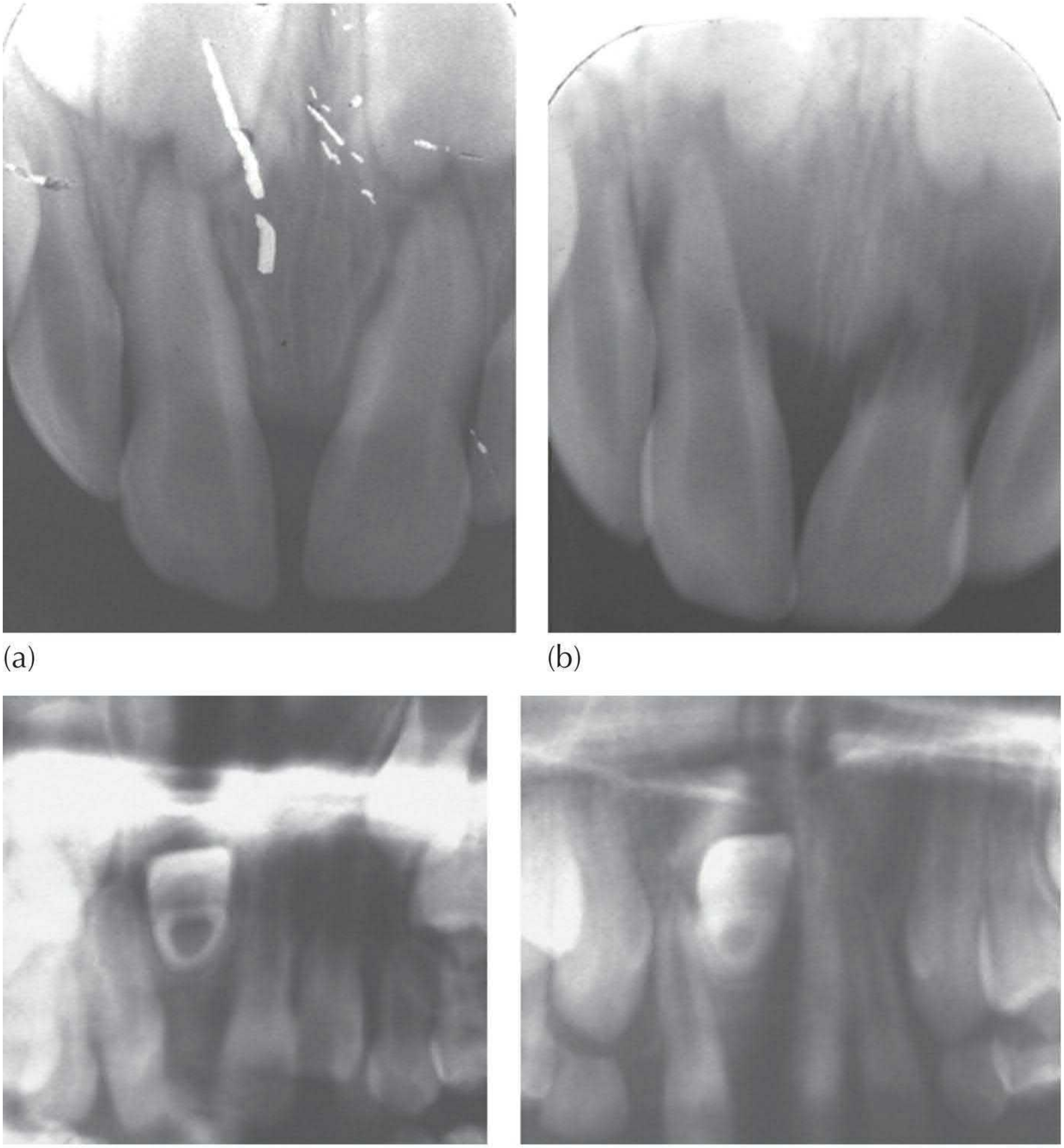
The second periapical film (Figure 6.15b) was taken six months later and shows considerable inflammatory resorption of the root of the left deciduous central incisor, and less on the right side. However, a concomitant subtle change in the relative positions of these two unerupted permanent incisors was noted. On the right side, the incisal edge of the permanent incisor was more superiorly located in relation to the left incisor and to the root of its deciduous predecessor. The discrepancy was nevertheless small and it was not recorded in the notes of the case.

The child was not seen again until he was 7.6 years of age. The initial diagnosis of dilaceration of the right central incisor was made on the basis of a panoramic view (Figure 6.15c) taken at that age (i.e. 3.7 years post trauma). Note that the anatomical labial surface of the crown faces superiorly, with the orientation of the crown portion being slightly above the horizontal. The crown tip was displaced very high up in the maxilla and its pulp chamber was very large. The child was referred for an orthodontic examination, which he failed to attend. Instead, a further 2.4 years elapsed before he was finally seen in the Department of Orthodontics of the Hebrew University–Hadassah School of Dental Medicine. A new panoramic film (Figure 6.15d) was made and it showed the crown of the incisor to be markedly higher than before and more upward tilted, above the level of the floor of the nose. It was located slightly to the right of the anterior nasal spine. Its anatomical palatal surface was now facing anteriorly and its pulp chamber was much smaller in diameter, indicating that root development had continued.

Research into the development of 'classic' central incisor dilaceration

An observational, retrospective, CBCT study of a group of 41 children from Wenzhou, China, was carried out in order to investigate root morphology and root development in classic incisor dilaceration [22].

The researchers found that the roots of these teeth were shorter than those of their homonyms and they consequently assumed that there had been a temporary arrest of odontogenesis due to trauma that had caused an irritation of Hertwig's epithelial root sheath. From the CBCT cross-sectional slices of the affected teeth, it was observed that the developing roots were very close to the palatal periosteum. Furthermore, they noted that the degree of dilaceration was greater in the older children in that sample. From these two findings, they concluded that it was likely that the influence of this close proximity to the palatal periosteum, together with the longer period of root development in the older children, had the combined effect of exaggerating the disfigurement of the newly developing root. Accordingly, they recommended that treatment of incisor dilaceration be undertaken as soon as diagnosis had been made. The intention was to distance the developing root from the palatal mucosa and to reduce the duration of its formation, thereby minimizing the degree of root dilaceration that would occur. In so doing, these researchers showed the evidence that Stuart had observed 36 years earlier [38]. The implication was that therapeutic alteration of the direction of root growth is possible during its pre-calcification developmental stage.



(a) (b) (c) (d)

Fig. 6.15 Dynamic development of a ‘classic’ dilaceration. (a) A periapical view of the maxillary incisor area of a 3.11-year-old child taken within hours of the trauma. (b) A six-month follow-up film shows considerable inflammatory resorption of the root of the left deciduous central incisor and less on the right side. (c) Anterior section of a panoramic view, taken at age 7.6 years. (d) Anterior section of a second panoramic view, taken at age 10 years. Note the difference in size of the root canal, which is represented in its cross-section, during the 2.6 years between these two panoramic views.

Unfortunately, not every child is brought to the orthodontist at age 7 years. Indeed, many orthodontists will send away a child of this age and advise the parent to bring the child back in or close to the early permanent dentition stage, at 11–12 years. At that age there are more permanent teeth in the mouth to sustain a fixed multi-bracketed appliance and the child might be that much more manageable. At that age, too, the full expression of the anomalous dilacerate root growth will have occurred and the final form of the dilacerate incisor would see the root develop in the arc of a tight circle in the bucco-lingual plane and the apical portion at right angles to the coronal portion of the root (Figure 6.11). The tooth will then present a much more daunting challenge, because the need for apicoectomy and root canal treatment will be mandatory.

The location of the unerupted incisal edge of the dilacerate incisor is usually very high up on the labial side of the ridge, close to the root of the nose, with its labial aspect facing superiorly and posteriorly and the palatal side, including the cingulum, facing forwards (Figures 6.14 and 6.15d). The tooth needs to be brought to its proper place, which will involve considerable labial root torque, in order to align its crown portion with the other teeth and matching its normally erupted antimere. Achieving this will cause the root apex to point labially in contact with, and sometimes actually bulging, the periosteum of the alveolar ridge.

Treatment in the early mixed-dentition stage (phase 1)

As discussed in the earlier part of this chapter, from the point of view of the affected tooth, orthodontic correction at the age of 7–8 years is the preferred time. This is principally due to the fact that alignment and labial root torque of the tooth will encourage an improvement in the form of the uncalcified portion of its root. This, in turn, reduces the likelihood that apicoectomy and root canal therapy will be needed. The prognosis of a vital incisor, when compared to a non-vital, root-treated and root-shortened central incisor, is far superior and it will also not suffer a deterioration of its natural colour over time.

This phase 1 treatment will probably be completed by the age of 9–10 years, at a stage when the dilacerate incisor is still likely to have an open apex. In the more favourable cases, the shape of the newly calcified and elongated root will have improved considerably and will be fully encompassed by alveolar bone, which will then likely render apicoectomy superfluous.

Retention of the phase 1 treatment outcome

At the end of a phase 1 treatment in which a dilacerate incisor impaction has been resolved, the orthodontist is faced with a dilemma. If no retainer is placed, the affected tooth will quickly move out of alignment, and the incisal edge will tip labially. Although this relapse is relatively mild, being at the front of the mouth, it will be somewhat alarming to the patient. The reason for the relapse, aside from the usual post-orthodontic factors, is that the forward-facing and uncompleted root end is continuing to grow its apex and does so while pushing against the labial periosteum of the alveolar ridge. Since the periosteum is resistant, the continued root growth pushes the calcified and formed root backwards (i.e. lingually) and the crown labially – in a counterclockwise rotation (when the patient is viewed from the right side). Therefore, if retention is instituted, this retrograde rotational movement of the tooth will be resisted and the apexification process may cause the root end to bulge into the labial sulcus, thereby requiring early apicoectomy. For this reason, retention with a bonded or removable retainer, intended to prevent deterioration of an ideal alignment, should only be maintained for as long as there is little or no labial bulge of the developing root end. Regular follow-up examination is vital in order to ensure that the growing root apex does not perforate the labial mucosa and cause the demise of the tooth.

Accordingly, the wisdom of employing a retention appliance in order to rigidly hold the phase 1 outcome, with a bonded lingual wire, should be carefully weighed. The absence of retention will, within a very short time, undoubtedly permit the tooth to relapse to a degree and create an increased overjet of the affected tooth. It will not, however, restrict the unerupted maxillary canines from manoeuvring against the roots of the erupted lateral incisors in their efforts to erupt into the mouth. Artistic 3D tip-and-torque finishing for the dilacerate incisor should be postponed and dealt with solely in the second phase of orthodontic treatment at age 12 years, as part of the treatment of the overall malocclusion. The question of whether to perform an apicoectomy and root canal treatment should only be decided within the framework of a phase 2 treatment, when the full expression of apexification will have already taken place.

Since comprehensive orthodontic treatment cannot be completed until all the permanent teeth are fully erupted, the aim of early treatment of discrepancies in tooth position, rotation or axial orientation should be limited to preventing undesirable functional and health problems and a deterioration of the condition until a phase 2 plan is initiated in the permanent dentition.

With these principles in mind, the dilacerate incisor unquestionably justifies a phase 1 treatment. The impaction should be resolved, and the tooth drawn down and aligned in the arch. An extreme degree of corrective labial root torque will need to be undertaken, but this should be halted when the root end becomes prominent in the labial vestibular sulcus. Final root torque should only be performed towards the end of phase 2, at which time an assessment of the need for and extent of apicoectomy should be made.

Orthodontic traction of the crown of the tooth will bring it downwards in a labially oriented semi-circular movement, from its location in the root of the nose to the labial archwire. Together with labial root torque, this will fulfil two main functions. The first is to distance the developing root from its close proximity to and the negative effect of the palatal periosteum on root growth direction. The second function is to align the long axis of the *crown* to match that of the adjacent, unaffected, normal, contralateral central incisor. With a fully grown and curved root, however, the chances are that, well before the optimal degree of root torque has been reached, the root end will become palpable as a small, hard protuberance on the labial surface of the oral mucosa, covering the alveolar ridge. Continued and excessive torque, applied in order to achieve an ideally angulated crown, is likely to cause the root to perforate the labial oral mucosa and result in an abrupt 'finale' to the survival of the tooth. Even before that stage, the hard protrusion itself is highly vulnerable to traumatic injury, even from careless tooth brushing, since it has only the thinnest mucosal covering. With a minimal ulceration, the apex may become exposed, the mucosa is unlikely to re-heal over the protrusion and the tooth will lose its vitality.

Clearly then, when this stage is reached, the treatment will have arrived at a major crossroads and the following questions will need to be asked: should the root apex be amputated and a root canal procedure performed, before continuing to the optimal orthodontic outcome? Should the crown angle be corrected prosthodontically, with an artificial crown? Should the treatment cease at that point? Is there a difference in approach dependent on age? The answers to these essential questions will depend on the merits of each case individually.

As we have described in Chapter 1, the root of a healthy maxillary central incisor continues to elongate for about three years after the crown first appears in the mouth, until its completion at apexification. Normally, the direction of the growth of the root of a single-rooted tooth is in line with both the orientation of the crown and the eruption path and is a contributing factor in the eruption mechanism itself. While the root of a dilacerate tooth may be shorter because of the trauma it has suffered, the labial-lingual imbalance of further root growth leads to a labial and superior displacement of the crown.

Concurrently with this developmental pattern, the root apex will be developing against the periosteum on the palatal side of the anterior alveolar ridge, and will influence the apex to curve further [22]. This phenomenon is no different from that which occurs with the root apex of any other tooth that is developing in close proximity to an anatomically limiting factor, such as the floor of the nose, the maxillary sinus, the lower border of the mandible and the inferior dental canal [38]. In these circumstances, the subsequent growth of the root apex becomes reoriented into a direction that will usually be parallel to the plane of that structure. It will be seen, therefore, that unchecked continuation of root growth towards full apexification will result in driving the incisal edge of the incisor to a progressively inaccessible location, propelling it ever upwards towards the anterior nasal spine.

If this is permitted to continue, the resulting, tightly curved shape of the root may not permit full corrective realignment of the tooth to within the confines of the alveolar bony ridge. Overcoming the problem at that late stage would require surgical re-shaping/amputation of the apex, which would secondarily necessitate elective root canal treatment. The tooth would be left with a yet further shortened root, a reduced prognosis and, in the long term, the strong possibility of a deleterious change in colour of the crown.

Based on the evidence from the Chinese CBCT study [22], which was published a year after the treatment of Case 6 later in the chapter (Figure 6.18), it is reasonable to assume that early resolution of the impacted tooth and its alignment would distance the developing root apex from the palatal periosteum and, perhaps, lead to a more favourably shaped root end. This, in turn, could eliminate the necessity for root canal treatment, maintain the vitality of the affected incisor, and increase its root length and long-term prognosis. It would also avoid detrimental colour change and enhance the appearance of the treated outcome. All in all, no small bonus!

Case 6.4: Treatment in the early mixed dentition and the significance of its effect on the root shape of a dilacerate incisor

Let us now look at a treated case, which illustrates the degree with which the shape of the uncalcified apical portion of the root of a dilacerate central incisor may be altered by orthodontic treatment. The patient was a 7-year-old boy who was accompanied by his father at the first visit in November 2013. The parent reported that his left maxillary central incisor had erupted about half a year earlier, but the right central incisor was still unerupted (Figure 6.16a, b).

He had been referred by a paediatric dentist, under whose care the child had been over a period of 2–3 years. With the help of periapical and panoramic radiographs, she had recognized an abnormal orientation of the unerupted right central incisor. In an effort to encourage the spontaneous eruption of this incisor, the dentist had recently extracted the other deciduous incisors in the maxilla with the intention of providing additional space. Months later, nothing had changed and the mother was concerned. She had only the vaguest memory of a contributory history of trauma at about the age of 2 years.

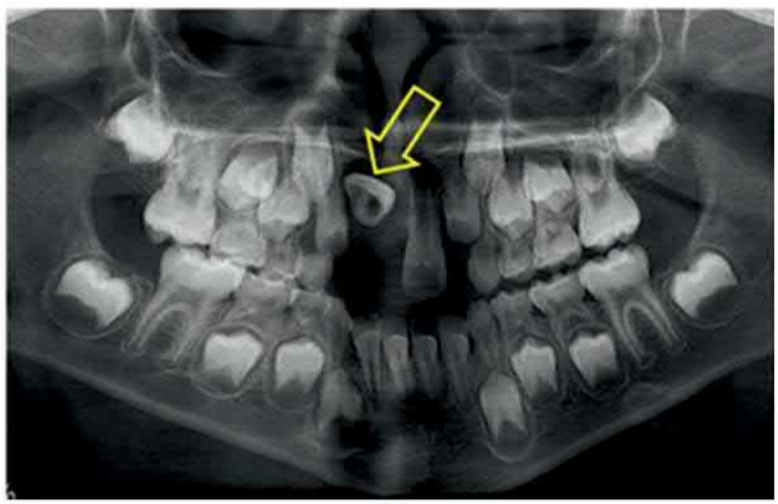
The intra-oral examination showed all four erupted permanent first molars and the mandibular permanent incisors, together with all the primary molars and canines in both jaws. The left central incisor was the only erupted permanent tooth in the anterior maxilla (Figure 6.16c, d).

From the radiographic records (Figure 6.16e, f)), the child's dental age was calculated, according to the Jerusalem method described in Chapter 1, to correspond with his chronological age. As was normal, all the existing permanent teeth (erupted and unerupted) displayed open root apices. The premolars and permanent canines had barely begun root calcification, while early root formation could be seen on the maxillary lateral incisors. The single erupted maxillary incisor exhibited about half of its expected final root length. The presentation of the dilacerate incisor on the panoramic film was through the long axis of its crown, which would be equivalent of an occlusal view of most other teeth. Planar 2D radiography offered no information in the bucco-lingual plane and it was therefore impossible to define the shape and length of the root of the tooth, which was masked by the superimposition of its own crown. Notwithstanding that, the clear indication was that the tooth was dilacerated in the characteristic ‘classic’ form. In order to confirm the presence, length and form of its root, a CBCT scan needed to be conducted.


(a)


(b)


(c)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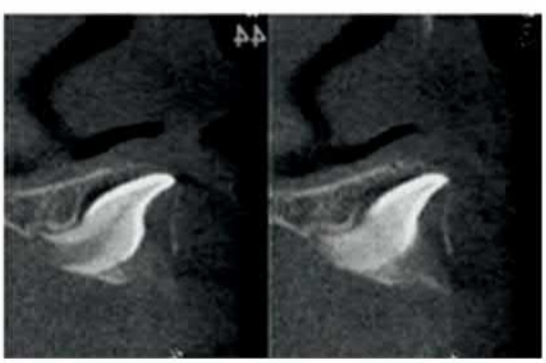
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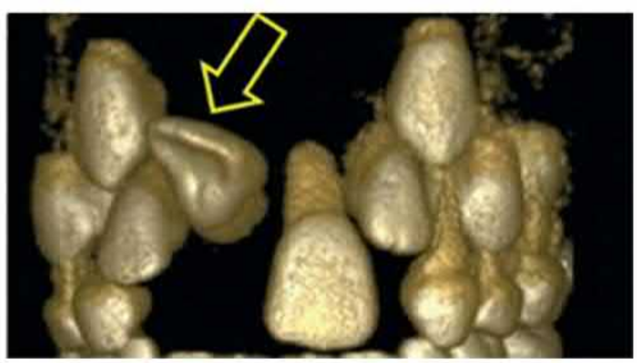
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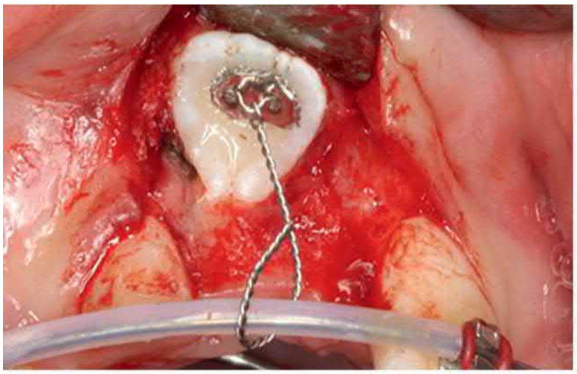
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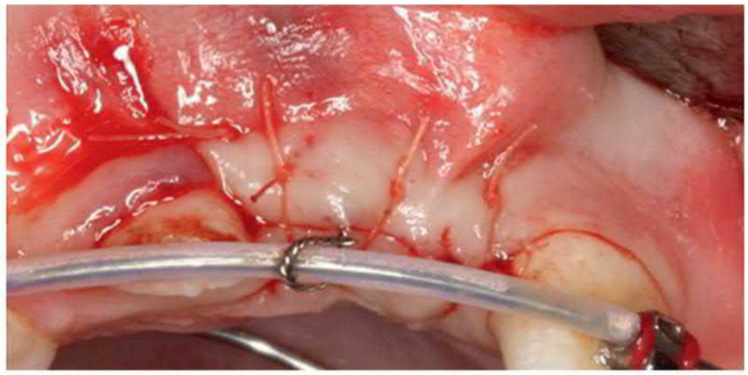
(h)


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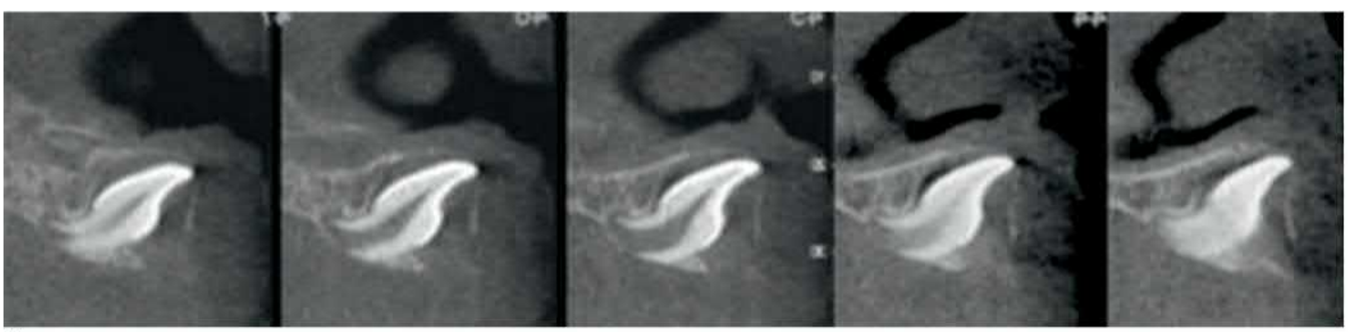
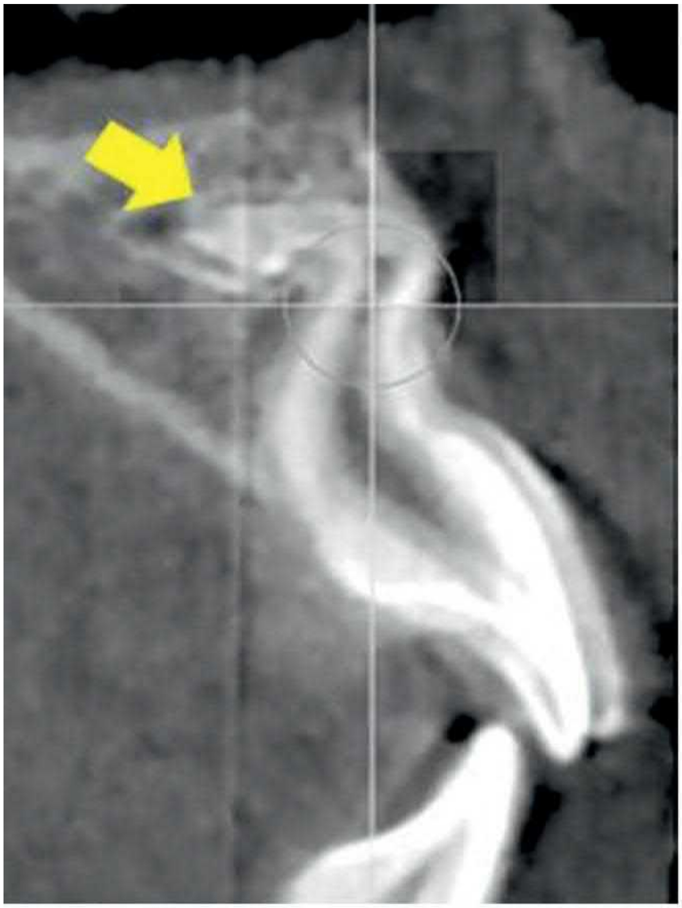


(t)

(u)



(v)

(w)

Fig. 6.16 (a, b) The occlusal and anterior views of the maxillary dentition when the patient was first seen. (c) Anterior portion of the cephalogram shows the incisal edge of the right central incisor to be located adjacent to the anterior nasal spine and pointing upwards (arrow). (d) The view of the tooth (arrow) in a panoramic film. Note the end-on view of the very large pulp chamber and root canal. (e) Part of a series of adjacent cone beam computed tomography (CBCT) cross-sectional cuts of the tooth to show the root curvature, the open apex and the proximity to the palatal periosteum. (f) 3D screen shot after all bone and soft tissue has been peeled from the tooth (arrow). (g) Closed surgical exposure revealed the palatal aspect of the incisor facing labially. The eyelet was bonded close to the incisal edge and the twisted steel ligature connector stabilized on the archwire, which was padded with a plastic sleeve for comfort. (h) The attached gingival flap was sutured back to leave only the ligature connector visible, curled around the slightly raised archwire, to activate the eruptive traction. (i) The reverse torqueing auxiliary in passive mode. (j) The reverse torqueing auxiliary engaged and activated. (k) The view from the right side illustrating the degree of labial root torque of tooth #11 required. (l, m) Occlusal and front views of the anterior dentition, showing the end of phase 1 treatment at the time of de-debonding. (n, o) Panoramic and periapical views at that time. (p, q) The occlusal and anterior views of the dentition 2.5 years post phase 1 treatment. The anterior teeth are taken from (r) the panoramic and (s) the periapical radiographic views, offering two different aspects of root apex direction (arrows). CBCT cross-sectional cuts can be compared (t) before treatment in the upper series and (u) at completion of phase 1, in the lower series. Note the highlighted apical root extension on the middle slice. Magnified views of the cross-sectional cut show (v) the extreme angle of the extension of the root apex and its posterior direction and (w) the obtuse 120° angle between the newly formed, modified apical portion of the root (green broken line) and the expected axis of the root apex that would have been developed without treatment (yellow broken line).

The phase 1 treatment began in December 2013. The maxillary molar bands were linked by a soldered transpalatal bar, with brackets bonded to the available deciduous teeth and the single maxillary erupted incisor. Following subsequent placing of brackets also on the newly and autonomously erupted lateral incisors, initial levelling was performed. The NiTi levelling wire was then replaced with a heavy stainless steel retaining arch, and this configuration provided the anchorage unit against which extrusive forces would be applied to erupt the incisor.

In March 2014, the dilacerate incisor was surgically exposed under local anaesthetic cover, with a closed exposure procedure (Figure 6.16g, h). An eyelet was bonded to the anatomical lingual aspect of the tooth close to the incisal edge, and light extrusive force was applied before the flap was re-sutured and the patient discharged.

Traction was renewed on subsequent visits and directed so that the incisor broke through the labial mucosa in the area of the attached gingiva. It reached the main archwire in October 2014. The lingual eyelet was removed and a bracket of the same type as those present on the other teeth (Tip-Edge PLUS™) was substituted on the labial aspect of the tooth.

In December 2014, an individual torqueing auxiliary was placed to move the root of the incisor labially, while monitoring the labial alveolus for palpable signs of the incisor root apex (Figure 6.16i–k). This specific auxiliary is highly efficient and has a very wide range of torqueing capacity, while applying a light and measurable continuous force. The long axis of the crown of the incisor was corrected by approximately 105° of labial rotational root torque from its original location, i.e. clockwise rotation when viewed from the right side. This was achieved partly by tipping the tooth down from its sub-nasal level and partly by virtue of this period of four months with the root torqueing auxiliary. A discussion of the biomechanics of the root torqueing auxiliary may be seen in Chapter 3 (Figure 3.12).

The intended treatment plan was completed by April 2015, after a phase 1 that lasted for 15 months (Figure 6.16l, m). The maxillary appliance was debonded and a simple Hawley retainer substituted. The intention was to limit the anticipated high rate of relapse that classic dilacerate teeth undergo following removal of the torqueing force, which is due to additional growth of the apex of the tooth against the labial periosteum.

Up until this point, the short phase 1 treatment had followed the normal protocol, as practised in Jerusalem, for the treatment of classic dilacerate incisors. The further development of the dentition was recorded on a new panoramic film and, together with a periapical view, revealed the status of the open apex of the treated tooth (Figure 6.16n, o). The patient was advised to return for routine follow-up six months later.

The patient failed to return for follow-up for 2.5 years, until October 2017. At this visit, the father reported that the retainer had been worn for six months only and was then discarded. Despite this alarming admission, on examination the tooth showed none of the expected positional labial relapse of its incisal edge. Its immediate post-phase 1 treatment outcome had remained completely stable. The crown of the dilacerate tooth was of excellent colour and form, exactly matching its unblemished antimere (Figure 6.16p, q), and was in the same location that it had been at the end of treatment. No changes were noted in the alignment that had been achieved in the phase 1 treatment.

A panoramic depiction of the anterior teeth is normally taken at an angle of –7° below the horizontal, and in this case it showed further growth of the closing apical foramen, with a circular feature (arrow) indicating a hooked end (Figure 6.16r). The periapical view of the tooth, which is normally taken at approximately +60° above the occlusal plane, showed a considerable and angled apical elongation (arrows) to the remainder of the root (Figure 6.16s).

In order more accurately to evaluate the root form and pattern of apexification, a new CBCT of this limited area was commissioned. This revealed an irregular but long and narrow apical portion at a very obtuse angle to the main curved original corpus of the root (Figure 6.16t, u). This new root extension was pointing posteriorly along the path from which the root end had come. The extension was sharply diverted in the palatally horizontal direction, at an approximate angle of 120° from the expected direction that the root would have taken had treatment not been performed (Figure 6.16v, w).

Despite the extreme degree of orthodontic movement that the tooth had undergone, its vitality was maintained. This was evident from the growth of this new apical portion and from the existence of a normal lamina dura around the new apex, as seen on the CBCT. Regardless of its odd configuration, the entire length of root was invested in alveolar bone, with no danger of any part of the root fenestrating through the labial or palatal bony plates. There was no tell-tale bulge of the labial oral mucosa covering the alveolar ridge in the vestibular area, nor on the palatal side.

The posteriorly directed orientation of this new apical portion was exactly the reverse of that normally seen in the typically completed dilacerate incisor root. It was therefore reasonable to conclude that the extreme degree of corrective labial root torque, effected by the appliance therapy, was directly responsible for the uncalcified root turning posteriorly rather than continuing on the facially curved path that would normally be expected in classic dilacerate incisors. It was as if the developing and uncalcified root apex had been progressively left behind as the calcified portion of the root of the incisor was being drawn labially with the torqueing movement. This had obviously been the result of the rapid torqueing movement on the uncalcified root-forming Hertwig's sheath – a therapeutically generated 'corrective dilaceration'. It may be safely assumed that this was also the reason for the total absence of relapse following discarding of the orthodontic retaining appliance.

It is generally accepted that success in the orthodontic/surgical modality of treatment of the classic dilacerate central incisor usually requires the surgical amputation of the curved apex of the root, which bulges the labial oral mucosa covering the alveolar ridge on its facial side. If this obvious growth-altering effect of orthodontic torqueing forces can be substantiated in a significant proportion of young patients, then the following advantages may be gained by performing a phase 1 treatment as early as possible, while the apices are open:

- It reduces the likelihood that elective apicoectomy and root canal treatment will be necessary.
- It therefore significantly improves the prognosis.
- It enhances the aesthetic quality of the result.
- It reduces/eliminates post-treatment orthodontic relapse.

Perhaps there are some disadvantages of treatment performed in this way. Without question, it must be admitted that the odd shape and orientation of the elongated root apex must raise the eyebrows of a traditionally conservative dentist, a specialist endodontist or a dental anatomist. But does it really matter if the tooth has a healthy periodontium, is vital, is positionally stable and has a beautiful crown? Is not the proof of the pudding in the eating?

It certainly provides a significantly longer root and promises a better prognosis than the root-treated and apicoectomized incisor that it would have otherwise become. There will also be no colour change in the crown and no reason why the long-term survival chances of this tooth should not be excellent. Should root canal therapy ever become necessary, for any one of a variety of reasons not necessarily related to the orthodontic treatment, then (and only then) will an apicoectomy be indicated, since endodontic access to the canal extension in the apical portion of the root will not be possible.

Given the several important advantages available from early treatment and the excellent results that are achievable, phase 1 treatment should be considered mandatory in these difficult cases and should be performed as soon as the diagnosis has been confirmed.

Treatment in the later mixed-dentition stage and thereafter

The maxillary central incisor normally erupts at age 7 years, with the root approximately two-thirds of its final length. The growth of the last third of this root is completed 2.5–3 years later, at the dental age of 10 years. This represents the cut-off point beyond which a dilacerate root form cannot be modified.

When a patient has a dilacerate maxillary incisor and is accepted for treatment, a considerable length of time will be spent between the first visit and the point where active traction may be applied to the tooth to begin to bring it down. During this period of time a clinical examination needs to be performed, followed by gathering of the necessary clinical and routine orthodontic radiographic records. It is very likely that a CBCT of the tooth will be required and, once all the usual diagnostic preliminaries are collated, the appropriate diagnosis and a treatment plan will be formulated. This will then be explained to the parent in a separate consultation visit, together with an explanation of the necessity for performing surgery. Once agreement is reached, the maxillary orthodontic appliance will need to be placed and levelling and alignment mechanics initiated, together with space opening for the impacted tooth. The orthodontic appliance will then be converted into its anchor mode, with the substitution of heavier slot-filling archwires and the means of applying traction to the impacted tooth prepared, in place of the lighter and more flexible initial archwires. Surgical exposure of the tooth will be arranged in accordance with the surgeon’s own time schedule.

The above preconditions will need to be successfully completed before the orthodontist may turn attention to the impacted tooth. It is reasonable to project that the period of time that will elapse before traction is applied to the tooth and before its apex begins to rotate away from the palatal periosteum would, at best, be not less than 6–9 months from commencement. The technical stage where the orthodontist could first achieve adequate alignment to apply labial root torque could easily take a further 5–6 months and it is the root torque that will have the greatest corrective effect on a deformed root. During this significant period, the apex is progressively closing. On the basis of this time-line, it seems that no orthodontic treatment commenced after the age of 9 years can have a corrective effect on the form of the apical portion of the incisor tooth. After this age, therefore, the chances are high that full correction of the position and orientation of a dilacerate incisor will need to include an apicoectomy and root canal treatment. Consequently, a phase 1 treatment designed to treat the incisor will offer no added value compared to awaiting the posterior teeth and treating the whole malocclusion in a single inclusive and overall treatment plan, at the age of 13 years.

Of course, there are other considerations to be taken into account that may justify initiating a phase 1 treatment *before* the complete eruption of the permanent dentition. Chief among such considerations is the child’s appearance, the quality of the smile and the social interaction with peers, particularly derision, teasing and bullying at school. Many parents will insist on a phase 1 treatment at age 9–11 years, knowing full well that a second round of treatment will be necessary relatively shortly thereafter.

On the other hand, in treating children in the 7–8-year-old age group, it is not always possible to complete a phase 1 treatment in the same short period of time, as noted in the last case. Any behavioural problems that a child may have in dealing with the surgery and the sensitivity of the soft tissues in the months of traction thereafter may turn a relatively simple and unsophisticated orthodontic manipulation into a dragged-out and difficult affair. As the result, the time-frame for the hoped-for changes in root form may pass without achieving the goal and the child will subsequently become a candidate for elective root canal and apicoectomy treatment.

Case 6.5: Treatment of a dilacerate incisor in the middle to late mixed dentition and the need for apioectomy

An 8-year-old female with a dilacerate right maxillary central incisor was referred for treatment by the residents in the Department of Orthodontics at the Hebrew University–Hadassah School of Dental Medicine (Figure 6.17a). She had had considerable caries experience, which was treated in the postgraduate clinic of the Department of Pediatric Dentistry at the School. She was a difficult patient in terms of her behaviour in the clinics of both departments and there were many issues with regard to preventive and restorative treatment. She was restless, impatient and highly sensitive to minimal discomfort and pain, to an exaggerated degree. The upshot was that the surgical stage of the treatment was reached quite late and by the time traction could be effectively set in motion, it was estimated that most of the growth of the root apex of the tooth had already occurred. The clinical photographic intra-oral views of the dentition show that space had been lost due to tipping of the adjacent incisors. The panoramic, occlusal and lateral cephalometric radiographs (Figure 6.17b–d) show the typical configuration and location of the classic dilacerate central incisor, adjacent to the anterior nasal spine.

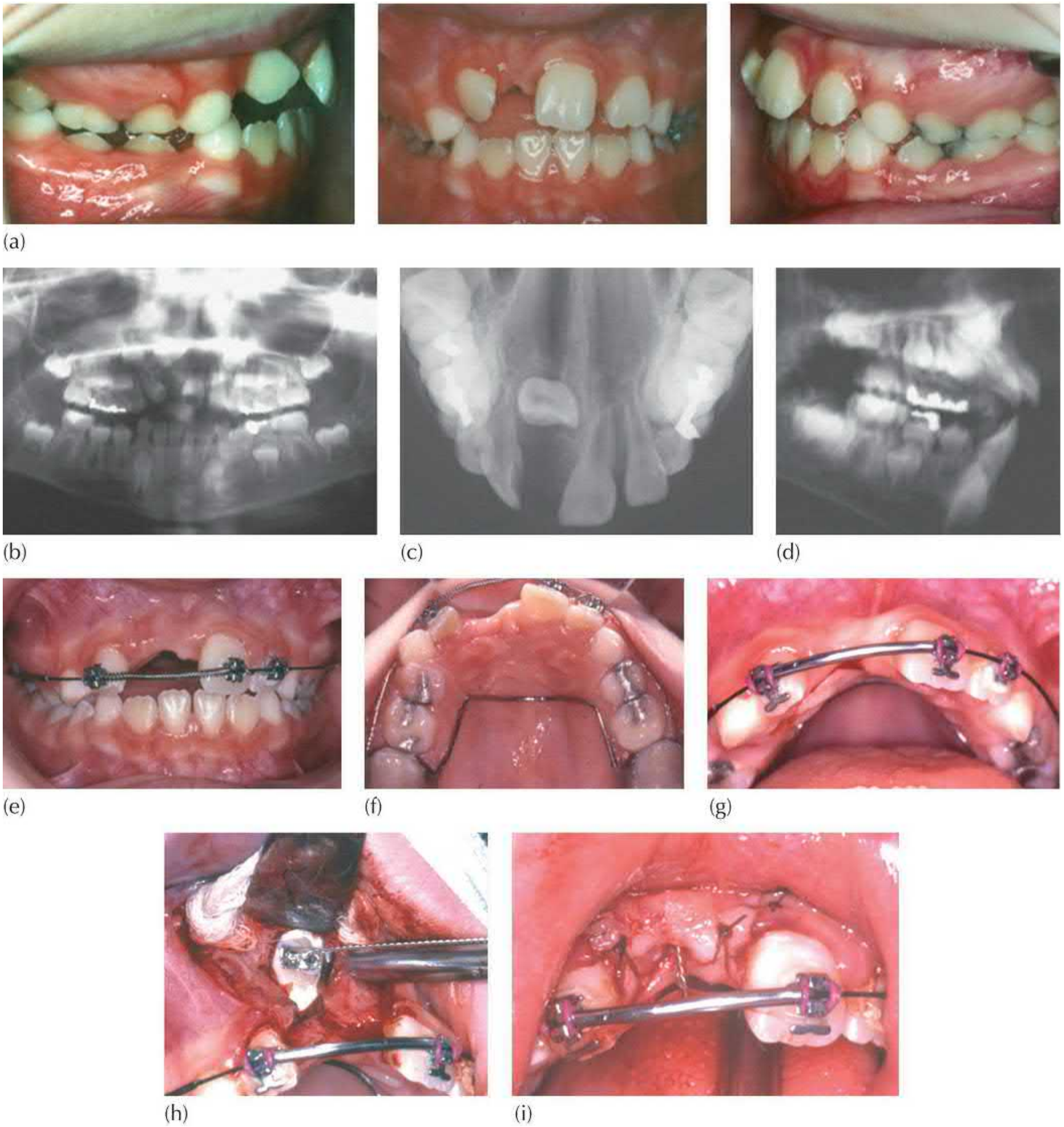
A modified Johnson's twin-wire arch (2 × 3) appliance (Figure 6.17e–g) was used to achieve a reopening of the incisor space with an open-coil spring, compressed between the brackets of the adjacent lateral incisor and central incisor of the left side. The space opening had been deliberately exaggerated and the spring was subsequently replaced by a measured and contoured steel tube to act as a space maintainer. A cut length of closed-coil spring would have served the same purpose.

The space-maintaining tube and the buccal tube arms, together with the rigid soldered palatal arch, constituted the very significant anchorage unit in this biomechanical system. In preparation for force application, a T-pin was inserted from the occlusal into the vertical slot of the Tip-Edge PLUS bracket of the two adjacent incisors. Note the use of a length of oversized steel tubing (Figure 6.17h, i), suitably adapted to the archform in the area of the orthodontically restored incisor space, as a space maintainer.

As was seen in this case and in common with all classic dilacerate impacted incisors, the crown of the tooth was located in the height of the labial vestibule. As such, an open surgical exposure was contraindicated for the following reasons: (a) it would be impossible to maintain a patent opening; (b) it would, of necessity, be fully within the area of mobile oral mucosa; (c) bonding an attachment in the ensuing weeks and months would be impossible to perform due to the sensitivity of the area; and (d) the final outcome for the tooth would be governed by a gingival attachment comprising a complete ring of fragile, mobile and highly vulnerable oral mucosa.

The preferred alternative two-stage surgical procedure that was performed in the present case did not suffer from these drawbacks.

The procedure involved raising a full labial flap, taken from the alveolar crest and comprising attached gingiva (Figure 6.17i). This was reflected upwards until the anatomical palatal aspect of the incisor was exposed on the labial side of the ridge. An eyelet attachment was bonded as close to the incisal edge of the tooth as possible and its twisted steel ligature drawn down to overlay the labial aspect of the alveolus. The flap was then re-sutured back to its former place, fully re-covering the alveolar bone surface, with the pigtail ligature protruding from the sutured edge at the crest of the ridge. The ligature was shortened and its end turned upwards into a simple hook. The middle section of the elastomeric chain was then raised and engaged in the hooked end of the ligature, thus applying immediate traction to the impacted incisor.



(a) (b) (c) (d) (e) (f) (g) (h) (i)

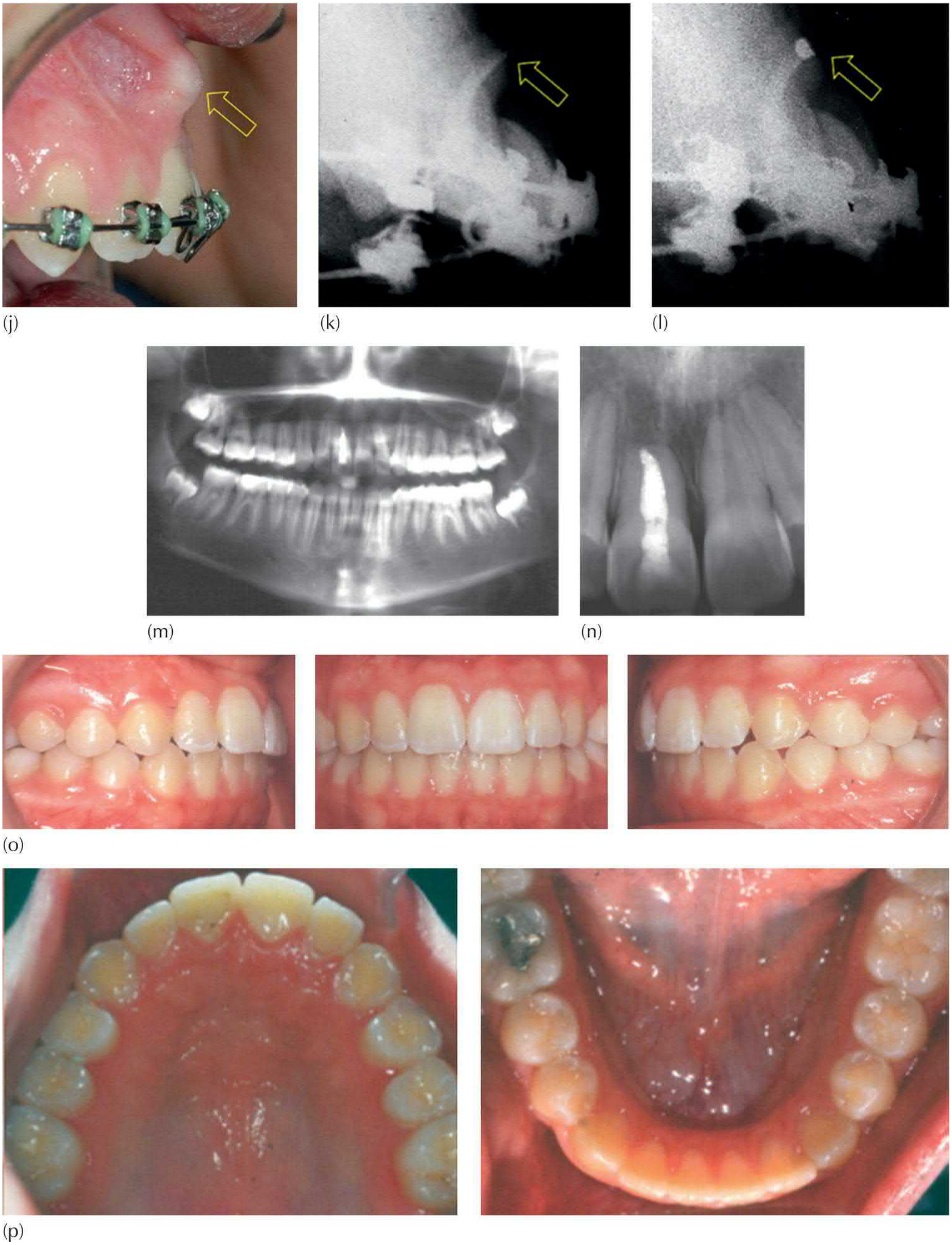


Fig. 6.17 (a) The initial malocclusion of the patient before commencement of treatment. Planar radiographs of the pre-treatment dentition: (b) panoramic view; (c) occlusal view. (d) Lower

anterior view extracted from lateral skull radiograph. (e, f) Johnson's modified twin-wire arch appliance seen from the frontal and occlusal aspects, after space opening. (g) Anterior view showing the configured tube holding the achieved space and the inverted T hooks in the vertical tubes of the brackets in preparation for traction. The initial horizontal cut for the attached gingiva flap was taken from the crest of the ridge. (h) A small eyelet attachment was bonded to the anatomical lingual aspect of the incisor. N.B. This was not close enough to the incisal edge. (i) The twisted steel connector was drawn down through the edge of the replaced and sutured flap. Note the elastic chain module stretched between the T pins on each of the adjacent incisors. The middle of this chain was raised and held in this flexed state by the terminal hook of the twisted wire connector, thereby transferring an extrusive force to the impacted tooth. (j) A clinical tangential view across the premaxilla to show the labial protrusion of the apex (arrow) under the periosteum and oral mucosa, before root treatment and apicoectomy (arrows). (k, l) Radiographic tangential views across the premaxilla before apicoectomy. (m, n) Panoramic and periapical views of the completed case. (o) The completed case with teeth in occlusion. (p) Occlusal views of the two arches in the completed case. See Online PPT & video Fig. 6.5 and Fig. 6.5 and 6.17.

This case scenario shows clearly that providing the tooth with adequate torque will bring its forward-facing root apex through the labial plate of bone, to become excessively prominent under the periosteum and oral mucosa of the alveolar ridge (Figure 6.17j–l). In order to achieve adequate torque, therefore, the prominent apex must be amputated, mandating the addition of an elective endodontic procedure. Radiographs of the completed treatment show the affected tooth after root canal treatment and apicoectomy (Figure 6.17m, n).

At the completion of the treatment, a fixed lingual twistflex bonded splint was placed and, at the time of writing, had already been present for five years. Given the relapse tendency that a treated dilacerate incisor tooth generally seems to display, an additional labial bonded twistflex wire had been placed on the central incisors, to enhance stability. It remained in place for one year before being removed.

In the final treatment outcome of the overall malocclusion at one year post treatment, the clinical crown is shown as slightly longer than that of its antimere. However, this is the only noticeable clue to identifying the affected tooth (Figure 6.17o, p). There were no visible differences between the two teeth regarding any other periodontal parameters.

How much labial root torque should be attempted in phase 1?

At this point in the treatment of such cases, the question arises as to how much root torque should be performed while the patient is still young enough for positive treatment-driven change in root shape to be possible, and how much torque should be left until phase 2 of the treatment, in the permanent dentition. It is quite clear that any significant torque of an incisor, in the older child, will tip the curved and apexified root end forwards, causing it to bulge out labially and altering the contour of the mucosa covering the alveolar process, as seen above. Yet for many cases, this will still not be sufficient to effect a complete and corrective re-orientation of the crown. Nevertheless, this should be considered as adequately representing the end of phase 1 and the appliances may then be removed.

Over the following few weeks and months, there is likely to be some minor relapse of the achieved root torque. This will be expressed as a minor reversal movement affecting the tooth axis due to a recoil of the bulging labial periosteum, or to a final and natural increment of apexification of the curved root end. This apparent relapse in the alignment should not be opposed and it should be explained *in advance* to the parent(s), who should be warned that it may occur.

It becomes apparent that, from the orthodontic viewpoint, the problem of root dilaceration represents a considerable challenge. In the young patient, a careful examination of the lateral cephalogram may reveal the shape and orientation of the root, although this will be much more accurately assessed on the cross-sectional cuts of a CT series.

As seen in Case 5 (Figure 6.17), in the very young patient early treatment may favourably alter the shape of the developing root. In older children, the more apical the location of the dilaceration vis-à-vis the coronal third of the root, the better the prognosis. A dilaceration situated apical to the coronal third of the root poses no serious impediment to orthodontic alignment and it should have an excellent prognosis. The crown of the tooth should be surgically exposed and an eyelet bonded to it. As before and in most cases, the only surface of the crown that is available for the eyelet will be the palatal surface. This surface faces the operator when the tooth is first exposed, while the anatomically labial surface of the tooth will be inaccessible, since it will be facing superiorly and posteriorly and will be buried in the hard tissue, adjacent to the anterior nasal spine. A stainless steel ligature is threaded through the eyelet, twisted into a pigtail and drawn downwards, to be ligated with an upward-stretched horizontal elastomeric module or a NiTi main or auxiliary archwire (as described earlier in this chapter and in Chapter 5). Care should be taken initially not to apply too much pressure, since the tension introduced by suturing the surgical flap may itself apply a considerable downward force to the tooth in the first few weeks.

As the tooth responds to the force, the crown will rotate downwards, causing the incisal edge of the tooth to become labially prominent, outlined beneath the oral mucosa on the labial side of the alveolar ridge. At the same time, the root apex will rotate forwards towards the labial plate of bone. For the most part, these cases may be completed without the root apex ever protruding excessively in the labial sulcus.

If the apex becomes prominent and further labial root movement is still desirable, this will indicate earlier apicoectomy. The labially directed portion of the root, corresponding to the post-traumatic developmental portion, will be sectioned in a line that is continuous with the labial side of the main coronal portion of the root of the tooth. The pulp will be extirpated and the root canal obliterated, using a combined conventional (coronal) surgical retrograde endodontic approach (see later Figure 6.19j–n). Further extrusion and appropriate root torqueing of the incisor may necessitate a second root-shortening procedure, but if the first procedure has been delayed as late as possible and the root apex amputation has been properly designed, this will usually be avoided.

The degree to which the final prognosis of the short-rooted central incisor will be compromised depends largely on how much root remains after the amputation has been performed. The site of the amputation is entirely dependent upon the location of the dilaceration and upon whether the amputation has eliminated a majority of the portion of the root apical to it, which developed after the traumatic episode. Thus, the closer the dilaceration is to the coronal portion of the root, the shorter will be the final root length at the completion of treatment and the poorer its prognosis.

Arrested root development

When a very young child suffers a very severe blow to the maxillary anterior dentition, it is likely to result in the loss of the deciduous incisors. At the same time and by transference of the force of the blow to the unerupted permanent incisors, these too may be significantly damaged. The dentine-producing ring of cells that comprises Hertwig's root sheath of the permanent incisors may have been so badly impaired as to have effectively caused disruption to or actual cessation of any further root development. While the adjacent teeth will continue to erupt, bringing with them vertical proliferation of alveolar bone, these teeth may lose their eruption potential. This phenomenon will only be discovered several years later, when the affected tooth or teeth fail to erupt at the appropriate time and a vertically deficient and bucco-lingually narrow, edentulous alveolar ridge becomes evident.

Unlike the contortions produced in the anatomy of the classic dilacerate tooth or in its severely displaced location, radiographs will usually reveal that the tooth has not deviated from a normal axial inclination, nor has it altered its relationship to the sagittal and coronal planes. However, in the vertical plane the tooth will be situated very high up in the premaxilla, with minimal or no root formation, depending on how much root had already developed at the time of the trauma (see later Figure 6.18).

In these cases, the unaffected teeth in both jaws will erupt at the appointed time, with continuation of their normal root development. However, the teeth that were injured in the trauma incident may, in rare cases, display pulp death and sequestration from the surrounding alveolar bone. No treatment will save these teeth and they will eventually need to be extracted.

Two other characteristics of arrestation in root development may affect unerupted teeth. In both cases, the teeth will have lost their natural eruptive potential, despite the fact that both are vital. In the first case, the root apices of the affected teeth are open, but the production of new root dentine has slowed down or has ceased. In the second case, the root apices will have closed prematurely and the tooth is left with very short roots, with no possibility of further root growth.

Faced with these extreme circumstances, OMFSs, orthodontists and paediatric dentists will likely consider these teeth to be unsalvageable and they will advise extraction. However, the answer is not necessarily the same for every case, and each must be considered on its own merits. No decision should be made until the practitioner first considers the following points in relation to the individual patient concerned.

The impacted permanent incisor tooth with a poor prognosis: Extraction

In a growing child, if one or more maxillary permanent incisor teeth are lost, there may be multiple repercussions. Even for a child as young as 8 or 9 years, the loss of an incisor presents disadvantages in terms of function, health, appearance and social interaction with peers.

Loss of the tooth means that the alveolar ridge will resorb considerably and there will be reduction in the height and volume of the alveolar bone in the area. A classic dilacerate tooth is located very high at the junction between skeletal and alveolar bone, so that an alveolar bone deficiency at the crestal bone level that existed before its extraction will become more severe after the extraction. Its labio-lingual width will also atrophy.

Some form of artificial replacement/rehabilitation of the missing tooth/teeth is necessary, but this too is fraught with difficulty. And so, what are the possibilities?

- A tissue-borne removable acrylic ‘flipper’ denture is one possibility, but it is inherently unstable and not something that many children can tolerate. As a consequence, the dentures are frequently removed from the mouth and lost. They may, of course, be stabilized using wrought clasps on the molars and elsewhere, but then they will raise the level of gingival inflammation in the palatal tissue, as well as causing decalcification and caries of the enamel on the lingual side of each tooth with which they come into contact.
- Another possibility is the use of any tooth-borne, resin-bonded (Maryland) bridge replacement, though this may require some invasive preparation of the adjacent teeth and may be unreliable in the long term [47]. It is unlikely that this restoration will remain for more than a few years, and in early adulthood an implant-borne permanent substitute will be

preferred. In addition, the device cannot mask the unsightly void between its cervical margin and the receded area of resorbed alveolar crest.

- An implant-borne artificial replacement is not an option in the young patient, even as a temporary expedient.
- Yet a further possibility is substitution, moving the lateral incisor into the place of the missing central incisor, the canine in place of the lateral incisor and the premolar substituting for the canine [48, 49].
- Autotransplantation of an unerupted premolar is, however, an option that may overcome most of these problems.

When our 8- or 9-year-old child needs orthodontic treatment for the overall malocclusion, the first four options above present a major obstruction to the placement of an orthodontic appliance and the conduct of its treatment. The final option is the only one that, after a period of biological integration and prosthetic modification, could be integrated into the regular orthodontic system. This is because the successfully autotransplanted tooth can respond to orthodontic biomechanics, like a normally erupted tooth. The only problem may be that the patient in need of a transplant for his potential incisor recipient site may not have an available and suitable donor tooth at the appropriate stage of development.

The impacted permanent incisor tooth with a poor prognosis: Eruptive rehabilitation and alveolar ridge restoration

If, instead of extraction, the damaged or anomalous tooth undergoes orthodontic extrusion and alignment to resolve its impaction, it will bring with it much alveolar bone, which will augment both ridge width and vertical height of the alveolus to normal dimensions.

The original trauma may have destroyed the natural eruptive potential of the teeth, which may have been left with their roots close to the nasal floor, without treatment. This is unquestionably a recipe for stunted root growth. If, however, these teeth have a normal periodontium and are supplied with an external, artificial eruptive substitute for their lost eruptive potential (i.e. orthodontic traction), perhaps they may now be drawn down towards their intended place in the line of the arch. We have found that, provided they still have open apices, orthodontic traction will also stimulate the open-ended root apices to generate new root growth. This experience has given us reason to believe they may be coaxed to erupt and then to develop spindly but functional roots in their new erupted locations, free from restrictive anatomical barriers (the nasal floor). This being so, there is hope for an improved prognosis, which may offer them a reasonable short- to medium-term span of useful and functional life. With suitable restorative enhancement of their crowns, these rescued teeth may then often be maintained well into the second and, sometimes, the third decade of life.

The short- to medium-term aim of the orthodontic treatment seeks to exploit the patient's own developmentally or cariously compromised natural tooth and to provide a temporary restoration, effective during the adolescent growth period. If this succeeds in being retained until the patient reaches majority, a definitive prosthodontic solution may be chosen in more favourable circumstances.

If this policy is adopted, the patient will benefit from the best provisional restoration (the patient's tooth itself) during his childhood and adolescent growth periods, as a unit independent of the other teeth in the dentition. The patient's mouth will not be cluttered with acrylic plates and wires. Healthy teeth will not have to undergo irreversible invasive procedures to prepare them as abutments. The provisional natural tooth can usually be enhanced prosthodontically to become an integral part of a good display of the maxillary anterior teeth and of the patient's happy smile. Indeed, bringing the impacted tooth into the arch provides an investment for the future, since an enhanced alveolar bone infrastructure will accompany the aided eruption of the tooth, as opposed to bone resorption that would accompany its extraction. This will materially assist in providing a solid base for an eventual implant, when the tooth finally fails.

For all these reasons, orthodontic alignment of an impacted and damaged tooth with a poor prognosis is to be preferred over a policy of extraction. For the most part, however, this procedure must be viewed as providing only a temporary solution that will hopefully last throughout the adolescent growth period. Once growth has ceased and conditions are more favourable, some form of permanent restoration will need to be considered. In the meantime, this decision will have been made much easier and will include a wider choice of prosthodontic modality options. The result will be much more satisfactory in the long term because of the enhancement of the bony ridge that will have accompanied the eruption and retention of the damaged tooth.

Case 6.6: Resolving the impaction of a severely damaged central incisor with a closed apex and a poor prognosis, for use as a provisional replacement in the medium to long term

A 7.4-year-old girl was brought to the orthodontist, having been referred by a paediatric dentist to investigate and treat her unerupted left central incisor. Several months earlier, the right central incisor had erupted and, at the time of examination, the right lateral incisor had just emerged through the gingiva. The left deciduous central incisor had been extracted some months previously. *There was no sign of the left central incisor*. The row of teeth on the left side included all the remaining deciduous teeth, as well as the first permanent molar. The alveolar ridge was very thin in the edentulous area and palpation revealed two small protuberances high under the mucosa, covering the labial vestibule, adjacent to the midline. There was a history of severe trauma at age 3 years, although diagnosis of the relevance of this trauma was only made at age 7.4 years, following the failure of the tooth to appear.

Routine radiographs were performed (Figure 6.18a–c**)** and then were followed up with a CBCT (Figure 6.18d). A periapical view of the unerupted left central incisor (#21) showed a wide vertical discrepancy compared with the erupting right incisor. The downward migration of the late-developing lateral incisor (#22) had also created a large vertical discrepancy between it and the compromised central incisor of the same side. The lateral incisor could be seen inferiorly located, tipping mesially into the eruption path of the central incisor and more advanced in terms of its eruption status. On this film, the unerupted central incisor showed little or no root development and there was neither a root end papilla nor a broad diverging root canal, which are the characteristics of an open and developing apex, as seen on the lateral incisor (Figure 6.18b, c). The panoramic view and cephalogram showed the incisor to be close to the floor of the nose, although its crown orientation was normal. In addition to confirmation of location, the CBCT cross-sectional slices of the affected incisor show a sharp crown–root angle, with the superior/labial aspect of the root lying parallel to the line of the floor of the nose. This demarcation line was considered to be the likely location where the acute traumatic episode had caused cessation of crown formation, where the minimal root development was almost at a right angle to the general orientation of the crown. It was in close relation to, and likely dictated by, its relationship to the plane of the floor of the nose.

The CBCT also revealed that the impacted left central incisor had marginally more root substance than had been apparent from the planar films, although this was still very minimal. The 3D view of the anterior dentition showed the significant height difference between the two central incisors and the extent to which the small left lateral incisor was migrating downwards and mesially under the central incisor.

Once again, the question had to be asked whether an orthodontic response to extrusive forces could be elicited from a severely traumatized tooth, with a prematurely apexified and short root, a large hypoplastic crown–root defect, which was located about 15 mm higher than its desired location adjacent to the floor of the nose. And further whether, in the event of a successful response, such a tooth would be sustainable for 10–12 years, to last into young adulthood in terms of health, function and appearance and to reach the stage when a successful artificial replacement could be considered.

One aspect, however, was of some certainty: it was reasonable to expect that if a biomechanically generated eruption of the tooth could be successfully navigated, it would bring with it a substantial amount of alveolar bone, which would then enhance the prognosis of the eventual placement of an artificial implant-borne replacement for both the tooth and the ridge.

In considering these questions, one must consider the alternatives, in relation to this particular patient. The initial situation exhibited a markedly atrophied alveolar ridge, both in width and in height. Extraction of the impacted tooth would have reduced this still further. The lateral incisor was very small, peg-shaped, with a narrow cemento-enamel junction (CEJ) cross-sectional area. Accordingly, this could not be a candidate for its movement into the central incisor location for later prosthodontic enlargement. In addition, as far as a 7.4-year-old child is concerned, implants cannot be considered as a line of treatment for the next 10–12 years. Thus, a series of temporary solutions would be needed, individually adapted to the stages of the developing dentition, during the transition from a deciduous to a permanent dentition.

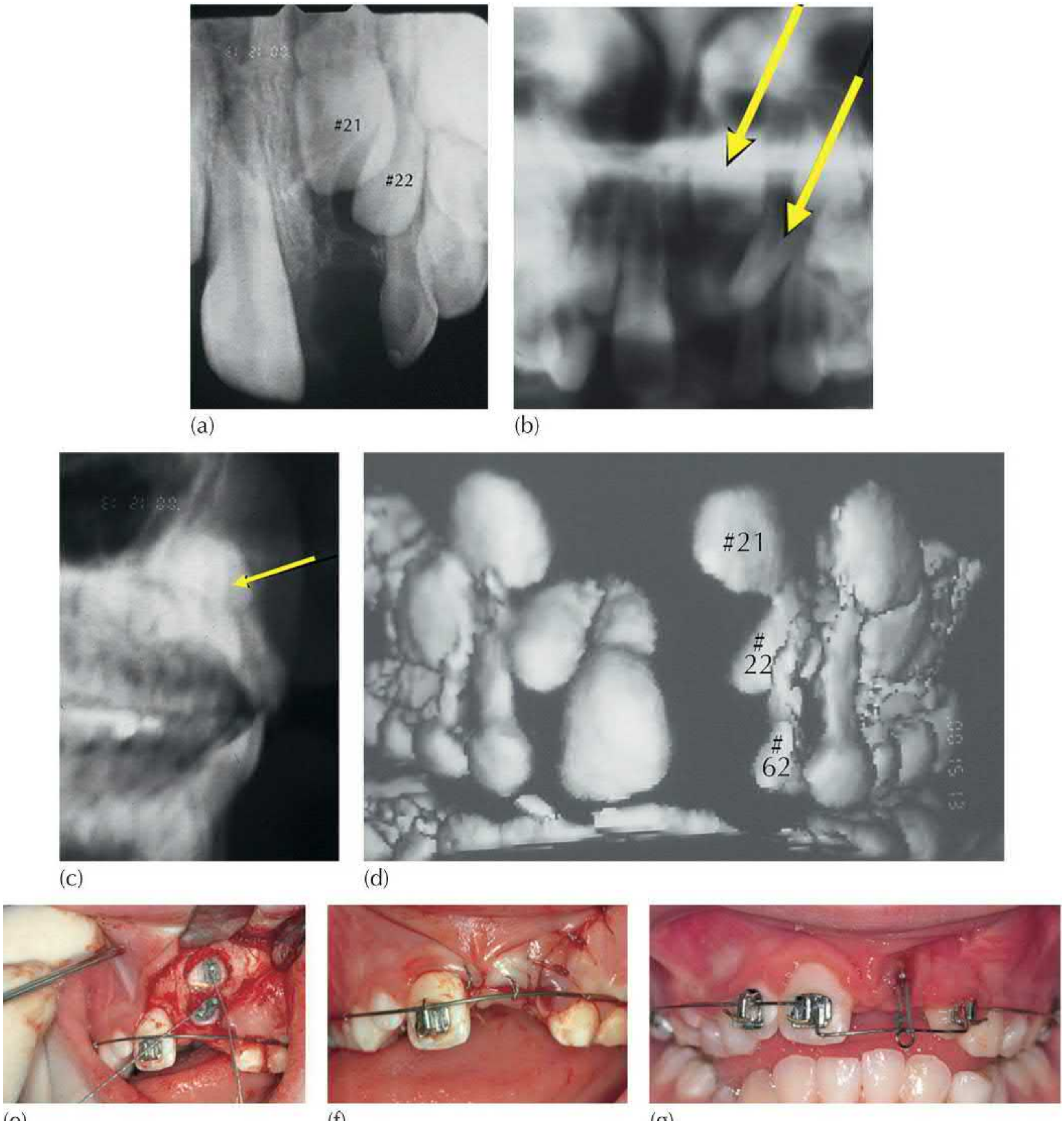
These considerations and assessments were explained and discussed with the parent, together with an explanation of the principal unknown factor: what would be the response to attempted forced eruption and what would be the long-term prognosis of a successful outcome. At these discussions, the parent had also been presented with the important aspect of the potential benefits for the child. In the event, the parent considered the two alternatives and opted for the treatment that would aim to resolve the impaction of the incisor tooth.

As in the previous cases described, a 2 × 4 type of appliance was placed and a composite labial arch (Johnson twin-wire arch) comprising an anterior stainless steel spring hard, round 0.016 in. gauge wire was friction-fitted into the long 0.020 in. side tubes, which, in turn, were slotted into the 0.036 in. soldered round tubes on the molars.

Surgical exposure was performed (under general anaesthesia), with a full attached gingiva, labial flap, taken from the crest of the ridge. This needed to be reflected up to the full height of the vestibule in order to expose enough of the crown of the central incisor to provide an adequate enamel surface for the bonding of an eyelet attachment. At the same time, an eyelet was also bonded on the lateral incisor, whose eruption path had taken it in a mesially directed line, causing a potential impediment to the eruption path of the central incisor. The deciduous lateral incisor was also extracted. The twisted stainless steel pigtail ligatures exited the surgical scene through the sutured edges of the labial flap, to complete the closed surgical procedure. These ligatures were separated and labelled, for subsequent identification in the orthodontic environment.

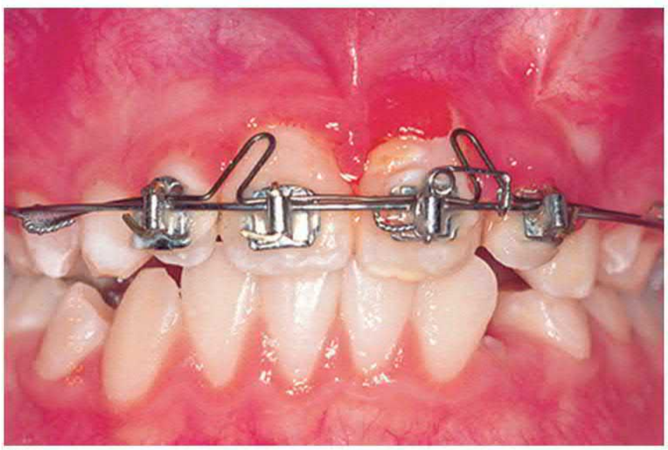
At the end of the surgical procedure, the compound archwire was replaced in the molar tubes and ligated into the bracket on the single erupted anterior permanent incisor, making it a '2 × 1' appliance (Figure 6.18e–g) and illustrating its versatility in this type of phase 1 clinical scenario. The pigtail ligature, which belonged to the central incisor, was free and unattached to the archwire, while light extrusive force was applied to the lateral incisor by raising the labial archwire and turning the twisted pigtail ligature connector around it, to hold it in this upward flexed position.

In the months that followed, the lateral incisor responded well. It erupted quite quickly and was then tipped distally using an open-coil spring, to provide space for the central incisor. By the time space had been re-opened, orthodontic brackets were placed on both lateral incisors. Through the agency of the twisted ligature that belonged to the impacted tooth, a similar eruptive force was applied to the central incisor from the flexed archwire (Figure 6.18h, i). The impaired central incisor responded well. The follow-up radiograph (Figure 6.18i) revealed a mesial hypoplastic/resorptive lesion at the area of the sharp crown–root angle of the tooth, which had apparently been caused by the traumatic episode so many years earlier.




(h)


(i)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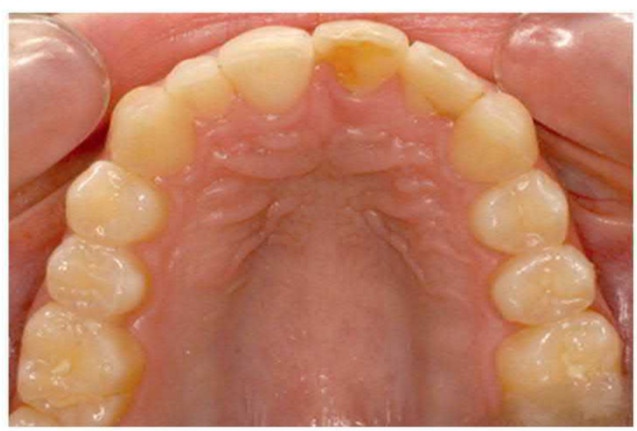
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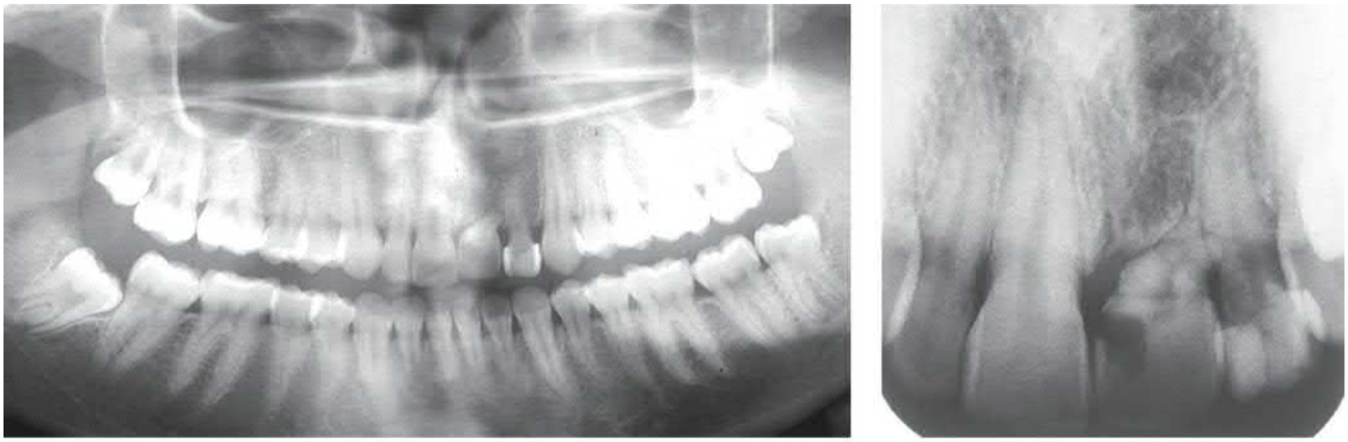


(n) (o)

Fig. 6.18 (a, b) The initial diagnostic periapical radiograph and anterior section of the panoramic view (arrows), at age 7.4 years. (c, d) The anterior section of the cephalogram and a 3D screenshot of the teeth from a video clip. (e) Surgical exposure and eyelet attachment bonding of the two left maxillary incisors. Note the archwire lying above the Begg bracket. (f) Flap re-sutured to its former place with only the lateral incisor ligature hook engaging the archwire. The central incisor ligature hook was unconnected. The archwire was engaged in the bracket, applying extrusive force. (g) Space re-opened, lateral incisors bracketed and force applied to the central incisor connector. (h) Periapical radiographic follow-up of the extrusion of the teeth. The immediate post-surgical radiograph shows eyelet attachments bonded to the two left incisors, each with a twisted pigtail connector. The connector belonging to the central incisor is unconnected to the system. The lateral incisor twisted ligature is activated by drawing its hooked end directly to the archwire, under tension. (i) The lateral incisor has been erupted and moved distally to create space, using a coil spring. This has permitted active traction to be applied to the central incisor. (j) Conclusion of phase 1 treatment at age 8.6 years. Final alignment of the long axis of the incisor with distal uprighting and lingual torqueing auxiliaries in place. (k) After debracketing. Note that the mesio-labial hypoplastic crown–root/resorptive defect had remained unaltered. (l) At three years post treatment, with night-time use of a removable acrylic retainer. Mild infra-occlusion of tooth #21. (m) Periodontal lesion still present and lingual encroachment of gingival tissue into resorption defect. (n, o) The root of #21 has not shortened further and no resorption is evident. The healthy and substantial bony trabeculation pattern will provide an excellent matrix for the future implant.

Once the central incisor had reached its place in the arch, a considerable degree of distal uprighting and lingual root torque was needed and this was accomplished by applying torqueing auxiliaries (Figure 6.18j). When adequate alignment had been achieved, the appliance was removed and the child was placed on six-monthly review, with no retaining devices. Phase 1 had been completed successfully and provided the child with front teeth that, in terms of appearance, were a great improvement, but less than ideal. On the other hand, she was now arguably socially undifferentiated from the majority of her untreated, pre-orthodontic classmates. As expected, the fully erupted central incisor possessed only the shortest root, which had not developed further, because the apex had been fully closed before the treatment started.

The duration of the phase 1 treatment was 14 months and was completed when the child was 8.6 years of age (Figure 6.18k). The child had indeed been provided with a front tooth, but the periodontal condition of its labial side was marred by the gingivally sited hypoplastic junction of the incompletely formed crown and its right-angled dilaceration. Oral hygiene had been poor during her treatment and a degree of chronic inflammation, with bleeding on probing, was present for most of the time. A periapical view of the erstwhile impacted incisor showed a thickened lamina dura and an asymptomatic radiolucent area at the CEJ of the tooth, which appeared to be external resorption.

At age 11.1 years, the full permanent dentition was established and there was slight positional deterioration in the alignment of the incisor, while its periodontal condition had remained unaltered. Although the hypoplastic junction of the incompletely formed crown had not changed, the area of external resorption was slightly larger, while remaining asymptomatic.

Phase 2 orthodontics was performed at age 14 years, took 13 months to complete and the peg-shaped left lateral incisor was then crowned to increase its size and improve its form. Thereafter periodic radiographic follow-up was instituted, until the patient reached the age of 18 years (Figure 6.18l–o). The central incisor was still in place, but had become mildly infra-occluded. Its hypoplastic lesion remained unaltered, although the colour of the tooth had deteriorated. The periapical radiograph showed further external resorption. The time had finally come for prosthodontic treatment. The patient was referred for extraction and implant rehabilitation of the tooth, which had served well as an admirable 'autogenous space maintainer' throughout her childhood and adolescent growth period. Its added value lay in the quantity and quality of the new alveolar bone that it had brought with it during the assisted eruption and the period of maturation, which had improved since the completion of the treatment.

Let us consider what was achieved for this patient. On her initial appointment she had been diagnosed with an impacted central incisor and it was noted as follows:

- It had been severely damaged by early trauma, with no hope of improving the length of its extremely short root.
- The root was dilacerate and externally resorbed.
- The root apex was prematurely closed.
- The anatomical form was compromised.
- It was dislocated a great distance from its desired location.
- Extraction was indicated, due to its very poor prognosis in terms of ever bringing it into alignment satisfactorily, its suitability for prosthodontic rehabilitation and its expected durability.

In the place of this severely compromised situation, the treatment provided gave the patient the following advantages:

- The tooth was erupted into the oral environment.
- It was brought to its place and into a fair alignment, adequate for a young pre-orthodontic child.
- The patient's *appearance* was enhanced.
- She had the best provisional restoration (her own tooth) through the adolescent growth spurt, until it could be satisfactorily replaced in young adulthood.
- The *health* of the adjacent teeth had not been compromised by iatrogenic 'prepping' for temporary or permanent fixed prosthodontic rehabilitation, which was avoided.
- The adjacent teeth had not been periodontally compromised, neither by the presence of temporary artificial tooth-bearing nor by tissue-bearing removable plates.
- Above all, there was an *investment in the future* insofar as an alveolar bone infrastructure had been created for the benefit of restoring a well-contoured alveolar ridge, which became ready

and suited to accept an implant-borne restoration.

Severe trauma causing arrested root development, with open root apices and non-eruption of four maxillary incisors

This is perhaps the type of case that has it all. Severe trauma to the anterior maxilla at a very young age is likely to damage Hertwig's root sheath. As a result, the output of root dentine will have been adversely affected, either temporarily or permanently. If the tooth remains vital but does not recover sufficiently, the further development of the root will cease and, with it, the eruption potential of the tooth itself will be lost. In such cases and depending on just how young the child was at the time, the incisor will stay in its embryonic location, high in the basal bone of the maxilla and immediately under the floor of the nose. It will not grow down, with subsequent alveolar bone growth failure.

Once again, questions need to be asked. This time, however, the desired answers to these questions could offer far-reaching, pervasive therapeutic opportunities. These questions are as follows:

- Can an orthodontic response to extrusive forces be elicited from a severely traumatized but vital tooth, with open apices and no significant root, located about 15 mm higher than its desired location, immediately under the floor of the nose?
- In the event of a successful response to extrusive forces, will the extrusion bring with it new alveolar bone?
- Can the tooth be expected to grow an adequately substantial root?
- Can such a tooth be sustainable for 10–12 years into young adulthood in terms of health, function and appearance and reach the third decade of life, before which a definitive artificial replacement cannot be considered a treatment option?

There is little to be found in the literature to support positive answers to these questions. It is a tall order! However, in such extreme circumstances, there may be little to be lost in trying. After all, the alternative (and indeed the default) is extraction, with all the negative aspects of alveolar bone resorption and unsatisfactory temporary prosthodontic rehabilitation, in an evolving and constantly changing dentition. In the event, empirical clinical experience is all that we have to offer the patient.

Case 6.7: Resolving the impaction of severely damaged central and lateral incisors with open apices and poor prognoses, for use as provisional replacements in the medium to long term

A very young child of 2.7 years of age was wearing protective headgear when he crashed the plastic buggy/cart he was riding in April 2014. He lost three maxillary deciduous incisors and suffered severe lip laceration and a horizontal dentoalveolar fracture (partial Le Fort I). The lacerations were sutured and the fracture was treated conservatively. Following immediate and follow-up treatment, attention turned to attempting to assess the damage to the unerupted developing permanent teeth.

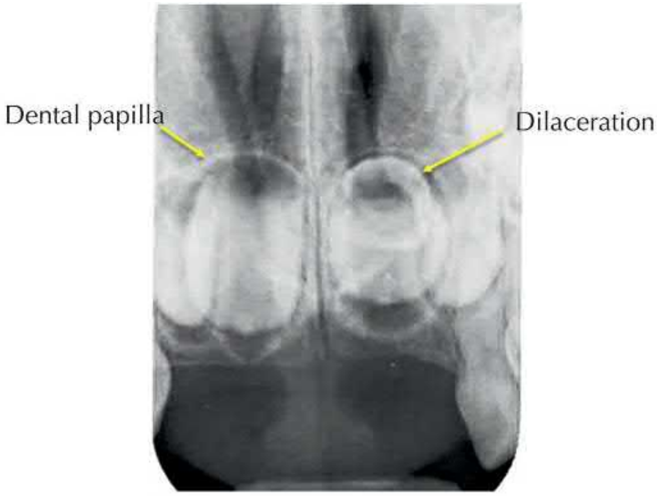
The periapical radiographs of the anterior maxilla, as would be expected at the time, revealed only the very earliest calcification of the permanent incisor tooth buds. These radiographs were combed for signs of abnormalities in their growth. It was noted that the crown of the left maxillary central incisor had become dilacerate, while the post-trauma continuation of enamel and dentine was continuing at a 90° angle to the pre-trauma portion. The radiograph showed the normally oriented developing adjacent incisors with an enlarged apical papilla, while the left central incisor showed a complete ring of dentine, encircling an enlarged pulp. This indicated that the crown and root were growing at a different angle, with the root being in a direct line with the line-up of the X-ray tube.

All four incisors were still located high in the maxilla, in close proximity to the floor of the nose and the line of the earlier horizontal fracture. There had been no progress in their downward migration and clearly no chance of normal eruption. Additionally, while the molar relations were quite normal, the premaxillary area was noticeably lacking in its forward development. The mandibular incisors were labially tipped and a fairly strong class III tendency was apparent, which was reflected in the relative protrusion of the child's lower lip and facial profile (Figure 6.19c, d).

In November 2018, the boy had reached the age of 7.1 years and the parents (the mother herself a senior OMFS) approached the author regarding the advisability and feasibility of actively erupting the impacted incisors. A CBCT examination was performed (Figure 6.19e, f), with the intention to evaluate the root lengths of the incisors, determine the orientation of each and assess the degree, as well as the direction and viability, of the dilacerate left central incisor.

The principles of treatment of these severe trauma cases are similar in nature to the treatment of the patients discussed earlier, but clearly in trauma cases, when all four incisors are affected, modification of the labial arch mechanism will be needed. Since there were no orthodontic brackets in the beginning, one might be tempted to call this a 2 × 0, heavily modified Johnson twin-wire appliance. When the four incisors need to be erupted vertically downwards, there is much greater dependence required on molar anchorage. The same basic part of the appliance, with palatal arch soldered to molar bands, is cemented into place before the surgical exposure is performed. However, an acrylic (Nance) button on the soldered palatal arch should be considered mandatory. Care should be taken that the acrylic button is not brought too far into the anterior palatal area, since this would interfere with the surgeon's flap design. Allowance must also be made to accommodate potential post-surgical swelling, which, if not taken into account, would be very painful for the patient and would compromise the healing process.

In the present context, a heavy self-supporting round steel archwire of 0.036 in. gauge was prepared and slotted into soldered 0.036 in. round tubes on the molar bands. It was held at a minimal 2–3 mm distance, labial to the line of the arch, with bayonet bend stops at the molar tubes (Figure 6.19g).



(a)

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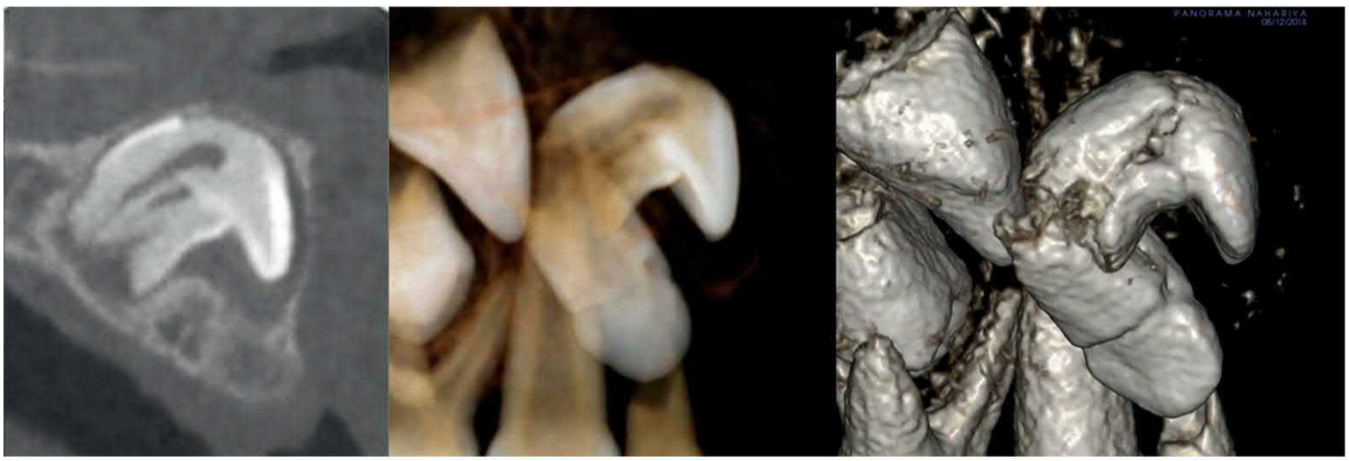

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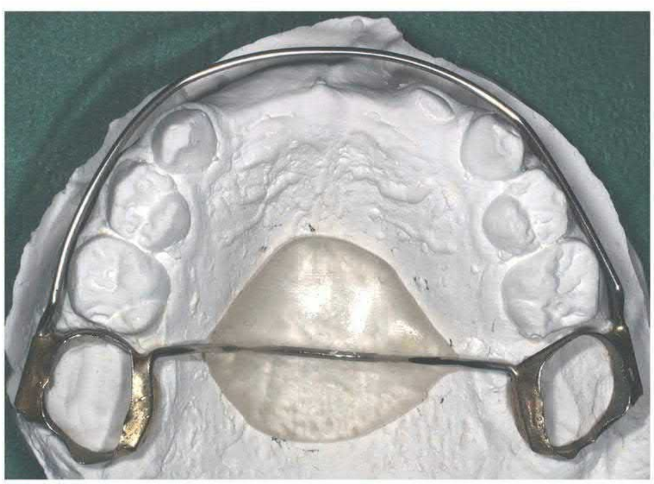
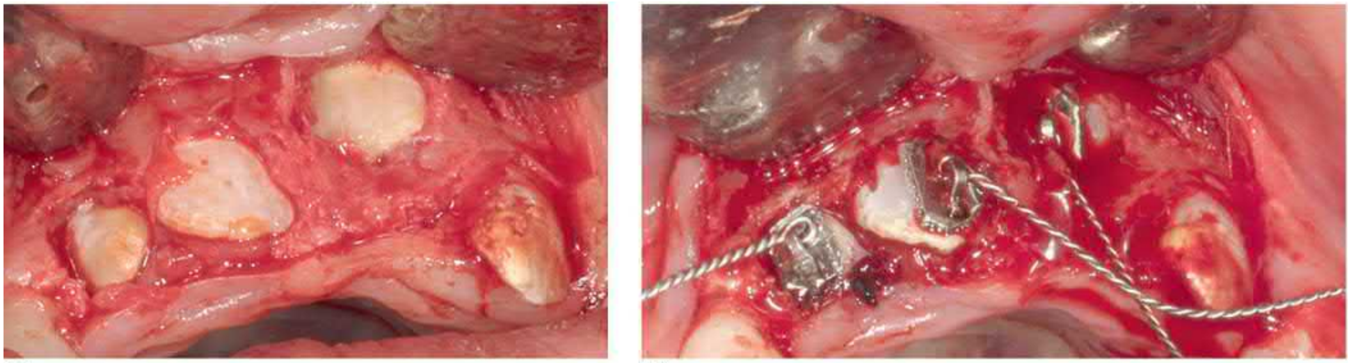
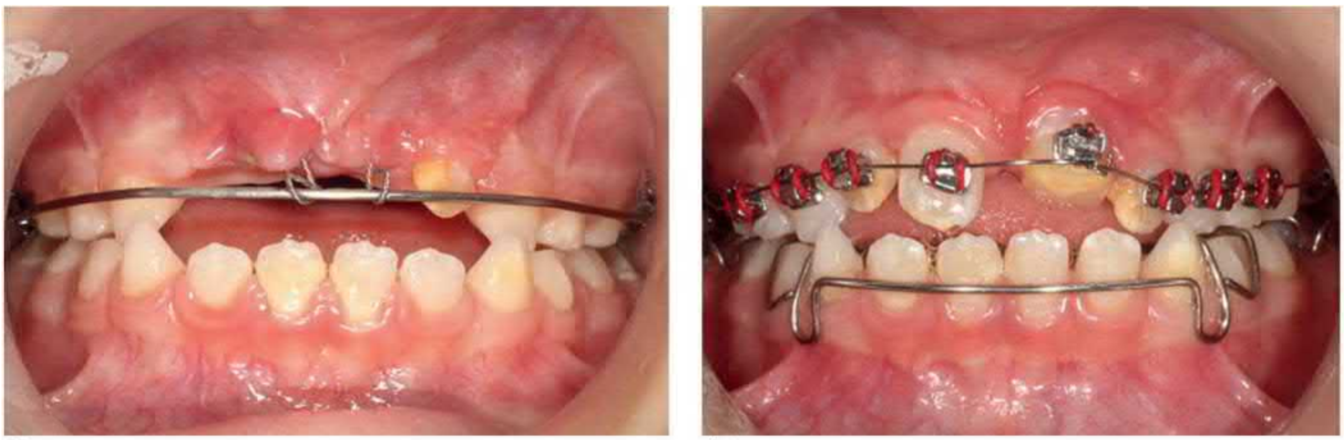


(g)



(h) (i)



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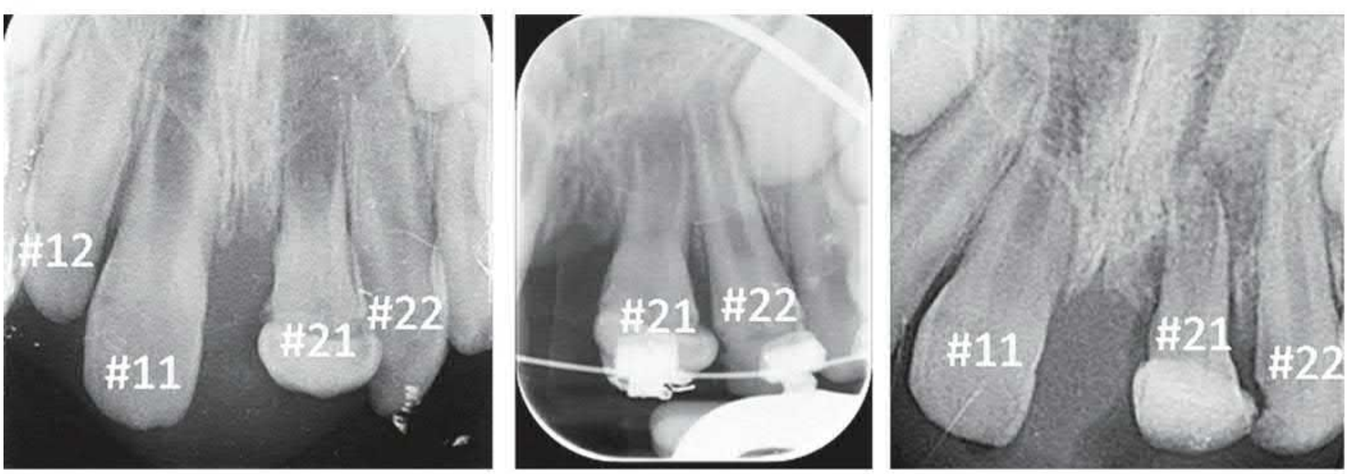
(l)



(m) (n) (o)

Fig. 6.19 (a) A periapical radiograph showing partially completed crown development of the four incisors and the beginnings of lingual dilaceration of the left central incisor. Note the complete ring of thin crown enamel of the left central incisor, showing horizontal alteration (dilaceration) of root growth. (b) Note the class III skeletal and soft tissue profile, the proclination of the mandibular incisors and the height of the impacted incisors. (c) Panoramic view of the dentition illustrating the height of the incisors vis-à-vis the floor of the nose and the anterior nasal spine. (d) March 2019 and age 7.4 years. Pre-treatment intra-oral views of the teeth in occlusion. (e) A 3D screen shot of the arrangement of the incisors, their height, their individual root lengths and their orientation, particularly of the left central incisor. (f) The dilacerate central incisor crown is imaged in the form of a cross-sectional slice, a transparent and a hard tissue 3D screen shot, to show its convoluted and invaginated composition. (g) The 2 × 0 appliance, showing molar bands with soldered transpalatal arch and acrylic (Nance) button. The heavy labial arch is held away from the anterior teeth by the bayonet bends that slot into the round molar tubes. (h, i) Surgical exposure and eyelet bonding. Surgery by Dr Eran Regev. (j) Full closure and sutured surgical flaps with twisted steel connector wires from the bonded eyelets bonded to the impacted central incisors, in a closed eruption exposure procedure, engaging the gently raised anterior area of the heavy labial wire. (k) Once the incisors had erupted, regular Tip-Edge brackets were substituted for the eyelets. (l) The completed phase 1 treatment in November 2020, when the child was aged 9.1 years. Post-orthodontic follow-up periapical radiographs, taken (m) in January 2020, (n) in July 2020 and (o) in March 2021. Considerable progress towards closure of the apices of #11, #12 and #22 is seen in these 14 months, together with an increase in the width and form of their roots. The more seriously damaged central incisor #21 shows a very wide and open apex, with minimal increase in length, thin walls and rarefied periapical bone pattern.

All four impacted incisors were then exposed in a closed surgical exposure procedure. An eyelet was bonded to each of them, with the pigtail ligatures directed through the sutured edges of the replaced surgical flap. The anterior portion of the heavy labial arch was raised with gentle finger pressure and ensnared by the four pigtail ligatures, either individually or together, thereby applying as light an extrusive force as desired to these four unerupted teeth. As the teeth began to move downwards, the length of twisted steel ligature that exited the attached mucosa covering the ridge increased until the extrusive force was spent. Activation was then renewed by shortening the twisted ligature wires and bending each of them into a new hook more superiorly and, once again, raising the labial arch. A simple mandibular removable appliance was used to reduce the incisor proclination in the lower jaw.

Following the traumatic incident at age 2.7 years, the maxillary left central incisor grew to be L-shaped (Figure 6.19f). The root end lengthened horizontally in a posterior direction, while the crown portion was found to be vertical and in line with the other incisor teeth. For this tooth to be viable, it had to be labially root-torqued to bring the root into a vertical position within the alveolar process. It follows that the crown portion would then become horizontal and point posteriorly.

The duration of this active phase 1 treatment was 18 months and was completed shortly after the child's 9th birthday, when the appliances were removed. No retention appliance was placed in the maxilla. Only the mandibular removable appliance continues to be worn at night, as a retainer against possible relapse of proclination of the mandibular incisors.

The future treatment planned for the left central incisor is first to await the maximum degree of root completion achievable. It will then be subjected to endodontic treatment, to amputation of its incisal pre-dilacerate part and reconstruction of an ideal shape, by prosthodontic crown rehabilitation.

It is possible that a severe traumatic episode, such as witnessed here and which had originally caused the early developing incisor teeth to lose their eruptive potential, may lead to a situation where one or more of these teeth may not respond to the orthodontically applied extrusive forces. In such an eventuality, none of the teeth would respond because a single tooth that fails to respond (due to ankylosis, loss of PDL integrity, etc.) will prevent the archwire from exercising its extrusive potential on all the others. In order to avoid this, it is essential to identify which of the teeth is/are unresponsive. A careful examination of the radiographs or a percussion test may indicate the one that is to blame. If nothing untoward is discernible on the radiographs, then the orthodontist will need to resort to disconnecting each of the hooked ligatures in turn and thereby identify, in the weeks that follow, whether or not the same extrusive force is left to continue to work on the others.

In these trauma cases, teeth that have not been offered orthodontic extrusion will remain in their existing location with vital open apices for several years after their due apexification dates, often without developing more root substance. However, when drawn downwards in an appliance-driven extrusive orthodontic system, these vital teeth will erupt, bringing alveolar bone with them. For the most part, they will also remain vital and will develop long, slender roots, with root apices that will eventually close.

It is good practice, at the completion of this phase of early treatment, to reassess the general orthodontic condition for additional elements that may compromise the patient's overall malocclusion. For the most part, however, the appliance should be removed and the patient placed on recall over a period of several years, until the eruption of the full permanent dentition. At that time, a new clinical assessment is made and an overall treatment plan developed for the entire dentition. In the meantime, as discussed earlier, the night-time wear of a simple removable retaining appliance may occasionally be advised, but in general this should be avoided as far as possible. However, maintaining alignment is not usually a major issue, nor should it be of any concern, since the newly erupted teeth will not undergo vertical re-impaction. The orthodontist should consider whether, in due course, retention would negatively influence the normal eruptive progress of the permanent canines. Delaying further treatment affords the orthodontist the opportunity to monitor the survival and progress of the erstwhile impacted tooth (or teeth) and to predict their long-term prognosis with greater reliability. This is a wise precaution before committing to overall orthodontic treatment that may often require taking irreversible steps (such as extractions).

Case 6.8: Resolving the impaction of severely damaged central and lateral incisors with open apices and a poor prognosis, for use as a provisional replacement, in a case with high caries incidence

This patient first attended the orthodontist at age 9 years, having lost alveolar bone height following traumatic avulsion of his anterior deciduous teeth from an accident at age 2 years (Figure 6.20a). Since that time, he had remained without anterior teeth. He was in the early mixed-dentition stage, presenting all four first permanent molars and the four mandibular incisors, while the remainder were all deciduous teeth. His caries incidence was high, with dental therapeutic experience involving the provision of amalgam restorations in the right maxillary and left mandibular first deciduous molars. Several deciduous teeth had already been extracted. He was instructed in the basics of oral hygiene and, once this showed appropriate results, treatment was commenced.

The panoramic radiograph taken at that time (Figure 6.20b) showed all the permanent teeth present in early developmental stages, the maxillary central incisors being displaced very high in the premaxilla, at the level of the floor of the nose, on either side of the anterior nasal spine. Discounting the obviously damaged and retardedly developed incisors, the overall dental age of the patient was approximately 7–8 years.

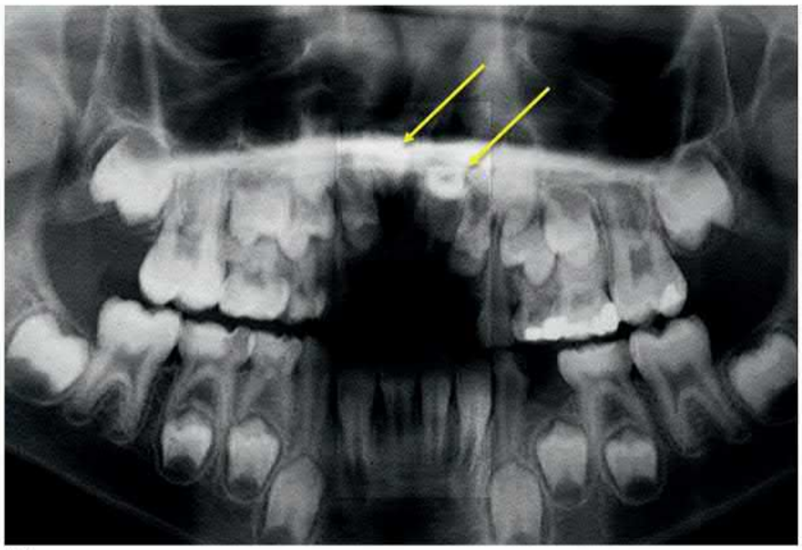
Unerupted maxillary central and, to a lesser extent, lateral incisors could be seen on the lateral cephalogram showing arrested root development (Figure 6.20c). The degree of calcification of these teeth matched that of a 3-year-old child, six years younger than his chronological age and approximately five years younger than his dental age. Better imaging of the teeth would have been helpful, but the patient was treated in the 1980s, well before CBCT was in clinical use.

Prior to the surgery, molar bands carrying a soldered palatal bar were placed and a removable self-supporting, 0.036 in. round stainless steel stopped arch was prepared for placement in the round 0.036 in. buccal tubes. The patient was referred for surgery, which was performed under general anaesthesia, in hospital theatre conditions.

The incisors were exposed with a labial approach (Figure 6.20d–f), using a full-flap design with a horizontal initial cut along the crest of the ridge and two vertical cuts distal to the deciduous canines up into the height of the labial vestibulum. The flap of attached gingiva was reflected superiorly to expose the labial side of the four teeth to about two-thirds of their crown height, with no attempt being made to clear the follicular tissue cover from the unexposed cervicular third of the tooth. Each of these incisor teeth showed hypoplastic patches on the crowns. Eyelet attachments were then bonded by the orthodontist, with the surgeon maintaining moisture control.

The surgical flap was re-sutured back to its former place to complete the closed procedure, leaving the four twisted steel ligatures from the eyelets to exit the surgical area at its sutured inferior edge.

(a)



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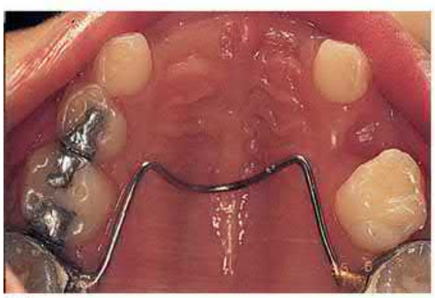

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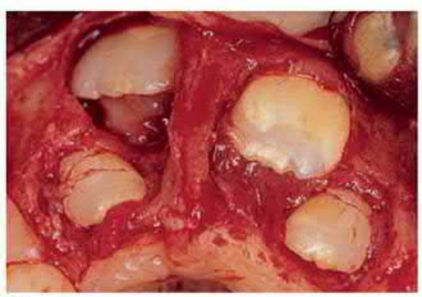

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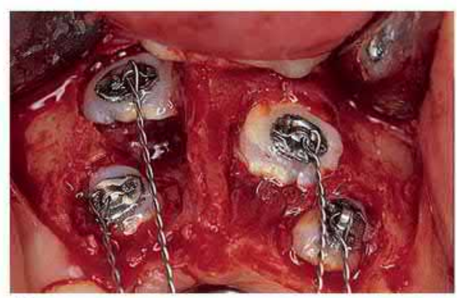

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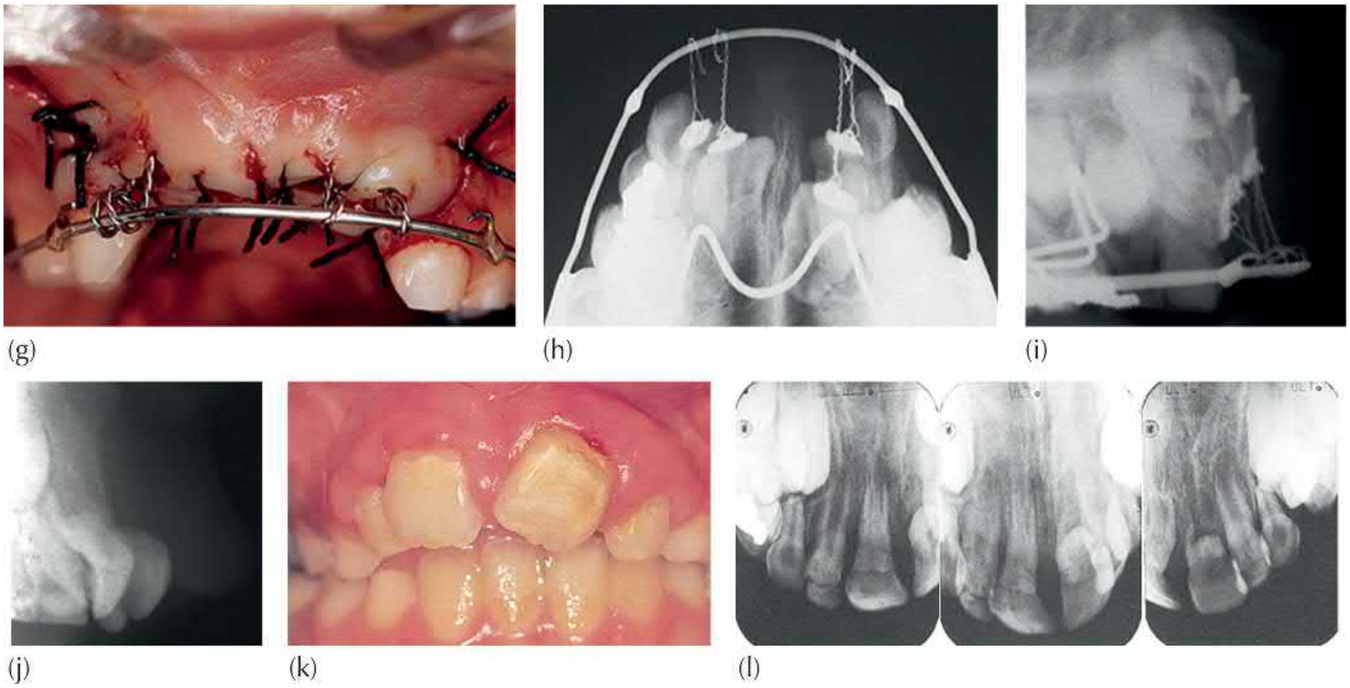

Fig. 6.20 (a) A 9-year-old child has lost alveolar bone height following traumatic avulsion of his anterior deciduous teeth at age 2 years. (b, c) At 9 years of age, the panoramic and lateral cephalograms show very little root development of all maxillary incisors. The central incisors were located at the level of the anterior nasal spine (arrows). (d) Occlusal view of soldered palatal arch. (e) Surgical exposure of the four incisors (note the large areas of hypoplastic enamel). (f) Eyelet attachments bonded. (g–i) The clinical intra-oral and radiographic occlusal and tangential views of the post-surgical condition, showing four twisted ligatures exiting the inferior edge of the fully replaced flap and engaged with the self-supporting labial arch. (j) Radiographic tangential (profile) view across the anterior maxilla, showing the altered developmental anatomy of the damaged teeth. (k) Clinical view of the anterior teeth at the end of phase 1, deliberately excluding mesial uprighting of tooth #21 because it had not developed a root. (l) Long spindly roots developed in three of the previously rootless incisors. The left central incisor fully responded to the extrusion, but had not developed a root.

Still in the operating theatre, the orthodontist then replaced the labial arch in the molar tubes and, while gently raising its anterior part, hooked the four pigtail ligatures around it to hold it in its vertically flexed position, thereby providing extrusive force to the four incisors. Clinical photographs were taken at the time and a lateral cephalogram and anterior occlusal radiographs were performed 24 hours post surgery, showing the considerable distance that these teeth needed to travel to reach the occlusal level (Figure 6.20g–i).

Over the succeeding months, the child attended the orthodontic office at 3–4-week intervals to re-activate the self-supporting archwire at each visit, by rolling up the ligatures close to the ridge mucosa and ensnaring them again over the raised archwire. As the teeth came down vertically, they were advanced labially to create a normal anterior archform and to provide space for their alignment (Fig. 6.20j–l).

This phase 1 treatment was completed nine months later, with all four incisors fully erupted and close to normal intermaxillary relations. The periapical radiographs of the incisors at the completion of this phase 1 mechano-therapeutic procedure show long and narrow roots, clearly indicating the rapid growth of the roots of three of these teeth, with their apices still open and offering the distinct possibility of further root growth (Figure 6.20l). In contrast, the root of the left central incisor showed no apparent growth, although it was not overly mobile. Nevertheless, the decision of whether to upright the tooth was left until the time for phase 2, together with all other tasks, to be addressed in the full permanent dentition.

The case was de-bonded and the child released to three-monthly and then six-monthly follow-up, without the need for retainers. The remaining deciduous teeth were allowed to shed normally, with no planned renewal of orthodontic treatment until the establishment of the permanent dentition, when it would once again be considered.

Unfortunately, the child was hyperactive, reckless and frequently involved in scraps and fights at school. The upshot of one particularly damaging incident was the loss of the two maxillary central incisors at the stage when the second orthodontic phase of treatment was due to begin.

Nevertheless, and while it is now regrettably impossible to offer follow-up records of this particular patient, this case and the earlier case presentations provide excellent exemplification of how orthodontic treatment may be used to exploit and maximize the potential for root development in trauma-damaged teeth with open apices. Due to the original traumatic episode, the teeth had lost their eruption potential and the ability to grow roots and it would be reasonable to assume that, without this intervention, the teeth would have been completely lost, together with the potential for growth of accompanying alveolar bone. The opportunity to develop alveolar ridges, with the promise of providing a suitable foundation for implant-based oral rehabilitation, would have been squandered.

Postscript

The post-treatment prognosis of the impacted tooth points to several factors, discussed in this section, specifically in regard to the following.

Root length

For teeth whose impaction is due to obstruction, the root length is usually normal, although in some cases it may be adversely influenced by the cramped circumstances in which the root developed *prior to* the treatment. Nevertheless, mild shortening of the root will not normally adversely affect prognosis.

Surgical exposure

Treatment that involves surgical exposure down to and sometimes beyond the CEJ, with complete removal of the follicle, is excessively radical. Such treatment will be harmful and will inevitably have a long-term debilitating effect on the periodontium. Despite the fact that eruption of the impacted tooth, in these circumstances, will bring with it new alveolar bone, it will nevertheless be insufficient to establish a bone level similar to that of the adjacent teeth. There will be an increased crown length as compared with an unaffected and normally erupted antimere.

Type and height of periodontal attachment

A relatively poor periodontal prognosis will likely be the consequence if the surgeon opens a window in the oral mucosa directly over the impacted tooth, above the attached gingiva. In such circumstances, steps should be taken at the time of the surgical exposure to properly manage the muco-gingival soft tissue, by raising a full flap from the crest of the ridge and by fully suturing the wound, either back to its former place (closed exposure) or higher up on the crown of the tooth (apically repositioned). If executed in either of these ways, the tooth will be erupted through or together with the attached gingiva and the periodontal result will be good.

As has already been pointed out, in cases of obstructive incisor impaction, the long axis of the unerupted tooth is abnormally oriented due to the presence of the extraneous displacing hard tissue. An unerupted mesiodens is usually palatally placed and the root of the incisor will have consequently been displaced labially. Accordingly, when the tooth is drawn vertically downwards following a closed exposure procedure, it will tend to break through the oral mucosa, above the attached gingiva. The newly erupted incisor will exhibit a long clinical crown, caused by the relatively labial prominence in the cervical region and a thin and delicate mucosal attachment.

In order to avoid this unfortunate outcome, traction may be applied in a downward and palatal direction in an attempt to draw it though attached gingiva. However, this may cause its root to tip labially, thereby increasing the amount of subsequent root torque that will be necessary.

A preferable approach would be to draw the tooth down until it bulges the labial oral mucosa and then, at this late stage, to pre-empt its eruption by performing an apically repositioned flap. The flap is raised from the crest of the ridge, immediately inferior to the unerupted tooth. The attached gingival tissue is then sutured over the labial (superior) aspect of the tooth. Further traction will bring the tooth down and into alignment, accompanied by the repositioned tissue. Attempting to perform this as a one-stage procedure, at the time of the initial exposure, may be appropriate if the vertical displacement of the tooth is relatively mild. However, in the case of a higher displacement, the two-stage procedure described here will produce a much better outcome.

A dilacerate incisor will require a similar surgical initiative. A closed exposure procedure in the first instance is probably the only reasonable surgical approach to take in these cases because of its extreme ectopic location in the root of the nose. As the tooth is drawn vertically downwards, its incisal edge bulges the oral mucosa, covering the labial side of the alveolar ridge, and the new horizontal orientation of its crown may be clearly outlined through the almost transparent mucosa. Here, too, one should wait until the tooth is well down and close to eruption before performing a similar apically repositioned flap. In this case in particular, the tightness of the suturing of the tissue above the crown of the tooth will itself exert considerable pressure and assist in the further traction of the tooth into its place. When the crown has been brought down to occlusal level, the extreme degree of labial root torque that is needed to properly and artistically reposition the crown of the tooth will then become apparent.

Treatment duration

As we have seen, treatment of impacted central incisor teeth is generally undertaken in the early to middle period of the mixed dentition. This means that it is classed as a phase 1 treatment, the aims of which are usually limited to resolution of the incisor impaction. Phase 2 becomes appropriate only in the fully erupted permanent dentition, at around the age of 12–13 years. In the event that a phase 1 treatment is embarked upon at a much later stage and if a more pedantic (and superfluous) level of aesthetic alignment and finishing is undertaken, then there is a distinct likelihood that phase 1 will run continuously and inexorably into phase 2, to result in one long period of comprehensive and excessive biomechanical therapy. In cases of this kind, there is a distinct danger of orthodontic treatment running parallel to the child’s entire school career.

The duration of phase 1 treatments and the implications for their success rate were evaluated in a study performed in Jerusalem [50] of obstructed and classic dilacerate impacted incisors. The study sample comprised 59 patients, 31 of whom had supernumerary tooth or odontome obstruction and 28 with dilacerations. Three stages within phase 1 treatment were defined:

- T1 – the pre-surgical period between the application of fixed orthodontic appliances and the referral for surgery.

- T2 – the period between the surgical exposure and engagement of the orthodontic bracket of the impacted tooth in the labial archwire.
- T3 – the period from the engagement in the archwire to completion of phase 1.

The results of the study pointed to the following. For the sample as a whole, T1 was found to be 5.2 months, with a range of ±4 months, the impaction resolution period T2 took 8 months (±5 months) and the T3 to completion was 6.3 months (±4.5 months). While each stage may individually not appear very long, in total they amounted to 19.5 months (±9 months), which is a considerable period. An analysis of the individual groups showed that the mean duration of treatment in the obstructed cases was 17 months (±7 months) and that of the dilacerate cases 22 months (±17 months). This difference was largely due to the greater complexity of treatment of the dilacerate incisors, particularly in the T3 period, where much labial root torque needs to be achieved. This is also reflected in the success rate of the two constituent diagnoses, with one failure (97% success) in the obstructed group and five (82% success) in the dilacerate group.

Relative bone height of the crestal alveolus

In Chapter 7 we will refer in great detail to alveolar bone within the context of supra-erupted teeth. For our purposes in this chapter, it is sufficient to mention that when teeth are supra-erupted, their vertical movement is accompanied by a vertical increase in their supporting alveolar bone. Thus, when the impaction of a tooth is resolved by augmenting the natural eruptive force following the removal of the causative agent, it will be apparent that the bone support of that tooth will be greater than that around normally erupting adjacent teeth [51–55]. However, this positive response on the part of the alveolar bone to extrusive forces is conditional upon the amount of pressure applied being within relatively narrow limits. A periapical radiograph taken immediately after completion of the extrusion will not show radiolucent areas where new bone is being laid down, since new bone does not show up on X-ray. A similar view taken 4–6 months after cessation of this movement, when the bone will have calcified and matured, will show the high level of its regeneration.

This situation is not achieved if excessive extrusive force is brought to bear on these teeth. Although eruption will occur rapidly, it will not be accompanied by the same regeneration of alveolar bone. The result will be characterized by the tooth having a long clinical crown and considerable mobility. In this case, a periapical radiograph performed even six months later will show a much reduced bone level around the newly and seemingly successfully resolved impaction. The prognosis of such a tooth will be impaired.

Preservation of vitality

During the surgical procedure, removal of awkwardly placed supernumerary teeth may lead to an unavoidable devitalization of the impacted tooth, particularly in a younger child and particularly when the mesiodens is located close to an incisor apex. Even in the hands of an expert surgeon, the demise of its pulpal tissue may still occur. Excessive extrusive force applied by the orthodontist may devitalize the tooth and will undoubtedly generate mobility and gingival recession, as it compromises its bony support. Preservation of tooth vitality is a potent factor in assuring the longevity of the incisor. It should be understood that even a well-executed root canal treatment may disappoint the patient, when its discoloration cannot be adequately reversed.

Oral hygiene

During the initial phase of eruption of an impacted tooth, the surrounding gingiva is sensitive, tender and bleeds very easily. This will usually make the younger patient very apprehensive of brushing the area regularly and to an adequate standard of cleanliness. This, in turn, may cause a secondary inflammation of the gingiva and a concurrent adverse effect on the regeneration of bone could be the result [56].

For this reason, the surgeon should be meticulous in the proper planning and execution of the surgical technique. The orthodontist must also be meticulous in the application of extrusive forces whose magnitude is difficult to control. Elastic ligation thread is used widely for applying traction to impacted teeth, by tying it directly and tightly between the attachment and a relatively rigid archwire. However, it is exceptionally difficult to accurately judge the amount of force being applied by this method. Accordingly, when it is the only practical method available, great care should be taken not to tie the thread too tightly. Indeed, it would be reasonable to say that wherever possible alternative methods should be used, as described in Chapter 4.

As the impacted teeth begin to respond to the traction force, orthodontists should be acutely perceptive and responsive to the changing relationship of these teeth to the soft tissues. They should be prepared to make the necessary alterations in force direction and, if needed, request muco-gingival surgery to be carried out in order to cause the tooth to exit the tissues in the best possible location, from both the periodontal and aesthetic points of view.

At the close of treatment in routine cases, vertical (up-and-down) ‘box’ elastics are often used to enhance intercuspation. These elastics are small and can produce forces that are very much in excess of those that are appropriate for a single impacted tooth. The force will be increased further during mouth opening. It is difficult to measure or control forces applied in this way. Nevertheless, this is a valuable tool and should be used with only the very lightest and largest of elastics. It should also be remembered that, as orthodontists, we are apt to apply more than adequate extrusive forces by the downward deflection of an archwire and we then place a box elastic in addition, just to be sure. The aggregate force may thus become substantially in excess of the physiological limit. Where patients are prescribed this form of vertical intermaxillary anchorage reinforcement, they should be instructed to wear the appliance all the time, including at mealtimes, removing it only for tooth brushing, thus maintaining a light continuous force.

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7
Palatally Impacted Canines

Adrian Becker

[Prevalence](#)

Aetiology: Local causes of palatal displacement

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Prevalence

In any population, the prevalence of palatally impacted maxillary canines is low, but various surveys have shown that the distribution based on ethnic origin is not always equal. The lowest frequency reported in the literature relates to Japan [1], where the anomaly occurred in only 0.27% of the sample population. Some very early studies among white Americans showed 1.4% (study by Cramer [2]) and 1.57% (in an undefined sample by Mead [3]). A study of a large number of full-mouth dental radiographs among patients in the USA revealed a frequency of 0.92% [4], while Brin et al. [5], in a study of an Israeli population, found a 1.5% prevalence. Thilander and Jacobson [6] reported 1.8% in their study of an Icelandic population, and 2.4% was found in an Italian sample [7]. More recent studies have shown little difference in their figures.

Montelius [8] was the first to demonstrate a difference between Caucasian and Oriental populations, finding a frequency of 1.7% for Chinese and a remarkable 5.9% for Caucasians. However, since his study did not distinguish between buccal and palatal impaction, little useful information may be gleaned from these figures in the immediate context. From the results of the work of Oliver et al. [9], the researchers indirectly indicated that Asians may suffer from buccally impacted canines more frequently than from palatal canines. This was more recently confirmed in the study of a large sample of 148 young Korean patients who displayed 186 impacted maxillary canines, which found that buccally displaced canines (BDCs) were three times more prevalent than palatal canines. The study also assessed the influence of the location of the impacted canine on root resorption of the neighbouring teeth in the sample [10].

A noticeably higher incidence of canine impaction was found among females, with a ratio of 1.5:1 in the Korean study just quoted, although the sample included both buccally and palatally impacted canines. Relating to palatal canine studies only, the female to male ratio was 2.3:1 in the

American group survey [4], 2.5:1 in an Israeli orthodontic group [11] and 3:1 in each of a Welsh orthodontic group [9] and an Italian sample [7].

Notwithstanding these epidemiological figures, a subsequent Israeli random population study [5] showed an approximately equal male–female incidence of the anomaly. Oliver et al. [9] suggested that, although a higher female incidence was indeed present in their study of a Welsh group of patients, this was most probably due to a more mundane explanation, namely the trend for more females than males to seek orthodontic treatment in the UK.

A person's appearance is rarely marred by the presence of an over-retained deciduous canine, since there is complete arch integrity and an uninterrupted display of teeth; consequently, any abnormalities are usually not disfiguring. That being the case, and if we are to accept a greater 'appearance/aesthetics' motivation for females seeking treatment more frequently than males, then, since there is little or no marring of the appearance, the diagnosis of an impacted maxillary canine alone does not seem to be an adequate reason for the preponderance of females seeking treatment. Motivation for treatment may therefore rather depend on the ability and persuasiveness of a particular practitioner in pointing out the potential hazards of non-treatment. There may be no basis to expect that this would convince more female patients than males to accept treatment.

Aetiology: Local causes of palatal displacement

Long path of eruption

From the days of Broadbent [12] in the 1940s and for a long period thereafter, the most common reason given for palatal displacement of the permanent maxillary canine was the fact that it had had a long and tortuous eruption path, beginning close to the floor of the orbit. It was observed that, compared with other permanent teeth, this tooth had much further to travel before it erupted into the mouth and that it therefore had a greater chance of 'losing its way'. Despite the absence of concrete evidence, this was standard teaching for several decades.

Over the years, however, it became glaringly obvious that there are many more associated factors involved in the aetiology of maxillary canine impaction, both in the immediate local arena and in the wider developmental and genetic context. Nobody with clinical experience in orthodontic practice today would claim there to be a single, solitary and specific cause for the palatal displacement of the maxillary canine tooth.

Space-occupying hard tissue entities of dental origin

Hard tissue pathology in the immediate area may cause displacement of a developing tooth. This is particularly so in regard to a displacing entity such as a supernumerary tooth or odontome, the diagnosis of which is highly definitive and presents an aetiological role that is easily understood. Space-occupying, extraneous entities of dental origin (Figures 7.1 and 7.2) will undoubtedly produce abnormal positioning of an unerupted permanent maxillary canine, although such entities are not frequently found in the canine area. The fact that the majority of impacted canines occur in situations where there is no obstructing entity compels us to look elsewhere for the main causes of impaction. Nevertheless, when a supernumerary tooth or an odontome (Figure 7.1) is present in the area, it disturbs the position and orientation of a developing canine tooth and will likely influence the eruptive force to express itself in a futile direction. Its timely removal may sometimes bring about spontaneous re-orientation and resolution, although this is by no means certain and active orthodontic intervention is usually necessary in the final instance.

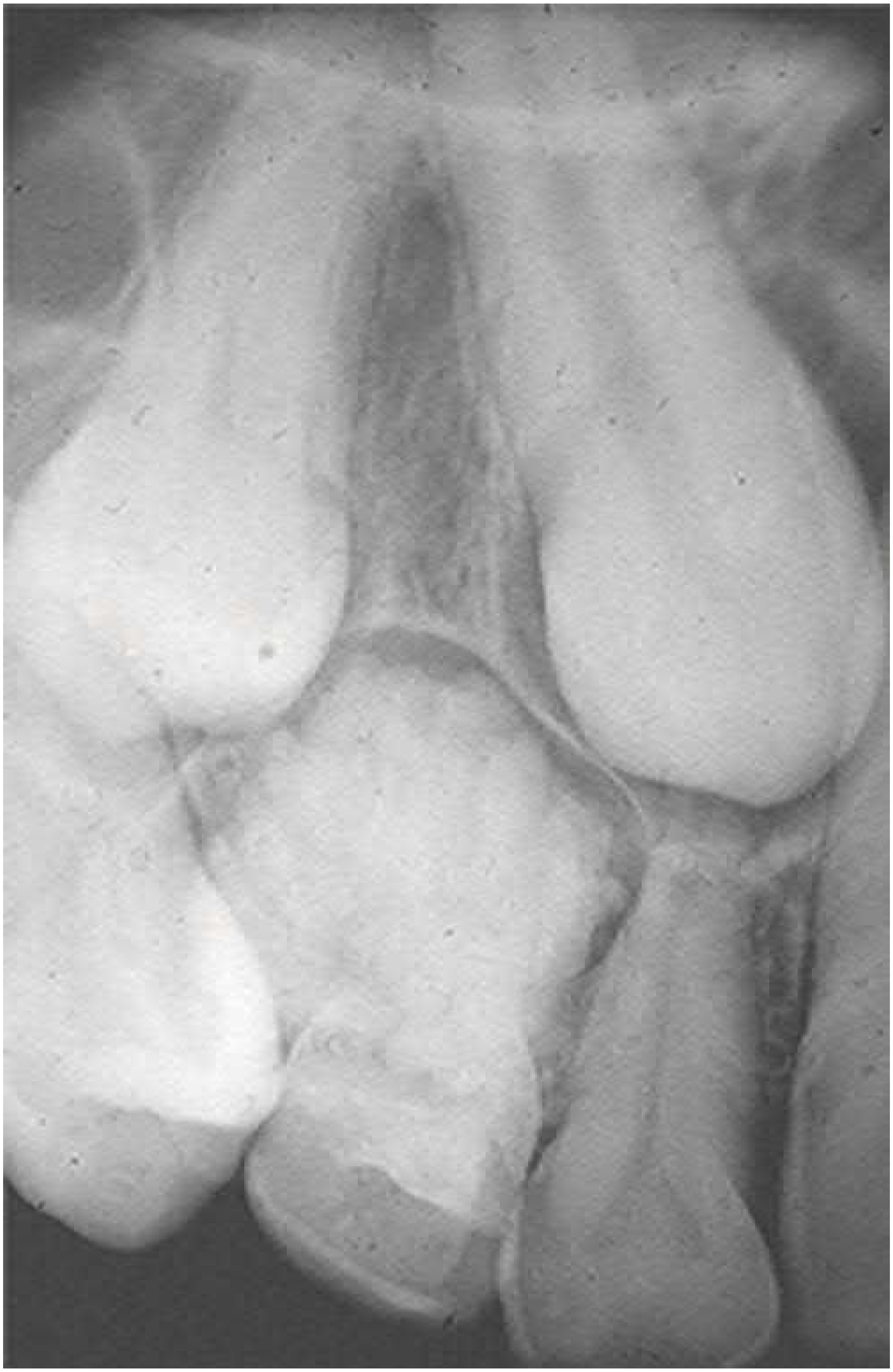
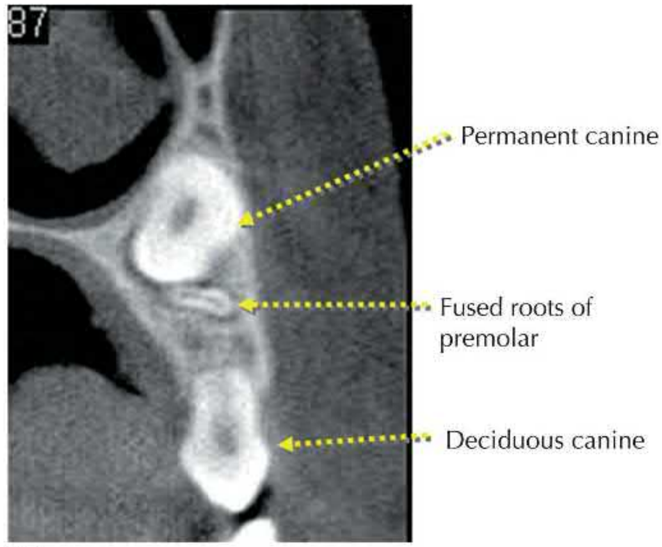


Fig. 7.1 Periapical view of the maxillary canine area shows impaction of the canine and first premolar, associated with an odontome and over-retained deciduous canine and deciduous first molar.



(a) (b)

Fig. 7.2 (a) A 3D cone beam computed tomography (CBCT) view showing the apical half of the root of a normally located first premolar to be turned 90° to the mesial, directly in the path of the unerupted canine, which is deflected mesially and superiorly and prevented from erupting. (b) The transaxial (vertical) CBCT slice across the canine in the area of the cemento-enamel junction cuts the deciduous canine longitudinally. It also cuts across the mesio-distally oriented horizontal portion of the root of the canine and the premolar, close to the apex of the premolar.

Courtesy of Dr N. Dykstein.

More surprising, perhaps, is the finding that in unilateral cases of central incisor impaction, there is a remarkably high frequency of eruption disturbance of the canine on the same side. It appears to make no difference whether this was due to obstruction by a supernumerary tooth or odontome, or because of dilaceration or trauma. These findings were gleaned from a study [13] that was undertaken of a sample of unilaterally affected cases of canine impaction. The research used the 'split-mouth design' to enable the unaffected side to be used as the control. The results showed there to be a significant increase in prevalence and severity of displaced canines of the ipsilateral (affected) side (41.3%), of which half the sample exhibited pseudo-transposition with the adjacent lateral incisor. Palatal displacement accounted for 9.5%, buccal displacement for 30.2%, and canine–lateral incisor transposition for the remaining 1.6% of the patients. This was in stark contrast to 4.7% in total on the contralateral (unaffected) side.

The overwhelming presence of canine–lateral incisor pseudo-transposition cases on the affected side may be explained by the fact that the lateral incisor tips mesially to encroach to a considerable degree on the space of the unerupted central incisor. The consequence of this is that the root apex tips distally and into a position where it interferes with the eruption path of the unerupted canine. The further eruptive development of the canine then bypasses the root of the lateral incisor and moves mesially into the pseudo-transposed relationship.

Abnormally located adjacent teeth

In the immediate vicinity of the canine, the normal sequence of eruption of teeth dictates that the maxillary lateral incisor and the first premolar precede the canine by approximately three years and one year, respectively. For as long as the canine is in its normal eruptive position, i.e. slightly buccal to the line of the dental arch, its path of eruption will permit it to erupt unhindered. However, if it is high up in the alveolus and if the premolar has erupted with a mesio-buccal rotation (a counter-clockwise rotation for the right premolar when viewed from the occlusal), then the palatal root of the premolar will have been mesially displaced by the rotation and will have moved directly into the path of the canine. This location, orientation and root form of the premolar may sometimes be strong aetiological factors in themselves. In certain unusual situations, the palatal root of the premolar may exhibit a mesial turn in its apical third, which will also provide a formidable obstacle in the path of the canine (Figure 7.2). Thus, a rotated orientation or abnormal root anatomy of the adjacent first premolar may provide the impediment that becomes the cause for the impaction of the maxillary permanent canine. In other impacted canine cases, the root apex of the adjacent erupted lateral incisor may be displaced distally, to interfere with the eruption of the canine, which may occasionally lead to a canine–lateral incisor transposition.

Crowding

Hitchin [14] contended that the reason for canine impaction was crowding of the dentition, although he offered no evidence to support his contention. In fact, an understanding of developmental anatomy should lead the experienced observer to contend quite the opposite.

Crowding of the dentition generally results in the exaggerated displacement of a tooth from its early developmental position in the arch.

The normal eruption path of a permanent canine is buccal to the line of the arch. The lateral incisor and first premolar, the teeth immediately adjacent to the canine, erupt before the canine. Accordingly, in a crowded dentition, the consequent reduction of space in the dental arch in the immediate area will prevent the canine from moving into alignment. Consequently, the continued vertical development of the maxillary permanent canine will be accompanied by its exaggerated buccal displacement, and will present the typical picture seen in the class 1 crowded case (Figure 7.3). Whether the tooth eventually erupts or remains impacted is irrelevant (although buccal impaction is uncommon in Caucasian population groups). It is therefore quite clear that the cause of this type of displacement of the canine is completely different from that involving its palatal displacement. The two conditions are totally different entities and should not be confused, nor be lumped together to form a single experimental group for clinical research, as if to offer a homogeneous sample of impacted teeth. For the purposes of study, it is far more logical to combine *all palatally displaced canines*, whether they are unerupted or erupted, since they share a common aetiology, although their clinical presentation may be different.

Fig. 7.3 Lingually displaced lateral incisors and buccally displaced maxillary canines due to dental crowding.

In a series of clinical research studies, Jacoby [15], Becker [16] and Brin et al. [5], it was pointed out that where crowding is present, the likelihood of palatal canine displacement is much reduced. Indeed, the studies have shown that palatal canine displacement is far more likely to occur when there is *excess space* in the dental arch.

Non-resorption of the root of the deciduous canine

From the impression gleaned from a clinical and radiographic assessment of a number of impacted canine cases, Lappin [17] observed that the deciduous canines were frequently over-retained, often displaying a long and unresorbed root. He theorized that it is the failure of the root of the deciduous canine to resorb that causes a palatal deflection of the eruption path of the permanent canine, leading to its impaction. While the mechanism that initiates root resorption of a deciduous tooth is unknown, we do know that it occurs when the dental follicle of an unerupted permanent tooth is in the immediate vicinity. It is important to emphasize that this theory of Lappin's was not based a controlled study, but merely conclusions that he had drawn from observation. However, it will be immediately obvious to the reader that it is equally plausible to argue the reverse, i.e. that resorption has not occurred due to the distance of the root from the unerupted permanent tooth, and therefore that the unresorbed root of the deciduous canine is *not the cause* of the displacement but its *result*.

Here, too, one may draw a parallel with other teeth. In cases where a second deciduous molar is over-retained, owing to the presence of a malposed premolar tooth germ, one may often see on the periapical or panoramic radiograph that one of the deciduous molar roots has totally resorbed, while the second root has only partially resorbed. The long spicule of unresorbed root that may be present retains the tooth against natural shedding, while the fully developed and unerupted second premolar is situated immediately beneath the crown of the deciduous tooth in the area previously occupied by the resorbed portion of the roots.

From this type of clinical evidence, which is so widely and frequently seen in practice, it is generally concluded that the presence and advancing eruption of the permanent tooth provide the stimulus for the resorption, and that the portion of the root that is distant from the unerupted permanent tooth may be unaffected by this process. On the basis of this, Lappin's view would appear to be 'putting the cart before the horse'. On the other hand, Lappin's conclusion might nevertheless be justified, since a number of studies [18–20] have shown that prophylactic extraction of the deciduous canines, in cases where there is potential maxillary permanent canine impaction, appears to encourage spontaneous eruption of a majority of quite markedly displaced permanent canines [7–9]. This will be discussed at length later in this chapter, under the heading 'Prevention and interception'.

Trauma

In a clinical report, Brin et al. [21] illustrated that when facial trauma leads to a cessation in the development of the root of a lateral incisor, this may be associated with palatal canine impaction. They explain this by assuming that the traumatic episode may have caused an actual displacing movement of the lateral incisor or, possibly, momentary impact contact between the incisor and the unerupted canine itself. A further possibility brings in the guidance theory, namely that the shortened root has failed to provide the needed guidance for autonomous eruption.

Soft tissue pathology

Yet another possible cause of arrested eruption is associated with dentally related soft tissue lesions. These occur very frequently, yet often go unnoticed or are ignored by the orthodontist. However, they may constitute significant aetiological factors. Over-retained deciduous canines are commonly non-vital by the age of 12 years, due to caries, trauma or extreme attrition. The resulting chronic periapical granuloma, by itself, is a soft tissue inflammatory lesion that causes chronic irritation, and it is distinctly possible that this will have a potent effect on arresting eruption or on deflecting the eruption path of an adjacent developing tooth (Figures 7.4 and 7.5).

(a) (b)

Fig. 7.4 (a, b) Periapical views of bilaterally impacted canines, each associated with a non-vital deciduous canine.

(a) (b)

Fig. 7.5 (a) Panoramic view of a patient in the mixed-dentition stage with a markedly displaced and unerupted right maxillary canine. The immediate area shows a large area of bone loss involving the canine and first premolar, associated with the non-vital deciduous first molar. Chronic periapical abscesses or dentigerous cysts represent soft tissue obstructions that will deflect the eruption path of the permanent canine. (b) Following extraction of the deciduous canine and deciduous first molar, there was spontaneous resolution, with eruption of the teeth. For no apparent reason, the deciduous canine of the opposite side was overlooked.

Courtesy of Dr A. Renert.

Extraction of a diseased deciduous canine usually eliminates the granuloma and, with it, the displacing factor for the permanent tooth. An examination of the efficacy of prophylactic extraction of the deciduous canines will be discussed in the ensuing pages of this chapter. There was no mention in the methods and materials of the above-mentioned articles [18–21] of whether individuals with non-vital deciduous canines had been included in the study sample. One may be permitted to wonder just how many of the deciduous canines referred to were non-vital. The fact that a high percentage of the permanent canines had later erupted spontaneously allowed the researchers to claim that this was the apparent sequel to the extraction of the deciduous predecessor. But it may also be argued that their successful eruption was attributable to the concurrent elimination of a periapical lesion in a non-vital deciduous tooth.

In rare instances, a periapical granuloma develops into a radicular cyst by stimulating the rests of Malassez in the area and this expanding, space-occupying, epithelium-lined balloon, filled with liquid, will displace adjacent unerupted teeth. It is more likely, however, that a long-standing granuloma at the apex of a deciduous canine may induce cystic change in the follicular sac of the adjacent unerupted permanent canine. This begins as benign enlargement of the follicular sac surrounding the permanent canine and increases to become a dentigerous cyst. The hydrostatic pressure within the cyst overcomes the innate eruption force of the tooth, thereby arresting the downward progress of the tooth and, in more advanced cases, even causing the tooth to ‘back up’ along its former eruption path. The cyst may continue to enlarge laterally by initiating pressure resorption of the adjacent bone, until the cyst lining comes into contact with the roots of adjacent teeth. This will displace them into an adjacent area of potentially resorbable bone.

One of the methods of treatment of a dentigerous cyst involves opening the cyst to the exterior – marsupialization – allowing for drainage and effectively defusing the displacing factor. The cut edges of the opening are pared back and the cyst cavity lightly packed with ribbon gauze soaked in Whitehead’s varnish or other antiseptic and anaesthetic. The area previously occupied by the cyst remains lined with follicular epithelium. Lacking the increased hydrostatic pressure, bone begins again to fill in behind this epithelial lining, which undergoes metaplasia as it becomes continuous with the oral epithelium. The residual cyst cavity slowly shrinks and teeth that had previously been located in the cyst wall begin to migrate with the returning bone into more accessible positions. Here again, prophylactic extraction of a deciduous canine, undertaken in order to resolve potential palatal canine impaction, may be successful in producing spontaneous eruption. This will have been due to the simultaneous and inadvertent rupture and evacuation of an associated and enlarged follicular sac/early dentigerous cyst. The reader is referred to several illustrated examples of this process in Chapter 14.

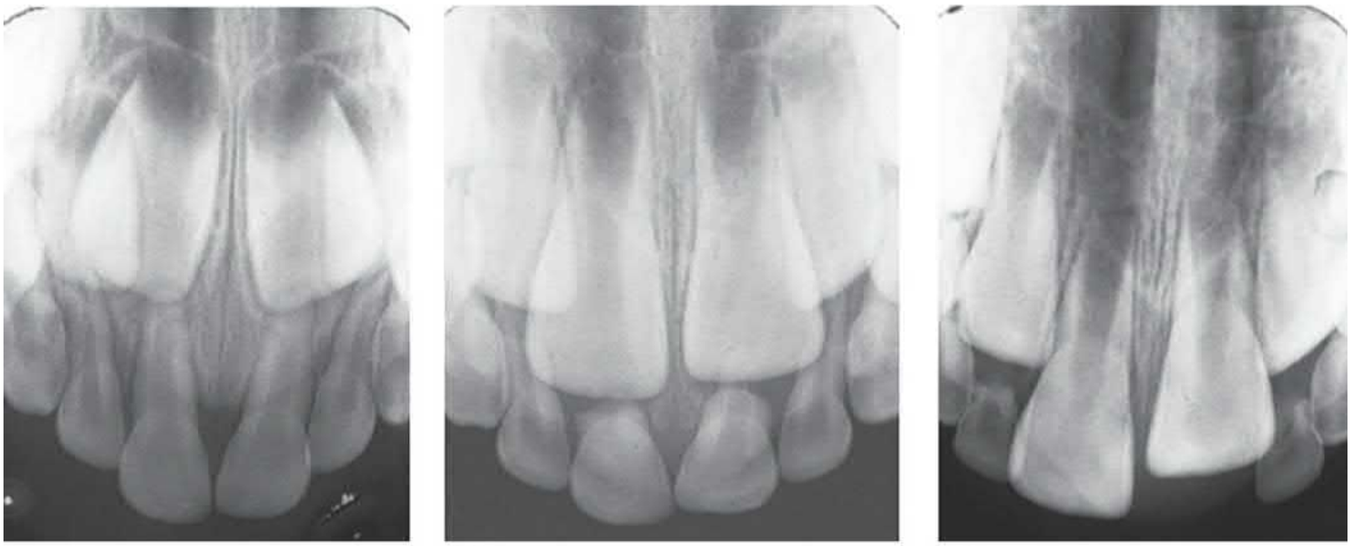
Normal development of the maxillary anterior teeth

The following account of the natural dynamics of eruption and alignment of the maxillary anterior teeth, which was first described by Broadbent so long ago [12], has become a well-recognized and established cornerstone of the orthodontic literature and has withstood the test of time. It is widely quoted and is accepted as axiomatic to the narrative of normal growth and development. It has come to be known as Broadbent’s ‘guidance theory for the normal eruption of the maxillary anterior teeth’.

In the quest to determine the keys to the aetiological conundrum of palatal displacement of the permanent maxillary canine teeth, clinical research has mostly looked to developmental anomalies of the dentition, in general, and to the co-existence of genetic factors related to the incisor teeth, in particular.

The hypotheses that have hitherto been proposed have concerned themselves with aberration in the normal process by which the maxillary anterior teeth erupt. In order to assess these hypotheses, an overall understanding of normal development in this area is required. Accordingly, we present here Broadbent's description of this normal developmental process.

In the middle period of the deciduous dentition, a periapical radiograph of the premaxillary region will already display the fully completed deciduous incisor roots. It will show the overlapping shadows of the permanent central and lateral incisors more or less in the same vertical plane (Figure 7.6a) and at the level of the apical area of the roots of the deciduous incisors. The canines will appear to be sited higher up. The overlap of the permanent teeth crowns is due to the fact that these relatively wide permanent teeth are all contained in a narrow area and, at this time, are located palatally in the alveolus. The developmental position of the lateral incisors is palatal in relation to both the central incisors and the permanent canines. For these reasons, the periapical view will give the appearance of severe crowding.



(a) (b) (c)

Fig. 7.6 (a) Periapical view of normal incisors at age 3 years. Note the degree of overlap of unerupted permanent central incisors and lateral incisors. (b) The same patient at age 5 years. The central incisors have migrated inferiorly and labially relative to the lateral incisor and the reduced degree of overlap. (c) At 6.5 years the central incisors are erupting. The lateral incisors have migrated labially into the arch to completely eliminate the overlap.

Courtesy of Prof. B. Peretz.

During the early eruptive movements of the central incisors, a progressive resorption of the roots of the deciduous incisors occurs. The permanent incisors migrate slowly across from the palatal side of the arch to the labial as they proceed in their downward path, until the teeth erupt into a more labial perimeter than was defined by the deciduous incisor teeth before their shedding. During this process, the wide crown portion of the central incisors will have moved downwards and labially, ahead of the lateral incisors (Figure 7.6b). As this occurs, the progressively narrower cemento-enamel junction (CEJ) area and the root portion of the central incisor come to lie mesial to the unerupted lateral incisor crowns. This leads to the fairly rapid provision of space in the alveolus at this level [22]. The lateral incisor migrates labially into this area as it begins its downward eruption path. This downward eruption movement distances the lateral incisor from the permanent canine crown. This then provides more space for the lateral incisor (following closely after the central incisor) to move labially.

The illustration in Figure 7.6(a–c) shows an overlap of the teeth at age 3 years and how the normal incisor development occurs, with advancing age, due to labial and vertical migration of the incisors. The developmental position of the maxillary lateral incisors is lingual to the line of the arch, but when there is potential crowding of the early mixed dentition, there will be insufficient space for the lateral incisors to migrate labially between the root of the erupting or newly erupted central incisor and the deciduous canine teeth. This is the manner in which it normally comes into the dental arch. For the most part, therefore, the lateral incisor will continue to develop downwards, but in a lingual position, and will erupt lingual to the adjacent teeth.

A parallel environment is created when a second deciduous maxillary or mandibular molar is extracted before its due time, causing the first permanent molar to drift mesially into the available space. Since the developing second premolar is normally located marginally lingual to the line of the arch, its continued vertical development and eruptive path will be in an exaggerated lingual direction, due to the reducing space between the two adjacent teeth.

With the eruption of the central incisors, the lateral incisor crowns move from a lingual relationship with the central incisor roots into a direct distal relationship, initially at a higher level. As this occurs, the presence of the lateral incisor crowns displaces the developing roots of the central incisors towards the midline and towards one another, since these are at the same level within the alveolar bone. With the central incisor apices held together in this way, the crowns of these teeth are flared distally. A developmentally normal median diastema is thus produced, creating an anterior dental arrangement that Broadbent termed the ‘ugly duckling’ stage (Figure 7.7a) [23, 24].

During the next year or so, the lateral incisors descend along the distal side of the central incisor roots, thus releasing their ‘hold’ on the narrowed inter-radicular width of the central incisor root apices and allowing the roots to drift apart. The lateral incisors continue to move inferiorly along their eruptive path, progressively reducing their constricting influence on the central incisor roots until they reach the distal side of the necks of the central incisor crowns. At this point, their presence and their continued downward migration serve to provide a mesially directed force to the crowns of these teeth, thereby moving them towards one another and partially closing off the median diastema. The long axes of the central incisor teeth will also have changed, with the roots becoming more parallel to each other. The lateral incisor long axes, however, will be relatively flared in the coronal direction, with their root apices close to those of the central incisors.

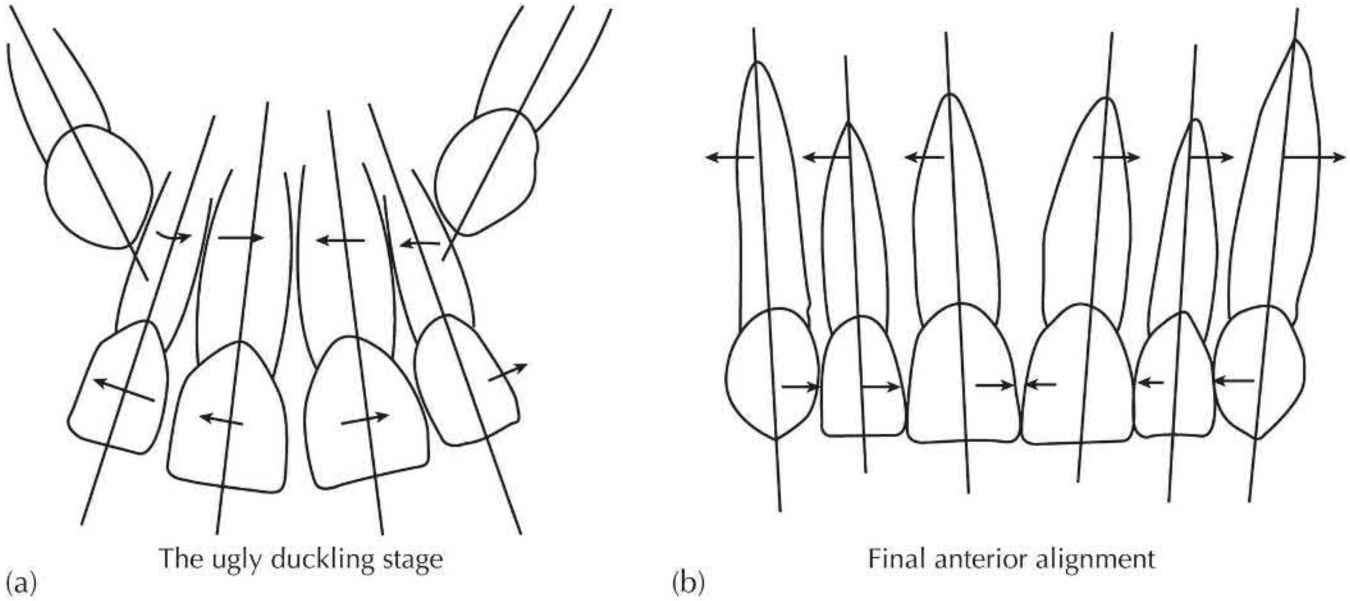


Fig. 7.7 (a) In the early stages the unerupted canines are mesially directed, restricting the incisor roots to the area of the midline, thereby flaring their crowns distally, to create spacing.

Source: Based on Broadbent BH. The face of the normal child, Angle Orthod 1937; 7: 183–208 and Becker A. The median diastema. Dent Clin North Am 1978; 22: 685–710. (b) As the canines descend towards the crown, down the distal aspects of the lateral incisor roots, their influence is reversed. They apply a mesially directed force on the distal surfaces of the lateral incisor crowns, which closes off the anterior spaces and encourages a distal root flaring.

A periapical view of the area at this time will show the unerupted permanent canine crowns of each side pointing mesially towards the lateral incisor apical area. They will appear to be the containing influence that causes the apical convergence of the incisor roots and the reason that the median diastema has not completely closed. Subsequent follow-up radiographs of the area will show the permanent canines altering their relationship to the lateral incisors as they move downwards along the distal side of the root of the lateral incisors and on to the incisor crowns. Having initially constricted the roots of the lateral incisors mesially, the downward descent of the canines alters the direction of their influence on the lateral incisor crowns, to tip them mesially. This brings about an uprighting of the long axes of the incisors on each side and a closure of the anterior spacing (Figure 7.7b). The canines' own long axes become more vertical as they progress and as the roots of the deciduous canines become resorbed. With the shedding of the deciduous canines, they finally erupt with a slight mesial inclination, taking up their place in the arch by moving the crowns of the incisors towards the midline, thus closing off the diastema completely [12]. As all this occurs, the long axes of the incisor teeth change from being apically convergent to becoming more parallel to each other and even slightly divergent.

From as early as two or three years prior to their normal eruption, and throughout the period of their downward progress, the permanent canines are conspicuously palpable on the buccal side of the alveolar ridge. This will continue to be the case until their normal eruption, which will occur at the age of 11–12 years.

From this description of normal development of the anterior maxilla, it is clear that there is much that can go wrong in this scheme of events that may have an effect on the eruption path of the canine. It seems obvious that a relatively small discrepancy in direction or degree of influence of one of the factors involved will 'throw a spanner in the works' and undermine this fragile scheme, to cause the canines occasionally to become palatally displaced.

Miller [25] and Bass [26], in their early studies of impacted canines, reported that there appeared to be an unusually high prevalence of congenitally missing lateral incisors associated with palatally impacted canine teeth. They theorized that, in the presence of these two features, the permanent canine lacks the guidance normally afforded by the distal aspect of the lateral incisor root. As we have seen in the course of normal development, the canine initially has a strong mesial developmental path. This changes soon afterwards as, according to this theory, the canine is guided downwards, along the distal aspect of the lateral incisor root. It was Miller's and Bass's view that the absence of this guiding influence is the cause of the canine continuing in its initial mesial and palatal path, instead of being guided downwards. Thus, the tooth then becomes impacted in the palatal area, posterior to the central incisors, and fails to erupt in its due time, if at all.

Miller's concept was founded on information gleaned from the study of six such cases. In addition, he assumed that since a peg-shaped or otherwise abnormally small lateral incisor develops a root of more or less normal length, such a tooth would provide the required guidance for the normal eruption of its adjacent canine. He therefore rationalized that these anomalous teeth could not be an aetiological factor in canine impaction.

Following the treatment of several hundred cases of this type by the present author, it seems clear that Miller's theory is unfounded and indeed mistaken. Our studies show that palatal impaction of the maxillary canine appears to be associated far more with the occurrence of anomalous lateral incisors than with congenital absence of lateral incisors. Furthermore, it is possible to build a stereotype of the typical maxillary impacted canine patient (Figure 7.8), in which the patient is characteristically a 15-year-old female, with well-aligned and normally related dental arches, slight spacing and no real malocclusion. The teeth are small, the lateral incisors particularly so, the incisors lack their normal rounded contour, there may be missing teeth, dental development is late and the patient's motivation for treatment is predictably low.

Fig. 7.8 Late-developing dentition showing spacing, small peg-shaped lateral incisors, teeth of poor anatomical contour and minor class I malocclusion.

A series of clinical research studies was initiated in Jerusalem, in which a sample of patients with a palatally displaced canine was investigated. In the first of such studies [11], a comparison was made with the published data for normal populations (Figure 7.9) and a wide and highly significant discrepancy was found in the numbers of normal, small, peg-shaped lateral incisors adjacent to an affected canine. In the interests of accuracy, a random study was later performed by the same research group [5] to quantify the various types of lateral incisors found within the general population of the same geographical area, using the same definitions of anomaly. In the general random population, 93% of all lateral incisor teeth were of normal shape and size, compared with only 52% in the palatal canine sample. In a random population Israeli sample, missing lateral incisors were found in approximately 1.8% of the cases [27], which contrasted markedly with the 5.5% found among the impacted canine cases [11] – three times as frequent (Figure 7.8). These figures are valid for the Israeli population sample studied. It must be noted, however, that congenital absence of maxillary lateral incisors in a meta-analysis of the collected data from a large number of different population studies was found to be lower, at 1.55% for males and 1.78% for females [28].

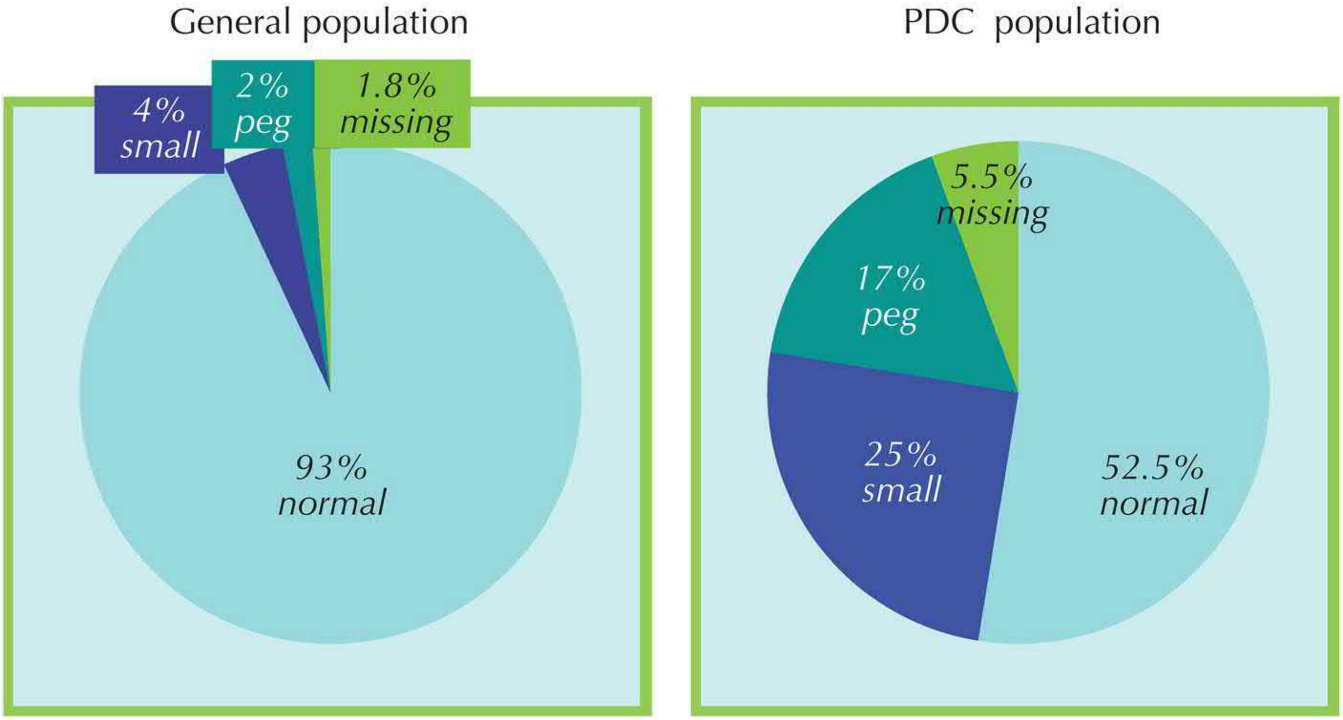


Fig. 7.9 Lateral incisor anomaly in patients with palatally displaced canines.

Source: Reproduced from Brin I, Becker A, Shalhav M. Position of the maxillary permanent canine in relation to anomalous or missing lateral incisors: a population study. Eur J Orthod 1986, 8, 12–16, with permission of the European Journal of Orthodontics.

These results do indeed support the view of Miller and Bass regarding the part played by the lateral incisor as a guide in the normal eruption of the permanent canine and that, without this guidance, normal eruption is compromised fivefold. Nevertheless, Miller's rationalization regarding the positive role of anomalous lateral incisors appears to be very much misplaced. Small lateral incisors were noted in only 4% of the random sample, while the palatal canine cases showed this anomaly to be six times as frequent (25%). Furthermore, only 2% of the general population had peg-shaped incisors, while 17% (nine times the population frequency) were seen in the palatal canine group. Similar results have since been shown in confirmatory studies of patients with palatal canines that have performed the same investigations on children from Wales [9] and the west of Scotland [29].

In the first study from the Jerusalem group [11], a hypothesis was presented based on the fact that the anomalous small and peg-shaped lateral incisors develop very much later than normal lateral incisors. While no figures are available for the extent of this delay, it seems clear from clinical observation that it may be as much as three or four years – even though we are dealing with teeth whose calcification normally begins at age 10–12 months.

The guidance theory of impaction

Let us now try to apply the results of the studies referred to above to what I have called the 'guidance theory of impaction' (or perhaps more accurately, an 'absence-of-guidance theory of impaction').

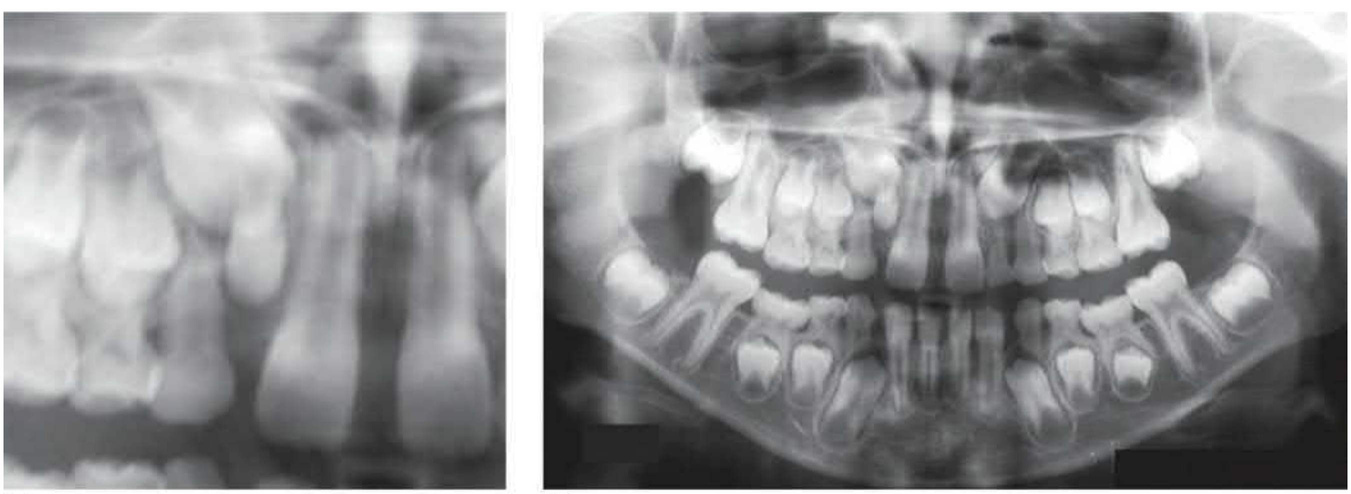
The guidance theory comprises five elements:

- *Normal eruption*. The theory adopts Broadbent's original view [12] that, given the timely and normal development of a lateral incisor in the early developmental stages, guidance for the canine is provided by the presence of the lateral incisor and a buccal path of eruption is to be expected, with the tooth palpable on the buccal side of the alveolar ridge.
- *First-stage palatal impaction*: It is postulated that, at the critical time when the permanent canine would normally have guidance from the root of the lateral incisor, the root of an *anomalous* lateral incisor is insufficiently developed to provide it. The situation is, initially, identical to that seen in the case of the absence of the congenital lateral incisor. The result is that the canine migrates mesially and palatally and usually in a downward direction, into the vertical alveolar process, where it proceeds towards the palatal periosteum. The palatal periosteum will likely then halt further progress of the tooth, or it may alter the eruption path to a more horizontal direction, across the palate. In either instance, this constitutes a first-stage palatal impaction.
- *First-stage palatal displacement with secondary correction*: For the most part, however, the palatal periosteum deflects the eruptive potential of the developing canine from its first-stage displacement, in a downward direction. The alveolar process in the canine region is V shaped in cross-section, therefore the progressively narrowing alveolus, with continued vertical movement, will tend to guide the aberrant canine in a buccal/labial direction. These corrective movements of the palatally displaced canine are the characteristic feature of what may be termed the first stage of palatal displacement with secondary correction (Figure 7.10).
- *Second-stage palatal displacement*: In cases of congenital absence of the lateral incisor, a canine, which was not palpable buccally at any point in its earlier development, may often erupt more mesially than normal and into the line of the arch. If there is an over-retained deciduous lateral incisor or canine, the corrective movements of the canine will cause the initiation of root resorption of these deciduous teeth. Following their shedding or extraction, the permanent canine will then erupt into the line of the arch, though often in a more mesial location, since it will veer towards the space provided by the absence of the lateral incisor. In addition, if a late-developing lateral incisor is present at this late stage, it will now lie directly in the path of the displaced canine. The resultant physical presence of an unresorbable permanent lateral incisor will bring an abrupt halt to its attempts at corrective movement. Any further vertical development of the canine will be restricted to the palatal side of the dental arch, thus completing the second stage of palatal displacement.

Fig. 7.10 A series of periapical radiographs of an untreated girl, taken between age 8 and age 15. The lateral incisor (#12) is peg shaped and extremely late developing. It provides no guidance for the canine (#13), which may be seen to progressively move to the mesial, passing by the lateral incisor, to finally erupt palatally and mesial to it.

- *Second-stage impaction with secondary correction*: As we shall see later in the discussion of treatment timing, extraction of an over-retained deciduous canine, or even the anomalous lateral incisor itself, may often lead to spontaneous eruption of the impacted tooth in the line of the arch and sometimes even slightly buccally displaced.

Let us now take a look at this from a different perspective. Maxillary lateral incisors normally erupt at age 8 years, when their root development is between one-half and three-quarters complete, as with any other normally erupting permanent tooth. However, the development process of these teeth is notoriously inconsistent and they are among the most frequent to be congenitally missing from the dentition. Confirmed as a microform, or lesser degree, of severity of agenesis, these teeth are also among the most frequently deficient in their form, with small and peg-shaped crowns [30–34]. In these circumstances, their development can be as much as three or four years retarded in relation to the patient's overall dental age. Thus, a 10-year-old child may be seen with an unerupted lateral incisor and from the radiograph it will be determined that the crown is peg shaped. Typically, there may be only one-third or less of the expected root development (Figures 7.10a and 7.11a, b). These features are well recognized as genetically determined traits.



(a) (b)

Fig. 7.11 (a) Anterior section of a panoramic view of a 10-year-old boy with delayed dental development conforming to age 7–8 years overall. The crown of the unerupted lateral incisor is reduced in size and peg shaped, while its developing root is of a length normally seen at age 5 years. (b) The full panoramic view shows congenital absence of the right lateral incisor. The left canine has migrated mesially into a position where it may be expected to cause the resorption of the root of the deciduous lateral incisor and, possibly, the canine.

If we now refer back to the description of the normal development of the anterior teeth, we are reminded that, at the age of 8–10 years, the unerupted canine is normally to be found at the distal aspect of the root of the lateral incisor. Maxillary canines are ontogenically stable teeth, in terms of shape, size and developmental timing vis-à-vis the other teeth in the particular dentition. On the other hand, the lateral incisors are ontogenically unstable teeth. If a late-developing peg-shaped or small lateral incisor is present, with only the very earliest degree of root development, it should be patently obvious that the canine will not find the guidance that would enable it to descend along its normal eruption path (Figure 7.10b–d). Thus, the eruption path of the canine frequently takes a more palatal path into the downward converging, V-shaped, alveolar ridge until it comes into the close proximity of the periosteum of the medial (palatal) aspect of the alveolar process. The V-shaped alveolar process takes on the role of a secondary guide, encouraging the canine to descend further. A year or two later and still unerupted, it arrives on the lingual side of the now-erupted anomalous lateral incisor that, by this time, will have developed a more substantial root. The root of this lateral incisor then becomes an obstruction that impacts the canine on its palatal side.

There are several elements in this process that clearly indicate that the erupting canine, in the progress of its eruptive movements, is strongly influenced by environmental conditions, which determine the degree of success of its final eruption status location, or indeed its impaction. Small, peg-shaped and missing teeth are more frequently found among females than among males, in the approximate ratio of between 2:1 and 3:1 (as discussed earlier in this chapter). Furthermore, the maxillary permanent canine erupts earlier in females, which could mean that earlier lateral incisor guidance will be necessary for its normal eruption. These genetically determined features provide the (sustainable) hypothesis that palatal canines are more frequent in females and that anomalous lateral incisors are a more powerful causal agent than congenitally absent lateral incisors.

It is quite clear that heredity plays an important role in this hypothesis. The assumption is that the genetically determined factors (small, peg-shaped, missing lateral incisors, spaced dentitions, retarded development, etc.) provide the environment that leads to the absence of guidance for the canine, thence to its abnormal palatal path, and finally to its subsequent impaction. It is important to note that the guidance theory of impaction considers that the canine is a tooth like any other, with no exceptional properties or behaviour of its own, as has been suggested elsewhere. This theory recognizes it as being merely the environmentally influenced victim of genetically governed, abnormal circumstances.

As we have illustrated above, BDCs are usually found in crowded dentitions. Nevertheless, there is a small but significant proportion of BDC cases where there is no crowding on which to lay the blame for the buccal displacement. A study was undertaken by the Jerusalem group to investigate the features of dentitions of BDC cases where no crowding was present and to compare them both with BDC cases where crowding was present and to cases in which the canines had erupted normally. The results revealed reduced dimensions of the maxillary incisors in BDCs in dentitions in which no crowding existed, in comparison to the other two groups. More specifically, the lateral incisor was the only tooth that was consistently smaller when compared to both crowded BDCs and normally erupted canine cases [35].

As pointed out earlier in this chapter, small lateral incisors develop very late, growing adequate root length at a time that is too late for them to influence the developing canines. It may therefore be reasonably postulated that it is this lack of guidance from the anomalous adjacent lateral incisor that provides a cogent alternative explanation for the buccal displacement of the canines in a non-crowded dentition, rather than a purely genetic background as the all-embracing aetiological factor. Thus, the aetiology appears to be more similar to that which triggers the palatal displacement of canines than may be generally believed. The canine simply takes the simplest available buccal path instead.

It becomes clear that the relative timing of the development of the lateral incisors vis-à-vis the canines is of crucial importance to the immediate micro-environment, particularly in relation to the occurrence of eruption disturbance of the canine. This may be summarized as follows.

The root of a normal maxillary canine begins to develop at age 6–7 years and reaches two-thirds to three-quarters of its estimated root length at 11 years, which corresponds to the time of its eruption. Actual progress of the canine along its eruptive path probably begins at age 8.5–9 years, when approximately half its root will have developed and when it is in need of guidance.

A normal lateral incisor at that age will have already erupted and will have grown more than two-thirds of its final root length. The crown of the canine will be located high up in the anterior maxilla, closely related to the developing apical third of the incisor. In this way, the conditions for guidance of the canine will have been realized and, in general, it erupts unaided at its due time two years later. The partial time overlap of odontogenesis of the separate growth systems of the two individual teeth dovetails to enable the canine to achieve its eruptive ambitions.

Since the ‘normal’ eruption time of a small or peg-shaped lateral incisor is still measured by its achieving two-thirds of its root length, it may first appear in the mouth as much as three or four years late, at age 11–12 years. By this time the fate of the path of eruption of the canine is sealed and, like a boat without a rudder, it is likely to lose its way (Figures 7.12–7.14).

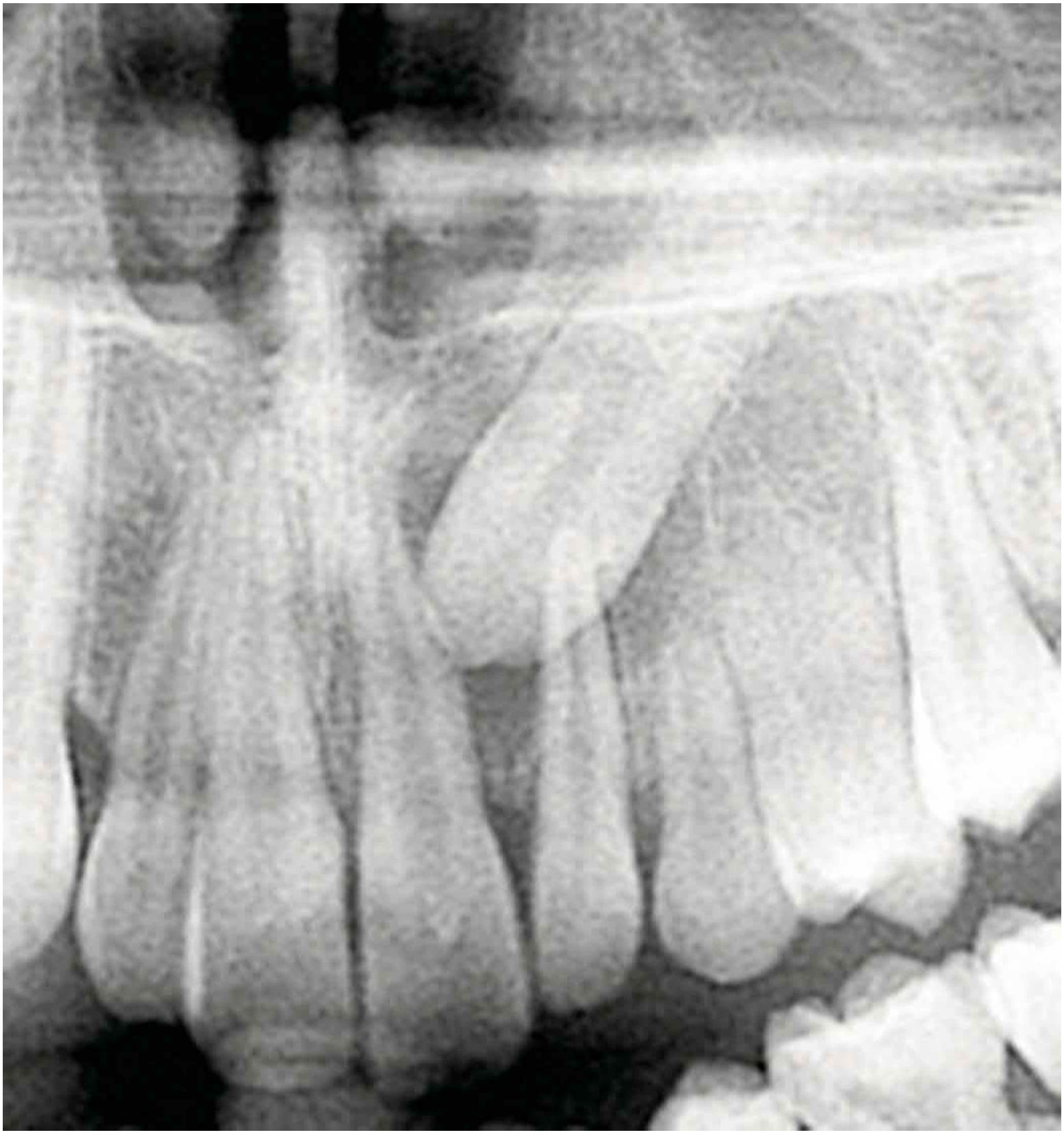


Fig. 7.12 Panoramic view of a 12-year-old girl with a palatally impacted left maxillary canine. There is an enlarged dental follicle surrounding its crown and the deciduous canine has a long unresorbed root.

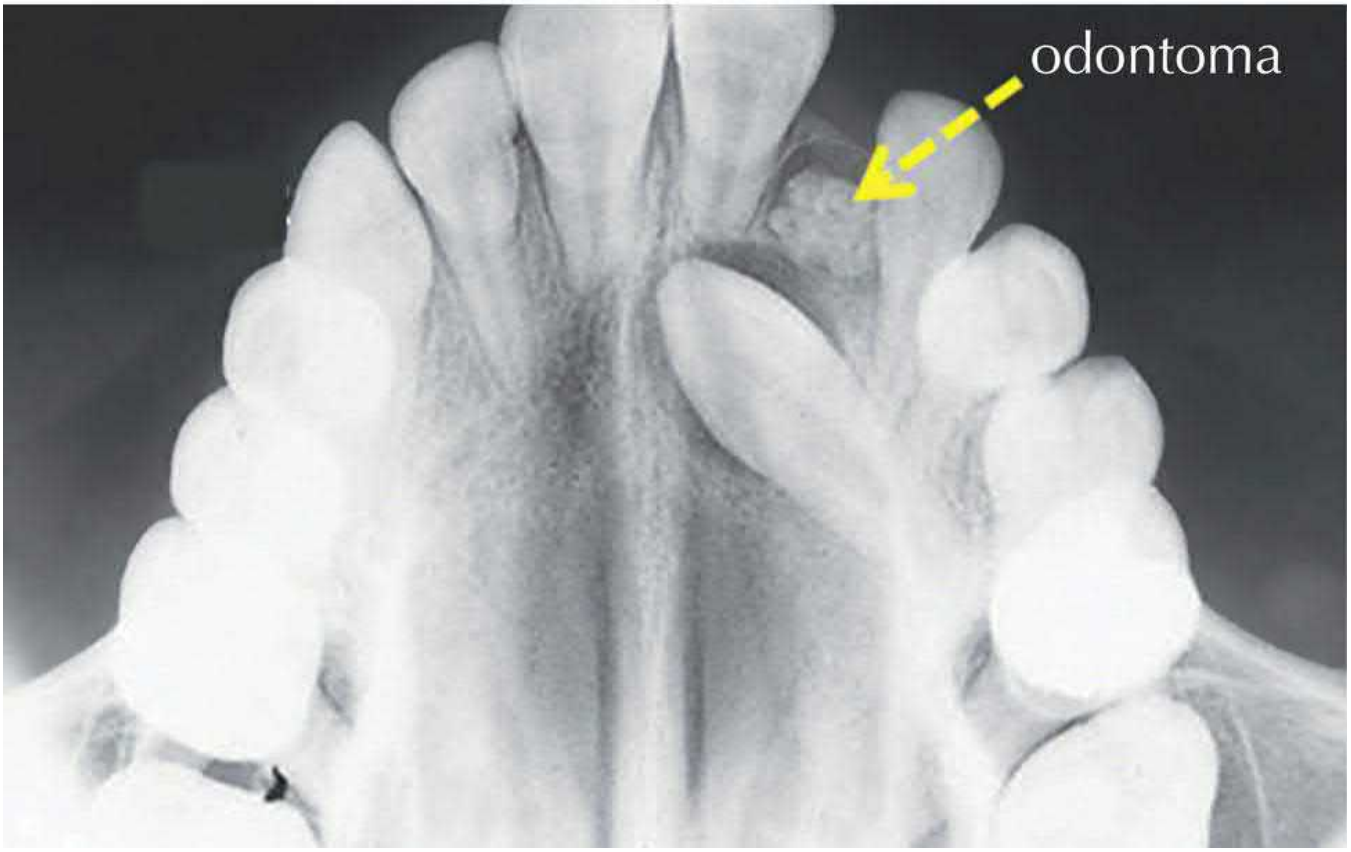
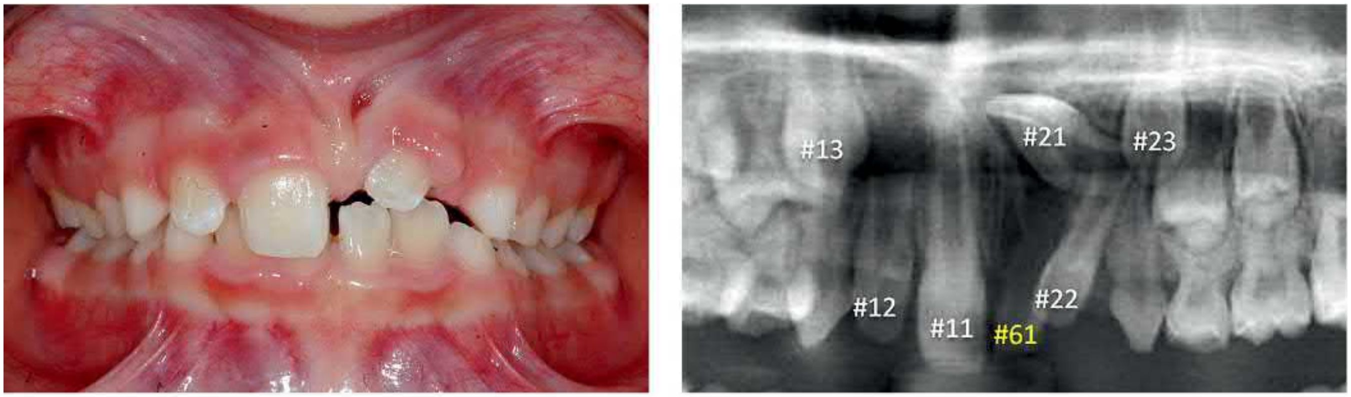


Fig. 7.13 Odontoma causing impaction of the canine.



(a) (b)

Fig. 7.14 (a) Intra-oral view of an 8-year-old child with an unerupted left central incisor. The adjacent lateral incisor has erupted and is strongly tipped mesially, encroaching on the space for the missing tooth. (b) Panoramic film of the same patient, taken prior to the extraction of the deciduous central incisor (#61). The permanent central incisor (#21) is dilacerated, with its crown in the area of the anterior nasal spine. The long axis of the lateral incisor (#22) is strongly tipped, displacing the root end distally and into close relation with the canine crown (#23).

The genetic theory of impaction

In the light of strong evidence of heredity in cases of palatal canine displacement, considerable support has been afforded to the theory that genetics is the direct cause of this condition. Other comparative factors have been dismissed as being secondary or indeed as yet more hereditary factors. In short, the theory proposes that the palatal canine is simply one more link in the chain of proven genetically linked phenomena. In the studies of the families of children who display palatally displaced maxillary canines by Zilberman et al. [36] and Bartolo et al. [37], the parents and siblings of these children were examined for the same related anomalies. Initial results showed that the incidence of small, peg-shaped and missing lateral incisors, late-developing dentitions, spaced dentitions and other missing teeth among these close relatives was very high. In addition, a much increased rate of palatally impacted canines was noted. This evidence seems to favour heredity as the main causal agent for these associated features, *including* the impacted canine.

As we have already seen, the guidance theory contends that the presence of these attendant phenomena creates an environment favourable to the development of palatally displaced canines. As was to be expected, the lateral incisor phenomena were found to occur in an unusually high proportion of these cases. On the other hand, the theory that these phenomena are *genetically* determined and frequently occur together, including canine displacement, is equally tenable, but would appear to be an over-simplification. The fact that extraction of adjacent deciduous canines and anomalous lateral incisors, together with orthodontic space opening, greatly improves the chances of canine eruption therefore leads to the conclusion that local factors cannot be ignored as exerting a powerful influence on the aetiology of canine impaction [38–43].

Abnormality in the embryonic dental lamina and primary displacement of the tooth bud

From time to time, maxillary canine positional ectopy occurs completely detached from the influence of other teeth or other neighbouring structures and is expressed in many and various ways. This makes it very difficult to draw comparisons with the more usual pattern of palatal or buccal displacement. It is reasonable to assume that genetic factors play a decisive role in where the entire tooth bud develops and is located. In such cases, it seems that the original site or orientation of the anlage from which the impacted tooth developed was itself abnormal. These conditions are genetically determined and therefore they are most likely to occur bilaterally.

If we traced the horizontally oriented semi-circular and virtual line that links the apices of all the teeth in either jaw, we would find that it conforms to and is parallel with an ideal archform that is produced by the naturally aligned crowns of an ideal dental arch. The apical line emanates from the embryonic dental lamina, is located in basal bone (as opposed to alveolar bone) and is not subject to positional alteration during growth. On the other hand, the crowns of the erupted individual teeth also form a horizontal line, which will be established after the individual teeth have travelled through vertically growing alveolar bone. On their way, the individual teeth are highly likely to be influenced by the local conditions that create malocclusion. These include factors such as dental crowding, early and retarded shedding of deciduous teeth, abnormal soft tissue posture and behaviour during swallowing and other functions. When there is irregularity in the form of the line that joins the crowns, it does not alter the apical semi-circular line. Thus, while the apices of these teeth largely conform to the horizontal apical line, the crowns of the teeth themselves tip this way and that in a crowded or otherwise irregular dentition.

For the most part, the root of a palatally impacted canine conforms to this scheme, to the extent that even when the crown is located at the palatal midline, the root apex lies on the same horizontally oriented semi-circular line. The orientation of the apex-to-crown axis of each tooth follows the path taken by that tooth and indicates where it originated.

Tooth transposition

Tooth transposition is the name given to the infrequent condition in which two adjacent teeth reverse their order in the dentition. A more descriptive and comprehensive definition defines transposition as the positional interchange of two neighbouring teeth and especially of their roots, or the development or eruption of a tooth in a position normally occupied by a non-neighbouring tooth [42].

In Chapter 6, we discussed the unilateral transposition of maxillary canine and lateral incisor that may occur when the adjacent central incisor is impacted. The erupted central incisor of the opposite side and the lateral incisor of the same side tip towards one another in a simple space loss movement, in much the same way as so frequently occurs when deciduous teeth are prematurely lost. In particular, the mesial tip of the crown of the lateral incisor reciprocally creates a strong distal tip of its root apex, which becomes displaced distal to the mesially migrating canine. These cases are entirely due to the very local eruption disturbance of the impacted incisor, which will usually occur unilaterally and most likely will have a non-genetic aetiology.

However, the patterns of other examples of transposition are vastly different. For the most part, they occur bilaterally and each side is very similar to the opposite side in any given individual. Some, in fact, are virtual mirror images of one another. Indeed, on the lateral head cephalogram, the two sides may be so identical that the left and right sides are exactly superimposed.

Transpositions of this type usually involve a maxillary canine and first premolar exchanging their order, but they may also occur between a mandibular canine and lateral incisor.

The orientation of the long axis of the canine in the bilateral cases often brings the root apex to a point at some distance from its normal location on the apical line, both mesio-distally and bucco-lingually. This will occur since the origin of the anlage of the tooth on the dental lamina was misplaced *a priori* – a primary genetic displacement of the tooth bud.

Notwithstanding the fact that there may potentially be adequate space in the arch for the normal eruption and alignment of the maxillary permanent canines, nevertheless the premolar will generally erupt autonomously but with its root apices mislocated mesially, with a strong distally tipped crown, and its root apices in close mesial proximity to the crown of the unerupted canine. Typically, the root apex of the canine is displaced distally and its long axis is more horizontally directed (Figure 7.15).

Fig. 7.15 Maxillary canine/first premolar transposition. An example of bilateral hereditary primary tooth germ displacement. Note the posteriorly displaced canine apices and the mesial location of the left first premolar apices, and other anomalies.

Fig. 7.16 Despite the absence of crowding, the canine has erupted in an abnormal location. The left side (not shown here) is similar. Is this evidence of a lack of guidance on the part of the adjacent

peg-shaped lateral incisor or hereditary primary tooth displacement?

Peck et al. [38, 40, 42] have studied maxillary permanent canine transposition/first premolar transposition (Figure 7.16) and have found a strong hereditary influence in its aetiology. They justifiably and correctly point out that this very specific type of canine anomaly cannot be construed as deriving from misguidance by the lateral incisor. Neither can it be explained in any way by the size, form or timing of the development of these two inter-related teeth. With somewhat questionable justification, however, they then extend their reasoning to cover *all* maxillary canine displacements, maintaining that the aetiology of all palatal impaction is also under total genetic control (Figure 7.17).

As opposed to the theory of Peck et al., we prefer to define canine/first premolar transpositions as primary tooth germ displacement [43]. In other words, the site of their development is not in its expected location in the jaw and in relation to the other teeth. In the developed dentition, this is reflected in an abnormal position of the root apex, which is initially assessed clinically by the mental exercise of virtually extending the orientation of the long axis of the tooth crown. This emphasizes the distinction between them and other, more common forms of displacement, which have an environmentally influenced aetiology.

Fig. 7.17 The left side of a case of bilateral hereditary primary tooth germ displacement. The right side (not shown here) mirrors this arrangement.

Canine/first premolar transposition and the more mundane palatal canine displacement are both aberrations of tooth position, but there is no justification for assuming that the aetiology of one is the same as for the other, and there can be no basis for equating transposition with palatal displacement. These transpositions are caused by an abnormality in the dental lamina that produces a primary displacement of the developing tooth bud, which most often occurs bilaterally. This does not, therefore, present a valid basis on which to refute the ‘guidance theory of palatal canine impaction’ [44–46]. On the other hand, it certainly does present a valid basis on which to support a genetic theory for canine/premolar transposition.

Problems with the genetic theory of canine impaction

The Human Genome Project was the world's largest collaborative biological project. It constituted an international scientific research project with the goal of determining the sequence of nucleotide base pairs that make up human DNA, and of identifying and mapping all of the genes of the human genome from both a physical and a functional standpoint. The Human Genome Project originally aimed to map the nucleotides contained in a human haploid reference genome (more than three billion). It was launched in 1990 and was completed in April 2003. A gene specific to palatally impacted canine teeth has not been discovered.

It is axiomatic that the right side of any patient is genetically identical to the left side and, as such, any genetic condition of the patient's right side will also manifest itself on the left. While the phenotype expression may vary, the genotype will be identical. There cannot be a situation where a person suffers from a general medical condition that has a genetic aetiology that affects just one side of the body. That said, however, in several hereditary conditions the *degree* of penetrance of the gene may vary between one side and the other, resulting in varying degrees of expression of the characteristics of that condition. Cleidocranial dysplasia (CCD), which will be dealt with in full in Chapter 21, is an autosomal dominant inherited disease for which the RUNX2 gene is specifically responsible. An affected patient may show variation in gene expression and have more supernumerary teeth or more impacted teeth on one side than the other, but both sides are affected. As we have noted, missing, small and peg-shaped lateral incisors are three varieties of expression of a single genetic factor and, as such, we may frequently see a peg-shaped or small lateral incisor on one side of the mouth and a missing antimere on the other. In genetics, bilateralism is the rule rather than the exception.

It would follow from this principle that if canine impaction were under genetic control, then we would expect to see *bilateral* canine impaction in the majority of cases, and only a small percentage of cases may show a lesser degrees of impaction on one side compared to the other. This therefore begs the question of why epidemiological information, gleaned from the findings of many studies in random populations and in large samples of orthodontic patients and reported in the orthodontic literature, seems to indicate a range of 60–75% preponderance of unilateral canine impaction.

If indeed canine impaction is genetic then, in the studies comparing monozygous (identical) twins to dizygous (fraternal) twins, one would expect to find monozygous twins with a higher degree of concordance for impacted canines than dizygous twins. However, the results of such a study found a similar degree of concordance for ectopic canines in both groups, thus clearly indicating an epigenetic aetiology [37].

For more than half a century, it has been accepted that small and peg-shaped incisors represent a weak or partial expression (incomplete penetrance or microform) of congenital absence [30–35, 47]. It follows, therefore, that if palatal displacement of a maxillary canine is dictated by genetics, then one would expect to see this form of ectopia more frequently associated with congenital absence of the adjacent lateral incisor than with a lateral incisor of reduced size. This is justified on the basis that extreme expression of a genetic feature is significantly rarer than the range of its milder forms. However, not only does this not occur, but the reverse appears to be true. There is a significantly higher proportion of palatal canines involved with anomalous lateral incisors than with congenital absence [9–11, 29, 48].

In order to confirm or negate this reported tendency and to provide a firm scientific base for this apparent paradox, a study was designed in which the investigated sample consisted of patients who were taken serially from the files of the Orthodontic Departments in the Universities of Jerusalem and Tel Aviv and from private orthodontic practice in Israel [49]. In this patient base of approximately 12,000 consecutively treated orthodontic patients, the individuals who comprised the investigative sample in the study were required to show an anterior maxilla with the following pre-treatment conditions:

- Unilateral congenital absence of the maxillary lateral incisor (side unspecified).
- A unilateral anomalous lateral incisor (small or peg shaped) on the contralateral side.
- Unilateral maxillary canine impaction (side unspecified).

Given such rigorous criteria of selectivity, only 19 patients remained to form the experimental group. The null hypothesis of the investigation was that if (a) reduced or peg-shaped lateral incisors are hereditary and represent a microform/incomplete penetrance/partial expression of congenital absence and if (b) palatal displacement of maxillary canines is a hereditary condition and associated with the lateral incisor anomaly, then it would be logical to assume that the palatally displaced canine will occur far more frequently in association with congenital absence of the lateral incisor than with the dimensionally diminutive tooth. Not only was this not so, but the results of the study showed that, in an overwhelming majority of cases (84%), the palatal canine was found on the side of the anomalous lateral incisor, with only three cases (16%) found on the side of the missing tooth. From this, it was concluded that environmental factors are strongly bound up with the causation of palatal displacement of the maxillary canine and could be explained in terms of the second-stage impaction already described.

If the behaviour of the canines were indeed governed by genetics, it is to be expected that a greater severity of the genetic trait (congenital absence) would be associated with a greater frequency of canine impaction. From the genetic viewpoint, it is surely paradoxical that canine impaction is more frequently associated with anomalous incisors, which are the weaker genetic pattern.

Associated clinical features

Population studies in several countries have shown that the teeth in males are generally larger than those in females. It has also been shown that patients with impacted maxillary canines have smaller teeth than is seen among unaffected patients [5, 11, 15, 42, 50]. However, while male patients with palatal canines have small teeth, this is not a characteristic of their female counterparts [50]. Oddly, the teeth of impacted canine–affected males were found to be similar in size to the teeth of the unaffected females from control samples.

Both male and female patients with palatal canines often have missing teeth, which may be third molars, maxillary lateral incisors, mandibular and maxillary second premolars, or mandibular central incisors [5, 7, 25, 26, 35, 41, 51].

A fact that has largely escaped attention in the literature is the one so well described by Newcomb over half a century ago [52], that ‘with few exceptions … potential impaction of permanent teeth is seen in patients exhibiting moderate to severe retardation of dental maturation [and] a slow rate of permanent teeth formation’. This clearly stated theory, that small and missing teeth in a dentition are associated with late development [52–54] led Newcomb to recommend that ‘it would be useful … to correlate dental and bone ages’ among these patients. Newcomb based his conclusions on dental age as determined by the eruption status of the dentition. However, no specific study was ever undertaken to investigate this connection until much later. The Jerusalem group investigated the comparison between dental and chronological age in 55 children with palatally impacted canines. The children were assessed for dental age on the basis of the root development of the dentition, as measured on radiographs and using the principles outlined in Chapter 1. This is a more accurate method of dental age assessment than eruption status, since the latter is open to the influence of local environmental factors.

In approximately half of the cases examined in the study, development was seen to be in line with the norms for their ages, while in the remainder, significant developmental delay was seen. However, it was clear that advanced dental development did not figure in any of the affected cases, thus underlining the absence of a normal distribution for dental development and a strong tendency for lateness [48].

This study also emphasized sexual dimorphism in the pattern of delayed dental development of the male and the female patient. Among affected males, a dental age significantly younger than the chronological age was found to be twice as frequent as among affected female counterparts. In one-half of the males examined, late dental development was observed, accompanied by the presence of smaller than average teeth and a high frequency of lateral incisor anomaly. The other half of the male sample showed a timely developed dentition, a statistically non-significant increase in the incidence of lateral incisor anomaly, and mesio-distal width reduction only in the maxillary central incisors and first molars. This latter male sub-group therefore resembled the unaffected cases that were incorporated in the control group in this study. Among the females, however, late dental age was accompanied by only a slight increase in lateral incisor anomaly, and general tooth size was not affected.

In the light of such contrasting and partially conflicting findings regarding tooth size and retarded dental development as seen in males and females who exhibit palatally displaced maxillary canines, it is clear that the results of studies of tooth size, congenital absence and dental age that involve a combined male–female group of patients will be very confusing. Indeed, this combination may obscure other important differences that may exist between the sexes.

Infra-occluded deciduous mandibular molars have also been found in larger numbers in patients with palatal canines [7, 48]. Two opposing explanations for this phenomenon both seem to be cogent, even persuasive. As has been seen above, the first theory assumes that the canine aberration is totally hereditary and is linked with the associated hereditary factors of lateral incisor anomaly, late dental development and small and missing teeth. To this list must now be added infra-occluded deciduous molars as a further hereditary factor. The opposing theory observes that over-retained and infra-occluded deciduous molars are often found in situations where their premolar successors are small or congenitally absent. Despite the different theoretical viewpoints, both accept the likelihood of partial resorption of the roots of the deciduous molars, sometimes involving only one of the widely divergent roots. This results in over-retention of a surviving root of the deciduous molar, which, under these circumstances, is more likely to become infra-occluded than a tooth that sheds normally and in its due time. As has been already discussed in this chapter, dentitions with small or missing second premolars are often associated with lateral incisor anomalies, which have been shown to be allied with palatal canines. With this explanation, therefore, the association between infra-occluded mandibular molars and palatal canines may be described as an indirect one, which is linked to hereditary factors that have caused changes elsewhere and that generate the guidance factor that locally causes the canine aberration.

As if the long list of components noted and discussed here is not enough, there are still many other inconsistencies that serve to challenge the appropriateness and acceptability of a purely genetic theory of maxillary palatal canine impaction. This then fuels the search for other contributing, co-existing or alternative causes, and we will find that some of these alternative suggested causes provide more compelling arguments that appear to undermine the indisputability of the genetic scenario.

In Chapter 7, relating to impacted maxillary incisors, we were at pains to point out that an early first phase of treatment is indicated in order to resolve the impaction of the affected tooth. In the long-term follow-up of many of these maxillary incisor impaction cases, it was observed that there seemed to be a substantial number of patients in whom there was a serious disturbance in the eruption of the canine of the same side. Accordingly, a study was undertaken of children who had been treated for maxillary incisor impaction, to monitor the further development in the months and years following the resolution of the incisor impaction in their first phase of treatment [55]. Abnormality of position and disturbance of eruption were seen in the canine on the same side as the previously impacted central incisor in 41.3% of cases. Of these, palatal canines were present in 9.5% and in 1.6% the canine and lateral incisor were transposed. A whopping 30.2% showed BDC, of which half were in a pseudo-transposed CI_2 relationship (Figure 7.18a). This was in stark contrast to the contralateral canine, where the rate of abnormality of position and disturbance of eruption was only 4.8% (Figure 7.18b), which is similar to the figure for the presence of impaction of maxillary canines in the general population (see Figure 7.9).

The abnormality of the canine in the affected side was expressed in several different ways, namely palatal impaction, buccal ectopia and pseudo-transposition with the lateral incisor. The frequency with which disturbance of canine eruption occurred was many times more likely to occur on the side where the central incisor had been impacted, featuring in almost half of cases. This is highly indicative of environmental influence (see Figure 7.18a, b).

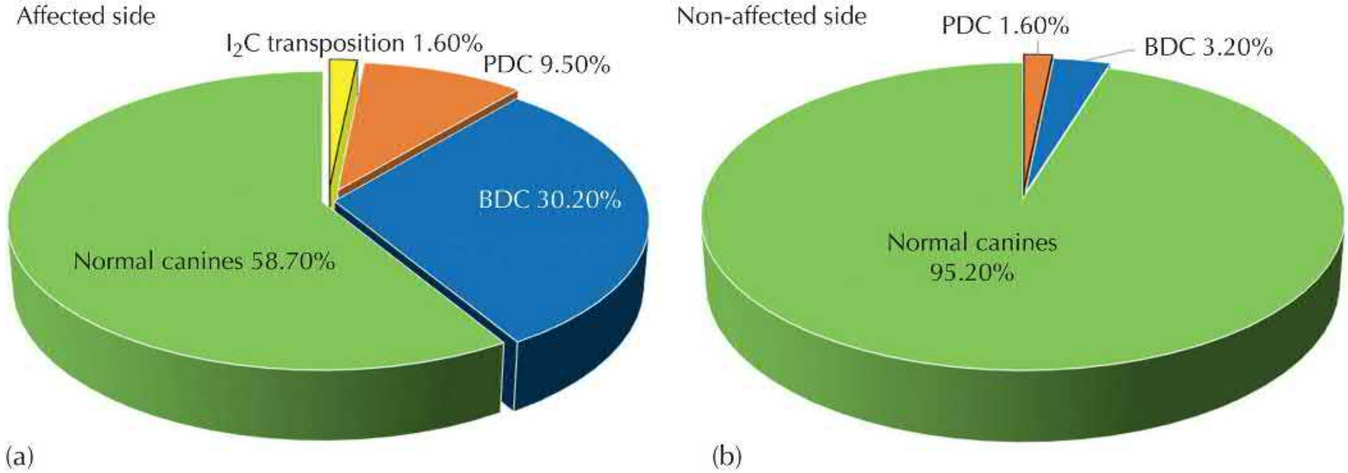


Fig. 7.18 (a) Eruption status of the canine on the ipsilateral (affected) side, previously treated for an impacted central incisor. (b) Eruption status of the canine on the contralateral (non-affected) side.

In a radiographic study [56] of a series of 122 Israeli patients with multiple congenitally missing teeth, 20.4% of the maxillary permanent canines were congenitally absent. Moreover, 42.4% were mesially displaced, of which 5.7% became impacted and mostly adjacent to the missing lateral incisor location. Of the remainder, 5.6% were distally displaced and only 26.4% were positioned in their correct locations, mainly adjacent to an existent lateral incisor. From an analysis of all these results, it was concluded that displaced and impacted maxillary canines were to be found very frequently in this highly special group of patients. However, the small sample size precluded the drawing of definitive conclusions.

The overall conclusions that need to be drawn from this discussion must surely be that the causation of palatal displacement or impaction of the maxillary canine is not due to any single factor. Local anomalies or obstructions deriving from healthy but redundant dental hard tissues, such as supernumerary teeth, odontomes and unusually curved roots of adjacent teeth, will all create physical barriers against which the canine may impact. In a similar fashion, pathological soft tissue entities, such as granulomas and cysts due to carious breakdown of the deciduous canine, can equally be considered an obvious cause.

With regard to the question of total genetic control relating to anomalous or missing lateral incisors, late dentitions and infra-occluded deciduous molars, we have seen that there are two schools of thought. One considers the path of eruption of the canine to be pre-ordained by a genetic master plan. The alternate view sees the same genetically directed milieu as setting the scene for a locally, environmentally driven eruption disturbance of the canine.

Further evidence for the validity of the guidance theory will come later in this chapter, when we discuss preventive counter-measures, in which the local environment is altered in favour of spontaneous eruption. These counter-measures may include orthodontic space opening, prophylactic extraction of the deciduous canine or of a miniscule permanent lateral incisor, or elimination of a soft tissue lesion or hard tissue body. All of these provide the impacted tooth with an improved environment for self-correction.

So, while the aetiology of this dynamic scenario may arguably be directed either by genetic or by environmental factors, the evidence should be sufficient to cast doubt on the simplistic and dogmatic view that the palatal canine itself is solely under genetic control. More than 20 years ago, we wrote that ‘there is currently too little robust statistical or genetic evidence to definitively ascribe malposition of the permanent canine as an isolated disorder of either genetics or environment’ [49, 55]. Times have changed little in the interim, but a more rational approach to aetiology has evolved.

Complications of the untreated impacted canine

Morbidity of the deciduous canine

Early morbidity of the deciduous canine is common for two reasons. First, its root may have become significantly resorbed, even in the event that its unerupted successor is quite distant from it. The resorption causes prolonged mobility and eventual but delayed shedding, which sometimes prevents the possibility of replacement by the permanent tooth. This chain of events will have created a problem in terms of rehabilitation, since the space is usually too small for alignment of the misplaced permanent canine or for a satisfactory artificial alternative, such as a fixed bridge pontic or implant.

The second reason for the common occurrence of morbidity relates to the relatively high susceptibility of the deciduous canine to interproximal (particularly distal) caries. As has been pointed out earlier, it is common to find a fairly extensive distal cavity in this tooth from around the age of 11 or 12 onwards. The tooth may have been deliberately left untreated by a general practitioner on the misplaced assumption that it would shortly be shed and replaced with the imminent eruption of the permanent tooth. The practitioner may have been unaware of the possible impaction of its permanent successor.

Cystic change in the follicle of the permanent canine

Loss of vitality may occur very early on in the carious process in the deciduous canine teeth. This is due to the narrow width of the hard dentine of these teeth and their relatively large pulp. Necrosis of the pulp and periapical pathology may then develop, without the accompaniment of pain or swelling. Under these circumstances, there may be close proximity between the resultant infected apical granuloma and the healthy follicular sac surrounding the unerupted permanent canine. The irritated follicular epithelium, which is derived from the reduced enamel epithelium of the tooth-forming organ, will likely become enlarged and will be clearly visible on a periapical radiograph. The inflamed epithelial cells may proceed to undergo cystic change, which will further increase the size of the fluid-filled balloon-shaped entity, and develop into a dentigerous cyst (Figure 7.19). There is no histological feature that may differentiate between the cells of a developmental dentigerous cyst and the cells seen in follicular epithelium and the only distinguishing character is one of size. In strictly radiological terms, an enlargement of the follicular sac to beyond 2 or 3 mm is generally considered to represent cystic change, which may also occur without any relation to pathosis of the deciduous canine. As these cysts expand, they resorb surrounding maxillary bone and the consequent raised intra-cystic hydrostatic pressure may cause the permanent canine to back up along its original eruption path, to a location higher in the maxilla.

Fig. 7.19 A dentigerous cyst surrounds the crown of an impacted canine. Note how bone of the alveolar crest has been resorbed several millimetres apical to the cemento-enamel junction of the tooth due to hydrostatic pressure within the enlarging cyst.

Alternatively, the chronic periapical lesion on the deciduous canine may itself become cystic – a radicular cyst – and its subsequent enlargement may displace the adjacent teeth, including the unerupted canine. (The subject of cysts in relation to impacted teeth will be described separately in Chapter 14.)

Crown resorption

The dental sac surrounding the completed crown of a tooth holds the surrounding tissues away from direct contact with the crown of the tooth. The integrity of the sac may degenerate with age if the tooth remains unerupted, resulting in the bone and connective tissue coming into direct contact with the enamel of the tooth. In time, osteoclastic activity will slowly resorb the enamel and replace it with bone – a process known as 'replacement resorption' or 'ankylosis'. Repeated radiographs of the tooth over a long period will reveal a progressively poorer definition of the profile of the crown, with the enamel becoming less and less contrasting in its transparency, highlighting this bone-for-enamel substitution (Figure 7.20). Subsequent surgical exposure of the crown of this tooth will show a pitted surface, which will be difficult to detach from the surrounding, adhesive connective tissue and bone.

This condition is much more likely to occur in elderly patients in whom the impaction has been left untreated and remained quiescent over several decades [57]. This is arguably one of the principal reasons why, when attempting treatment of impacted teeth in adults in the fourth or fifth decade of life, the chances are high that the tooth will not respond to orthodontic force [58].

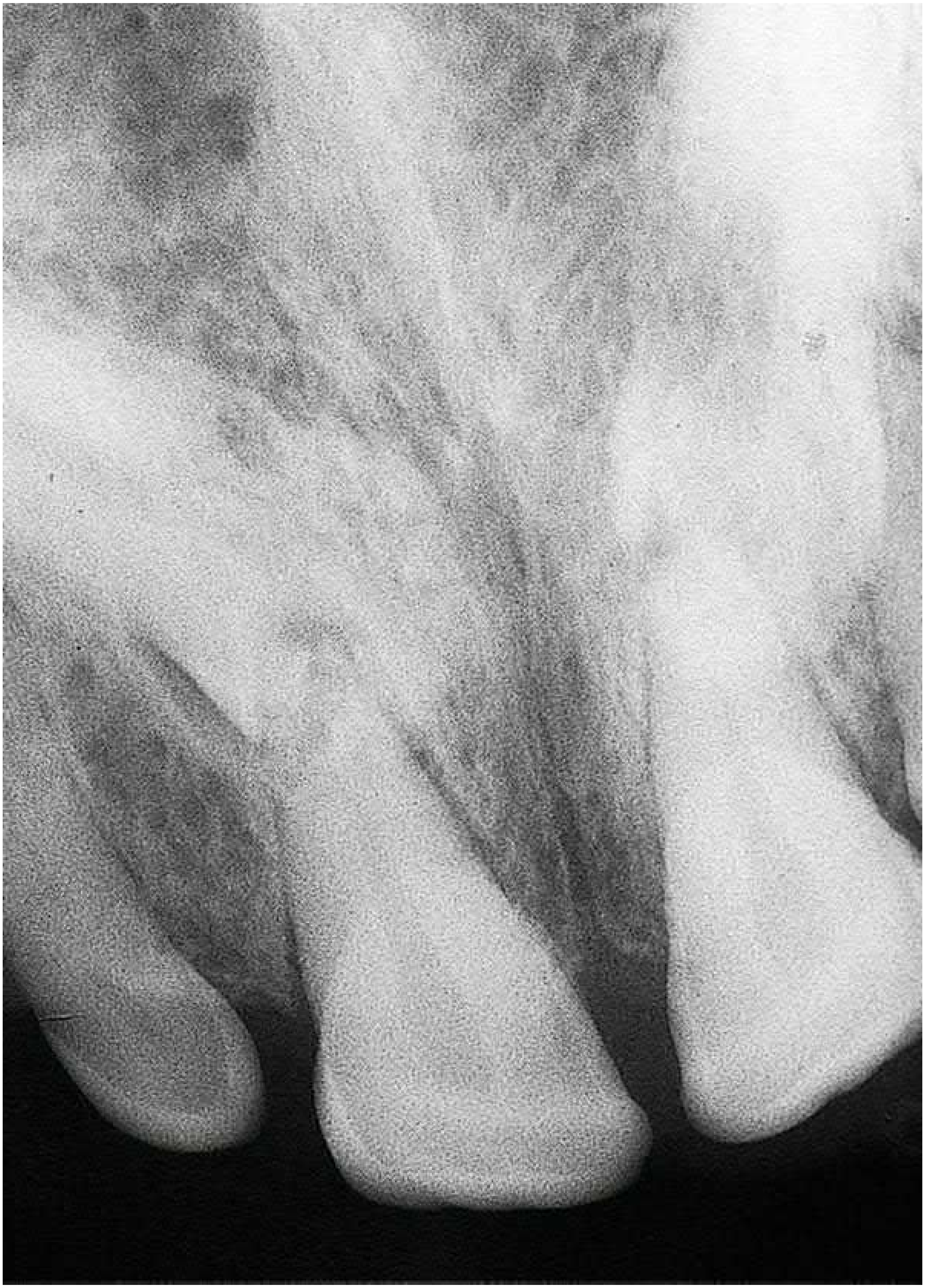


Fig. 7.20 Periapical view of maxillary incisor area in a 63-year-old female, showing advanced replacement resorption of the crowns of two impacted canines. The follicles of both teeth are almost completely absent and the teeth are very radiolucent, with poor definition.

Resorption of the roots of the incisors

The proximity of the follicular sac or, possibly, of the crown of an unerupted permanent tooth to the roots of its deciduous predecessor appears to be the trigger that initiates the process of root resorption. This is probably the result of the pressure thereby caused. The dynamics of this resorption process are then maintained by the continued eruptive movement of the permanent tooth, which advances into new areas vacated by the resorbing root and alveolar bone. This is a pathological process when affecting the permanent teeth, although it is analogous to the normal process of transition from the deciduous to the permanent dentition.

Little is known about the cause of the resorption of the roots of deciduous teeth that leads to their eventual shedding and why this does not normally occur to the roots of permanent teeth. Histologically, there is no way to tell the difference between the dentine of a deciduous tooth and that of a permanent tooth. Under certain conditions, however, the presence of an unerupted permanent canine tooth may be associated with the resorption of the root of the adjacent permanent lateral (Figure 7.21) or central incisor [13, 58–67], as well as the roots of the first premolar. Furthermore, and in a manner similar to that seen with deciduous teeth, the progress of this undesirable phenomenon depends on further eruptive movements of the impacted tooth.

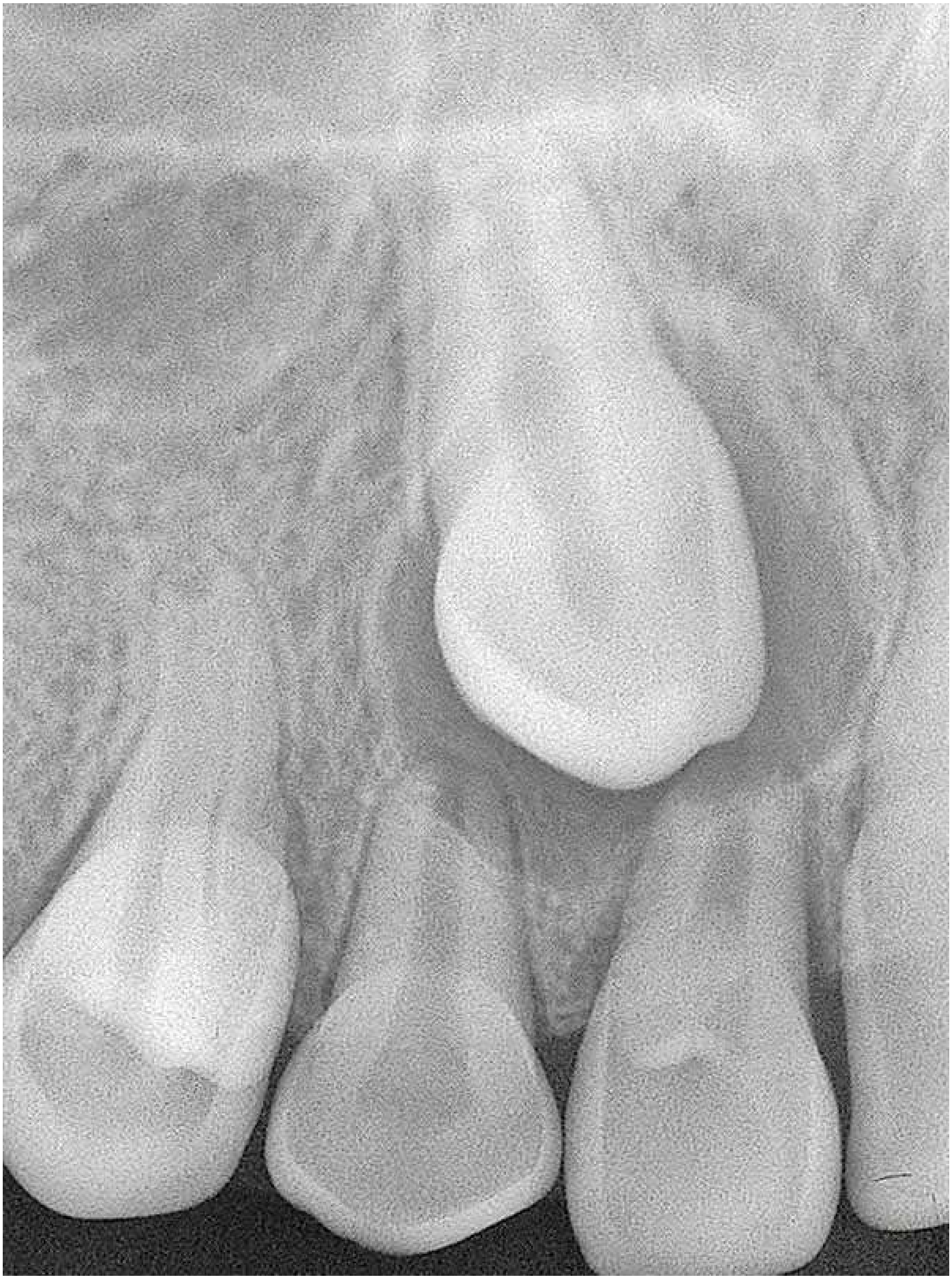


Fig. 7.21 The impacted canine crown is surrounded by a large dentigerous cyst, with associated physiological root resorption of both the deciduous canine and the pathological resorption of the permanent lateral incisor.

In this context, it is perhaps pertinent to observe that the maxillary canine and, occasionally, the third molars are almost the only permanent teeth whose eruptive attempts, both successful and unsuccessful, may cause significant resorption of the roots of neighbouring teeth. They are also the only permanent teeth that normally develop in close proximity to the root surface of other permanent teeth, rather than to their crowns. In contrast, the premolar teeth develop in a restricted area, encompassed by the roots of the deciduous molars and at a distance from other permanent teeth. However, in occasional instances, an aberrant and distally tipped second premolar may escape the confines of the encompassing mesial and distal roots of the deciduous molar and may migrate distally, come into contact with the mesial root of the first permanent molar and cause its resorption (see Figure 7.2). Central incisors and first molars erupt before their adjacent neighbours and the lateral incisors initially come into contact with the crowns of the central incisors, close to the cervical area. During most of its pre-eruption period, however, the maxillary canine develops much higher up in the maxilla and in close proximity to the roots of the adjacent lateral incisor and first premolar. Similarly, unerupted third molars in crowded positions in the ramus or tuberosity areas may come into close relation with the root portion of the second molars, where similar damage may be caused.

Diagnosis

Unlike impacted mandibular third molars, unerupted permanent maxillary canines rarely cause the patient pain or swelling and neither do they adversely affect the patient's appearance. An over-retained deciduous canine may have a relatively poor appearance compared with a properly aligned permanent canine but, for the most part, patients are unaware of the presence of an impacted canine and do not seek treatment for the over-retained deciduous canine. The discovery of canine impaction is therefore usually made during routine dental examination by the general dentist or paediatric dentist.

Inspection

The maxillary permanent canine normally erupts at a dental age of about 11 years. Its non-appearance at this age should invite clinical inspection and radiographic investigation, especially if its antimere is present.

Under normal circumstances, the maxillary incisor teeth are spaced and flared laterally until the age of 10 years, as described earlier in this chapter. Should this situation still remain at age 11 or 12 years, the clinician should be suspicious, since this may indicate that there is a detail missing from the mechanism that causes the smooth transition from Broadbent's ugly duckling stage into the final adult alignment, with interproximal incisor contacts. Indeed, a wide and persistent median diastema may just be the symptom that brings the patient to the office to request treatment, unaware of the impacted canine.

It is unlikely that a missing lateral incisor or a conspicuous peg-shaped incisor will be overlooked. Nevertheless, care should be taken to examine the size and shape of existing lateral incisors. Central and lateral incisors, whose crowns have mesio-distal straight or incisally tapered sides and lack the classical proximal contour, are usually small teeth and often develop late. Some of these are conspicuously peg shaped, a condition defined by their widest mesio-distal dimension being at the CEJ.

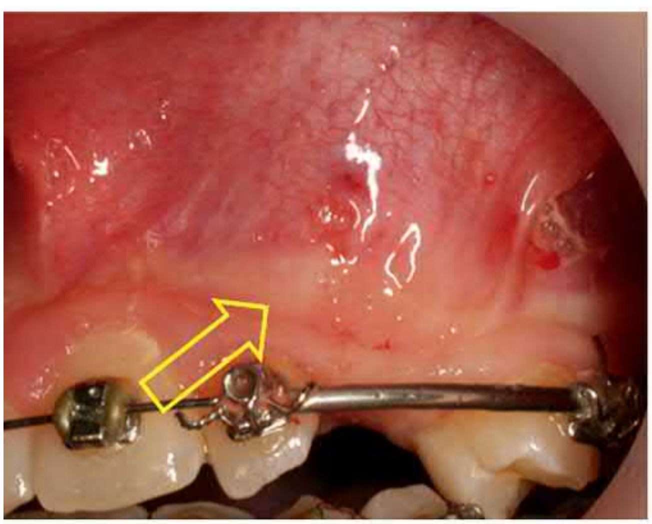
Furthermore, the discovery of a late-developing dentition and a dentition in which there are missing teeth, other than the lateral incisors, should also be treated with a degree of caution.

We have reported already that all these factors have been linked with palatally displaced canines. This possibility should be thoroughly investigated, both at the time when the phenomena are first noticed and in subsequent follow-up examinations that may have been scheduled to oversee the smooth changeover from the mixed to the permanent dentition.

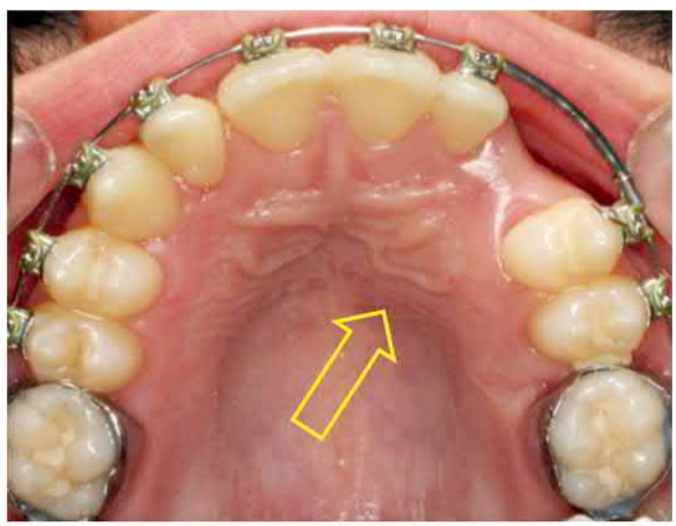
Abnormally positioned unerupted canines frequently affect the positions of neighbouring teeth, particularly lateral incisors. We have already pointed out that the root apex of a palatally impacted canine is usually in the line of the arch, with the crown mesially displaced, in addition to its palatal tilt. This brings it into close relation with the palatal side of the lateral incisor, often labially displacing the incisor root. Clinically, this will be identified by the root being very prominent on the labial side of the ridge or by a lingual tilt of the crown of the tooth, sometimes into a cross-bite relationship. In contrast, a lateral incisor, whose root orientation indicates a strong palatally directed apical displacement, suggests that the unerupted canine is labially placed and, at least to a degree, also somewhat mesially directed (see Figure 6.16).

Palpation

We have noted that, under conditions of normal development, the permanent canine is palpable buccally above the deciduous canine for two or three years prior to its eruption. The labial aspect of the alveolus should be palpated above the attached gingiva and up to the reflection of the oral mucosa. A wide convex contour of the bone is indicative of the canine immediately beneath it (Figure 7.22a). Care should be taken not to confuse this with the narrower profile of the unresorbed root of a deciduous canine. In the event that this contour is concave, the palatal side of the alveolar process should be palpated to see if there is a clue to the canine's location there (Figure 7.22b). The deciduous canine should always be tested for mobility. If this test is even mildly positive, it will suggest that the permanent canine is fairly close to the desired eruption path and that severe displacement is unlikely. In this situation, the unerupted canine may not be palpable on either side of the alveolar ridge.



(a)



(b)

(c)

Fig. 7.22 Palpable canines (a) labially displaced (arrow); (b) palatally displaced (arrow). (c) Neither canine is palpable in this patient. The clinical examination reveals labially and distally flared lateral incisors. These are the clue to the similarly bilateral canine location, as confirmed in this cone beam computed tomography 3D screenshot.

As has been stated earlier, when there is a strong, palatally directed, apical displacement of the root of the lateral incisor, it is likely that the canine is also mesially directed. In this case, the convexity of the unerupted cuspid will usually be palpable high in the labial vestibule and much closer to the central incisor root than to its normal position in the arch. The contour of the alveolus, above the deciduous canine, may well be concave. Given the unusual distance of the permanent canine from its normal position, its deciduous predecessor will have most of its root intact and will consequently exhibit no pre-shedding mobility.

Consider the case shown in Figure 7.22c. An examination of the locations and long axis orientations of the two lateral incisors and their distally tipped and labially flared axial relations will provide a good tentative assessment of the location of the unerupted canine, by inspection and palpation alone. The geometrical extension of the long axes of both lateral incisors will meet in the midline close to the anterior nasal spine. At the same time, there is no obvious convex in the ridge where the canine would normally be palpable. A careful palpation of the midline area in the height of the labial vestibulum will probably also not find the tell-tale labial bump of the canines. It is clear, however, that the canines can be found in this location and only this can account for the angulation of the lateral incisor.

Clearly, radiographic and cone beam computed tomography (CBCT) examinations are essential and the CBCT 3D screenshot in Figure 7.22c confirmed the positional diagnosis of the impacted canines.

Preliminary radiography

As we shall see later in this chapter, in order to properly plan the strategy of mechano-therapy for a particular case and to obtain a pre-treatment assessment of the periodontal prognosis of the treated result, it is essential to know the exact locations of both the crown and the root apex of the unerupted tooth. While a single periapical radiograph is to be considered essential to identify pathology, such as dental caries, apical granuloma, root resorption, obstruction and cystic change, it must be supplemented by other films that will help to precisely locate the unseen tooth, in the three planes of space and in relation to the adjacent teeth and other entities.

The use of a second periapical radiograph in the parallax method has the advantage of simplicity of technique and provides both the orthodontist and the surgeon with important information regarding positioning, although the exact locations of crown and apex are difficult to compute from these pictures. On the other hand, a true lateral view (as seen on the lateral cephalogram), paired with a vertex occlusal or postero-anterior cephalometric view, is technically more difficult to obtain, but will provide accurate 3D positional information on the unerupted tooth in its most comprehensible form. Nevertheless, these films involve a high radiation dosage for a relatively poor return of information provided.

The central portion of a panoramic radiograph, however, covers the incisor region in the postero-anterior view and depicts a palatal displacement as an overlap of the impacted canine on the roots of the incisors. This is by far the most popular method used today. The reader is directed to Chapter 4 for a description of how this film may be used alone, or in combination with a periapical film, with an occlusal film or with a lateral cephalogram, to extract a great deal of information regarding the position of an impacted canine.

It is important to remember that plain film radiography cannot provide reliable information in the bucco-lingual plane. Accordingly, incisor root resorption that may have occurred will likely remain undiagnosed until it is well advanced. Additionally, the bucco-lingual distance that separates the impacted tooth from its neighbour is very difficult to assess from these films, and this may be an important factor in planning the strategy for the biomechanical resolution of the impaction. For both these reasons and certainly in relation to the rare and more involved cases, it would be fully justified to subject the immediate area to a computerized tomographic (CT) examination, using a cone beam volumetric scanning machine (CBCT). This will certainly provide maximum positional information, but should not be considered *de rigueur* in regard to canine impaction in the early to middle mixed-dentition stage. On the other hand, when it is advised, it is mandatory to reduce the dosage of ionizing radiation to the absolute minimum, as described in Chapter 4 and in accordance with the ALARA (as low as reasonably achievable) principle.

For the large majority of these cases in the mixed-dentition period, the use of simple 2D planar views is adequate to give a good interpretation of the location of the tooth and its relationship to the surrounding neighbours. This will enable the practitioner to decide whether interceptive procedures or early treatment should be undertaken in the mixed permanent and deciduous dentition, or whether the situation be allowed to evolve and develop into the full permanent dentition state before treatment is commenced.

It is at this stage that the orthodontist must make the important decision on whether early treatment will simplify later treatment, or whether it will unnecessarily create the need for two stages of treatment: one for the immediate resolution of the canine impaction and the second for the overall malocclusion, to be dealt with when all the permanent teeth have erupted. It should be remembered that the appliances used for both stages are largely the same. To place them and remove them, only to replace them after a long intermediate two- or three-year period of freedom, will often cause pointless duplication, be unnecessarily expensive and unreasonably extend the total time the patient is in braces. Many are the occasions when an intended short (12–18 months) interceptive course of early treatment takes longer than expected and drags on indefinitely, waiting for teeth to erupt. The patient remains in braces continuously from the age of 9 or 10, when the aberration is first diagnosed and treated. This may then be just the prelude to a further period of two to three years of routine orthodontic treatment to treat all the other elements of the overall malocclusion as they develop. Since dentitions with impacted canines tend to exhibit late development, these patients may then have reached the age of 17 or 18 years before they complete the treatment and will likely have been in braces for 10% of their life expectancy. Seven to eight years of 'non-stop' wearing of appliances will unnecessarily place a heavy toll on a patient's forbearance, which in itself may have a strongly negative influence on compliance in the latter and, arguably, more critical stages of the treatment.

For the most part, therefore, this is an unacceptable treatment protocol and what is needed is to consider a forward-looking and critical approach to early treatment, in order to avoid unwarranted over-prescription. This is the true context of proper treatment planning and treatment timing, and it should be an integral part of the expertise of the trained orthodontic specialist. It will represent the quantum difference between such a person and the untutored generalist, who will often blindly offer treatment for individual symptoms as they arise. At best this may be short-sighted and at worst it borders on unethical exploitation.

Treatment timing

By the age of 9–10 years, it is usually possible to palpate a developing maxillary permanent canine tooth on the buccal side of the alveolus, high above its deciduous predecessor. In the presence of crowding, particularly after the eruption of the first premolar, the bulging of the unerupted canine is accentuated. The greater the degree of crowding, the greater will be this displacement and the more palpable will the canine become, as the eruptive process brings it further and further down on the facial side of the dental arch. It also follows that the greater the buccal displacement, the greater the risk that it will erupt through oral mucosa, higher up on the alveolar process, rather than through attached gingiva, closer to the crest of the ridge.

In the event that the tooth is not palpable at this age, radiographs should be taken to assist in locating the tooth accurately and to secure other information regarding the presence, size, shape, position and state of development of individual unerupted teeth, including any pathology. In a patient younger than 9 years, the radiographs will not usually show abnormality in the position of the unerupted canine teeth, even if the canines are not palpable and even if they are destined subsequently to become palatally displaced. Many of these non-palpable canines will finally erupt into good positions in the dental arch in their due time, provided that there is little or no mesial and palatal displacement of the crown. It is quite common that even canines with an initial mild palatal displacement will achieve spontaneous eruption and alignment despite a first-stage displacement, if they undergo secondary correction (see 'The guidance theory' earlier). Other canines will not erupt, however, and their positions may worsen in time, as may be seen in follow-up radiographs.

Prevention and interception

The bilateral unerupted maxillary canines seen in the patient in Figure 7.23a had a mesially angulated orientation and each was enveloped by enlarged dental follicles. Both canines were mildly displaced on the palatal side, as confirmed by supplementary periapical radiographs. The deciduous canines were over-retained with long and almost complete roots. They were extracted at this time, as an interceptive measure with the express purpose of encouraging spontaneous re-orientation and eruption of their permanent successors.

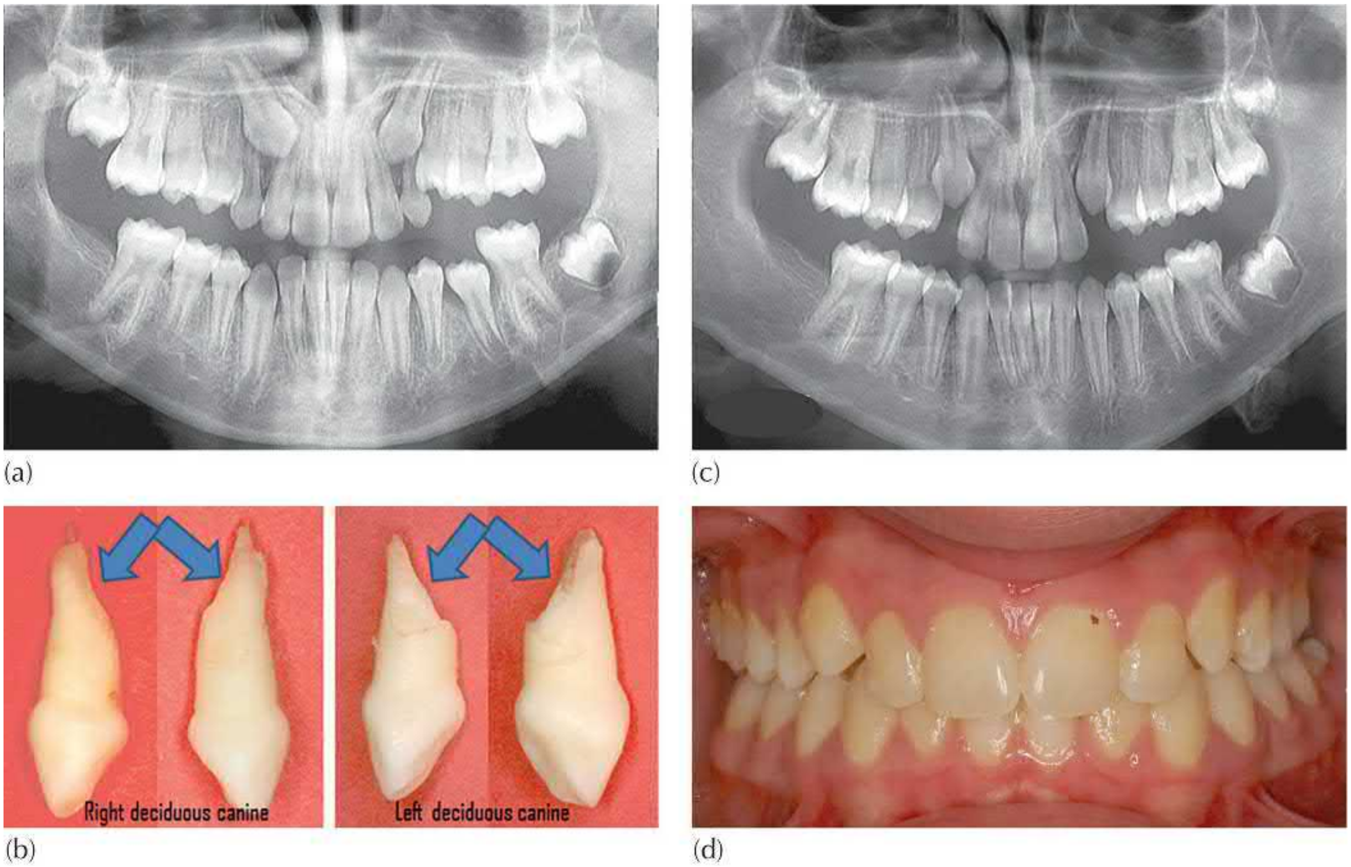


Fig. 7.23 (a) A panoramic view of the dentition of a boy aged 11 years, showing mesially angulated unerupted maxillary canines, with enlarged follicles. Both canines were mildly palatally displaced (confirmed with supplementary views). The deciduous canines were over-retained with long and almost complete roots. Note the congenital absence of the mandibular right second molar and late development of the left second mandibular molar. (b) The extracted deciduous canines showing the resorption craters in profile (arrows) from the mesial and distal aspects of each. (c) A panoramic view taken one year after extraction of the deciduous canines shows a favourable alteration in the orientation of the canines, whose normal eruption appears imminent. (d) A clinical photograph taken 18 months later, prior to the commencement of orthodontic treatment, slightly labial to the line of the arch.

When the apical areas of the extracted deciduous canines were inspected, each of them exhibited a resorption crater on the lingual side of the apical area of the root, again confirming the erstwhile palatal path of eruption of the permanent canines (Figure 7.23b).

At the outset, the canines showed a mesially oriented long axis, clearly constricting the apices to the midline area and flaring their crowns. When extraction provided space distal to the permanent canines, these teeth re-oriented their long axes and began to descend in a normal eruption path (Figure 7.23c). Although their eruption was fairly slow, they finally erupted 18 months later and took up their position on the buccal side of the ridge, despite having begun on the lingual side (Figure 7.23d).

As has been discussed earlier in this chapter, we have established that a genetically determined, lateral incisor anomaly creates an alternate local environment, one that permits the unerupted canine to follow an abnormal, palatally deflected and (often) futile path of eruption. Simultaneously, it actually offers ample evidence that spontaneous, corrective changes in the eruption path of a potentially impacted canine will occur when appropriate remedial alteration of these environmental conditions is carried out.

This now leads us to discuss what types of proactive environmental alteration can effect positive change in canine eruptive behaviour.

Improving existing conditions or creating new favourable conditions for autonomous eruption of the canine can be achieved in one or more of the following steps. The purpose of these steps is to alleviate anterior crowding by providing space distal to the canine, thereby encouraging it to adopt a more distal and buccal eruption path, to encourage it to erupt under its own steam.

- Extraction of deciduous teeth (see Figure 7.5).
- Extraction of permanent teeth.
- Increase of space in the arch in the immediate area.
- Distalization of the posterior teeth.
- Rapid maxillary expansion.

Extraction of deciduous teeth

Deciduous canines

As was indicated earlier in this chapter, several authorities have advised the extraction of the deciduous canine teeth in an attempt to encourage the permanent canines to erupt [20, 68–71]. A number of studies have been carried out in this area. However, the researchers first needed to evaluate the effectiveness of the panoramic radiograph in predicting canine palatal impaction.

Why choose a panoramic view? This is simply because this is arguably the most common view initially prescribed by an orthodontist when seeing the patient for the first time and it reveals the presence of an aberrant canine immediately. Several characteristics make the presence of the aberrant canine difficult to miss, such as its height in relation to the other teeth, the orientation of its long axis and its location in relation to the deciduous canine and the adjacent permanent teeth. These features may not be quite so obvious on a periapical series.

It is recommended to see the patient and diagnose the existing palatal positioning before the age of 11 years. By and large, studies have shown that extraction performed at this time offers a good prognosis for the natural eruption of the canine; indeed, 78% of the canines in one sample erupted into a clinically correct position [18]. Nevertheless, caution must be advised in interpreting these results, since the study did not include an untreated control group. Accordingly, it does not put us in a position to determine just how many of these teeth would have erupted without this preventive treatment [19], while other canines will impact despite the indicated extractions (Figures 7.24 and 7.25).

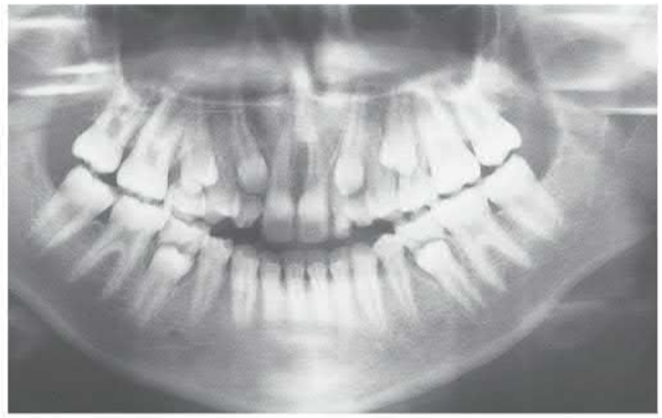
From their study, Ericson and Kurol concluded that the prognosis becomes less favourable as the palatally displaced canine’s mesial overlap of the lateral incisor root increases and as the angle between the long axis of the canine and the mid-sagittal plane widens [18]. They also noted that if positional improvement of the canine was not evident within 12 months of the prophylactic extraction, it was unlikely that improvement would occur.

Under certain specific circumstances, it may be assumed that the extraction of a maxillary deciduous canine may be a useful measure in the prevention of incipient canine impaction. Before such extraction is undertaken, the following conditions should be met to achieve maximum reliability:

- The diagnosis of palatal displacement must be made as early as possible.
- The patient must be in the 10–13-year age range, preferably with a delayed dental age.
- Accurate identification of the position of the apex should be made and confirmed to be in the line of the arch.
- Mesial overlap of the unerupted canine cusp tip on the panoramic view should be less than half-way across the root of the lateral incisor, i.e. up to the central long axis of the incisor or less.
- The angulation of the long axis should be less than 55° to the mid-sagittal plane.

The last two items on this list represent conditions that, if not fulfilled, may still lead to spontaneous eruption and alignment. Notwithstanding that the chances of this occurring do exist, prophylactic extraction may still be worth considering.

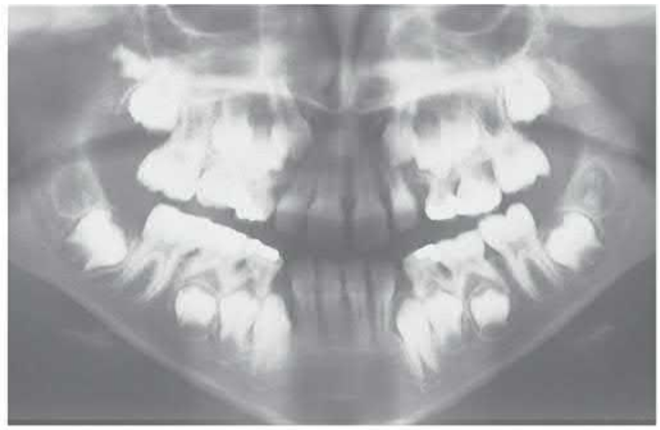
(a)



(b)

Fig. 7.24 (a) A case diagnosed from this panoramic view as exhibiting right-side lateral incisor absence, a peg-shaped left lateral incisor, together with bilateral palatal canine displacement. The child was referred for extraction of the deciduous canines and the peg-shaped incisor. (b) A year later, a repeat film showed that the extractions had not been carried out, yet there was great improvement in the position of both canines and normal eruption of the canines was expected after exfoliation of the deciduous predecessors.


(a)


(b)


(c)

Fig. 7.25 (a) A case of early crowding treated by extraction of four deciduous canines, at age 8 years. No hint of impending palatal displacement of the canine is discernible on this panoramic film. (b) One year later, the incisors were erupted and spaced. Extraction of the four deciduous first molars (the second stage of a serial extraction protocol) was advised. (c) The panoramic view taken a year later reveals the maxillary right canine in a palatally displaced location, despite early extraction of the deciduous canine. Later orthodontic treatment of this case may be seen in Fig. 7.47.

The work of many other researchers over the years, in Belgium, Sweden and Italy, largely confirms these findings [68–72].

Prior to the introduction to orthodontics of evidence-based treatment decisions, the author had already found merit in the simultaneous extraction of the adjacent first deciduous molar, together with the extraction of the deciduous canine. The justification for this 'pearl' was based on the rationale for the first and second stages of the classic serial extraction protocol of Birger Kjellgren in Sweden [73]. In his article of 1948 in the *Acta Odontologica Scandinavica*, republished in the *European Journal of Orthodontics* in 2007, he recommended extraction of the deciduous canines as the means to provide immediate space for the spontaneous eruption and alignment of the incisor teeth. The reasoning behind the extraction of the deciduous first molar was to cause the early and rapid eruption of the first premolar, well before the canine. The large crown of the premolar erupts and a much narrower cervical area of root is substituted at the level of, and distal to, the crown of the unerupted canine. Eruption of the premolar creates a potential void distal to the canine, which encourages the latter to drop back into the space that has suddenly become available, before the due eruption date of the canine. This is often sufficient to redirect a potentially wayward canine and encourage its more normal eruption. The clinical research of the group in Bologna, Italy, has demonstrated that the combined extraction of deciduous canines and deciduous first molars has indeed shown greater efficacy in its positive influence on canine eruption and has provided the evidence base for the adoption of this extraction protocol [74].

There are several question marks to be raised in connection with these studies. Whether or not cases with non-vital deciduous canines were included in the study samples was not mentioned in the methods and materials sections of any of the above-quoted articles. One may be permitted to wonder just how many of the deciduous canines in these study samples were non-vital, particularly in the early days when dental caries was much more endemic. A high percentage of the permanent canines may have later erupted spontaneously in what may dubiously have been claimed to be the sequel to the extraction of a vital and healthy deciduous predecessor. Similarly, it may be argued that their successful eruption could have been attributable to the concurrent elimination of a periapical lesion.

Periapical pathology is frequently missed or disregarded when studying the radiograph and therefore not taken into account as a potential causative agent. The occurrence of non-symptomatic soft tissue pathology (specifically, chronic periapical abscesses associated with non-vital deciduous teeth and enlarged dental follicles or early dentigerous cysts) represents a potentially powerful arresting and/or displacing impediment in the path of the unerupted tooth. Soft tissue pathology of this kind may lead to quite severe displacement and impaction of the unerupted permanent canine. The tooth's elimination may often have a favourable autonomous outcome even when displacement is quite extreme (Figure 7.5). (The reader is referred to Chapter 14 for a description of the treatment of teeth impacted in positions of extreme displacement by dentigerous and radicular cysts.)

As we have seen, there is no truly reliable method of early detection of a potential palatal displacement [19]. Accordingly, a claim that it was the pre-emptive extraction of the deciduous canine that had elicited the normal eruption of a permanent canine must be viewed with some reservation on the basis of the present state of our knowledge. Clinical experience with the serial extraction method would lead us to be encouraged by the procedure in many specific cases. However, if the intention is to apply the method on a community health basis, an accurate assessment of its efficacy has still to be determined. Moreover, long-term follow-up of patients is mandatory to monitor any unwanted collateral consequences of the multiple extractions. Follow-up of this nature is much more difficult to pursue, oversee and correct in a public health system.

Extraction as a means of prevention

First premolars

Impacted maxillary canines can and do occur in any type of malocclusion, although it appears that patients with incisor crowding, with class II malocclusions or bimaxillary protrusion seem to be less prone. Many of the patients within this minority group will be considered to be extraction cases and the choice of teeth for extraction will usually devolve on the first or second premolars.

The reasons for the choice of the first or second premolar are inscribed in the history of orthodontics itself. It offers significant potential benefit to the displaced canine, due to the proximity of these teeth to the canine-vacated alveolar ridge area, which facilitates the immediate provision of space close by. It also affords considerable opportunity for spontaneous improvement in the canine position (Figure 7.26) prior to the early levelling and aligning stages of mechano-therapy.

Where extraction of the premolar is executed, a waiting period of perhaps 6–12 months may be recommended following the extraction, during which time the canine will often answer the call and erupt spontaneously. In the best of circumstances, canines erupt very slowly; however, when premolars have been extracted, there is almost always a degree of distal migration that occurs during the eruption process. This potentially offers simplification of the treatment and reduction of the duration of the active tooth-moving period.

For this to be true, one must discount the fact that space maintainers and non-active multi-bracketed appliances may need to be left in place from the time space has been created until full eruption has occurred, when orthodontic brackets may be bonded to the erstwhile unerupted canines. For impatient teenagers for whom orthodontic appliances are an unwanted and irksome encumbrance, the difference between active appliances and retaining appliances is largely irrelevant, since for them the treatment appears endless.

(a) (b)

Fig. 7.26 (a) The left side of a case with bilateral maxillary palatal canine impaction. The maxillary deciduous canines, deciduous second molars and first premolars were extracted and an attachment placed on each of the exposed canines. No active orthodontic treatment was commenced. (b) The same patient seen 14 weeks later. Both second premolars erupted spontaneously and both canines have erupted into palatal cross-bite and to a similar degree. The attachment was placed at the time of surgery as a precaution, in the event of non-eruption.

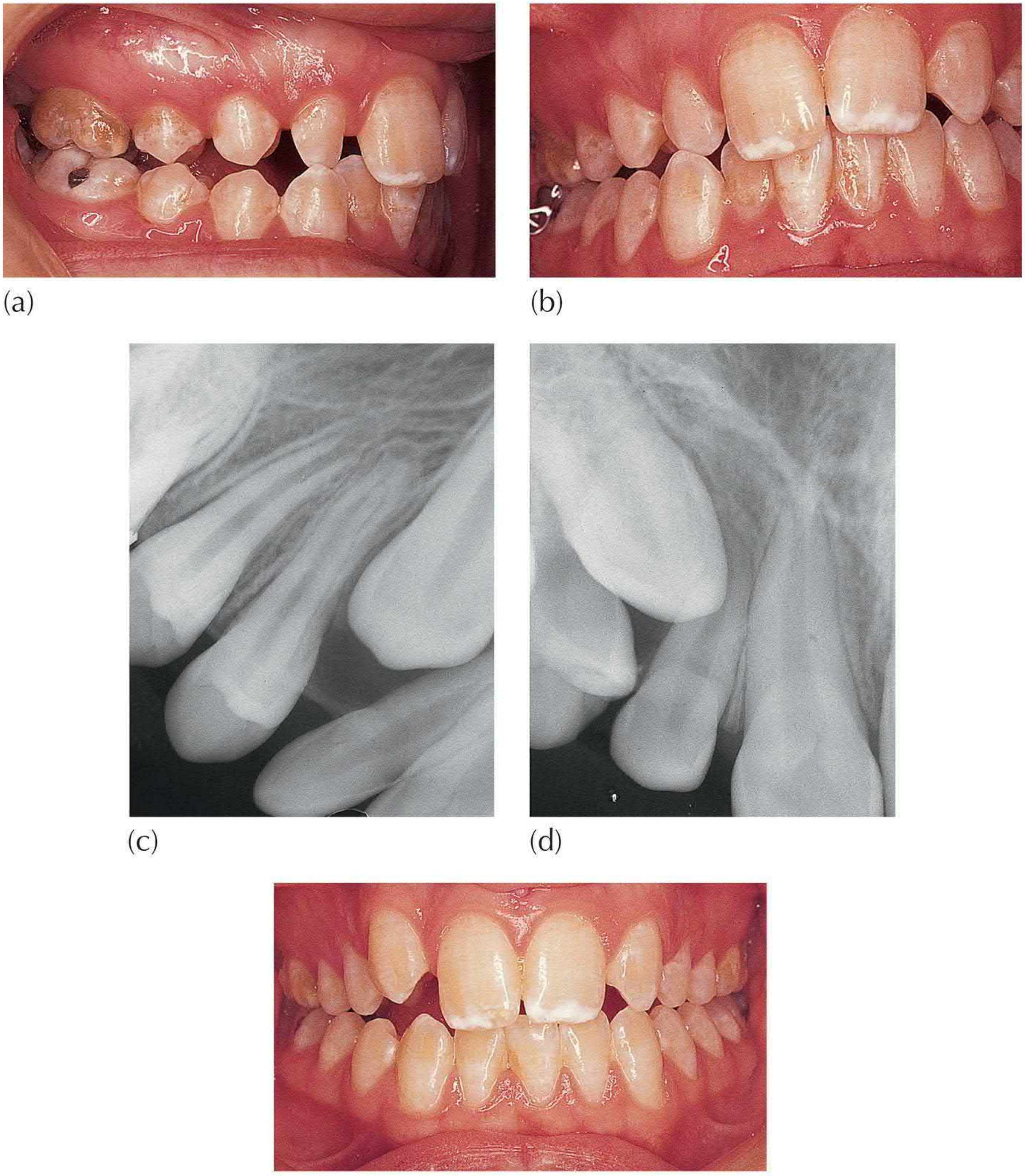
Lateral incisors

We have discussed at length that many of the cases of impacted canines we see are associated with anomalous lateral incisors. At the end of the treatment of the impaction, it is often necessary to prosthetically rehabilitate the anatomically deficient form of the lateral incisors using composite build-ups, crowns or laminates to make them aesthetically acceptable, particularly those that are peg shaped. We have also learned that these cases frequently have spaced dentitions, generally comprising small teeth. It is unusual to find crowding or the need for extractions in the overall treatment of impacted canine cases. Nevertheless, if extractions are prescribed in order to treat the overall malocclusion, consideration should be given to choosing to extract these anatomically deficient lateral incisors as an alternative to the more conventional choice of healthy and anatomically perfect first premolars.

We have described how the guidance theory of eruption of the canine offers a cogent argument of how palatal displacement of the canine may occur. In the cases we described as a first-stage displacement, it was pointed out how the tapered vertical walls of the alveolar process on the palatal side steer the vertically and palatally directed eruption on a more buccal course, to produce a secondary correction. This process continues until the developing canine comes up against the palatal side of the root of a late-developing lateral incisor, which forms a barrier to its further progress. A second-stage impaction is thus created. Logically, the removal of this barrier should lead to a natural improvement in the position and eruption status of the impacted canine (second-stage impaction with secondary correction). Clinical experience shows this to be largely true (Figure 7.27a–e). Extraction of the lateral incisor is not an appropriate procedure for most cases, due to the obvious aesthetic challenges that it raises. However, in those patients where it is indeed indicated, treatment time may often be markedly reduced. It should be noted that a normally sized canine adjacent to a central incisor may create a marred and unsatisfactory appearance, particularly if the central incisor has a poor crown profile, which is frequently seen. This also raises parallel aesthetic challenges, Furthermore, by lining up the canine and first premolar in place of the lateral incisor and canine, respectively, a discrepancy between the sizes of upper and lower anterior teeth may compromise the occlusion. Each of these three alternative treatment decisions has its relative pluses and minuses. Each offers compromise or one sort or another and each may have its place in the wide variety of different circumstances that occur in practice.

Orthodontic space opening

Up to this point, the only preventive measures we have described have all involved encouraging the impaction to resolve spontaneously by the extraction of teeth adjacent to the unerupted canine, namely the deciduous canine [73, 74], the permanent lateral incisor and the first premolar. An alternative and sometimes supplementary line of preventive treatment involves the generous opening of space for the unerupted teeth, using active orthodontic appliances. One of the primary functions of orthodontic treatment in impaction cases is the creation of such space in the dental arches. When this is achieved, unerupted teeth may often begin to improve their positions spontaneously, as will be seen on repeat radiographs, and they may often erupt without surgical intervention (Figure 7.28). This is likely to have been due to an alteration in the relation of the canine crown to the roots of the incisors and a consequent alteration in the guiding influence of these teeth. As such, it provides further evidence to support the guidance theory of impaction.



(a) (b) (c) (d) (e)

Fig. 7.27 (a, b) A palatally impacted right canine was adjacent to the peg-shaped right lateral incisor, while the opposite canine has erupted autonomously in place of the congenitally absent lateral incisor. (c, d) These periapical films were used to diagnose the palatal position of the canine by parallax. Note also that the peg-shaped lateral incisor root still had an open apex, although the apices of the first premolar are in the final stage of closure. The lateral incisor was extracted. (e) The canine migrated spontaneously and erupted on the buccal side of the alveolar ridge. This case typifies second-stage impaction with secondary correction.

Further discussion of the four methods of obtaining adequate space for the canines will be addressed in the latter part of this chapter, when we deal with the general principles of mechano-therapy.

Rapid maxillary expansion

Over the past few years there has been positive interest in the efficacy of the rapid maxillary expander as a means of prevention. There may not seem to be any logical reason to suppose that skeletal, mid-palatal, suture-splitting, lateral expansion should provide the impetus for the spontaneous correction of an incipient canine impaction – a coronal response to a sagittal problem [75]! Nevertheless, a study by the same Italian researchers has shown that the method used on 7.6–9.6-year-olds will increase the chances of eruption from 13.6% for an untreated control group to 65.7% for the group treated with rapid maxillary expansion [75–77].

The diagnostic criterion used by the authors for confirming impending impaction was a reduction of the distance between the unerupted canine and the midline in these very young patients. As the basis for the validity of the diagnosis, this does appear to be somewhat difficult to justify, particularly in a group of children of this age.

Fig. 7.28 (a–c) A class II, division 2 case with crowding in the maxillary arch and severe space loss due to early extraction in the mandibular arch. (d) A panoramic view shows a palatally displaced right maxillary canine. (e) A similar radiograph taken following distal movement of all four molars and space reopening. Note improved positions and prospects of all the unerupted teeth, particularly the canines. (f–i) The post-treatment dental alignment and occlusion. The maxillary right canine and both mandibular second premolars erupted unaided.

In summary and on the basis of the evidence from the many studies in this very popular area of clinical research, we may conclude that there are several steps that may be taken in order to reduce the chances of palatal impaction of maxillary permanent canines, provided that the patient is seen early enough. These steps include the extraction of deciduous or permanent teeth, as well as creation of space by local movement of adjacent teeth, by distal movement of posterior teeth or by rapid maxillary expansion. The utilization of two or more of these methods in a specific case will, in all probability, be synergistic [78].

Mechano-therapy

Most impacted canine cases are not identified early enough to take advantage of the preventive steps referred to above. They will usually have been seen by the orthodontist for the first time only after the initial and, by then, more obvious diagnosis has been made by the generalist or paediatric dentist. Frequently it will be a co-existing malocclusion that will have been the reason for the patient requesting treatment. The impacted tooth may have been discovered as a chance finding only as the result of the orthodontist's routine clinical and radiographic examination.

The periapical radiographs should be carefully scrutinized to discover any evidence of canine-related resorption of the lateral incisor roots. Should this be evident, orthodontic treatment, designed to rapidly deflect the developing canine away from the incisor, should be undertaken as soon as possible. If the resorption is advanced, and in the relatively unlikely event that this is an 'extraction case', consideration should be given to extracting the affected lateral incisor. A reasoned approach to the problem of incisor root resorption associated with an impacted maxillary canine will be discussed at length in Chapter 9.

For the most part, however, there is no justification for rushing into treatment simply because palatal displacement has been diagnosed. The patient must first be prepared for the treatment to be undertaken, initially by explaining the nature and ramifications of the problem with the assistance of the radiographs, CBCT and digital scan/plaster models as visual aids. The principal function of this exercise is to overcome the complacency that most of these patients display, since their problem is not one in which the facial appearance and oral function are compromised and neither is it one that generally causes pain, inflammation or swelling. The aim is to inspire motivation and to lay the foundation for much-needed future cooperation.

The dentition must then be protected against the incipient dangers that the placement of appliances is likely to generate. The measures that will need to be adopted include a high level of oral hygiene and the use of appropriate fluoridating procedures, both at home and in the dental office, as well as the treatment of any tendencies towards carious or periodontal lesions.

After a period of a few weeks, during which the patient will, hopefully, have undertaken these oral hygiene responsibilities on a regular basis, an oral examination should show an absence of plaque on the teeth with pink, firm and stippled gums. This being so, the time will be ripe to begin orthodontic treatment. In the case of a non-cooperative patient, treatment should be withheld until these conditions are fulfilled. Should the dental awareness of the patient be too low for this ever to occur, then alternative treatment modalities should be considered. One such alternative method would be prosthodontic replacement, although this and other methods will be just as reliant on a good level of oral hygiene to be successful. In this way, an operative decision may be delayed for a significant length of time, provided that there are no signs of morbidity, particularly root resorption. During this period of delay, periodic radiographic monitoring will need to be carried out on an infrequent but regular basis. Postponement for a few months or even a year is rarely a problem in straightforward orthodontic terms and if it serves to bring the patient round to the ways of proper home care, then the time spent will have been worthwhile.

Unfortunately, as already mentioned, dental development of these patients is often delayed, which is why they may reach the permanent dentition stage with the canine impaction diagnosis being made only at the age of 14 or 15 years. From a social point of view, the patient may be less inclined to wear appliances if further postponement is entailed, but this may often be compensated by the patient achieving a greater degree of maturity and, with it, enhanced motivation and cooperation.

From the strictly developmental point of view, the best time for therapeutic intervention is when the root of an affected tooth is of a length that is seen at the time of normal eruption. In the case of the maxillary canine, this is about three-quarters of the potential root length, which is virtually always present by the time the diagnosis of palatal impaction may be determined (see the definition of impaction in Chapter 1).

General principles of mechano-therapy

When a patient arrives at the orthodontist's office and a palatally displaced, unerupted canine is diagnosed, treatment must be planned in a disciplined manner. We have seen in Chapter 6, in regard to the impacted maxillary central incisor, that orthodontic preparation of the case is required, and that surgical intervention is not to be undertaken in a haphazard or unplanned manner. In general, appliances appropriate for use to disimpact, erupt and align maxillary central incisors are the same appliances that are used to align the other teeth, with very little modification. For impacted incisor cases, the patient will be in the early mixed-dentition stage and the time is not ripe for the treatment of an overall orthodontic problem. Accordingly, a first phase of treatment is planned to deal only with the incisor anomaly, while leaving the remainder of the malocclusion to be treated in a second-phase intervention much later. This is not so in the present context where, with the exception of the impacted canine, the full permanent dentition is usually erupted. It is for this reason that the local anomaly and the overall malocclusion are dealt with together in one full and comprehensive orthodontic treatment plan.

A diagnosis of the overall malocclusion needs to be made and a problem list created, which will include the palatal canine. The problem list is then sorted into a treatment priority list, in which alignment of the impacted canine should precede many of the other items, although only after space has been prepared for it in the dental arch. The same principles that were used in the planning of treatment in Chapter 6 are applicable in the present context, the difference being that we will now be dealing with the treatment of the entire dentition and not merely the area immediately adjacent to the impacted tooth.

These principles should be adapted to the new circumstances, as follows:

- The appliance should have the capability to rapidly level and align all the erupted teeth in the same jaw and to open adequate space to accommodate the impacted tooth by adopting controlled crown and root movements. As before, this space is required both at the occlusal level and between the roots of the adjacent teeth for their entire length. This stage initially requires the use of fine levelling and aligning archwires, and thereafter the space will likely be created with the use of a more substantial base arch and sliding mechanics.
- With the initial alignment achieved and no further movement of individual erupted teeth required, these teeth are transformed into a composite and rigid anchorage unit, in which each tooth plays an integral part. This is achieved with a heavier wire, whose gauge is as large as the bracket will take, in order to allow as little 'play' as possible of the wire within the bracket, thereby maximizing the anchorage value of each included tooth.
- The surgical exposure of the crown of the impacted tooth should be performed in a manner that will achieve a good periodontal prognosis of the treated result. For a closed procedure,

an attachment is bonded to it and the flap fully closed, with only a fine ligature wire exiting through the gingival tissue from the re-covered tooth. Alternatively, an apically repositioned flap procedure or window technique may be indicated and a dressing placed as required, while the placement of an attachment may be performed then or at a later date.

- The heavy archwires that have been used to buttress the anchorage are aimed at preventing movement of teeth and are thus totally unsuited to the application of light forces with the broad range of action that is needed. The myopic (but unfortunately popular) use of a single light flexible archwire to attempt to achieve both is reckless and ill-advised. Accordingly, customized auxiliary means of traction need to be designed to erupt the impacted tooth along a path that is free of obstruction from the roots of adjacent teeth. When the impacted canine is located mesial to the lateral incisor, there is no direct path from the canine to the space created for it in the arch, since the root of the lateral incisor stands directly between the two. This means that the tooth will need to be diverted in a different direction first, to circumvent the obstruction, and only then drawn along a new and unimpeded path to its place [79–82]. This will be discussed later in this chapter.
- A class II or class III dental relation will usually be reduced at this time. Final detailing of the position of the formerly impacted tooth should be performed together with that of all the other teeth in both jaws.

These principles are by no means immutable and the orthodontist should always be prepared to re-evaluate and adapt them in the light of other findings in a particular situation and to suit a particular case.

There is one specific scenario for the patient suffering from a palatally impacted canine in which there is a race against time. This scenario is in relation to the treatment for class II and class III cases, where there is a mild skeletal component. Many orthodontists prefer to treat patients with an inter-arch size discrepancy using orthopaedic/functional appliances, where the aim is to capitalize on as much of the patient's innate catch-up growth of the deficient jaw as possible. Most of the traditional and so-called orthopaedic/functional appliances are constructed as removable plates with a mandibular protrusive 'construction bite' (such as Clark's Twin Block, the Harvold, the Activator, the Fraenkel and others). Similar effects may be achieved with fixed functional appliances (such as the Herbst, the Jasper Jumper, the Carriere and others). In these cases, there are several potentially conflicting factors that need to be carefully managed and prioritized in relation to treatment sequence. These may be listed as follows:

- The results in orthopaedic/functional treatment are best attained during the pubertal growth spurt. For females, therefore, early use of these appliances would be of prime importance, whereas the timing for males is less critical.
- Maxillary canine impaction is much more frequent in females, who complete their growth earlier than males. Again, therefore, early use of these appliances among females would be of prime importance.
- Patients with palatally impacted canines frequently exhibit an overall late dental development, which could mean that menarche and the cessation of growth may even occur before the eruption of the full permanent dentition (i.e. a mature 15–16-year-old girl with a dental development more akin to age 11–12 years).
- Resolution of the impaction of the canine itself may take considerable time and, although not dependent on whether further growth may be expected, that part of the treatment can only be commenced after completion of the orthopaedic phase. Accordingly, treatment duration

may sometimes continue well into the patient’s late teens.

In general, therefore, orthopaedic/functional treatment will be advised first, aimed at reducing the skeletal discrepancy while there still is the promise of growth. In the present context, treatment does not necessarily need to wait for the shedding of all the deciduous teeth and eruption of the full permanent dentition. It would likely be best initiated in the middle to late mixed dentition. The canine impaction would then be treated only when the dental arches had been brought to a class I relation and in the late mixed/early permanent dentition period.

Resorption of the roots of adjacent teeth and the ‘surgery first’ protocol

In the previous sections of this chapter, we have endeavoured to outline the order of procedures in the most usual cases of impacted canines. It is now appropriate to turn our attention to two very important exceptions to the order of things that we have outlined.

The high-priority rating for an impacted canine that is causing an ongoing resorption of the roots of adjacent teeth will overrule space considerations and will constitute a matter for immediate and urgent attention. In Chapter 9, the discussion and illustrated examples presented will concentrate entirely on those cases in which the progress of the resorption has proceeded at an alarming rate and, without rapid action, could lead to loss of the incisor tooth. Accordingly, once incisor root resorption has been positively identified, the full focus of treatment should be urgently directed at distancing the impacted tooth from the adjacent root. In the absence of space in the arch, the tooth should be exposed as early as possible and traction applied to erupt the tooth either into the palate or into the labial vestibular area. In these locations, the tooth is out of harm’s way and further resorption of the incisor root will be not occur [13, 65], even when subsequent orthodontic movement to modify the position and angulation of the damaged incisor is performed with forces directed from the appliance. Only then may space be provided in the normal way and the canine re-aligned in due course.

In order to provide space for an impacted tooth, there is a sequence of tasks that orthodontists normally adopt with fixed orthodontic appliances that constitutes a largely standardized protocol. The sequence first entails levelling and alignment, which are achieved with the use of light, springy, usually nickel–titanium (NiTi) archwires. Only when a heavier and more rigid base arch can be inserted do we begin to create space, using compressed open-coil springs and sliding mechanics. If this is performed on round cross-section archwires in a horizontal bracket slot, the adjacent teeth are largely moved bodily in a mesial and/or distal direction. If rectangular archwires are used at any stage in this initial sequence, then torqueing movements of the root apex in a lingual and/or labial direction will also be introduced. Under the heading of ‘Diagnosis’ earlier in this chapter, we described the need for awareness of clinical clues that may be present and may indicate the position of the impacted tooth, by virtue of the displacing effect that the tooth has on the positions of the neighbouring teeth, particularly lateral incisors. On the radiographs of the area, one may usually discern a cause-and-effect relation between the angle of the unerupted canine and that of the lateral incisor. It follows, therefore, that virtually every ‘corrective’ root movement performed during the levelling and alignment stage will have the effect of forcing the root of the incisor against the crown of the impacted canine. In some cases, this may encourage a re-alignment of the orientation of the long axis of the canine, which may then rekindle its innate eruptive potential and spontaneous resolution of the impaction may occur, thereby obviating the need for exposure surgery. By the same token, however, it may further displace the unerupted canine into a more inaccessible location and worsen the chances of its salvation.

The third and most dangerous possibility is that the clash between the two teeth may result in resorption of the root of the incisor. This distressing outcome will paradoxically be seen alongside what appears superficially to be the 'success' of the incisor uprighting effort. Radiographic monitoring of the initial few months of treatment, using simple periapical views, should certainly be considered. In the event that there is unexpected difficulty and duration of what is normally a simple and rapid movement, this should alert the practitioner to suspect that there is an uncharted root or there has been an adverse and unplanned movement of a neighbouring tooth that is preventing the canine from moving.

Creating space for the canine

There are essentially four ways in which space may be provided for the palatally displaced canine:

- *Closing incisor spaces*: As was pointed out at the beginning of this chapter, the final stage in the physiological process of anterior space closure occurs when the canine erupts and influences the lateral incisor to tip mesially. In the patient with impacted canines, this does not occur and the resultant incisor spacing is due to failure in the progress from the ugly duckling stage of development to completion of the natural alignment [12, 24]. In any case, we have seen that impacted maxillary canine teeth are often intimately associated with small and peg-shaped lateral incisors and with small teeth in general. For both these reasons, therefore, it is common to find incisor spacing in these patients (Figure 7.29). The spacing may be closed off by moving the central and lateral incisors mesially, thereby increasing the space in the canine area.

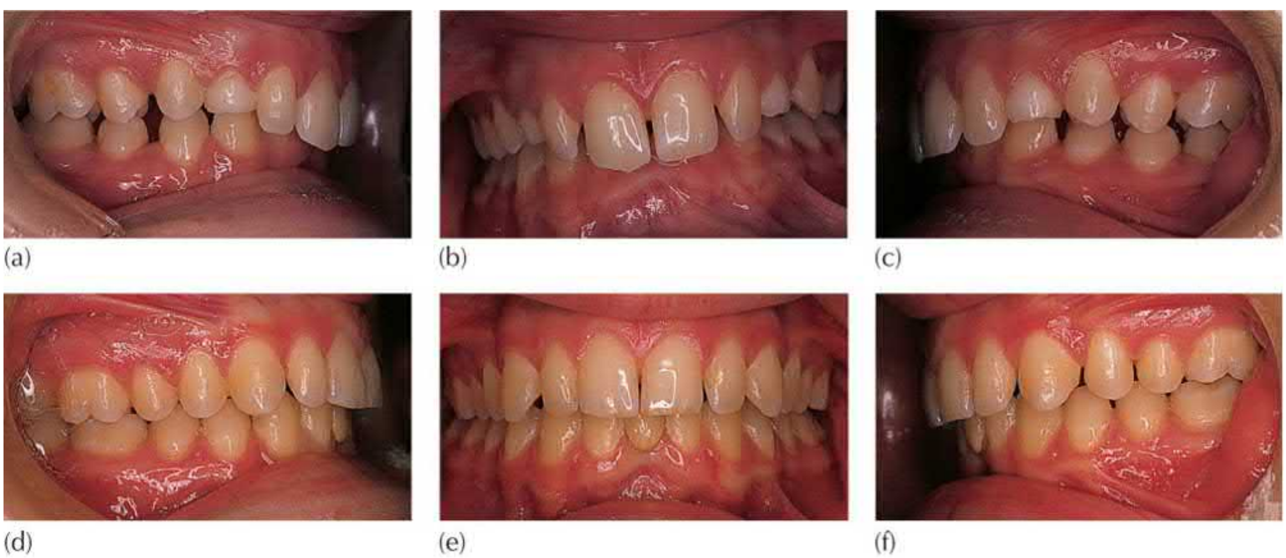


Fig. 7.29 (a–c) Inadequate space for unerupted permanent canines with inter-incisal spacing. (d–f) The permanent canines in place at the completion of treatment. N.B. A mandibular incisor was congenitally absent in this case.

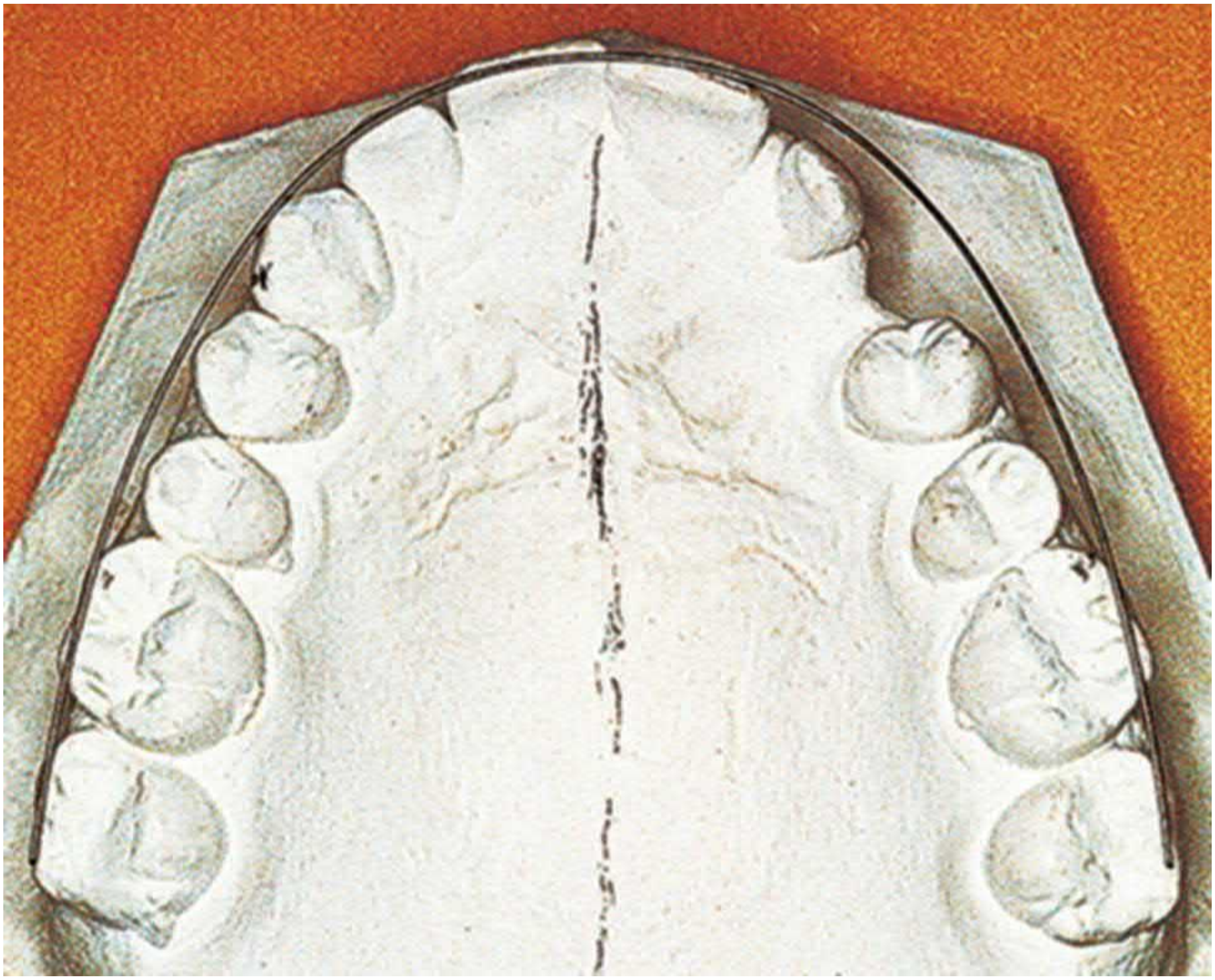


Fig. 7.30 A standard preformed archwire illustrates the narrowed and flattened form of the dental arch on the area of the untreated unilateral impacted canine, compared with the normal right side.

- *Improving archform*: When the maxillary permanent canine erupts normally, it does so along a more buccal path than the deciduous canine and slightly buccal to the lateral incisor and first premolar, earning the designation 'cornerstone of the arch'. Comparing the two sides of the maxillary arch in a unilaterally affected patient, one finds that, in the canine areas, there is a much narrowed maxillary width on the side of the impacted canine than on the normal side. This being so, the typical adult dentition in such cases will, with the exception of the deciduous canine of the affected side, include a laterally flattened or collapsed archform (Figure 7.30) and space loss in the immediate area, with space opening more mesially [9]. In only 15% of cases is actual crowding apparent [15, 16]. Exploiting improvement in the form of the arch in this region will add two or three millimetres of space for the displaced tooth (Figure 7.30). This is almost automatically achieved with any fixed orthodontic appliance and preformed arches.
- *Increasing arch length*: Studying the maxillary dental arch from the occlusal aspect, it may often be noted that there is mesio-palatal rotation of the first molars. Additionally, mesio-buccal rotation of the first premolar is also a frequent occurrence in these cases. Correcting these rotations can provide the much-needed millimetre or more of space on each side. If crowding is mild, the use of extra-oral headgear [83] or class II traction against open-coil

springs is recommended in order to move the maxillary molars distally. This will provide the extra space, which may then be concentrated in the canine area, using a multi-bracketed appliance system (Figure 7.31) and simple aligning mechanics.

- *Extraction of teeth*: When crowding is more severe, particularly where there is also a class II dental relation that needs to be treated, the extraction of a premolar tooth on each side of the dental arch in the maxilla, and usually in the mandible, will be required. With the extraction, space for the impacted canine is immediately and very locally available. This procedure has three advantages: first, appliance therapy to provide the space will be superfluous. Second, following the loss of the first premolars, alignment, levelling and rotation of the remaining teeth are very much simplified. Third, with a local anaesthetic already covering the area and a surgical wound being inevitable, it is logical to extract the deciduous canine and expose the impacted canine at the same time, in order to reduce to a minimum the number of surgical interventions and post-surgical discomfort. Accordingly, in extraction cases it may sometimes be recommended that the surgical exposure be undertaken prior to the placement of an appliance (Figure 7.26).

When orthodontic appliances are placed at the initiation of mechano-therapy, the achievement of good archform in the maxilla is an important first step. After the initial levelling wires, space is concentrated in the canine areas by one of these methods, and interproximal contacts are established elsewhere in the maxillary arch. A heavier-gauge archwire is then firmly ligated into the maxillary appliance, the space for the canine retained and a full-width rectangular base arch should be employed.

The space that has now been re-opened for the canine may be maintained using the same coil spring, which will need to be deactivated. However, it is difficult to adjust the spring to maintain the space accurately and one will usually find that the space will increase or decrease slightly over the succeeding months. Furthermore, a coil spring quickly fills with food particles and is impossible to clean effectively. A much better alternative involves using a measured and slightly curved length of stainless steel tubing, or a measured closed-coil spring, which is threaded on the archwire and tied between the brackets of the premolar and lateral incisor, in place of the open-coil spring. This adds much rigidity to the archwire in the area of greatest importance and helps in resisting distortion, as well as providing an excellent and firm base from which to apply force to the impacted canine. Many of these canines have to be moved over a long distance to bring them into the arch and several will require root movement of different types before they may be properly brought into position and the case completed. This inevitably expends anchorage. The precautions described above will contribute much to the preservation of anchorage.

During orthodontic treatment, as with any other prescribed form of medical or dental treatment, attention is paid to choosing the appropriate approach that offers the maximum benefit while sustaining the minimum possible adverse collateral changes that may be caused by the treatment to the health of the dentition and its supporting tissues. To this end, orthodontists must ensure an adequate level of oral hygiene before and during the period during which the procedures are performed. They should also be careful that the forces generated by the appliances are employed within certain limits, compatible with physiological tooth movement, so that permanent and irreversible damage is not inflicted on the dentition.

Fig. 7.31 Creating space by distal movement. (a–e) The initial clinical views of a mildly crowded dentition with incisor retroclination and a deep incisor overbite. The left deciduous canine is in cross-bite. (f, g) A safety, removable, acrylic high-pull headgear appliance with the facility to move posterior teeth selectively distally (with two expansion screws) to torque the incisors (Bass torqueing spring), in addition to the overall distalizing effect. Note the facility to use class III

intermaxillary elastic from the Adams clasps on the molars, to aid in the distal movement of the mandibular dentition. (h, i) More than adequate space has been created for the canine to be aligned. Note how ill-advised labial traction from a palatal eyelet has introduced a degree of undesired rotation into the canine as it achieves its place in the arch. This needs to be redressed in the final stage. (j–n) The treated result seen five months post treatment.

In an extraction case, the decision regarding which teeth to extract is usually made on strictly strategic criteria, insofar as certain teeth require to be brought to particular places and appropriate anchor teeth need to be chosen in order to achieve this. Given a good prognosis of all of the teeth in the mouth, with no severely carious teeth and excellent periodontal health, the criteria of orthodontic treatment strategy will be the exclusive guide to this extraction decision. However, when one or more teeth are present whose long-term prognosis is in doubt (such as a molar tooth that is in need of root canal treatment and a post-and-crown restoration), this becomes an additional factor that must influence the choice of tooth for extraction. Long-term logic would not be served if the immediate and beautiful orthodontic results were to be predicated on teeth that would not be present in the mouth a few years later, while healthy teeth of excellent prognosis had been sacrificed in the name of strategic convenience.

In a case where teeth require to be extracted as part of the overall orthodontic treatment, maxillary canine impaction presents a similar dilemma. The canine is a tooth that has an important role in the establishment of a good functional occlusion. It has a long root and contributes much to the patient's appearance, particularly the smile. These attributes make it a very valuable tooth and one worth the expenditure of considerable effort to bring it into its correct position. Its substitution by a first premolar is not usually quite as aesthetically pleasing. At the opposite extreme, it is inappropriate to automatically and blindly extract an impacted canine with a good prognosis in preference to an erupted first premolar, just as it is inappropriate to extract a first molar rather than a first premolar simply because the molar has a small occlusal restoration. But what if the long-term prognosis of the canine is poor because of its initial intractable position or as a consequence of its having been through the processes of surgical exposure and orthodontic alignment over the period of many months or years that were spent in its meticulous alignment? In such a case, it is arguable that it would have been better to remove that particular canine at the outset and to have brought the first premolar to its place [84].

Since extraction cases are very much in the minority among patients with palatally impacted canines [16, 43, 81], every effort must be made to bring the canine into the arch and to do so in a manner that will provide it with its best possible periodontal prognosis and appearance. The clinician must carefully assess the several factors that affect the prognosis of the results of treatment in each individual case, prior to the beginning of treatment, in order to be in a position to make the optimal decision regarding the choice of tooth for extraction.

The need for a practical classification of palatally impacted canines

At the time that the patient's records are being studied in order to formulate the appropriate treatment plan, it would be helpful if there were a way to assess the long-term prognosis of an impacted canine, even before treatment is started. In the absence of such a possibility, it is crucial to seek a key that may help us decide which canines, in periodontal terms, will be adversely affected and whose impaction will take an inordinately long time to resolve.

Two factors stand out as being the most fundamental in determining the long-term prognosis of any treatment designed to bring an impacted tooth to its desired location. The first that must be taken into account relates to the level of surgical trauma (to provide clinical access to the unerupted tooth) that will inevitably be inflicted on the tooth and its supporting structures. The second is the requirement to offer satisfactory ways to orthodontically release the tooth from its locked-in position and to move it into alignment. This will highlight the relative biomechanical difficulty in applying appropriately directed forces of good range.

For the reasons that are fully elaborated in Chapter 5, it has been our belief that a closed surgical procedure is the preferred line of treatment for a majority of the more difficult cases. This procedure incorporates minimal exposure through the follicle, leaving the remainder of the follicle in place, attachment bonding and full-flap closure, aimed at primary healing, together with immediate activation of the traction force. Indeed, for those difficult cases in which the teeth are deeply located and/or entangled with the roots of adjacent teeth, open surgical exposure is not even an option. This is not the situation in the simpler cases, where the teeth are more closely located to the target site. In these cases, there will be no discernible difference whether an open or a closed technique is used. In the more difficult cases, there are individual preferences among surgeons, with an enormously wide array of nuances in their surgical techniques that cannot be analysed and evaluated in the broad volume of research that has been published in the 'open-versus-closed' debate. This issue is discussed at length in Chapter 5 and a long, representative and by no means exhaustive list of literature references is presented there.

In much the same way, orthodontists also have their own very individual approaches to biomechanical resolution. Does a tooth that is subjected to a whole range of different types of orthodontic movement pay a periodontic penalty in the final analysis? Will there be a difference in comparison with one that is more simply aligned?

Teeth that are mechanically erupted bring with them a generous amount of alveolar bone. It has been shown in studies in Israel [85–87] that the assisted eruption of buried teeth with the use of orthodontic appliances produces a collar of alveolar bone around the erupted tooth that is greater than that seen on autonomously erupted adjacent teeth or on the canine of the other side. These studies have shown this to be true only where surgical exposure was conservative and did not involve removal of the entire follicular sac and instrumentation of the CEJ area. Radical surgery might arguably facilitate eruption of the tooth, but it leads to less bone support than is present in a naturally erupted tooth, and considerably less than that seen encompassing a similarly impacted tooth that has been minimally exposed.

The most likely explanation for this is to be found in the procedure that prosthodontists call 'forced eruption' [88, 89]. When one side of a tooth is fractured or destroyed by caries to below the height of the crestal bone, an infra-bony pocket is produced. One of the forms of treatment that is prescribed to eliminate this is to mechanically erupt the tooth away from the bone margin and thus to orthodontically reverse the relationship between the prepared crown shoulder or cavity margin and the alveolar bone. At the same time, the other sides of the same tooth, whose relationship with the bone was normal to begin with, are extruded together with their adjacent alveolar bone. This generates excessive bone in the latter areas, extending more coronally than is normally seen. Sometimes this needs to be reduced by periodontal/osseous surgery.

In relation to the resolution of impaction, it has been shown [85–87] that, in contrast to extrusive movement, teeth that undergo root uprighting and torqueing movements end up with a significantly lower crestal bone level than untreated controls. The histogram in Figure 7.32 shows the comparative influence on the relative bone support of impacted canine teeth of the various types of conservative versus radical surgical exposure and extrusion/tipping versus root movement orthodontic forces.

In the study that produced this histogram, the surgical procedures were divided into two distinct groups, depending on the extent of the exposure. The 'lighter' surgical procedures were those in which the crown was exposed only widely enough to place a small bonded eyelet, while maintaining a dry field and controlling haemorrhage, without involving removal of bone down to the CEJ. These were termed conservative exposures and they were labelled X_L. The 'heavier' surgical procedures were labelled X_H and included all those in which the exposure was more radical and extended to the removal of alveolar bone down to the CEJ, before an attachment was bonded.

The biomechanical appliance therapy procedures that needed to be incorporated in the resolution of the impaction were similarly divided into two groups. For obvious reasons, an extrusive movement element was needed to be performed in all impacted canine cases. The first group was those in which the teeth needed only to be subjected to "simple" orthodontic movement, because their movement was completed with the use of only tipping and rotation forces. These were classified as M_L. Canines that additionally required mesio-distal or bucco-lingual root uprighting/torque mechanics were categorized as experiencing more substantial forces and were labelled M_H.

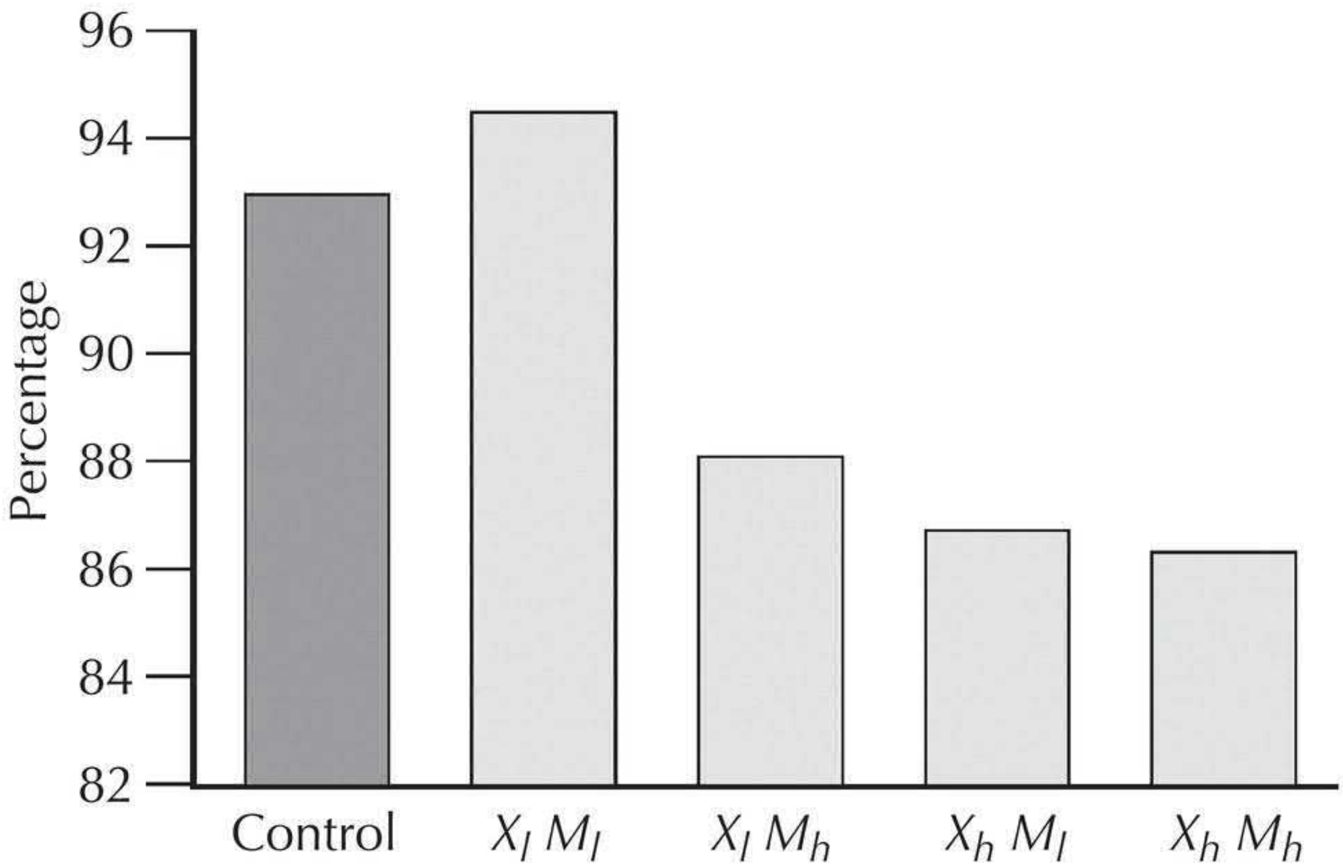


Fig. 7.32 Bone support levels in the treated canines (light bars) compared with the normally erupted opposite canines (dark bar); X_l, minimal surgery and primary closure; X_h, surgery in which the follicular sac was removed down to the cemento-enamel junction; M_l, orthodontic tipping, extrusion and rotation movements only; M_h, root uprighting and torqueing movements.

Source: Adapted from Kohavi D, Becker A, Zilberman Y. Surgical exposure, orthodontic movement and final tooth position as factors in periodontal breakdown of treated palatally impacted canines. Am J Orthod 1984; 85: 72–77.

In order to compare the treated cases in this study with the normal situation, the unaffected and naturally erupting antimeres, on the opposite side in the unilateral cases, were examined. The estimation of bone support was calculated as the ratio of the distance between root apex and the height of the crestal bone, on the one hand, and the distance between root apex and CEJ, on the other. This was expressed in the form of a percentage. In Figure 7.32, the column entitled 'control' represents the maxillary canines that had erupted naturally, without the need for orthodontic traction. Here the baseline bone level mean was found to be 93%.

In the simpler treated cases, in which the closed eruption exposure was conservative and orthodontic movement included extrusion, tipping and rotatory components only, X_lM_l, showed significant bone regeneration with a value of 94.8%. This was higher than the baseline bone level, due to the 'forced eruption effect'.

When orthodontic movement involved root uprighting and/or root torque, together with conservative surgery, this was labelled X_lM_h and the crestal bone level was measured at 89.2%. When the biomechanical element was light, together with surgery that had involved complete removal of the follicular sac down to the CEJ, the situation was described as X_hM_l and the bone support dropped to 88.4%. The level of bone support was at its lowest when surgery was most radical and when root movement was an essential part of the orthodontic resolution. Thus, for the X_hM_h group, the bone support was 86.3%. The conclusion drawn from these figures was that when both orthodontic and surgical involvement are heavier, bone support is adversely affected. However, it was also clear that surgical involvement is the more significant negative influence.

These findings may indeed provide a reliable future assessment of the periodontal prognosis of the teeth concerned and may serve to evaluate and offer a prognosis of long-term health, following the proposed impaction resolution treatment. In other words, using this simple method of categorizing the proposed surgical and orthodontic procedures for a specific impacted tooth, it becomes possible to determine the expected post-treatment health of an impacted tooth *before treatment is even begun*.

One last factor, which is often forgotten or unfortunately ignored, relates to root resorption that may occur in the impacted tooth during the extended period required for its alignment. In a large proportion of routine orthodontic treatments, minor and inconsequential resorption of the root apices of teeth is sometimes apparent. The reasons for this are not clear and although some clues are available, there is, as yet, no known key that may be used to confidently predict those patients in whom resorption will occur. What is found, however, is that the resorption process almost invariably stops when orthodontic tooth movement is completed [13, 65, 90–92].

In most patients who have undergone major orthodontic movements, resorption is exceptionally small and of no clinical significance. Nevertheless, there are occasional cases where these unfortunate effects may account for the loss of 3 or 4 mm of the original root length. Although there have been dissenting reports [93], the overriding opinion is that there is a linear relationship between resorption and treatment duration [94–96]. Accordingly, in the absence of definitive information regarding the mechanisms involved, it would seem wise, for those patients who are prone to root resorption, that orthodontic treatment should be kept to a minimum in terms of duration and complexity. A planned optimal result for those individuals may thus fall short of the ideal.

For the resorption-susceptible case, it is indeed possible that all the precautions that we have described may be followed scrupulously and a good periodontal result may be obtained [97]. However, unusually severe resorption may account for a final residual root length of, say, 12 mm. A 2 mm difference in height between crestal bone and the CEJ may give a relative bone support of only 83% in this patient. Thus, for cases in which there is a short root and a greater CEJ-to-crestal bone height difference, the relative importance of root resorption as a compromising factor in long-term tooth survival increases and the long-term prognosis will be adjusted accordingly.

Monitoring for early indications of incisor root resorption, using periapical radiographs, should be performed during the course of the mechano-therapy of a given impacted canine. However, since the position and, more specifically, the orientation of the tooth are changing during the orthodontic treatment, comparison with earlier films may be unreliable. It should also be remembered that even when significant resorption is noticed, it is unlikely that the orthodontic treatment will be stopped much before full eruption of the impacted tooth has been accomplished. Less (i.e. partial eruption) would render the canine valueless for all practical purposes and under almost any circumstances.

The efficacy of radiographic monitoring is only important at the point in time when the crown of the tooth has been brought into its place in the arch, and a decision has to be made concerning root uprighting and torqueing movements. Are these movements merely desirable in the interests of a meticulous aesthetic alignment? Or are they essential, where their absence would be to the long-term detriment of the treatment result? If a periapical radiograph, taken at this juncture, shows that significant resorption is evident, its severity must be offset against the relative importance of producing these root movements [97, 98].

The Jerusalem classification

All forms of surgery inflict trauma that, in the present context, may influence the periodontal prognosis. In order to simplify the discussion and to exclude complicating factors, we shall assume that the most appropriate surgical technique has been chosen for exposure of a given impacted maxillary canine, and that this procedure is performed with a high level of expertise. We have concluded above that (a) trauma generated by surgery is greater when access to the impacted tooth is difficult and (b) orthodontic alignment is more complex when the impacted tooth has a greater displacement, particularly if the root apex is not in the line of the arch. Though seemingly unconnected, both these factors, relate to the position of the tooth, which will subsequently dictate the quality of the supporting structures of the outcome. Accordingly, it becomes clear that the patient's best interests are served if, at the time of treatment planning, an accurate visualization of the exact location of the buried tooth is made. It follows that if palatal canines are classified in relation to their 3D location in the maxilla, they will essentially be grouped in accordance with their therapeutic prognosis.

The classification that is offered here is based on two variables:

- The transverse relationship of the crown of the tooth to the line of the dental arch, which may be close or distant (to the midline).
- The height of the crown of the tooth in relation to the occlusal plane, which may be defined as high or low.

Determining the location of the crown of the impacted tooth is achieved by employing the radiographic methods that we have outlined earlier. The use of CT scanning has made this exercise much simpler and more relevant. It provides the clinician with a 3D image of the impacted tooth and shows that tooth's proximity to adjacent hard and soft tissue structures, with accuracy and infallibility. This positional determination may be subsequently visually confirmed at the time of surgical exposure. An orthodontist who is present in the operating theatre when the tooth is exposed by the surgeon will sense a feeling of intense satisfaction at being able to bond an attachment to the exposed tooth and apply immediate and directionally appropriate extrusive traction, thus providing complete control of the destiny of the impacted canine.

In this section, several cases will be presented to illustrate the salient clinical features of the impacted canines in each of the classification groups. An approach to treatment will be discussed within each group and how this needs to be adapted to suit the variety of individuals that may be seen in each. Where relevant, cases that were treated inappropriately will also be presented, with the aim of revealing how inferior results occurred and to discuss what alternatives could have been employed to prevent the compromised outcome.

Group 1

- Proximity to line of arch: close.
- Position in maxilla: low and overlapping up to middle of lateral incisor root.

Typically, palatal canines that are close to the line of the arch and low in the maxilla indicate a good prognosis, insofar as the tooth is usually palpable in the palate and readily accessible to surgery (Figure 7.33a–j). These canines represent by far the most common form of palatal impaction. In its simplest form, the canine is opposite its intended space and is not rotated. The root apex is in its correct location and root movements are rarely necessary.

Planning the orthodontic strategy

Aligning, levelling and space opening will need to be completed before the surgery, using a graded series of gauged archwires. With the tooth immediately opposite its place in the arch, orthodontic alignment will require some extrusion, but principally a buccal tipping movement. Thus, direct force application between pigtail and archwire will encourage the impacted tooth to erupt and be tipped towards its place in the dental arch (Figure 7.33e).

Surgery

If the canine is only mildly displaced to the palatal, it may be approached from the occluso-buccal aspect (Figure 7.33d), in which case only limited bone removal is needed to reach it. A labial flap is raised from the crest of the ridge or from the gingival margin of the deciduous canine, which would need to be extracted. The free edge of this flap would comprise attached gingival tissue. The flap in this case may be re-sutured higher up on the labial surface of the crown of the canine. This is an open exposure with an apically repositioned flap, which leaves the crown of the tooth exposed.

For a more palatally located canine, utilizing the reflection of a palatal flap, its location is immediately obvious under its bulging but thin covering of bone on the inner (medial) surface of the alveolar ridge. Minimal removal of the eggshell-thin bony covering is needed to reach the follicular sac and access for bonding an attachment to the tooth is good. The canine crown is thereby separated from the oral cavity by the very thick palatal mucosa firmly bound down to the bulging but thin bony cover of the follicular crypt. The crypt itself is often quite wide and, together with the bony cover and thick palatal mucosa, may be quite distant from the surface, despite the fact that it had originally appeared to be a relatively superficial canine tooth.

An open surgical exposure is advantageous insofar as it may elicit some spontaneous eruption of the canine over the succeeding many months. The surgeon will remove a circular section of the thick palatal attached mucosa that overlies the tooth, and generously remove bone and follicular tissue down to the CEJ of the canine. However, even with this rather radical procedure and the placement of a surgical pack, the possibility is significant for the wound to heal over and deny clinical access for the orthodontist, leaving a disappointed young patient with the unwelcome prospect of renewed surgery.

A closed exposure would be preferable in cases where the canine lies more deeply embedded and an attachment requires to be bonded to it. After suturing of the full flap, the pigtail ligature from the attachment may be drawn through the sutured edge in the direction of the main archwire.

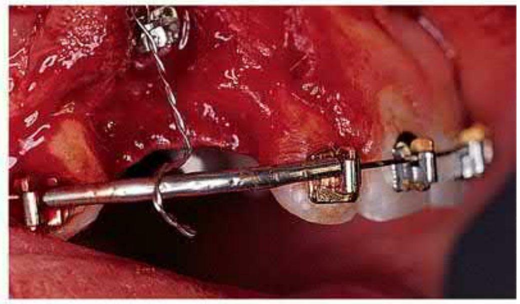
Problems that may be encountered

In the simplest group 1 case, ligation to the eyelet may be sufficient to complete all the movements required. Alternatively, if surgery has exposed a sufficient length of the clinical crown, a conventional bracket may be placed immediately. However, it should be remembered that, as the tooth moves buccally, it gathers gingival tissue ahead of it and, if oral hygiene is not excellent, the exuberant gingival soft tissue will become inflamed and be impinged upon by the bracket. Undoubtedly, wider exposure of the crown will eliminate this, but will compromise the periodontal tissues in the final analysis. Thus, it is wiser to use an eyelet initially and replace it, as and when necessary, when the tooth reaches the main archwire.

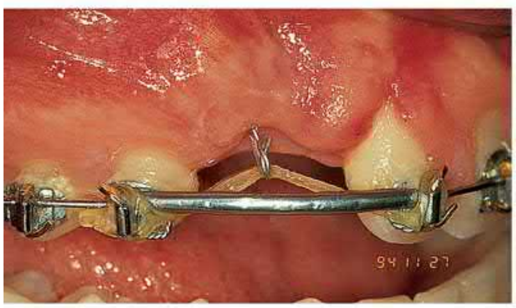
(a)

(b)

(c)

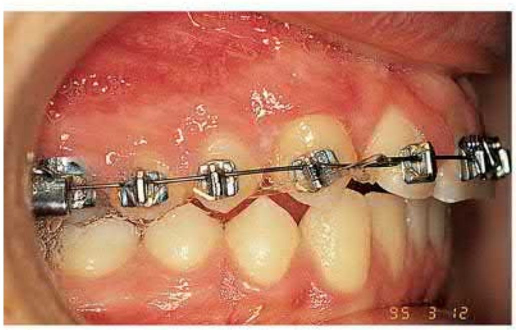


(d)



(e)

(f)



(g)

(h)

(i)

(j)

(k)

Fig. 7.33 (a, b) Intra-oral views of the initial condition. (c) View of the pre-surgical orthodontic set-up. (d) Exposure and attachment bonding with vertically drawn steel ligature, prior to suturing. (e) A 'slingshot' elastic module is stretched between the brackets of the lateral incisor and first premolar. (f) At three months post surgery an inferiorly and laterally offset light wire arch is substituted and the tooth ligated with steel ligature wire to achieve full eruption. (g) An orthodontic bracket was substituted to effect appropriate finishing. (h, i) Periapical view, showing comparable supporting bone levels in the treated and untreated canines. (j, k) The gingival appearance shows comparable gingival levels on the treated versus the untreated side.

Complications

Group 1 canines in their initial positions may be complicated by rotation, mesial crown displacement or palatal root displacement.

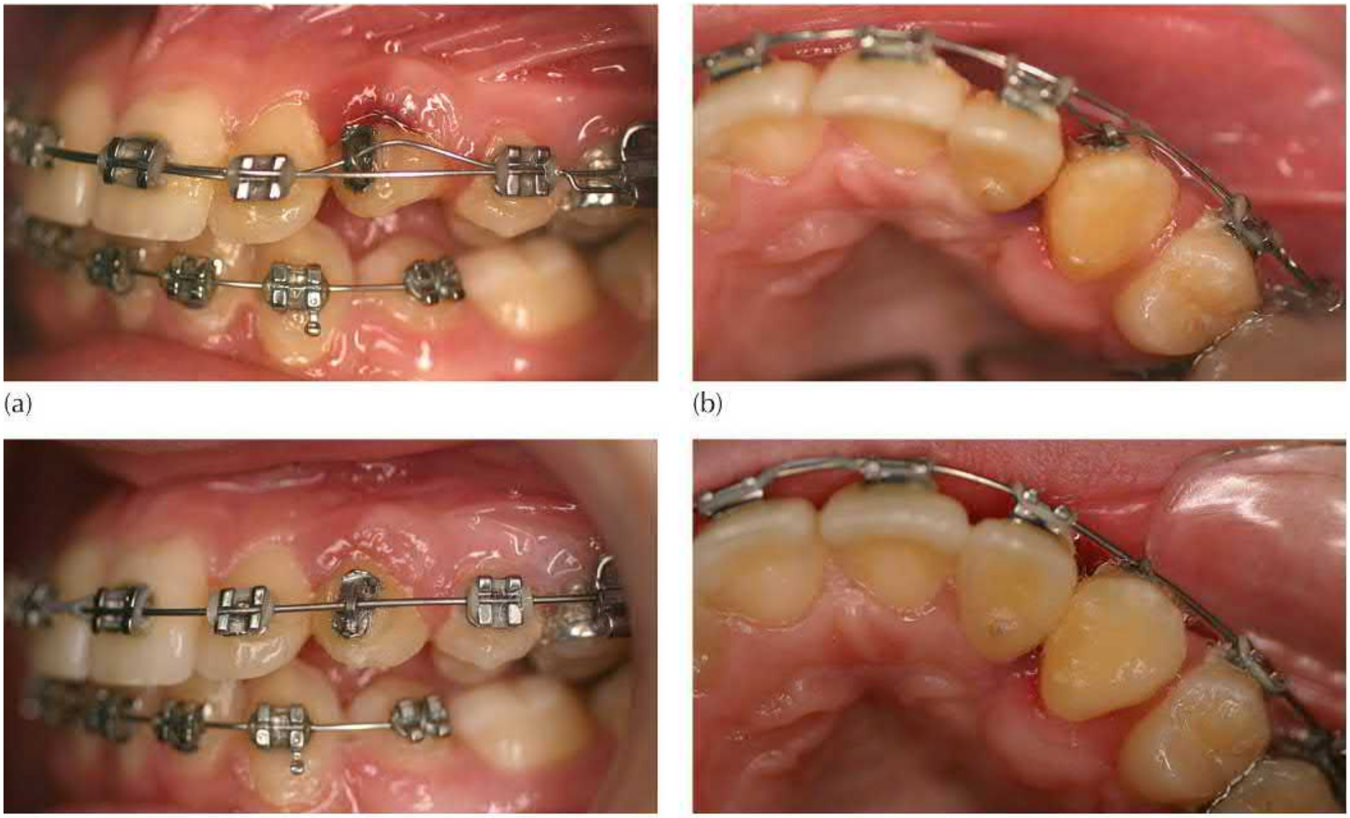
Rotation

A unilateral case of a group 1 canine is seen before treatment, from the right side and from the front (Figure 7.33a, b). The canine was relatively high, although its palatal deflection was relatively minor. Accordingly, surgery was performed from the buccal side, after more than adequate space had been prepared, by closing the incisor spacing using a coil spring and sliding mechanics. The space was retained using a curved length of over-sized and measured steel tube between the lateral incisor and first premolar brackets (Figure 7.33c, d). This was placed before the surgical episode in order to brace the archwire against distortion, when immediate traction would be applied. A closed surgical procedure was undertaken, with the attached gingival flap raised from the gingival sulcus following the extraction of the deciduous canine.

An eyelet attachment was bonded to the labial surface of the canine by the attending orthodontist. The surgeon sutured the surgical flap back to its former place, taking care to lead the pigtail twisted stainless steel ligature connector through the sutured inferior edge of the flap. The orthodontist then shortened the connector and turned its end into a hook, applying a 'slingshot elastic' by stretching an elastic chain from the bracket of the lateral incisor to that of the premolar, raising its middle upwards to ensnare it in the ligature hook (Figure 7.33e) with a controlled and measurable light extrusive force. The patient was then free to leave the surgeon's office. The canine erupted quickly and the main arch was changed to include a vertical offset to bring it down to the occlusal level. The final radiographs show a good bony picture and clinical photographs reveal an appearance that makes it difficult to distinguish the previously impacted tooth (Figure 7.33h–k).

Mesial crown displacement

A mesial crown displacement is very commonly seen in association with the mesio-lingual rotation that we have just described (Figure 7.34). It will still be classed as a group 1 canine if it lies at the distal aspect of the lateral incisor. Whether or not the rotation is present, the proximity of the anatomical labial surface of the canine to the lateral incisor creates constraints on the placing of an attachment at the mid-buccal position of the canine crown. As a general rule, this space is too small for the placement of any of the types of conventional bracket, all of which are much bulkier. To overcome this, many practitioners bond the conventional bracket, with its rigid and contoured base, on the irregular palatal surface of the tooth, to which it is totally unsuited. The reliability of the bond is much lower, thereby increasing the risk of detachment to almost 50% [99].



(a) (b) (c) (d)

Fig. 7.34 Using an eyelet for eruption and rotation. (a, b) With the canine only partially erupted but markedly rotated, the original vertically oriented eyelet (bonded at the time of exposure) was exploited to rotate the tooth, using a fine (0.014 in.) nickel–titanium auxiliary archwire, under the main 0.018 in. stainless steel base arch. (c, d) Four weeks later, the tooth had completed its rotation and an edgewise bracket was substituted.

Courtesy of Dr H. Corimlow.

A further drawback to using a regular bracket on the palatal aspect of the tooth is that traction applied directly between it and the archwire will substantially increase the existing and adverse mesio-lingual rotation of the tooth. This will be very difficult to correct later and will significantly add to the amount of mechano-therapeutic manipulation that the tooth will have to undergo. As a result, the periodontal prognosis of the tooth may be compromised unnecessarily.

Traction from an eyelet placed in the ideal mid-buccal position on the tooth, even if it will have to be more incisally located due to the physical limitations imposed by the proximity of the lateral incisor, will bring about a corrective rotational movement as the tooth is drawn towards the target area. Palatal siting of a bracket or an eyelet increases the risk for a complication (detachment) and, while it solves one problem (the impaction), it creates another (increased rotation) that may be just as formidable.

It is relatively easy to bond an eyelet close to the ideal mid-buccal position of the exposed tooth and to draw elastic thread from it to the rigid tubing that has been placed on the archwire, in order to maintain the canine space in the arch. It may be advantageous to tie the elastic thread to the bracket of the first premolar to increase the mesio-buccal rotational component of the traction.

The premolar will not move to close off the canine space because of the presence of the stainless steel tubing/closed-coil spring space maintainer. Nevertheless, extended periods of traction are likely to bring about adverse changes in the dental midline by tipping of the incisors in that direction.

The type of rotation that the canine generally presents is a mesio-palatal (mesial surface turned to the palatal) rotation, with the buccal surface of the tooth facing mesially towards the root of the lateral incisor. This means that during treatment the appliance must incorporate a rotational mechanism to bring the tooth into alignment. The simplest manner in which to do this is to initially place the eyelet on the anatomic mid-labial surface of the crown of the canine, which faces anteriorly towards the lateral incisor. The eyelet is oriented vertically in the long axis of the tooth (Figure 7.34).

A full-arch NiTi auxiliary wire, together with a heavy main arch, is the method of choice [100] once the eyelet become accessible supra-gingivally. The fine and super-elastic NiTi auxiliary wire is threaded directly through the vertically oriented eyelet, which introduces a strong rotatory element into this auxiliary archwire. This will then exert a two-directional force that will both bring the tooth to its place in the arch and, at the same time, bring about a very efficient correctional rotation (Figure 7.34). The heavy main arch will be slotted passively into the brackets of all the previously aligned erupted teeth in the arch, bypassing the canine. Its function is to maintain the level of the occlusal plane and the archform, which may be altered with the rotatory component produced by the sole use of a NiTi wire. It is, however, essential to check that the ligation of the auxiliary into the other brackets of the appliance is not too tight, since this will limit the canine movement by generating binding in the brackets. The efficiency of the NiTi wire is dependent on its free-sliding ability.

A good alternative involves the use of a 'slingshot' elastic (see Figure 2.6) or elastic thread tied between the brackets of the two adjacent teeth. The space that was earlier created for the canine is maintained by a cut length of stainless steel tube or closed-coil spring that has been threaded onto the main archwire, thus additionally increasing its rigidity (Figure 6.17i). The middle of the slingshot elastic tie is drawn towards the impacted tooth and ligated under tension into its eyelet. While the canine is being moved towards the line of the arch, it is also being rotated about its long axis in a corrective mesio-buccal rotatory movement. Since the stainless steel tube space maintainer will not allow individual movement of the adjacent teeth, the direction of rotation may be changed or increased to fit other types of rotated palatal canines by tying the elastic thread from the eyelet directly to either the premolar or lateral incisor teeth.

Palatal root displacement

A palatally displaced root apex of the canine, whose crown is also palatally displaced, presents the difficult technical hurdle of moving the tooth bodily without it being slotted into an archwire. To overcome this hurdle, the correction must be made in its several constituent parts. The crown will first need to be tipped to the archwire and any existing mesial crown displacement and/or rotation will need to be corrected, in the manner that we have just described. At this point the eyelet attachment is removed and replaced by a conventional bracket. With the canine crown in place and a main archwire firmly ligated into the bracket, the palatal inclination of the crown-to-root orientation of the tooth will become obvious, particularly when viewed from the palatal side. The palatal surface of the tooth, with its large cingulum, will be bulging inferiorly, while the buccal surface tips labially and superiorly. In many of these cases the amount of labial root torque needed is considerable, which will mean that the cingulum is very prominent and will occasionally create a premature occlusal contact with its mandibular antagonist.

To correct this exaggerated angular discrepancy, using a rectangular cross-section edgewise wire, requires a series of torqueing adjustments. The applied force thereby created is impossible to measure and its plane difficult to control. Employing a full rectangular arch, which is torqued in small stages on the canine, only means that each adjustment must, of necessity, be of very short range and it will be a long time before the long-axis inclination will be seen to improve. Equally, the converse presents an opposite reactive force torqueing the roots of the adjacent teeth, which provide the anchorage for this difficult movement. These adjacent teeth are being torqued lingually at each torque-adjusting stage and then buccally as the torqueing force is expended – a classic example of 'round-tripping' that, when considerable torque needs to be applied to the canine, can be quite damaging to each of the teeth involved. This, in the case of a small lateral incisor or one with a partially resorbed root that is associated with the impaction, may undermine the long-term prognosis of the incisor.

In these cases, there are advantages to the use of a heavy round slot-filling archwire to control the occlusal plane and to serve as the base arch to a labial root-torqueing auxiliary. The heavy round base arch provides the fulcrum about which a customized simple auxiliary spring will buccally rotate the root apex (root torque). The forces of the spring are very easily quantified and controlled and the range of their action is extremely broad. The use of a heavy round cross-section base arch eliminates the reactive root torque on the adjacent teeth.

Regardless of the type of orthodontic brackets employed, there are considerable advantages to using a torqueing auxiliary that derives its anchorage from the narrowed archform of a heavy main archwire. This will effectively eliminate distortion of the dental arch and will avoid the creation of unwanted and potentially damaging 'round-tripped' torqueing side effects on the adjacent teeth.

Group 2

- Proximity to line of arch: close to incisor root.
- Position in maxilla: forward and low – lingually overlapping more than half the width of the lateral incisor root.

In this group, the root apex of the canine is usually to be found in its correct mesio-distal location in the line of the arch and at more or less the correct height. However, the CBCT will show the crown of the tooth to be tipped palatally and mesially to a point mesial to the middle of the lateral incisor root and in close proximity to its palatal/lingual aspect (Figure 7.35). A more severe example of the group 2 canine finds its crown located between the roots of lateral and central incisors [15, 79, 80] and, just occasionally, mesial even to the root of the central incisor, in the midline itself. The tooth may not be clinically palpable.

Fig. 7.35 The periapical view of an extreme example of group 2 canines. The left canine is located between lateral and central incisor roots and the right canine is mesial to the central incisor root at the midline raphe.

Planning the orthodontic strategy

Direct traction to the labial archwire is sometimes possible, from an eyelet placed on the palatal side of the tooth. However, if traction is performed in this manner, the surface to which the attachment will need to be bonded (i.e. the lingual surface) will lead the way and will inevitably cause the canine to 'roll' over the root of the lateral incisor, increase existing rotation and risk damage to the incisor. Furthermore, the operator is likely to be faced with having to perform a 180° rotation once the tooth reaches the intended target area of the archwire. Few will dispute that this task is formidable, but before the adventurous clinician even begins to argue that it is not insurmountable, the following three questions should be considered:

- How long will the de-rotation strategy prolong the appliance therapy?
- Will relapse due to the post-rotational rebound factor be a likely sequel?
- What would be the health prognosis of the periodontium at the completion of the correction, after this superfluous and deliberately iatrogenic rotation?

For many of the impacted teeth in group 2, the intimate relation between canine crown and lateral incisor root will block movement of the canine when traction is applied direct to the labial archwire. The inexperienced operator may then be tempted to respond by increasing the pressure applied to the tooth. The unfortunate consequences of such action are that, within a fairly short period of time, there will be signs of loss of anchorage on the other teeth, characterized by the production of a cross-bite tendency, a midline shift to the unaffected side and tooth mobility, not to mention the possibility of damage to the lateral incisor root. It is important to realize that for the group 2 canine, there is no direct unencumbered path to its appropriate place in the arch.

Accordingly a completely different approach is needed. Thus, the tooth must first be moved in a different direction, to free it from potential entanglement with the incisor roots and to provide it with a direct path to its desired location. The most practical manner of doing this is to draw the canine vertically downwards (towards the tongue), erupting it into the palate. From this new vantage point, the tooth will have a clear path to its place in the arch without any interposing roots. By this initial movement, the group 2 canine tooth will have effectively been converted into a group 1 canine. It may then be moved directly across the line of the arch, towards the labial archwire, in the manner described above in relation to the group 1 canine.

In order to facilitate this two-stage modification, the pigtail ligature wire must be drawn through the middle of the fully replaced surgical flap and not through its sutured edge. The exit point of the ligature wire through the flap should be made immediately opposite the buried tooth, in order that vertical traction may be applied with ease and relative comfort for the patient. Vertical traction to a palatally sited eyelet will not cause a rotation of the impacted tooth as the tooth erupts.

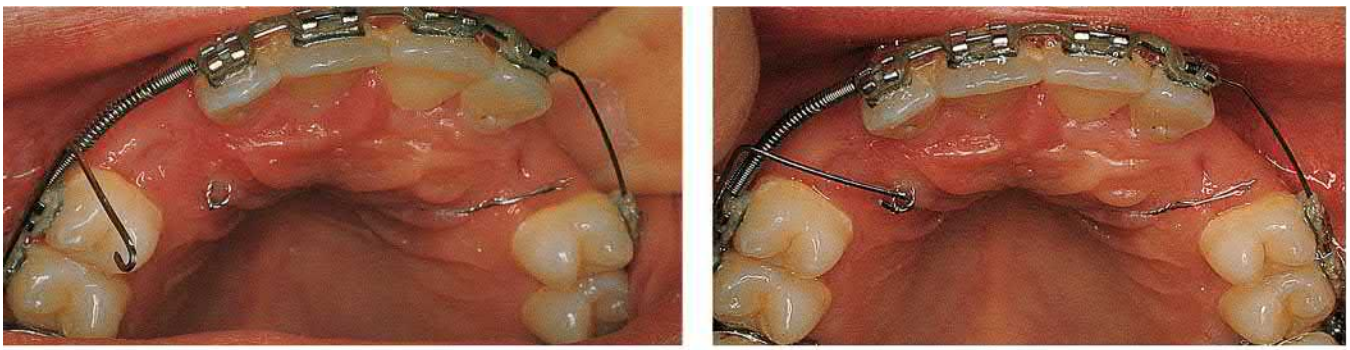
Three types of maxillary spring auxiliary may be used to bring about the vertical traction that is needed in this first stage of the resolution. These are the ballista [79], the active palatal arch [80, 81] and the light auxiliary labial arch [82]. With each of these methods it is essential to tie a heavy base arch into the brackets of all the teeth on the labial side. This will hold the opened space for the canine in the arch, resist secondary distortion of the occlusal plane and archform and provide a sound anchor base from which to apply the force to resolve the tooth impaction.

The *ballista* [79] (Figure 7.36a, b) is a unilateral spring of rectangular wire, which is held in the auxiliary rectangular buccal tube and where rotation is countered by the fit of the wire into the rectangular cross-section tube. Round wire may also be used, in which case it is prevented from rotating in the buccal tube by doubling back the wire on itself, as it exits the distal end of the buccal tube, so that it lies against the buccal surface of the tooth, occlusally alongside the tube. In both cases, it proceeds forwards until it is opposite the canine space. At this point, it is bent vertically downwards towards the lower jaw and terminates in a small loop. With light finger pressure, the vertical portion is turned inwards and upwards, across the canine space towards the exposed canine. In this active mode, it is ensnared by turning the pigtail ligature from the canine around its terminal loop, to hold it close to the palatal mucosa. By doing so, torsion is introduced into the horizontal part of the wire, which provides the vertical traction. The resulting equal and opposite reactive force is thus transferred to the anchor molar.

The elasticity of the steel ballista spring exerts pressure to return to its original vertical position, which in turn applies extrusive force to the unerupted tooth. If the impacted tooth is fairly resistant to movement or if the distance that the tooth needs to be moved is great, buccal molar root torque may occur, which is a sign of loss of anchorage. To overcome this, a rectangular main arch or a soldered transpalatal arch may be used.

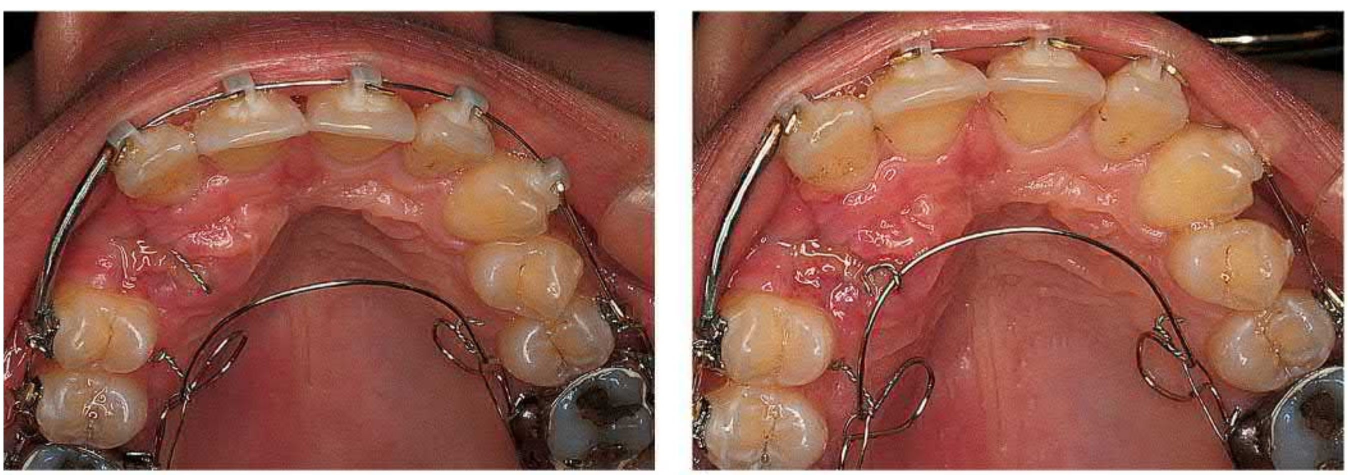
The second type of spring is the *active palatal arch* [80, 81] (Figure 7.37). It is made of a fine 0.024 in. (0.6 mm) palatal archwire with an omega loop on each side, slotted into a soldered round lingual horizontal molar tube of 0.024 in. (0.6 mm) gauge. By elevating the downward-activated palatal archwire and hooking the pigtail ligature around it, the unerupted tooth comes to be erupted through the palatal tissue, in a direction slightly distant from the other teeth.

The third possibility is the *auxiliary labial archwire* [82]. This device (Figure 7.38) requires no advance preparation of any sort, such as the soldering of lingual tubes. It is most conveniently fashioned from an archform blank of 0.014 in. (0.35 mm) or 0.016 in. (0.4 mm) diameter round stainless steel wire by forming a vertical loop in the area of the impacted canine. This loop has a small terminal helix. The auxiliary is tied into all the brackets of the arch, in piggyback style over a heavy main arch, with the extremities slotted into a spare tube on the molars or left free, distal to the second premolar brackets. In a similar manner to the ballista, the vertical loop is activated by raising it palatally across the canine space and ensnaring it in the pigtail ligature in the palate. The auxiliary labial wire draws its activation from its curved archform, which does not therefore transfer a reactive torqueing force to the molar.



(a) (b)

Fig. 7.36 (a) The coil spring on the archwire had created space for the canine. A ballista of rectangular wire in its passive mode, pointing downwards. (b) Using light finger pressure, the looped end of the spring is turned inwards and upwards towards the palate, where it is ensnared by the stainless steel twisted pigtail ligature from the unerupted canine.



(a) (b)

Fig. 7.37 (a) The active palatal arch in its passive mode, lying several millimetres away from the palate as seen from the occlusal. (b) The same view after the active palatal arch has been gently raised towards the palate and ensnared by the pigtail hooks, thereby applying vertically extrusive traction to the unseen right canine, high up in the palate.

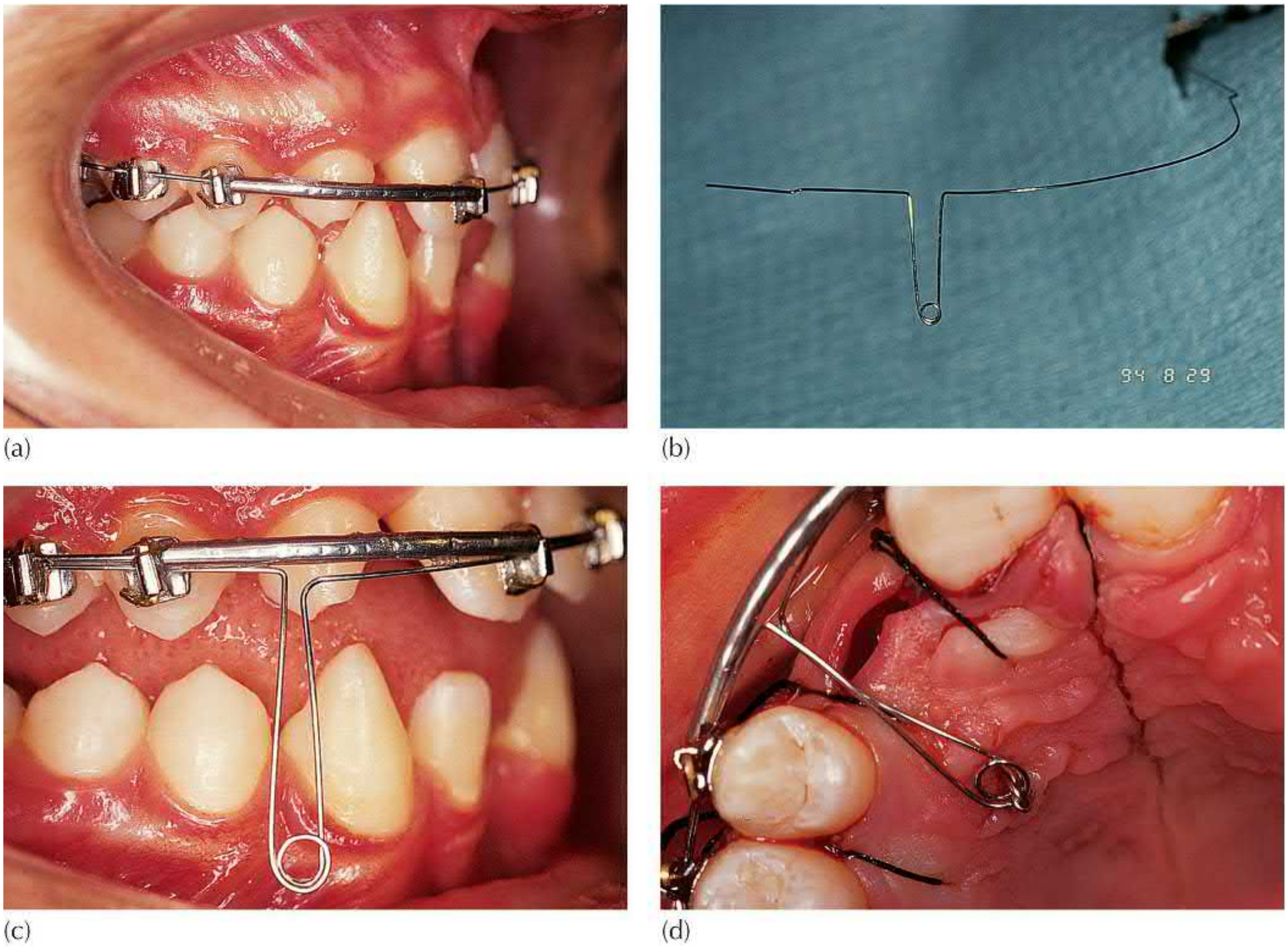


Fig. 7.38 (a) Initial treatment had created space and a heavy base arch, carrying a stainless steel tube space maintainer, was in place. (b) A typical auxiliary labial archwire of 0.016 in. gauge with its vertical loop and terminal helix. (c) The auxiliary labial archwire was tied into the brackets piggyback style over the heavy base arch, immediately prior to surgical exposure. (d) Following extraction of the deciduous canine and full-flap closure, the vertical loop was gently raised and turned inwards, with its helix secured into the terminal hook of the pigtail.

This is a particularly useful method for a bilateral impaction, when two different loops will need to be inserted into the archform. If, however, it is used without a base arch, as has been recommended elsewhere [101, 102], it will extrude the adjacent teeth and thereby alter the occlusal plane. It will move the molars buccally and additionally will alter the horizontal arch form in the incisor area. This active labial arch should always be used as an auxiliary to a heavier stabilizing arch.

In the construction of the ballista and auxiliary labial wire, it is important to calculate in advance the length of the active arm. This may be done by pinpointing the intended location of the eyelet on the tooth and its projected exit from the palatal flap, either on the plaster cast or directly in the mouth, by palpation of the bulge in the palate. Alternatively, the location may be estimated from the radiographs and particularly by measuring the 1–1 distance between the location of a main arch and the chosen bonding site on the canine on an axial slice on the CBCT, which will provide greater accuracy. The distance between this point and the labial archwire represents the optimum length of the active arm. If the arm is made shorter or longer, it will be difficult to approximate it to the palatal tissue and the arm will stand uncomfortably away from the palatal mucosa and interfere with tongue activity. If it is made too long, it will draw the tooth away towards the midline as it vertically erupts it and, with it, the apex of the canine will be similarly drawn down and palatally, adversely altering the tooth's centre of resistance away from the line of the arch. This means that its final alignment will require more labial root torque than would otherwise have been necessary. It is therefore preferable to err on the side of a shorter active arm.

In addition to maxillary springs, a fourth approach extrudes the canine vertically downwards to eliminate its clash with the root of the lateral incisor. This is the *mandibular removable or fixed appliance*. This method requires no maxillary appliance at all in the first instance [103]. Vertical extrusive force is derived from a either a fixed multi-bracketed appliance or a removable appliance in the opposing jaw by means of a simple latex elastic ring. This is applied by the patient between the clasps of the mandibular appliance, or a hook on the fixed appliance and the pigtail ligature in the palate. In order for this to be efficient, several clasps used for retention of the removable plate on the teeth need to be included in the design and the anatomy of the individual teeth must lend itself to good retention, otherwise the plate will be easily dislodged by the vertical intermaxillary elastic force.

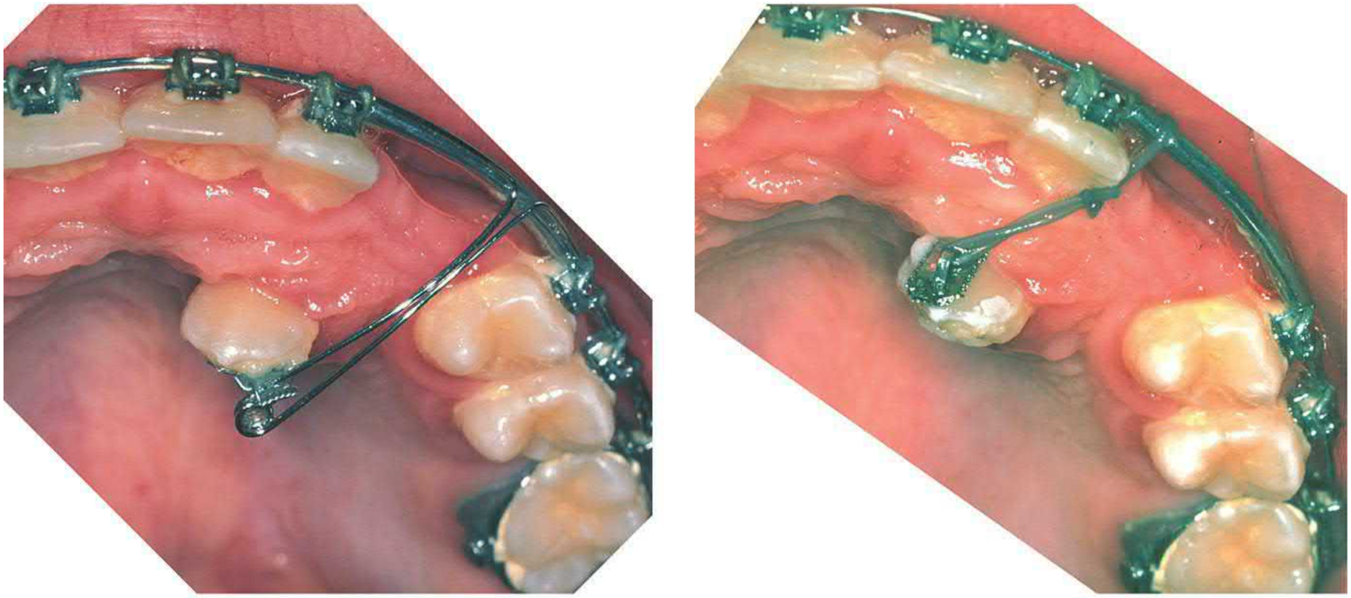
A more reliable variant for applying intermaxillary force is contingent on the use of a *temporary anchorage device* (TAD). A screw implant may be placed in the mandible, in the inter-radicular bony area between the canine and first premolar, on either the lingual or buccal side of the ridge, depending on the required direction of traction. Traction in the form of latex elastic rings may be applied by the patient between the implant device and the pigtail ligature. This represents what is termed 'direct traction'.

If a maxillary appliance is present from the outset, it will be more manageable for the patient if the elastic is stretched between the TAD and engaged in a hook attachment on the maxillary appliance, to ensure the anchorage. A customized spring traction device would then be built into the appliance itself, under the control of the orthodontist. In this manner, the orthodontist controls the traction applied to the impacted by other means, while the elastic rings from the mandibular TAD ensure the anchorage base against intrusion of the adjacent maxillary teeth. This represents 'indirect traction' from the implant to reinforce the anchorage of the whole appliance on that side of the maxilla, thereby enabling the safe and controlled application (by the orthodontist) of a separate extrusive force to the canine.

A maxillary multi-bracketed orthodontic appliance will inevitably be needed later, to move the tooth into the line of the arch and to achieve levelling, aligning and finishing for all the teeth. The full orthodontic appliance need not then be placed until the tooth has erupted through the palatal mucosa.

The direct traction method has one other important application, which relates more to an impacted canine in a 30+-year-old patient, in whom the chances of the tooth responding to orthodontic force will have waned [58]. The tooth needs to be tested for positive movement before proceeding to the placement of full appliances. This can be done by exposing and bonding a button attachment to the unerupted exposed tooth and drawing an elastic chain from it to a TAD placed at a convenient site in the posterior palate or in the opposing jaw.

Regardless of which method is employed, the successful resolution of a group 2 canine impaction will find the newly erupted tooth, surrounded by a wide rim of palatal mucosa and bone, located on the lingual side of the alveolar ridge (Figure 7.39). However, it will still be well above the occlusal plane, due to the shape of the palatal vault, and there is advantage to be gained by substantially erupting it. The more the tooth is erupted, the easier it will be to place an attachment on its labial aspect and enable the tooth to be moved buccally towards the line of the arch, without the bracket impinging on the attached and thick mucosal cover of the vertical alveolar ridges, yet encouraging a simultaneous corrective rotation. The above methods of vertical extrusion are very efficient, their range of action is very broad and they are not self-limiting. So, when one of these methods is employed, it will be essential to see the patient every 3–4 weeks thereafter, in order to monitor progress. If the patient misses appointments at this critical stage, over-eruption may occur and lead to occlusal trauma as the tooth moves across the line of mandibular teeth.



(a) (b)

Fig. 7.39 (a, b) With the eruption of the canine into the mid-palate, the eyelet position has to be rebounded to the labial anatomical aspect of the canine, to enable labial elastic traction direct to the archwire, which encourages simultaneous corrective rotation.

For the extrusive first stage of the two-stage manoeuvre, the position of the eyelet is not critical and bonding should be performed to the most convenient surface available (Figure 7.39a). No adverse rotation of the tooth will occur while it is being moved vertically downwards. The tooth must be cleared of the lateral incisor root and extruded until it has an unobstructed and direct path to the labial archwire. A second eyelet should then be bonded, this time on the mid-buccal aspect, which will have become accessible as the result of the initial extrusive movement. The second stage of traction may then commence, with the application of force from the second eyelet directly to the labial archwire (Figure 7.39b). Because the point of application of the force will now be applied to the mid-buccal aspect, the new force direction will also provide a corrective rotation of the canine.

A fundamental warning note must be added here. Direct traction to the archwire should only be performed from an attachment sited in the mid-buccal position on the crown of the tooth. Traction applied at any other site will engender an unwanted rotation as the tooth progresses towards its place in the arch – a rotation that will require correction in an extra and superfluous phase of orthodontic treatment.

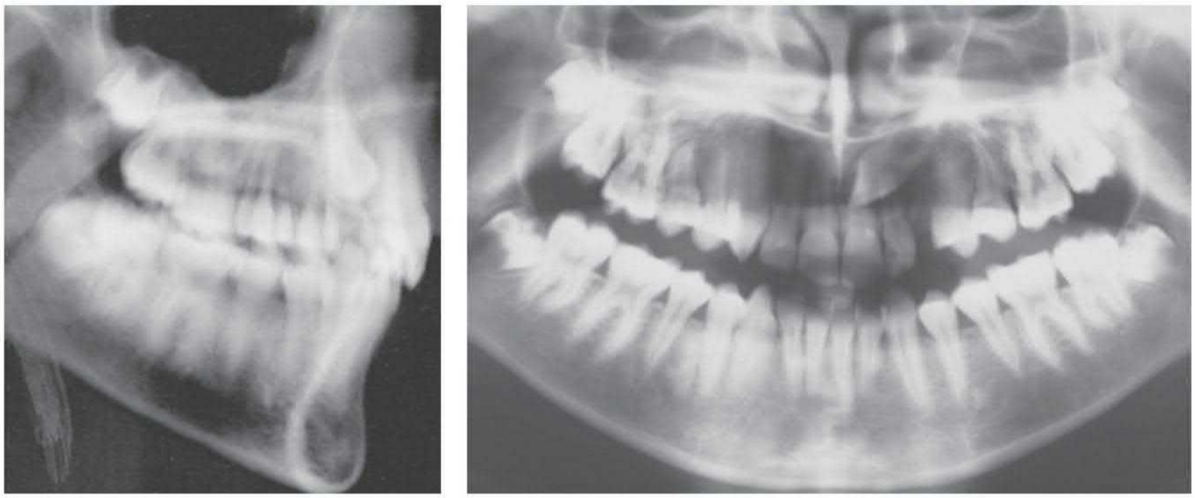
Surgery

Surgical exposure in this group is complicated by the occasionally unavoidable simultaneous exposure of the roots of adjacent teeth. Aggressive surgical techniques may occasionally open the way for the orthodontist to bond on the labial surface, but not without considerable damage to the adjacent exposed incisor roots caused by the radical removal of bone.

With the position of the crown of the impacted canine situated mesial to the root of the lateral incisor, several operative problems present themselves. In the first place, surgical exposure has to be carefully undertaken not to damage the roots of the incisors. The temptation to expose too widely should be resisted and only enough of the most conveniently accessible surface of the tooth to permit bonding should be uncovered. The palatal surgical flap should be replaced in its entirety in order to provide maximum protection and tissue re-attachment for the exposed incisor roots and the area of exposed bone and to re-establish a normal periodontium.

The practicalities of both the biomechanics and the surgical exposure of a group 2 canine are quite involved and a case (Figure 7.40) is presented with a view to illustrating how a considerable number of relevant factors, both large and small, need to be addressed if good results are to be obtained.

(a)



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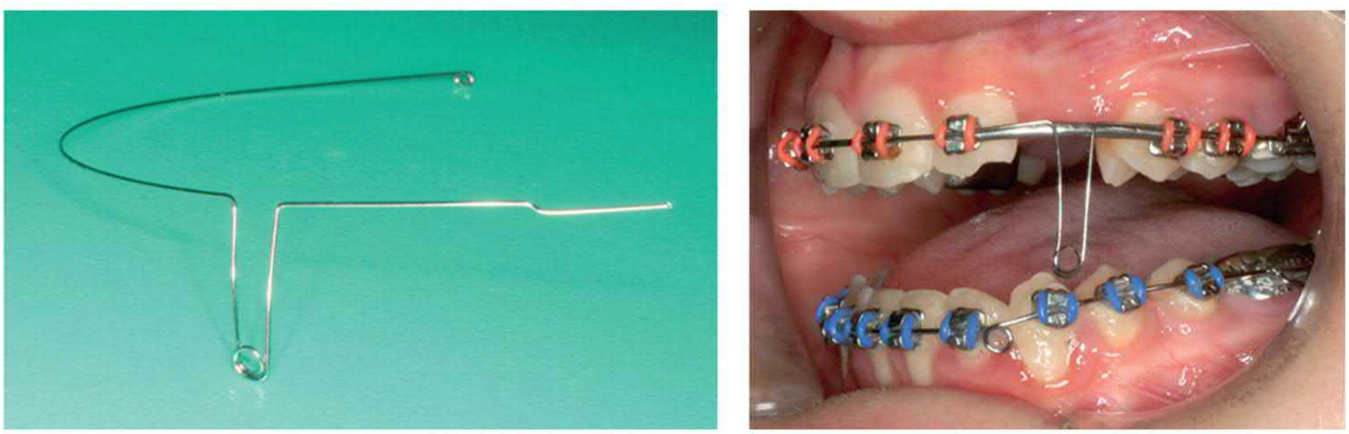

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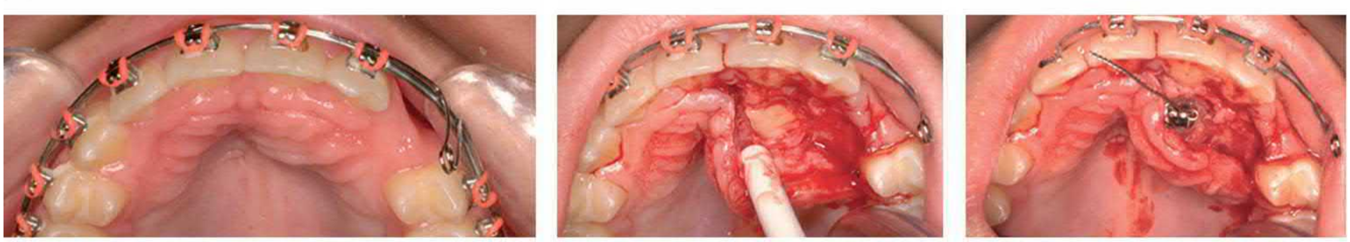

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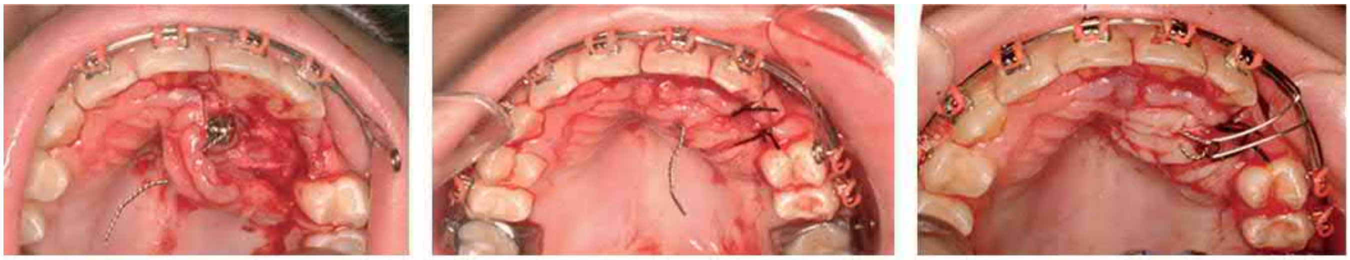

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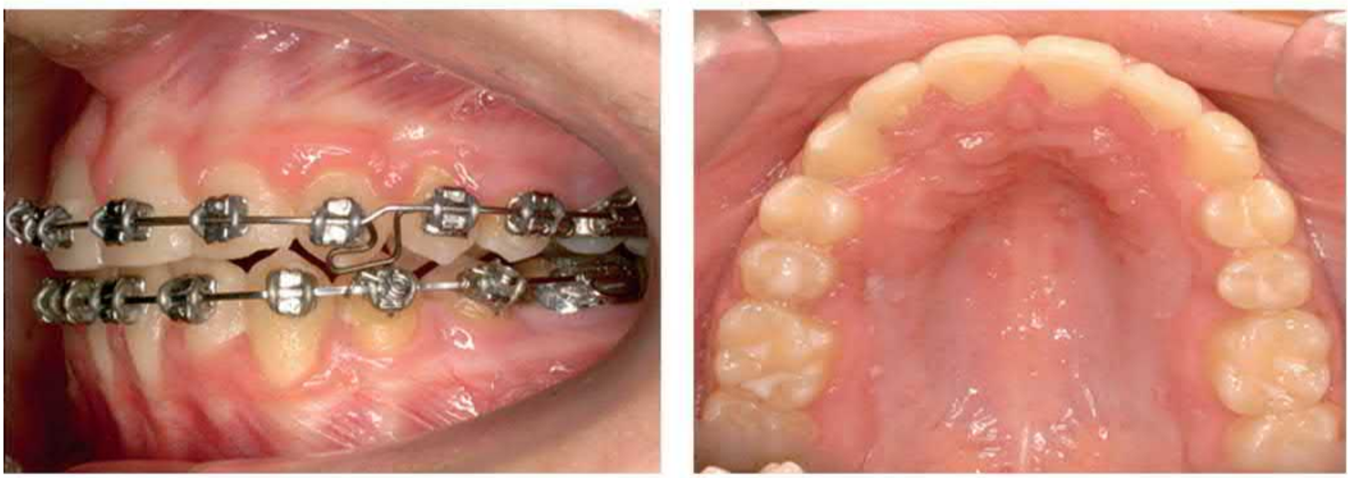
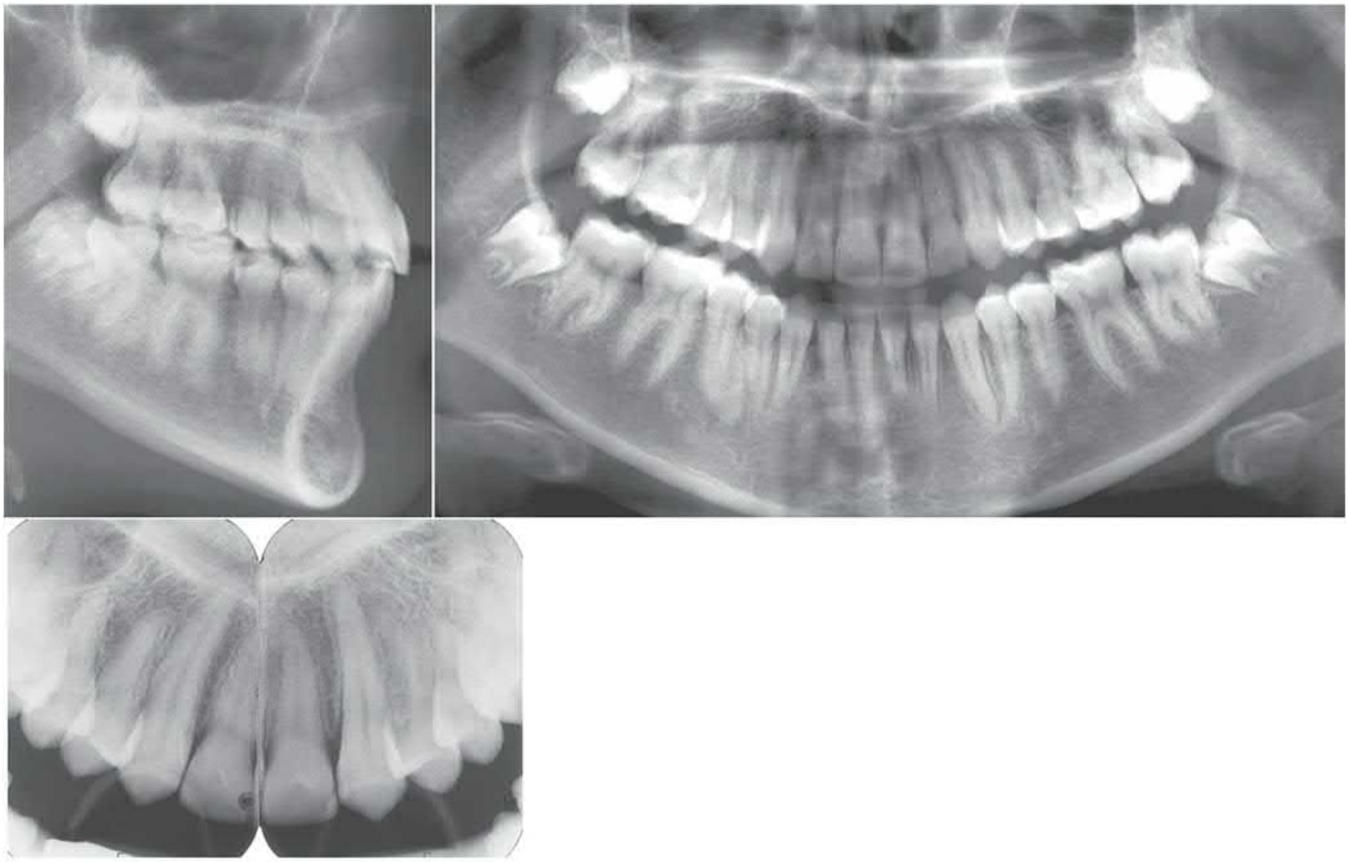


(g)

(h)



(i)

Fig. 7.40 (a) The initial intra-oral view of the teeth in occlusion. (b) The initial pre-treatment lateral cephalogram and panoramic view. (c) The auxiliary labial arch, showing how it was placed in piggyback style over the main arch, in preparation for the surgery. Note the presence of a section of over-sized steel sleeve, curved into the arch form and threaded onto the archwire, to maintain the space in the arch and to increase archwire rigidity. (d) Exposure surgery and attachment bonding, with the auxiliary archwire in place. Surgery by Dr Harvey Samen. (e) The twisted steel connector is passed through a piercing in the surgical flap prior to suturing back into its place. The connector is turned into a small hook and shortened, after the vertical loop of the auxiliary archwire is ensnared into a horizonal activated mode, providing immediate extrusive traction. (f) Several weeks later, the canine may be seen to strongly bulge the palatal form, which required a minor surgical excision of the thick palatal mucosa, covering the tip of the tooth only. From a new eyelet on the labial aspect of the crown, labial tipping of the canine then brought the tooth to the archwire. (g) Labial root torque was applied using an auxiliary torqueing arch, together with minor finishing procedures, at the conclusion of treatment. (h) Intra-oral photographs of the teeth in occlusion at the completion of treatment. Note the appearance of the gingival area and the difference in crown length between the treated left maxillary canine and the normally erupted right canine. Fig. 7.40(i) The cephalogram and the panoramic views seen at the completion of treatment, together with periapical views of the immediate vicinity of the treated canine and that of the normally erupted contralateral canine. (This case was first published in Becker A, Chaushu S. Impacted teeth and their orthodontic management. In Gill DS, Naini FB (eds), Orthodontics Principles and Practice. Oxford: Wiley-Blackwell, 2011.)

The patient was a 13-year-old healthy female, with a class I malocclusion in the permanent dentition stage, retroclined maxillary and mandibular incisors and a deep anterior overbite. The dentition was mildly crowded and there was reduced space for the maxillary left, palatally impacted, permanent canine (Figure 7.40a). The initial panoramic radiograph with the lateral cephalogram (Figure 7.40b) confirmed the palatal impaction, as well as the presence of the four third molars, with calcification of their crowns almost completed. The location of the maxillary left canine was diagnosed as being displaced high in the palate, in close proximity to the left-side incisor root apices, in the palatal midline. Given that the crown tip of this canine was more than 30 mm from its intended post-treatment target location, at the significantly resorbed bony ridge, this was a difficult group 2 canine.

Following alignment and levelling of the two dental arches, with the provision of adequate space at the target site, a heavy 0.020 in. round base arch was placed, with a measured, over-sized and curved steel tube sleeve holding the space. At the surgical appointment and immediately prior to the introduction of local anaesthesia, an auxiliary 0.016 in. stainless steel archwire, with a long vertically oriented loop, was ligated in piggyback style over the main arch (Figure 7.40c). The auxiliary archwire was left in its passive vertical mode throughout the surgical procedure and was sufficiently removed from the surgical area not to compromise the surgeon's access. The hard swelling, high in the palatal vault, represented the location of the impacted canine, as may be seen in the occlusal view (Figure 7.40d).

A palatal flap was raised from the cervical margins of the teeth, up to the midline, leaving the incisive canal bundle intact (Figure 7.40d). The canine was minimally exposed, revealing only its palatal aspect, but emphasizing its close relation to the midline raphe and its proximity to the roots of the incisors. A small metal eyelet attachment was bonded by the orthodontist to this aspect of the crown tip of the canine, being careful to distance the orthophosphoric gel etchant from the CEJ.

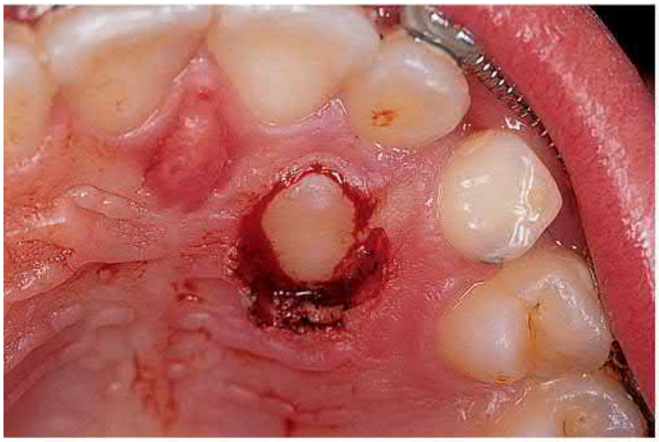
A small piercing of the surgical flap was made opposite the location of the attachment, using a wide-bore canula, through which the twisted steel ligature was drawn prior to the full closure and suturing of the flap (Figure 7.40e). Once this was completed, the orthodontist turned the long loop of the auxiliary labial archwire lingually and superiorly to engage it in the twisted steel ligature. The ligature was firmly hooked around the loop such that the loop lay under extrusive tension, lightly against the palatal mucosa (Figure 7.40e).

Three months and two adjustments later, the palatal area bulged due to vertical progress of the canine, which was still covered by thick mucosa (Figure 7.40f) but considerably distanced from the incisor roots. A small window opening was made in the thick, resistant palatal mucosa immediately over the tip of the canine, to permit the rapid eruptive progress of the canine. A second eyelet was placed in a corrective position on the disto-labial corner of the canine, which substituted for the eyelet that had been bonded at surgery. Traction was then applied with elastic thread direct to the labial archwire (Figure 7.40f) to bring the canine into its targeted place.

At this point an individual, full-arch torqueing auxiliary was ligated in piggyback style, to perform the much-needed bucco-lingual relocation of the root of the canine (Figure 7.40f, g).

The periodontic results of treatment to resolve impacted teeth are usually characterized by considerable gingival recession of the formerly affected and now treated canine, compared with its unaffected antimere. In the present case, the clinical crown of the affected case was shorter than that of its antimere and showed no recession nor other periodontal pathology. The final test of success is when there are no tell-tale clues as to which tooth has been impacted, not visually, not clinically and not radiographically. The post-treatment clinical photographs and radiographs show highly satisfactory results in the treatment of this case (Figure 7.40h, i).

In a group 2 case the canine is usually mesio-palatally rotated, which places its labial surface in a completely inaccessible position, facing the incisor roots and likely in direct contact with one or other of them. This means that only the palatal aspect of the canine is available for bonding the attachment. Probably the most common mistake made in this situation is to attempt to draw the canine directly to the labial archwire from an attachment bonded to the anatomical palatal surface of its crown. In a further case (Figure 7.41a–c), the group 2 canine was surgically exposed and the deciduous canine subsequently extracted. The canine crown was mesial to the lateral incisor root, which partially obstructed the direct path of the canine to its targeted place. Force from the archwire to the palatal attachment increased the rotation of the canine that was already present. It had also caused 'rolling' of the canine over the incisor root, leading to much gingival irritation, with swelling and acute pain, with the tooth ending up at the canine location, 90° rotated.



(a)

(b)

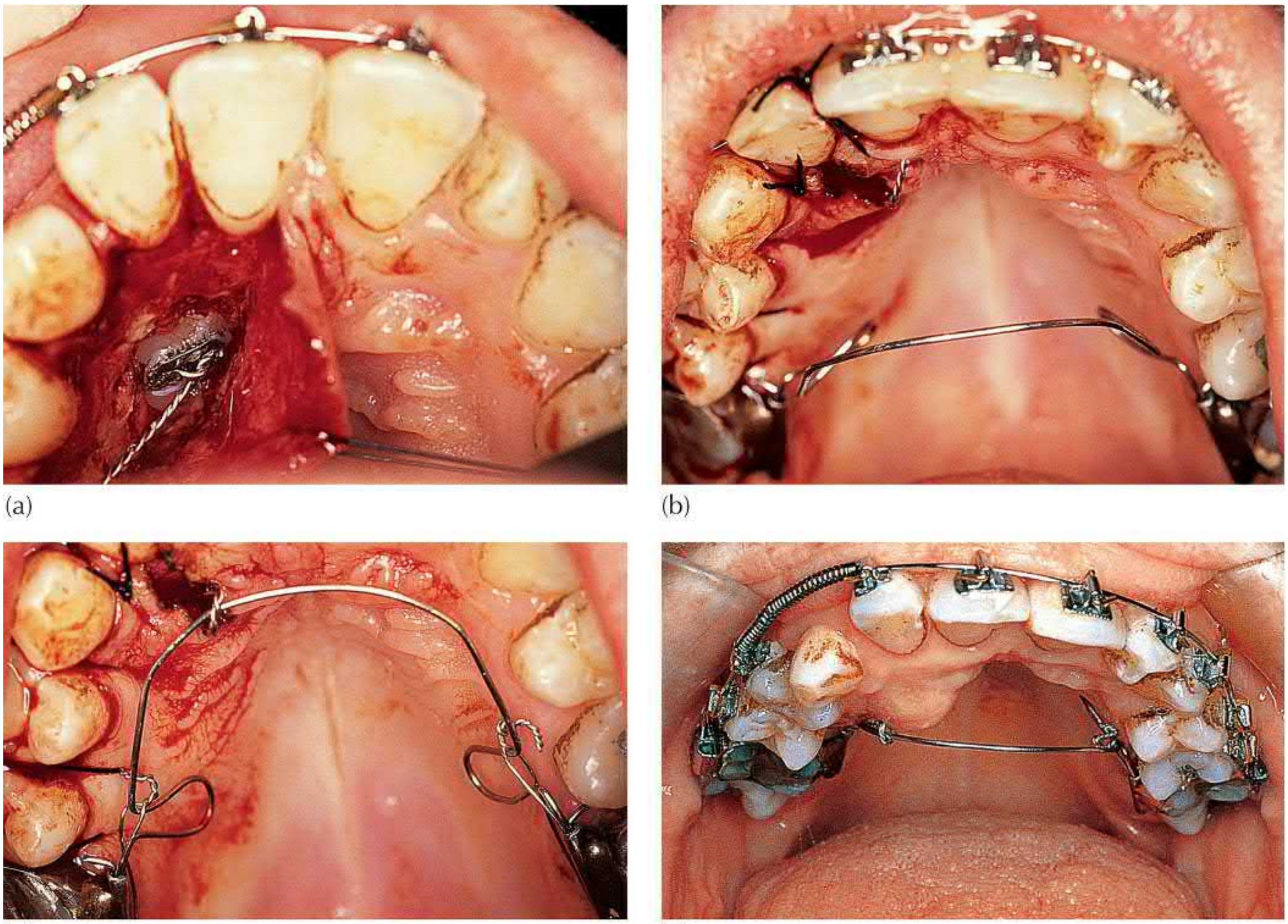
(c)

Fig. 7.41 (a) A group 3 canine was exposed with an open procedure and healing was by secondary intention. (b) An edgewise bracket was bonded to the anatomical palatal aspect of the canine. The tooth was drawn from this palatal attachment using an elastic ligature directly to a flexible labial archwire. (c) The tooth reached the archwire with its rotation significantly increased. Note the swollen appearance and poor contour of the surrounding gingiva.

Problems that may be encountered

As the tooth initially progresses in the vertical eruption path that has been planned for it, the thick and resistant palatal tissue bulges more and more, although it may not allow the tooth to erupt through it (Figures 7.40f, 7.42a–d). Increasing traction forces will not improve the chances of progress of the impacted canine. The tissue resistance will divert the forces of the auxiliary labial arch to be redirected against the anchor unit. This will result in the appearance of an open bite, intrusion of the adjacent teeth and a serious disruption in archform. A very limited and superficial surgical removal of the thick mucosa immediately over the crown of the tooth will be needed to eliminate this obstacle. This may be achieved without releasing the traction mechanism. The situation should be left without additional activation for a further two or three weeks, during which time the tooth will often be seen to advance at considerable speed.

Once the tooth in the case in Figure 7.42 was well erupted at the level of the occlusal plane, a new eyelet attachment was bonded to its anatomically buccal surface (Figure 7.42e). The attachment was then drawn in a direct line to the labial archwire and to the prepared space provided for it in the initial orthodontic phase of the treatment. Initial rotation of the canine was still present when this second phase of the traction began, but corrected itself steadily as the traction proceeded, with a well-placed attachment in the mid-labial position on the buccal surface leading the way.



(a) (b) (c) (d)

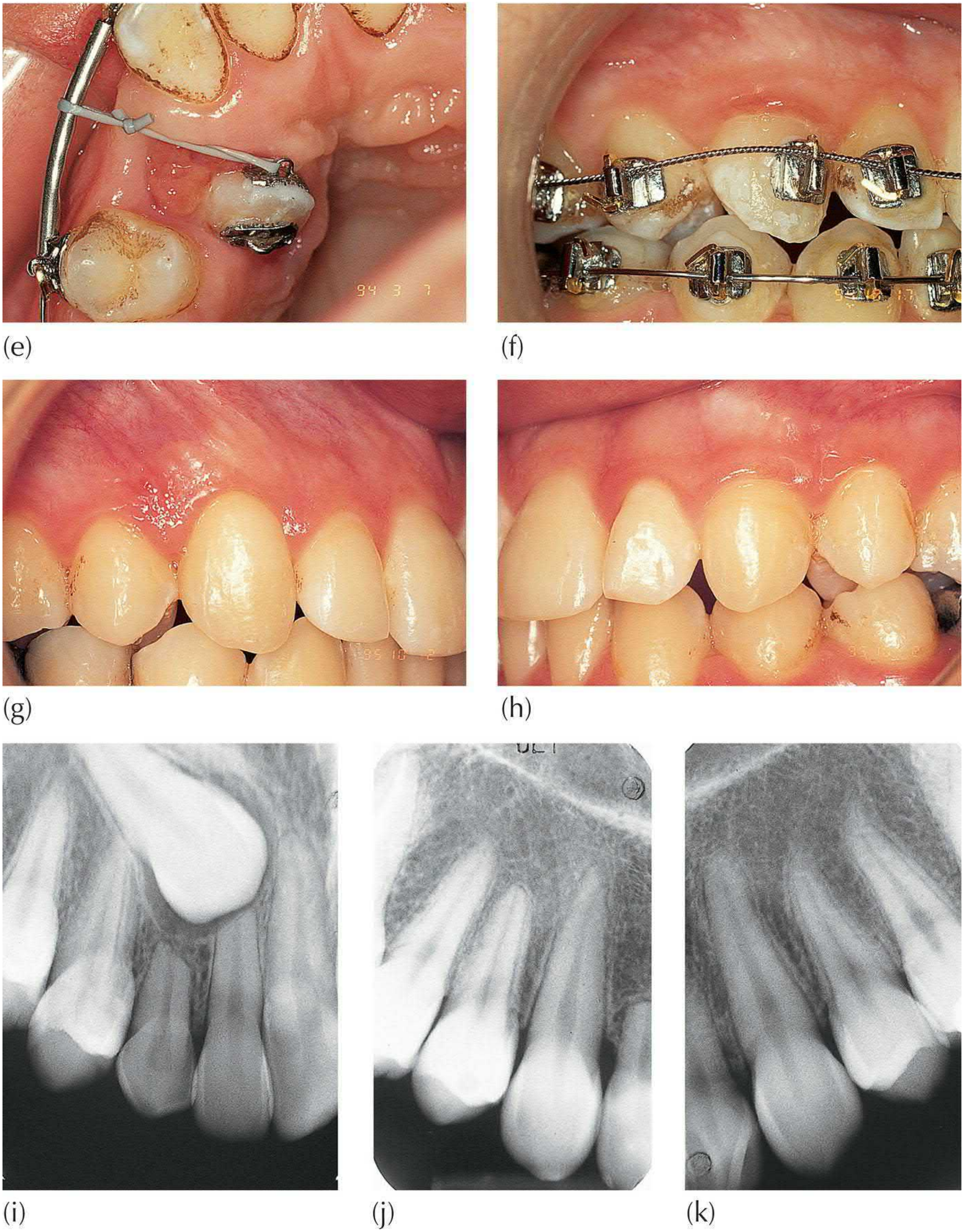


Fig. 7.42 (a) Minimal exposure and eyelet attachment bonding of the palatal aspect of a group 2 canine in a 17-year-old female. The tip of the cusp was not exposed due to its proximity to the incisor root. (b) Suturing was completed with the pigtail emerging through the divided flap. The

palatal arch was in its passive state. (c) The palatal arch fully tied in and distanced from the palate prior to ligation to the pigtail ligature, i.e. active. (d) Seen three months later, after two intervening visits for adjustment, the archwire had become distanced from the palate and the canine was bulging the contour of the palate almost to the occlusal level. (e) A minimal re-exposure was performed preparatory to buccal movement and the deciduous canine was extracted at the same time. A second eyelet was bonded slightly mesial to the mid-buccal position and elastic ligation drew the tooth directly to the archwire, with a favourable rotation vector from the second eyelet. (f) At 13 months post surgery, the canine was in the arch and a bracket was substituted for the eyelet. (g, h) The gingival health of the treated canine was good, but its clinical crown was longer than the untreated left canine. (i) The periapical view shows the resorbed root apex of the right lateral incisor prior to treatment. (j, k) Post-treatment periapical views to show comparable bone support of the treated canine, with that of its untreated antimere. Significant resorption of the lateral incisor root was noted, despite the circuitous eruption path that had been employed.

Even with good oral hygiene during the traction period, much exuberant gingival tissue preceded the canine during its orthodontic traction towards the line of the arch. Premature substitution of a conventional bracket, which is larger and bulkier than the eyelet, may result in tissue impingement, particularly as the tooth comes into close proximity to the adjacent teeth. The orthodontist should not relinquish the use of the eyelet until no further buccal and rotational movement is required.

Complications

The initial location of the tooth may be complicated by one or both of the following conditions:

- *Rotation*: As with the group 1 canine, a mesio-lingual rotation is common and is largely corrected during the second stage of the resolution. That is the stage when traction is made direct to the archwire, from the newly placed second eyelet on the mid-buccal surface of the tooth.
- *Palatally displaced root*: Occasionally a tooth in this group may present with the root palatally displaced, in addition to the displacement of the crown (i.e. a palatal translation of the entire tooth). This situation will complicate the appliance work and will require the introduction of buccal root torque and often some mesio-distal root uprighting. These forces may only be applied once the crown has been engaged by the main labial archwire.

In summary, it will be appreciated that a group 2 canine has to be approached with a good measure of preparedness. From the surgical point of view access is not difficult, but exposure must be performed carefully to avoid exposing and damaging the roots of the adjacent teeth. The orthodontic appliance may need to execute as many as five different types of movement, involving both crown tipping and root movement, i.e. vertical and/or posteriorly directed extrusion to move the tooth away from the incisor roots, buccal tipping to the line of the arch, rotation, mesio-distal root uprighting and buccal root torque. From the periodontal point of view, the prognosis of the result is dependent on the smooth execution of each of the surgical and orthodontic operative procedures. Mismanagement of any part of the orthodontic or the surgical stages may not be germane to the question of whether the final alignment of the tooth will be technically successful, but it will be critical in determining the final bone level (Figure 7.42j, k), periodontal condition, clinical crown length, gingival architecture and the final appearance that may be achieved (Figure 7.42g–k).

Group 3

- Proximity to line of arch: close.
- Position in maxilla: high.

In this group the root apex of the palatal canine is situated very high in the maxilla, predominantly in the general bucco-lingual line of the arch, but in its correct location in the antero-posterior plane. The crown is high and only relatively mildly palatally displaced. It is not usually palpable.

Surgical and orthodontic strategy

Access to this tooth may be either from the buccal side or the palatal side, with advantages and disadvantages to both approaches, since there may be a significant thickness of bone both on the buccal side and the palatal side of the tooth. Considerable bone removal is needed to reach it from either side, with corresponding difficulty in the application of an attachment. The orthodontic treatment entailed in aligning such a tooth in essence involves extrusion, together with a buccal tipping movement.

The buccal approach

From the buccal side, the tooth is approached in the same way as for a buccal impaction, as has been described in Chapter 3. With this approach, the surgeon may have greater difficulty in locating the impacted tooth and will be more dependent on the radiographs.

Ostensibly, the apically repositioned flap [104, 105] would appear to be a good approach, since it offers suitable access for the application of orthodontic force direct to the archwire. It also ensures that an adequate band of attached gingiva be raised as a part of a split-thickness flap above the level of the impacted tooth to accompany that tooth in its subsequent downward path. In other words, the buccal tipping movement would precede the extrusive movement.

However, when viewed from the surgical point of view, it will be apparent that this approach takes no account of the location of the canine in three dimensions. The method may indeed be very suitable for a buccal canine with vertical displacement, but in the case of a more superiorly displaced palatal canine, this type of exposure would leave a considerable expanse of periosteum and freshly cut alveolar bone open to the oral environment. The flap would normally need to be sutured several millimetres lateral to the crown of the tooth, unless considerably more bone were to be removed on the buccal side of the crown of the tooth to enable the flap to bridge the large gap between the labial mucosa and the palatal tooth. Furthermore, the maintenance of the exposure of a canine crown, palatal to the line of the arch, would secondarily cause a denuding of the interproximal areas of the roots of the adjacent lateral incisor and first premolar teeth. In addition, post-surgical discomfort with this method is more severe and more prolonged than with a closed exposure procedure [106, 107]. Consequently, it is clear that this method may be suitable only for cases of very minor palatal displacement.

One approach, which has been used for many years and was widely advocated [17, 108–110] for mildly palatally impacted canines, is the reduction of the size of a full labial flap reflection. It is subsequently partially replaced over the exposed tooth, together with a surgical pack, thereby covering the tooth and surrounding tissues during healing. This method shares features with the apically repositioned flap procedure described earlier. In the case of a group 3 canine, however, it must be understood that a considerable mass of alveolar bone is present both inferior and inferio-buccal to the canine, which must be traversed by the tooth. In order to overcome this physical impediment, the above-referenced advocates of the method recommended the surgical channelling of bone to free a path in the direction of the targeted location (Figure 7.43). Experience with this procedure shows that while it lives up to its expectations regarding the provision of access and the enablement of direct traction, it does so only by the planned sacrifice of much of the alveolar bone in the immediate area. The treated result leaves an aligned canine with a healthy gingiva, but unacceptably reduced bone support, poor bony contour, poor gingival contour with deficient interdental papilla and a long clinical crown. Taken together, the method offers a poorer periodontal prognosis than could be achieved by other means.

The tunnel approach

An excellent modification of this method was described by Crescini et al. [111] in which the buccal plate of bone is preserved, while the impacted tooth is drawn through a tunnel in the bone provided by the vacated socket of the simultaneously extracted deciduous canine. This method is particularly suited to the group 3 canine. A full labial flap is reflected to include attached gingiva from the crest of the ridge and the impacted tooth exposed from its buccal aspect, leaving intact the buccal plate inferior to it. The deciduous canine is extracted and its socket extended and widened sufficiently to allow the passage of a fine wire through it, reaching to the impacted tooth (Figure 7.44). It is not necessary, however, to widen it to the full diameter of the crown of the canine, which must pass along this path. Considerable time will elapse before a markedly displaced canine reaches the coronal end of this 'eruption tunnel' and much reparatory bone will be laid down in its path, well ahead of its final and unimpeded eruption. Nevertheless, the progress of the biomechanically encouraged eruption may be achieved with little more difficulty than that of impacted teeth in more favourable locations with unimpeded paths of eruption.

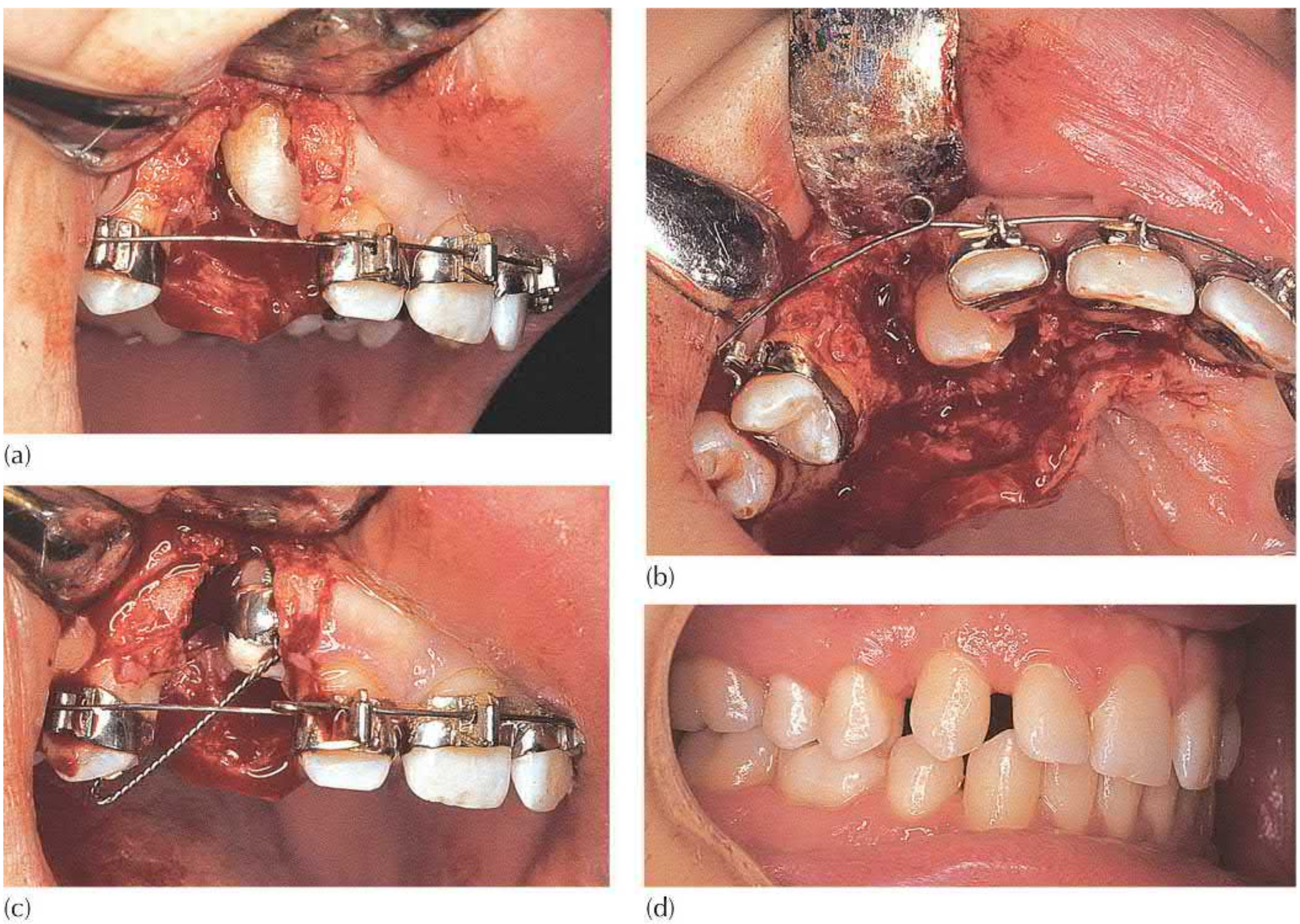
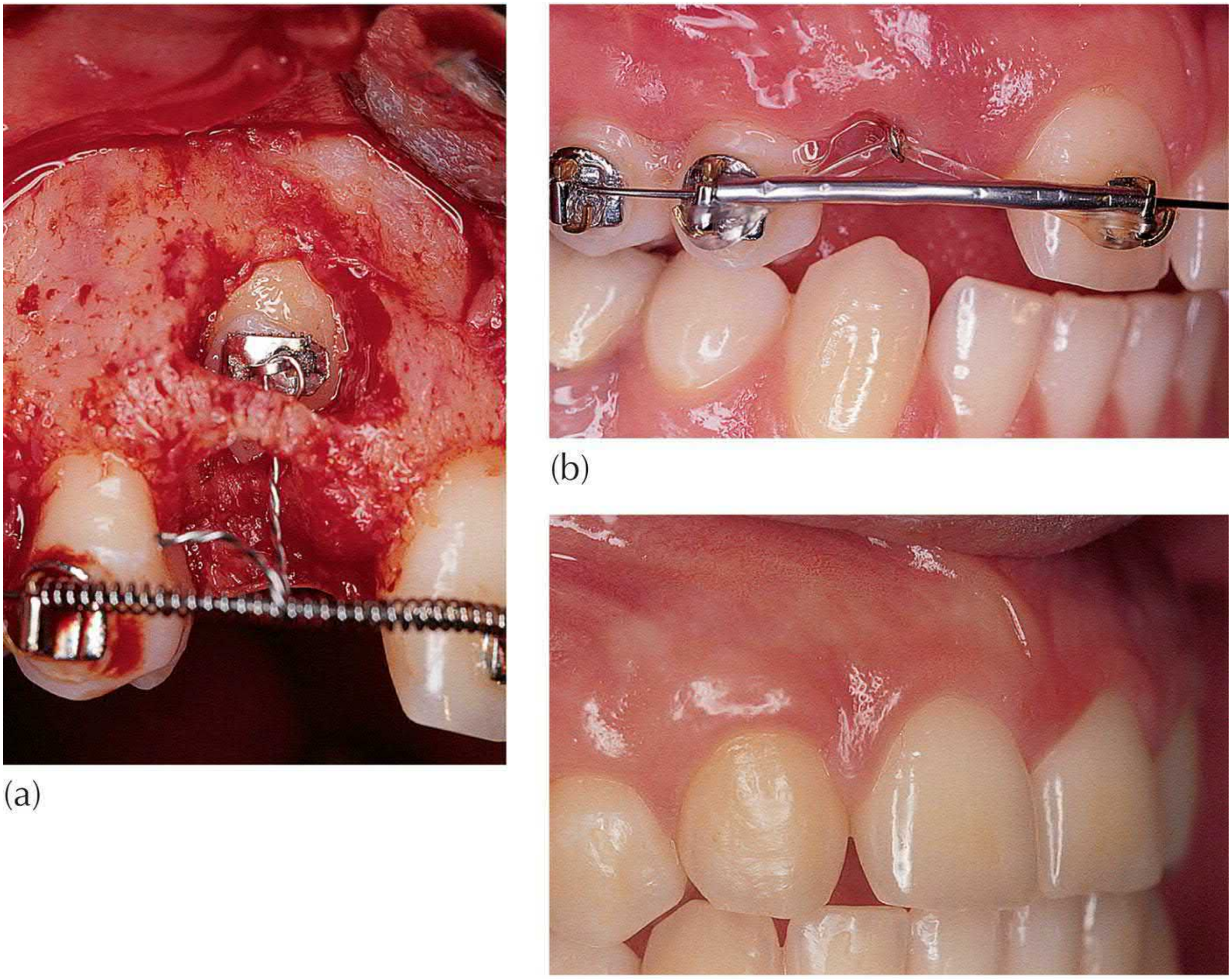


Fig. 7.43 A case treated by the author circa 1972, using an approach recommended at the time. (a, b) The group 3 palatal canine had been exposed from the buccal side and bone channelled to clear

a direct path to the archwire. (c) With the band cemented to the canine, the radical nature of the surgery may be seen. (d) The aligned canine shows a healthy gingival appearance, but a long clinical crown and a lack of normal bony contour, with deficient interdental papillae.

In view of the narrow eruption path planned for this tooth in the present context, it is clear that the only attachment suitable for bonding at the time of exposure is a small eyelet. The eyelet is threaded with 0.012 in. or 0.014 in. soft ligature wire, ready for bonding to the newly exposed impacted canine. Following appropriate acid etching of the enamel surface, the attachment is loaded with the bonding agent and its steel ligature pigtail is lightly curved and threaded into the immediate area of the exposed tooth, continuing into the prepared tunnel until it emerges from the occlusal end of the deciduous canine socket. At this point, the eyelet attachment is pressed firmly into place on the impacted tooth and cured. Feeding a gold chain down the tunnel is impossible, since, unless the chain is led down using a wire ligature threaded through the terminal link as a pathfinder, the individual links will adhere to the bloody walls of the prepared deciduous tooth socket.

The surgical flap is fully sutured to its former place and visual contact with the impacted tooth is then lost. Control of future movement of the canine is exercised through the application of force to the steel pigtail ligature or gold chain, the extremity of which may be seen to extend through the sutured edges of the flap within the deciduous canine socket at the crest of the ridge. Any excess of length of the ligature is cut and the end of the twisted ligature is fashioned into a small hook, to which elastic traction may be applied (Figure 7.44). The surgical method affords good access to the canine and a minor degree of difficulty in threading the ligature through the vacated deciduous canine socket. Orthodontic traction may be efficiently applied and the treatment result shows a good bony profile and an uncompromised periodontal result, similar to that seen on normally erupted teeth [111] (Fig. 7.44c).



(a) (b) (c)

Fig. 7.44 (a) Crescini's 'tunnel' approach. Note the preservation of the buccal plate. The stainless steel pigtail is drawn inferiorly through the vacated socket of the deciduous canine. (b) At 2.5 months post surgery, the 'slingshot' elastic module has brought the canine into a buccally palpable position. (c) One year after completion of treatment. Note the gingival height, wide attached gingival band and good bony contour. The lateral incisor is congenitally missing.

The palatal approach

If the canine is more palatally displaced, surgery approached from the buccal side will be excessively radical, involving the removal of comparatively large quantities of labial bone. In these circumstances, a palatal approach is to be preferred. Following the raising of a full palatal flap, the canine will be revealed high up, palatal to the roots of the adjacent teeth, which occasionally may themselves become denuded in the exposure process. The vertical wall of the alveolar process will be inferior and lateral to the canine. Bonding of the eyelet attachment is performed in the usual manner to the most conveniently accessible site, which will be the palatal side of the tooth, although the buccal surface, close to the tip, is occasionally sufficiently approachable (Figure 7.45). In this situation many surgeons will remove a part of the flap – an open exposure procedure – in order to leave the impacted tooth in visual contact with the exterior and will place a pack to cover the open area.

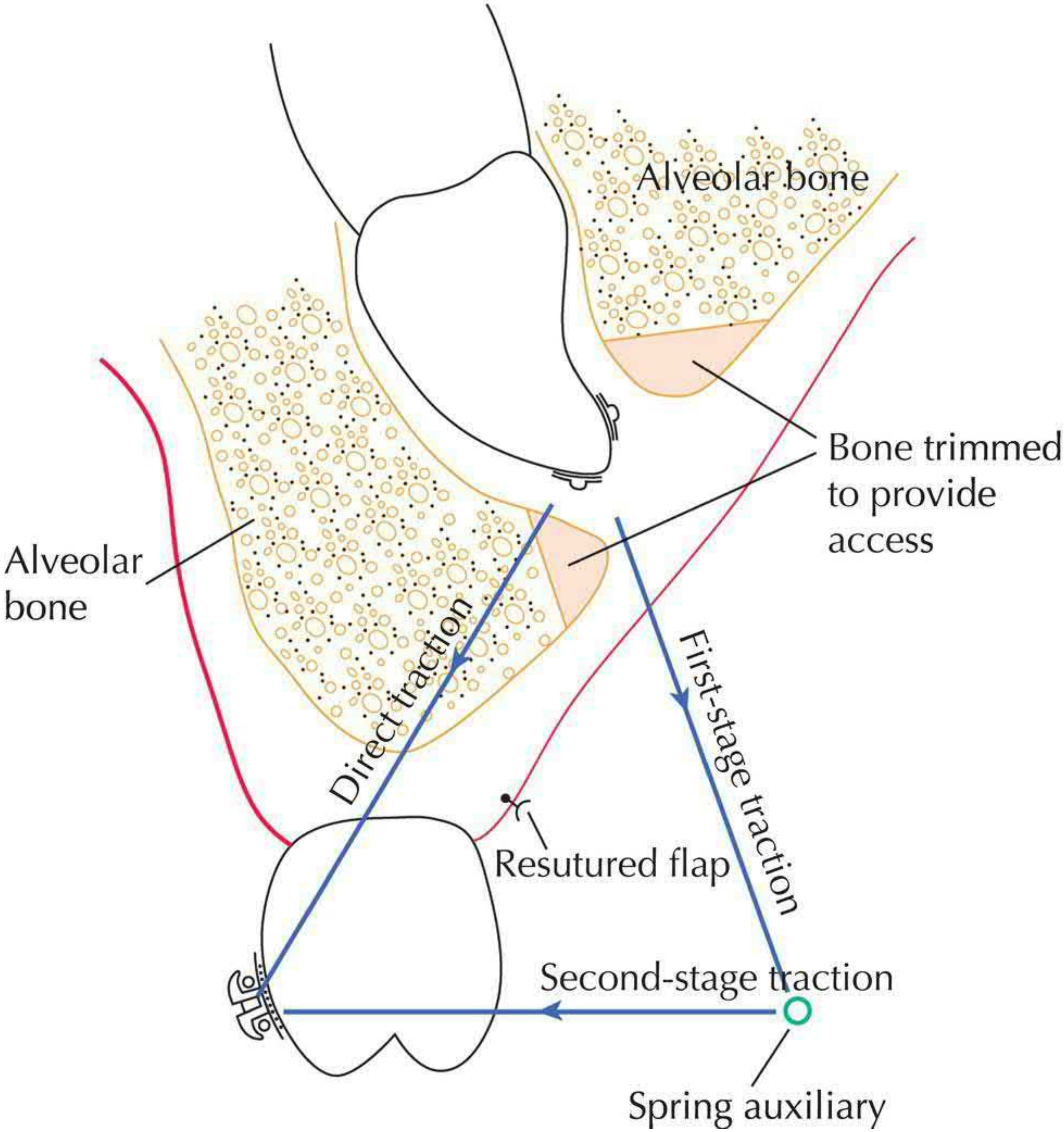


Fig. 7.45 Direct traction vs. two-stage traction in the group 3 canine.

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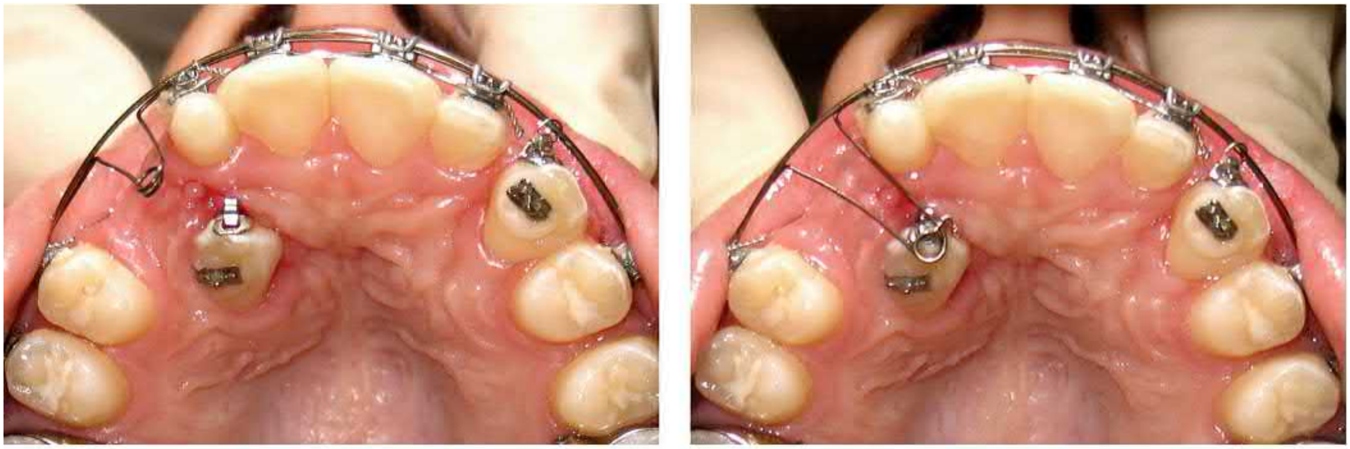


(a) (b)

Fig. 7.46 Acute periodontal pain from prematurely attempted buccal movement in a group 3 canine. (a) The patient had bilaterally impacted palatal canines and these were drawn vertically downwards using an active palatal arch (see Fig. 7.37). The left-side canine erupted ahead of the right and the active palatal arch was discarded. New eyelets were bonded and traction was applied in a buccal direction on each. The left canine moved rapidly into place, but the insufficiently erupted right canine became partially buried in the vertical alveolar process and caused acute inflammation and pain. The swelling and redness can be clearly seen. The remedy is to irrigate the area, prescribe mouthwashes and return to the vertical eruption stage. An auxiliary labial archwire was placed, seen here in its passive mode, unattached to the eyelets. (b) The auxiliary labial archwire in its active mode to elicit further vertical eruption prior to the second attempt at buccal movement.

If the stainless steel pigtail ligature is drawn towards the labial archwire, so that its extremity comes through the deficient part of the flap, the application of orthodontic forces will give rise to significant danger of irritation and infection of the area. This is caused by the tooth being drawn buccally by its ligation to the labial archwire. The resultant direction of this force will cause the impacted canine to be drawn laterally against the alveolus and its healing granulation tissue. The exposed tooth will become reburied in these tissues (Figure 7.46) as it proceeds downwards and buccally, which will lead to inflammation, false pocketing, the likely occurrence of an acute lateral periodontal abscess and acute pain and swelling.

In view of these complications, it is advised that orthodontic strategy for group 3 canines be approached in the same manner as with group 2 canines, i.e. by dividing their resolution into two distinct stages (Figure 7.47). Because of the considerable risk of exposing the root surfaces of the adjacent teeth, a closed eruption surgical procedure is to be preferred. This will require a much more limited entry into the dental follicle and limited exposure of enamel surface – enough only to provide a bonding site for a small attachment under conditions that permit adequate haemostasis. More radical removal of bone around the mesial and distal curvatures of the crown and complete enucleation of the follicle are both unnecessary and harmful to the final periodontal outcome and prognosis of the aligned tooth [112].

Orthodontic traction is first applied in a lingual and vertically downward direction, in order to erupt the tooth into the palate, palatal to the line of the arch, and to bring it down to the occlusal level. As it comes down, over the succeeding weeks and months, it is accompanied by a wide collar of newly formed alveolar bone. As was noted in relation to group 2 canines, in many cases the palatal tissue is very resistant and bulges more and more as the tooth progresses, preventing the tooth from erupting. This will now create a situation that demands the very limited and superficial surgical removal of a small circular section of the thick mucosa immediately over the crown of the tooth – a procedure affectionately known in Israel as a circum-cision!

At this point, an additional eyelet should be placed on the buccal aspect, as appropriate for a group 2 case, and the direction of traction altered to a pure buccal tipping movement to bring it into the arch.

In contrast to the buccal approach described earlier, the vertically extrusive movement precedes the buccally directed movement, which will be a major improvement in terms of conservation of alveolar bone. The immediate area will thus display a normal bony profile, good crestal bone height, normal crown height and gingival architecture.

It is often possible to bond a conventional bracket to complete this second stage if there is enough gingival clearance on the buccal surface of the tooth, although this may not be necessary. Since neither rotation nor ectopic root apex position is common in these cases, the second-stage buccal tipping movement generally brings the canine into its desired position and inclination. The canine that is located in the position that we have described here presents different problems from those of group 2 cases. Direct traction is, under these circumstances, technically possible, though it is periodontally damaging. The most direct surgical remedy (from the buccal side) may be too radical and may, in the final analysis, leave the tooth with reduced bone support, unless the 'tunnel' approach [111] is used. However, for the palatal approach, a careful two-stage orthodontic movement will require minimal surgery and will avoid undesirable periodontal consequences. As pointed out earlier in regard to the use of an auxiliary labial wire or ballista, it is important not to make the active arm too long, since this would draw both crown and root apex of the impacted tooth palatally. In such an event, a tooth that might otherwise have had a normally located root apex will, iatrogenically, require substantial labial root torque in its final alignment.

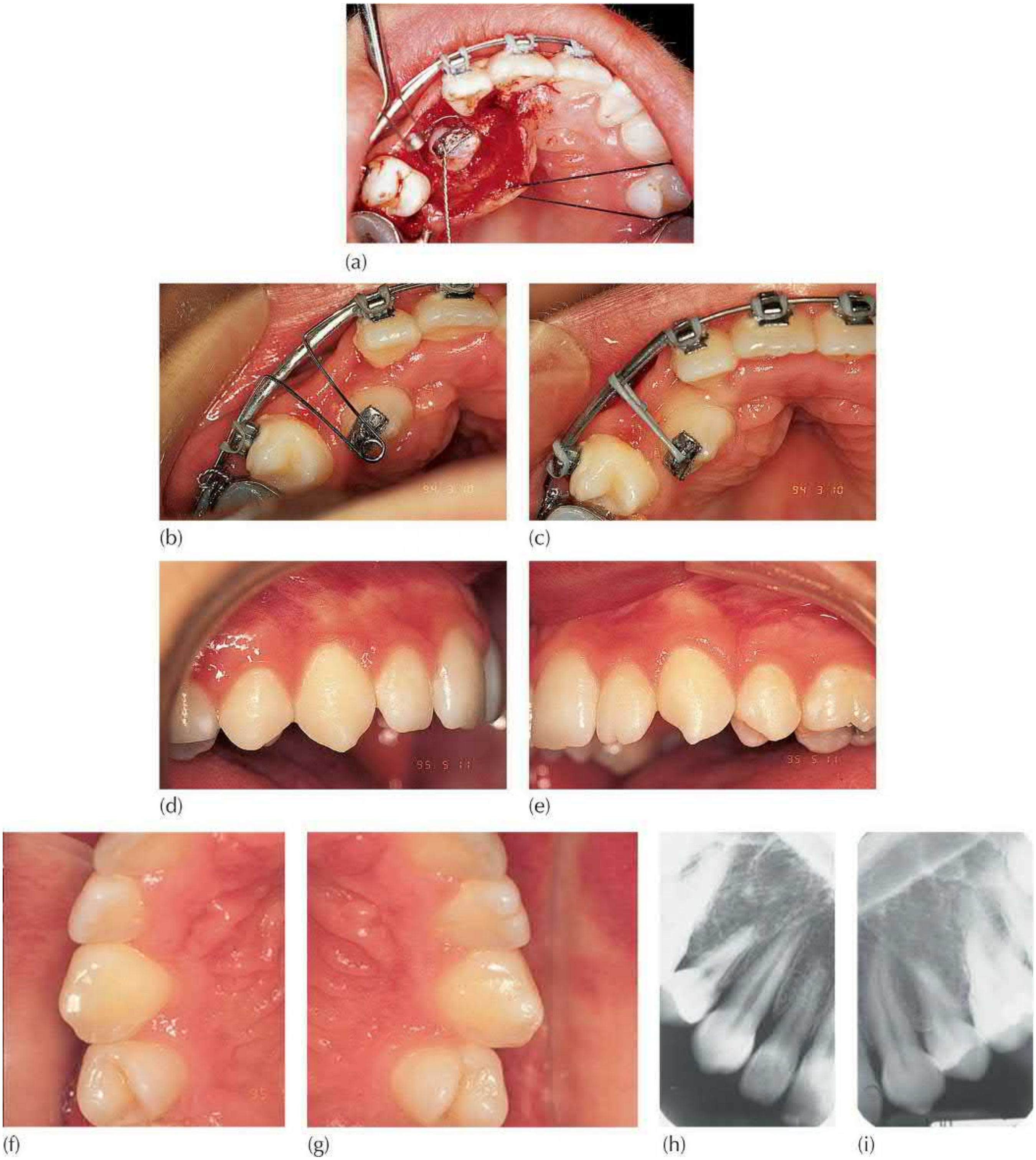


Fig. 7.47 (a) A group 3 canine exposed and viewed from the occlusal aspect to show the attachment bonded near the tip of the buccal side. (b) Six weeks later and without further adjustment, the canine has erupted through the closed flap. (c) Buccal traction to the buccally placed eyelet. (d, e) The post-treatment buccal views of the right (treated) and left (normal) canines. (f, g) The same views of the palatal sides of the two canines. (h, i) Periapical views of the treated (right) and untreated sides, showing comparable bone support levels.

In summary, therefore, the principal feature that distinguishes a group 3 case from a simple and straightforward group 1 case is its relative height in the alveolus. The root apex is usually in the line of the arch and the crown is only minimally displaced palatally, which often means that the tooth cannot be palpated. The group 1 canine requires a minimal degree of vertical development in mechano-therapy and mainly a buccal tipping movement from its more severe palatal position. The group 3 canine, on the other hand, has primarily to be extruded vertically. If only a very minor buccal component is needed, then a buccal approach to surgery, using the 'tunnel' method, may be the best method to adopt with the promise of a superior periodontal outcome.

Group 4

- Proximity to line of arch: distant.
- Position in maxilla: high.

When the crown of the palatally displaced canine is not directly related to the roots of the incisors, it generally points medially and approaches or even crosses the mid-palatal suture (Figure 7.48). It is not usually palpable.

Surgery

These teeth are generally at some distance from the adjacent teeth and little bone removal is needed to expose them, with scant danger of exposing the roots of other teeth. There is usually reasonably good access for the placement of a bonded attachment, although the immediate exposed surface is unlikely to be the buccal aspect of the tooth.

Planning the orthodontic strategy

Since in most of these cases there is normal positioning of the root apex, all that would appear necessary is to draw the tooth directly to the labial archwire. However, if the long axis of the tooth is close to the horizontal plane, it would be inappropriate to do this since the direction of this force would be virtually coincident with the long axis of the canine. This makes the mechanics highly inefficient and little progress will be seen in resolving the impaction. The procedure will become excessively taxing on anchorage and will give rise to a reactive movement of the entire maxillary dentition to the opposite side.

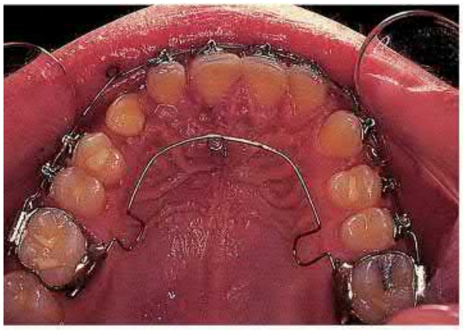
With the tooth close to the horizontal, a more cautious approach should be embarked upon. A wide downward tipping movement, in the arc of a circle with the apex as its centre, will be achieved more efficiently with the use of spring auxiliaries with the same vertical directional approach that has been described for use in group 2 and 3 cases. In their ligated and activated positions, the ballista and the light auxiliary labial arch mechanisms will lie across the palate, parallel to and closely mimicking the orientation of the long axis of the unerupted and horizontal canine itself. As these mechanisms develop their potential, they will move the canine in the same downward and buccally directed arc of circle that is needed for resolution of the impaction. In this situation, the centre of this movement is located on the archwire itself.

If the centre of rotation for this wide tipping movement of the canine would be at the root end of the canine, it would follow that, when the crown finally reaches its destination, the root apex position would be unchanged, vertically oriented and in the line of the arch. However, the centre of rotation of the canine will not be at the root end, but rather some short way along the apical portion of the root. Therefore, during the labially directed alignment of the crown of the tooth, there will be a concomitant, but relatively minor, palatal displacement of the root apex of the canine. This will necessitate some buccal root torque of the group 4 canine. It also follows that, in the unusual situation where there is a palatal displacement of the root apex at the outset, considerable torque will be required. This presents a major clinical problem.

Problems that may be encountered

Technically, torque cannot be efficiently applied until the crown of the tooth has reached its place in the arch and its newly bonded, conventional orthodontic bracket is firmly engaged by the labial archwire. At that juncture, the crown of the canine is at the occlusal level and has a strong buccal tilt. This places the palatally displaced root low in the palate, with its profile clearly outlined under the muco-periosteum. That critical portion of the lingual side of the root closest to the crown of the canine, which has a markedly convex shape, causes a distinct bulging of the mucosa covering it. In the clinical context, some dehiscence of this lingual area of the CEJ is usually present. Additionally, the cingulum area of the palatal aspect of the crown is very prominent and is likely to interfere with the occlusion.

It is important to recognize that in group 4 and many group 2 cases, considerable lateral movement of the canine is required, most of which involves tipping. Moreover, substantial buccal root torque is quite frequently needed and this will take a long period of time to achieve. The forces on the canine are resisted by an equal and opposite reactive force, acting over a long period, on the entire anchor unit (i.e. the remainder of the maxillary dentition as a whole). Loss of anchorage will be noticeable by virtue of the movement of the dental midline to the opposite side and a cross-bite tendency on the affected side. In order to minimize this, a heavy base arch should be used to maintain the alignment. In some cases, the use of intermaxillary S-elastics will be a necessary adjunct, i.e. from the buccal of the lower molar to the lingual of the upper molar on the side where a cross-bite tendency has occurred, and from the lingual of the lower to the buccal of the upper on the contralateral side. In the more critical circumstances, relatively heavy slot-filling rectangular arches will be essential as an anchorage buttress. One should also consider the suitable placement of a TAD for the prevention of these relatively serious side effects. The most modest would be a simple metal screw, placed in the maxilla for direct traction application or in the opposing arch for use with intermaxillary elastics or, preferably, a palatal mid-plant.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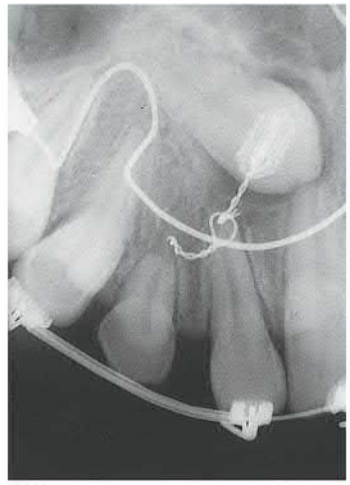
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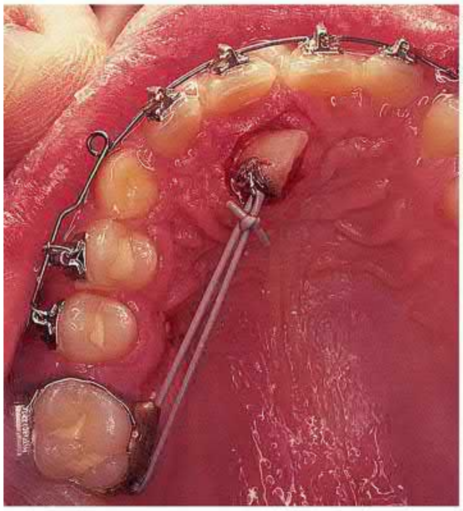

(c)


(d)


(e)


(f)


(g)


(h)

Fig. 7.48 (a) The active palatal arch in place to erupt a group 4 canine that has traversed the midline. (b) Post-surgical periapical radiograph shows space opening and an active palatal arch ligated to the bonded attachment. (c) After three months of traction, minimal re-exposure of the now very superficial and palpable canine was performed. A posterior component was achieved using elastic thread to the lingual tube of the molar of that side. (d) Disto-buccal followed by purely buccal traction was also performed. Distal tipping and buccal root torque were later needed. (e, f) Intra-oral views to compare the buccal gingival health and clinical crown length of the treated (right) and untreated canines. (g, h) The same on the palatal side.

A bilaterally affected case provides the opportunity for neutralizing the loss of anchorage by pitting one side against the other, so that midline and occlusal alterations will not occur.

To summarize the group 4 cases, the clinician must be alert to difficulties in the mechanics that may be inherent in the initial location of the canine and the orientation of its long axis. Care must be taken to preserve orthodontic anchorage by properly planning the mechano-therapeutic strategy of reducing the canine displacement. The practical limitations imposed may lead to adverse effects on the periodontic status of the lingual aspect of the tooth, where occlusal interference may be present in the interim, until the root position is corrected. Finally, following long, meticulous and successful treatment of group 4 canines, there appears to be a strong tendency to relapse that will result in the canine crown dropping back a millimetre or two into an edge-to-edge relationship with the opposing teeth and sometimes into a cross-bite relationship. This seems to occur even after a fairly lengthy period of retention. In such a case, the tooth may require permanent splinting. Sometimes the orthodontist is guilty of underestimating the amount of labial root torque that is needed in these cases, since an under-torqued canine will be prone to such positional relapse.

Group 5

- Canine root apex mesial to that of the lateral incisor or distal to that of the first premolar.

This type of impaction should strictly speaking be within the definition of 'transposed'. To be completely consistent with the definition of transposition, the canine apex should be in the line of the arch in the place of the root apex of the adjacent tooth, independent of mesio-distal or bucco-lingual crown location. Partial transpositions or pseudo-transpositions, on the other hand, are more common, where the apices are displaced to a more limited extent and the order of the crowns of the teeth has reversed.

Canine-first premolar transposition (CPm_1)

The impacted canine that is transposed with the first premolar CPm_1 presents an awkward relationship between these two teeth. In the clinical examination of some patients, the main indication is the distal angulation of the crown of the erupted premolar. The crown appears otherwise normal, but a periapical or panoramic radiograph will show that its apices are displaced mesially and, often, in the direct eruption path of the unerupted canine. In some instances the premolar is vertical but the canine is palpable in the line of the arch and located between the first and second premolars.

Since the canine is high under the oral mucosa, an apically repositioned flap is the most appropriate means by which the tooth will be rendered accessible. A periodontist will probably be the most skilled surgeon to perform this procedure.

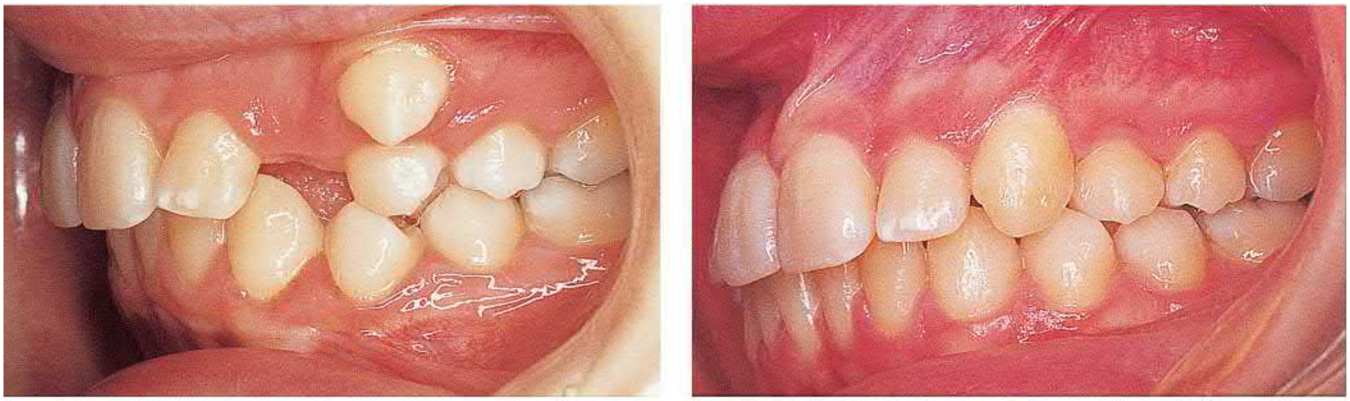
The canine-first premolar (CPm_1) transposition must be considered in a 3D context. Thus, if the premolar crown is in its ideal erupted location, in the arch adjacent to the second premolar, and if there is a strong mesial displacement of its root, it is highly likely that there will be a palatal displacement of its long axis. On the buccal aspect of the ridge above the premolars, there will usually be a bulge, which clearly identifies the position of the unerupted canine. In many cases this tooth will erupt spontaneously, although it will emerge high on the buccal side of the alveolar ridge, above the keratinized gingiva and invested in the loose oral mucosa (Figure 7.49).

Canine–lateral incisor transposition (I_2C)

Similarly, in cases of canine–lateral incisor (I_2C) transposition, a 2D approach would be inappropriate. Such an approach would eliminate the ability to assess the manner of a bucco-lingual displacement from the line of the arch of each of the teeth, notwithstanding the clearly visible reversal of the positions of the crowns and/or roots of the two teeth.

The more troubling and usually surprising presentation of this transposition involves the inter-relationship between the canine on the one hand and each of the incisors on the other. The transposition affects their malalignment in all three dimensions (Figure 7.50) and there will be discrepancies in the mesio-distal, bucco-lingual and height locations of the crowns and roots of the teeth concerned. The root of the lateral incisor is distally and palatally displaced and is often palpable in the anterior palate. The crown of the tooth is strongly tipped mesially and often rotated mesio-labially, overlapping the distal of the central incisor. Instead of being parallel to one another, the roots of the central and lateral incisors diverge in the apical direction, with the central incisor root standing more vertically, while the lateral incisor root is markedly oriented both distally and palatally.

The canine itself is mesially located, mesially tipped and sited superiorly and labially to the lateral incisor apex, although it is not often palpable. This arguably defines the status of the canine as a labial rather than palatal impaction in relation to the lateral incisor.



(a) (b)

Fig. 7.49 (a, b) A maxillary canine/first premolar transposition, treated to reverse the transposition. Note the distal crown angulation of the first premolar in (a), indicating mesial displacement of its roots.

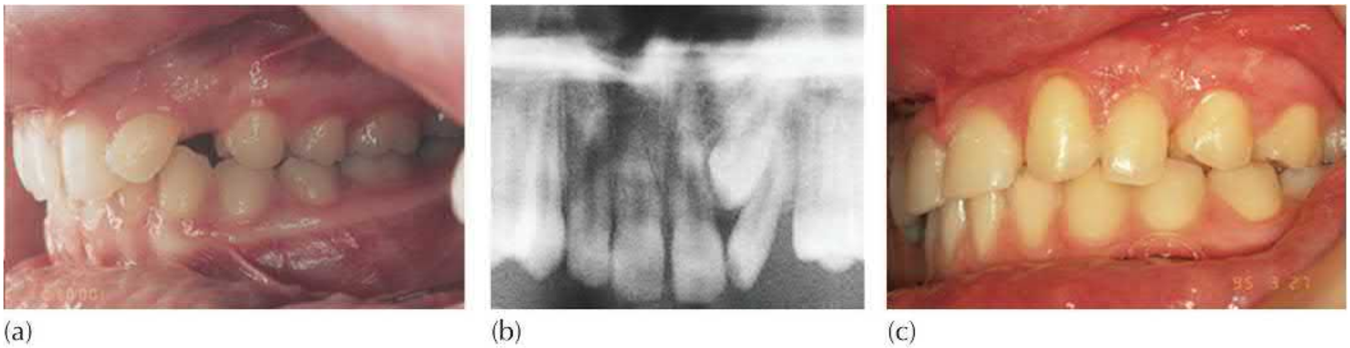


Fig. 7.50 (a, b) Canine/lateral incisor transposition seen intra-orally and on panoramic radiograph. (c) The completed alignment of the teeth in the transposed order. To maintain the reverse order had been a conscious decision. Grinding of the incisor edge of the lateral incisor needs to be performed to avoid occlusal interference and to improve appearance but, had the diagnosis been made with the information available on cone beam computed tomography, the diagnosis and the treatment plan may have been different.

Further eruptive movement of the tooth brings the crown tip further mesially and the tooth finds its way between the bucco-lingually divergent incisor roots on the palatal side of the root of the central incisor. Thus, the canine traverses the alveolar ridge obliquely with its crown on the palatal side of the central incisor, while its root is high up on the labial side of the lateral incisor. The body of the canine root proceeds above and labial to that of the lateral incisor. This is an uncommon configuration, but it is exceptionally difficult to diagnose using only plain film radiography. This may nevertheless be achieved, without the benefit of CBCT imaging, in the following manner:

- Viewed clinically from the front of the patient, the orientation of the long axis of the lateral incisor will usually exhibit a distal displacement of the root in the apical (crown-to-root) direction. The crown of the canine will not be palpable on the labial or palatal sides of the ridge.
- Viewed from the occlusal aspect, with the patient's head tipped back, the long axis of the lateral incisor will be seen as palatally displaced in the apical direction and the outline of the root may often be seen to bulge immediately beneath the palatal mucosa. Its orientation will be out of line of the long axis of the adjacent, more upright central incisor.
- A panoramic view will show the canine 'riding high' over the lateral incisor and partially superimposed on it. The root apex of the canine will be above and in line with, or possibly distal to, that of the lateral incisor, though more superiorly located.
- Two periapical views employing Clark's *lateral* tube-shift method will place the canine crown palatal to the root of the central incisor on which it is superimposed.
- The periapical views taken with the *vertical* tube shift are more useful in the present context. From this more vertical angle, the image of the canine will alter its superimposition on the two incisors, in the opposite 'up-and-down' direction. By comparison with the first periapical view, the view from the more vertically shifted second image shows that the canine overlaps a more apical area of the central incisor root, but a more coronal part of the root of the lateral incisor.

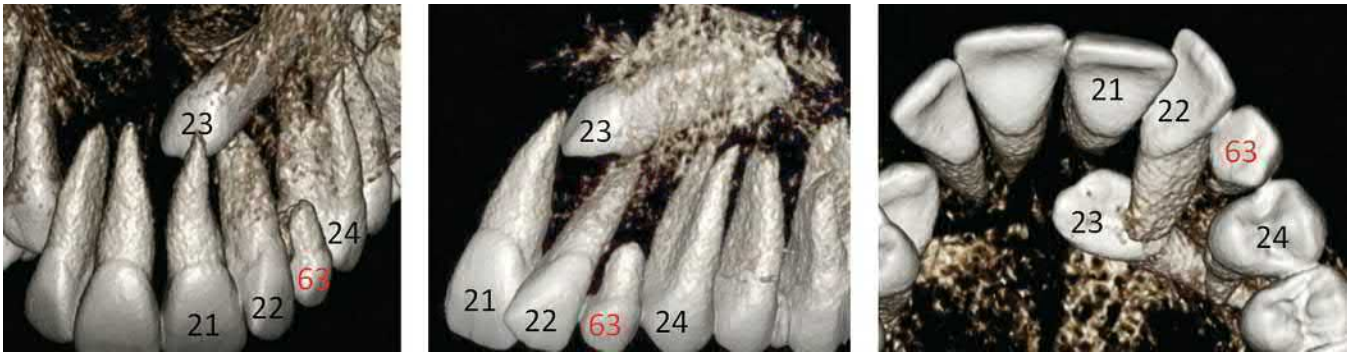


Fig. 7.51 Anterior, left side and occlusal screenshots from the video clip of cone beam computed tomography to illustrate the 'labio-lingual' canine (#23) and how it inserts itself between the divergent long axes of the roots of the central (#21) and lateral (#22) incisors – or is the canine the cause of the incisor root divergence? See Video XX on this book's website.

The picture of the arrangement of the maxillary incisors, classically seen in a class II division 2 malocclusion, is presented by central incisors tipped lingually and lateral incisors tipped labially. This arrangement appears to be associated with this particular version of the group 5 canine, presumably due to the wide divergence of the central and lateral incisor roots in the bucco-lingual plane (Figure 7.51). In view of the very different eruption times of the incisors and canines, it would seem that the complexity of this impaction is the result of the incisor presentation and not its cause. Given the passage of time, however, the canine will continue to express its persistent but futile eruptive potential and likely wedge itself further between the roots of the two incisors. This must be considered a contributory cause for a worsening of the divergence of the axial orientations of the two incisors. The distance between their root apices grows, as illustrated by the central incisor becoming more retroclined and the lateral incisor more horizontal.

The 2D approach to planning treatment in these cases rests on the presentation of these teeth on the 2D panoramic view. The lingual orientation of the central incisor crown and the labial orientation of the lateral incisor crown are completely lost on this film, as is expected from any 2D film. But here, with the exaggerated displacement of their apices in the opposite directions, an essential piece of geographical information is missing, which is crucial for diagnosis and treatment planning. It is likely that it was on this incomplete information that the management of the case illustrated in Figure 7.50 was planned and executed.

Misplaced 'machoism' and a sense of challenge may be the driving force behind the decision to position the teeth in their correct order. After all, we are orthodontists and this is the sort of challenge for which we have been trained. It is difficult to pass over an opportunity to display our initiative, dexterity and clinical excellence. Sometimes this is justified – but by no means all the time.

It should always be remembered that the reversal of a transposition of necessity dictates that the two teeth have to pass by one another in an alveolar process where the bucco-lingual width is suitable for just one of them. True, when teeth are moved buccally or lingually on the ridge, there is a concomitant bucco-lingual expansion of the alveolar process. Clinically, however, there will be loss in bone height and a dehiscence may occur, particularly if oral hygiene is inadequate or, paradoxically, when tooth brushing is compulsively aggressive (as seen in some individuals). Furthermore, the biomechanics are difficult to perform with adequate root control and root proximity may develop during the exercise. This latter could seriously compromise bone support on that surface of the two roots and some loss of attachment or root resorption is inevitable.

The different views provided by the CBCT show the inter-relation between the teeth very clearly and this should assist the orthodontist in devising a method to resolve this very awkward entanglement. It should be clear that the canine is locked in between the roots of the incisors and that traction direct to the labial archwire, which is labial and inferior to the tooth, will jam its crown between the crowns of the incisors, obstructing its movement. The only place where the tooth may be directed labially is high up between the widely distanced apical areas of the incisor roots. This is the only 'window of opportunity' for salvation in these cases. It should be apparent that surgical exposure and traction will need to be approached from the labial aspect.

Based solely on the information provided by the lateral tube-shift method of the canine-to-central incisor, the orthodontist is likely to run into trouble for contending that a palatal approach is the only way to provide surgical access to this I_2C transposed canine. After all, we have seen that for any other palatally impacted canine, the exposure must be performed on the palatal side of the ridge and the tooth drawn palatally away from the incisor roots, towards its place in the arch (I_2C). The approach to the canine from the labial in this I_2C transposition is impeded by its being partially hidden on its labial side by the presence of the central incisor root. Additionally, the orientation of the long axis of the canine goes way up above the root apex of the distally and lingually displaced lateral incisor. All the above are likely to indicate to the unsuspecting orthodontist that, for both surgical access and orthodontic traction, the way to go is from the palatal side.

However, this is not so. A CBCT for cases of this kind is essential and it will show that palatal access for surgical exposure of the crown of the canine is problematic. The tooth is high up on the palatal side of the root of the central incisor, much bone will need to be removed to reach it and attachment bonding will be fraught with difficulty. Over and above this, however, a palatal approach would be disastrous to the outcome of the case and lead to failure. It should be understood that traction applied to the canine from a palatal auxiliary will draw the root of the canine against the labial side of the lateral incisor root and displace its apex palatally while, at the same time, the lateral incisor root would obstruct the progress of the canine. Attempting to extrude the canine medially, towards the midline and on to the contralateral half of the palatal area, might provide the opportunity to direct it around the lateral incisor root, but it would displace the tooth well beyond the range of orthodontic endeavour. Accordingly, regardless of which palatal approach is adopted, the outcome of such a manoeuvre would likely be the loss of both these entangled teeth.

Orthodontic/surgery strategy

We may then ask what the ideal approach to this situation is. As with any other case, orthodontic alignment and levelling need to be performed, followed by space opening for the impacted tooth. Ligating an archwire into a correctly placed lateral incisor bracket will tend to upright this tooth and, if that archwire is rectangular in cross-section, will also apply labial root torque to it. Both these acclaimed 'straight wire' attributes are strongly contraindicated in this specific scenario and will cause the plan to backfire. This is because they will rapidly close the mesio-distal and labio-lingual divergent orientation between the roots of the two adjacent incisors and, with it, the escape route of the canine. Accordingly, it is preferable to leave the lateral incisor without a bracket at this stage. Alternatively, the wire may initially be loosely tied to the archwire, outside of its slot, although this cannot be done with a self-locking bracket. A third alternative is to temporarily bond the lateral incisor bracket with its slot parallel to the occlusal plane, rather than in its usual location perpendicular to the long axis of the tooth. In each of these options, there will be no uprighting force on the tooth and the 'window of opportunity' for the canine will be preserved. The window of opportunity is discussed and illustrated in greater detail in Chapter 8.

From the surgical point of view, the tooth must be exposed on the labial side, using a wide flap raised from the area of attached gingiva. Because of the location of the canine and its proximity to the root apex of the central incisor, only a small portion of the more distally presenting surface of the canine should be exposed. This surface is readily accessible with relatively little bone removal. The follicle is conservatively opened, wide enough for the bonding of a small attachment at that site. The tooth cannot be drawn directly down to the main archwire, because of the presence of the incisors below. Instead, the canine must be directed disto-labially in a horizontal direction, for it to have a clear path of exit from the palatal to the labial side of the ridge between the widely divergent roots of the central and lateral incisors. To achieve this, the stainless steel pigtail or gold chain connector will need to be drawn labially outwards and distally through a small puncture in the oral mucosa portion of the fully replaced surgical flap. It cannot be drawn through attached gingiva in the first instance.

An auxiliary archwire of 0.016 in. (0.4 mm) stainless steel is prepared with a horizontal loop fashioned in the target area of the canine, as seen earlier in this chapter, but it must point out of the semi-circular archform. The loop should be slightly shorter than the measured distance between the height of the tooth from the main archwire. The auxiliary archwire is best ligated into its place before the surgical exposure begins. It does not interfere with the surgeon's field of activity. When the surgical flap has been replaced and sutured, the loop may be raised upwards and, under light finger pressure, engaged by the twisted ligature pigtail.

The patient leaves the operatory with active labially and distally directed extrusive force being applied to the canine, and instructions to see the orthodontist about two weeks later to check that all is well, although it is unusual to see much change at this point. Four to six weeks later, however, the patient may well be complaining of soreness of the inner surface of the lip, because the loop will be protruding away from the alveolar ridge, signifying movement of the tooth. The loop should then be pressed firmly back to the ridge under finger pressure and the steel ligature rolled up to hold it in its re-activated place.

After a relatively short period of time, often within a month or so, the canine bulges the labial tissue as the tooth is drawn labially, indicating that it has moved clear of any contact with the incisors. Once the canine has moved labially and is palpable on the labial side of the ridge, a bracket may be safely placed on the lateral incisor. Care should be exercised not to draw the canine too far labially, since this is likely to cause it to erupt through the mobile oral mucosa above the attached gingiva. At this point, therefore, mesial root uprighting of the lateral incisor should be undertaken in order to permit distal and palatal movement of the canine into its designated location. The final alignment manoeuvres that will then be needed include uprighting of the canine, with considerable labial root torque of the lateral incisor and simultaneous lingual root torque to the canine. This can usually be performed using a simple reciprocal torqueing auxiliary. The degree of labial root torque required for the lateral incisor is quite considerable, but should not be attempted until the canine has reached its place in the arch.

The intra-oral clinical views of the dentition of a 12-year-old male (Figure 7.52a) describe a class I malocclusion with mild generalized crowding in both jaws. The lateral incisors were small and the deciduous left maxillary canine was over-retained.

The panoramic view of the teeth (Figure 7.52b) shows two over-retained second deciduous molars and a left maxillary deciduous canine. The maxillary left permanent canine has migrated mesially between the roots of the central and lateral incisors, but there is no information on this 2D film to tell us whether the canine was buccally or palatally displaced vis-à-vis the incisor roots.

The CBCT axial slice, which is parallel to the occlusal plane, had been cut across the roots of all the maxillary teeth, sufficiently high to include the crown of the impacted canine (Figure 7.52b). There is an obvious enlargement of the follicular sac surrounding the crown of the canine, but it may be clearly seen that the mesial aspect of the canine overlaps the central incisor on its palatal side. The lateral incisor root is markedly displaced towards the palatal periosteum, suggesting that it has been influenced by the presence of the canine crown, which is labial to it. On the cross-sectional slices, the canine may be seen labial to the roots of the palatally tipped lateral incisor and lingual to the central incisor.

Orthodontic treatment was initiated to align the maxillary dentition and to make space for the canine. The lateral incisor bracket was deliberately placed with its slot parallel to the occlusal plane, in order to eliminate the possibility of premature root uprighting, before the canine could be palpated on the labial side of the ridge. The auxiliary 0.016 in. steel archwire was ligated into place immediately prior to the exposure procedure.

Surgery was approached from the labial side, care being taken not to proceed too far towards the crown tip of the canine in order not to damage the central incisor root. The attachment was placed distal of the centre of the labial aspect of the canine, with the twisted steel ligature protruding through the middle of the raised flap, which was then sutured back into place.

Using light finger pressure, the loop of the auxiliary arch was raised and engaged in the twisted steel ligature, as close as possible to the flap mucosa, to apply labial force on the impacted canine. Due to missed appointments, the patient was next seen six weeks post surgery, with the canine having erupted through the oral mucosa, above the lateral incisor (Figure 7.52d). The mandibular appliance was only placed during the finishing stages of treatment in the maxilla and the overall treatment (Figure 7.52e), and appliances were subsequently removed after 18 months of treatment.

Gold chain or twisted steel ligature?

In I_2C cases, care should be taken not to make the loop of the auxiliary labial arch too long. After flap replacement and suturing, the auxiliary archwire is ligated into the brackets and its loop is raised from its horizontal passive position and ensnared into the twisted steel ligature, in order to apply the required labially directed traction. Ideally, its length should be a couple of millimetres short of the height of the vestibulum at that site, otherwise the patient will suffer unnecessary after-pain and swelling caused by the over-extended loop, which will lead to ulceration of the very mobile and delicate oral mucosal tissue of the lip and cheek.

Use of gold chain in the attachment is more limiting than the twisted steel ligature. This is because the gold chain requires an additional steel ligature to tie it to the loop of the auxiliary archwire. Therefore, the loop cannot be brought into light contact with the oral mucosa and will stand a couple of millimetres away, increasing the likelihood of ulceration of the inner surface of the lip/cheek. This will occur significantly later with the twisted ligature, which grasps the loop directly it exits from the mucosa.

Group 6

- Erupting in the line of the arch, in place of the incisors, and resorbing their roots.

The teeth that fall into this last category of impacted canines are only marginally displaced buccally or palatally, since most of them do not merely generate resorption, they actually move into the crater area where resorption of the incisor root has occurred. This causes further resorption, permitting the canine to advance in line within the bounds of its innate eruption potential. In other words, the resorption process is powered by an entirely asymptomatic, ongoing, dynamic, destructive lesion that may advance at some speed. The impacted canine tooth, which is associated with the resorptive lesion, is not usually palpable in the clinical examination, neither on the labial nor on the lingual side.

In addition, because of the minimal labio-lingual distance discrepancy between the resorbing and the resorbed teeth, there will be difficulty in the interpretation of the plane film radiographic methods used in determination of the exact 3D location of the tooth. This difficulty in diagnosis is markedly increased if there is little or no radiographic superimposition of the image of the crown of the impacted tooth onto the remainder of the resorbed incisor root. This will occur due to a superiorly placed canine that is more or less in the direct line of the long axis of the resorbing tooth, where the resorption begins at the root end and progresses along this general line of advance.

It is unclear why resorption of the roots is caused by unerupted permanent teeth, in particular the maxillary canine, which are in close proximity to the roots of their neighbours. Nevertheless, a cause-and-effect relationship is present and it has been conclusively demonstrated that even the most advanced resorption process largely ceases when the impacted tooth is removed from the area of the affected roots [13], whether this be by extraction or by orthodontic movement.

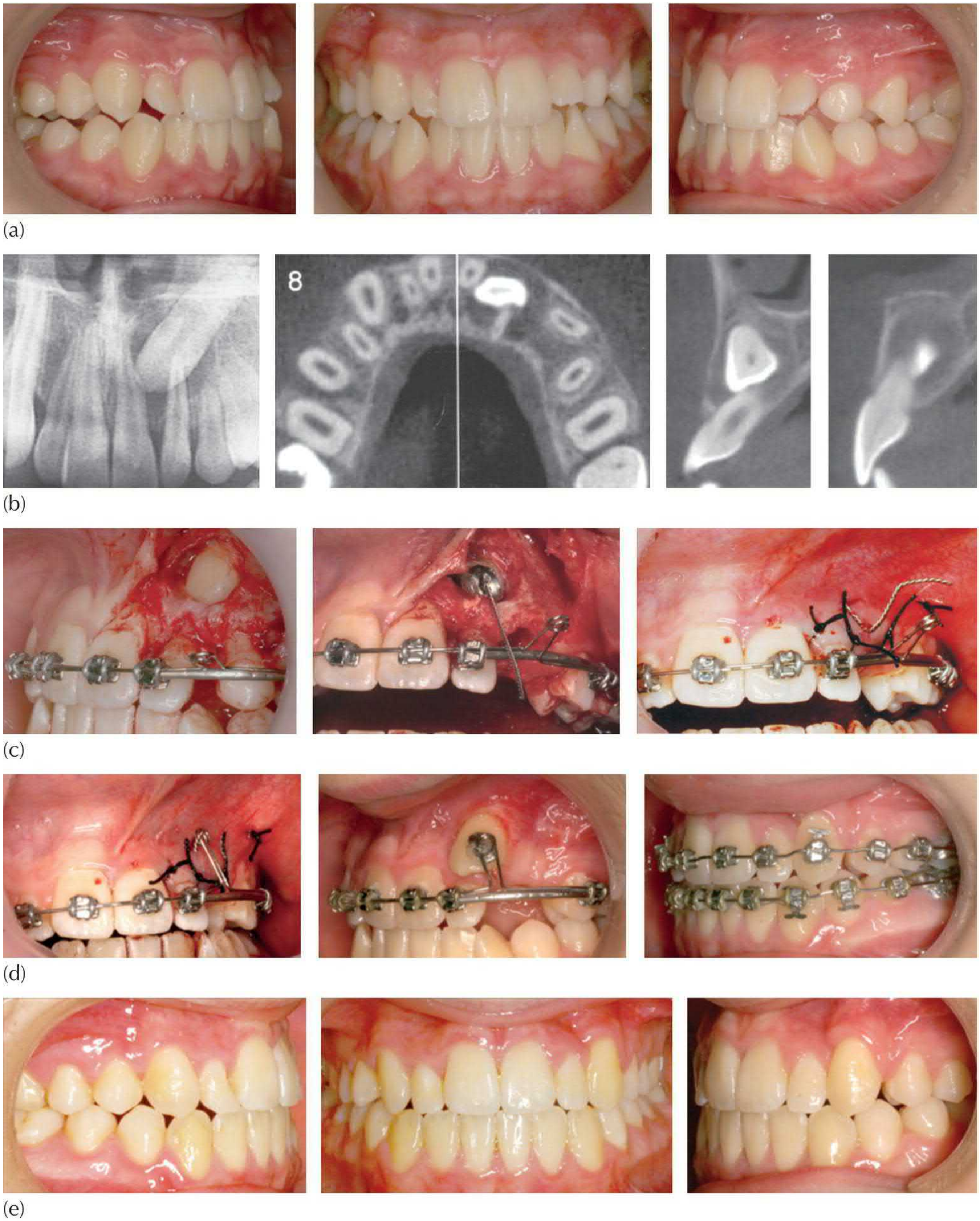


Fig. 7.52 (a) Intra-oral views of a 12-year-old male with a left maxillary impacted canine. (b) The anterior portion of the panoramic view shows a 2D view of the superimposed canine crown on the incisor roots. Both the axial and the cross-sectional cuts shows the canine located labially to the lateral incisor root and lingual to the central incisor root. (c) The canine is exposed on the labial

side of the lateral incisor, but caught behind the central incisor root, with bonded attachment in place. The twisted steel ligature protrudes through the re-sutured flap. (d) Traction applied from the horizontal loop of the auxiliary labial arch. Due to missed appointments, the tooth erupted through the inferior part of the oral mucosa. The left side is in the closing stages of treatment. (e) At one year post treatment, the gingival area around the previously impacted tooth that had exited through the oral mucosa remains mildly inflamed.

The type of root resorption that is seen frequently in the routine orthodontic treatment of patients without impacted teeth, although disquieting, is fairly innocuous in nature. While it is a cause for wariness and caution in advising treatment, and for careful monitoring during treatment, it is not usually more than a marginal phenomenon, which stops when active tooth movement stops. The detection of this common type of root resorption occurring during treatment may make the case for shortening the duration of appliance therapy and limiting its goals to the essentials only. However, when the cause of the resorption is very specifically related to the proximity of an impacted tooth, the character or type of resorption appears to be quite different, insofar as its behaviour is more aggressive [13, 113]. It follows that, with the very survival of one or more teeth at stake, early diagnosis is crucial in order to initiate appropriate treatment. This condition constitutes one of the very few situations in which orthodontic treatment may be considered a quasi-emergency.

In view of the very special nature of this type of canine impaction and the difficulty in gaining an accurate picture of its extent, its rate of progress and the consequential implications for its treatment, the next chapter is devoted to a comprehensive discussion of this important topic, which haunts even the most experienced and proficient orthodontic practitioner.

Treatment duration

It is probably stating the obvious that orthodontic treatment of a malocclusion involving an impacted canine will take longer than the treatment of a similar malocclusion involving a fully erupted dentition. Indeed, the presence of an impacted canine will clearly introduce an extra dimension into the treatment, which cannot usually be addressed at the same time as other necessary orthodontic movements.

As we have already seen in this chapter, the initial part of treatment of these cases is the same as with any other case. Alignment and levelling need to be achieved, requiring the use of one of the modern, sophisticated, fixed orthodontic appliance systems. At the appropriate stage in the treatment, passive and heavy archwires are inserted to fill the bracket slots, thus converting the whole appliance into a multiple-anchor unit, incorporating all the teeth in one or both jaws. Further progress in the treatment of the overall malocclusion is placed on hold while purpose-designed auxiliaries are introduced into the system, designed solely to reduce the impaction of the ectopic tooth/teeth. Thus, therapeutic attention is diverted away from the overall malocclusion and becomes focused solely on the impacted tooth and its resolution, until it is brought into alignment with the other teeth. Once the canine becomes an integral part of the alignment scheme, renewed attention is directed to bringing the overall malocclusion to its desired outcome.

Treatment duration is influenced both by objective factors (i.e. factors related to the 3D geometry of the canine ectopy) and subjective factors (i.e. factors inherent in the treatment provider).

Objectively, there are factors that require extended treatment times. These include the height of the impaction [114–116], the horizontal position of the crown of the canine in relation to the adjacent teeth and the maxillary dental midline [115, 118], the sector of overlap of the incisors (as seen on a panoramic radiograph) [115, 118] and the orientation of the tooth [114, 115].

Subjectively, a more imaginative orthodontist with a penchant for original design, based on sound mechanical principles, will usually be able to fabricate a device that is particularly suited to a given situation. Others may rely on standard 'cookbook' solutions that require more frequent and more numerous adjustments. The more efficient the auxiliary, in terms of its traction force level and range of action, the fewer will be the visits for adjustment and the shorter the treatment duration.

Studies described in the literature have shown that the average duration of treatment of orthodontic cases for unilateral cases that exhibit impacted canines has been variously reported as 26.3 months [117], 19.7 months [58], 22 months [119] and 25.8 months, and for bilateral cases 32.4 months [114]. While these treatment periods do not seem unduly long compared with many routine malocclusion cases, it will have been noted that many impacted canine cases have normal alignment and jaw relations, with adequate space within the dental arches and, apart from the aberrant canine, little in the way of malocclusion. Accordingly, most of the treatment period will be concentrated on canine resolution, while the biomechanics needed for the remainder of the treatment will be minimal, straightforward and of short duration.

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8
Buccally Impacted Maxillary Canines

Adrian Becker

Canines impacted in the line of the arch

Buccally displaced maxillary canines

Palatally impacted labial canines

The 'window of opportunity'

Buccally impacted canines with distal displacement

Canines impacted in the line of the arch

Before our discussion on buccally displaced canines (BDCs), we must briefly refer to the subject of a medium-sized group of maxillary canines that are neither buccally nor palatally displaced, but are within the line of the arch. These impacted teeth are often palpable from the buccal side by the significant bulge in the profile of the alveolar ridge. This may initially be misinterpreted as being buccal displacement of the tooth itself. However, it should be remembered that it is not the tooth that is palpable, but rather the labial gingiva/oral mucosa covering a thin shell of alveolar bone that, in turn, overlies the dental follicle. The follicle itself may often be enlarged, a feature frequently diagnosable on the panoramic or periapical view. This combination of factors is what has caused the enlargement, while the tooth itself commonly lies deep within that labial bulge (Figure 8.1a–c).

It will certainly be necessary to create space for an impacted canine of this type, but that space will need to be larger than for most other canines, because, as a panoramic or periapical view will show, the orientation of its long axis will be mesially inclined. It is this mesial inclination that leads to a mesial displacement of the root of the lateral incisor and a distal tip of the incisor crown. Furthermore, the distal surface of the root of the canine may well be seen on the radiograph to be in direct contact with the apex of the palatal root of an adjacent and rotated first premolar. The canine appears to be unable to free itself to erupt, unless the incisor itself is made to tip its crown mesially during the initial space-opening procedure.

This standard orthodontic preparatory alignment and levelling movement substantially reduces the angulation between the long axes of canine and incisor. It will also move the apex of the lateral incisor distally, thereby initiating a tip of the crown of the canine distally and inferiorly, and the consequent reducing of the angulation still further. The initial levelling and alignment procedure generally occurs very quickly, within three to four months, and will often be sufficient to elicit autonomous resolution of the impaction and spontaneous eruption of the tooth into its normal place in the arch. Despite this encouraging indication, the canine may still take a year or more before erupting fully into the arch.

The reason that we have initially referred to this group of non-buccally impacted maxillary canines in this chapter on buccally impacted canines will now be clear. In the event that progress in eruption is not achieved within a few months after standard levelling, aligning and space opening, then minimal surgery will be appropriate in order to enable both the surgical and the orthodontic approach to the treatment of these canines from the buccal side – just as one would be required to do with buccally impacted canines.

Attachment bonding and labial traction from an auxiliary nickel–titanium (NiTi) wire or elastic ligature will be sufficient to resolve the problem. The type of surgery advised will depend on the height of the impacted tooth in relation to the gingival tissue. If there is a thick band of attached gingiva above the height of the unerupted tooth, then a simple window exposure will be ideal. Such a procedure will bring about the eruption of the tooth through this band while, in the long term, a width of attached gingiva will remain on the labial side of the tooth. Should this not occur, then an apically repositioned flap will ensure that the tooth will have a normal gingival attachment [1].

The case shown in Figure 8.1 illustrates these points well. As may often be seen in these cases, the patient depicted in this photograph exhibits a strong mesial inclination of the long axis of the canine (yellow dotted line), which is tipped slightly lingually, causing considerable mesial and lingual root movement of the lateral incisor (blue dotted line). The first premolar is rotated mesio-buccally, which has displaced its palatal root mesially, bringing the apex into close proximity with the cemento-enamel junction area of the canine (pink arrow). The canine is therefore blocked in its intended downward path by the two adjacent teeth.

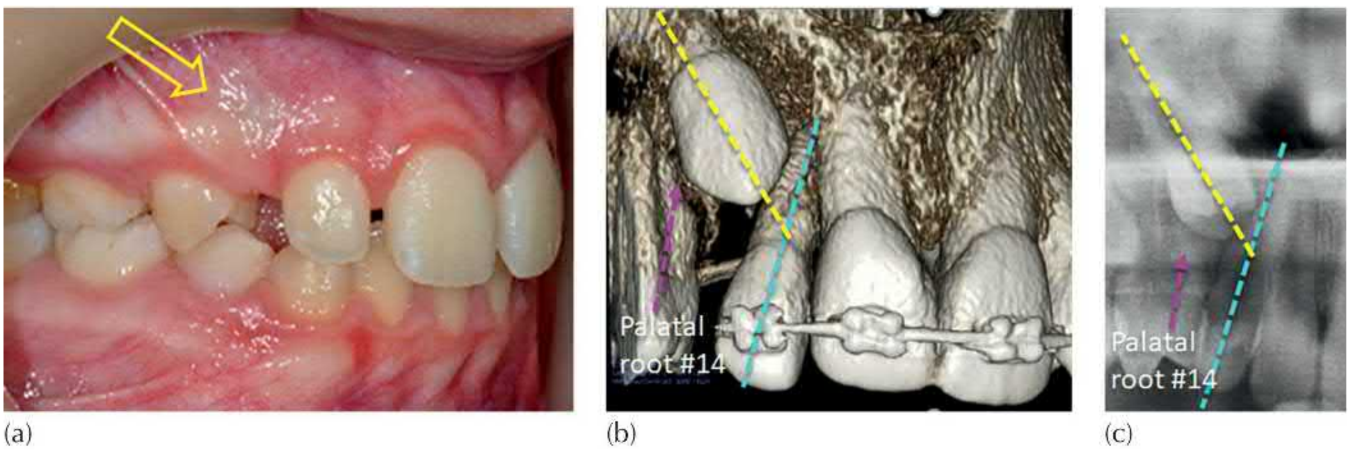
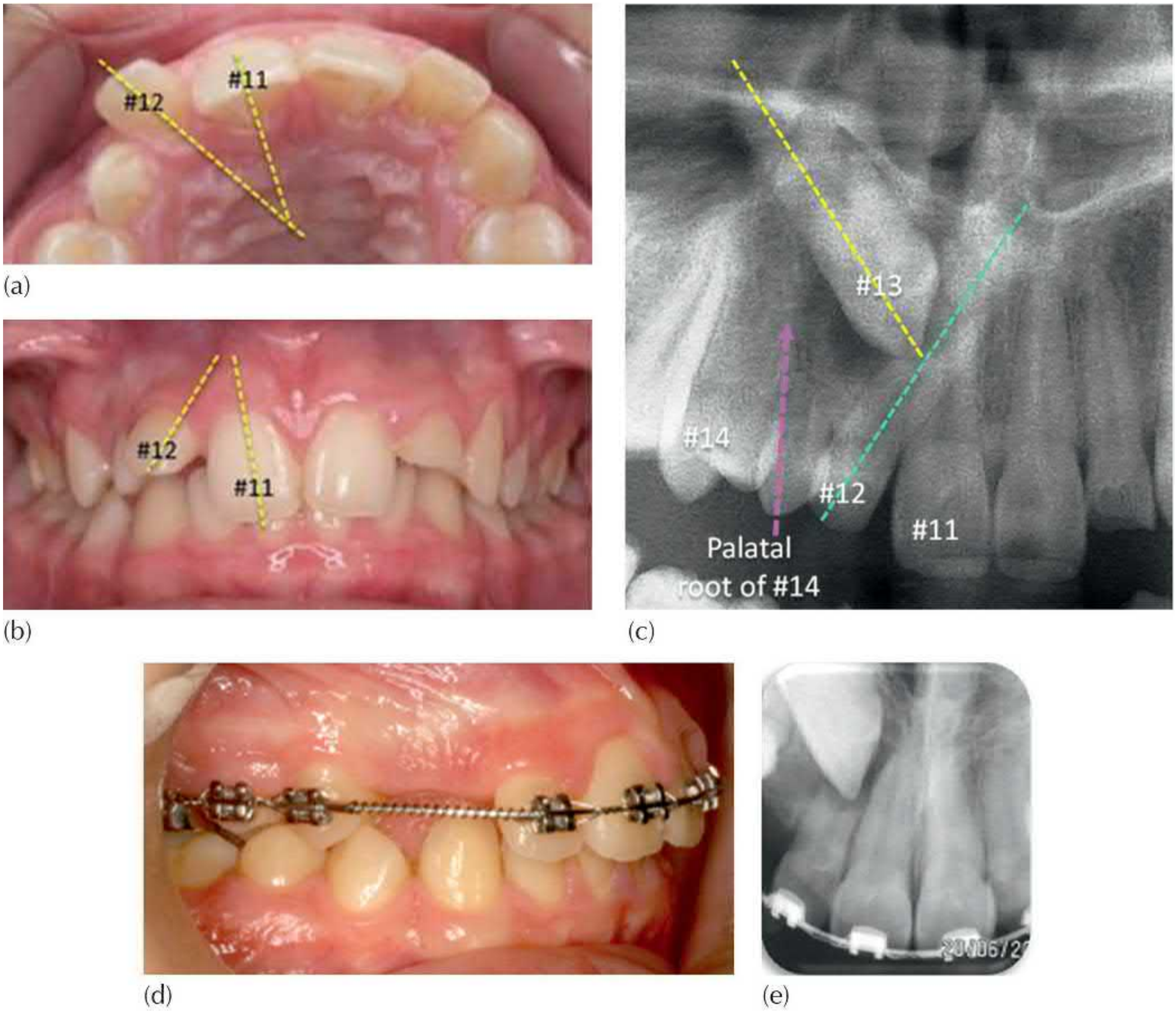


Fig. 8.1 The canine in the line of the arch. (a) The palpable bulge in the surface anatomy of the ridge to show where the tooth is located (yellow arrow). (b) A 3D view from the cone beam computed tomography to show the relationship between canine, lateral incisor and the first premolar. (c) From the panoramic view. The dotted lines represent the long axes of the canine (blue arrow), the lateral incisor (yellow arrow) and the palatal root of the premolar (pink arrow).

When the angle between the mesially oriented canine and the distally tipped lateral incisor crown is more severe (approaching a 90° angle between the long axes of the two), orthodontic alignment and levelling mechanics will be needed to bring the tip of the canine crown into contact with the lateral incisor root, in a more desirable (acute) angle of approach to its long axis. Two-dimensional (i.e. mesio-distal) biomechanics will not be sufficient to bring about the uprighting of the lateral incisor and the canine. This 'log jam' is highly likely to lead to resorption of the incisor root. Therefore, when faced with difficulty of this nature, the orthodontist should immediately suspect that the angle between the perpendicular orientation of the canine and the lateral incisor has not altered and that the only way that it will change is when there has been resorption of the incisor root, as seen in Figure 8.2. This suspicion should always be aroused if the usually fast and efficient mechanical system shows little progress in a short period of treatment.



(a) (b) (c) (d) (e)

Fig. 8.2 (a–c) Extreme mesial inclination of a line-of-the-arch impacted canine (#13), causing pressure on the distal of the root that causes flaring of the crown of the lateral incisor (#12). (d) The apparent completion of the space-opening stage, with lateral incisor alignment. (e) A periapical view of the canine/lateral incisor relationship with the unfortunate results of orthodontic space opening. Half the incisor root has resorbed.

The answer to the problem is the *3D approach* and there are just three ways to do this:

- The impacted canine must be moved to the buccal or lingual side of the ridge in order for it to be free of the mesial and distal restrictions.
- Distance the root apices of the lateral incisor and the first premolar as part of the space-opening procedure – movements that may be described as 'moving the goalposts'!
- Avoid placing an orthodontic bracket on the lateral incisor in the first stages. In a significant proportion of impaction cases, the adjacent premolar and lateral incisor teeth are also displaced. At the outset of treatment, it would be a serious mistake to attempt to bring these teeth to the line of the arch by ligating an archwire into their horizontal bracket slots. This would automatically generate highly efficient but inappropriate 3D mechanics of their roots into their ideal locations and angulations, but, in so doing, the roots of these teeth will be

moved into the intended eruption path of the impacted canine and will be held there subsequently by the archwire. The roots of the incisor and the premolar will then tenaciously stand in the way of correction of the canine. Accordingly, until the canine is safely in its place, it is best advised in these cases to leave the lateral incisor without a bracket, so that it is free and unrestricted from being influenced by the canine's corrective movements.

Figure 8.2 includes the anterior section of a pre-treatment panoramic view of a 13-year-old male, displaying an impacted right maxillary canine, which is located in the line of the arch. This case is remarkably similar to the case shown in Figure 8.1, but the consequences are very different, due to the 2D mind-set of the patient's orthodontist. The canine has a strong mesial apex–crown inclination and has an enlarged follicle surrounding the crown. The crown of the lateral incisor of the same side is seen to be flared distally, with its partially resorbed root apex pushed against, and to one side of, the adjacent central incisor, due to its intra-bony influence of the canine.

The clinical intra-oral view of the right side (Figure 8.2d) was recorded after 16 months of active treatment aimed at space opening. The orthodontist had not initially appreciated why there had been so much difficulty experienced in executing the relatively trivial and usually rapid task of levelling, aligning and space opening. As can be seen, more than adequate space had been successfully created at the occlusal level by using a rectangular archwire and an open-coil spring. The lateral incisor tooth had been uprighted and the first premolar had moved distally. The movement had secondarily introduced a distal tip and a mesio-buccal rotation of the premolar.

The periapical film that was taken at the same time (Figure 8.2e) revealed the reason that the space opening and alignment had been so difficult to achieve and so time-consuming. The uprighting of the root of the lateral incisor had come at the high price of resorption of the entire apical half of its root, which seems to have taken 16 months to achieve.

In the light of the serious danger of root resorption in cases of this type, it is advisable to create ample space for both the lateral incisor and the canine. This should be effected using an open-coil spring between the central incisor and the first premolar, intentionally bypassing the lateral incisor and the unerupted canine. Surgical exposure and attachment bonding of the canine should only be performed when there is more than adequate space available for both the canine and the lateral incisor, although a traction force should be applied only to the canine. The canine is then drawn labially across the line of the arch, carefully directed to eliminate its contact with the root of the incisor. It is only when this movement has been completed that the canine should be drawn downwards to the labial archwire and only then can the lateral incisor be safely bracketed, uprighted and aligned with the other teeth, without the risk of root resorption.

Buccally displaced maxillary canines

In Chapter 7 we referred to epidemiological studies that investigated the prevalence of palatal impaction of maxillary canines in different ethnic groups, in males and females within those groups and the relationship to the prevalence of buccally impacted canines. It was pointed out there that in Caucasian populations, palatal impaction was approximately two to three times more common than buccal impaction.

Yet, paradoxically, buccally displaced maxillary canines that have erupted into the mouth represent one of the most frequently encountered conditions in orthodontic practice. This would seem to indicate that in Caucasian populations, buccal canine displacement is considerably less likely to prevent eruption than palatal displacement. In contrast, another study found that Asian populations suffer more buccal impactions, while the frequency of palatal impaction in that ethnic group is very low [2].

Tooth size and arch length play an important role in differentiating between palatal and buccal impaction. The dentition with palatal impaction is characterized by an excess of space in the dental arches [3, 4], while the buccal impaction cases show distinct crowding [5, 6]. In males this appears to be more due to a deficiency in length of the dental arch, while in females it was found to be more related to larger than average teeth [5]. We have pointed out earlier that the developmental location of a normal unerupted maxillary canine is slightly buccal to the general line of the dental arch and that its two adjacent teeth (the lateral incisor and first premolar) erupt ahead of the canine. This being so, if there is any crowding, the space for the canine between these two teeth will be reduced, causing the canine to exaggerate the buccal tendency of its eruptive path (see Chapter 7).

An analysis of the dental age of the study sample in the latter two studies [5, 6] shows important differences in clinical features and characteristics apparently associated with buccal and palatally impacted canines and concludes that that these are two very different phenomena. While patients with palatal canines showed a strong tendency for delayed dental development, a similar study of a large sample of patients with buccally ectopic canines showed a normal dental age distribution [7]. When dental age and chronological age were compared, no significant difference was found.

The dental age of patients with palatally impacted canines seems to be divided into two distinct and separate trends. In half the cases the dental age was normal, whereas in the other half the dental development was very late, indeed by as much as two years or more. In none of the cases within the palatal canine group was there advanced dental development

Buccally ectopic canines in the absence of crowding

The inconclusive findings of these studies indicates that buccal ectopy (primary displacement) and buccal displacement (crowding) are difficult to differentiate one from the other and this confusion in terminology renders the findings unreliable. Among the individuals that we see with buccal displacement of the canines, there is indeed a small but significant number who do not display crowding that may account for this displacement. In order to attempt to shed more light on this confusion, the clinical features of the dentitions of a large sample of such cases were compared to those of a similar sample of BDC cases with associated crowding and to yet another sample of cases in whom the canine had erupted into its place [7].

The comparison made in the study of dental age, the chronological age and the mesio-distal tooth dimensions showed no difference between the patients in the three groups. The sole significant finding in this study was related to the adjacent lateral incisor tooth. This tooth frequently exhibited an increased incidence of anomaly and delayed development. This parallels the findings that have been recorded in relation to palatal canine displacement. The guidance theory and the genetic theory both offer cogent aetiological explanations for this phenomenon [8], as was pointed out in Chapter 7 (Figure 8.3).

In the absence of crowding, the canine may erupt higher up in the area of the vestibular oral mucosa and thereby create a poor gingival attachment. From the periodontal point of view, a thin and mobile oral epithelium covering the root will leave the patient with a delicate and easily traumatized attachment apparatus. The various surgical approaches to resolve the problem by exposure have been described in Chapter 5.

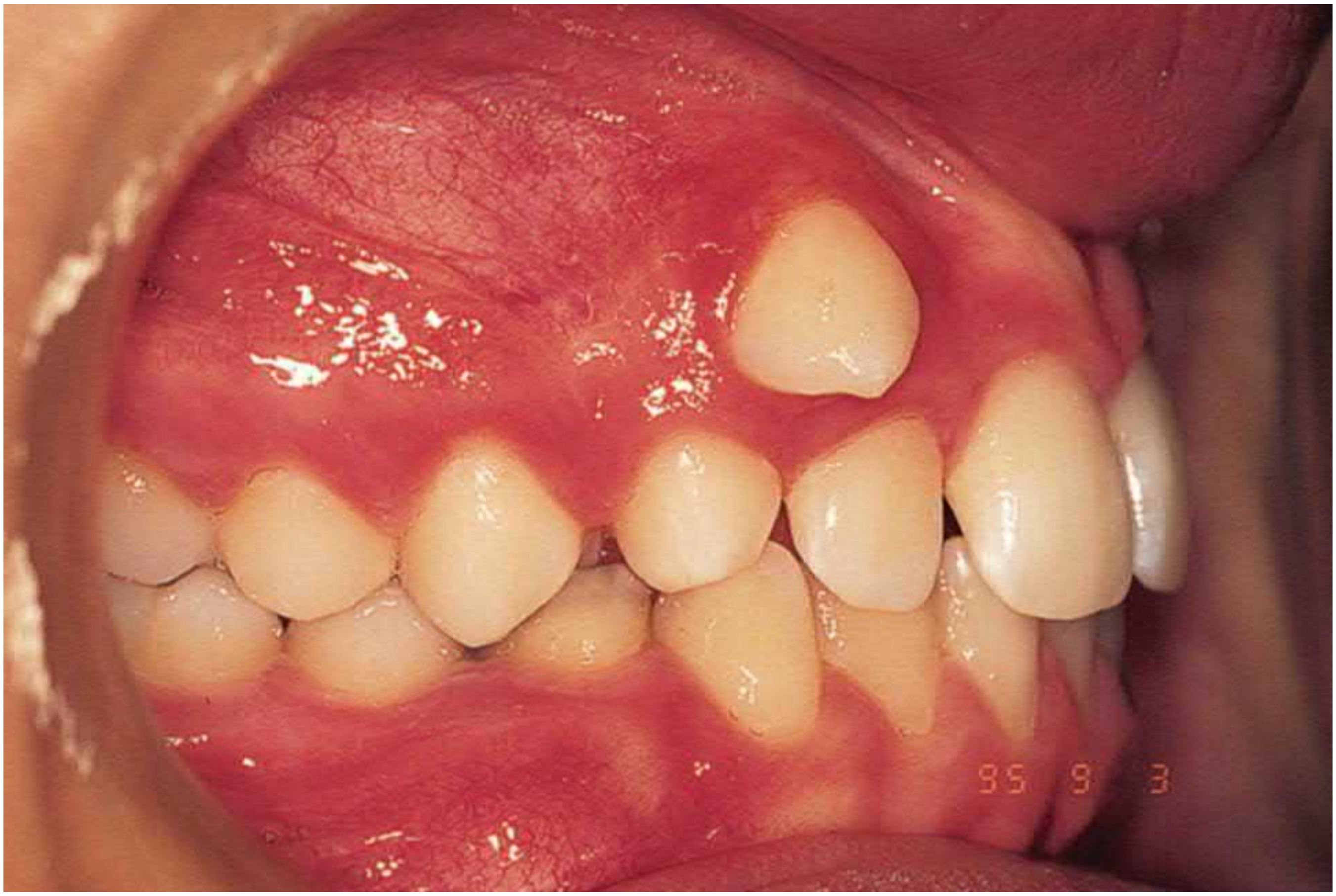


Fig. 8.3 A maxillary canine has erupted in an abnormal location. Is this primary tooth germ displacement or lack of guidance from the adjacent peg-shaped lateral incisor?

Buccally impacted canines with mesial displacement

Most BDCs will also have a mild mesial displacement, overlapping the distal side of the lateral incisor (Figure 8.4). These are so common in orthodontics that we may consider them routine, whether or not they are erupted. However, on occasion one may find that the degree of displacement of the unerupted canine crown is quite extreme, overlapping very high up on the mesial side of the root of the lateral incisor. In the early teen years these canines will progress more mesially and inferiorly, and may be found at the level of the apical third of the root of the incisor in the bony depression that is located in the height of the vestibular sulcus. Although these are often palpable, their unusual height and mesial displacement in the vestibule may lead to an erroneous initial clinical diagnosis of their location.

Fig. 8.4 Cone beam computed tomography transparency presentation of 3D screenshots showing bilateral labially impacted canines. The lateral incisors were absent and three deciduous incisor

and canine teeth persisted. Note the bilaterally symmetrical, mesially displaced apices of the premolars.

In Figure 8.4, the lateral incisors are absent and the deciduous right lateral incisor and both deciduous canines are still present. The long axes of the first premolars are abnormally displaced mesially and it must be assumed that the papillae of their uncompleted root apices are in close contact with the canines, diverting their eruption paths superiorly and labially. This type of canine premolar relationship is unusual, but not rare, and it may occur whether or not there is a missing incisor.

In most cases where the canine cannot be drawn directly down to its place in the arch, a pure labial movement of the canine is needed as a preliminary to the main treatment. The surgical approach used for the case illustrated involved a full-flap closed exposure procedure, in which the twisted steel ligature from the eyelet pierces through the flap at the height of the tooth. In moving the canine labially, there must be no vertical (downward) component, away from the containing influence of the roots of the two adjacent teeth. For this, the auxiliary labial arch, described in Chapter 7, is probably the most efficient method available.

It is advantageous to place the auxiliary archwire in its passive position (Figure 8.5a, b) before the surgery begins, since it does not interfere with the access required by the surgery. When the flap had been re-sutured to its former place, the twisted ligature was turned into a short hook to ensnare the loop of the auxiliary archwire in the vertically activated position, bringing it into light contact with the oral mucosa of the flap. In this way, a true lateral movement was applied to the tooth, avoiding a clash with the premolar and lateral incisor roots. Within a few weeks, the canine was to be seen bulging the labial mucosa. At that point, the auxiliary arch was removed and the tooth drawn distally until it was opposite its place and then directly downwards to the archwire, finally emerging through the attached gingiva. At this point it can be expected to offer a good periodontal prognosis and a normal appearance of the gingiva.

By carefully studying the orientation of the adjacent incisor at the clinical intra-oral examination, subtle indications regarding the location of a mesially displaced buccally impacted canine may be found on either side of the alveolar ridge. Because the canine shares the narrow bucco-lingual space in the alveolus with the incisor, a palatal displacement is caused of the root apex of the lateral and, occasionally, the central incisors. By tipping the patient’s head backwards and studying the anterior maxilla from the occlusal aspect, the astute clinician will note that the lateral incisor root has a strong palatal inclination, prominently outlined against the palatal mucosa. The tooth clearly needs considerable labial root torque. On the labial side of the ridge, the outline of a labial impacted canine is usually easy to see and to palpate. However, because it may be quite high in the vestibule, it may sometimes be missed.

The labial location of the canine may not be easy to confirm radiographically and the tube-shift method with two periapical films exposed at different angles may therefore be an obvious first step.

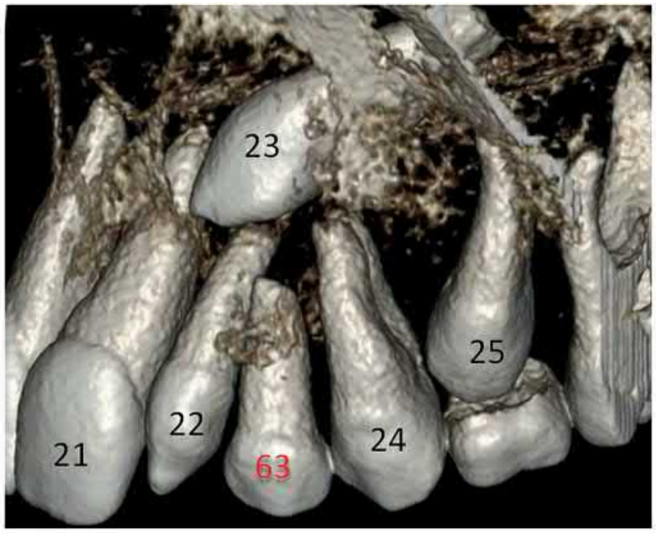
Given its height and location in the labial depression of the anterior maxilla, the radiographic image of the buccal canine on the panoramic view will be enlarged more than that of the incisors. Although the impacted canine is labial to the incisor roots, it is more distant from the film than the incisor crowns. A canine in this location is the exception that negates the effectiveness of the method described for determination of the labio-lingual canine position using a single panoramic view [9, 10]. Due to the acute angulation of the X-ray cone, periapical or occlusal radiography of these teeth will superimpose a labial canine on the incisor roots, at a lower level. However, the diagnosis will be enabled due to the combination of the steeply angulated periapical or occlusal view with a panoramic view (with its almost horizontally directed X-ray beam) and using the vertical tube-shift information, as seen in Figure 8.6(e, f). A lateral cephalogram will provide antero-posterior visual information of the crowns of these teeth relative both to the incisor roots and to the anterior nasal spine.

The canine in the case illustrated in Figure 8.6(g, h) is of this type and is a difficult one to treat. The practitioner chose to extract it, thereby allowing the remaining space to close by drawing the molar into a class II relation with its mandibular counterpart. The midline discrepancy was also corrected.

Palatally impacted labial canines

Let us now look at the case of a patient whose maxillary incisor arrangement accords with the archetypal class II division 2 malocclusion, and who has a mesially directed and labially impacted canine. This situation may degenerate into a complex canine/lateral incisor partial transposition. Typically, the root of this lateral incisor is tipped palatally and its crown proclined labially. However, the long axes of the central incisors of the class II division 2 case characteristically show lingually tipped crowns and a labial orientation of their roots, which are often palpably outlined in the labial aspect of the alveolar process. In such a situation we must be prepared for consequential problems.

If we mentally follow the long axes of the roots of these two incisors as they proceed in the apical direction, we will discover a large space developing between the bucco-lingual V-shaped divergence of the long axes of these two teeth. The resultant distance between the incisor root apices of these teeth can often be as much as 10 mm or even more. It will be appreciated that in these circumstances, a mesially migrating, labially impacted canine may progress beyond the mesial aspect of the root of the lateral incisor, through this V-shaped inter-radicular bony area, and proceed to the lingual side of the central incisor roots (Figure 8.7a–d). With the canine root now labial to the root of the lateral incisor and its crown now palatal to the central incisor, orthodontic resolution and alignment require considerable thought and planning to extricate the canine and eventually bring it into alignment.



(a)

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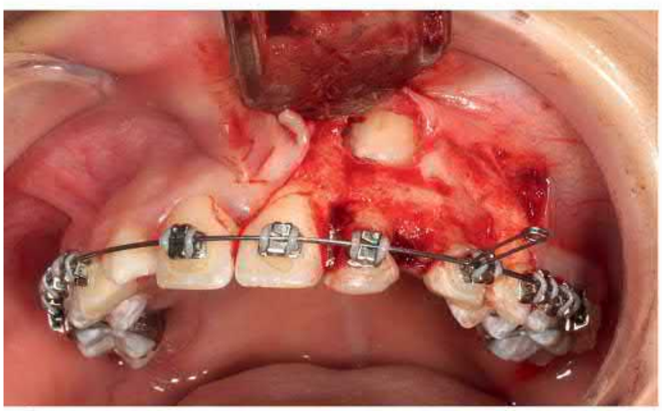

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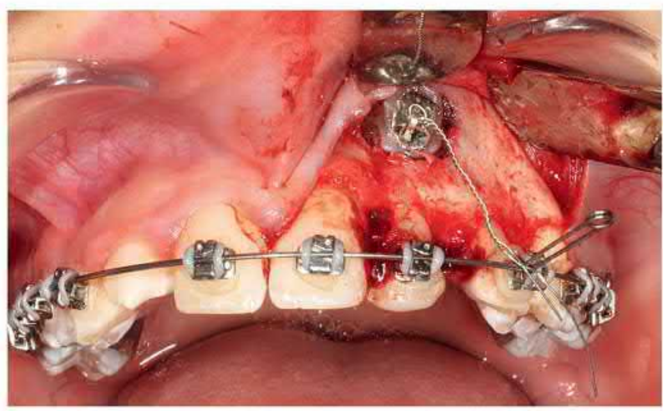


(e)

(f) (g)

Fig. 8.5 (a) A mesio-angular, labially impacted maxillary canine (#23) is high above the roots of the central and peg-shaped lateral incisors. The first premolar root apex (#24) is mesially displaced, which demanded distal uprighting before the canine could be drawn to its place. (b) The auxiliary labial arch, ligated into place over a heavier base arch, viewed from the front and (c) occlusally in its passive state, immediately prior to the surgery. Note the pre-surgical horizontal, passive mode of the traction loop of the auxiliary labial arch (arrow). (d) Full attached gingiva flap exposure of the labial canine. (e) Eyelet attachment in place with pigtail wire ligature. (f) Following re-suturing of the full flap, the horizontal loop was turned upwards and inwards with light finger pressure and held in place by a simple hook fashioned into the shortened twisted steel ligature, to provide a horizontally directed lateral traction force. (g) The aligned canine at 15 months post surgery, having experienced labial, distal and finally vertical traction.

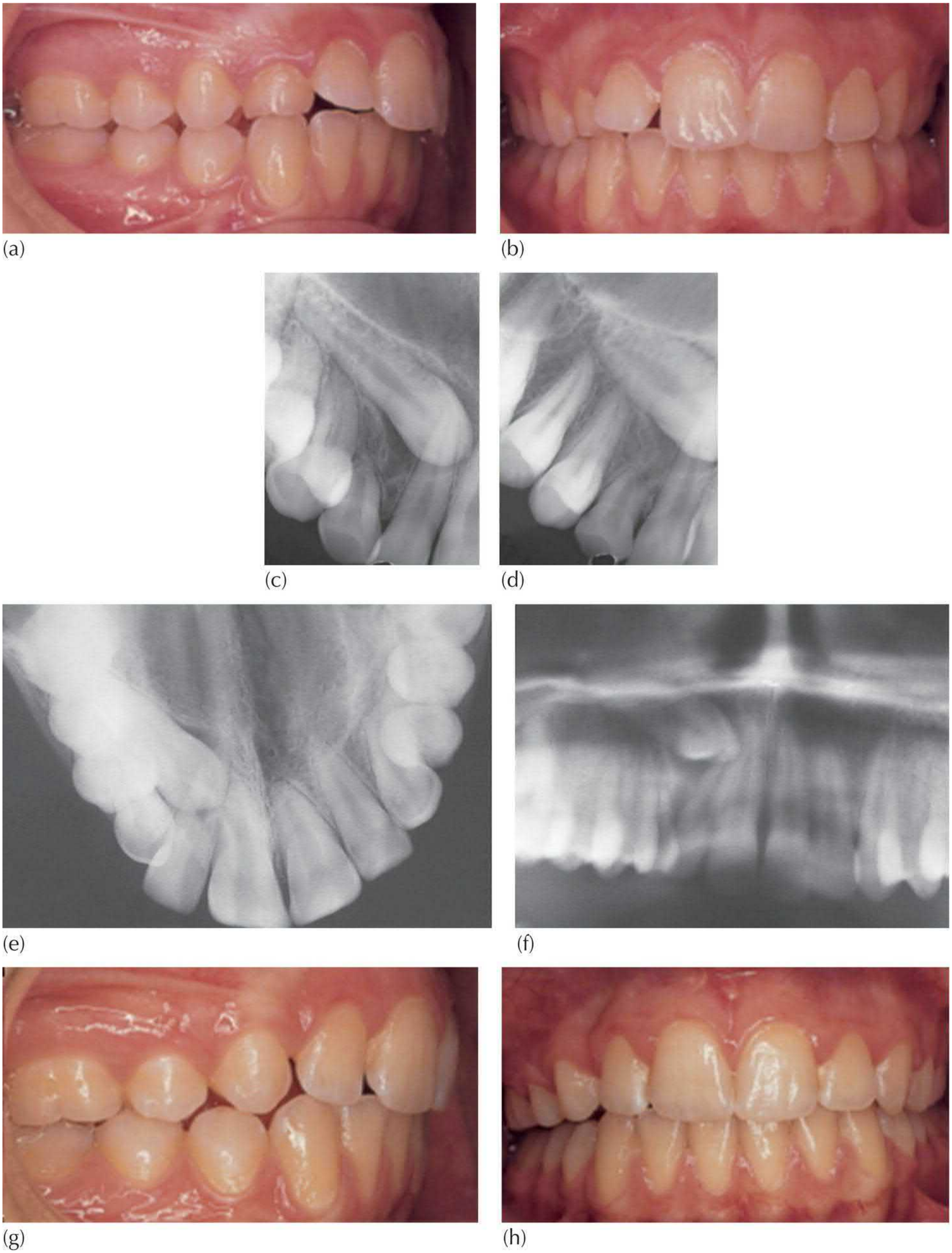


Fig. 8.6 (a, b) Clinical views showing an over-retained deciduous right maxillary canine. Note the characteristic labial and distal tipping of the right lateral incisor crown and its palatal root

position, indicating labial canine impaction. (c, d) Horizontal tube-shift periapical views indicate the labial impaction diagnosis. (e) Anterior occlusal view showing superimposition of canine crown and lateral incisor root on the right side. From this view, the canine could be inferior to the latera incisor root on the palatal side or superior to the root on the labial side. (f) A section of the panoramic view to show the severe mesial displacement and unusual height of the canine. Taken together with the anterior occlusal view, the vertical tube shift created confirms the labial impaction diagnosis. (g, h) Following extraction of the canine, the practitioner used a simple removable appliance to improve alignment and midline correction.


(a) (b) (c) (d)

Fig. 8.7 3D screenshots of the high left maxillary canine, which is labial to the lateral incisor and lingual to the central incisor. (a) The view from the right side. (b) The view from the front as would be depicted on a periapical view. (c) The view from the right side. (d) The palatal view. Parts (a) and (c) show the apical divergence of the roots of the central and lateral incisors, which is the 'window of opportunity' through which the canine must be drawn to resolve the impaction.

If positional diagnosis is based solely on the buccal object rule (using two periapical films radiographed at different angles), the palatal location of the canine crowns to the central incisors will be quickly and easily confirmed. However, without clinical observation and palpation or more sophisticated imaging, the relation between canine and lateral incisor will likely be overlooked. If orthodontists rely, as a matter of routine, solely on Clark's tube-shift method (Figure 8.8a, b), then it is likely that they will be blithely led into undertaking totally inappropriate treatment. They will have planned on a palatal surgical and orthodontic approach to the crown of the canine, from the palatal side. If carried out, this approach would involve orthodontic manipulation of the canine in a palatal direction, from the labial to the lingual, hinging the canine root around the root of the lateral incisor. This will inflict iatrogenic and possibly terminal damage to that tooth. In addition to this, the apex of the canine will be swung anteriorly to clash against the labial aspect of the labial alveolar plate, thereby negating any reasonable possibility of success. (A case of this type and with this unfortunate outcome is illustrated in Chapter 18.)

The only escape route available to the canine is to draw the tooth labially through the V-shaped incisor root divergence. This would necessitate exposing the crown from the labial side and applying traction in a labial and distal direction, in order to bring the tooth clear of the central incisor. The canine must then be directed distally and labially around the root of the lateral incisor and into its place in the arch.

When a case of this type is diagnosed, a quick treatment decision would need to be taken, since the canine is unlikely to remain static in this position. It will likely continue on until it eventually arrests at some point on its futile and ectopic eruption path, behind the central incisor and at the level of the inter-incisor contact, at the neck of the two teeth.

And so, what are the treatment options?

- To leave the canine untreated *in situ* – with suitable long-term radiographic observation and a passive supervision plan. This policy precludes any possibility of orthodontic correction of the incisor relationship and it always carries with it the risk that subsequent neglect of the patient's dentition will lead to additional complications in later life.

- To extract the impacted tooth and align the lateral incisor.
- To extract the lateral incisor, align the canine into its normal place and prepare for an implant to replace the missing incisor.
- To extract the lateral incisor, align the canine into the place of the missing incisor and draw the posterior teeth mesially to eliminate the space.
- To align the teeth in their transposed order.
- To expose the canine and bring it into its designated place in the arch, while realigning the lateral incisor to its normal place, with carefully planned directional orthodontic treatment.

Regardless of the lingual relation of the canine to the central incisor, the surgical and orthodontic approach must be from the labial aspect. This is dictated by the location of the canine on the labial side of the lateral incisor. Surgical access and orthodontic traction need to be negotiated very delicately between the bucco-lingually divergent roots of the central and lateral incisors.

In other circumstances, levelling and alignment of the teeth would be the first task in the treatment. A round or rectangular fully engaged NiTi archwire in the brackets would be effective to upright the roots of the two incisors in the mesio-distal plane and would torque them in the bucco-lingual plane. In the present circumstances, however, this would fully close the V-shaped escape root of the canine and thereby sign its metaphorical death warrant.

The main conclusion therefore is that no attempt at root uprighting or torqueing of the incisors should be undertaken until the canine is well clear of both incisor teeth (Figure 8.7). It should be obvious that the very presence of the canine between the roots will interfere with premature root movements. An orthodontist who is unaware of this principle would be mystified as to why the teeth do not move!

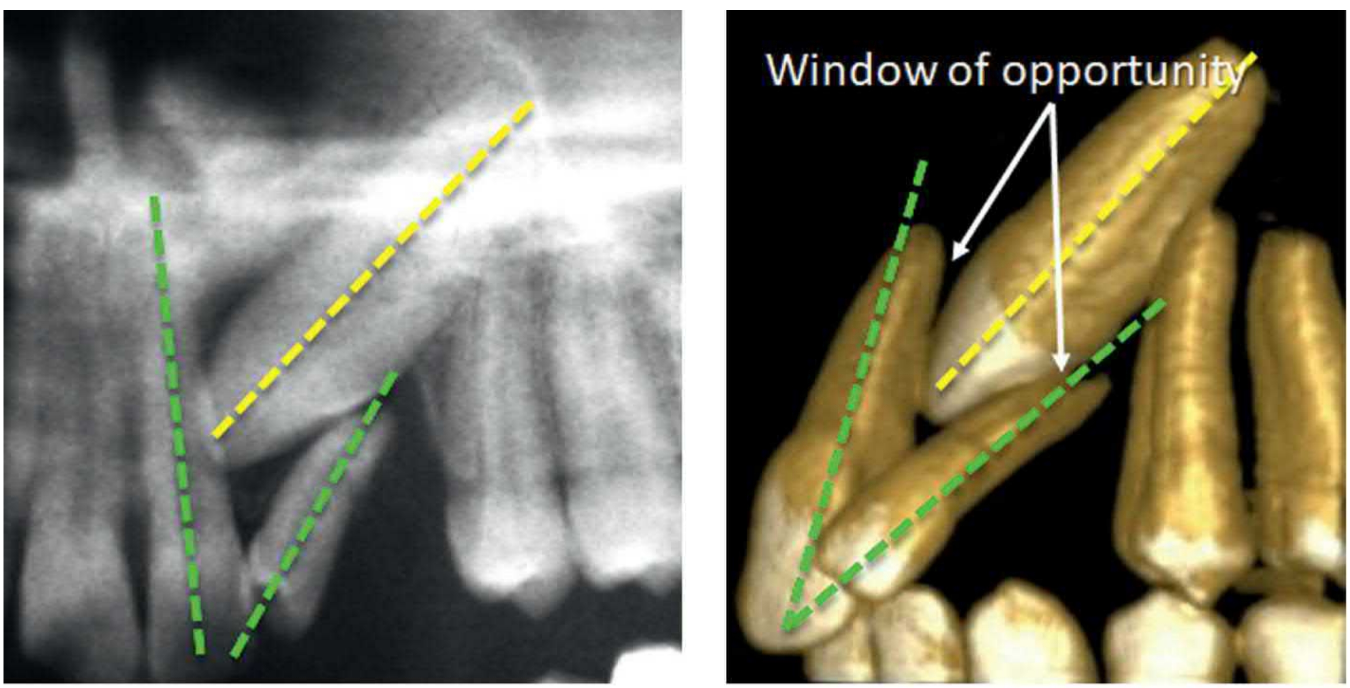
The 'window of opportunity'

For virtually the entire twentieth century, dentists only examined 2D planar radiographs produced by an X-ray conus directed across the labio-lingual line of the alveolar ridge. In this way, we 'flattened' the significant bucco-lingual dimension and 'lined up' teeth with palatally inclined roots, teeth with labially inclined roots and those with no bucco-lingual root inclination and made them all appear the same. This has obscured the fact that there is a concealed but valid escape route available to resolve the palatally impacted labial canine, which requires our special attention. In the present context (Figure 8.8a), 2D radiography depicts palatally impacted labial canines as mesio-distal root uprighting problems, while, in reality, they are a bucco-lingual discrepancy (Figure 8.8b).

So, what is the way out of this Catch 22? For reasons that will shortly be clear to the reader, resolution of the palatally impacted labial canine is dependent on the presence and exploitation of the 'window of opportunity'. There are three ways of addressing the different levels of severity of tooth displacement that may be employed to enable the adoption of the window of opportunity and, with it, the road to successful resolution:

- In this unique impaction scenario, one should leave the lateral incisor or the central incisor temporarily unbracketed, allowing it to remain at a divergent angle to the adjacent central incisor. Being unconstrained, it may, if necessary, be pushed aside by intra-bony contact with the crown of the unerupted canine, to which traction will have been applied. Only after the canine has become palpable on the labial side and then surgically exposed should an attachment be placed on the incisor and its roots uprighted and torqued as appropriate to its ideal location in the arch.

- A more accurate and sophisticated method of achieving the correct positioning of the incisor is available for these and for the more difficult cases. In this variant, all the teeth in the maxillary dentition are bracketed, including the lateral and central incisors. The brackets are bonded to their ideal locations on the labial surfaces of each tooth, such that a 'straight' wire will tip and torque each individual tooth to its correct 3D location and angulation. However, an exception is made for the lateral and/or central incisor teeth. For these two teeth, the bracket is bonded to the labial aspect, with the horizontal slot oriented parallel to the occlusal plane (rather than at 90° to the long axis of the tooth). In this manner and specifically with a round archwire, the angulation of those teeth will not be altered but will maintain the V-shaped inter-radicular divergence. Once the canine has been brought through to the labial of the incisors, the brackets may be relocated to their ideal locations, as may be needed for their realignment.
- If the orthodontist still does not have enough space between the incisor roots, consideration should be given to 'moving the goalposts', namely to actually increase the V-shaped inter-radicular angle of divergence. To achieve this, the brackets on the incisors should be located at a greater angle than in the previous option. In other words, the bracket on the lateral incisor should be initially placed at an angle that will actively move its root distally and the root of the central incisor mesially. The 'levelling' action of the archwire will increase the window of opportunity, which can be monitored by the degree in which the long axes of the crowns of the two incisors can be seen to diverge from each other, or by simply taking a periapical radiograph.



(a) (b)

Fig. 8.8 The 'window of opportunity'. (a) The anterior section of a panoramic view of a pseudo-transposed canine, indicating what appears, in a 2D format, to be a mesio-distal root uprighting problem of the incisors. (b) A 3D cone beam computed tomography screenshot showing how the discrepancy in the bucco-lingual axial relations creates the window of opportunity that is essential to resolve this bucco-lingual problem.

In these cases, the canine has to be drawn labially and distally between the incisor roots high in the vestibular sulcus, into the wider part of the V-shaped bony space above the labial archwire. This is difficult to manage, since the use of a high labial loop spring will easily ulcerate the very mobile mucosa of the lip and of the vestibular sulcus. Moreover, it will then create difficulty in attaining the additional objective of erupting the canine through attached gingiva, as we have seen in Chapter 7 (Figure 7.52d).

The 3D inter-relationship of the teeth and the possible existence of incisor root resorption create problems in diagnosis, particularly in the bucco-lingual plane, as pointed out in Chapter 4. Cone beam computerized tomography (CBCT) should always be performed to provide the relevant information needed to avoid failure.

For most other buccally impacted maxillary canines, surgical access is not problematic. On the other hand, the ability to provide a satisfactory orthodontic strategy to reduce the impaction, while still offering a good periodontal prognosis, will be more limited. This is particularly true of the high buccal canine tooth that needs to be moved buccally, distally and inferiorly, in a manner that circumvents the root of the adjacent lateral incisor. The canine must be drawn in a semi-circular flanking movement around the lateral incisor root, in an area where the alveolar ridge is too narrow to comfortably allow one root to pass by another. As the canine is moved labially, the bony alveolar plate will respond and become more prominent as it remodels to accompany the tooth movement. This bony remodelling does not add width to the same degree as the dental movement; accordingly, the root of the tooth will lose some of its labial bone and soft tissue support. While muco-gingival surgery performed at the time of exposure is possible [2], its prospects are in fact very limited. For these reasons, one must expect a long clinical crown with a less than ideal periodontal outcome.

Given these potentially negative consequences, the more severely displaced buccal canines of this type may occasionally need to be extracted, and, as far as possible, the deciduous canine left in place. In such an instance, it is recommended to provide additional space mesially and distally, to allow for the crown of the deciduous canine to be prosthetically enlarged in anticipation of a later implant restoration, after the deciduous tooth is finally lost. If the deciduous canine has a poor prognosis, an early decision should be made regarding space closure or space opening and appropriate, controlled orthodontic space closure should then be carried out, with or without a compensating extraction on the opposite, unaffected side. Alternatively, there will be a need, as part of the overall orthodontic treatment, to undertake orthodontic preparation of the case for an implant-borne replacement crown.

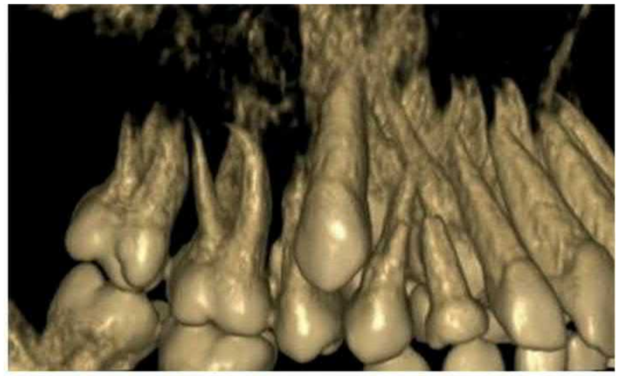
Buccally impacted canines with distal displacement

It is unusual to come across buccally located canines that are also displaced distally. These are almost invariably, to a greater or lesser extent, transposed with the first premolar tooth (Figure 8.9a, b). Many of the transposed canines erupt high in the vestibular sulcus, where they are invested with loose oral mucosa rather than with attached gingiva. Others do not erupt and, depending on the orthodontic treatment plan, may need to be surgically exposed. However, in these cases the orthodontist will frequently decide to actually align the teeth in their transposed order. As a general rule, these transposition patients present with the first premolar crown in its normal place, but with its roots displaced mesially and giving the tooth a distally inclined apex-to-crown long axis. The premolar may be moved quickly and simply by mesially tipping it into the site vacated by extraction of the deciduous canine, thereby creating space for the canine at the location of the first premolar. The canine will usually respond with autonomous eruptive movement.

In many cases these buccally located and distally displaced canines may descend without the application of orthodontic forces, although full eruption may take many months, even as much as a year or more. Nevertheless, even though there may be no apparent reason for a retarded eruption, a good number of such teeth either remain unerupted or in their partially erupted state for a very long time without significant progress (Figure 8.9c, d). Therefore, after the initial treatment for mesial movement of the first premolar, the impacted canine should be exposed and actively drawn to the labial archwire. This may be achieved by using light elastic traction or an auxiliary NiTi wire placed piggyback style over the existing heavier base arch. It is to be pointed out that it is counterproductive to leave an orthodontic appliance in place for all this time without exploiting it to bring about the eruption and alignment of the canine. Indeed, its long-term continued presence runs the risk of producing deleterious side effects, such as caries and periodontal inflammation. Accordingly, when the impacted tooth shows no signs of erupting within a reasonable period of time after space has been prepared for it, surgical exposure, orthodontic traction and alignment should be performed.

If the tooth is situated above the level of the line of the attached gingiva, the ‘window technique’ exposure will leave it with an undesirable labial attachment consisting of highly mobile oral mucosa, possibly with a direct connection of the mucosa joining the cheek epithelium to the free gingival epithelium of the premolar. This connection will follow the erupting tooth and make for a localized shallow vestibulum, which is prone to damage from minimal trauma. In such a case, an apically repositioned flap or a fully closed flap exposure will be more appropriate, in order to bring the tooth down by direct traction to the labial archwire of the appliance.

(a)



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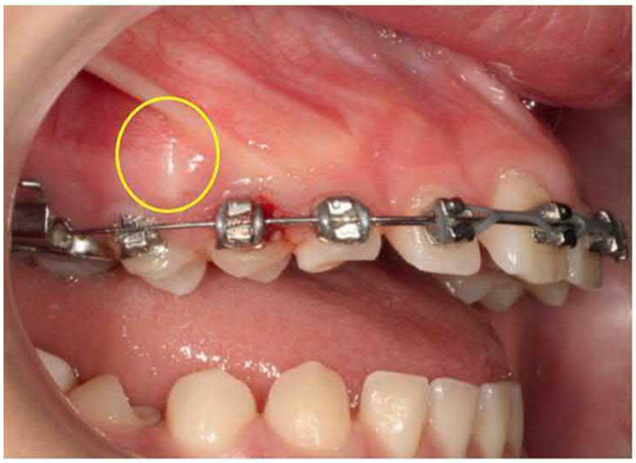

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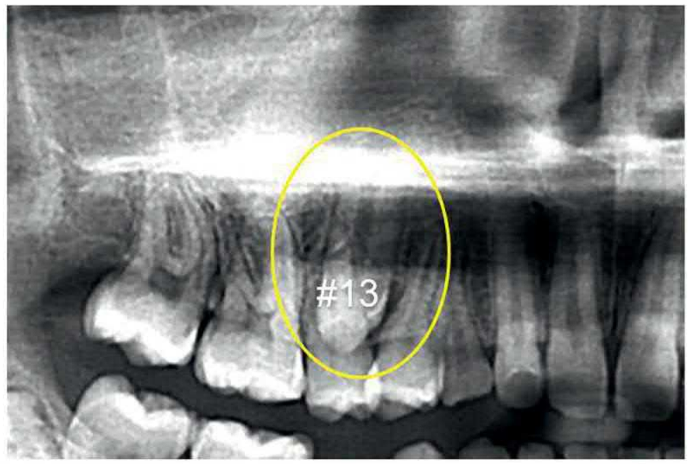

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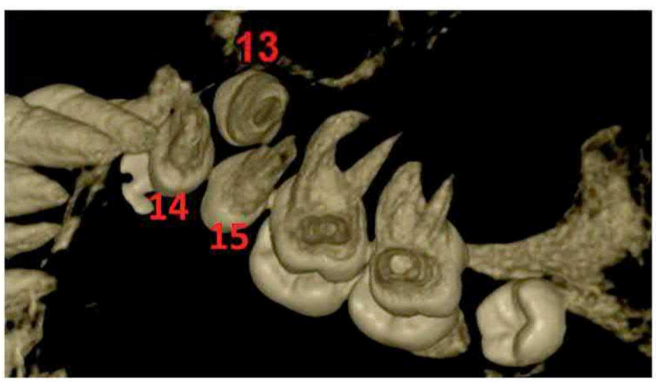

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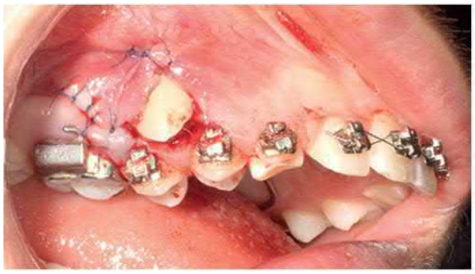
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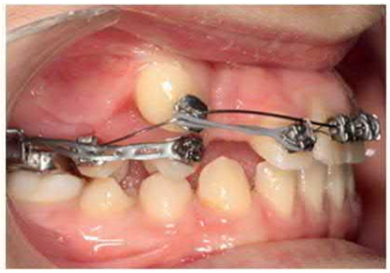
(j)


(k)


(l)


(m)


(n)


(o)


(p)

Fig. 8.9 (a, b) A general panoramic view and a 3D cone beam computed tomography screenshot showing the transposed canine. (c, d) A distally displaced maxillary canine, transposed with the first premolar and superimposed on the second premolar. It is palpable clinically (circle) and seen clearly on the panoramic or periapical radiograph. (e) The 'bird's eye view' of the bucco-lingual relation of the canine to the two adjacent teeth. (f–h) Surgical exposure of the canine crown. (i) The attached gingival flap was relocated more posteriorly to maintain partial cover of the crown of the canine. (j) An eyelet attachment was bonded to the mesial corner of the crown. Mesial elastic traction of the canine was guided by a light labial archwire through the vertically oriented eyelet, while the premolar was drawn posteriorly. (k) With the canine opposite its final location, bucco-lingual root movement (torque) will be needed. (l) The preliminary alignment of the canine shows the need for a very considerable degree of lingual root torque, typical of cases of transposed teeth, giving rise to gingival recession and a long clinical crown. At the same time, buccal root torque was also obviously needed in the lateral incisor and first premolar. (m) A simple but broad-range, reciprocal torqueing spring, suitable for this difficult situation. (n, o) The completed alignment at the time of appliance debonding. (p) Panoramic radiograph taken at appliance removal.

Many clinicians are inclined to assess the severity of a transposition by reference to the respective locations of the crowns of the two affected teeth. This, however, is clearly not the correct approach and the only valid assessment of severity is the potential distance of the root apices of the teeth from their normal locations, in both the mesio-distal and bucco-lingual planes. It is this aspect that will become relevant when they subsequently come to pass by each other in the narrow bony alveolus. Having adopted an erroneous approach, the practitioner may be further drawn into attempting to bring the teeth to their ideally corrected order. However, this is a task that requires considerable clinical skill and an extended treatment time. Due to the need for the two teeth to pass by each other in the narrow alveolar ridge, the likelihood is that gingival recession will ensue, leading to a long clinical crown on the canine and, in due course, consequential periodontal problems.

It is suggested that the optimum approach may be to commence the treatment while the displaced canine is still relatively high, when it can easily be moved mesially. If, on the other hand, the impaction is only recognized late (Figure 8.9a, b), it will be essential, prior to undertaking the treatment, to check whether it is indeed possible to have the roots of the two teeth pass by each other in the narrow alveolus.

In most examples of this type, the essential aim is to attempt to reduce the danger of root proximity of the affected teeth during correction, particularly since the canine is generally buccal and the premolar generally lingual. The actual situation will need to be checked with a CBCT view from above the apices of the teeth (Figure 8.9e) in order to be sure that they do not cross over one another in the bucco-lingual plane. If there is a high canine, a closed surgical exposure may be preferred (Figure 8.9f–i), although this method can only conveniently be used when the direction of traction is vertically downwards. It is not easy to adapt this method to efficiently deal with a situation where the direction of traction has more than a minor degree of mesial or distal component, since the elastic thread or closed-coil spring that may be used will cause soft tissue impingement.

If, as in the illustrated case, full correction of the transposition is to be undertaken, it is wise to initially place an eyelet attachment on the mesial aspect of the exposed canine, so that mesial 'pull' traction will not generate mesio-lingual rotation on the tooth as it moves forwards (Figure 8.9j, k). Once the crown of the tooth has been moved into its correct mesio-distal location, the eyelet should be removed and a bracket of the type used on the other teeth may be placed on the tooth in its ideal mid-buccal position.

When complete transpositions are treated to ideal alignment criteria, two teeth will have mesio-distally passed by each other within the narrow confines of the bucco-lingual width of alveolar bone. When they reach their destinations, they will require to be torqued in opposite directions to a very considerable degree, although this may be very difficult to achieve. It should be obvious that the mesio-distal movements of the two teeth can only be performed on a round wire base arch.

The case described here was treated using TipEdge PLUS™ brackets (Figure 8.9k–m) because of the versatility of the system and its ability to accept Begg-type uprighting and torqueing springs. The simplicity of root-moving auxiliaries, with their very broad range of action, is particularly suited to answering the need for very wide breadths of mesio-distal uprighting and bucco-lingual torqueing of the long axes of the previously impacted teeth (Figure 8.9n, o). These movements are an essential requirement when treating impacted teeth and, even with the most efficient auxiliary springs, will take a great deal of time.

The treatment of the case took 31 months, very little of which was spent closing off a minimally spaced dentition, with no true or essential malocclusion. Almost the entire therapeutic endeavour was concentrated on treating a single tooth, from a host of multifarious aspects.

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9
Resorption of the Roots of Neighbouring Teeth

Adrian Becker and Stella Chaushu

Impaction and the transition from deciduous to permanent dentition

Can resorption be equated with dental caries?

Prevalence of resorption

Aetiology, diagnosis and prevention

Treatment

Exposing the impacted tooth without devitalizing the adjacent tooth

Can the resorbed tooth be moved without causing further resorption?

Severe incisor root resorption

Impaction and the transition from deciduous to permanent dentition

One of the essential characteristics of the primary dentition is that the roots of *deciduous* teeth physiologically resorb in relation to the development, the eruptive progress and the proximity to their permanent successors. This leads to a smooth transfer through the five- to six-year transitional mixed-dentition stage of the growing child and on to the permanent dentition in the adolescent. In contrast, resorption of the roots of *permanent* teeth does not normally occur at all, even when there are unerupted or crowded teeth in the close vicinity of their roots. Nevertheless, in relatively exceptional circumstances, unexpected and therefore abnormal resorption of the roots of certain permanent teeth may indeed occur, and must be viewed as pathological. The 'aggressor' teeth involved in such cases are principally the maxillary canines and, to a much lesser extent, the mandibular third molars, which cause resorption of the roots of the maxillary lateral/central incisors and the mandibular second molars (the 'victim' teeth), respectively.

Generally, in the dental development of a child, the first permanent maxillary molar erupts in its due time, at the dental age of 6–7 years. This is four or five years before the deciduous second molar is due to exfoliate and before the second premolar will normally erupt. An aberration of this normal developmental process occurs when an erupting maxillary first molar becomes entrapped in the sub-gingival distal anatomical concavity that is the site of the cemento-enamel junction, where the crown of this first molar meets the distal root of the deciduous second molar [1].

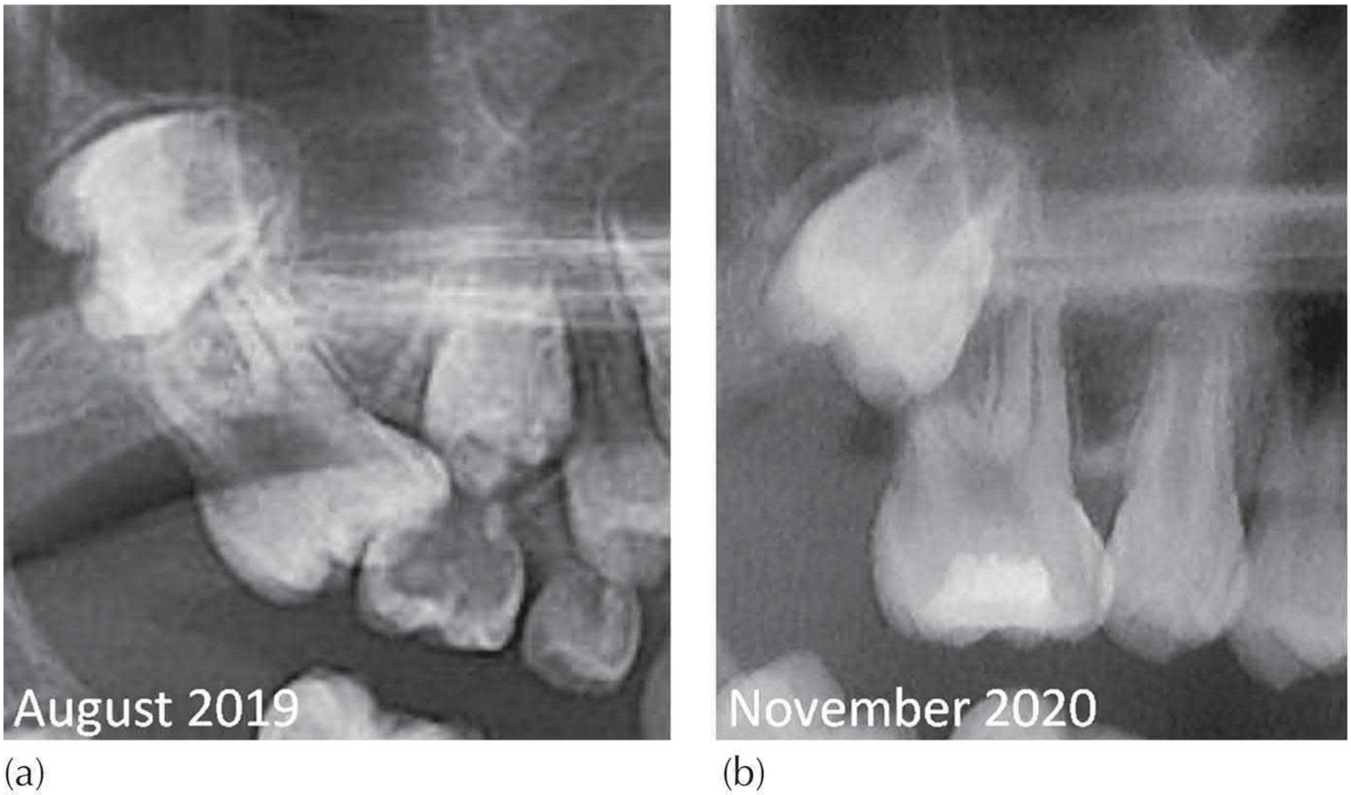


Fig. 9.1 (a) Right-side molar region of a panoramic radiograph of a 6.10-year-old child with an ectopic maxillary first permanent molar impacted under the distal crown edge of the second deciduous molar. There is total resorption of all the dentine of the roots and within the crown of the deciduous second molar. (b) A follow-up radiographs after treatment with a simple removable appliance had distalized and uprighted the permanent molar. The deciduous molar exfoliated a few weeks after the appliance was inserted.

In this situation, resorption of the sub-gingival area of the root of the deciduous tooth will occur and will proceed at a rate and extent dictated by the angulation of the eruptive path of the permanent molar (Figure 9.1a). In many of these cases, there is a mesial inclination of the permanent tooth that is not usually present in normal development. Experience indicates that this is more likely to be seen in children with both a short maxillary dental base and large molar teeth – both permanent and deciduous.

The result of this process is that much or all of the disto-buccal root of the deciduous molar will disappear in the resorptive process, while the distal portion of the crown of the tooth will remain and may become hollowed out as its dentinal interior disappears, leaving an unsupported enamel shell. This then becomes a complicating factor, since this unresorbed enamel ledge of the deciduous molar effectively arrests further occlusal migration of the permanent tooth. In view of the fact that it is the mesial corner of the occlusal surface of the permanent molar that comes into contact with the enamel ledge of the deciduous molar, any further expression of eruptive potential will generate or exacerbate an existing mesial orientation of the long axis of the permanent tooth. Indeed, further resorption may cause the disappearance of its distal root. The deciduous second molar may also tip mesially and its distal aspect may extrude, as the result of the eruptive push from above.

There are many instances where the resorptive process of the distal root and the resorption of much of the interior dentine of the crown will leave the area that was originally the cemento-enamel junction becoming a knife edge of undermined enamel. Nevertheless, even despite these unfavourable circumstances, the tooth is in fact entirely asymptomatic and its extraction is to be discouraged as far as possible, for the following reasons:

- The unerupted second premolar now faces little resistance to its very premature downward eruptive migration and it can even descend into the partially evacuated enamel shell of the crown of its deciduous predecessor. However, the premolar at this stage has virtually no root and its early eruption should be held back as far as possible, to enable a substantial root length to develop while the tooth is still protected within its developmental follicle. Extraction of the deciduous molar will accelerate the eruption of the premolar in a rudimentary, delicate and undermined state.
- Loss of the deciduous molar will help the permanent molar to complete its eruption and will initiate an unrestrained forward drift in a mesially tipped condition. This will also bring its apices forward, indicating a degree of mesial translation. As a consequence, simple distal tipping of the tooth into the upright state can no longer relocate it into its ideal position. It will now require some distal bodily movement if adequate space is to be reclaimed for the premolars and canine.
- In addition, assuming that space may have been completely regained by a phase 1 treatment and assuming that the molar is in a good class I relation to its antagonist, space maintenance will still be an essential ingredient in the follow-up period until both premolars and the canine have erupted. Just a few days without a lost space maintainer will inevitably lead to a renewed and rapid mesial tip of the molar. It would therefore be appropriate to decide, at this point, whether a non-extraction protocol will be a practical line of future treatment [2].

Refraining from extraction would require moving the permanent molar distally and disengaging it from the deciduous molar (Figure 9.1b). The literature in orthodontics and in paediatric dentistry is replete with methods of achieving this and many interesting, customized gadgets and devices have been described.

So, what are the benefits of de-impacting the permanent first molar in its ectopic location and leaving the deciduous tooth in place?

- Impaction of the permanent molar begins while the tooth is only partially erupted and relatively high in the alveolus. At this point in time, the deciduous molar is preventing its mesial and vertical migration. Therefore, only a minimal degree of distal tipping is needed to relocate it to its ideal position.
- Leaving the second deciduous molar in its place [3] obviates the need for artificial space maintenance.
- Even in situations where there are significantly resorbed distal roots, the tooth is not necessarily condemned to an early demise. By and large, they it will remain in place and asymptomatic for most of the full designated duration.

Further discussion, including the justification for conservative Phase 1 treatment of this problem in the very young orthodontic patient, can be found in Chapter 11 of this book. The three conditions that need to be satisfied to be able to achieve a satisfactory treatment approach and a stable result are discussed there, together with a description of an appliance that is up to the task.

Can resorption be equated with dental caries?

When caries reaches the pulp in any erupted tooth, infection will have been introduced into a tissue that cannot contain the swelling that is associated with the natural inflammatory reaction, because it is enclosed within a sealed pulp chamber, reminiscent of a household pressure cooker. In any other tissue, swelling would subside eventually by the natural healing process; however, infection in the pulp chamber causes strangulation and subsequent death of the dental pulp, usually accompanied by considerable pain.

There is a narrow wall of dentine of the root that separates the periodontal ligament (PDL) of a deciduous molar from its dental pulp. Accordingly, very little resorption of the root will need to occur before the resorption front reaches the pulp itself. When this stage of root resorption is reached, many practitioners will mistakenly assume that there will be an emergency pulpitis. They will have equated the situation with that occurring when a carious process within the tooth reaches the pulp and will not have realized that what appears to be the cause of an infection is in fact a sterile resorption of the root. As a consequence, their mistaken treatment of choice will likely be to advise extraction of the affected tooth – a conclusion inconsistent with an understanding of the biological facts.

It is to be emphasized here that resorption is a sterile process and the breakdown of the dentinal wall between connective tissue surrounding the root and the pulp chamber causes the cellular elements of the PDL and of the pulp to merge and to undergo a progressive metaplasia. This is not accompanied by inflammation, swelling or pain and, as the resorption advances, the pulp chamber opens up further, with vital connective tissue of the PDL becoming contiguous with the pulpal tissue.

In such a circumstance, the pulp is no longer enclosed in a solid casing and, although deep caries may still cause an infective inflammatory reaction of the underlying pulpal/gingival tissue, an acute pulpitis can no longer occur. At the gingival extremity of the crown of the deciduous molar, the enamel resists resorption, while beneath it dentine is resorbed. As a result, the unresorbed enamel edge of the crown of the tooth will rest on the gingiva. This unresorbed enamel edge represents the coronal side of what was the cemento-enamel junction (CEJ). The fact that the practitioner may be able to probe this sharp enamel edge is evidence that part of the interior of the crown is open to the intra-oral environment and therefore to saliva-borne bacterial infection. Nevertheless, pain and inflammation are not commonly associated, since the pressure element is absent. If the permanent molar is moved distally and freed from its impaction, the resorption ceases and the situation can usually remain stable for several years. It will then only be re-awakened when the permanent successor sets out on its eruption path.

Since resorption of the roots of permanent teeth has wide-ranging clinical implications, a discussion of the various aspects of this phenomenon is clearly warranted. In the above paragraphs, an overview of resorption in relation to the shedding of deciduous teeth is presented. It is now appropriate to draw a parallel between this physiological phenomenon and the pathological process whereby the innate potential of an impacted tooth to erupt has caused resorption of the roots of its erupted permanent neighbour.

The situation we have described will also occur when the invading resorption front, from the tissues surrounding the crown of an advancing impacted permanent maxillary canine, meets the dental pulp of a permanent tooth. There is no distinction between the character, quality or histology of the permanent versus deciduous tissue resorption fronts. They are one and the same and, while the first is a completely physiological process, the latter is considered a pathological process, simply because root resorption is not a normal, desirable or accepted feature when it affects a permanent tooth. It would be helpful if we could characterize or identify the differences that may exist between a deciduous tooth that does resorb and a permanent tooth that does not, but the factors involved in this quirk of nature have, to date, resisted discovery.

With the rapid evolution of imaging technology from planar 2D radiographic representation, through rotational tomography, to spiral computerized tomography and cone beam computerized tomography, accuracy and reliability of diagnosis of the resorption of incisor roots due to an aberrant unerupted canine have leaped from 12% [4, 5] through 38% of lateral incisors and 9% of central incisors affected to a greater or lesser extent, i.e. from 47% of affected individuals in total [6] to 66.7% of adjacent lateral incisors and 11.1% of adjacent central incisors affected, respectively [4–6]. Obviously, the increase represents the inclusion of the very early and the minor resorptive lesions that had previously evaded detection and now form the majority of those discovered by the new technology. It is certainly pertinent to claim that the finding is largely of little clinical significance. However, it should be remembered that all the severe resorption craters (Figure 9.2a–3) started 'life' as seemingly insignificant minor resorption lesions.

Occasionally one may find an aberrant mandibular second premolar developing low in the alveolus, with a strong distal tilt, and indications of resorption of the mesial root of the first molar (Figure 9.3). In each of these circumstances the crown of the impacted tooth will be in close contact with the root of its neighbour. This situation is not normally seen in other areas, where unerupted teeth are to be found at or slightly above the level of the cervical area of the crowns of the adjacent teeth. Nevertheless, the reason that resorption of the roots occurs routinely and physiologically in deciduous teeth and rarely and pathologically in these exceptional permanent teeth is not understood.

Prevalence of resorption

Early studies of the incidence of discernible root resorption of lateral and central incisors adjacent to an impacted maxillary canine were conducted using plane film radiography, which was the standard of care in the late 1980s. These studies revealed that approximately 12% of the cases in the samples studied were affected [4–6]. While this finding in itself was alarming, the authors of these studies and others were at pains to emphasize that, due to the limitations of plane film radiography, this figure was probably understating the actual extent of the problem [6].

It will be readily understood that an unerupted palatal canine is to be found closer to the palatal surface of the incisor roots than to any other surface of the root. Consequently, if there is root resorption of the incisor, it would be logical to assume that it will be palatal surfaces that are most likely to be affected. By the same token, a labial canine may cause similar damage to the labial surface of the root of the adjacent incisor. Furthermore, because the canine generally approaches the root of the incisor from above, along a path that is at an angle to the long axis of the resorbing incisor, the resorption process usually affects the incisor roots obliquely. However, the labial and palatal surfaces of the roots of the teeth are generally impossible to view using traditional plane film radiography. It is these palatal and labial root surfaces that, if affected by resorption, are least likely to be recognized in plane film radiography; that is, until the extent of the lesion is sufficiently well advanced for it to alter the mesio-distal profile of the root or the relative radiolucency of its projected shadow.

In line with technical progress in the development of diagnostic radiology, computerized tomography (CT) presented the solution that could overcome this 'blind spot' in bucco-lingual imaging (see Chapter 4). Accordingly, when a similar study of root resorption was undertaken by the same researchers [7], this time using spiral CT scanning in place of the earlier plane film radiography, it revealed signs of root resorption in almost half the cases affected by an aberrant/ectopic and unerupted maxillary canine. The actual figures in this study showed 38% of lateral incisors and 9% of central incisors affected to a greater or lesser extent, or 47% of affected individuals in total. In a more recent study, in which the imaging modality employed this time was three-dimensional volumetric cone beam computerized tomography (CBCT), the figures were higher still, with 66.7% of adjacent lateral incisors and 11.1% of adjacent central incisors affected. All the cases that exhibited central incisor resorption also showed resorption of the lateral incisors and in all the cases in the study the impacted tooth and the incisor root were in close proximity [6].

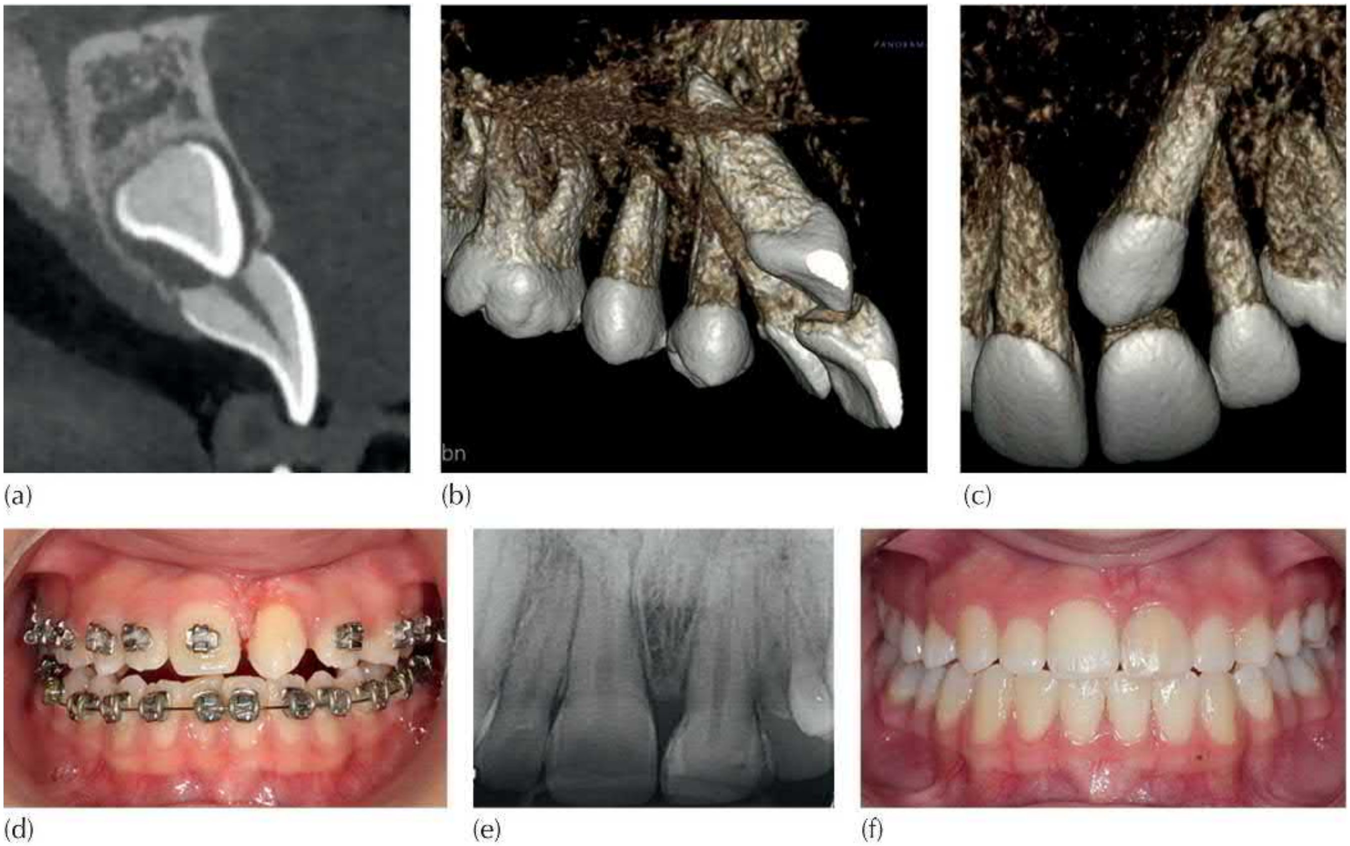


Fig. 9.2 An extreme example of resorption of the entire root of the central incisor, by the eruptive movement of the impacted canine, from the cone beam computed tomography (CBCT). (a) A cross-sectional slice. (b) The view from the right side in a CBCT 3D screenshot. (c) A frontal CBCT screenshot. (d) In the final stage of treatment to bring the canine into the place of the extracted incisor. (e) A periapical radiographic view of the relocated canine width provisional crown. (f) Intra-oral view of the completed rehabilitation of the canine in the guise of a consummate central incisor.

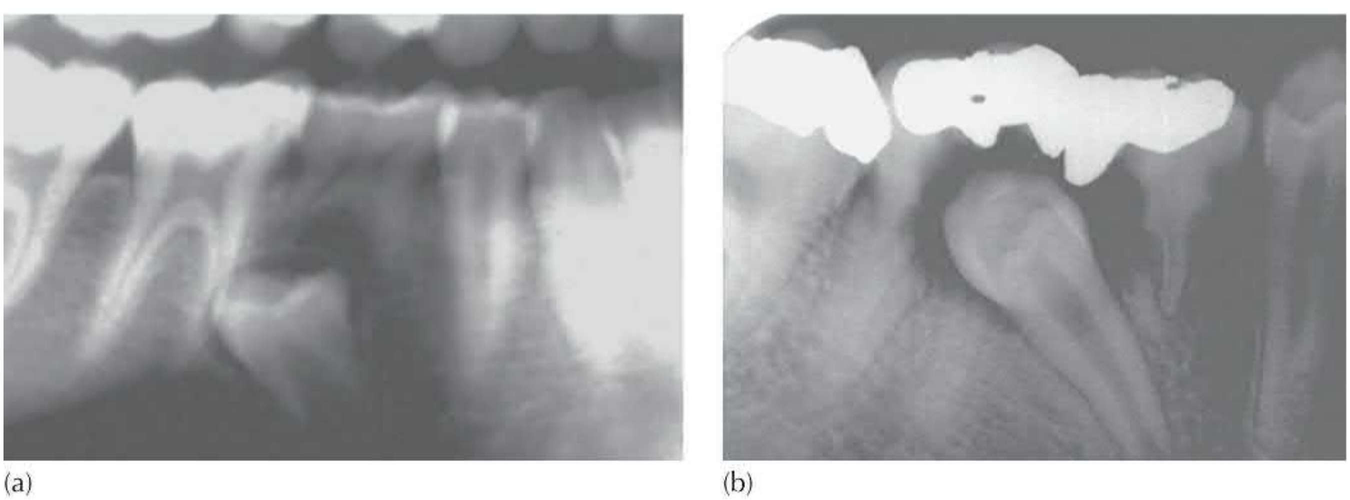


Fig. 9.3 (a) A section of the panoramic view of a female patient aged 12 years, showing a late-developing second premolar with a distal inclination. (b) A periapical view taken 2.5 years later. The second premolar had caused large-scale destruction both of the root and of the crown under the amalgam restoration of the first permanent molar.

Of course, in a significant proportion of the patients with an impacted canine in whom root resorption was shown to occur, the canines will eventually erupt and the roots of the incisors may suffer little or no further resorption in the long term. The eruption may be generated by a spontaneous change in the orientation of the canine in relation to the affected incisor root, as has been shown in anecdotal case reports [8]. Another trigger for the eruption may be due to orthodontic treatment carried out in order to create space for the canine by an appliance-generated movement of adjacent teeth [9–11], as described in Chapter 7, or by the prophylactic extraction of deciduous and/or permanent teeth [12–14] (see Figures 7.23, 7.26, 7.27).

Aetiology, diagnosis and prevention

Over the years, clinicians have searched for clues, specific tell-tale features, which may indicate a link between an impacted canine and the risk of incisor root resorption. Obviously, in the absence of any signs of premature occlusal contact or symptoms of pain, the mobility of an incisor would offer such an indication *after* the fact. However, the quest was for an associated anomaly or phenomenon in the dentition that could predict the occurrence of incisor root resorption *before* it occurred.

Two studies that investigated sexual dimorphism as a factor in the prevalence of this phenomenon found it to occur three to four times more frequently in females than in males [6, 7]. Single and multiple anecdotal case reports published in the orthodontic literature, as well as the author's own clinical experience, had indicated that, in relation to those cases in which the resorption was unusually extensive, affecting over more than a third of the incisor roots, the phenomenon seemed to be almost completely limited to females [15]. A study of these severe cases and their treatment was initiated by the Israeli group and its wide-ranging findings were published in 2005. Below are some of these findings:

- When a case of resorption of the root of an incisor occurs as the result of an impacted canine, the process is rapid and the patient should be treated with urgency.
- Once the impacted canine has been distanced from the root area, resorption ceases.
- The resorbed incisor can be subsequently moved orthodontically without further resorption, although radiographic monitoring is advised as a precautionary measure.
- The radiographic reappearance of an intact lamina dura, periodontal ligament and bony trabeculation in the periapical area are signs of cessation of the resorption process.
- At one year or more in post-treatment follow-up, even severely resorbed teeth are not unduly mobile and do not necessarily need to be permanently splinted.
- Root canal treatment in these cases, as a means of reducing further resorption, is inappropriate.
- The teeth are not discoloured and appear to have a fairly good long-term prognosis.
- Cases of the severity discussed here are rare, but there appears to be a much greater prevalence of the condition among females.
- Early radiographic monitoring of cases of aberrant canine eruption is needed to detect

resorption as early as possible.

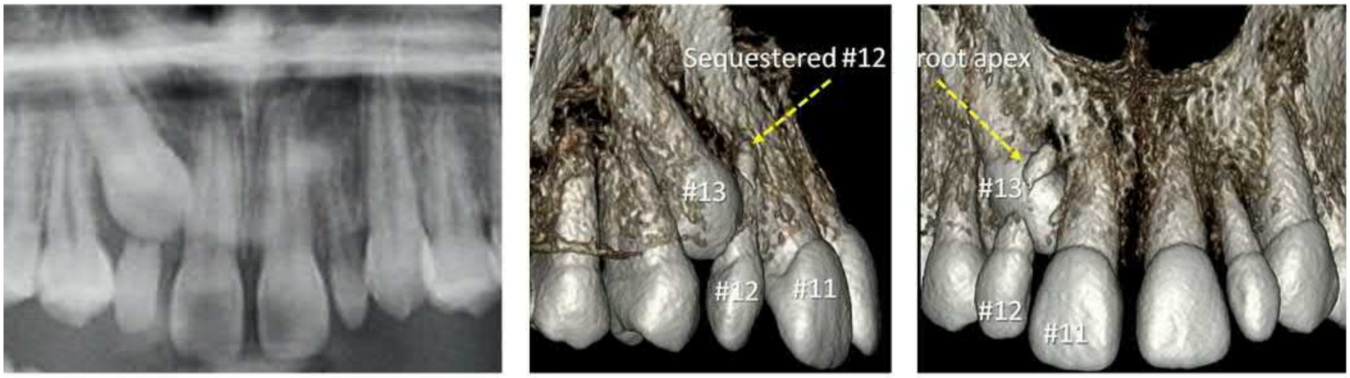
- Surgical exposure and orthodontic traction of the canine should be performed as early as possible, even before other stages in the treatment plan are undertaken, e.g. levelling and aligning, space opening, etc., which would normally take precedence.

Another factor that has been investigated is the question of whether the presence of an enlarged dental follicle surrounding the crown of an impacted canine is an indication of root resorption. Two studies were performed by Ericson and Kurol's Swedish group and they found there to be no apparent cause-and-effect relation between an enlarged follicle and root resorption [6, 15]. Notwithstanding that, other clinicians have indeed expressed concern regarding this question [16].

A majority of cases where resorption has been confirmed show only a very mild and clinically insignificant degree of actual root loss, but this could be because we are dealing with young patients and the resorption lesion might still be in its relative infancy. However, it should also be remembered that all severely affected cases begin the pathological process that leads to this advanced state as a very small initial resorption lesion. If these had been diagnosed earlier, they may have markedly improved the prognosis. This reasoning provides part of the justification for the use of CT as a crucial tool for the establishment of a definitive diagnosis.

A good example is presented in Figure 9.4a, in which the very clear image of the right impacted canine superimposes on the root of the adjacent lateral incisor. This anterior segment of the panoramic view gives no indication of the presence, length, shape or integrity of the root of the incisor. On the left side, where the adjacent canine had erupted autonomously, there appears to be a degree of radiolucency in the distal aspect of the cervical area of the left lateral incisor. When a CBCT was performed (Figure 9.4b, c), the unerupted right canine could be seen nestling in what had hitherto been the mid-coronal portion of the root of the incisor. Almost the entire root had been resorbed by the advancing canine. The sequestered apical portion appears to have escaped the resorptive appetite of the canine 'aggressor' (see Online PPT & video Fig. 9.4).

As we have pointed out in Chapter 7, a number of studies relating to the aetiology of palatal canine impaction have been published over the past 20 years. These studies have established a firm link between palatally displaced maxillary canines and anomalous lateral incisors. However, in the course of an investigation of the prevalence of resorption of an incisor adjacent to a palatal canine, the presence of anomalous incisors appeared to be less frequent. Indeed, the phenomenon was found more often to be associated with a normal-sized adjacent lateral incisor [17]. A plausible and logical reason for this distinction may be that anomalous lateral incisors are part of the aetiological milieu of canine impaction (arguably due to lack of guidance), but are less likely to be associated with incisor root resorption (arguably due to the presence of excess space). In contrast to this reasoning and in relation to incisor root resorption, the reverse is true: it is arguably due to crowding that may be associated with normally sized incisors.



(a) (b) (c)

Fig. 9.4 (a) The panoramic view of the anterior maxilla in this 13-year-old girl shows the right canine apparently superimposed on the root of the very small lateral incisor. (b, c) In the 3D screenshots of this case, the canine is seen to have been associated with severe resorption of the middle part of the root of the lateral incisor and to have sequestered its apex. The picture gives the surreal impression that the root of the peg incisor is continuous through the crown of the canine. See Online PPT & video Fig. 9.4.

The conclusion drawn from this study clearly demonstrates that the practitioner would be well advised to investigate the possible existence of resorption in any impacted canine patient who shows no lateral incisor anomaly. This factor should be taken into consideration in deciding the strategy of the orthodontic treatment and the timing and sequencing of the individual tasks within the overall treatment plan.

Treatment

When the diagnosis is made of impacted canine-related resorption of the incisor root, a lack of positive action on the part of the orthodontist or surgeon carries with it the danger of further resorption of the root of the incisor. Furthermore, for as long as the impacted tooth remains in close proximity to the resorbing root, its continued penchant for resorptive chaos remains and may even worsen, as a result of any initial orthodontic alignment or any continuation of space-gaining procedures that may have been under way. The resorption process seen in many of these cases is rapid and it has been shown conclusively that it will advance significantly during the preparatory levelling, aligning and space-gaining orthodontic phase [16]. On the other hand, as has been pointed out earlier, the creation of space in the arch by moving the adjacent teeth, one or more of which are themselves being actively resorbed, might be a factor that will change the course of the canine, causing its eruption path to deviate favourably and to spontaneously erupt (Figure 9.5). This represents a more passive approach to increasing the distance between the two teeth, and is characterized by attempting to move the resorbed tooth/teeth away from the canine. However, the canine has already proven itself able to advance and resorb, and there is no evidence to contradict the concern that perhaps the canine may actually follow close behind the appliance-generated movement of the adjacent tooth and continue its resorptive assault.

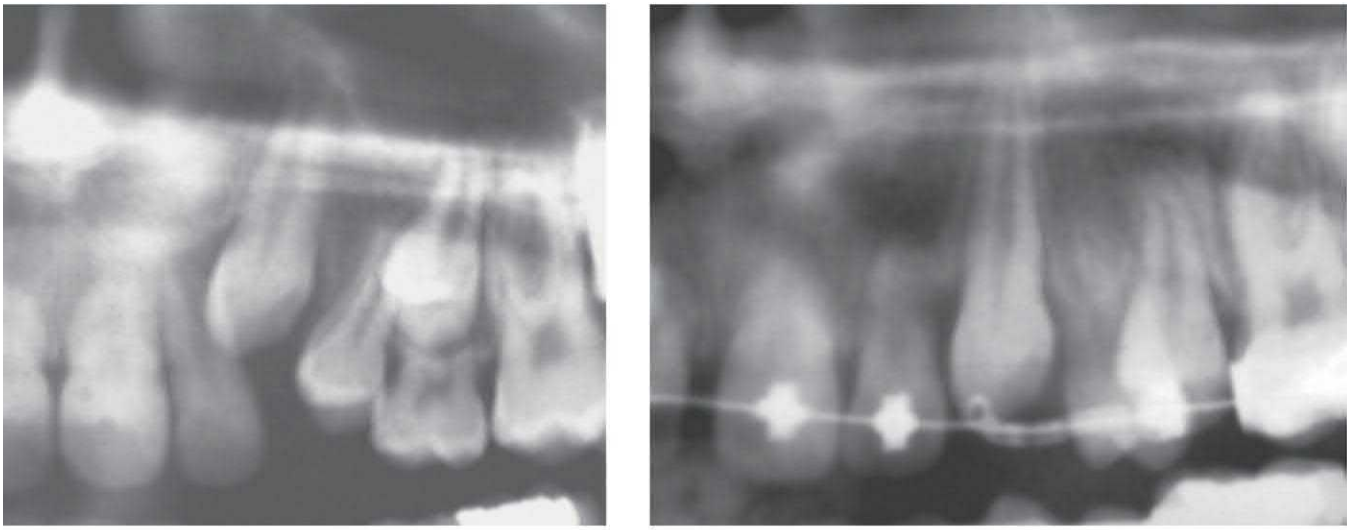
Following trauma to incisor teeth of young individuals, dental traumatologists and paediatric dentists recommend elective root canal treatment as a means of limiting or preventing the resorption that frequently occurs in these cases [18]. However, there is no evidence that the same treatment will minimize or eliminate the resorption caused by the proximity of an unerupted canine. These circumstances are very different and no decisions should be made based on an unsubstantiated parallel between the two.

Treatment options

Three possible lines of treatment are available, and each has its advantages, disadvantages, unanswered questions and a manner in which it influences the outcome.

First option: Extract the impacted tooth

One of the very basic principles in medicine is that, in order to successfully treat a disease, it is necessary to remove the cause. In the present context, the cause of the resorption is the unerupted tooth, and simple logic will dictate that its extraction will offer the bonus of eliminating what may be a problematic impaction, from the point of view of the provision of surgical access and mechano-therapeutic difficulties. However, if this apparently logical line of treatment is followed, then a healthy canine will be extracted and the incisor with the resorbed root will be left in place. Then, if significant root loss has occurred and the remaining root is very short, it may be reasonable to assume that the tooth does not have a long-term prognosis.



(a) (b)

Fig. 9.5 Root resorption, space opening and spontaneous eruption. (a) The left impacted canine has caused a marked oblique resorption in the root of the lateral incisor. (b) Following the orthodontic creation of space, the canine is seen to be erupting spontaneously, revealing the much resorbed lateral incisor. Both central incisors have short rounded roots, for which, and despite their distance from the impacted tooth, the canine might indirectly be held responsible.

If the incisor is not in its ideal position, it will need orthodontic treatment to move it into alignment. In the past, it had been considered chancy to prescribe orthodontic treatment for fear of re-kindling the resorptive process in the already damaged tooth, thus potentially adversely affecting its prognosis still further. It has, however, been clearly demonstrated that further resorption is unlikely to occur once the canine has been distanced from the resorption area and, specifically, that actual subsequent movement of the affected tooth will not be accompanied by renewed resorption [16]. If an implant is contemplated as the ultimate substitute for the extracted canine, accurate root-paralleling movement of the resorbed lateral incisor will be mandatory in order to provide adequate space between the roots of the adjacent teeth.

Alternatively, it may be wiser to draw posterior teeth forwards in order to close the space. This would increase the length of time that orthodontic forces will need to be applied to this endangered tooth, thus again reducing its prognosis still further. Although it could be argued that perhaps a fixed cast bridge might reduce the amount of orthodontic movement to which the tooth will need to be subjected, it should not be forgotten that a resorbed lateral incisor will also not make a reliable abutment. With a premolar in the canine position, the appearance may be mildly compromised and canine protection of the occlusion would not be present.

We have learned the welcome fact that distancing the canine causes arrest of the resorptive process. Notwithstanding that, when the resorbed tooth is required to undergo complicated orthodontic manoeuvres, which will often involve extensive root uprighting and torqueing and even using the tooth as an anchor unit in the closing of extraction space, then we must be prepared that perhaps the compounding of these multiple factors may eventually take its toll. This must be evaluated at the planning stage and monitored during the treatment.

In these severe situations, leaving the deciduous canine in its place in the hope of its enjoying long-term survival must be considered a real possibility. Given the degree of displacement of the aberrant canine, it is quite likely that the root of the deciduous canine has remained untouched by the normal resorption process affecting deciduous teeth and, in such a case, the tooth may last for many years before implant and/or prosthetic replacement is needed. However, if its position needs to be altered as part of the overall treatment of the malocclusion, or in order to enable the placement of an appearance-improving restoration, then such necessary orthodontic movement may itself trigger the physiological resorption that may not otherwise have occurred.

Second option: Extract the resorbed tooth

Extracting the 'victim' tooth, i.e. the incisor tooth that has suffered resorption due to the eruptive behaviour of the canine, may appear unjust, but it must be considered as the pragmatic choice on the assumption that it has a poor prognosis. By its extraction, the treatment of the impaction is much simplified. Whether or not the deciduous canine will also be lost in the overall long-term planning strategy, the permanent canine would be aligned in the lateral incisor site, with the accompanying poor appearance and lack of a canine-protected occlusion [16, 19]. To address the aspect of the poor appearance, orthodontists, prosthodontists and 'aesthetic' dentists might prefer aligning the impacted canine in its normal place in the arch and performing a one-tooth implant to rehabilitate a lateral incisor and thus to achieve a more normal and uncompromised appearance [20].

Third option: Non-extraction

This is perhaps the most difficult and most adventurous line of treatment, the more so since the literature offers little evidence for us to believe that the outcome can provide hope for a stable future. In the first place, without the expedient of extraction the canine impaction is much more difficult to resolve, since the tooth will need to be surgically exposed, attachment bonded and drawn away from the resorbing root, in a separate orthodontic manoeuvre, before the more usual directional forces are applied to bring it to its place in the arch. In the second place, the lateral incisor has a shortened root and will almost certainly require to be moved orthodontically. It may need to be splinted for the duration of its assumed reduced life-span. Thirdly, this incisor may become non-vital as a byproduct and complication of the surgical exposure and may subsequently require root canal treatment. These factors appear likely to reduce its long-term prognosis still further.

On the other side of the scale, it has been noted in the previous chapter that most palatally impacted canines and a minority of buccally ectopic canines are to be found in conditions of spacing and the mildest malocclusions. These may generally be considered to be non-extraction cases. Accordingly and logically, this approach potentially offers the prospect of the greatest gain for patients and, if carefully managed, may even provide a method of allaying their worst fears.

Fourth option: 'Wait and see'

It has been proposed that there is a fourth alternative in this situation – a 'intentional inactivity' or 'wait and see' option (Figure 9.5). An anecdotal series of three cases has been reported in all of which severe resorption of incisor roots had been noted adjacent to impacted maxillary canines [9]. The patients were followed up clinically and radiographically for a long period on a half-yearly recall basis, without treatment of any sort being provided. Each of the canines eventually erupted, although the progress of spontaneous resolution of the impaction generated further root resorption. It is a *sine qua non* that additional damage to the roots of the adjacent incisors was fully anticipated at the outset in these three patients, both by parents and patients, although the full extent of its expression could not be predicted. It is therefore reasonable to assume that the significant risk that these teeth would be lost during this observation period was accepted as a calculated decision. The dilemma that faced the clinicians was whether more damage would have been inflicted iatrogenically had the impacted teeth been treated by the orthodontic/surgical modality.

It is germane to attempt to answer this question in relation to group 6 impacted canines in general. To do so, it becomes necessary to examine the anatomical, surgical and orthodontic contexts of the dilemma and discuss the several factors that need to be carefully considered.

The anatomical context

The first factor addresses the anatomical relationship between the impacted tooth and the tooth afflicted by the resorption and their respective locations in the alveolar process. The adjacent incisor tooth is located in mid-alveolus, in the bucco-lingual plane, having been the first to erupt some three to four years earlier. The palatally impacted canine generally follows a high and mesially angulated path towards the root of the incisor. The approach of a palatal canine is on the distal or disto-palatal aspect of the root of the incisor, some way down the root from the apex (Figure 9.5), while a buccal canine will be on the disto-labial side. Resorption occurs in the precise area where there is maximum proximity of the two and will only be discernible radiographically if it also affects the distal profile of the root of the incisor and is not hidden by the superimposition of the two teeth.

In some of the most extreme cases, which are the subject of the present discussion, the canine is not guided by the distal surface of the root of the incisor, but rather comes down from above its apex, obliquely resorbing most of the full width of the root as it progresses inferiorly into the area vacated by the resorbing root.

The canine will also be situated in mid-alveolus. In one scenario, further progress finds the incisor root being resorbed obliquely, with the destruction proceeding coronally at an alarming rate, until the crown of the still-unerupted canine reaches one side of the CEJ of the incisor. At this point no further resorption can take place, since the enamel of the tooth crown will not resorb but will act to deflect the progress of the canine to one side, where it may then erupt. The incisor does not then shed naturally, since the oblique resorptive process will have left a longish spicule of root that will hold the tooth in the alveolus, although the tooth may (but not necessarily) become slightly mobile. The incisor crown is also likely to be displaced in the opposite direction to the canine's new eruptive path due to the eruptive force of the latter acting obliquely on one side of the incisor's CEJ.

The surgical context

If we are to try to change the course of what appears to be inevitable, i.e. serious damage or even loss of the tooth by resorption, it would be logical to attempt to distance the canine from the resorption area immediately after the diagnosis has been established. In the orthodontic/surgical modality of treatment, this means that surgical access must be provided and an attachment placed. This will enable appropriate orthodontic forces to be applied direct to the tooth in order to effectively draw it away from the immediate area, by diverting it from its present eruption path.

Because of the inter-relationship between the crown of the impacted tooth and the resorbing root apex of the incisor, accuracy of positional diagnosis is vital to avoid simultaneous collateral surgical damage to the root area of the incisor tooth. A wide flap is reflected, exposing the crown of the impacted tooth immediately beneath its thin bony covering. A small opening is made in the bony crypt to expose that area of the crown of the impacted tooth most superficially accessible and most distant from the resorption site. No attempt should be made to seek out the root apex of the incisor, or even to 'gently probe' the area.

It will be appreciated that good radiographic diagnostic technique (specifically CBCT) should be considered an essential diagnostic aid that will contribute enormously to the accurate determination of the preferred exposure site. From the resultant images produced it will be possible to establish the direction in which the tooth must be moved. This may be in a labial direction or in a palatal direction, depending on the labio-lingual location of the crown tip vis-à-vis the residual root end.

In this situation, exposure of the crown, clearance of the follicle and bone removal to the maximum width of the crown and down to the CEJ (as recommended by Kokich for the more accessible palatal canines [21]) would appear to be strongly contraindicated, since it will surely inflict unnecessary trauma to the resorption area and lead to devitalization of the incisor.

In these highly sensitive situations, it is recommended that the area of crown to be exposed, should be on an aspect of the crown as far as possible from the site of resorption. It should be exposed minimally, with an opening only large enough for placement of the small eyelet, while permitting adequate haemostasis during the bonding procedure (Figure 9.6b–g).

An eyelet attachment is then bonded on the enamel surface of the tooth, in the most accessible site available, and the twisted steel ligature is made to point in the direction of the traction that will be applied. The full flap is then sutured back into its former place, leaving only the ligature wire peeking through it, either at the sutured edge or through a small pierced hole in the flap, but in the direction that traction has been determined. Primary closure is essential in these cases, to protect the wound from damage or infection of the vital tissue at the root end of the lateral incisor.

If, following the earlier resorption, the canine crown tip has crossed over to the labial side of the incisor roots, a labial resolution will be required and a labial surgical approach is to be preferred. In this case, the attachment needs to be bonded in a convenient place on the crown and its ligature protruding through the flap, high in the labial sulcus. If the tooth is palatal, a palatal approach will be dictated, with the palatal aspect of the tooth being exposed and an attachment bonded there. Traction will need to be directed in the horizontal plane in a posterior horizontal direction. If the cusp tip of the canine crown is vertically above the resorption-truncated incisor root, the tooth should not be drawn vertically downward towards the main archwire or elsewhere, neither on the palatal nor on the labial side of the alveolar ridge, until it is well clear of this impediment. Failure to take this important precaution will increase the propensity of the canine for resorbing the incisor root. It will undermine the anchorage and will arrest any progress of resolution of the impaction.

The orthodontic context

As discussed in Chapter 8, directional traction must be designed to meet the demands of each individual case. Nowhere is this more crucial than for the cases that we are discussing here.

Ballista springs [22] and light auxiliary arches [23], as described in Chapters 6 and 7, are particularly suited to the provision of light continuous and directed force over a wide range of movement. They are useful when designed to produce forces in a labial or vertically downward direction and they may be directionally modified to include apical or mesio-distal force components. These are sometimes helpful in elevating a canine over the root apex of an incisor or drawing it in a wide labial sweeping movement around the root of the adjacent tooth.

When a canine needs to be moved posteriorly in the horizontal plane, one may use a transpalatal arch carrying three or four welded or soldered loops. Elastic thread may then be tied from the steel pigtail wire or gold chain, which is ligated to the eyelet attachment on the canine, to one of the soldered loops most suitably placed to provide the optimum directional pull. Exploiting the lingual cleat of a molar band may sometimes be adequate in many of these cases. Using these simple and mainly custom-designed accessories, rapid movement of the crown of the impacted canine may effectively and significantly separate it from the resorption area.

It is clear that, in cases where the canine crown is in close association with a resorbing incisor root, it is quite inappropriate to adopt Kokich's approach [21], since that is more suited to open surgical exposure of an impacted canine uncomplicated by resorption of the root of the incisor. It will be recalled that the Kokich recommendation involves bone and follicular tissue being completely eliminated around the full width of the crown of the buried tooth, down to the CEJ, and a large circular opening being made in the thick palatal mucosa, with placement of a periodontal pack to maintain its patency.

To adopt this method in the present context would seriously endanger the vitality and survival of the resorbing incisor. It would potentially be very damaging for a case where canine-related incisor root resorption is present. The sole remaining alternative is to follow his counsel 'not to interfere with Mother Nature' in a hoped-for trade-off between the uncertain likelihood of spontaneous eruption and the near certainty of additional collateral resorption [9, 22].

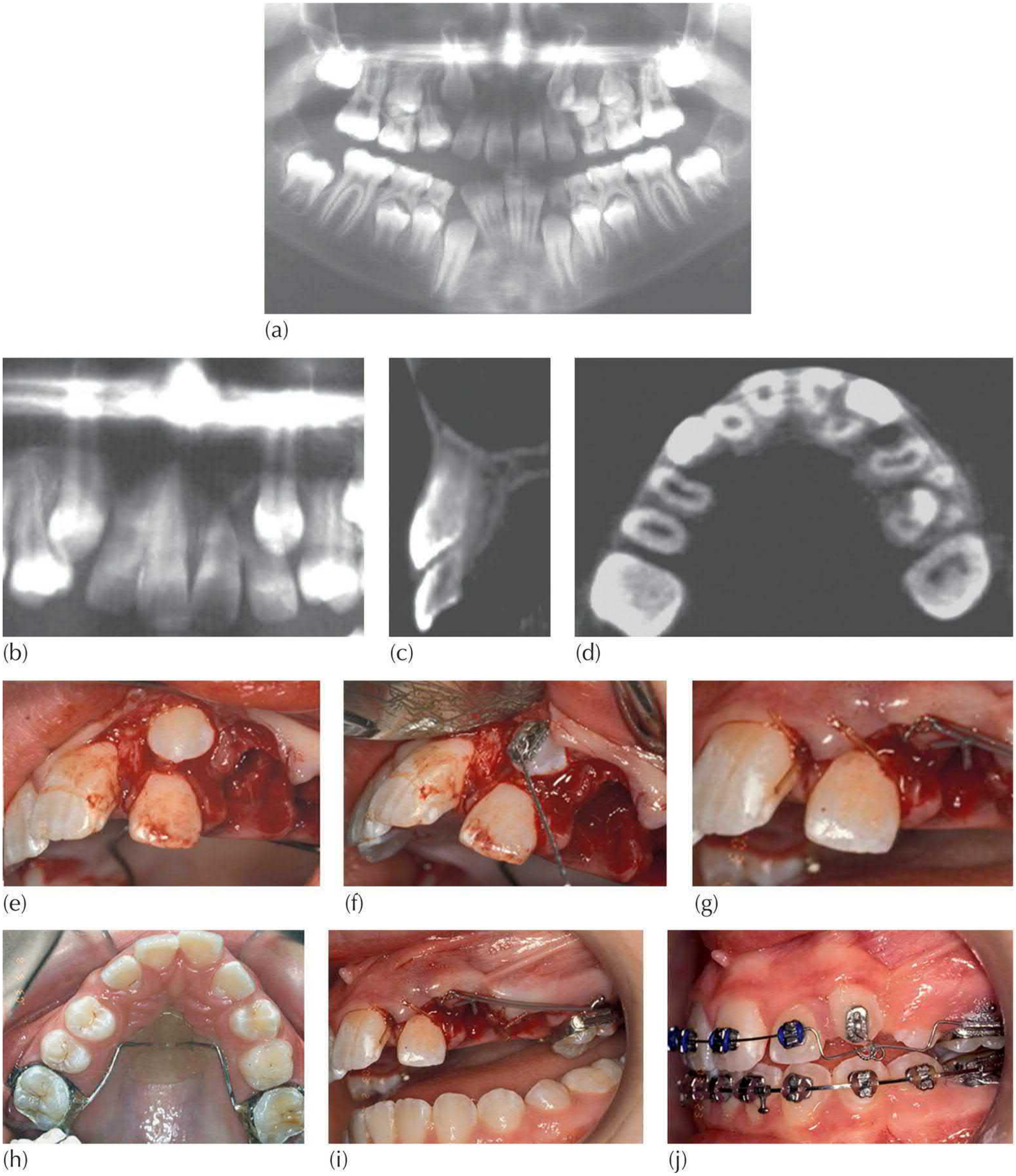

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Fig. 9.6 (a) A poorly executed panoramic radiograph of a female patient aged 10 years, showing no apparent incisor root resorption. (b) A new panoramic view of the premaxillary area of the same patient taken two years later shows unerupted canines. The crown of the left canine is encompassed by an enlarged follicle/dentigerous cyst and the four incisors show root resorption, which is more severe on the left side. (c, d) The cone beam computed tomography cross-sectional and axial views show the canine migrating into the resorption crater it had carved in the incisor roots. (e) Closed surgical exposure. A flap of attached gingiva was raised from the crest of the ridge. (f) An eyelet is bonded with vertical orientation of the eyelet. (g) Full replacement and suturing of the flap, with elastic traction applied to the twisted and shortened twisted ligature hook. (h) Initial traction set-up. A transpalatal arch soldered to two molar bands, with a Nance acrylic button for anchorage, was placed before the surgery. (i) The first premolar and second deciduous molar were extracted at the time of surgical exposure of the labially impacted canine. An elastic tie was drawn directly from the bonded eyelet to the molar hook as an integral part of the procedure. (j) The anterior orthodontic brackets were placed five months after the surgery and only after the canine had been sufficiently distanced. (k) Immediately following debonding of the appliances. (l, m) Periapical views of the teeth immediately prior to debonding. (l) The right incisor roots are rounded and obviously resorbed, but to a modest degree. (m) The dull radiolucent shade of the root of the left incisors indicates a longitudinal resorption of the area on the labial side of the root, opposite the erstwhile location of the canine. The left central incisor root was short and its end irregular. Nevertheless, it does not seem to be more resorbed than in the pre-treatment films. (n) Follow-up periapical radiographs taken at patient's five-year post-treatment recall visit. (o, p) The excellent appearance of the final result.

For the past 40 years or so, in a large proportion of impaction cases, the Jerusalem research group has employed the closed exposure approach with the application of directional force, as has been described in this text. As a major referral centre for the treatment of impacted teeth in the wider geographical area, a disproportionate number of cases have been referred to us, particularly those with severe resorption, but also including other, equally serious and difficult forms of ectopy. The findings of investigative studies [16] have enabled us to draw favourable conclusions. The standard procedure dictates that a conscious effort be made, during the surgical episode, to expose a limited area of available enamel surface and to place a bonded attachment. An efficient light directional orthodontic means of traction, with a wide range of activation, is then immediately applied. The patients have been rewarded with an eruption process that has occurred with considerable speed. The periodontal and aesthetic results will have made the previously impacted teeth indistinguishable from their normally erupting antimeres and from other untreated teeth.

To summarize the points from this discussion, it should become clear that the first and most urgent priority to be addressed is the phenomenon of root resorption of the incisor tooth due to an impacted canine, which will need to be treated by distancing the canine. The earlier this is done, the greater the chance of preserving as much of the root of the affected tooth as possible. It should precede all other goals of the orthodontic treatment, including relegating to second place the essential orthodontic opening of space in the arch for the canine,

Exposing the impacted tooth without devitalizing the adjacent tooth

As with any impacted tooth, the use of radiographic imaging for accurate positional diagnosis and for scouring the immediate area for additional pathology is of extreme importance, before embarking on arresting the root resorption. In the context of pre-surgical planning, a CBCT should be considered mandatory. Logic dictates that a labial canine needs to be exposed from the labial side and orthodontic traction similarly directed, while a palatal canine needs to be exposed and traction applied from the palatal aspect. However, many of the impacted canines that cause root resorption will have advanced into the resorption defect of the root itself and will accordingly be located to a greater or lesser degree within a progressively enlarging apical resorption crater. The hollowed-out crater will often have a peripheral lip, which may be higher on one side than on the other, with the crown of the canine located within it. This canine is neither labial nor palatal to the line of the arch and traction may thus be applied from either the labial or palatal sides. It would be wise to draw it to the side where the lip of the crater is lowest, which can only be accurately seen on a good CBCT slice. However, it will be appreciated that exposing and bonding an attachment to the crown of the invading canine is fraught with risk and carries with it the distinct possibility of causing loss of vitality of the affected incisor, with all that that entails.

Case 9.1: Poor radiography causes belated diagnosis

The panoramic film in Figure 9.6a relates to a female child aged 8.5 years and illustrates an apparently normally developing dentition, with unerupted canines, premolars and second molars, as would be expected at this age. According to the extent of root development and the absence of apexification of the roots of the erupted permanent incisors and molars (see Chapter 1), the dental age of the child was 8–8.5 years. There was a marked degree of potential crowding for the maxillary canines, with their crowns enclosed by enlarged dental follicles. This panoramic radiograph was of low quality, but the patient refused to submit to a re-take. The orthodontist evaluated the radiograph as best she could, decided that orthodontic treatment would be premature at the time and requested that the child return with a new panoramic radiograph a year later. Incisor root resorption was not apparent on the radiograph at the time.

The child only returned two years later and the new radiograph indicated an enlarged follicle/dentigerous cyst encompassing the unerupted left canine, associated with severe resorption of the roots of both left-side incisors (Figure 9.6b). The right-side incisors were affected to a lesser degree. In order to evaluate the resorption further, a CBCT was performed and the cross-sectional and axial slices showed an advanced oblique area of resorption replacing most of the root of the tooth, associated with the labially superimposed and unerupted canine (Figure 9.6c, d).

Having determined on which side of the alveolus to perform the exposure, it was important to decide, together with the surgeon, whether an open or a closed procedure would best be advised. A closed procedure was executed by raising a broad, full-thickness flap from the attached gingiva around the necks of the teeth and extending it superiorly by blunt dissection, to reveal the underlying bone (Figure 9.6e). The immediate surgical field comprised a very thin shell of bone, which was not visible either on radiographs or on the CBCT (Figure 9.6b–d). The impacted canine lay beneath this thin bony layer and separated from it by the enlarged dental follicle. Using the various radiographic and CT images as guides, the exact locations of the crown of the tooth and of the resorption front were accurately determined on the exposed bony surface. The thin bony cover was then lifted off, as close to the tip of the cusp as possible, to expose the dental follicle immediately over the crown of the tooth. More importantly, however, it was recognized that it must be as far away from the resorption front as possible. The opening in the follicle was small, but large enough for the orthodontist to bond a small eyelet attachment (Figure 9.6e, f).

The treatment plan called for the extraction of the maxillary first premolars, together with the deciduous left second molar at the same time as both canines were exposed, with an eyelet attachment bonded to each (Figure 9.6e, f). An appliance had been prepared ahead of the surgery, which was based on a transpalatal arch soldered to molar bonds and incorporating an acrylic Nance button, to take advantage of the palatal vault as a source of anchorage. At this sensitive point in time in terms of the resorption of the incisor teeth, this comprised an adequate anchor base from which to apply traction on the canines.

Direct elastic traction was applied to the twisted steel ligature connector that exited the inferior edge of the re-sutured surgical flap (Figure 9.6g–i). The elastic chain was engaged directly in the buccal hook of the molar band, prior to the more usual sequence of orthodontic treatment procedures.

Once the canines were both clear of the roots of the incisors, orthodontic brackets were placed on the incisors. Brackets were exchanged for the eyelets that had been placed on the canines at the surgical exposure visit, only when the canines were adequately erupted in their targeted locations (Figure 9.6j). Orthodontic treatment duration was 19 months and the appliances were removed (Figure 9.6k) in favour of a removable retainer.

The periapical radiographs that were taken to reassess the root resorption and the prognosis of the continued presence of the incisors (Figure 9.6l, m) showed remarkably little change from their immediate pre-treatment radiographs. Furthermore, the bony picture was excellent, showing regeneration of bone in areas that had earlier shown much bone loss.

The patient remained under review for a further five years post treatment. The subsequent periapical radiographs indicated excellent bony recovery and good bony trabeculation, and an unchanged arrested resorption status of the incisor roots (Figure 9.6n). Furthermore, the clinical appearance of the teeth, the height and quality of the gingivae in relation to the adjacent normally erupted teeth, was excellent (Figure 9.6o, p).

Can the resorbed tooth be moved without causing further resorption?

The aetiology of resorption of the root of a tooth adjacent to an impacted tooth is closely associated with the proximity of the latter and its potential for eruptive movement. This is both the precipitating and the continuing factor for the resorption and will continue to exist so long as the impacted tooth remains in the immediate vicinity. There is good clinical evidence to show that further resorption, *from this cause*, will not occur after the impacted tooth has been distanced [16]. On the other hand, it would be prudent to recognize that the affected tooth had re-started its life with a potential disability. It would be tempting providence to unnecessarily extend treatment for many months in the quest for ‘perfection’, when good results in terms of health, function and appearance may perhaps be achieved with less.

During the period of active root resorption, the immediate area of alveolar bone is rarefied and appears on a radiograph as a dark radiolucency. The tooth itself exhibits a varied degree of mobility, depending on how much of the root has been lost. While the impacted tooth is being moved away from the immediate area, the resorbed tooth must be treated with great care. It should not be used as a support for the orthodontic appliance or a counterbalance to forces exerted elsewhere. With certain exceptions, the tooth should not carry a bracket or be tied into the orthodontic scheme until several months later.

In the weeks and months of treatment that follow, the impacted tooth will be moved away. The resorbed tooth will quickly become much firmer due to the deposition of new bone at the former resorption front, which will be clearly discernible on a routine periapical film. However, in view of the reduced root length, correspondingly reduced forces should be used, in order to maintain a physiological level for the ratio of force per unit of root surface. Six months or so should be allowed to elapse before a bracket is placed on the resorbed incisor and the tooth included in the overall orthodontic scheme. Care should be exercised in applying orthodontic forces in the first weeks thereafter to move it into its desired position, and before including root uprighting and torqueing forces. Functionally optimal rather than ideal finishing procedures should be the rule and all duly monitored on periapical radiographs, but stricter standards of excellence may finally be offered to many and even most of these cases in the final instance.

Since the resorbed incisor is vital, and assuming its crown is of normal shape and colour, the likelihood of achieving a normal appearance is excellent. If the impacted tooth has been erupted through attached gingiva, its periodontic parameters will be good (Figure 9.7).

Case 9.2: Treatment in the presence of root resorption – when should treatment be discontinued?

Figure 9.7 follows the progress of an 11-year-old female treated in the early 1990s, in whom the aberrant left maxillary canine had caused severe resorption of the adjacent lateral incisor, although this was not known at the outset. In the initial condition, the overall orthodontic condition appeared very minimally compromised (Figure 9.7a). The occlusion was class I, with good alignment and interdigitation of the posterior teeth on the right side, a rotated right canine, good incisor alignment and a normal overbite and overjet. The left side showed the over-retention of the left maxillary deciduous canine and some minor space loss for the left second premolar in the lower jaw for the erupting second premolar. The anterior section of the lateral cephalogram (Figure 9.7b) showed the labially ectopic maxillary canine, while the central section of the panoramic film (Figure 9.7c) depicted the superimposition of the canine on the root of the lateral incisor. The superimposition made it impossible to determine from these planar radiographs (Figure 9.7d, e) whether or not there was a root on this tooth, despite the fact that clinically the tooth was not mobile. The case was treated before the advent of CBCT imaging.


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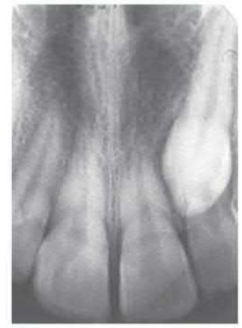
(c)


(d)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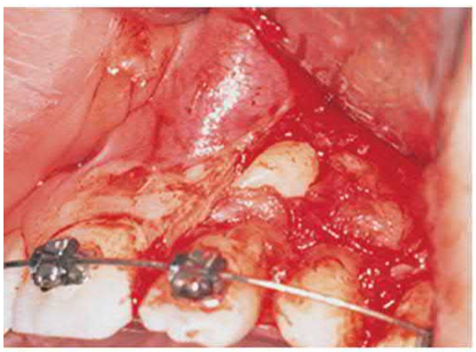
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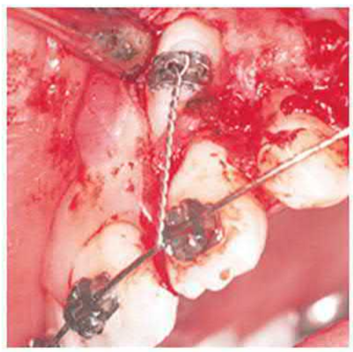
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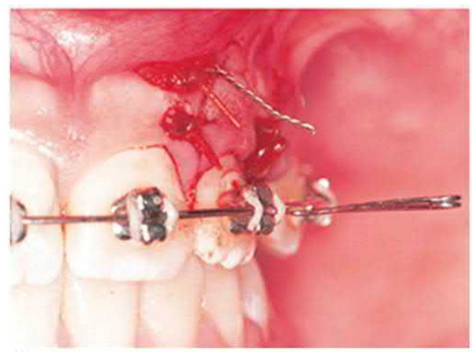
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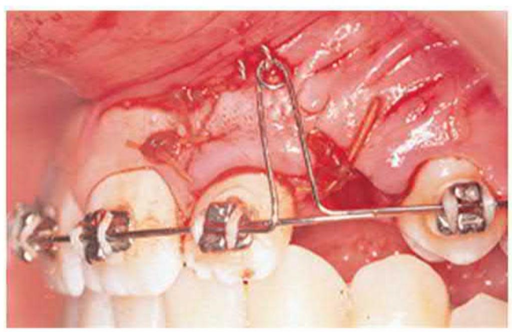
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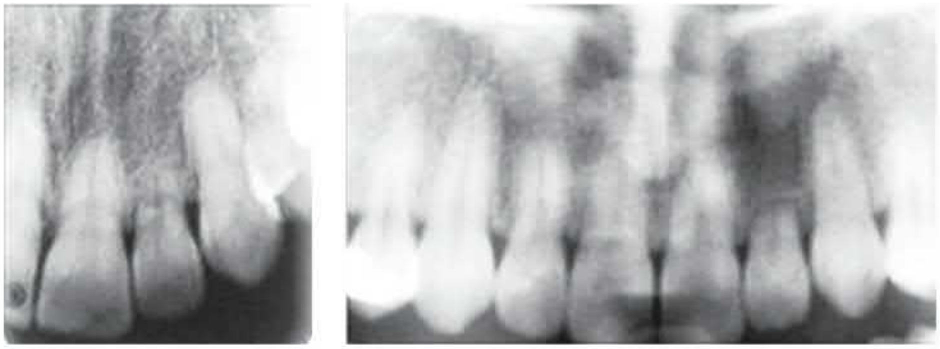


(r) (s)

(t)

Fig. 9.7 (a) Initial clinical intra-oral views of the dentition. (b, c) Section of the lateral cephalogram and panoramic film. (d, e) Two periapical views confirm labial impaction using the tube-shift method. (f) Full attached gingival flap in a closed surgical procedure. (g) The eyelet with twisted pigtail ligature. (h) The passive relationship between pigtail ligature and auxiliary archwire. (i) The occlusal view showing the horizontal, passive position of the traction loop of the auxiliary archwire. The unengaged twisted steel ligature exits through the surgical flap. (j, k) The loop has been raised and ensnared by the ligature. (l) At one month post surgery. (m) At two months post surgery. (n) At three months post surgery. (o) Periapical radiograph checking for the status of root resorption. (p) Post-treatment intra-oral views. (q) Post-treatment periapical radiographic views. (r, s) A periapical view of the resorbed lateral incisor and the anterior section of the panoramic view 7.6 years post treatment. (t) The intra-oral views at 7.6 years post treatment.

Surgical exposure of the tooth was limited to revealing only the disto-labial aspect of the crown of the canine (Figure 9.7f–h). The photograph in Figure 9.7g) was deliberately taken at this angle to illustrate how the orientation of the canine was in the same long axis as the lateral incisor inferior to it. A clinical assessment of the inter-relationship between the two indicated that the canine was clearly moving into a freshly resorbed area of incisor root. An eyelet was bonded to the disto-labial corner of the crown of the tooth and its pigtail ligature may be seen hanging loosely downwards. Traction was directed in a horizontal and labial path in order for the tooth to move away from the incisor root. The auxiliary arch was tied into the brackets of all the teeth in the dental arch in its passive mode, with the loop lying horizontally, ready to be raised and ensnared in the shortened and hooked pigtail ligature that was passed through a pin-sized hole in the fully re-sutured flap (Figure 9.7h). The loop was flexed upwards with light finger pressure and engaged by the pigtail ligature (Figure 9.7i–k). This auxiliary arch produced a light and highly controlled force acting on the canine. However, in this location and with this approach, erupting it through attached gingiva is not possible. There is no alternative direction to which this tooth can be successfully diverted without further clashing with the incisor.

The plan here was to await some improvement in the location of the canine, as would be indicated by the tooth bulging the oral mucosa on the buccal side. Then the tooth would be re-exposed using an apically repositioned flap procedure in order to place attached gingiva on the labial side of the tooth.

The child was seen one month post-operatively (Figure 9.7l) and the tooth had already partially exited through the oral mucosa, At two months post surgery (Figure 9.7m), the crown of the tooth had obviously cleared the root of the incisor. Accordingly, a distal direction of traction was applied, with a measured length of steel tube holding open the space between the incisor and the premolar. The disto-labial location of the eyelet permitted elastic traction to distalize the tooth without incurring undesirable rotation (Figure 9.7n).

At three months post surgery, the tooth had moved opposite its place in the arch and an orthodontic bracket was substituted for the eyelet, in preparation for the finishing phase of treatment. The periapical radiograph taken at five months post surgery, in order to check the status of the root resorption, presented considerably more root than had been realized at the outset. The appearance is typical of an oblique resorptive lesion, in which the labial side of the tooth had been 'shaved' off, leaving a long spicule of root on the palatal side of the tooth, visible on the periapical film as a more transparent and less contrasting texture.

In the 1990s when this case was treated, there were no evidence-based guidelines in the literature to indicate whether the resorptive process would gather momentum or would arrest when orthodontic forces were continued after resolution of the impaction. In view of the severity of the resorption process in this case, over-meticulous attention to root uprighting and torqueing of the lateral incisor was considered to be inappropriate. The case was therefore debonded without an attempt made to correct the root orientation of this tooth. The final clinical result is shown here without the correction of the incisor (Figure 9.7o, p).

Follow-up records of the case at 7.6 years post treatment are also presented here (Figure 9.7q–t) showing no change in the condition of the root of the resorbed lateral incisor. There was no hypermobility of the tooth and a removable retainer had been discarded three years earlier.

Severe incisor root resorption

It is clear that impacted canines and certain other types of impacted teeth have common properties that are patently the causes of resorption of their immediate neighbours. Maxillary canine teeth are the most common offenders among them and have also been the most studied and published in journals. Accordingly, this section of our discussion will be restricted to impacted canines. In terms of prevalence of the phenomenon, it was pointed out at the beginning of this chapter that the study by Walker et al. [8] found that in their sample of untreated impacted maxillary canines, as many as two-thirds showed positive signs of root resorption of the adjacent incisors. For the majority of these canines, the indications of resorption were very early signs. Nevertheless, the sample range was broad, a large number were graded minimal to minor, and many were considered relatively insignificant cases of resorption.

As we have already seen in several of the cases illustrated in this chapter, there are also those cases where the root resorption is very severe and rapid in its destructive progress. Despite the fact that they offer the same features as the more minor and slower forms, they also have other characteristics that are not common to the milder forms. This form of resorption has been called severe incisor root resorption (SIRR) and, as its name implies, it is destructive on a broad front.

The unfortunate combination of rapid onset and progress, obtuse/longitudinal presentation, as well as a total absence of symptoms such as pain and swelling, will undoubtedly take the patient by surprise. But it is no less disturbing for practitioners, who will likely run to their earlier records of the case to check if there might be signs of this positive diagnosis that they may have missed. There can be no question that this form of resorption is very different from the more common forms of resorption, although each is related to an impacted canine.

In order to learn the main features of SIRR and specifically its remarkably aggressive character, a study was performed in Jerusalem [24]. A sample of 55 consecutive patients (77 canines) with SIRR was investigated by a joint Jerusalem–Warsaw team of researchers. The criterion for inclusion in the sample was that the incisor root resorption was in excess of one-third of the root length, due to the association with the impacted maxillary canine. It was found that the most frequently affected teeth were the lateral incisors and that bilateralism was common. Most of the canines were severely displaced and vertically oriented. The resorption was present in both buccal and palatal canine cases, whose crown form was mainly normal, and principally affected the middle third of the lateral incisor root. The multivariate statistical analysis showed canines with enlarged dental follicles accounted for 8.3 times the prevalence of SIRR and that adjacent lateral incisor crowns of normal form were likely to be 5.8 times more susceptible compared with the control group. Furthermore, there was a significantly higher presence among female patients.

The conclusions of the study regarding the associated features and possible aetiological factors of SIRR were as follows:

- The aetiology of SIRR was multi-factorial, associated with both local and systemic factors.
- There was a markedly increased prevalence among females (5:1), suggesting hormonal or genetic factors.
- Canines frequently exhibited enlarged dental follicles.
- Patients with normal-size lateral incisors were more prone to SIRR than those with anomalous and late-developing incisors, suggesting reduced local space availability.
- Lateral incisors were more likely than central incisors to be affected by resorption.
- The pattern and direction of the resorption were mainly obtuse, with normal root length rather than root shortening. The resorption had affected the width of the roots.
- The rate of bilateralism was high, hinting at systemic or genetic links.
- SIRR was to be found with both palatal and buccal canines.
- The rate of occurrence was highest among those with severe canine displacement, particularly in the middle third of the incisor root.

Treatment of severe incisor root resorption

When the canine has caused root resorption of the lateral incisor, reaching down to the CEJ and to the gingival attachment, the likelihood of perforation, recession and secondary caries in the resorbed area is high. In these cases, the extent of the defect is never small and much of the length of that side of the incisor root will have been resorbed by the proximity of the obliquely or vertically directed eruption path of the canine. As the result of the serious damage to its structure, the tooth cannot be rehabilitated, and in this eventuality the only treatment available for the severely compromised incisor is extraction (Figure 9.8).

Case 9.3: Is cone beam imaging appropriate for a case of severe incisor root resorption

The case illustrated in Figure 9.8(a) was seen in the postgraduate orthodontic clinic of the Hebrew University–Hadassah School of Dental Medicine in Jerusalem. It was immediately clear from the periapical radiographs that the impacted right maxillary canine had caused resorption of the root of the lateral incisor and that, through the radiologically superimposed portion of the two teeth, there was a faint and indistinct image of the incisor root. The fact that the root was visible and that it had normal length raised the question of whether perhaps the tooth could be rescued from the resorption progress and even be retained. The area involved would almost certainly be the area of the incisor root facing the canine, which, using the tube-shift method, had been diagnosed as being on the labial aspect.

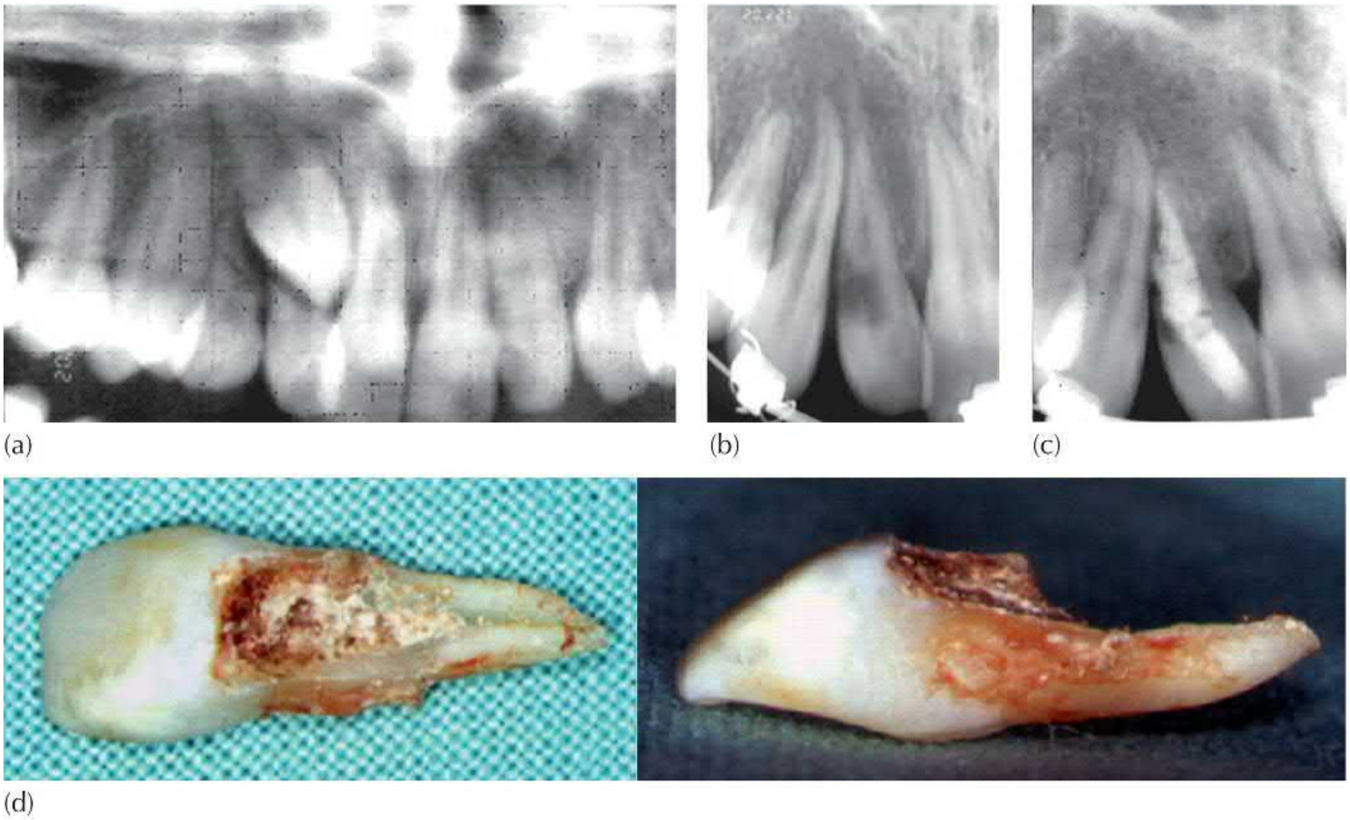


Fig. 9.8 The anterior portion of a panoramic view. (a) Resorption of the lateral incisor root by the impacted right canine. This case was treated about 30 years ago and before the cone beam tomography era. It was not possible with 2D planar radiography to assess the degree of resorption that had occurred. (b) Periapical view of the successful resolution of the canine impaction. Note the darkened (radiolucent) resorption crater in the cervical region, close to the gingival margin. (c) Periapical view taken during the root canal procedure, showing absence of a large section of the labial and distal wall of the root, from the cemento-enamel junction almost to the apex. (d) Views from the labial and mesial sides of the extracted incisor to show the extreme nature of the longitudinal resorption along the full length of the labial aspect of the root, not evident from the periapical radiograph.

There was no answer to this question when this patient was seen 30 years ago, because CT imaging was not then available for dental use in Jerusalem at that time. Today, CBCT imaging of the immediate area would provide a complete answer as to whether the tooth was salvageable, and would avoid the need for test treatment by trial and error. Nevertheless, an attempt to distance the canine was made, in the blind hope that it would reveal a lateral incisor that could be salvaged.

Surgical exposure of the canine was carried out together with extraction of the deciduous canine. Thereafter, orthodontic realignment of the impacted permanent canine was successfully completed within a few short months. A new periapical radiograph (Figure 9.8b) confirmed that the lateral incisor had a very substantial root length. However, it also showed a large radiolucent area in the cervical region of the root, close to the CEJ and the gingival margin. This meant that during normal masticatory function and possibly even simple tooth brushing, there was a real possibility of an accidental exposure of the lesion to the oral environment. An endodontist and a periodontist were consulted and they recommended root canal treatment followed by periodontal surgery to seal off the defect.

Endodontic instrumentation revealed a perforation of the labial wall of the root canal. Accordingly, the canal was temporarily filled with a radiopaque paste, as a marker to facilitate interpretation of a new radiograph. Figure 9.8c shows the radiopaque material having broadly spilled into the surrounding tissues. There was clearly no possibility of endodontic or periodontic rehabilitation for this tooth and consequently the tooth was extracted. A view of the extracted tooth (Figure 9.8d) shows the total absence of the labial wall of the root, from the cervical enamel edge of the crown up to a point a few millimetres from the apex of the tooth.

When the eruption path of a canine is obliquely/vertically directed and in close proximity to the root of the adjacent incisor, resorption of the incisor that may occur is characterized by a long and shallow resorption defect along much of the length of that aspect of the root. This phenomenon is clearly illustrated in this case report.

The location of the most coronal extent of the resorption and its proximity to the crestal bone and gingival attachment are the factors that determine whether the tooth can be retained. On the assumption that the lesion does not reach as far coronally as the gingival sulcus and the CEJ of the incisor, resolution of the problem will be simple and the prognosis for the tooth will be fairly good. The only treatment that would be required is orthodontic treatment, after the one-time provision of surgical access to the ectopic tooth. Mechano-therapy would be aimed at distancing the canine from the immediate area and thereby bringing about the cessation of the resorptive process. The tooth could then have been retained in its vital asymptomatic condition, with no labial wall to its root canal, but normal periodontal support. All this despite the ugly appearance of its unseen root, but with a lateral incisor crown of good form and unspoiled colour.

It will be appreciated that the resorbed area of the incisor root in a case like this should not be exposed. Neither is there any merit in removing its superficial resorption layer by root planing, even if the resorptive process has reached the pulp. As noted earlier, the resorptive breakthrough into the pulp chamber or root canal brings the connective tissue of the PDL into direct contact with the vital pulp tissue. That area of the pulpal tissue that is closest to the breakthrough undergoes metaplasia, merging with and becoming part of the PDL. This occurs without inflammation, without pain or swelling, without pathology, and therefore requires no treatment. On the other hand, probing, or otherwise clinically satisfying one's academic curiosity regarding the texture or topography of the defect, risks complications that will endanger the retention of the incisor. Such a tooth will likely last for a very long time, without the need for root canal treatment and without the need to rehabilitate the lost dentinal root tissue, even when its root is quite short. Resorptive activity of this kind usually occurs during the early stages of the mixed dentition and is clinically, histologically and radiographically indistinguishable from the normal developmental process, leading to the eruption of the canines into the dental arch. At this early stage, the central and particularly the lateral incisors, having erupted into the mouth only one to two years previously, will have open apices. This situation will alert the orthodontist to the possibility that early resorption of the incisor roots may indeed be occurring.

At the age of 7–9 years a good periapical radiograph or a well-taken panoramic view, together with periodic follow-up, is generally considered to be adequate to monitor for resorption of the incisors. It may not be perfect, but one cannot ethically justify subjecting every child of this age in the population to the relatively large blast of ionizing radiation needed for a CBCT examination and with periodic follow-up, just in order to identify the one or two affected children in the very wide catchment area of an orthodontic practice who are suffering from this relatively rare and non-lethal condition.

Case 9.4: Long-term regeneration and recovery after severe incisor root resorption caused by enlarged dental follicles

For a 10-year-old female patient in the mixed-dentition stage of development (Figure 9.9a), on the initial periapical films enlarged dental follicles were seen surrounding the crowns of the unerupted maxillary canines. Nevertheless, and despite the obvious crowding, the condition was considered too early for orthodontic treatment *per se*. Extraction of the maxillary left deciduous canine and deciduous first molar teeth was performed and the patient was placed on one-year recall, in the hope that waiting might encourage the left canine to improve its position.

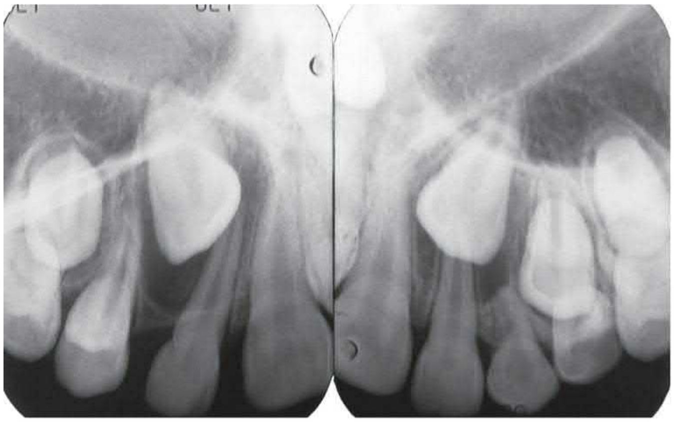
Thirteen months later, the new periapical views (Figure 9.9b) showed extremely aggressive root resorption involving both lateral incisors, apparently stemming from the eruptive advancement of the impacted canines. Urgent orthodontic treatment was advised for the labial impaction on the left side and the palatal impaction on the right.

Unfortunately, the case was treated in accordance with the standard protocol for impacted canines in general, and totally disregarded the urgency of the resorption problem. The orthodontist spent many months aligning and levelling the teeth and creating space (Figure 9.9c), before exposing the canines. During these valuable months, resorption of the incisors continued and, when the time eventually was considered ripe to begin to distance the canines from the incisors, little was left of their roots.

As may be seen from the new periapical radiographs that were taken when the canines had been aligned (Figure 9.9d), there appeared to be a total absence of alveolar bone surrounding the severely truncated remaining root stub. A dark (radiolucent) area had developed in its place. This radiolucent area was populated by new, minimally calcified alveolar bone. The incisors, not surprisingly, exhibited a marked degree of mobility, which needed to be countered by the placement of a twistflex bonded 3-3 retainer, both for the purpose of stabilizing their mobility and for retention of the orthodontic result (Figure 9.9e).

Follow-up radiographic monitoring at 5.5 years post treatment indicated a steady improvement of the bony picture in terms of its texture and trabeculation (Figure 9.9f). The former mobility of the teeth was no longer present, and the firmness was remarkably similar to that of the adjacent central incisors.

Whereas the lateral incisors had been brought into alignment and, from this point of view, the treatment had apparently produced a successful outcome, nevertheless the two teeth had lost almost all of their root to the resorption process. This was due to the considerable time ill-advisedly squandered in creating space before moving the canines away from the immediate area. Had the first item on the treatment priority list been surgical exposure and distancing, there can be little doubt that this would have left the lateral incisors with significantly longer roots.



(a)

(b)

(c)

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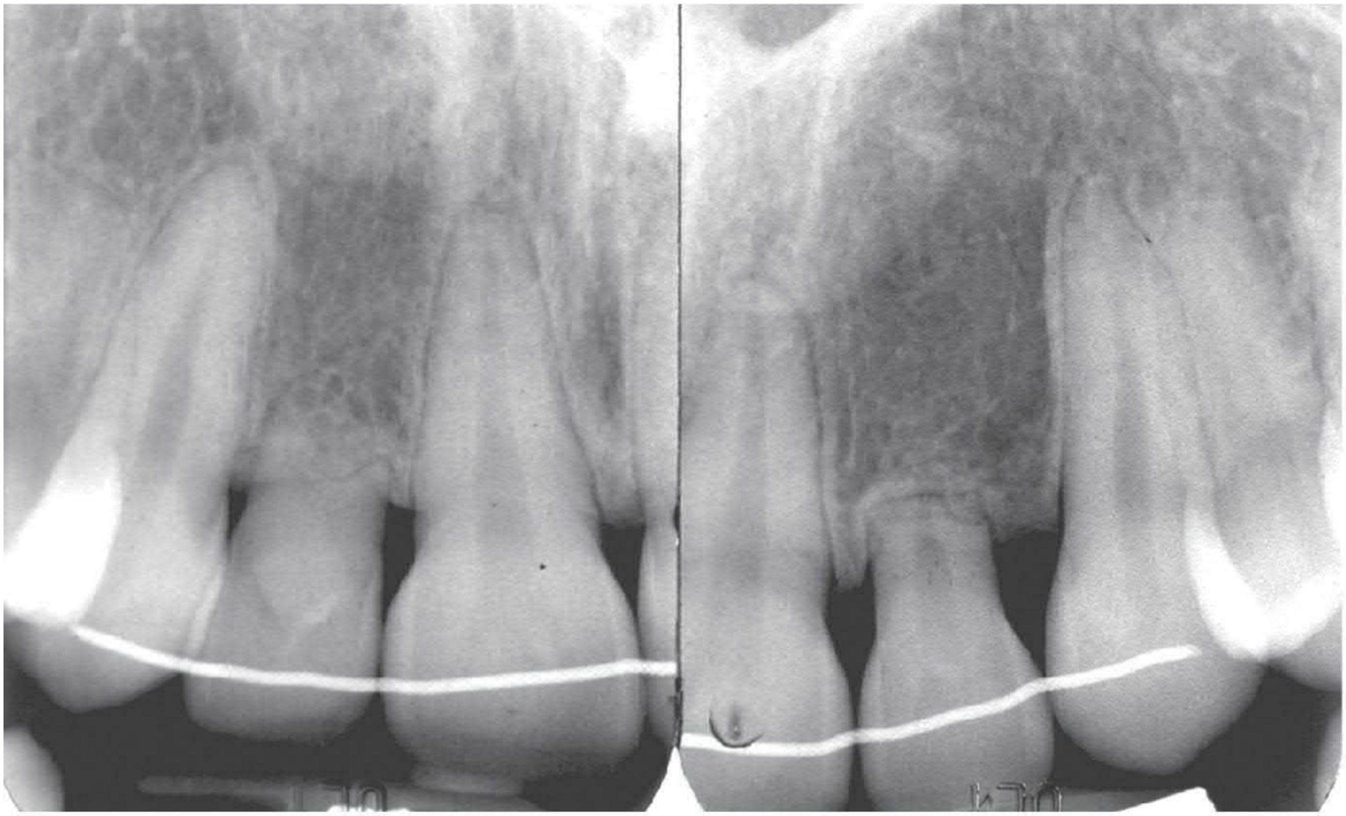
(e)



(f)

Fig. 9.9 Enlarged dental follicle and no apparent incisor root resorption. (a) Periapical radiographs of the canine areas, taken at the initial consultation of a 10-year-old female. The deciduous left maxillary canine and first molar (#63 and #64) were extracted to encourage eruption of the permanent teeth. (b) The same patient, seen 13 months later. The follicular enlargement has increased and the lateral incisors show rapid and advanced resorption. (c) The initial clinical photographs show a class III relation of the teeth on a skeletal class III base. The impacted right canine on the palatal side and the impacted left canine on the labial side. (d) The periapical view following alignment of the canines and immediately prior to debonding. (e).The completed case at 5.5 years post treatment. (f) The periapical radiographs taken at 5.5 years post treatment, showing arrested resorption and considerable bone condensation around the shortened roots, with good bony trabeculation.

Despite this criticism, a careful comparison of the radiographs at the completion of treatment to those seen after 5.5 years follow-up shows the significant improvement in bony support that these minimal-length incisor roots had gained in the interim. At the time the orthodontic movement of the canines was initiated, the lateral incisors were notably mobile and, to the dental practitioner, there appeared to be no future for them. That same dental practitioner would surely have expected a rapid deterioration of the periodontal picture. Instead, bony condensation had occurred around these root stumps and the bony trabeculation appeared to be very healthy. All this had occurred during those 5.5 years. The mobility of the teeth had largely disappeared, both with and without the bonded splint. There is reason to believe that with the splint, the accompanying expectation of a medium- to long-term future was now much more optimistic. There appears to be a fairly good chance that these teeth will last well into young adulthood.

Treatment priority planning

In Chapter 7 we set out a standardized protocol that offers an order of procedures for the successful completion of the treatment of an impacted canine, as an integral part of the overall treatment of the patient's malocclusion. Set out briefly here, it is as follows. The treatment begins with levelling and alignment, followed by space opening and consolidation of all the teeth in the arch into a compound anchorage unit, against which forces will later be applied to resolve the impaction. Only then is the surgical exposure of the canine and attachment bonding undertaken. The application of appropriate directional forces is made and the impacted tooth is brought into its place in the arch. Attention is then turned to the remaining tasks of the overall occlusion, followed by the performance of suitable finishing procedures, as needed.

Standardized protocols of treatment are usually well-tried and valuable practices that are adopted to resolve difficult complex tasks that we come across in our day-to-day routine. However, there are situations where the rigidity of the discipline involved in standardization may cause a potentially good treatment plan to go awry just because of a single exceptional feature that characterizes the particular problem. In the present context, failure to recognize the urgency of the case in Figure 9.10 nearly caused the entire treatment to fail. This is one of the very few cases that require urgent treatment in the practice of orthodontics and it is only a relative emergency – we do not have to take the patient to the office at the weekend! The reason for the urgency is the active and rapid resorption, which dictates the prioritization of treatment ahead of the other aims of the treatment.

The limits of conservative treatment for severe incisor root resorption

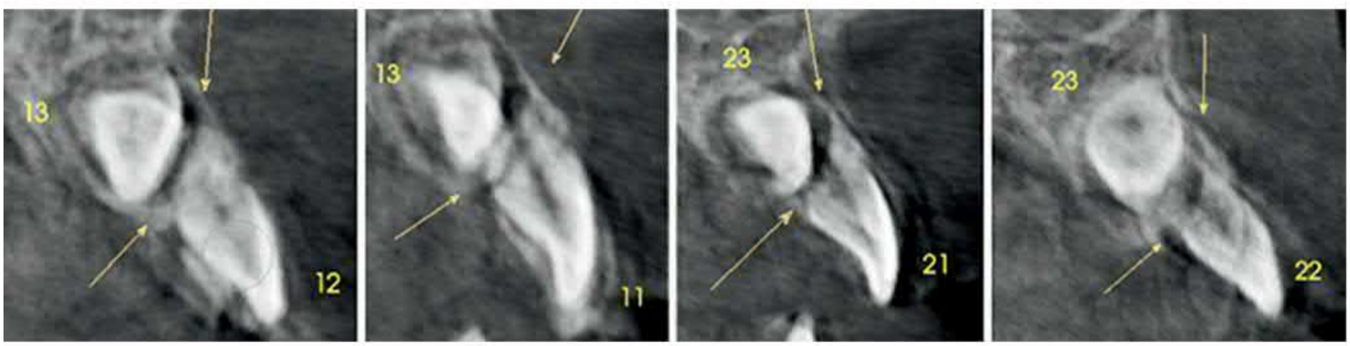
In the light of an overall inclination towards conservative treatment, it is pertinent to discuss why we should even consider saving these severely compromised teeth. Most of our colleagues in the other dental specialties, from oral surgeons, through prosthodontists and periodontists, to endodontists, will be aghast at orthodontists' attempt to resolve the problem, when it is clear to everyone that there is no way to regenerate lost roots. Our colleagues will mostly take one look at the radiographs and castigate us for attempting 'unnecessary' and 'impossible' treatment on teeth that 'obviously' have no future, maintaining that palpation will reveal that the teeth are excessively mobile. They will also point out that, given the amount and the speed of the loss of their roots till now, it is only the matter of a few weeks before these teeth fall out and, surely, their demise can only be hastened by recruiting them as anchorage units for the orthodontic extrusion forces applied to the canine.

(a)

(b)

(c)

(d)



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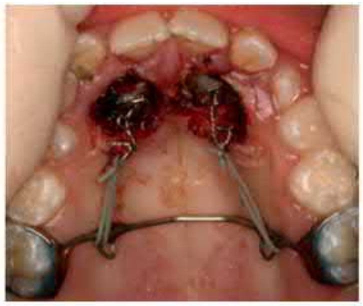

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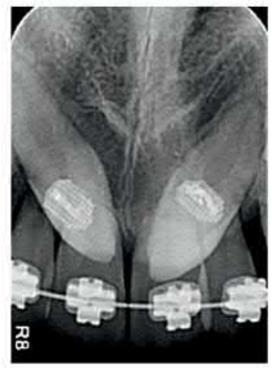

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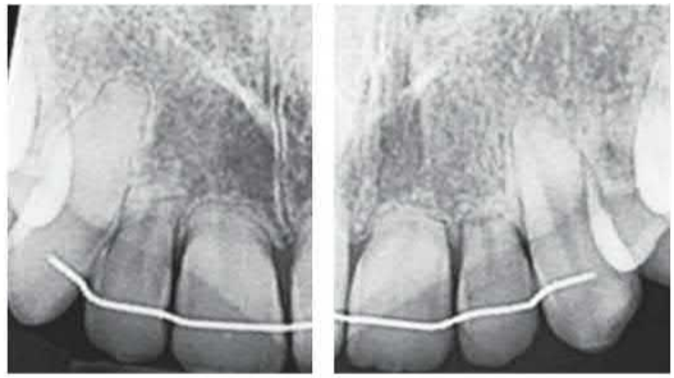
(p)

Fig. 9.10 (a) Intra-oral view of the teeth in occlusion before treatment, in November 2014. The maxillary left premolar was erupting mesial to its over-retained deciduous predecessor, into the canine location (arrow). (b–d) Initial panoramic, periapical radiographic and lateral cephalogram views, dated April 2014. (e) Cross-sectional views from the cone beam computed tomography images across each of the maxillary incisors to show the relationship between the impacted canines and the incisors and the severe degree of root resorption. The canine is labelled #13 on each of the frames and the incisor numbered according to the system of the Fédération dentaire internationale. (f) Intra-oral views of the teeth showing the initial orthodontic preparation immediately prior to surgical exposure of the canines. Note that the deciduous second molars and the deciduous right first premolar carry brackets as a precaution to reinforce the anchorage, if required. The blue elastic (separator) modules are a protection against chafing of the cheek mucosa, in the absence of a labial archwire, in the initial stages. (g) Occlusal view of the palatal area shows the molar bands and soldered transpalatal arch. The bilateral bulges in the anterior palate indicate the location of the impacted canines.(h) Two individual open exposure procedures were performed in November 2014 (see text) and small eyelets bonded on the distal aspect of each of the canines. Light extrusive force was applied between the twisted steel ligature connector and soldered loops on the transpalatal arch, to draw the canines away from the resorbing incisor roots. (i) In March 2015, the canines had erupted in a purely horizontal and posterior direction. (Surgery by Prof. Nardy Casap-Caspi.) (j) Orthodontic brackets were placed on the resorbed incisors in March 2015, after the canines had been erupted in the palate. Note how the unbracketed central incisors had elongated during the period that the canines were being moved. (k) Occlusal (l) anterior and (m) periapical radiographic views of the dentition at completion of the alignment and space-opening stage in December 2015. Note that traction on the canines was renewed from newly bonded eyelets on the mid-labial aspect of the crowns of the canines, to avoid unnecessary rotation during their movement towards the more substantial labial base archwire. (n) Intra-oral views of the dentition at two years after the completion of the limited orthodontic treatment that was planned. Only absolutely essential treatment had been performed in this highly compromised case and no attempt had been made to treat the class II relation of the left-hand side. (o) Panoramic radiograph taken at 3.5 years post treatment shows a significant degree of stunting of the roots of the maxillary canine and premolar teeth. The right canine pulp chamber is obliterated. (p) At 5 years post treatment, these periapical views show no further resorption of the roots of the maxillary incisors, good bony condensation around the truncated roots and very minor mobility.

There are two sides to the answer to this pessimistic argument:

- In the first place, as illustrated above, distancing the canines stops the resorption and leads to a repair of the rarefied area of bone adjacent to the lesion. With the cessation of the resorption and the bony repair, the teeth become markedly firmer. The radiographic picture shows bony fill-in and trabeculation of what was earlier a boneless void. Moving these teeth with light orthodontic forces does not then adversely affect them and, if required, a lingual bonded wire splint will add to the stability of the result and will vindicate the orthodontist's (not unjustified) confidence. At the end of this treatment period, patients will have their own teeth in their correct place and with no active pathological process to contend with. These teeth may therefore last, without further deterioration, for many months or years, hopefully into the mature adult dentition. To a large degree (although not completely), the alveolar ridge will be preserved by the presence of even these short roots. In addition, their crowns are usually anatomically perfect and aesthetically superior to any artificial temporary oral rehabilitation substitute.

- The orthodontist may alternatively accept the opposite thesis and have these compromised teeth extracted. The problems that then arise relate to holding the space for later prosthodontics and providing the child with a temporary partial denture, which may be fixed or removable. The edentulous section of alveolar bone will undoubtedly resorb in time and subsequent orthodontic treatment of other unconnected malalignments in this very young child will be much more difficult to perform with a temporary denture in place. Permanent replacement of the missing teeth will not be undertaken, at least until the child reaches young adulthood. It is to be noted that the most likely subject of this discussion is a 10–12-year-old child when the diagnosis is first made and treatment urgently needs to be planned.

Case 9.5: Severe incisor root resorption and the limits of the orthodontic modality for successful treatment

How then may we approach these cases? We shall discuss this question in the context of the case presentation of an 11.3-year-old girl, who was first seen in the clinic in April 2014. She had been seen by three or four orthodontists over a period of several months, each of whom had explained to the parent that the child would lose her four front teeth within a short time and that prosthodontics, rather than orthodontics, was probably the answer to her problem.

At her next appointment in November 2014 (two additional orthodontists had been consulted in the meantime), the child's parents brought the initial panoramic and periapical radiographs, a cephalometric analysis, facial appraisal and all the other diagnostic aids normally examined in the deliberations leading to a plan of action. They also brought a poor-quality CBCT. On examination, the child exhibited a convex profile, with a retrognathic lower jaw and a high lower lip line at rest, in relation to the maxillary incisors. She was in the late mixed-dentition stage, with four retained deciduous second molars and over-retained maxillary deciduous canines. Three of the deciduous first molars and the mandibular canines had shed during the past few months. The premolar teeth, the mandibular permanent canines and the permanent second molars were in various stages of eruption. The molar relations were class I on the right and a full unit class II on the left side (Figure 9.10a). The four maxillary incisors were at different heights, flared distally, notably mobile (grade II mobility), the maxillary dental midline deviated 1–2 mm to the right and the mandibular dental midline 2 mm to the left. The mandibular incisors were mildly retroclined, while the maxillary incisors were strongly retroclined and the overbite was deep, with a 70% vertical overlap and contact of the lowers high up and lingual to the cingulum of the uppers. The confirmatory cephalometric values were typical of Angle's class II division 2 malocclusion.

From the initial panoramic and periapical views (Figure 9.10b, c) that had been taken on the first visit in April 2014, the maxillary canines could be seen to be impacted and severely tipped towards the midline and the roots of each of the four incisors were resorbed down to the CEJ. The lateral cephalogram (Figure 9.10d) showed the superimposed right and left canines to be located where one would expect to see incisor roots. Given the orientation of their long axes, it was concluded that they had approached the incisors from above, on the palatal side, and had proceeded to encroach into the recently created resorption craters in their roots. This was confirmed on the CBCT cross-sectional images, from which the severity of the resorption could be seen (Figure 9.10e–h) and from the 3D video clip that was prepared from the very poor scan.

In order to attempt to assess the speed with which the roots of the incisors had been almost totally resorbed, it would be appropriate to point out certain developmental landmarks that relate to timing. From the initial panoramic radiograph, it appeared that the dental age of the patient conformed to her chronological age, namely 11.3 years. In the time framework of the dental development and the timing of eruption, this would mean that the central incisors would have erupted at 7 years and the lateral incisors at 8 years, each with approximately two-thirds of its final root length. Their roots, under normal circumstances, would have been completed by 10 years (central incisors) and 11 years (laterals). At age 9, when the central incisor roots would have been approaching their expected final length, the canines likely began to move down and mesially towards the incisor roots, but along their abnormal eruptive path. This means that roughly three-quarters of the roots of the four incisors had been resorbed within a time period of about 1.5–2 years.

A comprehensive problem list was put together, as follows:

- Impacted canines.
- Resorbed incisors with poor prognosis.
- Retroclined upper and lower incisors.
- Deep curve of Spee – excessive incisor overbite.
- Unilateral class II relation.
- Crowding in the maxillary dentition.
- Midline discrepancy.

The treatment options were many and wide ranging:

- No orthodontic treatment. Ignore the unilateral class II relation. When the incisors fail, refer for immediate temporary prosthodontic treatment.
- Extract the impacted canines without orthodontic treatment. Ignore the class II relation and ignore the incisor alignment and angulation.
- Extract two incisors and bring the canines into their place. Ignore the class II relation.
- Extract the four incisors and bring the canines into the place of two incisors, with prosthodontic replacement of the other two. Ignore the class II relation.
- Extract the four incisors and the canines, with prosthodontic replacement of six anterior teeth. Ignore the class II relation.
- Orthodontic treatment to resolve the canine impaction and align the maxillary incisors. Ignore the class II relation.
- Orthodontic treatment to resolve the canine impaction and to align the maxillary incisors. Resolve the class II relation and midline discrepancy.

A critical look at the treatment options

In the case in Figure 9.10, we were confronted with an extremely complex and mutually contradictory set of dilemmas, each of which pointed in a different direction and made a definitive treatment decision extremely difficult:

- It was recognized that denial of some form of treatment would result in further damage. The continuing and rapid resorption would cause the loss of the four incisor teeth within a few months and the aggressively advancing canines would erupt with a strong mesial orientation, close to the incisal midline.
- On the other hand, if orthodontic treatment were to be initiated, this would also cause further damage, since the biomechanical movement of actively resorbing incisor teeth would exacerbate the resorption.
- Although the extraction of the canines themselves would undoubtedly arrest the resorption, it could leave the patient with six missing anterior teeth.
- More significantly, despite their abnormal locations, the canines were the only uncompromised anterior teeth, with long and healthy roots and good crown anatomy.
- Choosing two of the four incisors for extraction on the basis of their position or their prognoses would be difficult, since they were all similarly compromised in the extent of their resorption. Furthermore, a fixed bonded orthodontic appliance would be needed and it would be impossible to treat without including brackets on the two remaining compromised incisors.
- Extracting all four incisors would make temporary artificial replacement mandatory. The canines would then need to be aligned, which would be difficult to achieve in the presence of artificial temporary substitutes. Post-treatment prosthodontic rehabilitation would be needed in the short to medium term and then definitively with implants at the age of 18–20 years.
- Extracting the four incisors and the impacted canines would be a heavy price to pay for an 11-year-old child, dentally, psychologically and socially. On the positive side, extraction and immediate replacement with a removable acrylic denture would offer the fastest and least complicated result in the short to medium term, notwithstanding its many shortcomings, inconveniencies and hardships for a young person. However, it should be remembered that the patient was in the mixed-dentition stage and many other changes would be taking place in the development of the occlusion of the other teeth in the next two or more years.
- Full orthodontic treatment, aimed at aligning the teeth, creating space, resolving the canine impaction, treating the class II relation of the molars, reducing the overbite and re-aligning the dental midlines, represented a long and complicated treatment for this child, carrying with it significant risks even for a patient with non-resorbed teeth. Unnecessarily long, involved and sophisticated treatments would certainly increase the chances of causing further resorption, loss of teeth and abject failure of the case.
- Orthodontic treatment limited to resolving the canine impaction and providing incisor alignment, without eliminating the class II relationship, would be aiming for a compromised result. This would still not be without its risks and doubts, even if successfully performed.

This last option was considered to provide the patient with the best outcome for the lowest iatrogenic cost in potential collateral damage. The aim was hopefully to use her own damaged anterior teeth (each with its own pristine anatomical form) as 'provisional rehabilitation' until young adulthood. It was the method that maintained the maximum of the patient's existing dentition for the short to medium term. It was nevertheless recognized that at some future date, hopefully beyond the patient's growth period, prosthodontic rehabilitation of the anterior teeth would be needed following the demise of one or more of the incisor teeth.

The patient's parents were carefully apprised of the severity of the problem of the active resorptive process involving the child's anterior teeth and informed that with no treatment, she would lose them in a relatively short period. This was fully understood by the parents and, although they also signed a written statement to this effect prior to the commencement of the treatment, they were nevertheless reminded of this, by the orthodontist, at regular intervals during the treatment.

Stage 1

Given the already witnessed and exceptionally aggressive nature of the resorption in this patient, the surgical exposure and traction of the canines needed to be performed as an urgent priority, even before space had been provided in the dental arch to accommodate them [16, 24, 25]. In order to achieve this, molar bands were cemented into place with a soldered transpalatal arch, to act as the source of anchorage for the traction applied to the canines. As a precaution against loss of anchorage, which would be recognized by mesial tipping of the molars, brackets were bonded to the deciduous second molars and the erupted right first premolar (Figure 9.10f). Sectional rectangular arches were prepared, should they become necessary in order to resist this movement. No other brackets were placed and the incisor teeth were left untouched for as long as the resorptive potential of the canines was rampant, namely for as long as they were in close proximity of the incisor roots.

Surgery was performed in the operating theatre in January 2015 under general anaesthetic cover and the question of whether an open or closed procedure should be performed was discussed by the orthodontist and surgeon. In general, in these difficult circumstances, the preference would be for a closed procedure [24, 26, 27], since the wide muco-periosteal flap provides superior visibility, the bleeding area is at the periphery of the flap and it would be easier to identify the follicle and the crown of the tooth. It would also be easier to keep a distance from the resorbing area of the truncated incisor roots to decrease the risk of devitalizing them. For the same reason, bonding attachments to the crowns of the canines would be performed as far away as possible from this sensitive area, in view of the improved haemostasis. In the final instance, the surgical flap would be fully closed over, to protect against the inadvertent collateral exposure of incisor roots.

In the present case, however, the surgeon was concerned that with such extreme resorption, the mere opening of the soft tissue flap was likely to endanger the resorption front and cause incisor devitalization even before the canines were exposed.

An individual open exposure was performed on each of the two canines. Although canines may create a very palpable bulge in the pre-surgery palate (Figure 9.10g), the mucosa covering them is always very thick. When a circular piece of tissue was excised, the tooth lay in the depth of a narrow cylindrical mucosal opening, which oozed blood continuously from its 360° cut inner surface, thus making attachment bonding potentially unreliable (Figure 9.10h). The surgeon became fully operational in providing and maintaining haemostasis and a moisture-free surgical field, with the help of high-power suction, while employing an electrocautery to control bleeding points. This enabled an eyelet to be successfully bonded to the posteriorly facing aspects of the canines (Figure 9.10h, i). Elastic thread was then drawn from the eyelet attachments to the transpalatal soldered arch, providing immediate traction in a horizontal and posterior direction. In this way, the canines were distanced from the incisor roots to a position far from any contact with the walls of the resorption craters in the incisor roots.

Stage 2

When the canines had been drawn posteriorly in the palate and were erupted sufficiently, they were no longer considered a threat for further root resorption [16, 24]. This was the time to begin aligning and labially flaring the affected incisors, to create space for the eventual alignment of the canines.

Orthodontic brackets were placed on the incisors and on the newly erupted left first premolar and, in the absence of incisor roots, an initial ultra-light nickel–titanium archwire was tied into the brackets to achieve alignment and levelling (Figure 9.10j). When this had been completed, a stainless steel base arch was placed and open-coil springs were ligated between first premolars and lateral incisors (Figure 9.10k–m). The incisors were subjected to labial tipping and the overjet was temporarily increased until there was excessive space in the canine area to accommodate the newly erupted canines. At this time, treatment in the mandible commenced, with alignment and levelling (Figure 9.10l).

Stage 3

In order to facilitate drawing the canines directly to the archwire, without causing them to rotate unfavourably, new eyelet attachments were substituted on the anatomical labial aspect of the canines, in place of those that had been bonded on the palatal aspects at the time of surgery (Figure 9.10k, l). Elastic thread ties were applied from the canine attachments directly to the completely passive, heavy, round, labial archwire. In this manner, the buccally directed forces applied to the canines provided reciprocal anchorage for one another. The rigid main archwire additionally provided counteracting extraneous forces necessary to prevent the buccally directed forces from being transferred to the incisors and premolars. At this juncture, a mandibular fixed appliance was also placed (Figure 9.10l), with the aims of levelling the lower occlusal plane (curve of Spee) and achieving a degree of incisor proclination to assist in reducing the incisor overjet. With the relocation of the canines to their place in the arch, the eyelets were replaced by regular orthodontic brackets and the excess space closed up, by retracting the incisors and reducing the overjet to more acceptable proportions.

At this final stage, a re-evaluation of the situation was undertaken. It was noted that good alignment and root orientation had been achieved, although torque values of the treated canines were inadequate (Figure 9.10n). The radiographs showed no further reduction in root length of the incisors. There appeared to be an improved level of bone support for the incisors, following the elimination of the destructive influence of the previously unerupted canines, after they had been moved away from the area.

It was estimated that more damage would be done by using the affected incisors as units of anchorage, in the attempt to labially torque the roots of the canines, than to leave the canines in their present positions. Accordingly, treatment was declared completed and the appliances were removed (Figure 9.10n). Debonding brackets from teeth with such compromised support is not a procedure to be undertaken with relish. It required the greatest care to avoid excessive forces on these weakened teeth. Mobility was considerably reduced and the condition of the incisors had improved, in comparison with their condition at the initiation of treatment, 24 months earlier.

In line with the restricted aims of treatment as noted above, no attempt was made to address the class II relationship, although there was an unplanned improvement of the midline alignment. In late December 2016, a bonded lingual 3-to-3 twistflex steel retainer was prepared on a plaster cast and bonded on the maxillary incisors the same day, together with a simple removable Hawley retainer in the mandibular arch.

A post facto *overview of the case*

This patient was aged 13 years at the end of the treatment, and its outcome offered some justified optimism that the incisors would be maintained at least until she reaches an age where implant prosthodontics may be reasonably considered. At four years post treatment, the radiographs (Figure 9.10o, p) show excellent bony trabeculation, with healthy lamina dura around the root stumps and surprisingly little, if any, mobility.

In a published study, which was awarded the B.F. & Helen E. Dewel Clinical Research Award of the *American Journal of Orthodontics and Dentofacial Orthopedics* for 2016 [24], we reported that our experience has taught us that these severely resorbed teeth, given appropriate treatment, are often maintained well past this time and into the patient's third and, occasionally, even fourth decades. The present case will be followed over the next few years, when further lessening of mobility is expected following the cessation of orthodontic tooth movement. To date, this has been due to increased bone support, as bone maturation occurred and bony trabeculation was re-established.

The occlusion is far from ideal, particularly on the left side, where the molars are in a full class II interdigitation and the premolars and canine are cusp to cusp. Nevertheless, by comparison with the alternative approaches listed above, this has been the least aggressive, most conservative and most satisfying of all the available options. Many orthodontists might feel embarrassment to show this case to colleagues, who routinely present ideal alignment and occlusal outcomes. But, if we are to relate to orthodontics primarily as a health profession, there can be no excuse for denying treatment to a child threatened with such extreme root resorption and suffering from a potentially mutilated dentition of this enormity, simply because we cannot achieve an ideal board examination outcome.

In relation to this and similar cases, it must be emphasized that success can only be achieved if the following conditions are applied:

- The orthodontist is meticulous in the accurate positional diagnosis of the impacted tooth in relation to surrounding structures.
- The case is treatment planned and it is determined that resolving the canine impaction and saving the resorbed teeth are in the best interests of the patient – i.e. that the case would be best served without extracting them, as far as is possible.
- The direction that traction must take is determined.
- An appropriate simple mechanism for applying directional traction is designed and prepared.
- No brackets are placed and no forces applied to teeth that are undergoing active resorption, until the cause (the impacted adjacent tooth) has been removed from the immediate area.
- The impacted canine is exposed even before space has been provided for it in the dental arch, as a matter of urgency.
- Immediate extrusive force is applied by the orthodontist, who is personally present at the surgical scene.
- The orthodontist limits treatment by only undertaking orthodontic tasks that are essential, avoiding actions of lesser importance, *unless and until* simple periapical radiographic follow-up of the teeth in the affected area is conducted.

Following the philosophy of Confucius, the old Italian proverb says 'Il meglio è l'inimico del bene', which roughly translated into English means that '*perfect* is the enemy of *good*'. This is never more true than in orthodontics, particularly when dealing with a very complicated situation, where the fate of the entire case is in the balance.

Postscript

In summary, therefore, it is important to keep in mind that even severely resorbed teeth need not always be extracted. They may be treated and conservatively ‘encouraged’ to successfully occupy an important place in the scheme of the dentition for a long time, often for years to come. For this to happen, accurate 3D localization of the resorbed tooth and its surrounding structures is mandatory, in order to assist the surgeon in identifying the exact position of the impacted tooth in relation to the resorbing root face. Raising a planned soft tissue flap, minimal and precise bone removal and attachment bonding then follow. In these circumstances, a closed exposure procedure may be the only way to preserve the vitality and retention of the resorbed tooth. If we can successfully divert the canine from being a progressively worsening threat to its immediate neighbours, then both teeth may be rescued from this debacle.

To this end, surgery must be undertaken very early in the treatment in order to permit immediate orthodontic traction to distance the tooth from the resorbing incisor root in the planned direction. This will effectively and almost completely eliminate the resorptive process. The orthodontist’s attention should then turn to treating the existing overall malocclusion and creating space for the canine in the dental arch, which may take several months. During this time, the canine remains in a ‘neutral corner’ on the buccal or palatal side, depending on the escape route that is followed in its movement out of harm’s way. After full correction of the canine ectopy and ‘fine-tuning’ of the alignment of all the teeth, reparative periodontal procedures will generally be superfluous and the long-term prognosis of the canine will be excellent. In many cases, even those where there is a much reduced root length, the adjacent incisor will usually enjoy a fair to good prognosis and, for the most part, the tooth will last the patient well into adulthood. The gingival form, crown lengths and dental alignment should be such that even a dental colleague will be able to recognize neither the previously impacted canine nor the incisor that was affected by root resorption. By and large, the orthodontic/surgery modality of treatment should be capable of presenting a final appearance of the anterior dentition and prognosis that will be unsurpassed by any other form of treatment. This is true both at the time of completion of the treatment and in the long term.

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10
Resorption of the Impacted Tooth

Adrian Becker

Invasive cervical root resorption

Pre-eruptive intra-coronal resorption

Age-related replacement resorption

Invasive cervical root resorption

Invasive cervical root resorption (ICRR) is also known as external cervical resorption (ECR). A majority of the existing literature that deals with ICRR (ECR) refers to its occurrence in relation to non-vital teeth that have undergone intra-coronal bleaching. ICRR is known to occur with some frequency in the period after teeth have been bleached. Non-vital bleaching is performed by sealing a bleaching agent into the prepared pulp chamber in the most coronal portion of the root canal (the remainder of the root canal will have already been sealed off by the root canal filling). The bleaching agent may, however, seep into the more coronal accessory root canals of the tooth. In such an event, the effect on the immediately adjacent external cervical area is to generate a resorptive process, which is typically annular and uniform around the neck of the tooth [1].

The occurrence of resorption of the cervical area on one side of the root of a tooth has been researched in a widely quoted series of studies by Heithersay [2–5]. It is described there as a specific, recognizable and recurring event in its own right, seemingly unrelated to the presence of an adjacent impacted tooth, or indeed to any other factors that most usually cause resorption. Heithersay has identified other potential predisposing factors, such as trauma (15.1%), intra-coronal restoration (14.4%), surgery (5.4%) and intra-coronal bleaching (3.9%), while he saw no identifiable cause of the resorption in a significant number (16.4%) of the affected teeth. However, the common factor in the affected cases of this unusual phenomenon was found in the fact that patients had a history of having had orthodontic treatment. Previous orthodontic treatment had been provided for 24.1% of the patients in the study sample. Similarly, a study carried out by Mavridou et al. [6] revealed that the most common associations were with orthodontic treatment (45.7%), previous trauma (28.5%), parafunctional habits (23.2%), poor oral health (22.9%) and malocclusion (17.5%).

None of these studies, nor indeed the condition itself, would seem relevant or appear to merit discussion in a book on impacted teeth. However, among the orthodontically treated cases in the Heithersay investigations, arrested eruption was seen in five of the cases concerned. Indeed, among a surprisingly large number of instances of resistant impacted teeth, a focused investigation by the present author, with the use of appropriate radiographs and particularly cone beam computed tomography (CBCT) imaging, has revealed the presence of ICRR lesions affecting vital impacted teeth.

Let us consider what could be the cause of the resorption mechanism in a tooth that is unerupted. Could local trauma be a contributory factor? After all, it would be logical to assume that, since the impacted tooth lies within bone and soft tissues, it would be protected from trauma. However, this assumption is not totally justified, as there are undoubtedly cases of trauma to the deciduous dentition where the force of the blow is transmitted (Figure 10.1) and has led to ICRR of the permanent dentition, particularly the incisors.

Fig. 10.1 An impacted canine had resisted attempts to mechanically erupt it. The periapical film shows a distal resorptive lesion burrowing into the root of the left maxillary canine in its cervical region. The point of entry and the loss of integrity of the lamina dura (arrow) are clearly seen, even on this poor-quality film. See Online PPT & video chapter 10 Cases A and B.

It is probably true to say that, until recently, ICRR had never been studied and reported within the context of the *orthodontic* literature. In fact, for the most part orthodontists were, and are still, generally unaware of its existence as an independent entity, apparently unrelated to other forms of resorption. It is therefore understandable that orthodontists are ignorant of its potential of being a cause for non-eruption and as a contributory factor in undermining the treatment of a significant proportion of impacted teeth [7].

ICRR may also be caused by well-intentioned surgical and orthodontic procedures, which themselves cause local trauma in the form of tissue damage. Therefore, notwithstanding their potential benefit, under certain unfortunate circumstances the tissue damage generated may initiate ICRR. In Chapter 5 we discussed the dangers of radical exposure of an impacted tooth to beyond the cemento-enamel junction (CEJ), as well as testing for mobility of the tooth by pushing an elevator down the side of the tooth 'just to make sure the tooth is not ankylosed'. These practices and several others might well be the cause of ICRR in the tooth, although this may not be evident for many months or even years. The surgeon would most likely be unaware that the tooth had failed to move. Not so the orthodontist, who is then charged with following through with the case to its successful completion. Dubious orthodontic procedures, such as the application of excessive force (i.e. trauma), may also be the trigger for the initiation of ICRR.

In a PubMed literature search, 417 articles were found using the keywords 'external cervical resorption'. With the notable exception of a study performed by our own research group in Jerusalem, there was not a single article among them that referred to the fact that ICRR has a profound negative effect on the eruption mechanism of teeth. This, together with our unpublished survey of orthodontists referred to earlier, leads us to the conclusion that the dental profession in general, and orthodontic specialists in particular, are unaware that ICRR is an aetiological factor in the causation of impaction of the affected tooth and a factor preventing the tooth from responding to orthodontic forces.

According to the European Society of Endodontology position statement, 'External Cervical Resorption', which was published in 2018, ECR (or ICRR as it is termed here) is initiated in the periodontal ligament (PDL), in the cementum and in the dentine in the cervical area of a tooth. It advances into the substance of the root dentine and, in its advanced stages, may involve the pulp [8–10].

Most of the articles on ICRR in the literature are reports of a single case or a short series of cases, discussing its clinical presentation and its treatment. There is a paucity of reported studies regarding its histopathology and diagnosis. Over the years, the fact that there has been practically no representation of ICRR in the orthodontic literature has given rise to uncertainty of diagnosis and consequential inappropriate management [11, 12]. Clinical and basic science articles on ICRR are published almost exclusively in the journals of endodontics, traumatology and radiology, and this is in no small part responsible for ignorance of the condition, which is so relevant to orthodontists.

Diagnosis

Case 10.1: Invasive cervical root resorption in association with long-term infra-occlusion (see Online PPT & video chapter 10 Case A and D)

When attempting to treat an impacted tooth, one of the first tasks that most orthodontists undertake is to map out its exact location and orientation in relation to the surrounding structures. From this, we will know how to define the directions in which the tooth will need to be moved in the 3D model. We will spend considerable time mentally reconstructing the imaging information, planning the way to resolve the impaction and choosing the technique that will enable us to achieve it. This is a purely *technical exercise* that, in the majority of cases, provides most of the essential information for success in treatment. Few of us, however, will utilize those same radiographs and cone beam imaging information in order to make a thorough check to confirm a healthy periodontium and root surface integrity. This is the *biological exercise*: the search for *why* the tooth is resistant to an applied force. This constitutes the other half of the diagnostic conundrum.

Solely considering the technical details of treatment planning, while ignoring the biological basis for the condition, runs the risk of prescribing ill-fated orthodontic and surgical treatment. If, at a later treatment visit, the tooth does not respond, the orthodontist is tempted to increase the applied force. Several more visits come and go with no progress and the traction force continues to be increased. The tooth still does not respond, but now the neighbouring teeth begin to show signs of anchorage loss, with the intrusion of these teeth beginning to appear and the creation of an open bite. At this point the orthodontist comes to the conclusion that the tooth is ankylosed and refers the patient back to the surgeon.

Following the typical treatment pattern, surgeons see their role at this juncture as re-exposing the tooth and freeing the 'presumed' ankylotic connection. Their mission is to apply a force sufficient to break the supposed direct connection to the bone – a luxation. The tooth is re-exposed and in full view and, surprisingly, is found to be mobile – sometimes even extremely mobile, particularly if the orthodontist had progressively increased the traction force during the many months of unproductive traction.

So what has happened?

An impacted tooth that is mobile yet refuses to respond to orthodontic forces might appear to be a contradiction in terms. It is essential to understand that increased mobility is not a criterion for success in generating tooth movement. Correctly viewed, this will not be seen as a paradox if one realizes that for a tooth to move, the integrity of its PDL must be complete. The presence of an ICRR lesion represents a distinct physical break in the integrity of the PDL. A new area is thus created where the two tissues merge, between the ICRR lesion in the root dentine and its adjacent PDL. This abnormal fusion is not biologically equipped to respond to an orthodontic force that would normally activate the bone resorption and apposition mechanism that lead to tooth movement. Indeed, it serves as a barrier, preventing the tooth from moving. Moreover, as the ICRR lesion enlarges, osteoid tissue is often laid down in the resorption crater, which then creates a further obstacle to tooth movement by secondarily producing an ankylotic type of connection between the two.

The radiographic diagnosis of ICRR can easily be missed or mistaken for 'interproximal cervical burnout', which is normal and commonly seen on periapical (Figure 10.1) and bitewing radiographs.

A logical approach dictates that, if we can assume that the direction of applied orthodontic force was appropriate to the resolution of the impaction and if we can confirm that ankylosis is not a factor, then it follows that there must be a flaw in the periodontium, which does not permit the tooth to respond. It is to be noted that a healthy, complete PDL is a precondition for tooth eruption and orthodontic tooth movement. Therefore, by default, we are brought to a tentative diagnosis of ICRR.

Verification of the diagnosis is not easy, because it entails sub-gingival probing and periapical radiography from different angles. Many of these lesions occur in buccal or lingual areas of the root surface, which do not show up in plane film radiography. However, a careful examination of the relative radiolucency of the root and even of the crown of the tooth may provide the clue to the presence of the condition (see later Figure 10.3). This may appear as an atypical caries-like shadow, ballooning into the dentine of the root or undermining the enamel in the cervical region of the crown of the tooth. Since the tooth is still unerupted, it is easily overlooked or presumed to be an artifact and clinically only a periodontal surgical flap will reveal the lesion. It seems clear that the invasive nature of the condition destroys the normal structure and integrity of the periodontium, thereby annulling the histological changes normally associated with eruption, whether they be natural or mechanically driven.

If planar radiography does not reveal an adequate reason for the tooth having become impacted, the next step is to widen the search for the more elusive factor. This factor will likely provide the answer to whether the affected tooth will, in due time, respond to a proposed orthodontic treatment regime. Additionally, a good work-up of the CBCT will permit a more accurate diagnosis of the 3D location of the impacted tooth. The orthodontist will be using this excellent tool to extricate the important, missing, accurate, positional information on the tooth, as well as qualitative information on the possible existence of pathology such as ICRR.

It has been postulated that cervical root resorption may be initiated by a local inflammatory process, indicating infection, or even trauma, which is then seen as a requisite aetiological factor. A defective junctional epithelium has also been impugned. However, these assumptions appear to be largely speculative [13].

One of the earlier investigations that advanced our understanding of ICRR was carried out by a team of researchers in Sweden. The team created an experimental model for cervical root resorption in monkeys, in order to conduct a study of the significance of the junctional epithelium in the prevention of cervical resorption [14]. The researchers reflected a muco-periosteal flap on the mesial and distal sides of the canines in the upper and lower jaws, respectively. The crestal alveolar bone, together with adhering periodontal membrane and superficial cementum and dentin, were removed to a depth of 2 mm in an apical direction, using a round bur.

In half the teeth in the sample, the exposed dentine was covered with thin polycarbonate foil. Eight weeks later, the dentine surface had not developed an epithelial cover but had exhibited numerous resorption cavities, associated with moderately, chronically inflamed and cell-rich granulation tissue. Actively resorbing odontoclasts and osteoclasts were seen along the dentine and crestal bone surfaces.

During the same period, the dentine surfaces of the non-foiled teeth (i.e. the second half of the sample) were all covered by a dense squamous epithelium. The originally denuded dentine surfaces that did not come into contact with mucosal or periodontal connective tissue showed cementum repair in the more apical areas of the root. The reparative connective tissue, which appeared under the epithelial coverage, was cell rich and presented a mild chronic inflammation. In the cervical area, where the damage was adjacent to the oral environment, repair was characterized by epithelial proliferation down the side of the root, to epithelialize the exposed dentine and thus to produce a long junctional epithelium.

The authors of the study concluded that chronic inflammation in the granulation tissue, when in contact with the dentine, prevents the marginal gingival epithelium from forming a protective cervical cell layer in an angular defect, and thus generates the resorption process.

Indeed, perhaps the most remarkable phenomenon occurs when the resorption process reaches the pericanalar layer, which includes the predentine. This is the inner layer that separates the dentine from the vital pulp. It is here that the resorptive front abruptly stops, having been arrested by the relatively high organic content of this layer [14]. Nevertheless, it consequentially continues on to encircle the root canal, without actually breaking through to the pulp (at least until the late stages of the lesion).

Since ICRR is apparently not the result of bacterial infection, it does not stimulate the production of secondary dentine and, because it is asymptomatic, is often only discovered when the damage is well beyond repair. The final breakthrough of the lesion into the pulp occurs very late in its morbidity and will probably lead to the same merging of otherwise healthy pulpal and PDL connective tissues. In such a situation, the patient will usually be unaware of any problem, unless and until direct contact is made between the pulp and the oral environment, at which point a superimposed bacterial infection will inevitably follow.

The 'portal of entry' of resorption will be on the root surface and will continue to mushroom into the dentine (Figure 10.1). When the pericanalar layer is reached, the resorption proceeds laterally and in an apical and coronal direction, progressively enveloping the root canal [15, 16]. The anti-resorption effect of this layer will arrest the progress of the resorption, leaving a narrow layer of dentine and predentine around the pulp. It may sometimes include bone-like (hard mineralized) tissue, giving it an irregular radiographic appearance. In the long run, the enamel may become thinned down, leaving only an outer, rodless, translucent layer and producing a characteristic 'pink tooth' caused by the vascular pulpal and resorptive tissue [17].

In a situation where there is access to the oral environment, due to a periodontal defect or where there is a generalized periodontal disease, the portal of entry will not often be found in a more apical location along the root. The reason for this is that this is an area of incomplete epithelial coverage, which is isolated from direct access to the mouth and will typically repair with a cementum deposit on the root surface. However, a resorptive lesion, with a *cervical* portal of entry, will spread longitudinally in coronal and apical directions along the root, but also circumpulpally, and will eliminate much of the root substance (see later Figures 10.3 and 10.6).

The results of the Swedish study on the non-human experimental model did not succeed in identifying the aetiology of ICRR. However, it is generally accepted that the cause is in part due to trauma to the PDL and the cementum. Mavridou (see earlier discussion) has suggested that a stimulating factor is required to assist in the activation of clastic cells in the PDL.

As far as can be determined to date, identification of the causes of ICRR is by no means complete. However, trauma and orthodontic treatment are factors most commonly associated with this condition [2, 6, 9, 18]. According to the European *Society* of Endodontology position statement, confirmation of the cause-and-effect relationship between the likely aetiological factors still requires more research [11].

ICRR, as its name implies, it is generally found in the area of the neck of the tooth, close to the CEJ. Similar lesions may occasionally be found elsewhere on the surface of the roots of teeth. It seems likely that ICRR is caused by non-inflammatory infiltration of clastic cells, originating from the PDL, which gain direct access to the root surface through gaps in the cementum layer [6, 14]. The association of ICRR with previous trauma presumably derives from the loss of cementum, which will have occurred at a specific point on the root's surface close to the CEJ. The consequent loss of PDL integrity at this point will permit the clastic cells to come into direct contact with the root surface. The site at which the cells begin their work of destruction then becomes a portal of entry and the resorptive lesion will mushroom out into the body of the root.

ICRR has been shown by Mavridou [9, 19] to comprise three main stages, namely the establishment of the initial resorptive site or portal of entry, the resorptive process and its extension into the body of the root and the reparative stage, which involves remodelling of the lesion. Mavridou and others [19] have also concluded that the process is complex and dynamic and that resorption and repair can proceed concurrently, within the same resorption lesion.

The position statement ends with the comforting and confident note that prevention and control of the condition may eventually be achieved with new treatment strategies.

The importance of a clinical examination to invasive cervical root resorption diagnosis (see Online PPT & video chapter 10 Case C)

ICRR in an unerupted permanent tooth is characterized by the absence of a response on the part of the tooth to orthodontic traction force and by the tell-tale radiolucent area in the cervical area of the tooth, which may be seen on a periapical or panoramic radiograph. As we have noted, definitive diagnosis may be difficult to establish, particularly in an early lesion, and a CBCT will assist materially in recognizing the defect and mapping its extent. Because of the difficulty of achieving a definitive diagnosis, a thorough clinical examination assumes greater importance. Indirect recognition of the phenomenon may often be derived from the clinical examination and is therefore a very important first step in these cases. It may contribute much to the practitioner's initial diagnosis of the case and to the ability to inform the patient at an early stage of the questionable prognosis for the tooth.

It is common knowledge that when a deciduous second molar tooth is prematurely extracted, there is frequently consequential loss of space in the arch. This will have occurred due to the adjacent teeth mildly tipping into the area from both the distal and the mesial sides. The successional second premolar will either become impacted between the two adjacent tipped teeth or will find a pathway to erupt buccally or lingually displaced from the line of the arch.

From our own studies, we have reported on the clinical implications of infra-occlusion of deciduous molars: in relation to space loss, to their effect on axial inclinations of their immediate neighbours, to their height in relation to the occlusal plane and to their effect on the dental midline [20–22].

In the case of a markedly infra-occluded deciduous second molar, the teeth adjacent to it will characteristically show a much greater degree of tipping, with minimal space loss at the crown level. This will be evident because the apices of these adjacent teeth are displaced mesially and distally away from each other and from the infra-occluded tooth. Moreover, the occlusal levels of these same teeth, which are on each side of the infra-occluded tooth, have also been shown to be infra-occluded relative to the other teeth in the same jaw. In addition, there is often a deviation of the dental midline to that side, even in a spaced dentition and even though the midline is four teeth distant from the affected tooth.

We have referred to this here since these features bear remarkable similarities to those occurring when infra-occlusion is caused by ICRR to teeth of the permanent dentition. When an impacted permanent tooth has been prevented from erupting due to ICRR, the teeth adjacent to the site will also show all these features, including the same exaggerated degree of tipping and the same picture of infra-occlusion, as with those adjacent to an infra-occluded deciduous molar.

For example, in a 10-year-old child signs of this nature are usually more indicative of severe infra-occlusion of a deciduous molar, rather than of space loss due to an extraction and drifting of the teeth. This phenomenon has been attributed to a re-arrangement of the trans-septal periodontal fibres, which link a complete row of erupted teeth at a site immediately apical to the CEJ. Their normal orientation is horizontal, stretching from molar to molar, in an unbroken chain [20]. When a single tooth is infra-occluded, its CEJ alters in height in relation to that of its neighbours and, with it, the trans-septal fibres acquire a vertical component in their alignment [21]. With progressive infra-occlusion the vertical component becomes dominant, causing this very marked tipping and obvious lack of vertical development of the adjacent teeth [22]. As the trans-septal fibre orientation becomes more vertical, the mesio-distal attraction lessens and horizontal space closure between the crowns of the adjacent teeth ceases. The further development of the incomplete roots then continues to elongate the roots in the opposite horizontal direction and, in this way, the root apices of the two teeth that are adjacent to an infra-occluded tooth become more divergent [21].

Case 10.2: Progressive infra-occlusion caused by invasive cervical root resorption

A 12-year-old boy was seen by an orthodontist for a first consultation visit, complaining of an asymmetrical anterior open bite on the left side. The earlier records of the child revealed a periapical radiograph that had been taken a year earlier, which showed the incisal edges of the central incisors to be approximately at the same level (Figure 10.2a). The left central and lateral incisor were relatively under-erupted compared with those of the right side (Figure 10.2b). The parents delayed acceptance of the treatment plan for a further 14 months, but finally returned when they realized that the open bite on the left side had increased more, although the increase was greater for the central incisor compared with the lateral incisor (Figure 10.2c).

Despite the oblique view of the film, it was evident that the incisal edges of the central incisors had been at more or less the same level. Additionally, the film showed an ICRR lesion on the distal side of the left central incisor, with a very small portal of entry at the cervical level (arrow). The lesion may be seen to extend coronally and apically, parallel to and on the distal side of the root canal, with a narrow longitudinally oriented wall (the predentine layer) separating the two.

(a) (b) (c)

Fig. 10.2 (a) Periapical radiograph showing the central incisors at approximately the same level. The arrow indicates an invasive cervical root resorption lesion. (b) Intra-oral view of the anterior dentition, taken 12 months later, showing an open bite of the left side incisors only. (c) Intra-oral view taken 14 months later, showing further increase in the open bite.

Courtesy of Dr Menahem Friedman.

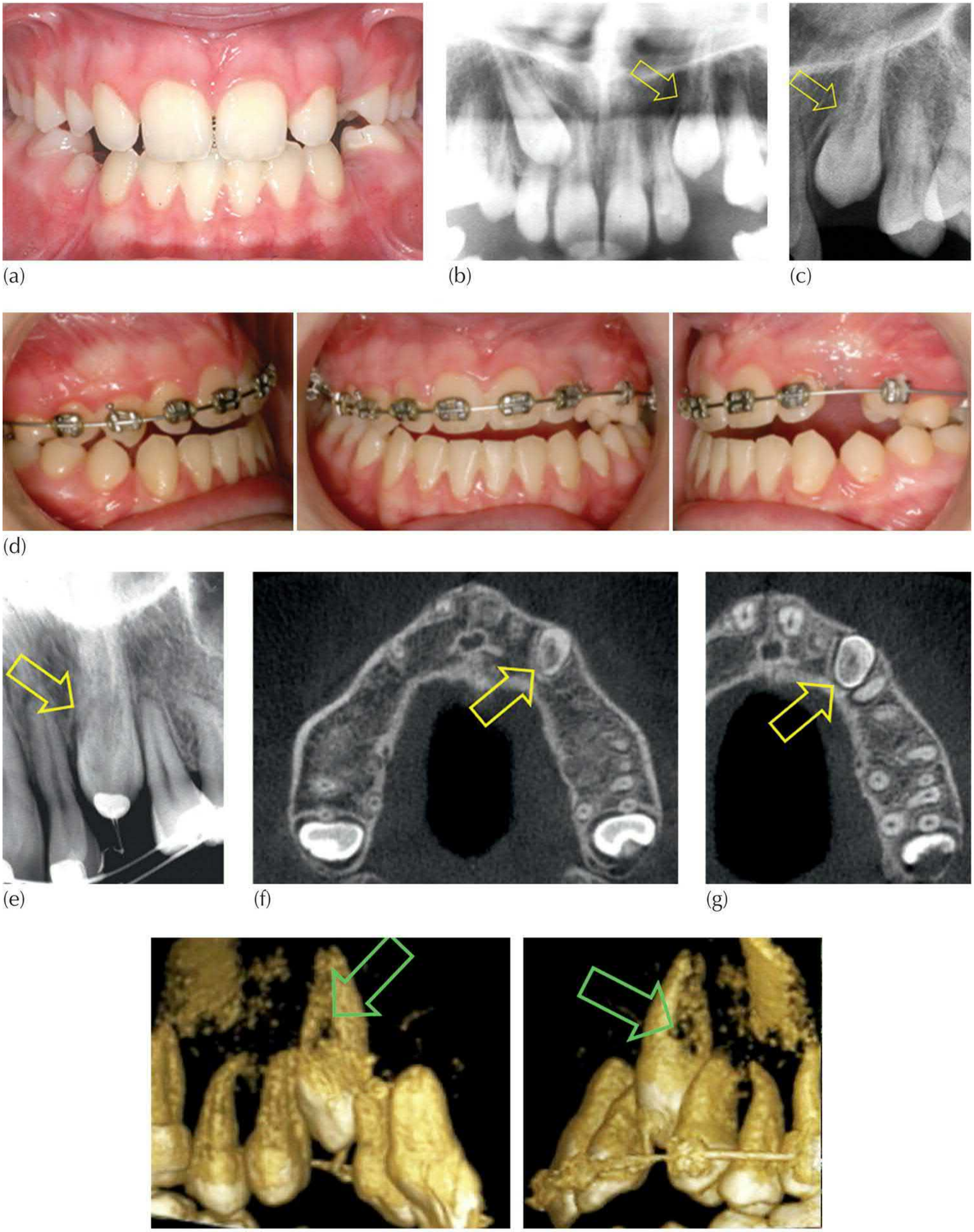
It was clear that the open bite had increased on the left side due to further infra-occlusion of the central incisor. The increase can be seen by comparing the periapical film to the first clinical photograph and is even more noticeable on the photograph taken 14 months later. The ICRR lesion had arrested the downward growth migration of the left central incisor, while the right-side incisors and other teeth in the canine/premolar areas had passively erupted as part of the patient’s overall growth. The two adjacent teeth had also become more tipped towards the affected tooth, whose space had reduced.

Case 10.3: The ‘red herring’ case

This case was referred to an orthodontist by the paediatric dentist, specifically for treatment of an impacted maxillary right canine, which had been discovered in a routine dental examination (Figure 10.3a, b).

The initial clinical photograph of the 13-year-old child shows the teeth in the late mixed-dentition stage, with healthy, well-maintained hard and soft tissues and a very minor malocclusion. The entire case had then seemed trivial and it was initially thought that it would progress to the full permanent dentition without orthodontic assistance. The occlusal relations of the posterior teeth were normal, with well-interdigitated teeth. The overbite and overjet were similarly normal, the incisors in occlusion, with no crowding and only the merest suggestion of a spaced dentition. The right deciduous canine was still present and both the permanent canines were unerupted. There was no history of trauma.

On the panoramic and periapical radiographs (Figure 10.3b, c), both permanent canines could be seen to have closed root apices. The left canine was pointing directly towards its place in the dental arch, with adequate space and no obvious interference from the adjacent teeth. It looked as though it would erupt imminently and unaided. The right canine appeared as a fairly typical palatal impaction, displaced mesially, superimposed on the lateral incisor root and to almost halfway across the root of the central incisor, encompassed by an enlarged dental follicle.



(a) (b) (c) (d) (e) (f) (g) (h)

Fig. 10.3 The 'red herring' case. (a) An apparently simple class I malocclusion with no crowding, but unerupted maxillary canines. (b) The right canine was impacted, classified as a type 2 impaction, with enlarged follicle. (c) The missed diagnosis of invasive cervical resorption of the mesial side of the root of the left canine is clearly visible on both the initial panoramic radiograph and on the periapical view (arrows). (d) After 28 months of treatment, the right canine is aligned, but an open bite has occurred principally on the left side. (e) The enlarged area of invasive cervical root resorption, diagnosed at 28 months of treatment in the 'woolly' appearance on a new panoramic radiograph and (f, g) in two axial slices from a cone beam computed tomography (CBCT) cut across the cervical area of the root and across the cervical area of the crown, respectively. (h) 3D screenshots from the CBCT, taken from the lingual and labial sides of the dentition, show the 'through-and-through' invasive cervical root resorption lesion in the root (arrow).

Treatment had involved the placement of molar bands and orthodontic brackets had been bonded to the incisors and on the first premolars at the start of treatment. It is pertinent to note that neither second premolar had been included in the set-up. The right canine was surgically exposed during the treatment, an attachment was placed and the tooth had been successfully brought to its place in the arch (Figure 10.3d).

The left canine, on the other hand, was only exposed when, several months into treatment, it had still not erupted autonomously. Extrusive forces were applied in an effort to erupt it, but it had been totally unresponsive. After 28 months of treatment, the intra-oral photographs showed the establishment of an asymmetrical anterior open bite, which was greater on the left side, up to and including the left first premolar, but involving only the bracketed teeth (Figure 10.3d). This was indicative of loss of anchorage. Clearly, the 'equal and opposite' reactive force to the unresponsive left canine had acted to intrude all seven teeth that were connected to the archwire, excluding the banded first molars. This demonstrated clearly that the case had been misdiagnosed and that what seemed an apparently simple problem, with minimal anchorage requirement, had been wrongly interpreted. As if to emphasize the degree of anchorage failure, the second premolars, which had not been ligated to the archwire, had remained in occlusion.

The reason the left canine had failed to respond was the presence of a significant ICRR lesion occupying the coronal half of the root of the tooth on its mesial aspect. ICRR can be seen both on the initial panoramic view and on the periapical film, taken at 14 months into treatment (Figure 10.3b, c). However, it had not been diagnosed at that time. It was only finally recognized on the periapical film performed at the 28-month stage of treatment. On this latter film, the 'woolly' texture of the tooth can be seen, together with the loss of a section of the lamina dura of the mesial side of the root (Figure 10.3e). At this point, the orthodontist referred the patient to an imaging centre for a CBCT examination, to assess the extent of the resorption.

In the canine section of the panoramic radiograph (Figure 10.3e), the magnitude of the lesion is seen to extend from the cervical area of the crown to a considerable distance along the root, with a fuzzy indistinct outer wall at the mesial side. There is a 'woolly' radiolucent (darker) appearance of the dentine in patches in the body of the root, extending beyond the root canal to the other side. The axial views (Figure 10.3f, g) confirm the broad spread of resorption across the entire linguo-mesial aside of the tooth, surrounding the root canal and extending into the crown; note the ring of enamel (Figure 10.3g). The portal of entry of the lesion can be seen (arrow) on the most lingual point on the axial slice of the root (Figure 10.3f).

The apparently 'crumbling' appearance of the root of the tooth seen from both lingual and labial aspects illustrates how advanced the lesion is. It seems to have created a 'through-and-through' hole right through the root from one side to the other (Figure 10.3h). This lesion had been the cause of failure of the tooth to erupt. Additionally, the significantly shortened incisor roots are due to resorption from the long-term reactive intrusive forces on these teeth, which had been the bulwark of the anchor unit, against the 2.4 years of fruitless extrusive force on the canine.

Case 10.4: The unresorbed predentine layer

Figure 10.4 shows a very advanced ICRR lesion involving the total width of the neck of the impacted incisor, which remains vital and asymptomatic. The (radiolucent) pulp is protected by the integrity of the pericanalar layer, which separates it from the diseased (radiopaque) dentine. The pulp and root canal are thus isolated from the resorption process by the intervening ‘sleeve’ of the predentine–dentine layer, which appears in 2D as two thin radiopaque lines (arrows) of the slice, but is in fact a single 3D cylindrical predentine sleeve. The lesion extends both apically into the root and coronally into the crown.

Case 10.5: Invasive cervical root resorption causing a lateral open bite

All these clinical signs (Figure 10.5a, b), together with the radiographic evidence seen in the panoramic view, are the clinical signs of ICRR of an impacted first premolar. The radiographic view shows the same ‘woolly’ texture within the crown and root, which indicates very advanced involvement of the resorption process, and which undermines the enamel of the crown and much of the root. There is a loss of integrity of the lamina dura on the entire mesial side.

The case illustrated is of a patient as seen on her first visit to the orthodontist, prior to the commencement of treatment. She exhibited an alignment and occlusion of the teeth, which had most of the signs of normalcy. The first molars were normally related, the incisor overjet and overbite were normal, the mandibular dentition was well aligned, with a very minor degree of spacing, the midlines were good and, on the left side, all the posterior teeth were in faultless alignment and occlusion. However, the ‘fly in the ointment’ was the stark contrast seen in the maxillary right quadrant, where the first premolar was the only tooth missing from the erupted dentition. It had initially been assumed to have been extracted, although no history of this could be elicited from the child or parent. The orientation of the canine and the second premolar showed exaggerated tipping towards the reduced space, as well as a lack of vertical development interproximal spacing in that quadrant, from midline to molar. There was a localized lateral open bite.

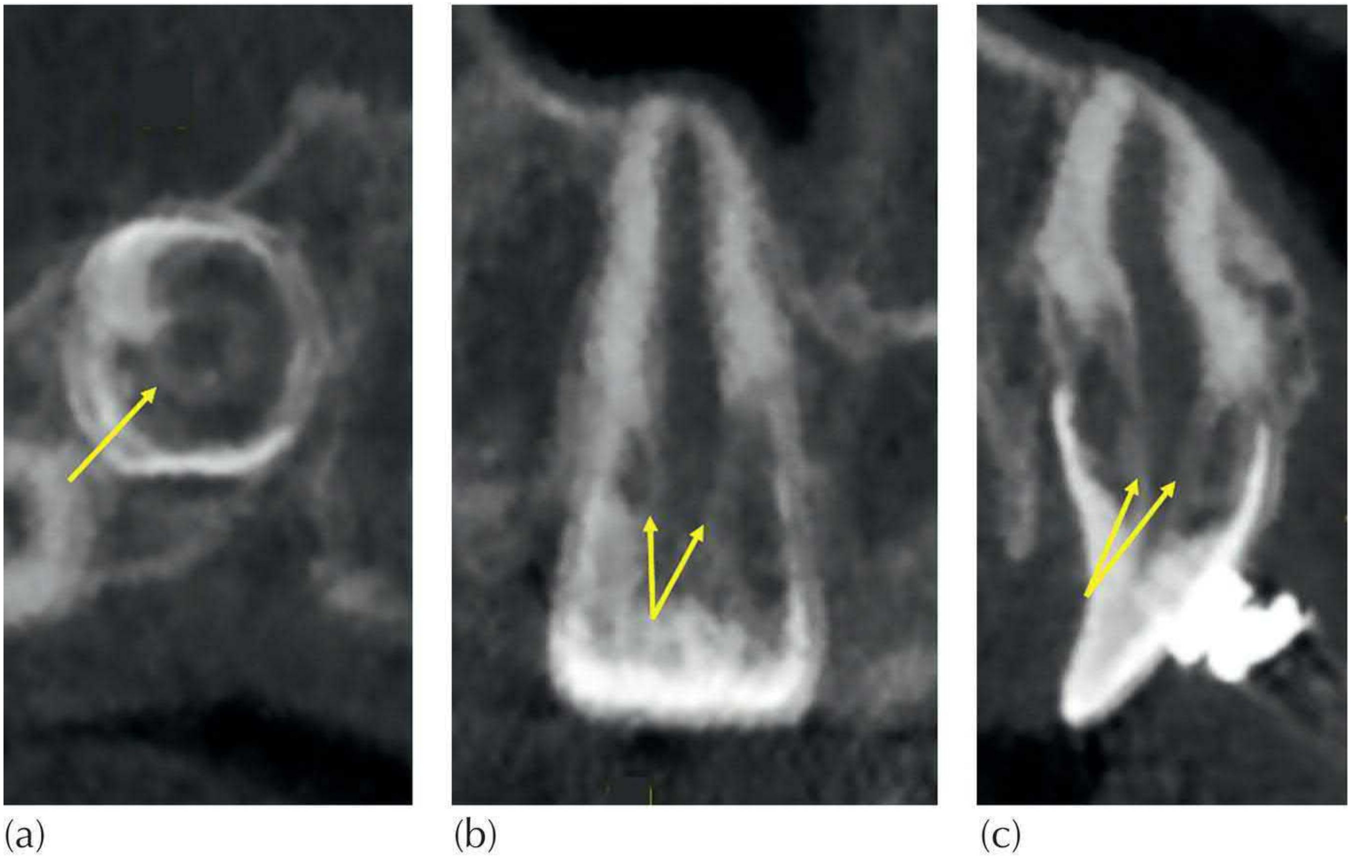


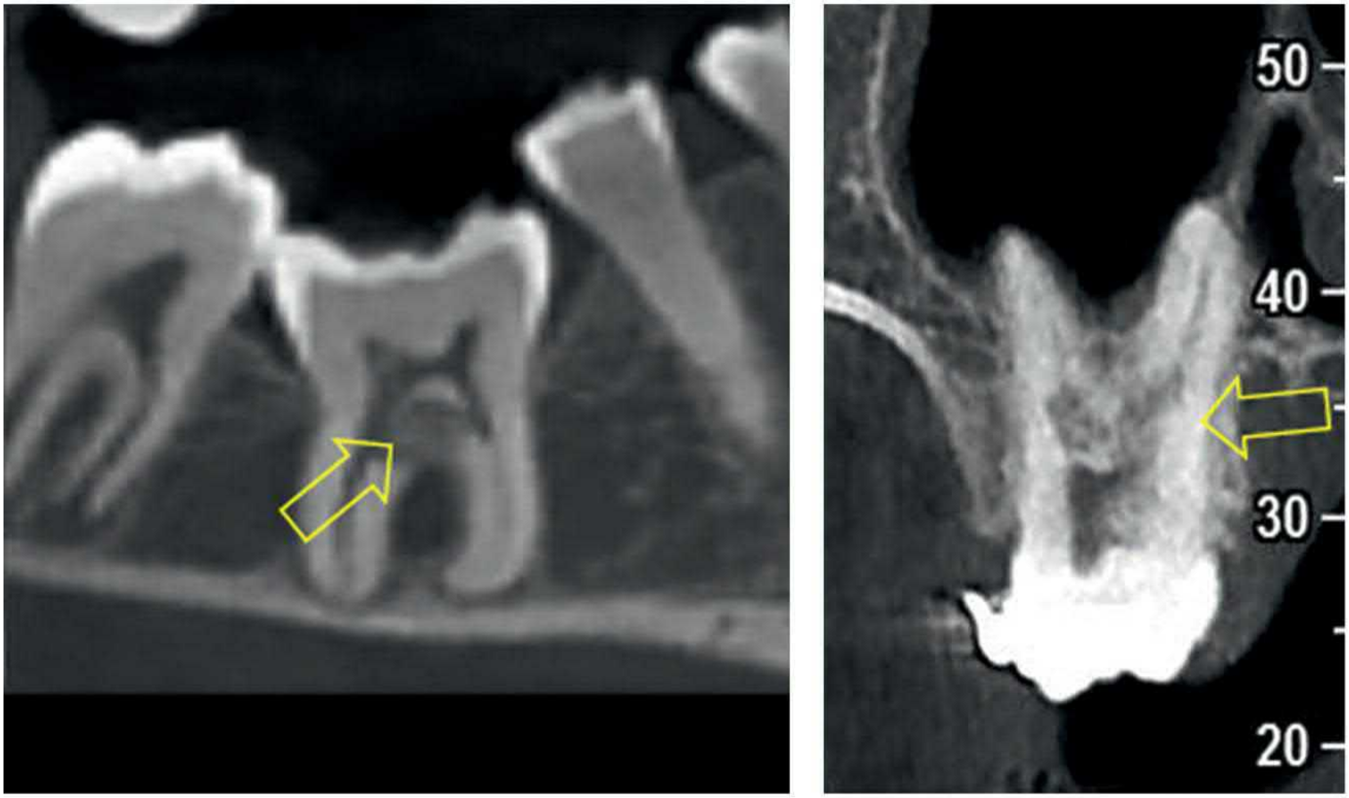
Fig. 10.4 An advanced invasive cervical root resorption lesion in an impacted incisor. The images were extracted from the multiplanar reformatting reconstruction of the cone beam computed tomography. (a) An axial slice in the cemento-enamel junction (CEJ) area. (b) A coronal slice and (c) a cross-sectional slice. The innermost dark (radiolucent) area indicates the root canal, encompassed by the slightly radiopaque pericanalar circle, indicated by the yellow arrows. The third concentric circle is the wider area of almost total root resorption, which is encircled by the delicate enamel outer layer at the CEJ. The enamel is thinned by resorption too, and unsupported other than by the soft, radiolucent, resorption mush.

(a)

(b)

Fig. 10.5 (a) The maxillary right first premolar is impacted and is apparently the epicentre of a force drawing everything else towards it. Abnormally strong tipping of the adjacent teeth, space opening further forward, infra-occluded adjacent teeth (lateral open bite). (b) A panoramic view. Although apparently unassociated, the central incisors have very short roots in comparison with the lateral incisors. An enlargement of the premolar area shows the ‘porous’ and ‘woolly’ texture of the invasive cervical root resorption–affected area of the tooth.

Courtesy of Dr Brian Jesperson.



(a) (b)

Fig. 10.6 (a) A longitudinal slice of an infra-occluded right mandibular molar showing invasive cervical root resorption affecting the furca area. (b) A cross-section slice of a similarly affected and infra-occluded maxillary first molar.

Cases 10.6 and 10.7: Invasive cervical root resorption in the furca of a molar in two unrelated individuals (see Online PPT & video chapter 10 Cases A and D)

It has already been noted that ICRR also appears in other locations, particularly in the furca between the roots of a permanent molar, where it seems to be less prevalent than in the cervical area. Two affected and unrelated individuals, with the presenting symptom being an infra-occluded permanent molar, are described here (Figure 10.6a, b).

In one of these individuals, the tooth concerned was a mandibular first molar (Figure 10.6a), with the tooth severely infra-occluded and a large radiolucent area in the inter-radicular bifurcation. The growth of the roots had become diverted at the anatomical barrier of the lower border, causing the root apices to become shortened and curved. The other molar was in the maxilla (Figure 10.6b) and its arrested eruption had caused the developing roots to express their growth potential in an upward direction and to protrude into the floor of the antrum to a significant degree. The presence of the ICRR lesion was the sole aetiological factor common to both.

Chapter 13 discusses the alteration in root form of impacted teeth in relation to the several aetiological findings that are seen in cases with infra-occluded teeth, among which ICRR features quite prominently.

Case 10.8: A case of historical interest

The case illustrated in Figure 10.7 is of historical interest. It illustrates a problem that was treated by the author almost 50 years ago, prior to awareness in the dental profession in general and in orthodontics in particular of the existence of ICRR and the relationship between ICRR and tooth impaction. At the time, few practitioners were placing attachments on unerupted teeth during the surgical procedure. Direct bonded materials were in their infancy and it was considered inappropriate to use acid-etch composite adhesives in the presence of an open and bleeding wound, because it was judged impossible to achieve suitable uncontaminated conditions for bonding. In Jerusalem, we were still using preformed canine and incisor bands, which were cemented to the impacted tooth during the exposure procedure. Elsewhere, the placement of TMS® threaded pins, set into the crown of the impacted tooth, was then still being widely advocated [23, 24].

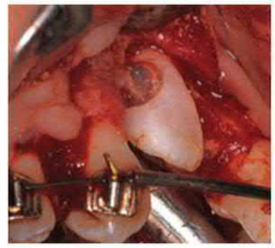
Under normal circumstances, the eruption of lateral incisors precedes the eruption of the canines and premolars by approximately three years and they generally erupt autonomously at the age of 8 years, even in a crowded dentition. Nevertheless, in the child illustrated (Figure 10.7a), the right lateral incisor was still unerupted at 12 years of age. Her dental age corresponded with her chronological age and, as was to be expected, this tooth could be seen on the radiographs to have a fully developed and apexified root (Figure 10.7b).

Extraction of the first maxillary premolars had been advised and carried out by the child's orthodontist, in order to provide more space for the expected spontaneous eruption of the incisor. The intra-oral picture (Figure 10.7a) displayed a lateral open bite and, specifically, showed the canine and central incisor adjacent to the impacted lateral incisor to be partially erupted and tipped towards the unerupted lateral incisor. An excess of space had been deliberately created with a coil spring and sliding mechanics (Figure 10.7b). Despite all this preparatory procedure, the lateral incisor steadfastly refused to erupt.

The patient was then referred to a surgeon for exposure of the lateral incisor. At the exposure, a large resorption cavity (Figure 10.7c, d) was found on the disto-labial corner of the CEJ, with sharp enamel edges at the crown and filled with a soft mush, quite different from carious dentine. There was no known and readily available diagnosis 50 years ago for this lesion in the orthodontic lexicon. An endodontist was called to the operating theatre where she excavated the mush, immediately generating bleeding from the pulp. The vital, normal and non-inflamed pulp was then extirpated and the root canal temporarily filled with calcium hydroxide paste. An amalgam restoration returned the tooth to its original anatomical form and an orthodontic bracket was placed (Figure 10.7c, d). Simple orthodontic traction was then applied to the tooth, which was drawn down to the archwire and into alignment with considerable ease and rapidity (Figure 10.7e).

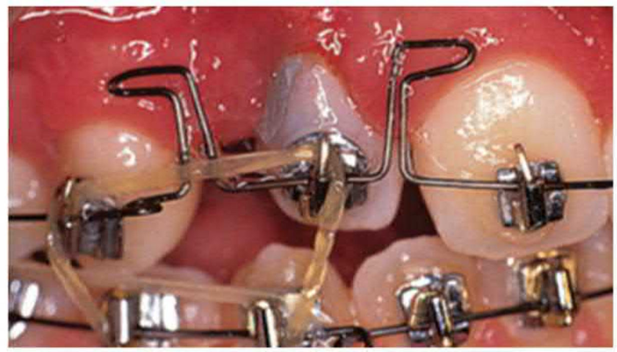
(a)

(b)



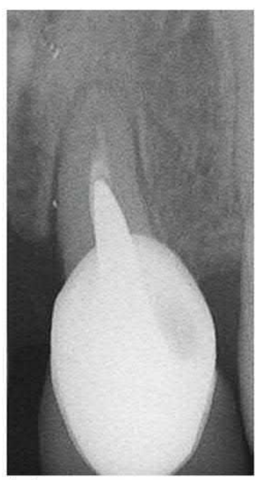
(c)

(d)



(e)

(f)



(g)

(h)

(i)

Fig. 10.7 (a) The practitioner's intra-oral photographs taken approximately one year after extraction of the first maxillary premolars. (b) Periapical view of lateral incisor after levelling and space opening. The portal of entry is seen on the distal side of the cemento-enamel junction area, with local loss of continuity of the lamina dura. The invasive cervical root resorption (ICRR) lesion has advanced into the crown and root. (c) During surgical exposure of the impacted tooth, the ICRR lesion after excavation of resorption mush. A vital pulp was exposed. (d) Following pulpal extirpation and temporary filling, an amalgam filling was placed. (e) Light continuous traction was used to successfully erupt the incisor. (Surgery by Prof. A. Shteyer, endodontics by Prof. I. Heling.) (f) Radiographic follow-up. Pre-surgical view of the affected tooth. (g) Periapical view of root-treated tooth with permanent post and crown at age 18 years. (h) Intra-oral view showing the elongated crown restoration. (i) Intra-oral views at the end of treatment. Note the less than aesthetic appearance of the treated incisor due to the necessity to cover the gingival recession.

The initial ICRR lesion was extensive, stretching well down the root of the tooth (Figure 10.7f) and, in order to ascertain that the margins of a final restoration would be supra-gingival, the tooth was further extruded. Root treatment was subsequently completed when the margins of the restoration had been extruded supra-gingivally. The incisor was finally restored at age 18 years, with a post and crown restoration (Figure 10.7g, h). The patient was left with a rather unaesthetic, elongated crown because of the perio-prosthetic requirement to orthodontically extrude the margins of the restored ICRR lesion, coronal to the crest of the alveolar bone. In the event, a long clinical crown, a short root and a high gingival level were the inevitable byproducts (Figure 10.7h, i).

This case attributes to ICRR the role of a potent cause of non-eruption and serves to emphasize the need to eliminate the ICRR lesion as an essential prerequisite for success with eruption mechanics.

Principles of treatment aimed at salvaging the impacted tooth

If an ICRR lesion is excavated with the aim of eliminating all the softened dentine mush, vital exposure of the pulp will be inevitable and undesirable. Furthermore, an immediate root canal procedure will need to be undertaken within a surgical field that, while suited to the performance of exposure of an impacted tooth, offers physical conditions far removed from being the ideal environment for endodontic success. ICRR should not be treated like dental caries. It is not caused by bacterial activity and, because it is sterile, it does not cause inflammation of the pulp, nor does it stimulate the formation of secondary dentine.

The separation between the contents of the ICRR lesion and the pulp occurs at the very thin pericanalar layer. The nutritive supply line of the resorptive process derives from the PDL and not from the dental pulp. The logical and appropriate procedure that these principles dictate is therefore the superficial removal of the affected dentine, in order to provide a shallow cavity whose outer wall is free of the resorption mush. The affected root surface that defines a (usually enlarged) portal of entry of the clastic cells is trimmed back until its perimeter comprises healthy dentine.

It is imperative to understand that there is no need to excavate all the soft mass in the depth of the lesion. If the cavity has been carefully and conservatively prepared, it may then be restored with glass ionomer or other restorative material. The clastic elements will have become sequestrated from their nutritive source and their activity will be arrested within the sealed-off cavity. The tooth will then respond to eruptive forces, both natural and applied, and the impaction will likely be resolved [25]. Definitive treatment of the isolated mush may be undertaken many months later and only after the restored margins of root surface have been extruded supra-gingivally, and after optimal conditions of access for endodontic and restorative treatment have been achieved.

Bonding attachments to impacted teeth at the time of surgical exposure is a very sensitive procedure, requiring intricate technique and dexterity, as well as good cooperation between surgeon and orthodontist. With practice, the whole procedure from flap reflection to bonding, to suturing, to applying traction need take no longer than 15–20 minutes. Nevertheless, for much of this time, the chairside assistant will be using high-powered suction to maintain a clear and dry field and, if the tooth is exposed all the way down to the CEJ and a little beyond, then that area of root surface will suffer drying out for an excessive period of time. This is a fact of which the surgeon and the orthodontist should be aware, since it creates a risk that the damage caused to the exposed cementum from the resultant cell death may then lead to a new ICRR lesion. Unfortunately, it is rarely considered.

Experience of three to four decades of direct bonding of attachments to enamel on impacted teeth has led to a more conservative approach to exposure surgery. It has, however, also generated further hazards. To etch the enamel of a tooth situated in the middle of an open surgical field can result in the orthophosphoric acid etchant being inadvertently splashed over alveolar bone and denuded root surface. While the necrotic bone and cementum may be removed by scavenger cells in the PDL, ICRR may be triggered by the acid etchant in the root surface of the tooth. Once started, there is no stopping the ICRR process, which will advance to destroy the body of the root as it spreads apically, coronally and circumpulpally.

Since the resorption begins in the cervical area, immediately apical to the gingiva, many endodontists and periodontists will request that the tooth first be orthodontically extruded to bring the lesion to the surface, to enable them to curette out the affected area in more congenial circumstances. Since, as stated earlier, the nutrient lifeline of the lesion originates from the PDL, restoring the defect with glass ionomer or other cementing or filling material will effectively eliminate the progress of the disease. However, we have already pointed out that orthodontic extrusion of these teeth will almost certainly fail to erupt the tooth, unless the lesion is an early one.

Diagnosis is rarely made early enough and, by the time corrective action is considered, bone may already have been laid down in the recently resorbed lacunae and the tooth will no longer be able to respond to the orthodontic forces. The only salvation in these cases is to eliminate the resorptive process *before* the attempt to supra-erupt the tooth, by an open flap procedure with sub-gingival curettage. This can only be done if the lesion is relatively limited and surgically accessible.

The resorptive lesion receives no sustenance from the pulp, from which, even in advanced cases, it remains separated by a progressively reduced thickness of dentine of the root and the pericanalar (dentine–predentine) layer. Accordingly, there is no urgency to remove all the mush from the depths of the lesion and to risk pulp exposure – certainly not in circumstances of poor vision of, and access to, the sub-gingival area. All that is needed is for the lesion to be sealed off from its connection with the PDL. The tooth may then be actively erupted with occlusally directed orthodontic force, until the temporarily restored lesion comes into view supra-gingivally. Only then should the debris of the lesion be cautiously and conservatively cleared and only then should suitable definitive restorative procedures be undertaken in conditions of much greater convenience and precision. There is room to consider leaving the deepest residual mush in the cavity, since it is not caries and its active ingredient will die in the absence of its supply line. Endodontic procedures are only necessary, electively, if the remaining tooth structure of the crown is inadequate to retain a large restoration.

Case 10.9: Severe loss of anchorage

In the 16-year-old male patient presented in Figure 10.8, it was unusual to note that the most significant piece of information received at the first (and only) consultation was that he had been referred to the author following 5.7 years of unsuccessful orthodontic treatment elsewhere. His treatment had been planned to resolve the impaction of a maxillary left canine.

When a case is transferred to another orthodontist in mid-treatment due to failure to resolve the impaction, the first thing for the orthodontist to do is to review the former orthodontist's *initial pre-treatment records*. There is always at least one reason for the failure of the treatment. The initial records may hold the key to its discovery. Only after this initial step should new records be taken and studied, before offering the patient further advice.

In the pre-treatment, extra-oral, facial and intra-oral occlusal views of the patient (Figure 10.8a), the anatomical midline of the face can be seen to pass through the maxillary right–left inter-incisal contact. In other words, the anatomical and dental midlines were identical. The pre-treatment dental alignment and occlusion (Figure 10.8b, c) showed a very mild class II malocclusion with small teeth.

The occlusal view also showed a symmetrical and spaced dental arch, with the left deciduous canine still in place. The yellow arrow indicates where the crown of the impacted canine could be palpated. The initial panoramic radiograph taken at that time (Figure 10.8b, c) showed all teeth present, including the developing third molars. The maxillary right and mandibular left central incisors had been root treated, following an incident of trauma. The deciduous left maxillary canine was over-retained and partially resorbed, while the permanent canine was impacted and markedly displaced, with its crown tip abutting the midline.

The patient was first seen by the author in March 2012 (Figure 10.8d), having experienced three 'open-and-pack' surgical exposures (open exposure surgery) together with elective luxation of the canine, which the surgeon had justified as being 'an aid to encourage eruption'.

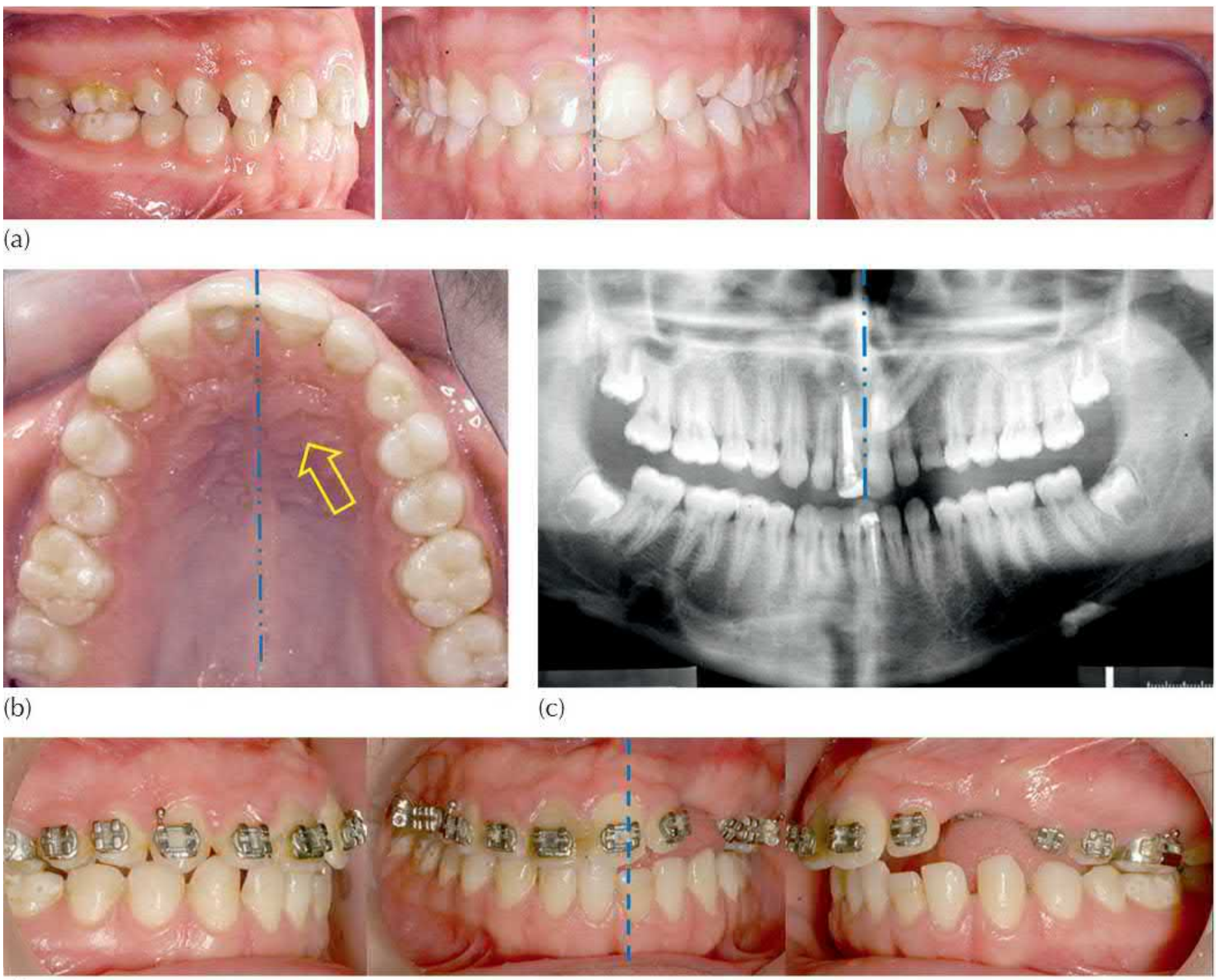
After 5.7 years in active treatment, the maxillary dental arch had become asymmetrical. There was a cross-bite on the left side, due to a narrowing of that side of the arch, and the bite had opened, due to intrusion of the incisors and premolars. The entire maxillary dentition in the anterior region had translated to the right, with a discrepancy of 5 mm between the incisive papilla (including the central incisors and alveolar bone) and the rest of the median raphe, which was unaffected (skeletal or basal bone). These were unquestionably characteristic of extreme anchorage loss, resulting from the absence of movement on the part of the impacted canine, which, in turn, had resulted from an efficient, but misdirected and unsupervised, application of force for an excessive duration.

In the posterior region, there was a cross-bite occlusal relation seen on the left side and a buccal cross-bite (scissors bite) relation on the right side.

Re-evaluation of the case

A study of the maxillary dentition from the occlusal aspect for this case is also very enlightening. In the normal situation, the median palatal raphe bisects the approximately semi-circular arch along which the teeth are arranged. Here it was easily identifiable and clearly seen in the pre-treatment records and was also confirmed by the molars being equidistant from it (Figure 10.8b). Every midline raphe is located on basal bone and is formed by the union of the skeletal palatine processes of the maxilla that comprise the two halves of the palate. As such, the location of the raphe is unaffected by dental movement.

By contrast, on the occlusal view of the maxillary dentition, at the 5.7-year stage of failed treatment, the shape of the maxillary dental arch had completely changed. The left-side teeth and alveolar ridge had been collapsed inwards towards the resistant, impacted canine and the distance to the median raphe was greatly reduced. Nevertheless, further back in the molar area, where the influence of the force of the appliance was much lessened, the width of the affected side of the palate had hardly been affected. In the occlusal view (Figure 10.8e), that part of the median raphe of the palate that was located on basal skeletal bone has been marked in blue. The maxillary dental midline at the front of the mouth (i.e. the short line drawn through the point of contact of the central incisors) is marked in green. It represents that part that had deviated, together with the incisive papilla, in coordination with the movement of the teeth and of the alveolar bone on which they were located. At the same time, there was a cross-bite of the premolars on that side and buccal cross-bite (scissors bite) on the right. It was clear that the entire maxillary dentition had been influenced by the impacted left canine (Figure 10.8f). The preformed main archwire was ligated to the individual teeth and held them together for their task as a composite anchor unit. This had failed, causing them all to be displaced further to the right. The dental midline had been carried along with them, creating a discrepancy between it and the anatomical midline (Figure 10.8f, g). Since maxillary anterior teeth are naturally sited on a rim or periphery of alveolar bone, which also encompasses the inferior part of the incisive canal, the anterior portion of the alveolar bone of the midline suture was now pushed to the right, along with the teeth. This was presented in the occlusal view as a sharp deflection of the anterior portion of the raphe and of the incisive papilla.



(a) (b) (c) (d)

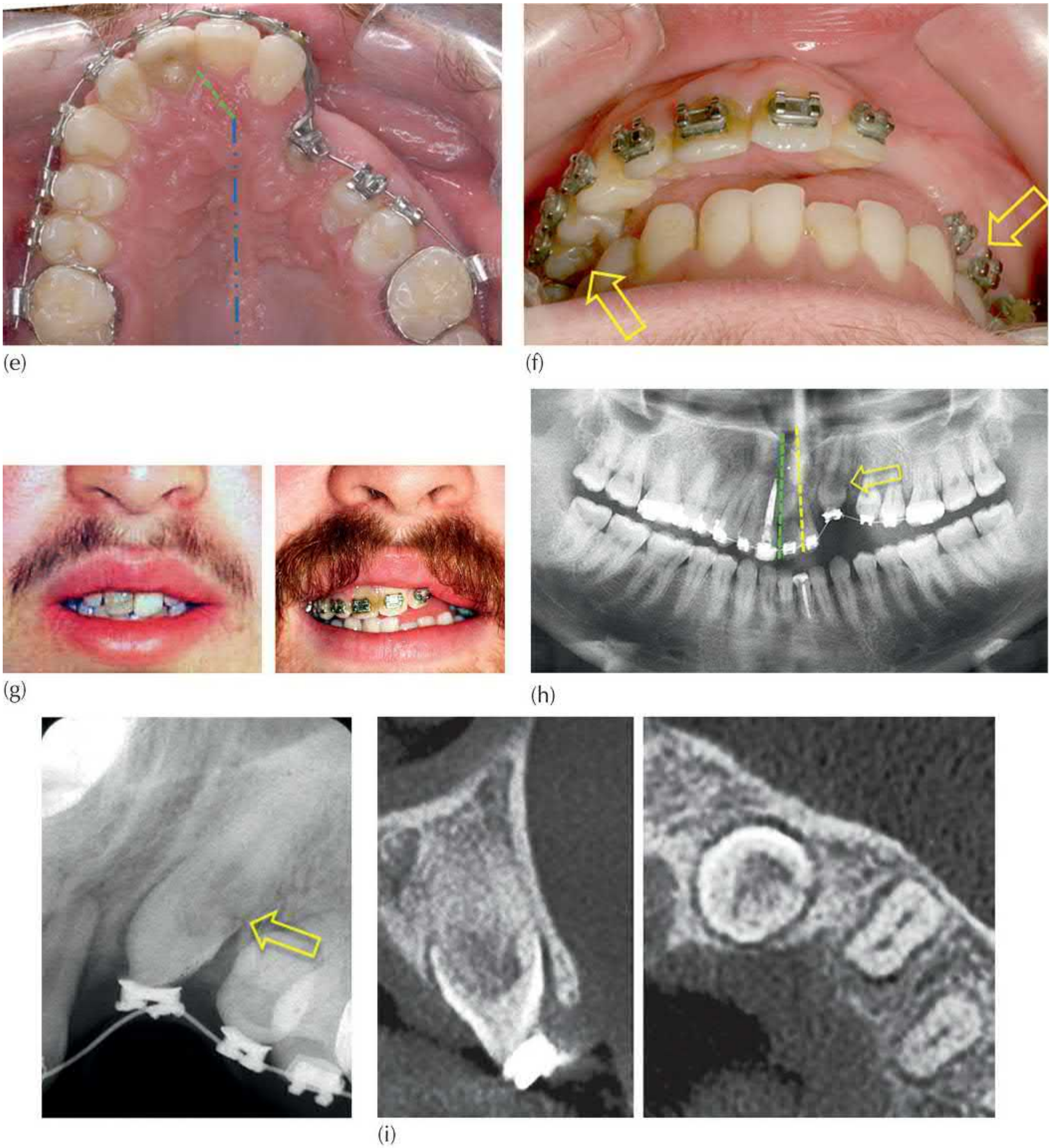


Fig. 10.8 (a) From the pre-treatment records of the patient. The blue dotted line indicates the anatomical (facial) midline, with is congruent with the maxillary inter-dental midline. The mandibular dental midline is approximately 1 mm to the right of the maxillary dental midline. (b) The pre-treatment maxillary occlusal view shows good symmetry. The yellow arrow indicates the location of the unerupted left maxillary canine. (c) The left maxillary canine is clearly seen on the panoramic view. The blue dotted lines indicate the congruent dental and anatomical midlines. (d) After 5.7 years' treatment, the intra-oral views of the occluded teeth show a large anatomical/dental midline discrepancy, together with the defective alveolar ridge in the canine area. (e) After 5.7 years of treatment, the occlusal view shows the narrowed arch due to gross

lingual movement of the premolar teeth and the displacement of the alveolar ridge and incisive papilla, diverting the anterior (alveolar) portion of the midline away from the median raphe (skeletal) portion. (f) The maxillary midline is diverted the width of a mandibular incisor to the right, while the arrows show posterior teeth movement into a left-sided cross-bite and right-sided buccal cross-bite (scissors bite). (g) *En face* comparison of the midline before and after treatment. (h) The panoramic and periapical views show the 'woolly' texture of the lesion on the distal aspect of the canine. (i) From the cone beam computed tomography images, a cross-sectional slice clearly depicts the dentinal changes wrought by the resorptive process and an axial slice can be seen to affect the distal part of the tooth.

Source: (h, i) Becker A, Abramovitz I, Chaushu S. Failure of treatment of impacted canines associated with invasive cervical root resorption. Angle Orthod 2013; 83: 870–876, with permission from Allen Press / https://meridian.allenpress.com/angle-orthodontist/article/83/5/870/59390/Failure-of-treatment-of-impacted-canines.

The panoramic and periapical views (Figure 10.8h) show the typical picture of ICRR, with loss of the lamina dura on the distal side of the left maxillary canine and with a 'woolly' radiolucency within the tooth, extending both coronally and apically into the substance of the tooth.

The cross-sectional (vertical) and axial (horizontal) slices taken from the CBCT (Figure 10.8i) show the degree with which the lesion had burrowed into the dentine of the root and crown. Several portals of entry of the resorptive lesion can be seen to have extended round to the labial side just superior to the CEJ. The tooth itself was asymptomatic.

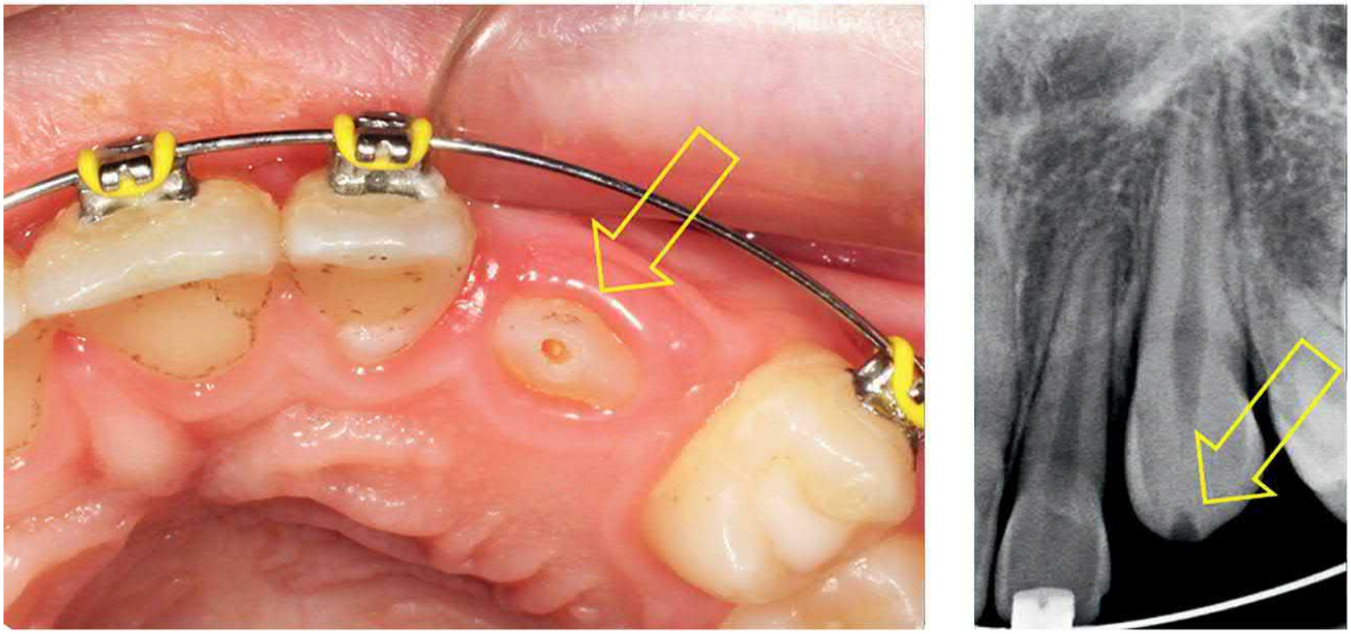
Pre-eruptive intra-coronal resorption

Pre-eruption intra-coronal resorption (PEIR) is an uncommon condition and is rarely recognized by anyone apart from paediatric dentists.

PEIR is also known in the dental literature by several other names, including 'penetrating crown resorption of an unerupted tooth', 'pre-eruption caries', 'occult caries', 'hidden caries', 'pre-eruptive dentine translucencies' and several other names. This multiplicity of names is itself evidence of the fact that most authors of journal articles that refer to the condition appear to be unaware of its nature [26]. They also tend to confuse resorption with caries. Most of the articles are individual clinical case reports, published in practical and clinical journals, and as such they ignore histopathological examination and do not present definitive diagnoses of the lesions concerned.

In a comparative population study of Australian and Saudi children, the prevalence of PEIR was found to be 2% (not statistically significant) and 0.6% ($p>0.1$), respectively. In that study, two conclusions emerged that are particularly relevant to the present context. First, the researchers found that the teeth most commonly affected by PEIR were the mandibular second molars and second premolars. The second factor related to eruption disturbance, insofar as 31% of the teeth with PEIR were found to be impacted [27, 28].

So let us examine what PEIR is and what is its cause. PEIR appears to be closely related to ICRR and its progress and microscopic features are probably identical. The basic difference is that ICRR enters through gaps in the cementum layer covering the dentine of the root of the tooth, while PEIR enters through the crown of the unerupted tooth, by way of a developmental gap or imperfection in the integrity of the enamel. It is most commonly to be found in the occlusal pits and fissures, buccal pits in molars, cusp tips on the crowns of various teeth (Figure 10.9) or *dentes in dente* on lateral incisors. For the most part, the imperfection is a tiny, innocent-looking pinhole. When discovered before the tooth erupts, it is sterile and asymptomatic, but it may progress and destroy most of the crown of the tooth, eventually including the enamel, before it is discovered. It differs from ICRR because the PEIR activity is arrested when the tooth erupts into the oral environment. Once erupted, it loses its nutritive supply line from vascular plexus in the follicle. The clastic cells, which had hitherto burrowed into the dentine of the crown and undermined the enamel, will die from being cut off from their supply line. Notwithstanding this and usually pursuant to the eruption of the tooth, the lesion may later become secondarily infected with true bacterial dental caries, mostly in the depths of the open imperfections or gaps in the crown. This is an additional reason for such misnomers as hidden caries, pre-eruption caries or occult caries.



(a) (b)

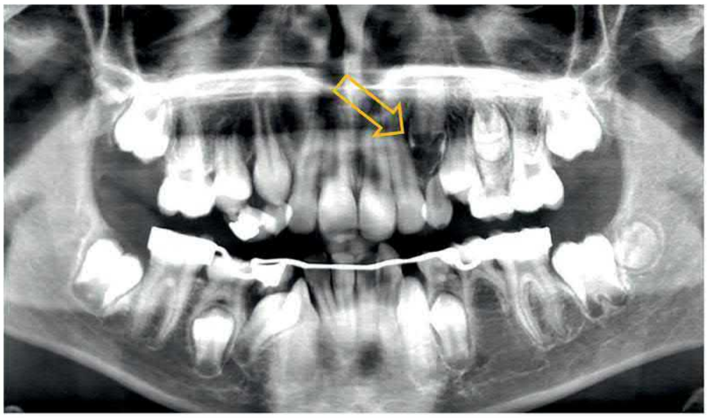
Fig. 10.9 A typical 'pinhole' pre-eruptive intra-coronal resorption lesion in an erupting tooth, (a) at the clinical examination and (b) in a periapical radiograph.

Case 10.10 The pinhole lesion

The chance finding of a PEIR lesion at the tip of the crown of the left maxillary permanent canine was seen and diagnosed at the clinical examination of a potential orthodontic patient. The patient had noted that the permanent canine had erupted three days before the photograph and radiograph were taken (Figure 10.9a, b), with a typical 'pinhole' lesion.

Case 10.11: The disappearing tooth

It is apparent that PEIR-affected teeth remain vital and continue their root development and completion of their root apices, quite regardless of the severity of the unchecked progress of resorption. The initial panoramic view of a 10-year-old child (Figure 10.10a) in the late mixed dentition who was affected by this condition showed the congenital absence of a mandibular left and maxillary right premolar. The casual reader might be excused for having mistakenly decided that the left maxillary canine was also congenitally absent. The left canine was present, as indicated by the arrow, but its entire crown had been totally resorbed, with only thin slivers of enamel shell remaining. The resorption front, as seen in the film, had already destroyed the entire crown and was poised to enter the root area. It may be reasonable to assume that the portal of entry and initiation of the pathological process was through a tiny imperfection at the tip of the crown of the tooth, far from the root. One would also assume that this is usually the reason that the root is unharmed. Of course, in time it would have undoubtedly continued its rampant destructive progress into the root.



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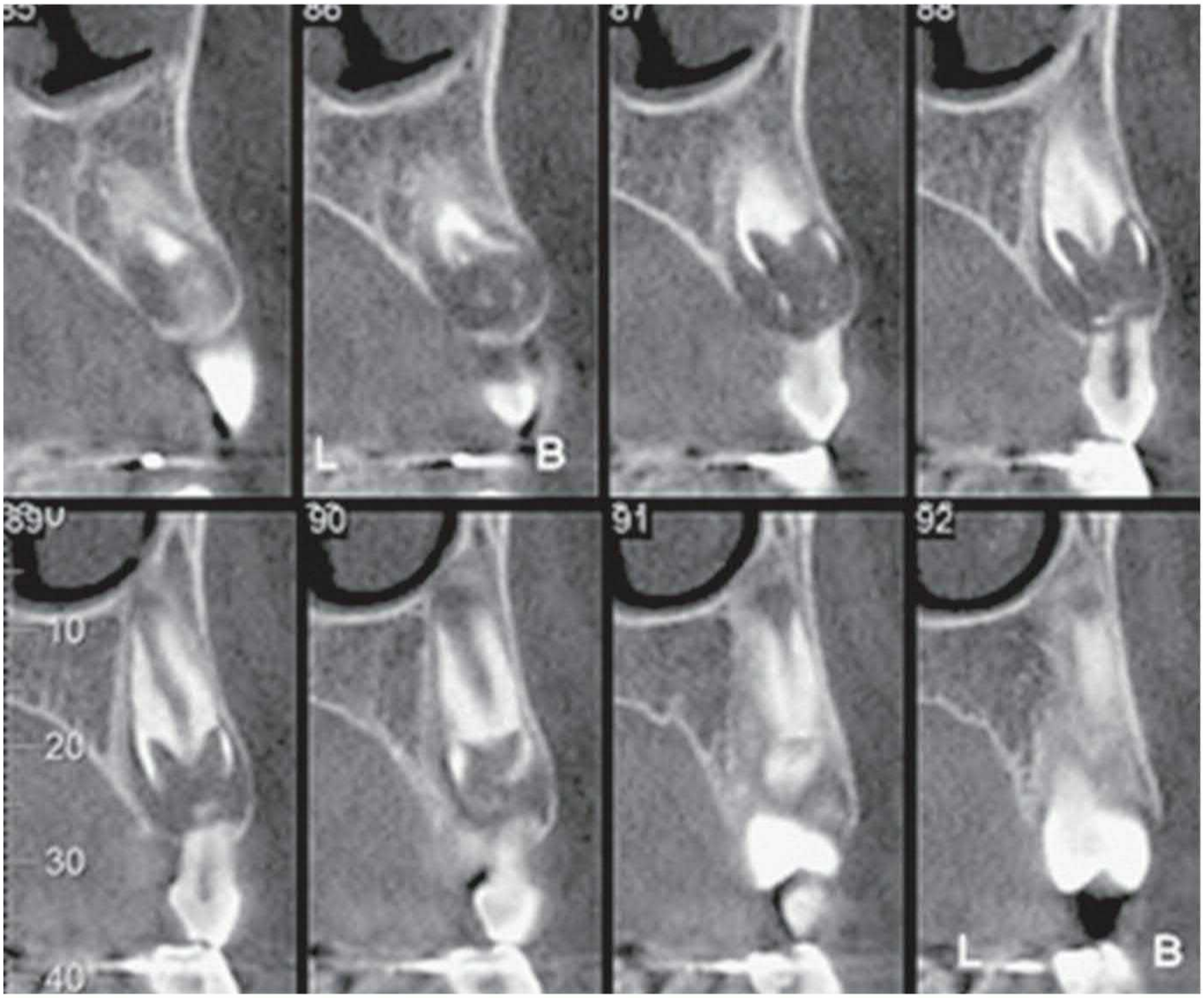

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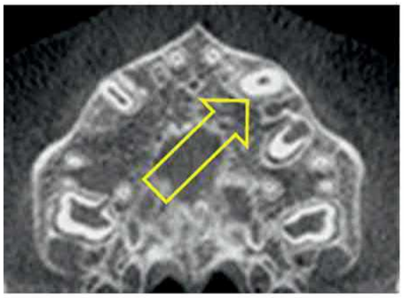

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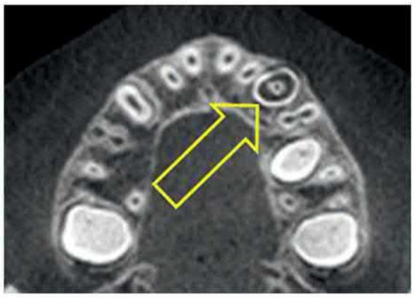

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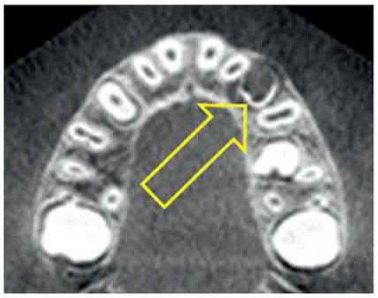


(e)

Fig. 10.10 (a) A panoramic view of the mixed dentition, with a lingual holding appliance in place, with missing permanent teeth. The crown of the left permanent maxillary canine (arrow) is almost totally resorbed, with only thin slivers of enamel shell remaining. (b) A series of eight cross-sectional cuts through the affected tooth shows the complete destruction of the crown of the tooth, with the enamel as the last element to disappear. There is no resorption of the dentine–predentine immediately surrounding the pulp, which appears normal. The tooth is non-symptomatic and periapical pathology is notably absent and typical of normal apical root growth. A similar series of axial cuts were made (c) immediately apical to the lesion, (d) through the thin enamel of the neck of the crown, showing its separation from the circumpulpal pericanalar layer by the radiolucent resorption mush of the former root substance and (e) through the almost totally resorbed crown.

Both maxillary canines were unerupted and had similarly developed root lengths. The eruptive state of the right canine was marginally more advanced, apparently as the result of having more space available to it.

From the cone beam imaging of the immediate area (Figure 10.10b), a series of eight cross-sectional cuts through the affected tooth show the complete destruction of the crown of the tooth, with the enamel apparently being the last element to disappear. However, it should be noted that there is no resorption of the dentine–predentine immediately surrounding the pulp, which appears normal. The tooth is non-symptomatic, the crown is encapsulated in its follicle, periapical pathology is notably absent and the root apex is wide open.

A similar series of three horizontal axial cuts (Figure 10.10c–e) made immediately apical to the lesion, through the area of the lesion and then through the resorbed crown field, presents a very thin enamel wall, which partially outlines the original form of the tooth. As with ICRR and because of its high organic content, the resorption had stopped short at the pericanalar layer encompassing the pulp. An axial cut across the root above the lesion (Figure 10.10a) shows the normal root appearance and texture. An axial CBCT cut across the crown at the level of the pulp chamber of this very advanced case of PEIR shows a rather striking picture of concentric and highly contrasting rings (Figure 10.10b). The innermost circle is radiolucent (black) and represents the dental pulp. This is bound by a narrow radiopaque (white) circle of the pericanalar layer, which, in turn, is bound by a wider radiolucent band (black) of the resorption debris. The outermost ring (white) is the narrow and radiopaque enamel exterior of the crown. The axial cut across the remains of the crown shows almost total radiolucent (black) mush, which is the residue of the former healthy dentine within the crown of the tooth (Figure 10.10c). This lesion must have been present a very long time to show so much destruction, including a severe thinning of the enamel, of which little has survived. Despite all this, the root apex continues to grow and the pulp remained vital.

Treatment of the unerupted tooth entails exposing the affected crown of the tooth to the oral environment, thereby isolating the lesion from its intra-follicular lifeline. The progress of the pathological resorption process will then abruptly stop. Since the resorption mush within the crown is not caries, meticulous excavation has little purpose. On the contrary, any instrumentation aimed at ‘cleaning’ and ‘sterilizing’ the cavity will almost certainly cause pulp exposure and necessitate immediate root canal therapy; this, in a surgical field where access is very poor and conditions of sterility (rubber dam, etc.) are impossible to achieve. Instead, a simple temporary dressing, placed to seal off the lesion, will suffice in the short term. Alternatively (and only for the short term) the exposed tooth and lesion may be left open, until full eruption and optimum conditions for clinical treatment become available. The mush itself will act as a protection against thermal stimuli and the tooth may therefore remain symptomless, unless, of course, it is subjected to occlusal forces.

In infancy, amelogenesis of a developing permanent tooth within its crypt is responsible for the shape of the tooth and is characterized by the formation of cusps, pits and fissures. Sometimes, a developmental fault occurs and a lack of protective enamel cover is to be found in the depths of crevices, folds and pits on the occlusal surface or *dens in dente* on the palatal aspect of an incisor, in buccal pits on molars and, occasionally, in a canine cusp tip or an incisal edge. This may have been the result of the presence of a minute gap in the integrity of the inner enamel epithelium, which is where amelogenesis is initiated. Consequently, in these microscopically small loci there is no enamel cover and the outer surface of the crown will be of exposed dentine. This constitutes a high-risk site for the development of early caries, within a short time after the tooth erupts. Pits and fissures are particularly prone to the development of caries and much of preventive paediatric dentistry is concerned with avoiding this eventuality.

All the above is reminiscent of ICRR, where the initial penetration is through gaps in the cementum layer that occur in the sub-gingival area at the unexposed neck of the tooth. In contrast, the PEIR process attacks through the enamel, where the integrity of its cover of the dentine is defective. It then proceeds to eat its way into the crown of the tooth on all fronts and in all directions, undermining the enamel and gathering momentum as it goes. Accordingly, the picture seen on a 2D plane film radiograph seems to show a semi-lunar radiolucency with its point of entry as the epicentre, although it is in fact a hemi-spherical lesion in 3D (see later Figure 10.11).

The pathological process is nourished from within the dental follicle, most likely via the vascular plexus of the outer enamel epithelium, rather than from the dental pulp. The progress of the lesion is stopped short of the pulp itself by the pericanalar layer, in a manner similar to ICRR. The resorption front is completely sterile and bears no relation to dental caries. The resorptive process rapidly progresses through the dentine, but when it reaches the inner surface of the hollowed-out enamel the rate of progress reduces, due to its very much higher calcified structure of enamel.

When the tooth erupts or when its crown is exposed surgically, the vital elements of the lesion will have abruptly lost their nutrient supply line and they will necrose, leaving an inert and dead mush within the crown of the tooth. Of itself the dead mush is harmless, except that it may become secondarily affected by dental caries after the tooth erupts into the oral environment, with its high bacterial population. For this reason, this mush-filled space should be treated soon after eruption. It is probably sufficient to use a composite fissure sealant, without the need to prepare the cavity other than to minimally excavate the mush, sufficient to retain a restoration. Notwithstanding that this may offend the sensitivities of the paediatric dentist, it should nevertheless be remembered that complete excavation of the resorbed area may require widely opening the occlusal or other surface of the tooth. This would be likely to risk accidental pulp exposure – particularly in view of the extent of some of these incursions and the broad pulp chamber that is characteristic of a recently erupted tooth [29–32].

There is no solid evidence to convince us that PEIR has any adverse effect on the normal eruption mechanism. Indeed, there are cases in which an effete lesion will only be discovered many months or years after the tooth has erupted, *having been misdiagnosed as dental caries*. However, there are also many examples of PEIR in unerupted teeth that are impacted deep down in basal rather than alveolar bone.

Three cases are presented here to illustrate some of the variations of the degree and extent of these lesions in different teeth.

Case 10.12: Unerupted mandibular permanent second molar

The left-side molar area of the panoramic film of a 10-year-old male is shown in Figure 10.11. The second permanent molar is unerupted, vital and asymptomatic and shows early root development (green arrow). Within the crown and undermining the occlusal enamel, one can see the large semi-lunar radiolucency that is a typical characteristic of PEIR. This was a chance finding on a routine panoramic view. The portal of entry of the lesion was in the depth of the occlusal fissure and the resulting resorption was very deep, reaching down to within a hair's breadth of the pulp. The extent of the lesion appears as the arc of a circle whose centre is in the deep occlusal fissure. Since this is a 2D rendition of a 3D phenomenon, it will be understood that the perimeter of the lesion is hemi-spherical rather than semi-circular. The radiograph shows the fine line of the pericanalar layer bridge (yellow arrow) separating the lesion from the pulp.

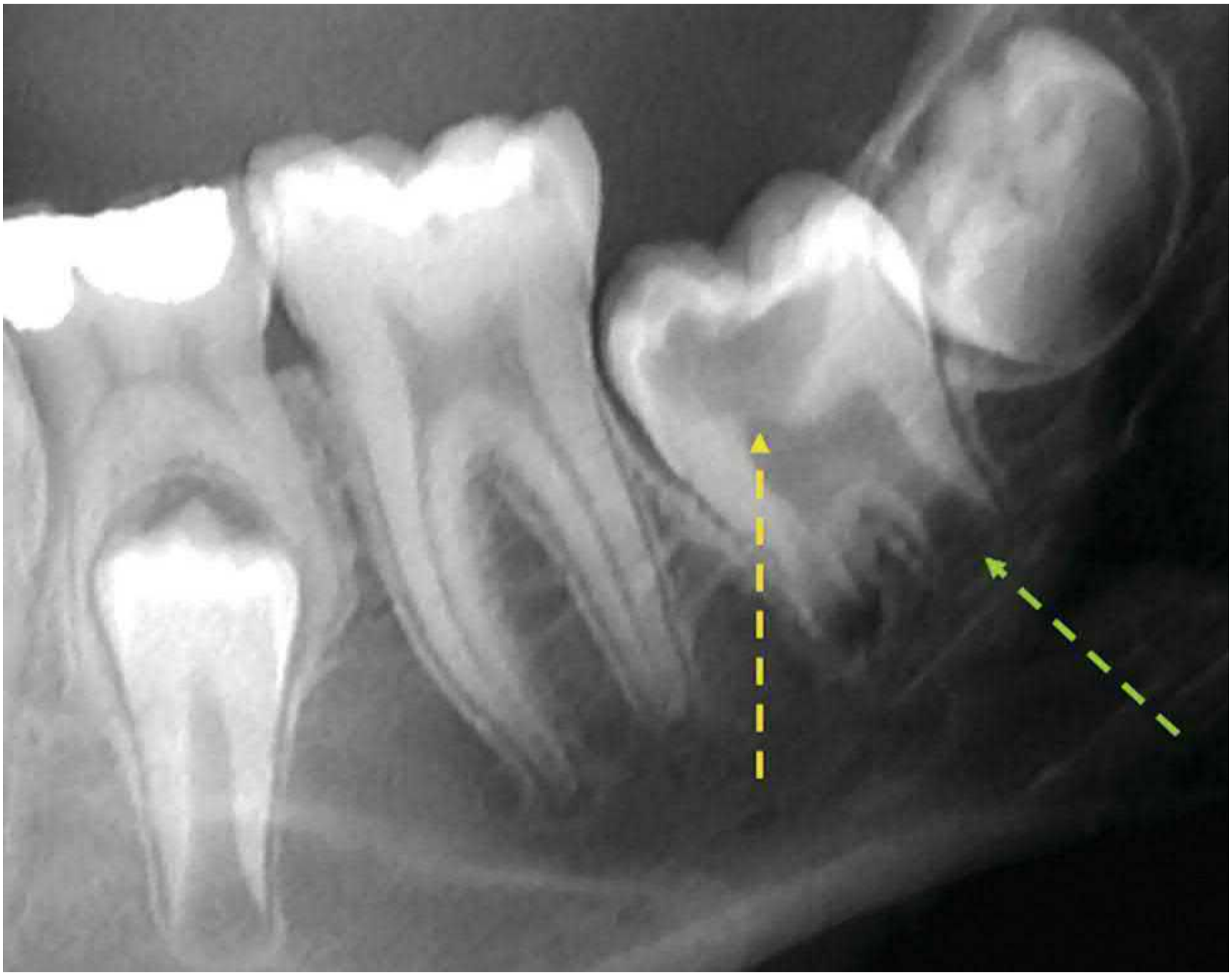


Fig. 10.11 Unerupted second mandibular molar with large semi-lunar pre-eruptive intra-coronal resorption crater arising from the central fissure of the crown. The resorptive lesion is separated from the pulp by a thin pericanalar bridge (yellow arrow) and the incomplete roots show normal, healthy apical papillae (green arrow).

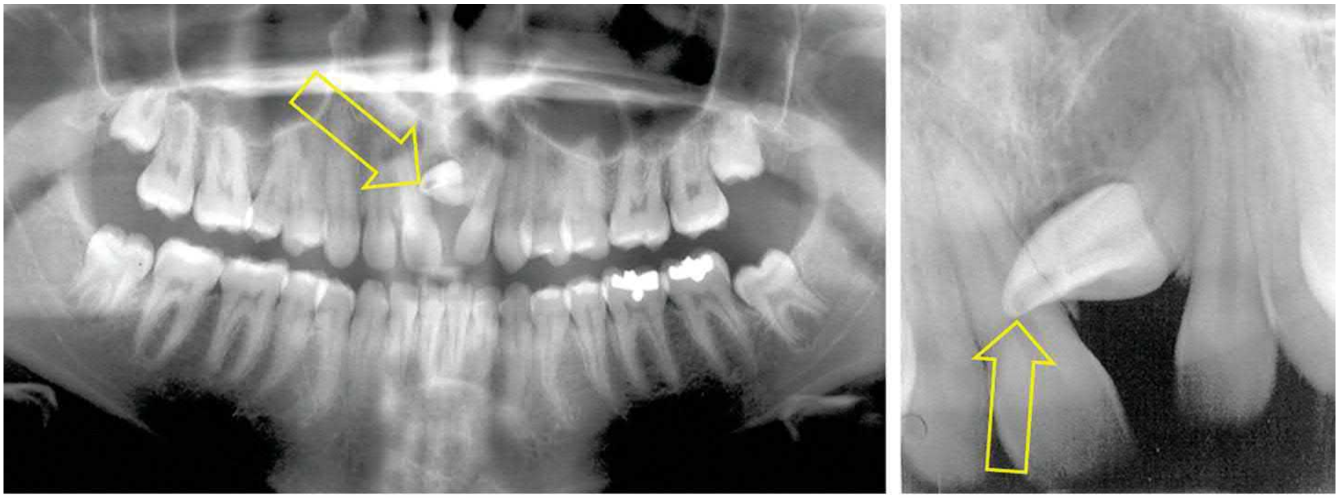
Case 10.13: Impacted dilacerate maxillary central incisor

The patient illustrated in Figure 10.12 was an 18-year-old female who had complained of a missing maxillary central incisor. The history revealed that she had suffered trauma in infancy, but treatment had never been sought. The patient had brought with her a number of radiographs and a CBCT imaging series on her first visit. The initial planar radiographs (Figure 10.12a) revealed the presence of an impacted and dilacerate left maxillary central incisor, which could be palpated on the labial side. The periapical and panoramic views of the anterior dentition show the right central incisor having tipped mesially across the midline and the left lateral incisor tipped towards it, thereby closing the space reserved for the impacted tooth, to approximately 2 mm.

At the mesial corner of the incisal edge of the tooth, as viewed on the periapical and panoramic films, there was a small radiolucent shadow. From the CBCT imaging, the 3D screenshots of the tooth (Figure 10.12b) clearly show the surface outline of a small defect disturbing the ideal form of the crown surface.

The most dramatic feature of the anomaly in this patient was seen on the serial cross-sectional cuts in Figure 10.12c, where an extremely deep resorption process had entered the incisal edge and proceeded into the body of the crown of the tooth, towards and almost reaching the pulp. The tooth was asymptomatic and vital. These cross-sectional cuts give the mistaken impression that the tooth was rootless, because the root was dilacerated in both the bucco-lingual and mesio-distal planes. This is confirmed in the periapical and panoramic films (Figure 10.12a).

At the closed surgical procedure, the tooth was exposed and the lesion restored conservatively, without the need for endodontic treatment. An eyelet attachment was bonded to the lingual side of the tooth initially and traction applied to draw the tooth down. The tooth responded to orthodontic treatment like any normal tooth and treatment was completed in the usual manner.



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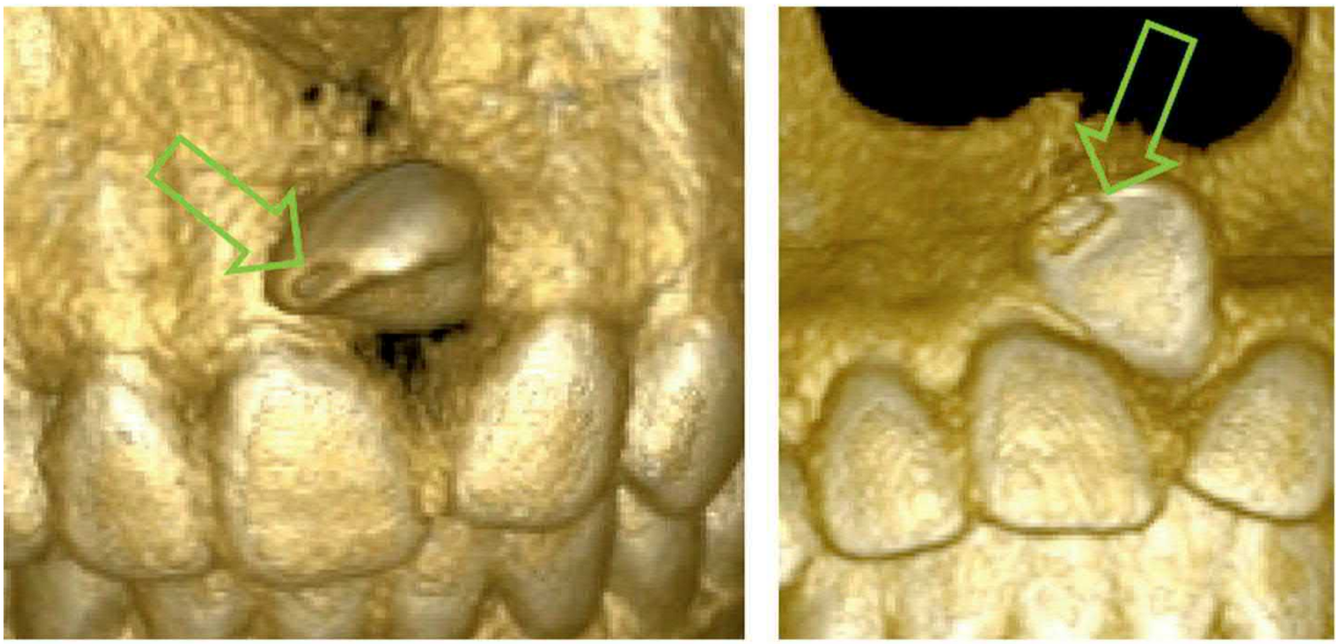

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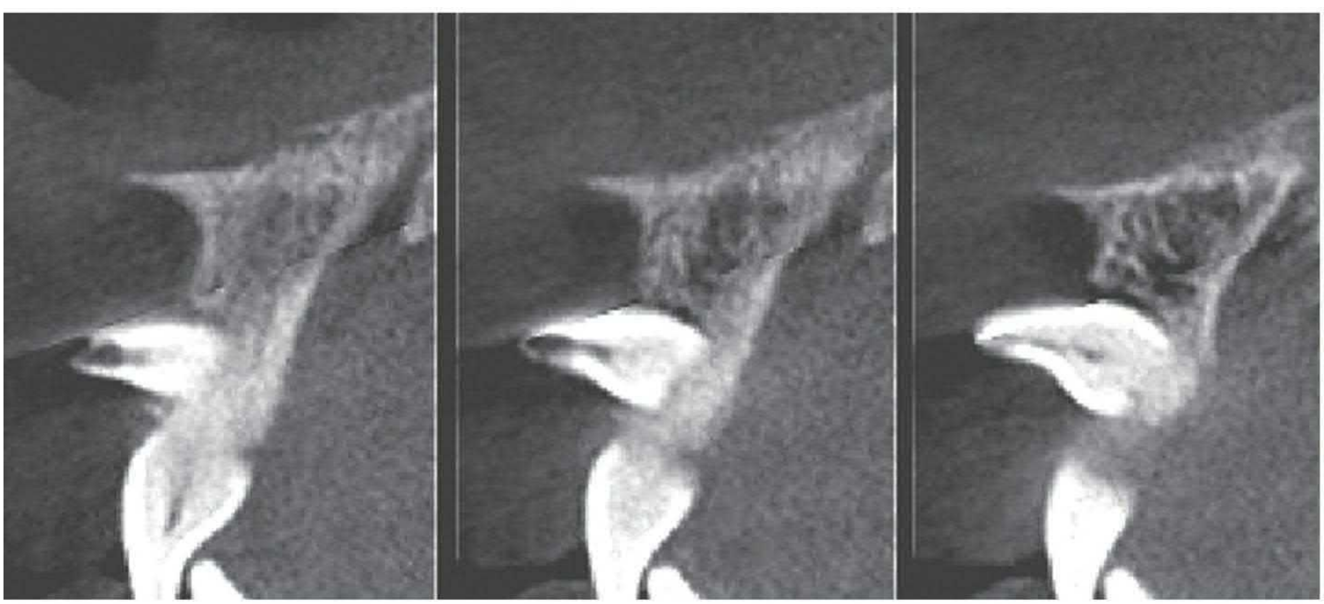

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Fig. 10.12 (a) A dilacerate central incisor with a 'small' pre-eruptive intra-coronal resorption lesion seen on the panoramic and periapical radiographs (yellow arrows). The circumscribed appearance of the incisal edge lesion can be clearly seen with a dark radiolucent shadow at the incisal edge (arrow). (b) In the 3D screenshots from the cone beam computed tomography, the surface outline of the anomaly on the incisal edge of the crown can be seen (arrows). (c) Serial cross-sectional cuts to show the extreme depth of the resorption process.

Case 10.14: Unerupted maxillary permanent canine

A 12-year-old male was referred by his dentist, after the practitioner had studied a routine panoramic radiograph of the boy's dentition. Armed with the patient's other records (Figure 10.13a, b), the orthodontist found that both the child's maxillary canines were unerupted and the deciduous canines were mobile, clearly imminently to be shed naturally. The radiographs showed a normal left canine, but a right canine that had lost the coronal half of its crown to resorption, together with all the dentine within that portion of the crown. An orthodontic appliance was placed for the purpose of levelling, alignment and the provision of space and the patient was referred to a surgeon to expose the tooth.

At surgery, a labial attached gingiva flap was raised from the crest of the ridge, to reveal an intact dental follicle around the crown of the tooth. The follicle was surgically reduced in height around the crown of the canine, to provide access to the tooth (Figure 10.13c). Approximately two-thirds of the crown were exposed, to display an enamel shell that was thinned to transparency and contained within it a soft core of resorption mush, with the consistency of cork. There was no sign of any healthy remaining intra-coronal dentine.

An eyelet attachment was bonded to the buccal surface of the thinned enamel wall, with a twisted steel ligature connector (Figure 10.13d, e).

At the same visit, a prepared auxiliary 0.014 in. stainless steel archwire, carrying a vertically directed 'swinging gate' configuration in the canine area, was ligated in piggyback fashion under the main arch (Figure 10.13f). The surgical flap was replaced, and lightly sutured, to cover the wound. The 'swinging gate' was raised upwards and lingually and ensnared by the twisted steel ligature, attached to the canine eyelet. This produced a very light, wide range and efficient extrusive force on the canine (Figure 10.13g, h).

This mush was left undisturbed, because surgical exposure had isolated it from its lifeline (the follicle). There was therefore no longer a danger of further resorption and it was simply left to necrose. The continued presence of the mush within the cavity served to protect the exposed dentine beneath from thermal and tactile stimuli. It served admirably as a temporary 'restoration' for the several weeks needed to complete the eruption of the tooth.

Three weeks later the tooth had erupted, with the intra-coronal resorption mush still present and no report of sensitivity of the tooth to hot or cold in the interim. The appliance was removed and the patient referred back to his dentist. Although the tooth was vital, the dentist decided that there was inadequate tooth material to support a permanent restoration.

Root canal treatment was therefore performed electively to facilitate long-term provisional and, later, permanent rehabilitation. The post-treatment outcome with a provisional composite restoration replacing most of the crown of the tooth is shown in Figure 10.13(i, j).

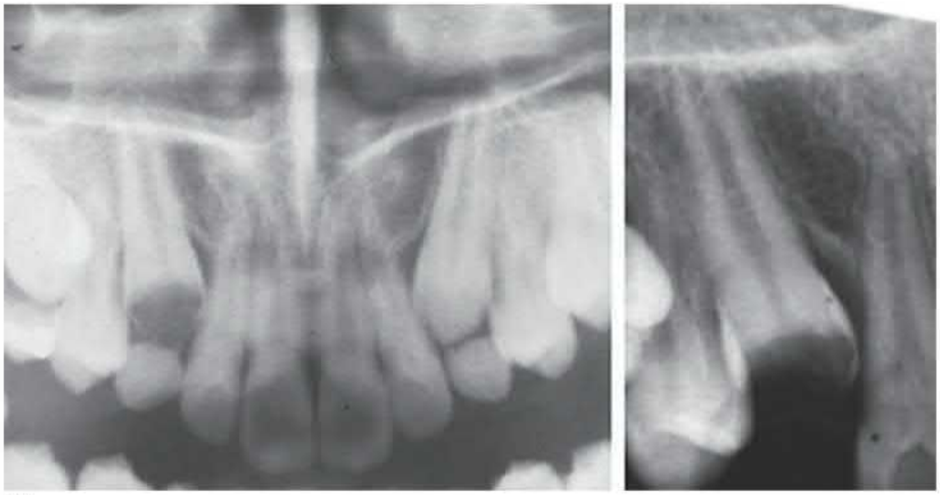
Unlike ICRR, which causes the tooth to resist eruption, in the case of a PEIR lesion unerupted teeth may often erupt normally. It must be assumed that the integrity of the dental follicle was undamaged and was able to carry out its function to initiate resorption of the alveolar bone, ahead of the tooth, and then to fuse with the overlying oral epithelium to open an eruption canal. On the other hand, as we have seen above, it is not unusual to find instances where the PEIR-affected tooth does not erupt. In such cases, the lesion should be separated from its nutrient source by surgical exposure, before applying orthodontic traction to the tooth. Although there are no evidence-based figures in the literature to support it, this approach has been successful in the relatively small number of cases that we have treated in this way.

Age-related replacement resorption

In the distant past, particularly in the years immediately following the devastation of Europe during the Second World War, advanced dentistry was unavailable to most. In those days it was not uncommon to see relatively young adults whose sole dental treatment had been the extraction of the remains of all their teeth and rehabilitation with removable, vulcanite or, later, acrylic full artificial dentures. On occasion and often several years later, a previously impacted tooth may have begun to make its appearance, erupting under the denture. Other impacted teeth were only ever randomly discovered as incidental findings in routine radiography.

Today, the orthodontist may be approached by a concerned adult patient or a prosthodontist with the request to resolve the impaction of an unerupted canine or molar, in order to include this potentially important tooth as an integral element in a case of oral rehabilitation. Among other considerations, the question then arises as to whether or not these teeth will respond to orthodontic forces applied to them at an advanced age. This was the subject of a study that we undertook [33], in which it was found that in a sizeable proportion of adults over the age of 40, the impacted teeth would not move. Only in a small, yet significant proportion of these failed cases was it due to a sterile and non-inflammatory replacement resorption of the crown of the tooth. In its simplest form, it is characterized by adhesions of the degenerating remains of follicular tissues direct to the coronal enamel of the impacted tooth, whose surface will have been roughened by the resorption. When an affected tooth with a mild degree of age-related surface replacement resorption is surgically exposed, there will be considerable difficulty in separating the soft tissues from the enamel surface and the debrided enamel surface will be pitted. Such teeth will not respond to orthodontic forces.


(a)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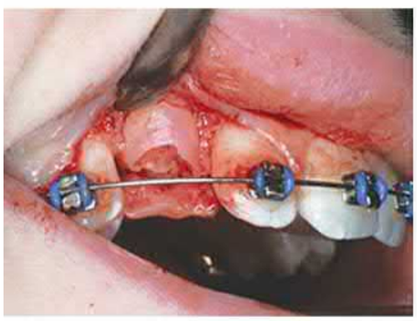
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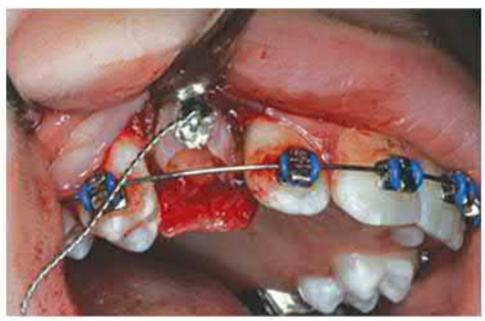
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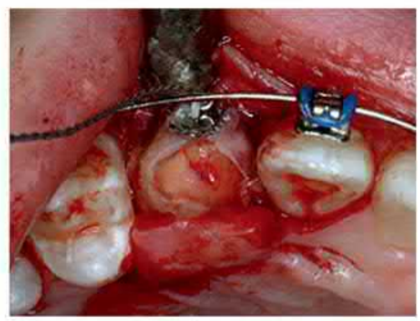
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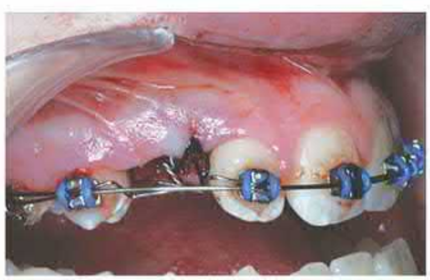
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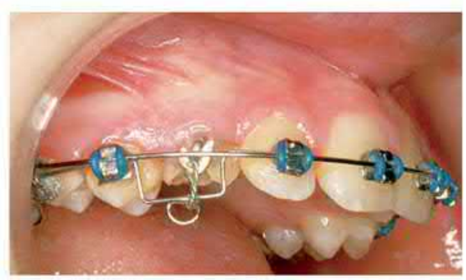
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(i)

(j)

Fig. 10.13 (a) The initial photographic intra-oral records. (b) Pre-treatment panoramic and periapical views indicate a normally developing dentition, with the pre-eruptive intra-coronal resorption–affected canine and its antimere in similar stages of development and eruption. (c) The crown of the tooth comprised only the cervical half of a thin and unsupported enamel wall. (d) An eyelet was bonded to the thin enamel wall at the time and ligated with a twisted steel ligature. (e). The occlusal view shows the mush filling the hollowed-out crown. (f) The 'swinging gate' in its passive mode, with the offset loop pointing downwards. The long twisted steel ligature from the bonded eyelet can be seen lying alongside. (g) The 'swinging gate' was turned lingually and raised up towards the suture flap. It was ensnared by the ligature in the activated horizontal position, providing extrusive forces. (h) Three weeks later, the auxiliary arch loop had returned to its passive vertical mode, having drawn the erupting canine with it. (i) The post-treatment outcome with root canal treatment and a provisional composite restoration.

Courtesy of Dr Peter Rosenfeld. (j) The completed root canal treatment.

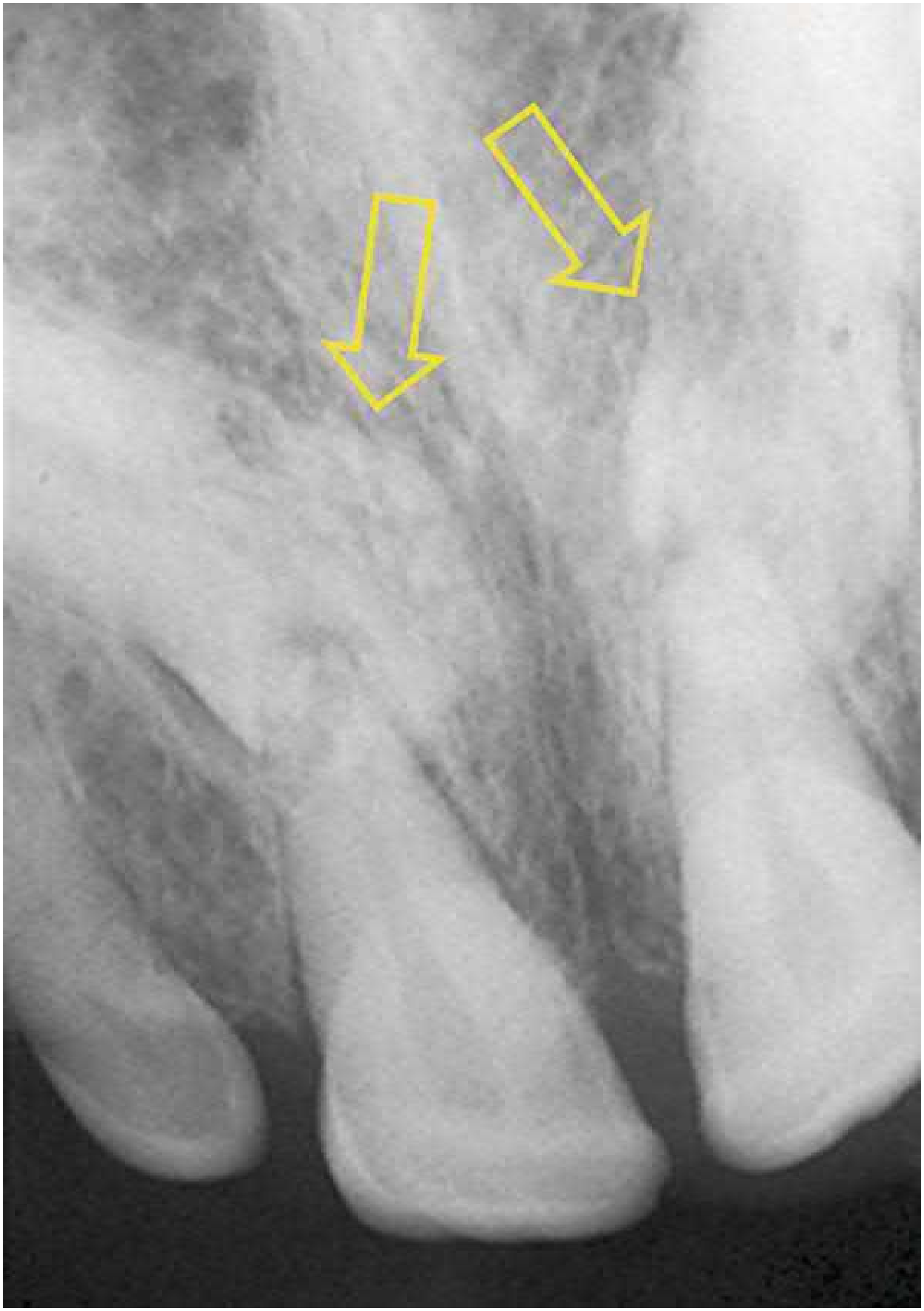

Fig. 10.14 Periapical radiograph of a 63-year-old patient with bilaterally impacted maxillary canines (arrows), which had undergone advanced resorption of their crowns and roots. The limited remains of the dental follicle are still visible on the distal side of the crown of the right

canine.

In the most advanced cases, enamel and dentine will be resorbed by invading clastic cells; the tooth will become progressively radiolucent and difficult to distinguish from the surrounding alveolar bone structure (Figure 10.14). In the most extreme cases, the presentation may be so advanced that the image of the tooth is unclear and its outline indistinct. Its radiopacity will have become reduced to such a level that only a careful examination of the radiograph will reveal its presence. By and large its dental follicle will have disappeared, as part of an age-related atrophy, and this will have brought the tissues into direct contact with the enamel. This tooth will thus have become incorporated into the surrounding alveolar bone and must be considered ankylosed.

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11
Impacted Permanent Molars

Adrian Becker

Maxillary first permanent molars

Mandibular first permanent molars

Mandibular second permanent molars

Maxillary second molars

Maxillary 'banana' third molars and second molar impaction

Mandibular third molars

Infra-occlusion of permanent teeth

Primary failure of eruption

First, second and third molars in each jaw bear similar anatomical features to one another and their developmental patterns are therefore similar too. Does this mean that they have shared patterns of impaction? Should there be a common approach to their corrective treatment, with the expectation of a similar degree of success in the outcome? To a certain extent, the three types of molar do indeed have a number of similar inconsistencies. However, for the most part their irregularities are not at all similar and each has distinctive characteristics unique to itself, within its own specific grouping and depending on the jaw in which it is located. That being so, the treatment approach must also be distinctive and must be tailored to face the clinical presentation of the various specific anomalies. Accordingly, in this chapter we shall deal with each of the three types of permanent molar, in both the maxilla and the mandible, individually.

Maxillary first permanent molars

Maxillary first permanent molars normally erupt at the age of 6–7 years and they take up a position in contact with the bulbous distal surface of the maxillary second deciduous molar. This will establish a tight interproximal juxtaposition, initially with a slight distal orientation of their long axis. In time and as the occlusion develops into its full permanent stage with the shedding of the second deciduous molars, the teeth will adopt a slight mesial orientation.

It is not often that there is a divergence from this pattern of occlusal development, but just occasionally the permanent molar appears to get stuck in a partially erupted state, in the depression formed by the distal surface of the deciduous molar, between the cemento-enamel junction (CEJ) and the distal crown convexity (Figure 11.1). This phenomenon has been attributed to a shortness of the maxilla and consequent crowding. Characteristically, the affected permanent molar will have developed a marked mesial inclination that, at this early stage of development, is abnormal and will also have initiated premature resorption of the distal root of the deciduous second molar [1, 2]. By doing so, it leaves a sharp edge of enamel at the dentino-enamel junction between crown and root and, due to the fact that enamel is not easily resorbable, it will effectively trap the permanent molar. In more advanced cases, the entire distal root of the deciduous tooth becomes resorbed and the resorbed root area on the underside of the distal part of its crown will end up sitting on gingival soft tissue. The pulp chamber of the tooth may lose its distal wall to the resorption process and the pulp will become exposed to the surrounding tissues, with which it becomes contiguous. Metaplasia then slowly converts the pulpal tissue into the same connective tissue as that of the surrounding area. Most often this will be a symptomless transition, with no inflammatory tissue reaction. The immediate area of gingival tissue may well be oedematous and it may bleed easily, though this will most probably be due to irritation and trauma from the sharp edge of the undermined enamel of the crown, rather than to pulp pathology.

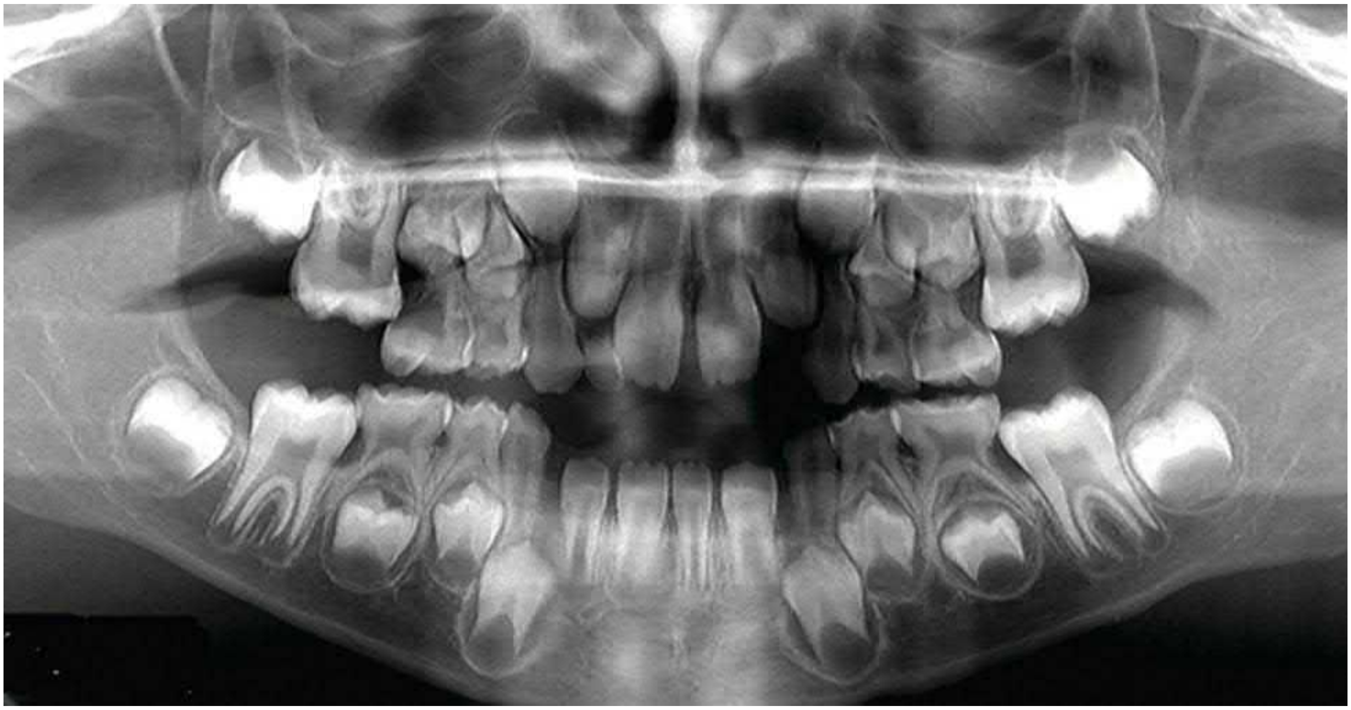


Fig. 11.1 A bilateral case of impacted first permanent molars, with complete disappearance of the distal root of each second deciduous molar. The crowding tendency is already established. Note the mesial angulation of the permanent molars.

In the more severe cases, therefore, it is sometimes possible to probe horizontally for some distance under the sharp distal edge of the crown of the deciduous molar, without causing pain or discomfort. The dentist may be misled by bleeding and the absence of pain and conclude, wrongly, that the pulp is exposed and that this is, therefore, a potentially emergency situation. However, this is not so, since the mesial and palatal roots are often unresorbed and yet maintain the tooth firmly in place for many months with no symptoms and no pathology *per se*.

Clinically, it would appear that the condition is more frequently unilateral, rather than bilateral. However, if we look carefully at panoramic radiographs of cases of the normally erupted permanent molar in a unilaterally affected very young patient, it is common to see considerable dystrophic resorption of the distal root of the second deciduous molar (Figure 11.2). This suggests a subclinical or spontaneously corrected, milder variation of the same condition.

Fig. 11.2 Although this appears to be a unilateral case of left molar impaction, careful examination of the intact side will reveal that the distal root of the deciduous molar has been resorbed away, suggesting a spontaneously resolved mild impaction. Note the contrasting angulation of the first molars.

The three elements of treatment

As readers will have seen during this work, I have always tried to emphasize the preference for avoiding extractions, if there is a chance of saving a tooth or to exploit its usefulness, even though it may be scheduled for eventual exfoliation or extraction. Here there is indeed such a chance and the alternative to extraction calls for a plan made up of three elements. The first action is to tip the permanent molar distally, to free it from its entanglement with the disto-cervical edge of the crown of the deciduous molar, while not endangering the deciduous molar. The second stage is to free the tooth to erupt vertically downwards to the occlusal plane, while preventing it from relapsing back into the resorption defect of its deciduous neighbour. The third part of the plan requires that the deciduous molar should remain in its place, asymptomatic and without the need for treatment, and thereby to re-establish the integrity of the arch and maintain space for a further few years until it finally succumbs and the permanent teeth erupt.

Many orthodontists will approach the problem by attempting to place an elastomeric separating ring around the contact area. However, unless the permanent molar contacts the deciduous tooth slightly apical to its normal contact area (which is not a normal condition), insertion of the elastomeric separation ring will be virtually impossible, since the mesial part of the permanent molar crown will have burrowed into the resorbed area of the root in the area of the CEJ. Even in those cases where the orthodontist may succeed in placing the ring, it is likely to be accompanied by considerable bleeding and will have the effect of creating an inadequate separation between the teeth. At the same time, it will also prevent eruption of the permanent tooth and will need to be removed after a week or two, in the hope that a degree of eruption will occur before the tooth re-impacts in or close to its initial position. The tendency for this kind of relapse is indeed common. An obstinate orthodontist may in the end achieve success with this method, but only by intermittent and repeated placement and removal. This may take a long time and many visits.

A variation of the above method uses brass wire [3] instead of the elastomeric separation ring. A brass wire ligature, tightly encircling the area of contact between the two teeth, will force the two molars apart in much the same way as with the elastomeric ring. Unfortunately, the permanent molar only moves distally to a small degree, because brass wire ligation is not elastic and the active ingredient comes from the bounce-back elasticity of the compressed periodontal ligament (PDL). It can thus only produce a small change. Each time the brass wire is removed, the permanent molar moves swiftly back into contact, hopefully with a modicum of downward movement, although the vertical component is usually disappointingly small. The ligation must therefore be repeated frequently.

A further variation proposes the placement of an orthodontic band on the deciduous molar, with a rectangular wire spring slotted into the tube or bracket on the buccal side [4]. A good range of spring action is difficult to achieve unless the spring loops into the buccal sulcus, as it approaches the impacted tooth. However, it is quite difficult to successfully perform re-activation, slotting the wire back into the attachment on the band and engaging the impacted molar. Pain, discomfort and ulceration of the oral mucosa are difficult to avoid.

In each of these variations to the method, a force is applied to the impacted permanent molar and the reactive force is directed solely at the adjacent second deciduous molar. The continued existence of the latter will be dependent upon roots that are in various advanced stages of resorption (caused by the impacting molar in addition to physiological deciduous resorption). As a consequence, the resorption process of the roots is likely to be aggravated by these forces and this deciduous anchor tooth may be lost very prematurely, sometimes even before the first aim of the procedure has been achieved. The result of this will be that the second and third elements of the three-part plan referred to cannot be realized, a separate space maintainer will need to be placed and some space will inevitably be lost by mesial movement of the permanent molar.

Without question, it is possible to construct an appliance that will include more dental units, with orthodontic brackets on the erupted permanent teeth and the other deciduous teeth. The aim of this would be to spread the load and minimize the reactive force on the weakened second deciduous molar. However, this would involve unnecessary widening of the scope and cost of treatment, which runs counter to the aim of early treatment in these cases. Treatment for this specific problem should be strictly interceptive in nature, leaving the overall treatment until the patient reaches the permanent dentition stage, five or six years later.

Case 11.1: A removable appliance

An active removable orthodontic appliance [5] has an acrylic base that is held in place on the teeth by strategically placed clasps of various types (Figure 11.3). In essence it is a Hawley retainer modified with the addition of an active element. Proper adaptation of the acrylic base in the palatal vault and snug contact with most of the teeth provide adequate anchorage potential to cope with the force from a spring cured into the acrylic base. Given that the patient is a 6–7-year-old child, who will have little or no appreciation of the importance of the intended treatment, the removable appliance has several advantages; particularly so if the child has no motivation and has management issues, as seen in most special needs children [6–8]. The sole intra-oral procedure that is needed is the taking of an alginate impression of the teeth. No other dental procedures need to be performed in the mouth, apart from teaching the child and the parent how to place and remove the appliance and, of course, general oral hygiene instruction. Adjustments, tightening of the clasps and activation of the springs are all performed by the orthodontist outside the mouth, at the chairside. Pain is not a factor and the entire process is an excellent way to overcome fear of the dental unknown and to introduce and encourage a very young child into becoming an exemplary patient. Children adapt to these appliances extremely well and the whole treatment regimen can be an eminently positive and successful method of achieving cooperation, since adjustments and activations of the appliance are made extra-orally.

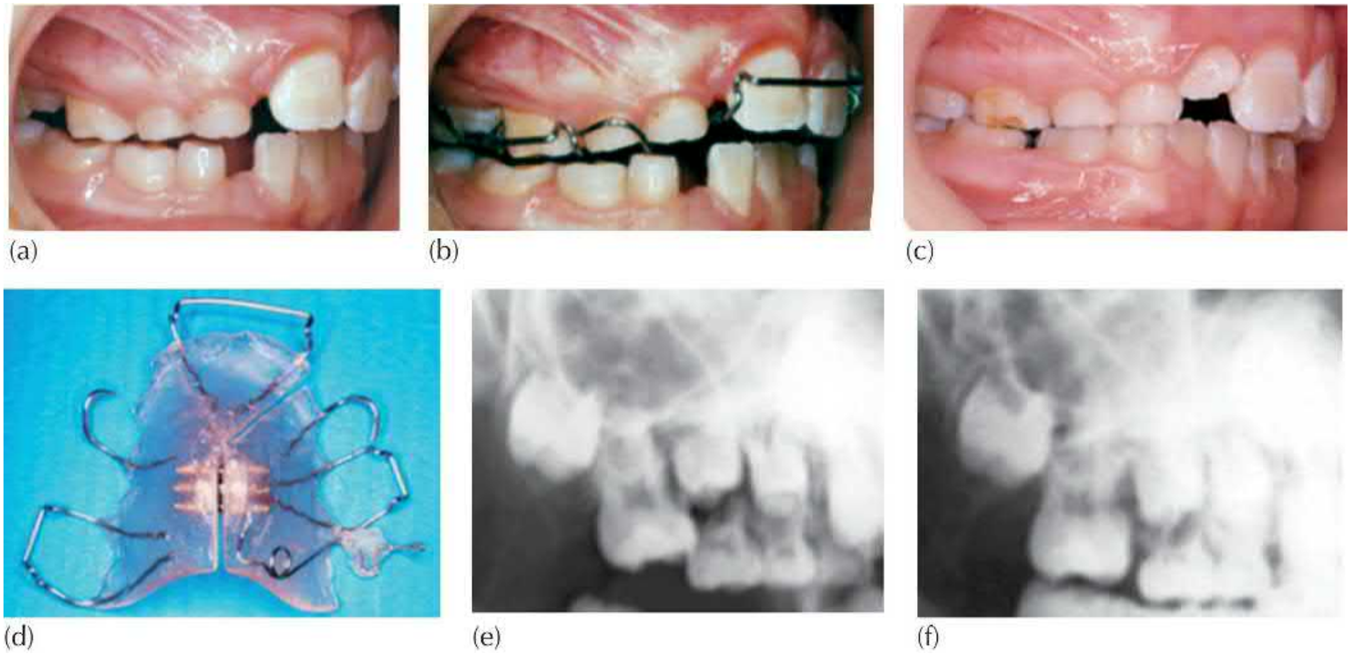


Fig. 11.3 (a) Incomplete eruption of the maxillary first permanent molar, due to abnormal angulation of its long axis. It has become impacted beneath the distal edge of the deciduous second molar crown. (b) A removable acrylic plate in place, with a distally activated finger spring for the molar. (c) The completed treatment with the molar uprighted and in occlusion. (d) The removable appliance comprises five retention clasps and a palatal 'finger' spring that crosses the occlusal surface of the mesially tipped and partially erupted first molar. (e, f) Lateral jaw radiographs before and after treatment.

Ideally in these cases, it is recommended to use several retention elements on the plate. An Adams' clasp on the deciduous second molar of the affected side and another on the erupted first molar or second deciduous molar of the opposite side are essential. A three-quarter circumferential clasp should be constructed to engage the buccal bulge of each deciduous first molar or the deciduous canines. A labial arch or a single clasp on the two central incisors is often a good stabilizing unit. A useful addition is to extend the acrylic base to cover the occlusal of the posterior teeth. This enhances the retention of the plate and also separates the teeth to provide better access to the occlusal surface of the impacted tooth and to simplify its movement.

A palatal finger spring should be extended from the middle of the palatal acrylic base and over the occlusal surface of the impacted tooth, terminating on the buccal side of the tooth. The end of the wire is doubled over, in order to provide the means of controlling the spring in its placement in the active mode, without leaving it sharp and pointed. The activated spring has a strong displacement component that will de-stabilize the plate unless the retentive elements are adequate. The anchorage for this simple movement is shared by all the teeth that come in contact with the plate.

The plate should be worn full time, including during meals, and taken out only for teeth brushing. The initial difficulties with speech and eating are overcome within days and the appliance becomes comfortable and fully integrated into the child's normal activity.

Movement of the tooth is usually rapid and, once a small gap has appeared and has bared the newly unencumbered mesial surface of the permanent molar, the shape of the spring should be adapted so that, in its passive mode, it rests in the newly created space between the permanent and deciduous molars. This will prevent the tooth from relapsing and, at the same time, encourage its vertical eruption towards the occlusal plane.

The clear advantages exhibited by the removable plate make it particularly suited for all three essential elements needed in the successful treatment of a maxillary permanent first molar impacted in this way.

Mandibular first permanent molars

Case 11.2: Impacted mandibular first molar of unknown aetiology

The six radiographs illustrated in Figure 11.4 represent serial panoramic films of a 6.11-year-old boy, recorded over the period of the subsequent nine years, till age 15.9 years. The reason for referral was the presence of a severely impacted mandibular first permanent molar, of unknown aetiology. There was also an unusual pattern of congenital absence of five teeth, solely in the mandible. In contrast, the maxillary dentition was complete and at this young age (6.11 years) most of the permanent teeth were still unerupted, as would be expected. Even his maxillary third molars developed subsequently, as may be seen in the later radiographs. The missing teeth comprised a single mandibular central incisor, both second premolars and both second molars.

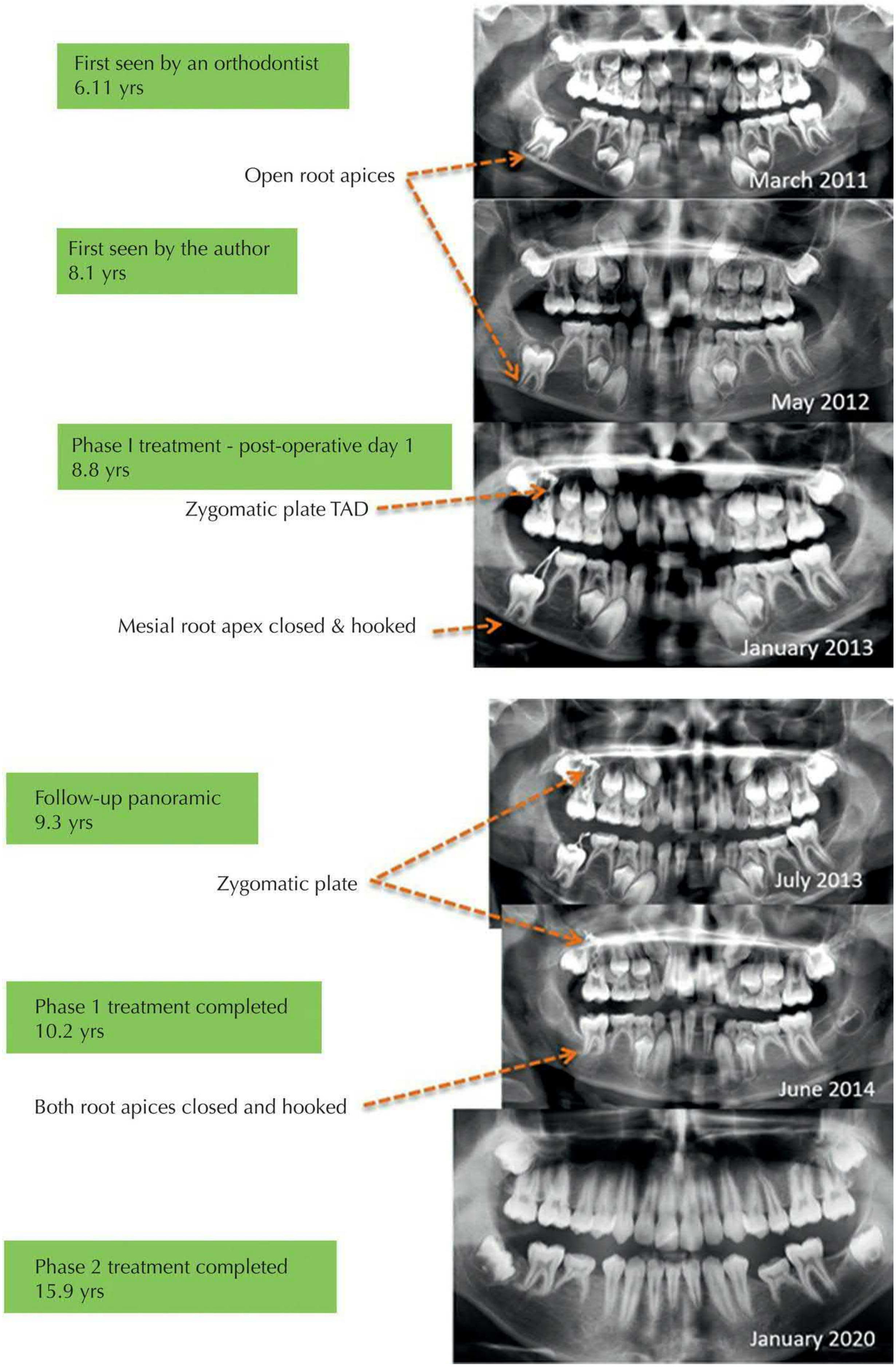

First seen by an orthodontist
6.11 yrs
Open root apices
March 2011
First seen by the author
8.1 yrs
May 2012
Phase I treatment - post-operative day 1
8.8 yrs
Zygomatic plate TAD
Mesial root apex closed & hooked
January 2013
Follow-up panoramic
9.3 yrs
Zygomatic plate
July 2013
Phase 1 treatment completed
10.2 yrs
June 2014
Both root apices closed and hooked
Phase 2 treatment completed
15.9 yrs
January 2020

Fig. 11.4 A series of six panoramic views covering a nine-year follow-up of the treatment of an impacted mandibular molar.

The March 2011 radiograph indicated a dental age of 7 years, according to the stage of development of the first permanent molars, although the degree of calcification of the roots of the unerupted premolars and canines was mildly delayed by comparison. The root development of the impacted mandibular molar was appropriate for his dental age and was equivalent to development that would normally see the tooth erupted, i.e. a little less than two-thirds the expected root length and with wide open root apices. However, while the straight form of the roots was normal, the apices were very close to the lower border of the mandible.

By any standard, this was a very young child with a highly unusual first molar impaction. As such, he presented several enigmas, as follows:

- There was no obvious reason why the tooth had not erupted. Accordingly, there was no way that an orthodontist could predict the chances of a successful response of the tooth to biomechanical augmentation of its apparently reduced eruptive potential.
- Even if its eruption could be achieved, it was quite clear that there would be considerable technical difficulty in designing a suitable mechanism that could apply the vertical force and the range of activity needed to achieve orthodontically generated eruption.
- Next was the question as to whether a 7-year-old child could be relied upon to cooperate with the day-to-day minor technicalities, once the invasive procedures had been completed under sedation or general anaesthetic.
- In addition, there were the further questions of how the form of the growing root apices would be affected by the anatomical barrier presented by the lower border of the mandible and what would happen to the root apices after they were distanced from it. Would passive eruption in the growing adolescent child be compromised?

When this patient was at the age of 6.11 years, a dentist had suggested the extraction of the molar, which the parent refused to accept. The family decided to wait a year to see if the fortunes of the tooth would improve. In May 2012, 14 months later, the dentist felt vindicated in the earlier decision to extract, since there had been no improvement. On the contrary, the roots had resorbed their way into the cortex of the mandibular border. Moreover, the crown of the tooth was arguably further from the occlusal plane and a greater width of alveolar bone covered its occlusal surface.

The patient was seen for the first time by the author at this juncture. The radiographs and the cone beam computed tomography (CBCT) provided by the dentist were re-examined in the search for a possible aetiological factor, but none was found. Any attempt at corrective treatment, therefore, would have to be purely empirical. The parents were apprised of the uncertainty of the outcome of any orthodontic/surgical treatment plan and of the importance of the tooth as an integral part of a functional dentition, particularly since five teeth were already congenitally absent from the lower jaw.

The plan that was offered to the parents was accepted and its invasive first stage was performed under general anaesthesia in the operating theatre of Hadassah Hospital, in Jerusalem, with appropriate intubation. The molar was surgically exposed and two separate bonded attachments were placed on the occlusal/buccal corner of the crown, each with a tightly twisted 0.013 in. soft steel pigtail ligature, taken superiorly through the re-sutured flap. These pigtails were foreshortened and fashioned into a short hook, close to the replaced soft tissue. A zygomatic plate was then screwed into the inferior aspect of the zygomatic process of the maxilla, with its free hooked end passing through a slit in the attached gingiva. A new panoramic film taken the day after the surgery (January 2013) showed the temporary anchorage device (TAD) plate and the two eyelet attachments in place. It also exemplified the conservative attitude taken by the surgeon in removing only enough bone on the mesial side of the occlusal surface to enable the orthodontist to bond the attachments, while the surgeon attended to the maintenance of haemostasis and a clean dry field for the bonding procedure. It will be noted that the mesial root of the molar had completed apexification and had done so by developing a distal-facing hook at the apex, influenced by the anatomical barrier that was the lower border of the mandible.

Following a short healing period, the child was taught how to place vertical up-and-down elastics between the TAD and the pigtail ligature hooks. The follow-up panoramic radiograph taken six months later (July 2013) confirmed excellent eruptive progress of the molar, with accompanying distancing of the apices from the mandibular border. The phase 1 treatment terminated 11 months later (June 2014), with the molars in occlusal contact and with no other orthodontic interventions performed at that time. The bonded eyelets and zygomatic TAD were removed.

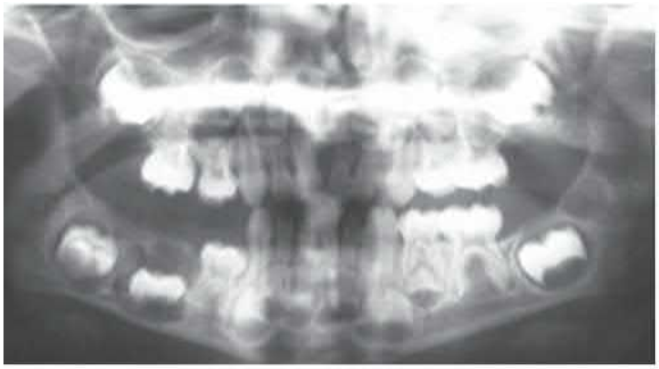
A more mainstream phase 2 orthodontic treatment was planned for the patient three years later, for the reduction of an excessive overjet, deep overbite and other minor demands of the malocclusion. From the post-treatment panoramic view (January 2020), it will be noted that space had been prepared for the eventual substitution of the infra-occluded deciduous second molars by two implant-borne second and third premolars on each side. This illustrates an orthodontic plan that attempts to provide an adequate occlusal table to match the full maxillary dentition, while not interfering with the bilateral newly developing additional mandibular molars.

The following aspects are worthy of note:

- The previously impacted molar erupted relatively rapidly, once light extrusive forces were applied to it, even though the aetiology of the failure to erupt spontaneously was never discovered.
- Its root apices began to bend to the distal as the result of their attempting to grow against the anatomical barrier.
- As seen in the post-phase 2 treatment film, the root apices did not revert to the original direction of growth, but continued on in their diverted path.
- It is enlightening to see just how much vertical growth of the body of the mandible had occurred between the molar root ends and the lower border of the mandible in the final film, compared with the earlier films.

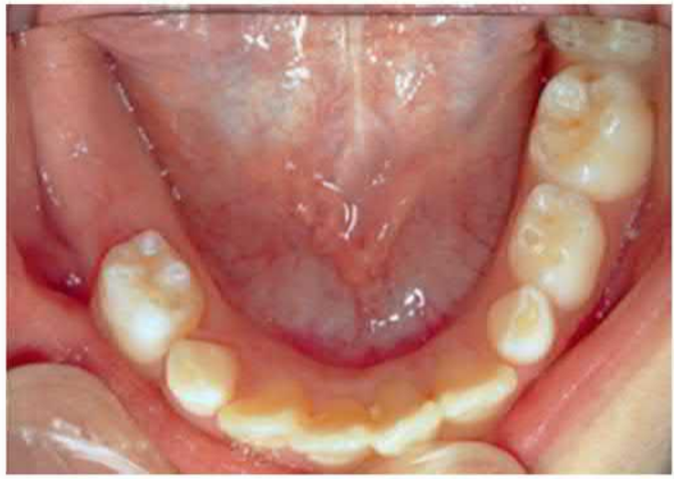
Case 11.3: Impaction of second deciduous molar and first permanent molar due to soft tissue pathology

A 4-year-old child was first seen in the Department of Oral and Maxillofacial Surgery at the Hadassah School of Dental Medicine in Jerusalem. The reason for referral was a diffuse radiolucent pathological lesion around the right deciduous second molar, the development of which appeared to have arrested at an early stage (Figure 11.5a). The adjacent deciduous first molar was seen to be infra-occluded. There appeared to be a similar disturbance in the development of the follicle of the first permanent molar. The comparison of the right (affected) and left (normal) sides emphasizes the degree to which the development of the second deciduous molar lagged behind that of the normal side. Surgical removal of the cystic lesion was undertaken and the pathology report yielded a diagnosis of ameloblastic fibro-odontoma. No teeth were extracted at that time.


(a)


(b)


(c)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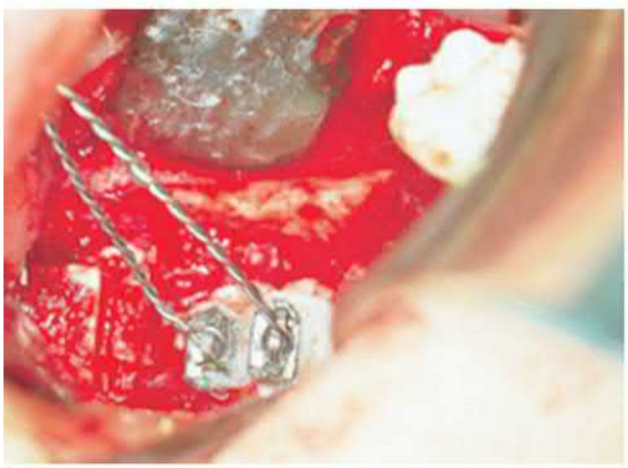
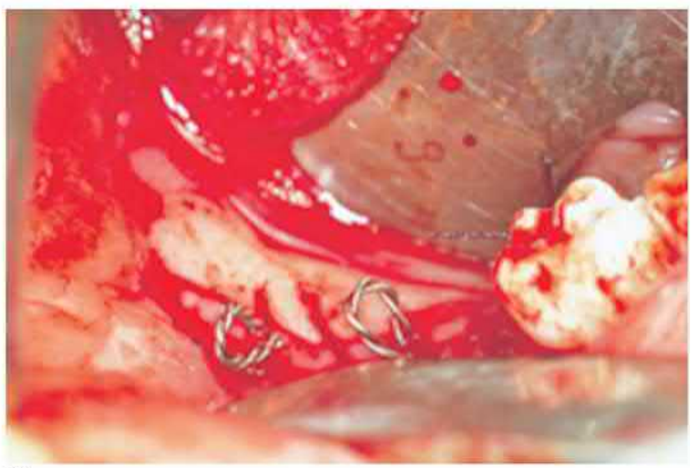

(e)


(f)

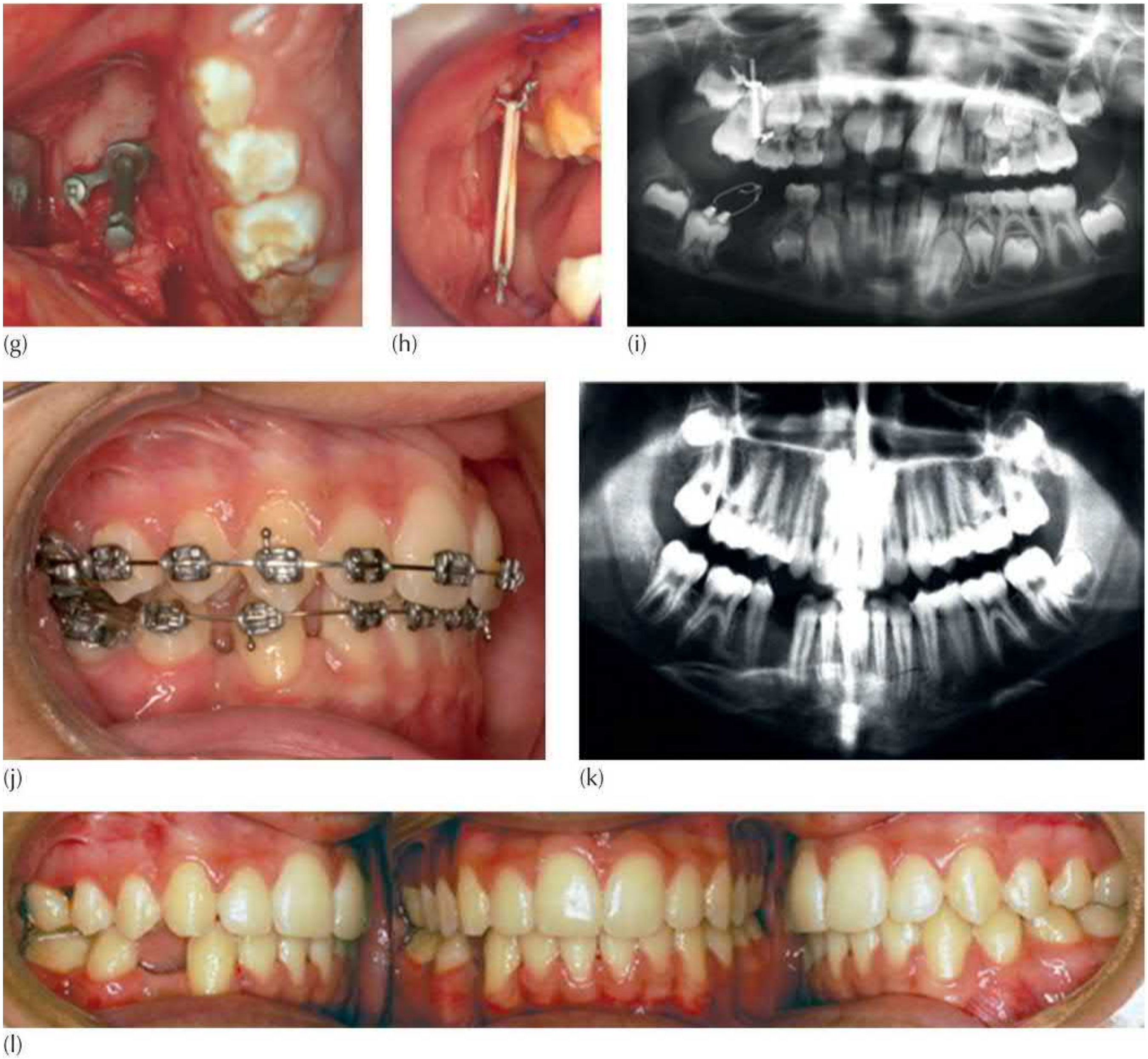


Fig. 11.5 (a) Panoramic view of a 4-year-old boy with an impacted first molar. (b) Two years later, healing with no signs of recurrence. (c, d) Right-side and occlusal clinical intra-oral views of the edentulous ridge at 8 years of age, before surgery. (e) At surgery, two eyelets bonded to the buccal surface of the permanent molar. (f) The two pigtail ligatures remain exposed after full flap replacement. (g) At surgery, the zygomatic implant in place. (h) Vertical elastics exert extrusive traction. (i) The panoramic view at this stage. (j) Initiation of phase 2 orthodontic treatment three years later, with fixed appliances for the first time. (k) Post-treatment panoramic radiograph showing normal root development of the previously affected teeth and adequate space preparation for a future implant to replace the missing premolar. (l) The final result of the orthodontic treatment. The first mandibular right premolar is located in the place of the second premolar.

When the child was seen two years later in follow-up (Figure 11.5b), healing was complete and there were no signs of recurrence. The first deciduous molar had erupted normally and both the second deciduous molar and first permanent molar showed the beginnings of root development. However, in contrast to the other molars, they showed no signs of eruptive movement. Once again, the discrepancy between the development of the affected second deciduous and first permanent molars and that of the same teeth on the normal left side was manifest and unmistakable. The second premolar had completely failed to develop.

A clinical examination was carried out when the child reached the age of 8 years, which revealed an edentulous alveolar ridge, with over-eruption of the maxillary second deciduous molars. Recommendation at this time was that surgical and orthodontic involvement were deemed appropriate (Figure 11.5c, d). The mandibular right first molar was deeply located in the basal bone, with its developing root apices within the compact bone, in close proximity to the lower border. At the surgical procedure to expose its buccal aspect, two eyelets were bonded to the buccal surface of the molar in such a way that the closed eruption procedure left only the two pigtail ligatures visible through the re-sutured muco-gingival flaps (Figure 11.5e–f).

A zygomatic implant was screwed into place and a pigtail ligature hook was tied to it, for use as a point of attachment for the up-and-down elastic traction (Figure 11.5g, h). The panoramic view at this stage (Figure 11.5i) illustrated how the developing root and the lack of eruption had caused a noticeable alteration in the shape of the lower border of the mandible.

Orthodontic treatment at this time was limited to motivation and encouragement sessions for the full-time wear of the intermaxillary elastics and making sure that the two pigtail ligature hooks remained serviceable. The tooth responded slowly to the force and, within about half a year, was showing early signs of erupting into the mouth. Full eruption was achieved in a further nine months and phase 1 treatment was thus concluded. The eyelets were detached and, under local anaesthetic, the zygomatic implant was removed.

Routine phase 2 orthodontic treatment, with traditional fixed appliances (Figure 11.5j), was initiated only when the full permanent dentition had erupted three years later. Treatment was completed within 30 months, with the first mandibular right premolar located in the place of the second premolar. The post-treatment panoramic radiograph (Figure 11.5k) showed the results of excellent ‘catch-up’ root growth, achieving normal root form and length of the previously, seriously compromised first permanent molar. There was also adequate space preparation made for a future implant to replace the missing premolar (Figure 11.5l).

This case illustrates the importance of understanding that the optimum timing for treatment of an impacted tooth is not necessarily the same as the optimum time for treating the rest of the dentition. Had the treatment of the molar been postponed to be treated only at age 12–14 years, the opportunity for stimulating root growth that was so convincingly exploited in this case would have been lost. On the other hand, continuing to treat the remaining items of malalignment and malocclusion at the age of 9 years, after the molar had successfully erupted, would have achieved little in terms of positive progress towards an improved outcome. Indeed, it is likely that the final result would still have been completed on the same date. Dissociating the treatment of an impacted tooth from the treatment of an overall malocclusion, using only an implant in the opposite jaw and an elastic band, makes it possible to resolve an impaction and bring about full eruption of a tooth without the use of a traditional orthodontic appliance and without causing ill-effects either to the adjacent teeth or to the teeth in the opposing jaw. With careful consideration of the use of a TAD, an orthodontist is no longer dependent on the presence of other teeth to influence the decision when to start and when to stop treatment. The practitioner may choose the optimum timing for treatment of the impaction based solely on objective considerations related to the impacted tooth, without reference to the other teeth, which may be treated at an entirely different time.

Mandibular second permanent molars

Impaction of the mandibular second molar is a relatively unusual phenomenon but, when it occurs, it is very similar in its appearance to the more common situation associated with third molars. The mesially impacted mandibular second molar may be partially erupted, but is frequently unerupted. It will usually be discovered during a routine dental check for interproximal caries, when it appears on the bite-wing radiographs. A periapical view or a panoramic scan will show detail of the tooth from crown to apex as well as its relationship with the unerupted third molar.

There are several aetiological possibilities for second molar impaction and these may be listed as follows:

- *Wide molar crown contour*: The teeth of some patients may sometimes show unusually wide crowns sited on narrow roots, which results in a deep concavity on both mesial and distal aspects of the teeth concerned. In the molar region, this presents the unerupted distally adjacent molar with a potential cul-de-sac beneath the distal bulbosity, into which it may migrate in its mesial and vertical eruption path (Figure 11.6a).
- *Posterior crowding*: This results when the horizontal body of the mandible is shorter than the aggregate of the mesio-distal widths of the teeth, with the third molar developing in the vertical ramus, where it is sometimes seen at a higher level than would be expected and with a marked mesial rotation of the tooth bud. This may reduce the space between it and the erupted first molar, to prevent the second molar from erupting (Figure 11.6b). Any expression of eruptive potential on the part of a developing, horizontally oriented third molar will then be directed mesially, towards the second molar, which in turn will be pushed mesially and become lodged below the distal bulbosity of the first molar (Figure 11.6c).

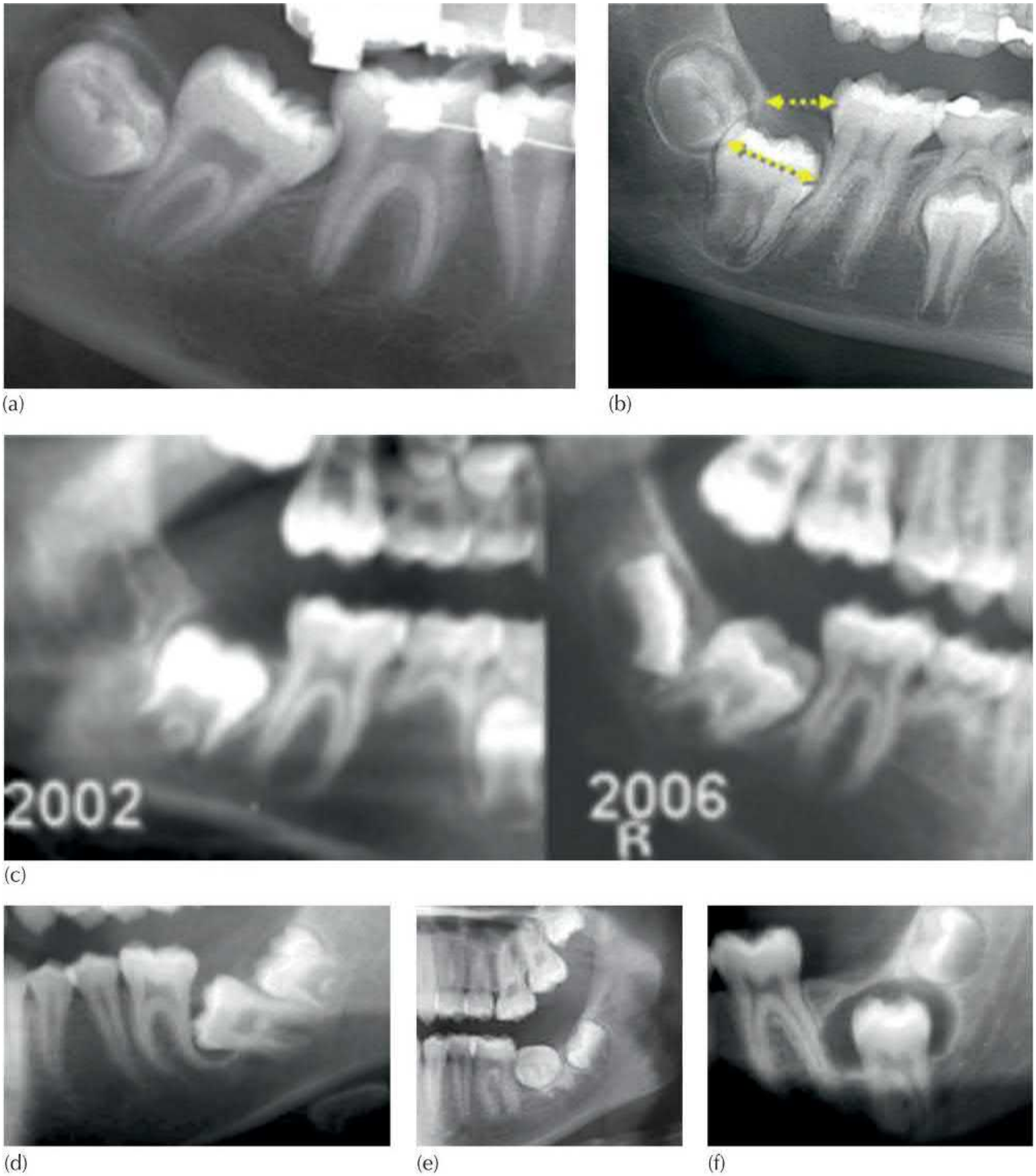


Fig. 11.6 Four different cases of impaction of second molars with different aetiologies. (a) 'Over-contoured' crown of the second molar entrapped by the similar contour of the first molar. (b) Development of the third molar in the anterior ramus, above the occlusal plane, has reduced the width of the eruption path of the second molar, to cause its vertical impaction. (c) Developing second molar mesio-angular impaction radiographed in 2002 and then in 2006 to show the influence of horizontal development of the large third molar crown in the vertical ramus and its subsequent mesial migration. (d) Development of the third molar in the anterior ramus, above the occlusal plane, has prevented the second molar from gaining height and tipping it to impact horizontally against the distal root of the of the first molar. (e) The buccal cusps are higher than the lingual cusps on this left second molar, i.e. the strong tip is to

the lingual. (f) A dentigerous cyst has prevented the tooth from erupting.

- *Abnormal mesial angulation of the second molar tooth germ*: The crypt of the developing second molar may sometimes be seen, *ab initio*, to have a mesial orientation. From this compromised position, the tooth will generally continue to progress along an eruption path that has thereby been dictated (Figure 11.6d).

There are further aetiological possibilities too:

- *Abnormal mesial angulation of the second molar tooth germ*: The crypt of the developing second molar may sometimes be seen, *ab initio*, to have a mesial orientation. From this compromised position, the tooth will generally continue to progress along an eruption path that has thereby been dictated (Figure 11.6d).
- *The tooth may also have a buccal or lingual tilt*: This will generally be revealed by palpation, although an occlusal radiographic view will usually serve to confirm it. Clues to a lingual inclination may also be seen on the panoramic view itself, since it is easy to distinguish between the form of the lingual cusps and that of the buccal cusps. In addition, it is unusual to see a vertical discrepancy of any magnitude in the superimposition of the buccal and lingual cusps of a molar tooth. A wide discrepancy therefore is indicative of a lingual or buccal tip (Figure 11.6e). Thus, when the lingual cusps are seen to be much lower than the buccal cusps, one may conclude that the tooth has a strong lingual inclination.
- *Mesial/distal root length differential*: Though it initially appears to erupt normally, there are cases where mesial angulation of the second molar has followed. This angulation seems to occur quite late in its eventually unsuccessful eruptive progress. Researchers at Tel Aviv University have recognized an association between a mesially tipped second molar and a shorter and earlier apexified mesial root. Assuming that the two roots develop at the same time and at the same rate, it is reasonable to conclude that a longer mesial or distal root will continue to grow after the root of the other has completed its growth, thereby contributing to the change in the orientation of the tooth in the opposite direction [9, 10].
- *Heredity*: This same study found an autosomal dominant hereditary factor, which was noted in comparing two different population samples [9, 10].
- *Enlarged follicle/dentigerous cyst*: As we have noted in regard to maxillary canines (see Chapters 7 and 14), an enlarged follicle or dentigerous cyst will often be associated with non-eruption. This is because the intra-cyst pressure overwhelms the natural eruption force of the tooth (Figure 11.6f).
- *Ankylosis*: As with any other impacted tooth, this diagnosis is rarely seen to be the aetiological factor, although many an orthodontist will exploit the convenience of this terminology when he or she has failed to move the tooth for other (usually undiagnosed) reasons. The confirmed presence of ankylosis means that orthodontic forces used to erupt the tooth will be unproductive. But it may offer the orthodontist a facile, self-serving, but false and convenient diagnostic tag that is difficult to refute.
- *Root entanglement with the inferior alveolar nerve*: See Chapter 13.

There may be an aggregation in the aetiological factors listed above and it is likely that a given case could be cumulatively associated with a combination of two or more of these potential causes. This may make the intellectual exercise of deciding which was the primary precipitating factor particularly difficult.

Local treatment

If the third molar is implicated in the impaction, or if a mesial and superior positioning of the third molar secondarily prevents the eruption of the second molar, then extraction of the third molar will usually be indicated. This will be in order to permit the resolution of the second molar and to obviate the additional and similar impaction of the wisdom tooth. Following the extraction and in the absence of further treatment, the second molar will frequently improve its position, thereby enabling its spontaneous eruption.

If the second molar does not erupt spontaneously, then orthodontic treatment will indeed be necessary, though on a local basis only and in the absence of any other form of treatment for a concurrent malocclusion [10]. The first part of the treatment involves the surgical removal of the overlying mucosa to expose the occlusal surface. It would be advantageous if the buccal aspect were also exposed, except that this is not always possible due to the oblique ridge on the outer surface of the mandible that runs backwards and upwards from each mental tubercle. This oblique ridge reduces the depth of the buccal vestibulum, making it shallower as it proceeds past the molar region to become continuous with the anterior border of the ramus. Exposure of the buccal surface of an unerupted second molar would then be difficult at best and frequently completely impossible. Accordingly, the only accessible surface may be the occlusal. The reader is referred to the beginning of this chapter, which described an approach to the treatment of a maxillary first molar using a simple removable appliance (Figure 11.3). This same procedure may be employed here, with the same basic design and the same mechanical principles [5].

Although there are many types of fixed appliance methods that may be employed to treat this stage of the treatment, their design is too frequently limited to just two or three teeth, which may not provide sufficient anchorage. Uprighting a second molar is notorious for causing the anchor teeth to move mesially or for the adjacent molar and premolars to be intruded and tipped buccally into a cross-bite relationship with the upper teeth. Every effort should be made to counter these adverse movement tendencies.

Ideally, teeth on both sides of the mandibular dental arch should be included in the anchorage unit [10] in order to minimize unwanted movement of other teeth in the arch, and particularly to eliminate the possible occurrence of lower incisor crowding. It is suggested that the minimum extent of the anchorage unit should include fixed bands on both first molars, joined by a soldered lingual arch, with orthodontic brackets on the premolars of the affected side. A useful alternative to the soldered lingual arch, particularly when there is bilateral impaction of the second molars, is to place a bonded multi-strand wire retainer on the lingual side of the incisors and canines and extend it to the mesial occlusal pit of the first premolar. In this way, the anchor unit will constitute a sectional arch on each side, engaging first molars and both premolars, together with the bonded retainer joining first premolar to first premolar. This will bring the 12 teeth anterior to the second molars into the anchor unit, still without the need for anterior brackets.

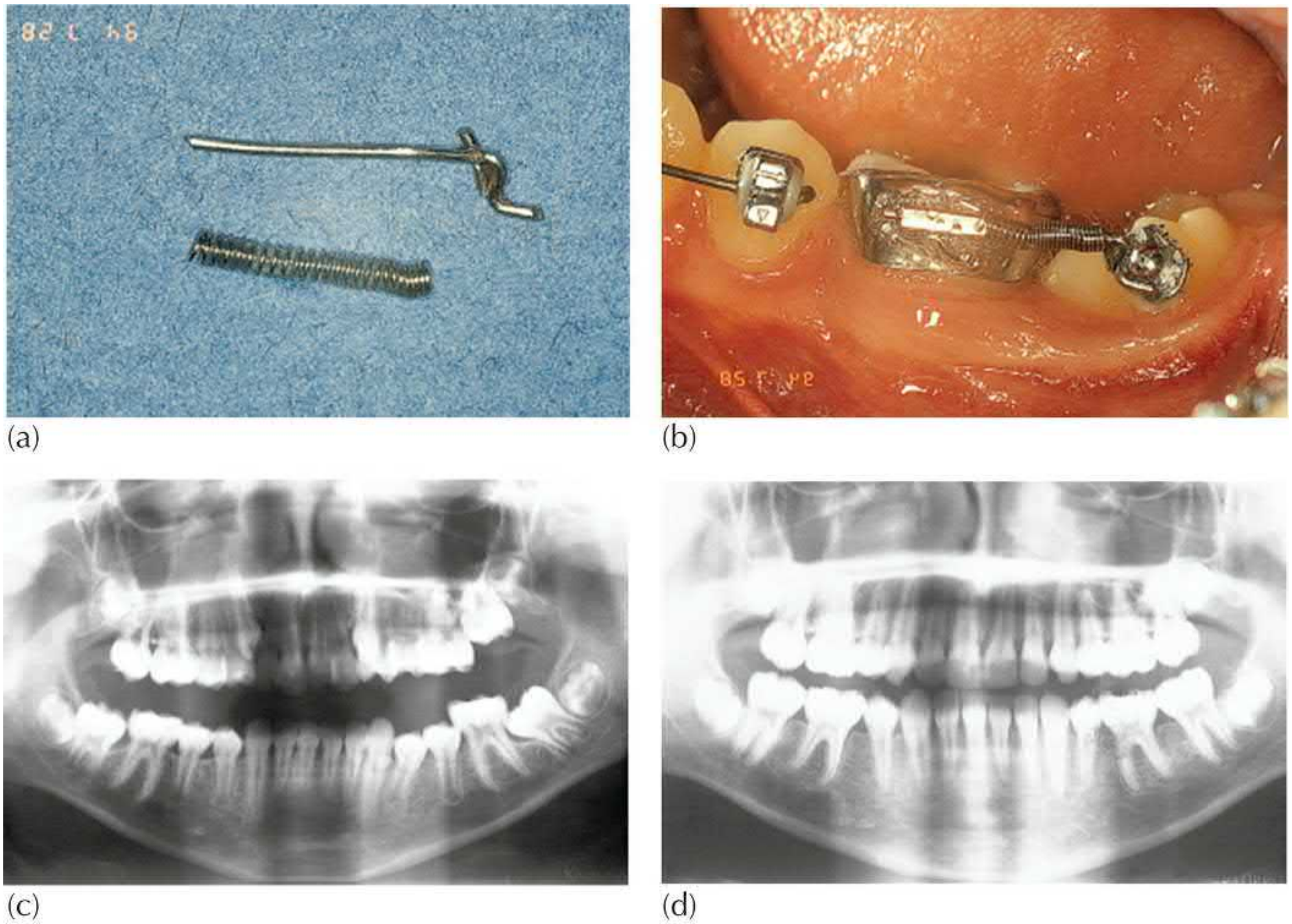


Fig. 11.7 (a, b) A coil spring is threaded onto a sectional archwire, which is slotted into the distal end of a buccal tube on the first molar band. The distal end of the wire carries a welded stop or cross-piece, which permits compression of the coil spring against a button or eyelet attachment on the second molar. A lingual arch and fully bracketed appliance is present for additional anchorage. (c, d) Panoramic views before and after treatment.

When the second molar is only mildly impacted and partially erupted beneath the distal bulbosity of the first molar, it is frequently possible to place a bonded tube or other attachment on its buccal surface and simply include it in the initial levelling arch that is used in the early stages of treatment.

For the more severe cases of impaction, however, one would need creative and problem-specific mechanisms in order to resolve the problem. The active element may be constructed in one of many ways, most of which are minor variations on a common theme:

- A free-sliding sectional wire is slotted into the brackets and the molar tube on the affected side and is activated by an elastic module, with the distal end of the sectional wire fashioned into a small hook, which in turn latches onto an eyelet attachment on the buccal or occlusal surface of the impacted tooth. This will tip the molar distally until the buccal surface rises sufficiently for a buccal tube to be placed. Thereafter the remainder of the treatment is completed with a buccal aligning archwire.
- A similar method can be employed using a compressed coil spring (Figure 11.7a–d) instead of the free-sliding sectional wire.
- A rectangular sectional arch can be used, containing an expanded open loop that is tied into

the brackets after being compressed against the attachment on the molar.

- A large and stiff open loop of rectangular wire is placed in the distal end of a buccal tube or wide Siamese bracket on the molar and is designed to widely encircle the impacted tooth, with a small helix at its extremity. By tying a stainless steel ligature between a bonded eyelet or button on the occlusal of this tooth and the small terminal loop, distal pressure is brought to bear on the impacted molar.
- A complete round wire loop with a distal helix may be slotted into buccal and lingual horizontal tubes on the molar band. Activation is made as for the previous option, by tying a steel ligature between the helix and an attachment on the tooth (Figure 11.8).

In cases of a more deeply sited tooth, seen on a radiograph to be well down in the junction between body and ramus, there will be two further problems. First, it is difficult to provide a sufficient area of access on the tooth for bonding an attachment. However, with good teamwork on the part of the surgeon and the orthodontist, it can usually be achieved. The second and more difficult problem involves the ability to devise a biomechanical method for applying appropriately directed traction and a solid anchor base that will resist unwanted movement. Applying forces by utilizing only adjacent teeth will intrude these teeth and generate a cant in the occlusal plane. Furthermore, the use of loop mechanics built into the archwire, as a means of applying uprighting, levelling or aligning forces, is extremely limited because of the shallowness of the buccal sulcus in the second molar area. However, the lingual sulcus is very much deeper than the buccal sulcus and, with a little ingenuity, it may be exploited to accommodate a suitably designed uprighting, levelling and/or aligning spring.

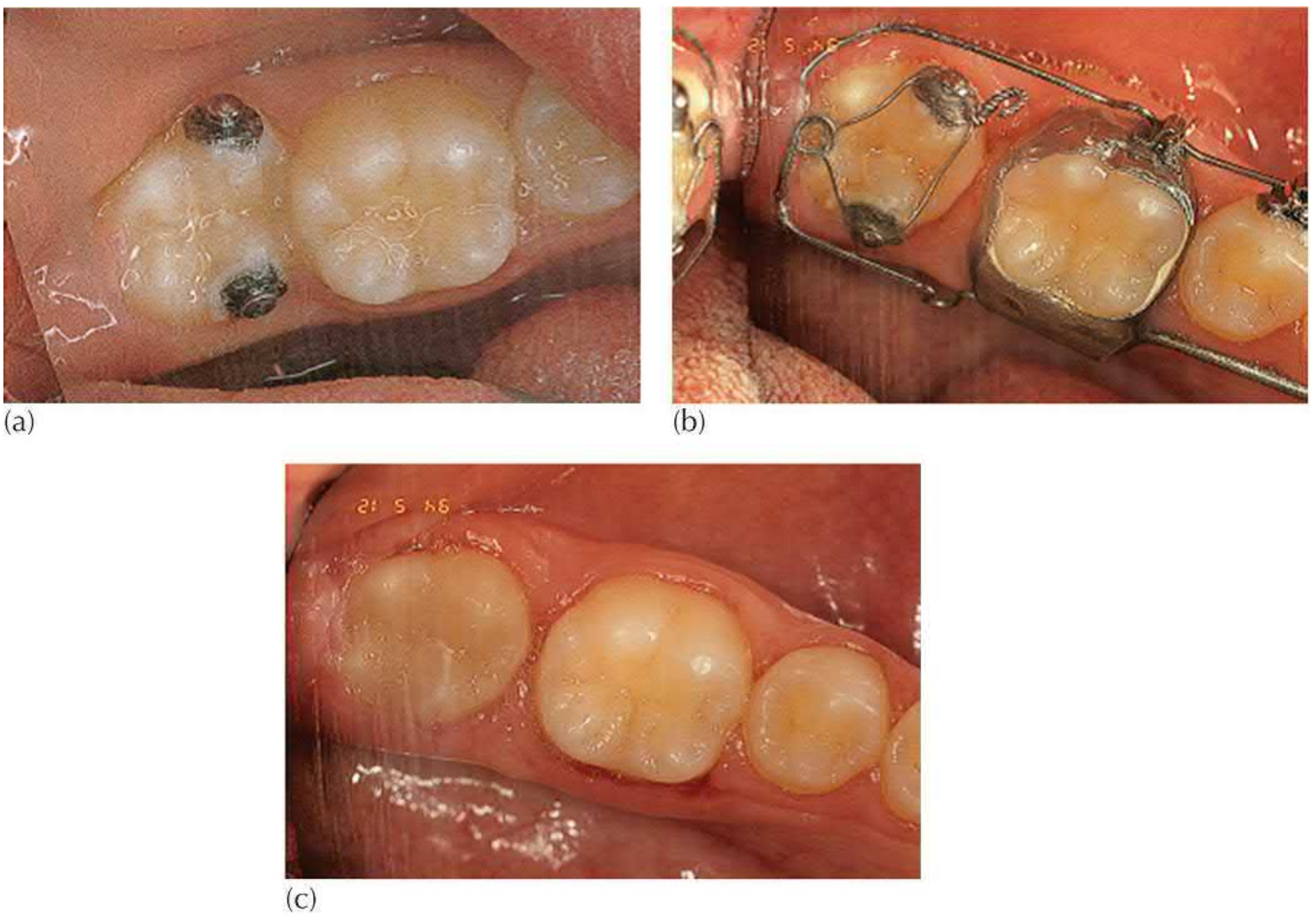


Fig. 11.8 (a) Button attachments bonded buccally and lingually to an impacted second molar. (b) A

wire loop carrying a distal helix is slotted into buccal and lingual tubes on the molar band. The wire loop is compressed by tying steel ligatures between the buttons and distal helix. (c) The final result.

Applying forces anchored on teeth in the maxillary arch will increase what is probably already a considerable over-eruption of the opposing molar, which has been caused by the long-time absence of its antagonist. In the past, the only method then available to bring about intrusion of the unopposed tooth was to use a high-pull headgear to maintain the vertical position of the molar while applying intermaxillary vertical traction to the impacted tooth.

Today, the problem would likely be approached using a temporary micro-screw in the maxilla. The advantages of such a TAD include the fact that an orthodontic appliance in the affected jaw is, at least theoretically, unnecessary. However, this presupposes that the application of the vertical force will raise the tooth and align it in its ideal position. In practice, simple extrusion is rarely adequate because the tooth usually needs other force components to upright it. Accordingly, an orthodontic appliance will be needed to complement the TAD in order to produce these aligning movements once the tooth is erupted and accessible for the placement of a suitable attachment. A significant unknown factor in such treatment is the patient's own ability to attach an intermaxillary elastic ring between the bone anchor and the hooked ligature wire that has been tied into the eyelet on the impacted second molar.

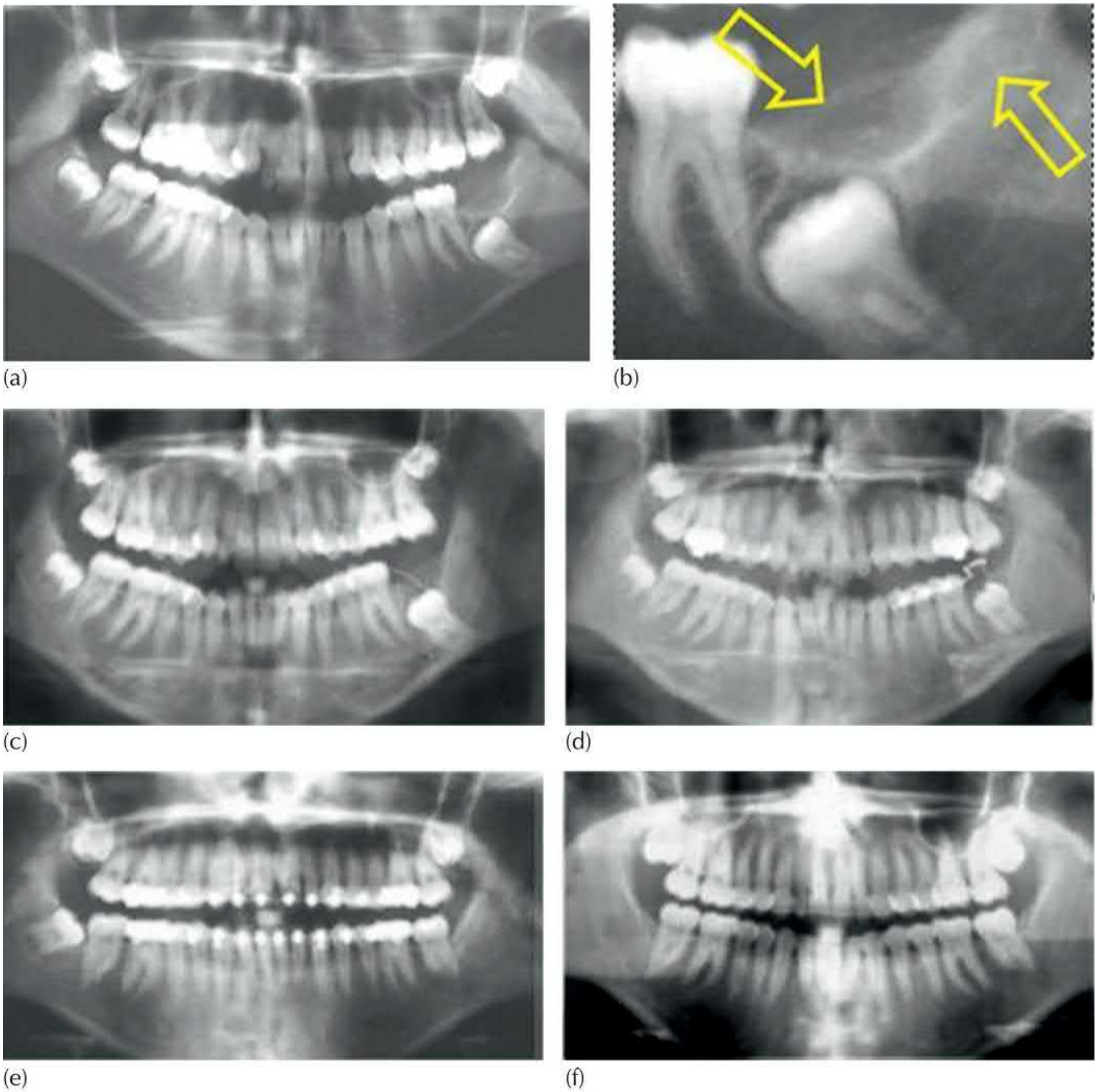


Fig. 11.9 Initial panoramic and periapical radiographs. (a) A second permanent mandibular molar was impacted deeply with roots at the lower border of mandible. (b) Close-up to show cystic/follicular tissue (arrows). (c) Following the excision of the cystic lesions and exposure of the deeply located molar, a twisted ligature wire attachment had been bonded directly to the tooth surface, in a closed surgical procedure. (d) The sectional archwire can be seen to have partially raised the tooth. (e) Following full eruption, a full multi-bracketed appliance was placed to treat the remaining malocclusion. (f) The case five years after completion of treatment, with bonded maxillary and mandibular 3-3 retainers still in place.

Case 11.4: Impaction due to overlying cystic pathology

The patient in this case was seen by an oral surgeon because of a deeply impacted mandibular second molar, whose root apices were developing at the lower border of the mandible (Figure

11.9a). On closer radiographic examination the surgeon had diagnosed the presence of two adjacent circumscribed and encapsulated lesions immediately superior to the tooth (Figure 11.9b) beneath the mucosa, which had altered the contour of the bony crest. The radiograph indicated the presence of some calcified granules within the more mesial lesion. In the absence of any other potentially aetiological factor, it seemed obvious that it was these two lesions that had prevented the tooth from erupting.

The surgeon therefore excised them and, at the same time, exploited the opportunity to extend the operation downwards to expose the second molar and place a twisted steel ligature (Figure 11.9c). The excised tissue was sent for pathological examination and was declared benign. It was only at this point that the patient was referred to the orthodontist for the first time.

This tooth required little more than vertical eruption to the occlusal plane. The aetiology was clear and a second concurrent and complicating aetiological cause was considered highly unlikely. This tooth would now need the most minimal of encouragement to erupt normally.

Brackets were placed only on the premolars and first molar of the same side. These were linked together using a rectangular sectional arch that continued to a free end, distally above the mucosa covering the unerupted tooth (Figure 11.9d). A twisted ligature hook protruding from the impacted molar was ligated with steel ligature to a downward-flexed offset at the free end of the sectional archwire itself.

Finally, multi-bracketed fixed appliances were placed in both jaws (Figure 11.9e) to complete the alignment of the dentition as a whole, following which fixed 3-3 bonded retainers were placed in both arches (Figure 11.9f).

Resolution of the impaction as part of a comprehensive orthodontic treatment plan

In these molar impaction cases, there will frequently be some form of accompanying overall malocclusion for which treatment needs to be prescribed. The resolution of the impacted tooth should be integrated into the general treatment plan. However, for many of the more seriously impacted mandibular second molars, the initial movements required to overcome the impaction itself need to be achieved by using intermaxillary elastics applied from a TAD in the opposite jaw, for which multi-bracketed fixed appliances are not immediately necessary.

Case 11.5: Distally tipped first molar, horizontally impacted second and third molars

In the routine half-yearly dental examination of a 13-year-old male patient, the dentist had diagnosed a severely impacted second molar in the left side of the lower jaw. The patient was referred to an oral and maxillofacial surgeon, who noticed the presence of a marked distal tip of the left first mandibular molar. He rationalized that this was due to futile and unrewarded eruption pressure from the impacted tooth. He further considered that extraction of the unerupted third molar might fulfil the forlorn and unrealistic hope that the second molar might improve its position spontaneously in the months and years thereafter. He then proceeded to extract all four third molars in the weeks that followed.

One year later, when the hoped-for improvement had not occurred, the patient was referred for orthodontic treatment for the overall malocclusion, including the impacted second molar. The orthodontist's examination revealed that the intercuspation of the molars was class I (Figure 11.10a), but the maxillary and mandibular incisors were retroclined, over-erupted into a deep overbite and increased overjet relationship. On the panoramic radiograph, the mandibular second molar could be seen (Figure 11.10b) lying at an 80–85° angle to the vertical, and its mesial cusps could be seen deeply displaced and in direct contact with the apex of the erupted first molar. The first molar was also mildly tipped distally.

Attention was given to the treatment of the impacted second molar from the very beginning of the orthodontic treatment, as it was clear that the surgeon's optimistic forecast had not materialized. The second panoramic film (Figure 11.10c) was taken shortly after placement of a zygomatic plate TAD in the maxilla (arrow) and after the simultaneously bonded eyelet attachment to the disto-occlusal corner of the surgically exposed second molar. In a comparison with the earlier film, there was evidence of excellent healing of bone in those areas. It also showed the newly sited orthodontic appliances in place. Interestingly, the position of the affected second mandibular molar had worsened. The tooth had become completely horizontal and its entire occlusal surface was jammed against the distal surface of the first molar, in apparent contact from root apex to the cervical area of the crown.

The initial stage of uprighting the second molar was controlled by a force system using up-and-down intermaxillary vertical elastics, which was independent of the traditional orthodontic biomechanics in operation on the other teeth. The elastics were changed daily and placed by the patient himself between the hooked extension of the zygomatic plate to the steel ligature linked to the bonded eyelet on the molar.

Treatment for the overall malocclusion was addressed with fixed appliances in each jaw individually, to level and align the teeth and to correct their buccolingual angulations. The inter-arch skeletal relations were addressed with class II inter-arch mechanics.

Once the molar had completed the majority of its uprighting, it was slightly above the occlusal level of the neighbouring teeth (Figure 11.10d) and had erupted sufficiently to provide access for the placing of a molar tube on its buccal aspect. This served to merge the two independent orthodontic systems into one. The maxillary appliance was extended to include an attachment on the newly erupted second molar, to control its vertical height. The two separate force systems had been planned to reach this point of progress simultaneously, which presented the opportunity to level both occlusal planes in the molar area, while completing the final movements of the previously impacted tooth (Figure 11.10e, f) and creating parallelism between the roots of the first and second molars.

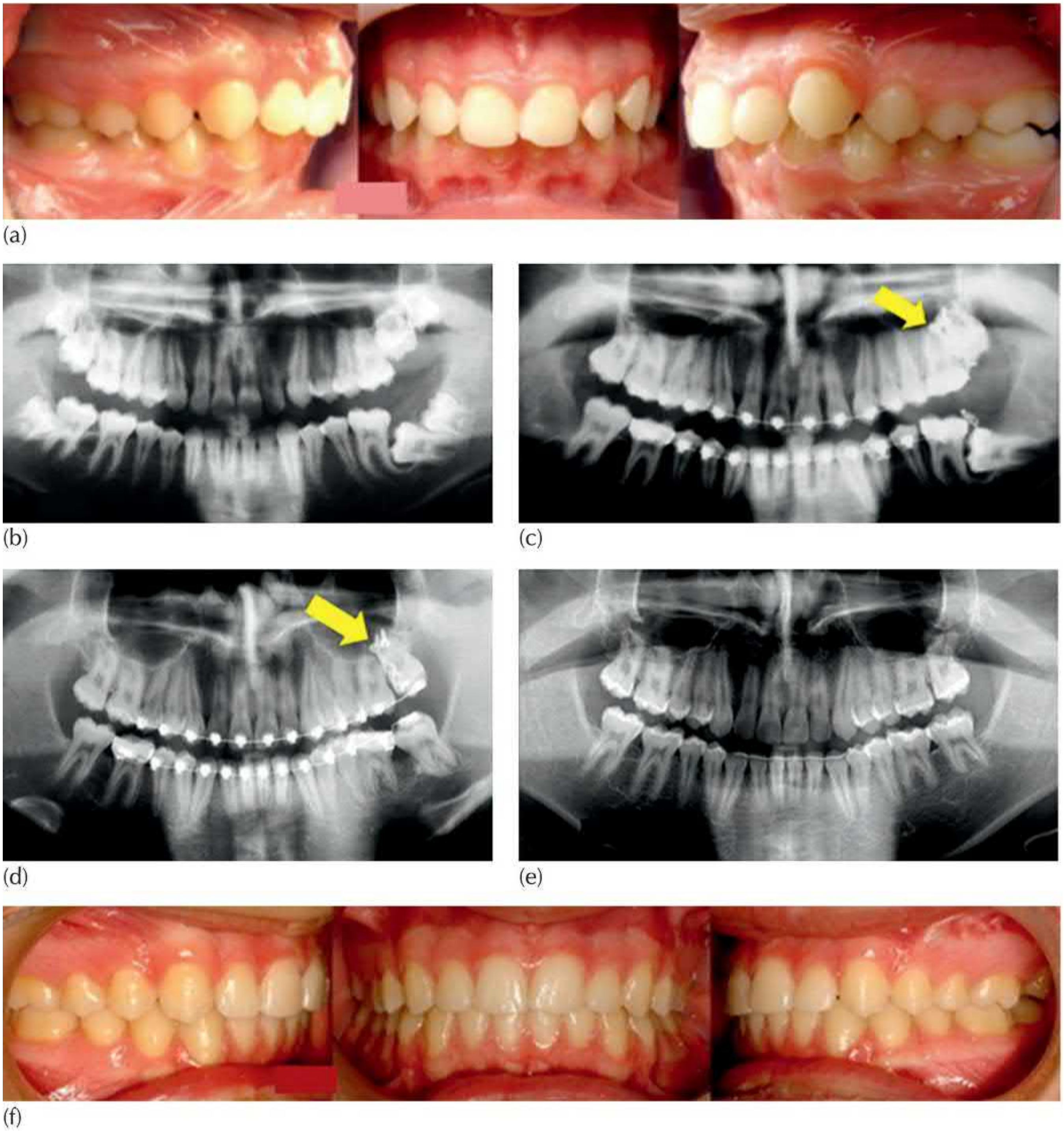


Fig. 11.10 (a) The pre-treatment intra-oral views of the teeth in occlusion. (b) Panoramic radiograph taken by the general dentist at the routine dental examination. (c) Panoramic view taken one year after third molar extractions, immediately after placement of orthodontic appliances and following surgery to place zygomatic plate temporary anchorage device (TAD; arrow) in the maxilla and an attachment bonded to the distal crown surface of the mandibular left second molar. (d) Panoramic view taken before removal of the zygomatic plate TAD (arrow), after eruption of the maxillary second molar and resolution of the mandibular molar impaction. (e) The completed case with mandibular 3-3 fixed retainer. (f) The completed case.

Maxillary second molars

Crowding is to be found in many patients at the distal end of the maxilla in the tuberosity area. The unerupted second and third molars are clearly 'stacked' almost vertically above the erupted first molar and above one another, rather than in a more horizontal, distally directed formation. Their root apices are mesial and their crowns point distally, mostly with a buccal component, which is clearly due to a basal shortness of the maxilla and/or disproportionately large teeth.

In this situation, it is quite likely that the second molars will fail to erupt, which means that both the second and third molars will remain impacted. Aside from delaying orthodontic treatment, it obliges the orthodontist to make a choice regarding extraction. Often, after the soft tissue covering and (usually) thickened mucosa is cut away, and provided there is no other obstacle, most second molars will spontaneously erupt. They will, however, often erupt buccal to the line of the arch, into a buccal cross-bite ('scissors') relationship with the lower second molar. Little natural improvement may be expected to occur, since growth of the maxillary tuberosity is largely complete by the age of 11 years [11]. Since this is marginally before the time that the second molar is due to erupt, the second molar will need to be aligned in one of the latter stages in the subsequent overall orthodontic treatment.

If resolution of the overall malocclusion demands a reduction in the number of teeth, priority consideration may occasionally be given to the extraction of this impacted second molar, together with appropriate balancing and compensating extractions in the other quadrants of the mouth. Extraction of mandibular second molars is not normally an extraction of choice; however, in the event of a very difficult impaction, it should now be considered. This would enable the dispersal of mild crowding to be effected with great facility in a distal direction, without the need for the extensive root uprighting movements that are relevant to premolar extractions. The orthodontist will be counting on the favourable eruption of the third molars (which will be significantly earlier in these cases) and their spontaneous alignment. Should this not occur, a further period of treatment will need to be initiated, three or four years later, in the young adult stage. Then it will be a question of correcting mesially tipped third molars from a location that may be reminiscent of the initial location of the extracted second molar.

Perhaps the best way to visualize the potential influence of the extraction of different groups of teeth is by examination of the panoramic radiograph. In the case of an extraction of a mesially tipped second molar, the loss of a first or second premolar and the mesial movement of the first molar may often cause the tooth to erupt. However, the tipping will remain and, in a few cases, may even worsen and result in the tooth appearing to 'fall flat on its face'. The above procedures may be applied to bring about third molar uprighting in exactly the same way as with second molars.

In the milder cases, when the second molar is impacted against the first molar and is mesially tipped 10° or less, uprighting may usually be performed by placing the initial archwire in the buccal tube of the second molar, which will have been placed perpendicular to its mesially tipped long axis. This, combined with an initial levelling wire and subsequently with more substantial stainless steel archwires as part of a full jaw strap-up, will upright the molar.

When the mesial tip is greater, and/or is located at or below the CEJ and the distal bulbosity of the first molar, the tooth will not respond to uprighting and will need to be treated more aggressively. This will necessitate surgical exposure and buccal tube bonding to the impacted tooth and the inclusion of this unit into a full mandibular fixed appliance. If the molar tube is placed on the buccal side of the second molar perpendicular to the long axis of the tooth, then the bracket on the first molar will be at a sharp angle to it and it will be impossible to fully engage an archwire. In that situation, the tube should be initially placed at a lesser angle and the tooth uprighted to this lesser angle of correction. Once achieved, the tube may then be removed and relocated in the same place on the molar, but at an angle that will achieve a further correction. For a badly tipped molar, this may need to be done three or four times until the tooth reaches the required orientation.

In the severest of cases, the buccal aspect of the mandibular second molar will not be accessible because the tooth may be lying horizontally and fairly low down. Surgically exposing the tooth from the occlusal will present the anatomically distal surface uppermost and the best that may be achieved is the placement of an eyelet on its horizontally oriented distal surface. There will also be no possibility of applying forces in the appropriate direction from an appliance on the teeth or from a TAD in the same jaw. Placing a long screw temporary implant in the anterior border of the ramus can be an alternative, but the direction of traction would be horizontally distal and thus almost parallel to the long axis of the molar. It will not provide for an efficient mechanism, since most of the force would be wasted by horizontally 'intruding' the tooth, with little elevation of the crown.

The only efficient manner to apply properly directed forces is from a location in the maxilla. Up-and-down intermaxillary elastics for this type of high-demand anchorage case would cause over-eruption of the maxillary teeth. Therefore, the use of a TAD in the opposing jaw will be essential.

Case 11.6: Extracting the impacted second molars

Extraction of the second molar, rather than premolars, has been offered as a panacea in cases of posterior crowding, particularly in the maxilla, and it has enjoyed a significant following of devotees over the period of several decades [12–17]. The aim of the treatment is to disperse the crowding distally into the extraction space, and to encourage the third molar to then erupt naturally into the residual space of the extracted tooth, with interproximal contact with the first molar. Many excellent anecdotal case reports have been published illustrating both maxillary and mandibular second molar extraction cases and the method undoubtedly has many advantages. However, the third molar is an unreliable tooth in terms of its size and shape and in the unpredictability of its final erupted status. Accordingly, an orthodontist using this extraction method must be prepared to offer renewed orthodontic treatment two to three years later, should the outcome of this simplified treatment not live up to expectations.

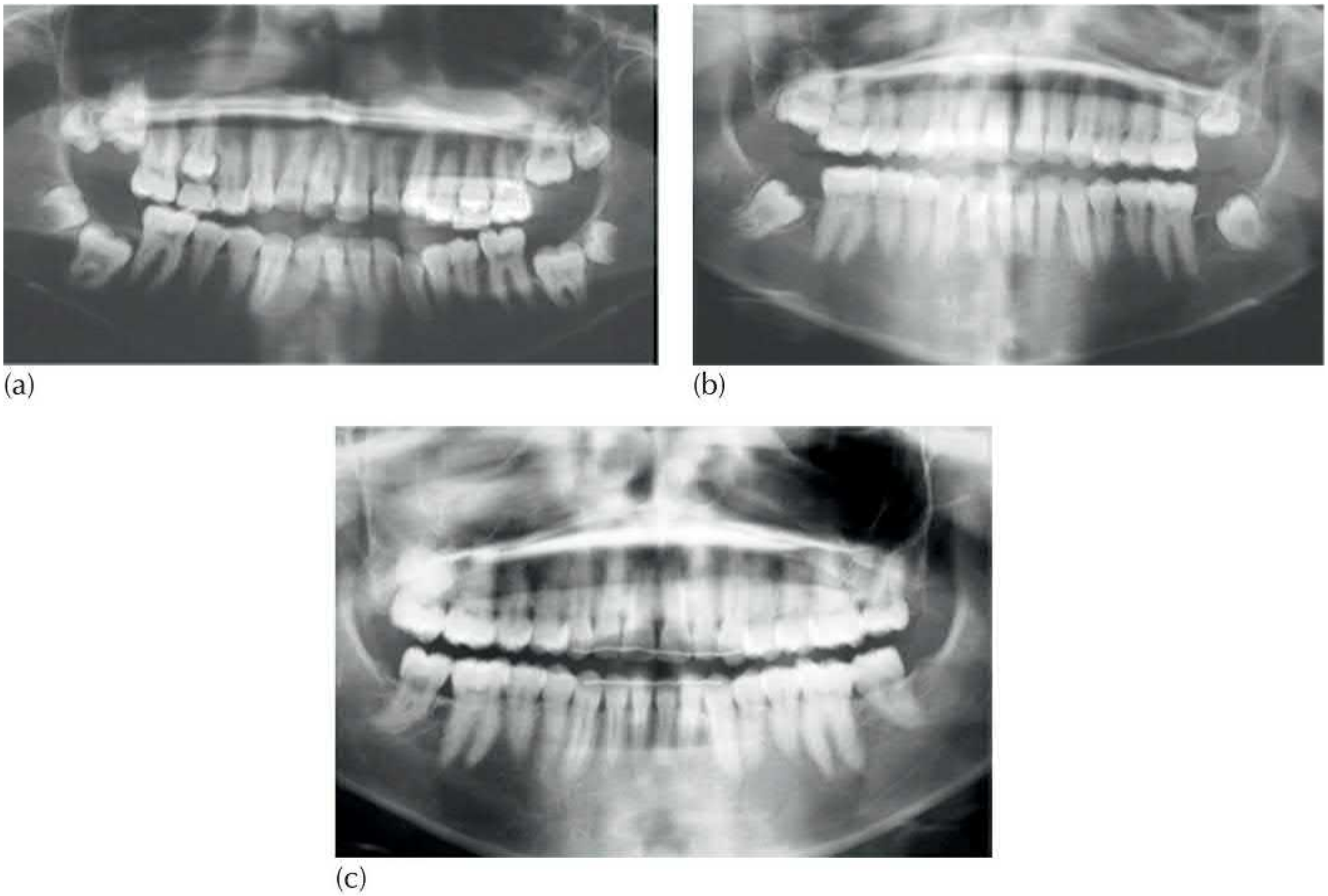


Fig. 11.11 (a) Pre-treatment panoramic view at age 13.2 years showing second molar abnormality. (b) Age 16.4 years, follow-up radiograph at the end of orthodontic treatment, to assess the third molars. (c) Age 19.3 years, the three-year post-treatment follow-up panoramic view shows the final outcome.

The case illustrated in Figure 11.11 was of a 13.2-year-old boy with a class II division 1 malocclusion relationship, with all four unerupted second molars abnormally located. Three second molars and the maxillary right third molar were extracted as part of the treatment plan. At age 16.4 years, a follow-up radiograph at the end of treatment showed considerable eruption progress of the third molars. Three years later, a new panoramic film showed the third molars in ideal alignment and fully juxtaposed with the first molars. This had occurred autonomously, without the need for professional intervention. Unfortunately, there are few reliable keys or guidelines by which this excellent result could have been guaranteed at the outset.

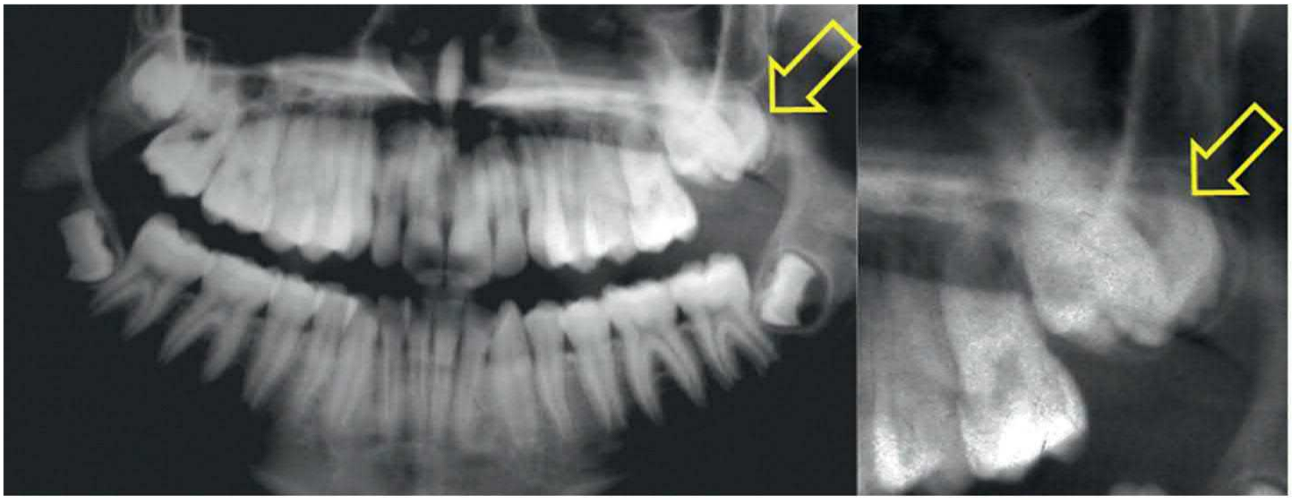
Maxillary 'banana' third molars and second molar impaction

A panoramic radiograph may reveal an additional possible cause for the impaction of the maxillary second molar. This is related to an anomaly in the development of the adjacent third molar. This latter tooth is seen on the radiograph as having a banana-shaped crown, with little or no root development. It is also located inferiorly to the crown of the second molar and it is this that most probably has been acting as an obstruction to the eruption of the second molar (Figure 11.12a). In fact, the adjacent third molar is probably both inferior and palatal to the second molar, but nevertheless obstructing its path of eruption. Identifying this tooth at the time of exposure and removing it would have been disconcerting for the surgeon, because of its unexpected position occlusal and lingual to the second molar. Nevertheless, following its extraction, the second molar will usually erupt rapidly (Figure 11.12b, c).

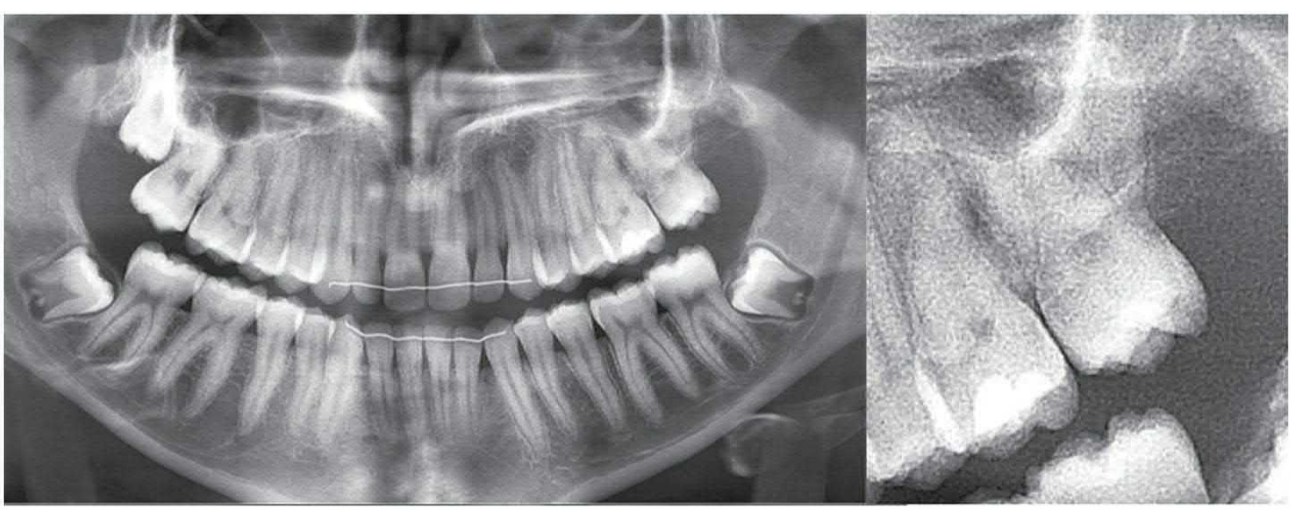
Case 11.7: Impaction treated by elimination of the adjacent banana third molar

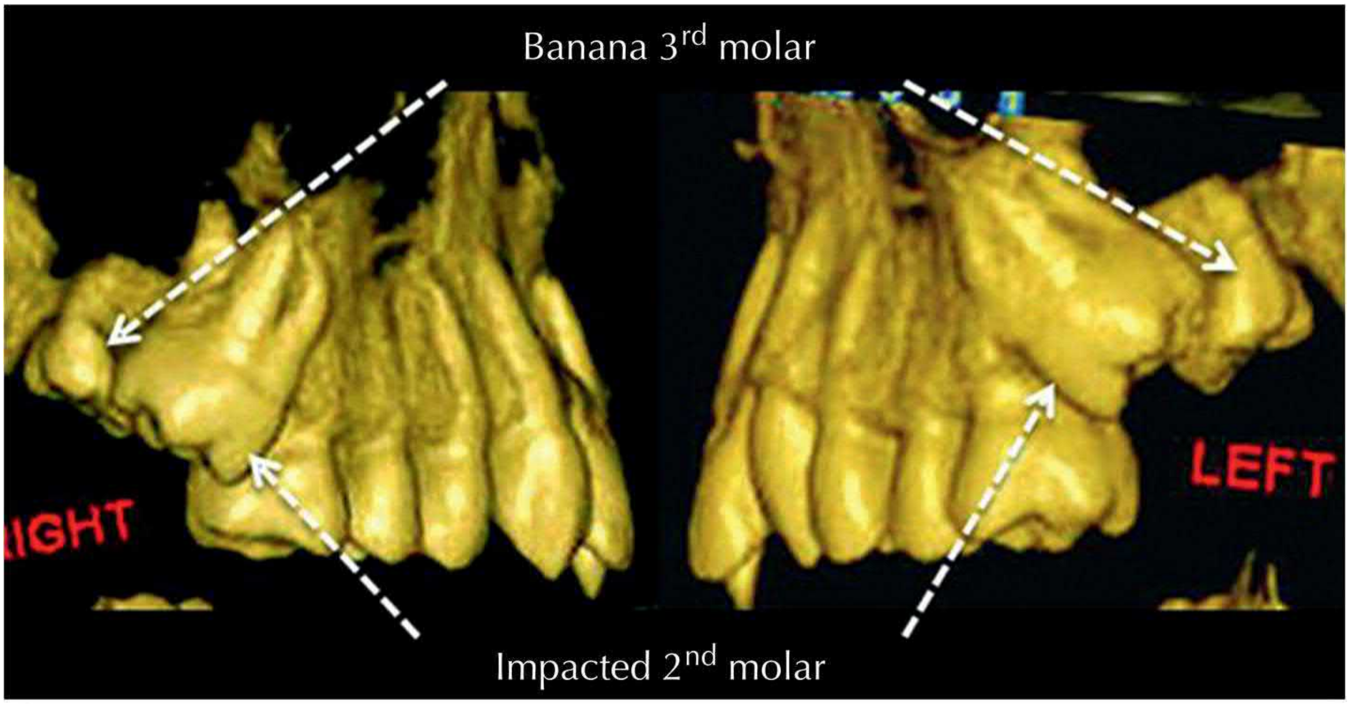
The patient described in this case was a 13.2-year-old female, whose erupted maxillary permanent dentition ran from second molar on the right side to first molar on the left. The left second molar was unerupted. The panoramic radiograph of the mouth showed that the second molar was present and impeded by a 'banana' third molar on which its image was superimposed (Figure 11.12a). The third molar was extracted and exhibited its unusual but fairly typical irregular 'banana molar' form (Figure 11.12b). The second molar was already erupting at the four month post-surgical follow-up appointment and fully erupted within a few months.

It is well recognized that if a child has anomalous crown forms, these will usually manifest themselves in certain particular teeth. If this is found with the lateral incisor, it will take the form of a peg-shaped crown or a noticeably small crown. Anomalies of this nature are genetic in origin and therefore mostly appear bilaterally. The features will be associated with the late development of that tooth, and frequently with late dental development in general. As has been discussed in Chapter 7, the anomalous features will not usually be the only dental anomaly exhibited by the child, but may be accompanied by other hereditary traits such as spaced dentitions or missing teeth. By far the most frequent anomalies will occur in the third molars in both jaws.


(a)


(b)


(c)


Banana 3rd molar
RIGHT
LEFT
Impacted 2nd molar
(d)

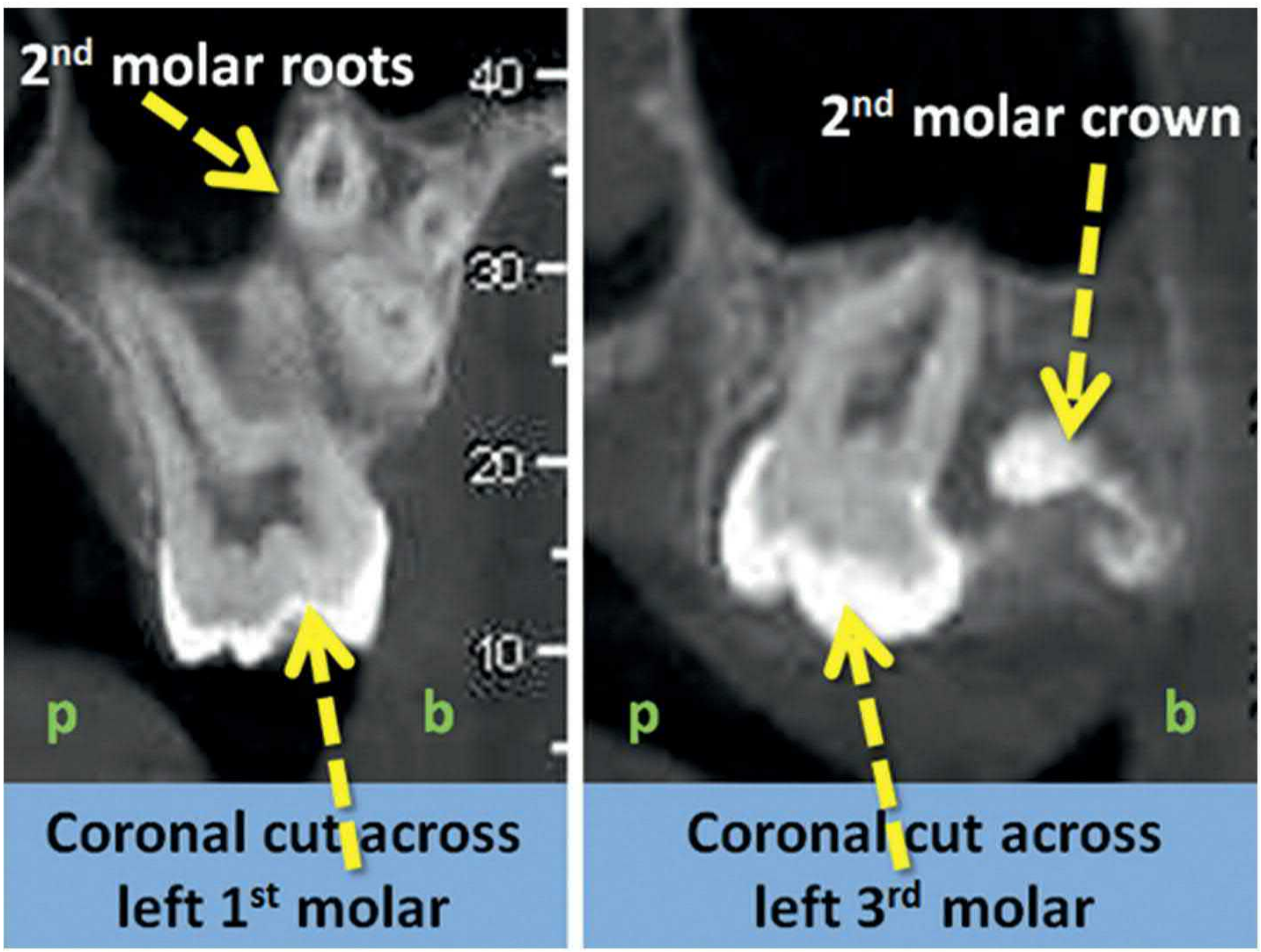

2nd molar roots
40
30
20
10
p
b
Coronal cut across left 1st molar
2nd molar crown
p
b
Coronal cut across left 3rd molar
(e)

Fig. 11.12 The ‘banana’ maxillary third molar. (a) In the panoramic view of a 13-year-old female, the left maxillary third molar is superimposed on the impacted second molar and is more occlusally located. The other second molars have erupted. (b) The extracted ‘banana’ molar from the occlusal and buccal aspects, showing its anomalous form. (c) The second molar erupted autonomously, four months after the extraction, although the panoramic view was taken many months later, at the completion of the orthodontic treatment. (d) 3D screenshots taken from the cone beam computed tomography of the patient show the extreme crowding that is present at the distal end of the maxillary alveolus. In order to accommodate the unerupted molar teeth, the roots of the second molars are severely displaced mesially and buccally, nestling in the distal concavity at the distobuccal aspect of the first molars. The third molars are developing disto-lingually and inferiorly, apparently confining the second molar with their mesially bulging morphology to prevent any vertical movement. (e) The vertical (cross-sectional) ‘cut’ across the alveolus of the left first molar shows the location of the three-rooted second molar on its buccal side. The cut that traverses the palatally displaced third molar shows its bulbous mesial cusp and the depression in the cemento-enamel junction area and how these may trap the more superiorly placed second molar from erupting vertically downwards towards its place in the arch.

Courtesy of Dr Yael Jacoby.

Such anomalies present in various shapes and sizes and with no particular predictable pattern or location. However, one may usually assume that, whether or not they are impacted, a high proportion of third molars demonstrate anomalies. The very existence, abnormality or absence of third molars is not a matter that will usually concern any practitioner, and it is highly unlikely that serious thought would be given to the prosthetic replacement of a third molar, after its extraction, if the remainder of the dentition is intact.

Nevertheless, as with most things there is an exception, which is the maxillary ‘banana’ third molar. In common with most other third molars, this tooth is usually unerupted and is an incidental finding in a routine orthodontic examination, in which the orthodontist has had the opportunity to review a panoramic radiograph or CBCT.

Why is this specific impacted maxillary third molar significant in the context of this book? The reason is that the impacted banana maxillary third molar is usually the cause of the non-eruption or impaction of the maxillary second molar.

The fact that the maxillary third molar develops at the distal end of the maxilla, in the tuberosity region, means that it grows in a very confined space, bounded by the second molar mesially, the pterygoid area distally. The maxillary sinus lies superiorly and the narrow alveolar process bucco-lingually. It seems likely that the convolutions of third molar roots are the direct consequence of the cramped environment at the end of the dental arch (an anatomical barrier), in which they have developed and which has similarly resulted in the anomalous ‘squashed’ morphology of the crown of the tooth (Figure 11.12b). In these cases, the third molar is typically developing on the lingual side to the second molar, itself buccally displaced, rather that fully distal to it. This is clearly illustrated both in the 3D screenshots (Figure 11.12d) and in the cross-sectional cuts (Figure 11.12e). In the 3D shots, the crowding of the root apices into the grossly inadequate and most distal end of the tuberosity causes the crowns of these teeth to flare out distally.

The case in Figure 11.13 was a male patient with a dental age of 14–15 years and with bilateral ‘banana’ third molars. The orthodontist will have initially seen the teeth on a panoramic film (Figure 11.13) and will undoubtedly have noted that the third molars appear superimposed on the unerupted second molar and that they also appear to be much larger than their immediate mesial neighbours. A ‘2D-’ or ‘flat earth-thinking’ orthodontist may be deceived into diagnosing this anamoly as a *dens in dente* or some form of odontoma, and might proceed to advise extraction of both teeth. A ‘3D-thinking’ orthodontist, on the other hand, will quickly realize that the apparent enlargement of the third molar is due to the technical, geometrical quirks of panoramic radiography. It will be remembered that all teeth that are lingually displaced from the focal trough have an increased distance from the receptor and will therefore project an enlarged image.

Fig. 11.13 The dental age of this patient is 14–15 years, given that the root apices of the maxillary canines and maxillary and mandibular second molars are almost fully closed. This labels the canines as exhibiting delayed eruption. The unerupted maxillary second molars are impeded high in the tuberosity area by the presence of the third molars, which are in the very early stages of root development.

Courtesy of Dr Jeremy Edel.

Typically, the banana third molar has the following identifying characteristics: (a) the crown is bucco-lingually narrowed; (b) its occlusal pattern may often be missing one or more of the molar cusps; (c) it calcifies later than its more normally shaped counterparts; (d) one may see a late teenager with only the very earliest beginnings of root formation of this molar; and (e) the CEJ of the tooth and the origin of its root development seem to be located more distally than normal in relation to the crown of the tooth, and this creates a very exaggerated and bulbous mesial contour to the tooth. This, in turn, creates a deep hollow or fossa in the mesial surface in the area of the CEJ.

For reasons that are not fully clear, the cramped circumstances of the retromolar area seem to be associated with a displacement of the third molar tooth germ to a location more inferiorly and lingually to the second molar. The peculiar anatomy of its mesial side entraps the second molar against the distal aspect of the first molar, thus preventing the eruption of both second and third molars.

Just occasionally, the third molar will bypass the unerupted second molar and erupt, leaving a small space between it and the distal surface of the erupted first molar (Figure 11.14).

Fig. 11.14 In this 18-year-old male patient, the banana third molars have erupted with a small space separating them from the first molars. On the right side, the peculiar anatomy of the bulging mesial aspect of the crown of the tooth and the more distally placed site of origin of the early developing root are well illustrated. The follicle surrounding the second molar of the right side has become enlarged and now may be termed a dentigerous cyst. Both second molars are unusually high in the tuberosity area. Extraction of the third molars will almost certainly resolve the cyst and lead to spontaneous eruption of the impacted teeth.

If, as we believe, the reason for the impaction of the second molar is the presence, form and location of the third molar, then it is logical to suppose that extraction of this anomalous tooth should bring about rapid eruption of the second molar. There is one very important factor that must be considered: when referring the patient to the oral and maxillofacial surgeon, it is strongly advised to draw the attention of the oral and maxillofacial surgeon to the exact location of the tooth, since it is very easy to err and the wrong tooth may be extracted.

For the most part, and particularly in the younger patient, the second molar erupts well and relatively rapidly. However, it may happen that, while the second molar may improve its position, it may not have the eruptive power to break through the healed and thickened mucosal tissue covering the ridge. In such a case, that mucosal tissue will need to be removed, to encourage normal (if late) eruption.

Follow-up of the case is advised, although large, active, orthodontic mechanics will not normally be required with these teeth, unless they erupt buccally, into a buccal scissors-bite relation with the mandibular second molars.

Mandibular third molars

Orthodontic theory in the past advocated, almost automatically, the 'prophylactic' removal of third molars, in the belief that this would prevent secondary mandibular incisor crowding in the post-retention period. Today, however, this theory has been challenged by efforts being made to bring wisdom teeth into the dental arch and making them useful functional dental units [18–20]. This trend is particularly pertinent in the latter stages of the treatment of a premolar extraction case, at a point when excess space has been closed by drawing the first and second molars mesially. A space will potentially open up at the distal end of the arch, which may sometimes be adequate to accommodate an erstwhile impacted third molar. In these instances, successful conservative treatment of the impaction, by orthodontic alignment, will provide the maxillary third molar with an antagonist. This in turn may allow both third molars to assume similar function ratings as any other tooth in the dentition.

The decision to upright a mesially inclined and impacted third molar must take into consideration its prospective final position in relation to the ascending ramus of the mandible, with its thick soft tissue investment. If there is adequate space at the end of the arch, there will be good indications for this treatment. However, if there is a likelihood that the final position of the tooth will be at the expense of a localized resorption of the anterior border of the ramus or chronic irritation of the exuberant and inflamed soft tissue covering it, the effort will have been wasted.

The indicated treatment will be very similar to that described for mandibular second molars. Distally inclined and impacted third molars are much more of a problem, since control of root uprighting at the end of the arch is poor and extraction is often to be advised.

Infra-occlusion of permanent teeth

Case 11.8: An infraoccluded mandibular molar of unknown aetiology

Let us review the case of a 14-year-old male, where the left mandibular first molar (Figure 11.15a, b) was found to be infra-occluded between the second premolar and the second molar. Its occlusal surface was visible, barely supra-gingivally, confined in the reduced space between the two adjacent teeth. These adjacent teeth were tipped over it and thereby reduced the mesio-distal space by about 4 mm for the eruption of the first molar. Apparently influenced by the infra-occlusion, the teeth further forward were spaced [21–23]. The type of impaction illustrated here is often associated with (or perhaps confused with) ankylosis or invasive cervical root resorption. See Online PPT & video chapter 10 Case A.

The reader should not be deceived into believing that the infra-occlusion was *caused by* the reduced space between the adjacent teeth. It will be remembered that the first molar erupts at age 6 years, while it is normal for the second premolar and second molar to erupt some five to seven years later. Accordingly, it will be realized that, in the case in review, the tipping of the adjacent teeth must be looked upon as the *result* of the infra-occlusion and not its *cause*. For this reason, it would be unreasonable to expect the infra-occluded tooth to erupt spontaneously by simply re-opening space (Figure 11.15c–e).

Based on this reasoning, space was opened in the present case and, under local anaesthetic, the infra-occluded tooth carefully luxated with marginally less than 'extraction-grade' forces. Extrusive orthopaedic forces (of above-normal orthodontic extrusion values) were then applied to the tooth, using direct elastic traction from two bonded buttons on the crown (Figure 11.15d, e), to the rigid and passive base arch that had been ligated into the brackets on the other teeth. This luxation procedure had needed to be repeated on one further occasion before the tooth responded. Finally, uprighting and rotational movements were applied to complete the case (Figure 11.15f–i).

If the lack of response of the tooth had indeed been due to ankylosis, then it will be appreciated that ankylotic fusion that had been severed by the luxation procedure would, in all probability, have re-ankylosed as the extrusive force was losing its potency. In order to maintain the momentum on positive extrusive movement, the patient should be seen at short intervals of 7–10 days to check and adjust the force as required. The aim of luxation was to fracture the link between the tooth and the adjacent alveolar bone. By applying orthopaedic forces of separation to the healing area, a microcosm of distraction osteogenesis is set up, the outcome of which sometimes results in eruption of the tooth (Figure 11.15i). However, the reliability of the method is open to some doubt.

Fig. 11.15 (a) Occlusal view of the mandibular dentition to show the severely infra-occluded left first molar, with tipping of the adjacent teeth. (b) Panoramic view of the initially diagnosed

condition. (c) A clinical occlusal view of the achieved space opening. (d, e) Periapical and panoramic views of the achieved space opening. (f) At eight weeks post luxation, the tooth achieved full eruption. (g, h) Post-treatment periapical and panoramic views at completion. (i) Intra-oral views at two months post treatment.

If the diagnosis had indicated invasive cervical root resorption rather than ankylosis, the lesion would have prevented movement of the tooth and, as a result, a luxation procedure would not change anything. On the contrary, a surgeon may be surprised when the tooth is first exposed to find that the tooth is already mobile. In this situation, the only way that this tooth may respond to the force is for the lesion to be eliminated, as has been explained and discussed in Chapter 10.

There is considerable confusion of nomenclature relating to teeth that do not erupt and reach the occlusal plane. Indeed, different terminology is often applied to the same condition. Some authorities use a specific term to describe a very specific condition, while others will use the same term with a much more general connotation. There are also language differences that alter in meaning when translated literally, and even if all parties are speaking English, an author's geographical location may determine the particular word used in a journal report.

Thus, clinicians and researchers from the Netherlands and Denmark refer to the condition in which there is arrested eruption occurring before the tooth penetrates the oral mucosa as 'primary retention' [22, 23]. Elsewhere, the same condition will be classified under 'impacted' or, specifically in the French- and Italian-speaking world, as 'included'. 'Secondary retention' in these same countries will refer to the condition where there is a cessation of eruption of a tooth after emergence, without a physical barrier. It could also refer to the ectopic position of the tooth due to ankylosis. In other places it has been termed 'submergence' or 'infra-occlusion'. The only recognizable similarity between these latter two forms of retention is that they both largely affect molars. These researchers as a rule use the term 'impaction' to mean a cessation of the eruption of a tooth caused by a clinically or radiographically detectable physiological barrier in the eruption path, or due to an abnormal position of the unerupted tooth.

There are several differences between primary and secondary retention. Primary retention (as used above) is more frequently seen than secondary retention. It occurs with equal frequency between the sexes. Primary retention occurs more often in the maxilla than in the mandible, while the opposite is seen in secondary retention. Primary retention may be seen in dentitions that have normal development of the second molar, as well as in dentitions with abnormal eruption patterns in the second molar region (late development and second molar agenesis). This is the case notwithstanding a generalized malocclusion. Secondary retention can occur in dentitions with normal development of the second molar, independent of the presence or absence of generalized malocclusion. Furthermore, primary retention is an acquired condition, judging by phenotypic differences between the primary and secondary retention. Indeed, variations of normal eruption of the second molar are seen in primary retention.

Over the past two decades or so, a Danish research group has concluded that a defective nerve supply to the tooth is possibly the cause of primary and second retention. They base their findings on the fact that innervation of the dental follicle appears to be an important factor for the continued development of the teeth [24]. Different groups of teeth have different sources of innervation, with one source covering one specific field. They point out that neural pathways can spread viral or bacterial infections, particularly herpes zoster and the mumps virus, in addition to other conditions. Children suffer many undiagnosed acute infections in their younger years and neural spread would seem to be a possible cause of a compromised nerve supply, with consequent effects on the teeth [24].

Unilateral occurrence of the primary or secondary retention phenomena suggests infection as the cause, while bilateral occurrence suggests a genetic aetiology, either directly on the eruption mechanism or indirectly by affecting the nerve supply.

Primary failure of eruption

The term 'primary failure of eruption' (PFE) was coined in 1981 by Proffit and Vig [25] and suggests a disturbance of the eruption mechanism that causes the complete or partial failure of a non-ankylosed tooth to erupt, although they were not able to give any molecular basis for this failure (see Figure 11.16). The condition is rare, affecting 0.06% of the population [26]. From other studies, the consensus is that PFE is characterized by the following:

- The posterior teeth are most frequently affected, with the first and second molars being more affected than premolars and canines.
- In the situation where a tooth is positively diagnosed for eruption disturbance, all teeth distal to it in the same quadrant of the jaw will be similarly affected.
- The affected teeth resorb the alveolar bone above the crown, but erupt only partially or fail to erupt at all.
- Both deciduous and permanent teeth can be affected.
- The condition is usually asymmetrical.
- Primarily non-ankylosed teeth tend to become ankylosed as soon as orthodontic forces are applied.
- The condition may be unilateral or bilateral and both dental arches and both sides may be affected.

Research on the molecular basis for PFE has recently placed the aetiological blame on mutations in the parathyroid hormone receptor 1 (PTH1R) gene. This potentially provides the key to distinguish PFE from isolated ankylosis and secondary retention [27–32].

(a)

(b)

Fig. 11.16 (a) A normal occlusion of the posterior teeth is present on the right side and a severe lateral open bite has developed on the left side due to primary failure of eruption. (b) The panoramic radiograph shows very marked infra-occlusion of the left mandibular first molar and, to a lesser extent, each of the teeth distal to the canines on the left side of both dental arches.

A strict differential diagnosis is of importance because it directs the clinician to the appropriate treatment. Teeth suffering from secondary retention, ankylosis and PFE will not be amenable to orthodontic treatment. However, it is only with PFE that the adjacent under-erupted teeth will also not respond to orthodontic traction, which is not the case with teeth adjacent to an isolated under-erupted tooth. Nevertheless, in the clinical context, if PFE is suspected in a patient, a genetic test for mutation in the PTH1R gene should be recommended prior to any orthodontic treatment to avoid ankylosis.

In these cases, orthodontic extrusion treatment cannot be offered as a panacea and many of these teeth may require to be extracted. If the degree of infra-occlusion is limited, prosthodontic increasing of crown height may be an answer. The only alternative would be to perform a localized osteotomy with orthodontic extrusion of the entire segment by localized distraction osteogenesis. However, in both these cases, the open bite may begin to recur in time as the other occluding teeth undergo passive eruption. The case illustrated in Figure 11.16(a, b) shows unilateral PFE in both jaws, with the posterior teeth in both arches markedly infra-occluded.

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12
Premolars and Mandibular Canines

Adrian Becker

- Mandibular canines
- Mandibular second premolars
- Maxillary second premolars
- Infra-occlusion of deciduous teeth and its influence on premolar successors
- Infra-occluded teeth cause arrest of vertical bone growth

With the notable exception of the third molars, the maxillary canines and central incisors are the principal teeth that may become impacted, although from time to time it may occur with other teeth. For some of these impacted teeth familiar patterns emerge, typically affecting the same tooth and, in many cases, with the same aetiology. In others unusual pathology may be involved, which may affect any tooth or group of teeth and is therefore non-specific, not falling into a rigid pattern. Nevertheless, even with a widely heterogeneous group, trends may be recognized and treatment protocols may be suggested to cover a good proportion of such cases.

Let us examine the likely possibilities.

Mandibular canines

Mandibular impacted canines are seen infrequently and, as a result, the more bizarre cases are published in the literature as single case reports [1, 2]. The authors of the few numerically significant epidemiological case series studies that do exist have created a non-specific, meta-analysis sample by assembling a number of individual cases, drawn from the international published literature [3].

Impacted mandibular canines are usually discovered by chance, since the condition is almost always symptomless. The over-retained deciduous canine may not raise the suspicions of a dental practitioner until well into the second decade of the patient's life and often even later. It seems possible that females are more frequently affected, although the evidence for this is tenuous, in view of the dearth of large-sample studies. The incidence with which this phenomenon occurs has been quoted as being 20 times less frequent than the parallel condition in the maxillary arch [4, 5]. While maxillary impacted canines that cross the mid-palatal suture have not been reported, mandibular canines do occasionally cross the symphysis (Figure 12.1) and have been reported to have reached as far as the permanent molar on the opposite side [4, 5]. They may sometimes be located on the lingual side of the alveolar process, when they will appear as a palpable hard swelling under the lingual mucosa. However, they are more frequently to be found buccally ectopic or in the general line of the arch, which is more likely due to the fact that the mandibular alveolar ridge is narrow and leaves little room for severe bucco-lingual displacement. They may indeed travel relatively large intra-osseous distances and some may become embedded in the chin prominence.

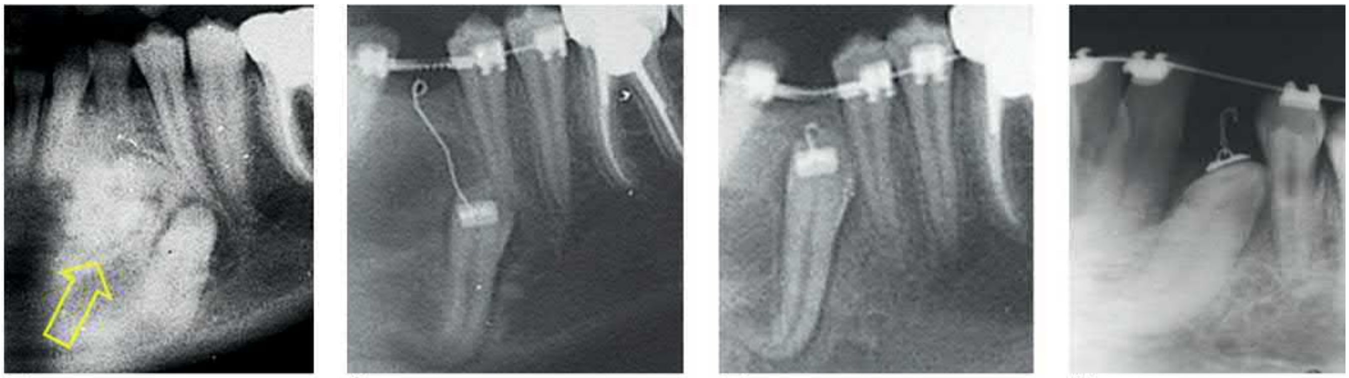
The first clue to the existence of an impacted canine is the over-retention and lack of mobility of its deciduous predecessor, a situation that should stimulate the clinician to perform a radiographic examination.

As far as the aetiology is concerned, there may be obvious local factors to which the condition may be attributed, including supernumerary teeth, odontomes (Figures 12.2, 12.3) and an enlarged dental follicle. However, a significant potential displacing agent is a soft tissue lesion, such as expanding radicular cysts that may have developed from non-vital deciduous first molars or canines (see Figure 14.7). Nevertheless, for most of these cases, including the rarer examples just referred to, there may be no apparent local cause and it seems likely that a hereditary, primary tooth germ displacement may account for the abnormal angulation of the long axis of the tooth. If this angulation is more than about 30° to the vertical, there is a fair chance that the tooth will migrate across the midline in a relatively short period of time, while an angle in excess of 50° will make this eventuality quite certain.

Fig. 12.1 The crown of the horizontally impacted right mandibular canine is transposed and inferior to the root apices of the four incisors. Note the congenital absence of four permanent teeth, with four retained and three over-retained deciduous teeth, three impacted permanent canines (with enlarged follicles) and three over-retained deciduous canines. Additionally, the maxillary first premolar roots are displaced mesially, blocking the eruption path of and in direct contact with the canine crowns.

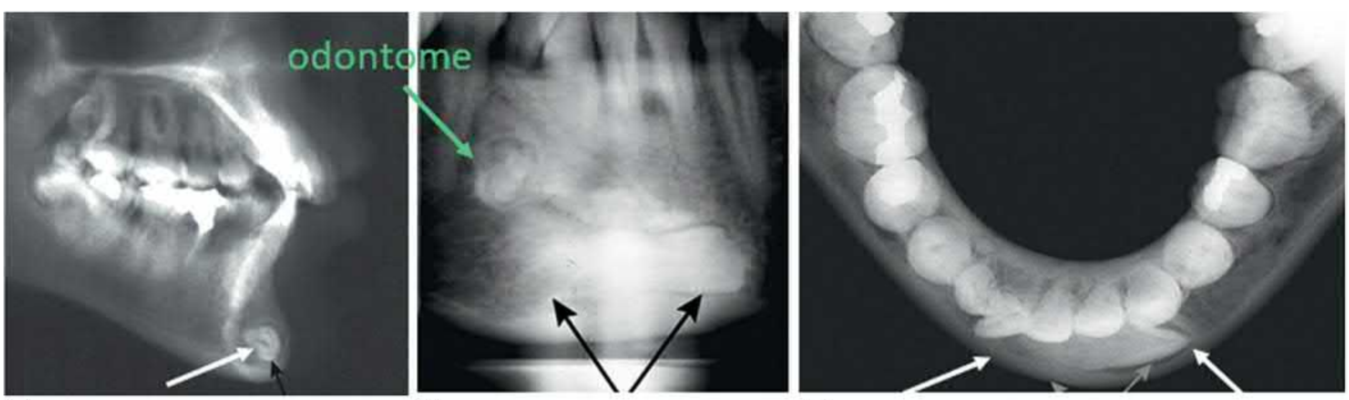
Although there is some anecdotal evidence pointing to a remarkably high speed of migration of these teeth, this is difficult to substantiate, since these cases are usually seen *post factum* and, even when seen before much of the movement has occurred, will be overlooked due to the fact that most patients will have been advised to have interceptive or corrective treatment. Few cases will be merely kept under observation (what might be termed supervised neglect), since a worsening of the situation seems inevitable.

As a general rule, interceptive treatment should be instituted as soon as the anomaly is discovered [6]. The extraction of the deciduous canine may exert a positive influence to alter the orientation of the aberrant permanent successor. By also extracting the first deciduous molar, the first premolar may often be influenced to erupt early, assuming it has about half of its expected root development. This will have the effect of providing more space in the alveolar bone, distal to the canine, because, with the eruption of the tooth, the broader diameter of the crown will have given way to the narrower root diameter adjacent to the canine. Removing a non-vital deciduous canine and/or first molar, particularly if these had been associated with an unresolved granuloma or with cystic change, may encourage a dramatic improvement, as discussed in Chapter 14 (see Figures 14.3 and 14.7).



(a) (b) (c) (d)

Fig. 12.2 (a) Panoramic view of the left mandibular canine, which has been grossly displaced distally and inferiorly due to an odontoma (arrow) and is in close association with the lower border of the mandible. (b) Shortly after alignment and space opening, surgical removal of the over-retained deciduous tooth and odontoma, with attachment placement on the canine. (c) Rapid improvement in position has occurred, due to both natural 'filling in' of bone and vertical traction. The tooth has a hooked apex. (d) A periapical view in the latter stages of resolution. Note that the tooth has responded well, despite having been re-covered with repaired and calcified bone after attachment bonding at the time of the closed exposure.



(a) (b) (c)

Fig. 12.3 (a) Lateral cephalometric radiograph shows the canine to be completely horizontal and at 90° to the mid-sagittal plane and the film. (b) Panoramic view of the mandible with mental region – the contrast of the mid-section over the chin has been adjusted to show the horizontally impacted canine, with compound odontome. (c) Occlusal view of the anterior mandible.

In cases where an impacted canine has migrated beyond the mesial side of the lateral incisor, the majority of authorities have advised extraction of the canine itself and leaving the deciduous canine in place. Alternatively, if the case is considered to be an orthodontic extraction, the advice would be that this is the tooth to be tagged for extraction, rather than the more usual choice of a premolar. Occasionally it will be the adjacent lateral incisor that might be the preferred selection.

Although corrective, non-extraction orthodontic treatment may seem to be the best choice, this in fact is illusory and most likely to be disappointing, particularly if the tooth is on the labial side and has migrated mesially. The panoramic film flattens the 3D horseshoe-shaped dental arch into a 2D flat picture and, by doing so, gives the clinician the misleading and deceptive impression of a simple 2D orthodontic movement. In essence, what has happened is that the labial canine has taken the 'outside lane' in the very tight curve of the narrow alveolar bone rim of the anterior part of the mandibular arch. Its resolution is a difficult 3D manoeuvre.

Good 3D imaging of the area will be necessary in order to decide whether orthodontic treatment can provide a good answer. The periapical radiograph will most often provide adequate qualitative information regarding the mandibular canine, unless it is very deeply displaced. This is due to the difficulty in inserting the receptor or phosphor storage plate (PSP) deeply enough on the underside of the tongue. In these cases, a panoramic radiograph may provide a better view of the tooth and its mesio-distal orientation and relations. A true occlusal view (see Chapter 4) will be required to provide the buccolingual dimension needed to accurately locate the tooth and it is important to remember that, for this view to be of value, the central ray of the X-ray machine should pass along the long axes of the mandibular incisor teeth (see Chapter 4). In the midline region, the missing dimension will also be depicted on the lateral cephalogram, which would have routinely been taken for the purpose of diagnosis and treatment planning (Figure 12.3).

Given the presence of the roots of adjacent teeth immediately superior to it and the narrow dimensions of the mandibular body in this area, there may be inadequate room for successful orthodontic manoeuvre, particularly when a partial or complete transposition of teeth is intended to be corrected. In this type of case extraction may sometimes be the only practical line of treatment, although re-alignment of the canine into its transposed order may often be the most practical answer.

A parallel anomaly occurring in the maxillary arch will usually be much more amenable to treatment because, in this case, the impacted tooth may be temporarily moved from the narrow alveolar ridge inwards into palatal bone to permit the movement of an adjacent tooth.

Lingually impacted mandibular canines will mostly present the root apex in its normal location and a lingual tipping displacement of the crowns of the teeth. The latter is due to an abnormal orientation of the long axis, frequently the sequel to an over-retained deciduous canine. Orthodontic re-alignment would be restricted to a corrective tipping movement of the crown in a buccal, extrusive and, possibly, distal direction.

In advance of the surgical exposure, a short period of orthodontic treatment is necessary to align the teeth in the mandibular arch and to prepare space at the appropriate site. A closed coil spring or custom-cut and curved length of steel tubing is accurately measured to maintain the space between the lateral incisor and first premolar and is threaded onto the main archwire. The tooth is then exposed, an attachment bonded to the buccal aspect and, unless the tooth is very superficial, the wound will be fully closed with the sutured flap. In this way, traction from the attachment direct to the labial archwire will be all that is needed to bring it to its place. The wire ligature pigtail, tied to the bonded attachment at the time of surgery, is rolled downwards to form a firm hook, close to the sutured gingival tissues. An elastic chain is placed across the span between first premolar and lateral incisor, and its middle portion is stretched downwards with a haemostat or ligature director and ensnared in the pigtail hook. This will provide a light, easily measurable and vertically directed force on the impacted tooth and will facilitate a wide range of action. Alternatively, an auxiliary nickel–titanium wire may be passed through this rolled-down pigtail and through the brackets of a number of teeth on each side, under the main arch, which should achieve the same effect. Either of these two alternatives is far superior to direct ligation of elastic thread from the hook to the archwire (see Chapter 2).

Migration, transmigration and transposition

Mupparapu [4] described buccally impacted mandibular canines as 'teeth that are remarkably prone to the most bizarre eruptive movements' and classified them into five types, as follows:

1. Mesio-angular, lying inferiorly to the front teeth and with its crown crossing the midline, which he termed a 'transmigrated tooth'.
2. Impacted horizontally below the apices of the incisors.
3. Erupted mesially or distally to the contralateral canine.
4. Impacted horizontally below the apices of the contralateral canine and premolars.
5. Vertical, coinciding with the midline.

The last class is in fact the only type that may be declared a true transposition *ab initio*, rather than a transposition caused by migration.

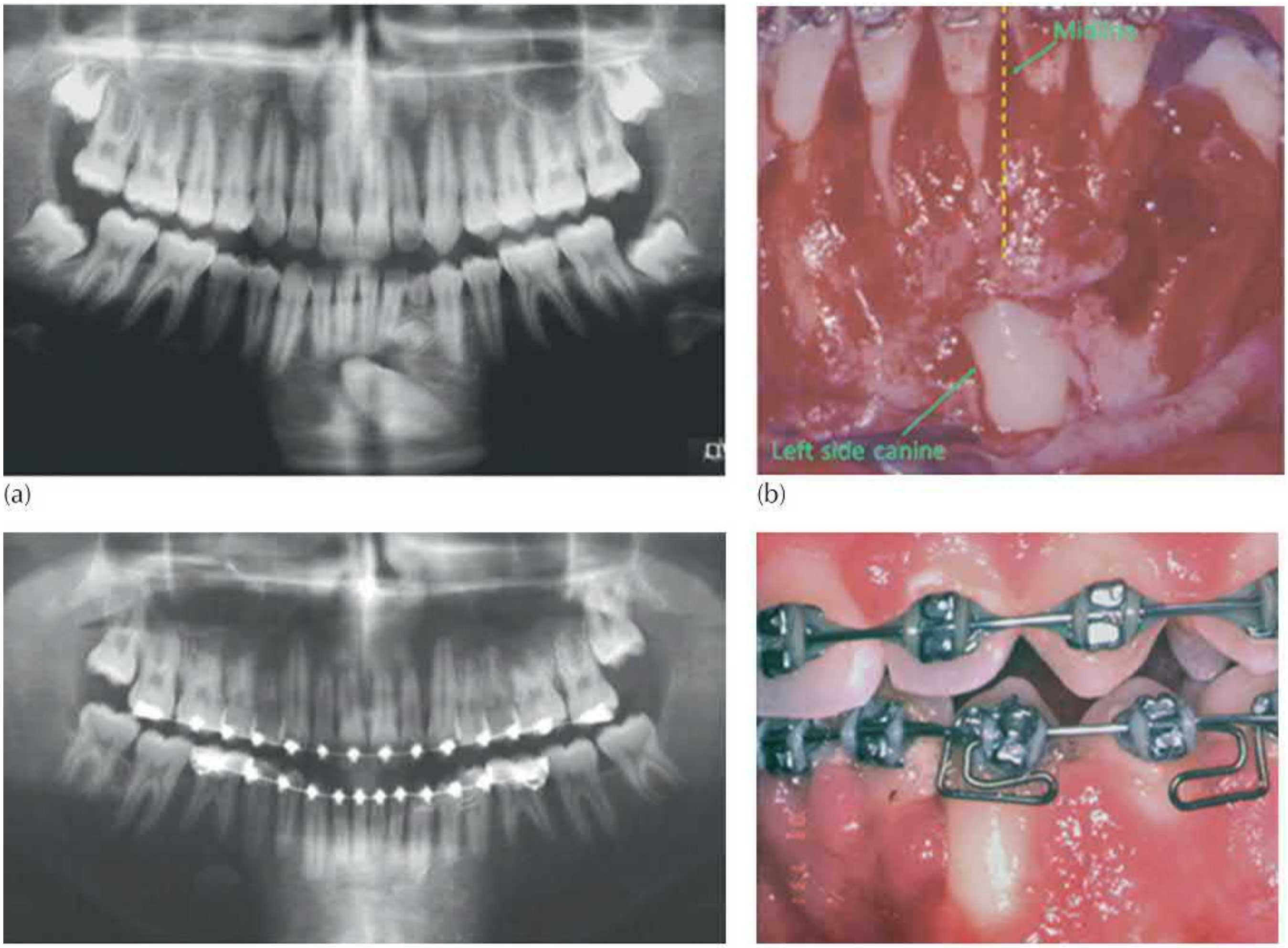
A separate examination is therefore warranted in regard to the buccally displaced mandibular canine, migrated, transmigrated or transposed, mesial to the lateral incisor. Although uncommon as such, it is nevertheless the most frequent form of transposition in the mandible [7, 8]. The crown of the canine will need to be moved buccally in order to circumvent the lateral incisor root, before being moved upwards towards the archwire. As with the parallel situation in relation to the buccally displaced maxillary canine, the orthodontic and periodontic prognosis for treatment of these teeth deteriorates in inverse relation to the amount and type of mechano-therapy used. Notwithstanding that, in a minority of these patients full resolution of the transposition may indeed be successfully achieved, but only provided that the cases are carefully selected, taking the periodontal prognosis into consideration [9] – not just the biomechanics.

In theory, it will seem possible to apply appropriate tipping and bodily movements in order to move the tooth back from whence it has clearly come. However, the more horizontal the tooth, the greater will be the need for a large component of force being applied through its long axis – a horizontal 'intrusion'. This, however, is clearly futile. The tooth will need to be drawn below the incisor apices with its crown exposed in a highly mobile mucosa and in the deepest part of the labial sulcus. Even the more amenable mesially migrated canines will need to be drawn distally and occlusally, but a lateral force component will be necessary in order to skirt the roots of one or more incisors. Once the crown of the tooth has been brought to its place in the arch, the canine root must be distally uprighted and then lingually torqued to an appreciable degree. Even in the most favourable circumstances, it will be appreciated that it is unlikely there will be much bone covering the root on the labial side of the treated tooth. Its clinical crown will be long and the marginal soft tissue on the labial side will be largely devoid of attached gingiva. Treatment will have been inordinately long in order to achieve an acceptable orthodontic result, but it will be accompanied by a poor periodontal outcome (Figure 12.4).

Three additional and alternative lines of treatment remain to be discussed in regard to non-crowded cases of buccally impacted mandibular canines. The clinician may:

- Extract the canine, leaving the deciduous canine in its place, provided its root is of reasonable length and prognosis.

- Extract an incisor and align the canine in its place, leaving the deciduous canine in place.
- Align the two teeth in the transposed relationship, which, in the mandibular arch, may offer the optimal solution [9], since the mandibular anterior area does not usually create an aesthetic problem and minimal crown re-contouring may provide adequate camouflage.



(a) (b) (c) (d)

Fig. 12.4 (a) A transmigrated mandibular left canine had traversed the midline, with over-retained deciduous canine and odontome. (b) At surgical exposure, the left canine is located inferior to the right central incisor and is situated below the depth of the vestibular sulcus. (c) Root paralleling of the teeth is good, but apical root resorption is present on all teeth carrying orthodontic attachments. There is crestal bone loss in the immediate area of the affected canine. The periodontal prognosis of this tooth contrasts sharply with the success of the orthodontic treatment. (d) In the final stages of orthodontic treatment aimed at completing the uprighting of its root and lingual root torque, the clinical crown is very long due to gingival recession and there is deep periodontal pocketing on the mesial side of the canine.

In the presence of crowding, in addition (or in preference) to a more conventional extraction choice, one must give consideration to the extraction of the deciduous canine and the adjacent permanent incisor, or, alternatively, of the deciduous canine and the permanent canine. The space thereby provided may then be used for the relief of crowding, as an integral part of a comprehensive orthodontic treatment programme that includes other aspects of the malocclusion.

One final thought in regard to a transmigrated mandibular canine relates to its innervation. It should be remembered that, regardless of the distance it travels, the tooth takes with it the blood vessels and nerve supply with which it was originally provided. This needs to be taken into account when considering where to administer the local anaesthetic for its surgical exposure or removal.

Mandibular second premolars

Crowding and space loss

Perhaps the most common cause of impaction of the second mandibular premolar is the early extraction of its deciduous predecessor, although such extractions have become less common with the decline of caries in the Western world. With the loss of the second deciduous molar, the adjacent permanent molar will usually tip mesially and 'roll' lingually. Additionally, there will be a degree of distal drifting of the first deciduous molar of the same side. Total elimination of the space for the mandibular second premolar, however, does not often occur. The result will be that this premolar will be blocked from erupting into the line of the dental arch. Given that its embryonic developmental position is slightly lingual to the line of the arch and that it has been prevented from migrating upwards by the post-extraction space loss, it will either move more lingually to erupt on the lingual side, or it may remain impacted, beneath the 'pitched roof' formed by the two adjacent erupted and tipped teeth.

The appropriate radiographic method for examining these cases is very similar to that described for mandibular canine teeth. The periapical view is used to provide detail as well as offering a lateral horizontal view in the mandibular premolar area. In theory, therefore, it may be supplemented by an occlusal view in order to provide the third dimension and thus enable accurate localization. Unfortunately, the occlusal view will have the X-ray beam passing through the full vertical height of the body of the mandible and, unless the tooth is markedly displaced to the lingual or buccal side, it will not be possible to distinguish it from the mass of bone. Nevertheless, if its presence can be confirmed in the periapical view and there is no clear view of the outline of the tooth on the occlusal film, it will be safe to assume that the tooth is close to the line of the arch and undeviated buccally or lingually.

Alignment requires space, which may be achieved by returning the drifted teeth back to their former or improved positions using a fixed orthodontic appliance with a coil spring. This may often require intermaxillary (class III) traction to reinforce the anchorage of the teeth in the lower jaw and to prevent undesirable incisor proclination.

There is also the possibility that extraction may be necessary, in which case, in order to treat an overall malocclusion, the impacted tooth or its immediate premolar neighbour may be the tooth that will have to be sacrificed along with a matching tooth in the other three quadrants of the mouth. With the provision of space by distal movement of the molar and/or by mesial movement of a distally tipped first premolar or by extraction of the adjacent premolar, an impacted premolar tooth may erupt with considerable speed and without further assistance.

From the periodontal point of view, surgical removal of unerupted mandibular second premolars, which may have been required in an extraction case, may leave a marked bony defect in the area. This will be the case even after full space closure has been achieved and adjacent teeth have been fully uprighted. The surgical removal may result in a deep mucosal fold or cleft in the interproximal area in the site where the extraction was made. However, the cleft may persist to prevent the regeneration of bone in the interproximal area and cause a periodontal defect.

Abnormal premolar orientation

The second deciduous molar of the lower jaw is commonly responsible for the non-eruption of its permanent successor, not merely when it is prematurely lost due to the ravages of caries, but also when its presence is abnormally prolonged. The second premolar tooth germ is not always in its ideal developmental position, directly between the mesial and distal roots of the deciduous molar. Indeed, an abnormal angulation or location seems to be a frequent finding.

The premolar may often be tipped more distally, thus initiating resorption of only the distal root and leaving the mesial root of the deciduous molar largely intact. This situation will lead to over-retention of the deciduous tooth, even if there is complete disappearance of the distal root and much of the intra-coronal dentine. A periapical radiograph will show the long-rooted premolar very superiorly positioned, almost inside the distal part of the crown of the deciduous tooth, while a long and thin spicule of the mesial root remains, grimly resisting exfoliation. A parallel scenario, which seems to occur less frequently, may occur with resorption of the mesial root, due to mesial tilt of the second premolar from early on in its development.

In either of these cases, as long as the degree of tilt is relatively slight and the tooth is relatively high up in the alveolus, the extraction of the deciduous tooth will usually suffice to achieve the rapid and trouble-free eruption of the premolar tooth. Space is never a problem in these cases, since the second premolar has a smaller mesio-distal crown width than its healthy deciduous predecessor.

A premolar tooth with a stronger distal tilt is usually situated more apically and the distal-occlusal aspect of its crown will be in close relation with the mesial root of the first permanent molar. The second deciduous molar is usually over-retained at the time of detection and will help preserve the space in the arch (Figures 12.5 and 12.6).

In terms of aetiology, it has been found that an exaggerated disto-angular malposition of the unerupted mandibular second premolar may often be associated with agenesis of its antimere [10] and with retarded dental development in general. In Chapter 7, we have alluded to the existence of a connection between second premolar anomaly and palatally displaced maxillary canines, both of which are similarly affected by an overall late dental development. It would appear significant that individuals with maxillary canine and mandibular second premolar anomalies manifest greater delay in dental development [11].

Fig. 12.5 (a) A late-developing left second premolar, horizontally oriented. (b) A year later, the tooth has moved distally to overlap the mesial root of the first permanent molar. (c) Extraction reveals oblique resorption of the mesial root of the molar.

Courtesy of Professor Yerucham Zilberman.

Fig. 12.6 (a–c) Serial periapical views of a failed attempt to bond an edgewise bracket to an inadequately developed second mandibular premolar.

In the above cases, when the deciduous molar is removed, a space-holding device should be used to prevent tipping of the permanent molar. An attempt may also need to be made to upright the premolar. An appropriate space-maintaining device may be designed in many ways, but classically a buccal and lingual bar may be soldered to two bands to form a simplified fixed bridge, which is then cemented to these teeth. Alternatively, a single rigid bar, with terminal loops or a mesh pad at each extremity, may be bonded to the buccal surface of the first molar and first premolar. This is a fairly good alternative method to upright the premolar, provided that it is well clear of the occlusion. However, the device may still become debonded by occlusal forces transferred through bulky and hard foods. Because of its small size, a debonded bar with terminal loops on a mesh pad presents a potential hazard, since it may be ingested or, worse, inhaled by the patient.

At surgery, only the mesial and occlusal aspects of the impacted and distally tipped premolar tooth should be exposed and, where possible, an eyelet carrying a twisted steel pigtail ligature should be bonded to this area of the crown of the tooth. The tooth is fairly deep down and an open exposure is likely to leave the mesial root of the first molar exposed and devoid of attachment. For this reason, the flap should be completely sutured back into its place, thereby making the stainless steel ligature wire pigtail, ligated through the bonded eyelet, the means of applying force to the unerupted tooth.

An elastic chain may be stretched between a hook on the fixed bands of the erupted first premolar and first molar, parallel to and overlying the rigid bar. Once in place, the middle of the elastic chain is drawn downwards with artery forceps and ensnared in the pigtail ligature to apply a vertical erupting force to the impacted tooth. The greater the degree of movement required, the more substantial must be the anchor base and, where indicated, a fixed lingual arch to the opposite molar may be advisable.

This region of the mouth does not provide easy access to permit acid-etch bonding. Indeed, the eyelet attachment may not even be an option, particularly when the orthodontist is not present to do this part of the surgical procedure (Figure 12.6). Had the orthodontist been present together with the surgeon, successful bonding would not have required the more radical removal of bone and soft tissue that was performed in the cases in Figures 12.6 and 12.7. In both these cases unnecessarily aggressive surgery had achieved the aim of the episode, but the price was paid in a reduced periodontic prognosis.

Because of the difficulty in bonding, it is common practice to use an open exposure procedure, leaving the exposed tooth covered with a surgical pack, particularly distally. The pack will be wedged between the premolar crown and molar root. The pack is designed to remain in place for two or three weeks to prevent the gingival tissues from healing over. The deliberate wedging of gauze into the distal area helps to divert the eruption path of the premolar into a more mesial direction, and this in itself may bring about spontaneous eruption. As was pointed out in Chapter

5, however, these procedures will make the establishment of an ideal periodontium less likely for both the molar and premolar, because the open surgery will have left the mesial side of the mesial root of the molar exposed, to the detriment of its final periodontal status. It is to be expected that in the final erupted position, the clinical crown of the premolar will be longer, the gingival attachment and architecture compromised, the bone support reduced and the prognosis poorer than normal.

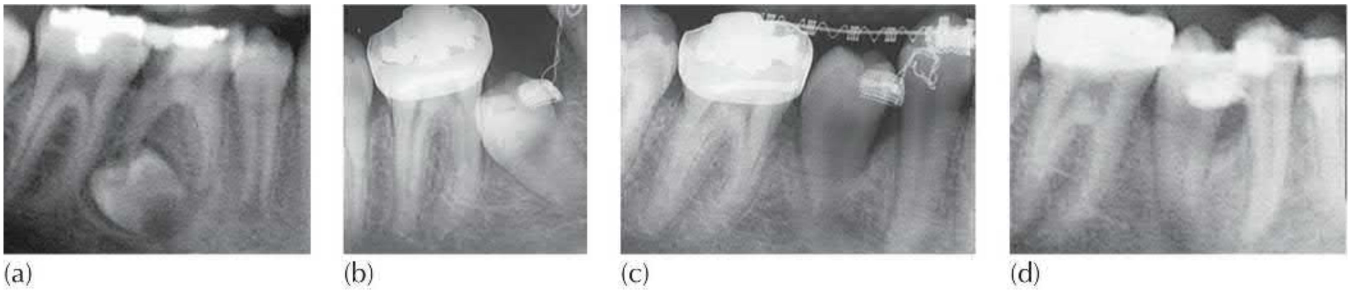


Fig. 12.7 (a) The mandibular second premolar is very late developing both in absolute terms and relative to the other permanent teeth. It is strongly distally tipped. (b) A year later, periapical view shows bonding of an attachment was achieved only after wide exposure and removal of much bone to achieve access for bonding an attachment. (c) A follow-up radiograph shows improvement in the position of the tooth, but crestal bone height is deficient. (d) The relevant section of the panoramic view of the final stages of treatment clearly shows the reduced periodontal prognosis of the right mandibular second premolar.

Courtesy of Dr Lucille Rothstein.

While there are many impacted second premolars that may be treated in this way, success cannot be expected in some of the more extreme cases and the tooth may have to be extracted.

There are occasions when extraction of the tooth is advised for other reasons, both objective and subjective. Care should be taken to follow up these cases once diagnosis has been established, since there may be a risk of resorption of the mesial root of the first molar. For as long as the impacted premolar is left untreated, without suitable and long-term radiographic supervision, this threat will remain (see Figure 9.3).

A lingually ectopic second premolar that is low down in the floor of the mouth and has migrated mesially in relation to the adjacent teeth is less commonly seen than the distally drifted teeth. In either case, direct traction to the labial archwire will not be practical. In such situations, the use of the same auxiliary labial arch (always as an addition to the main base arch, as noted regarding Figure 12.8 and as recommended for many palatal canines) has excellent application and can be used with great efficacy to provide the vertical and distal eruptive components.

Abnormality in development and location is common in the mandibular second premolar and there are many anomalies associated with it. It is well known that, in most population studies and excluding third molars, its congenital absence is more frequent than any other tooth with the possible exception of the maxillary lateral incisor. In common with the maxillary lateral incisor, its development is sometimes retarded in relation to the development of the rest of the dentition and commonly seen in company with agenesis of its antimere [11–14].

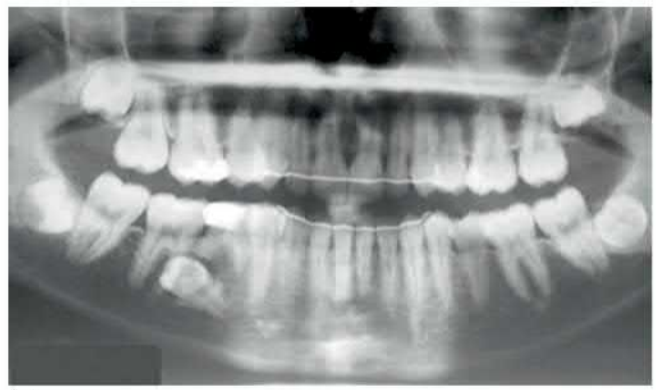
When the mandibular second premolar is late developing it will frequently exhibit a distal tip, frequently bilateral (Figure 12.7), and at the same time is seen with increased frequency accompanied by maxillary impacted canines [11, 15]. It is also seen together with late development of the dentition as a whole, a condition in which the prevalence of canine impaction is also increased [15–19]. Furthermore and in common with late-developing dentitions, the teeth are generally small and fairly normally aligned, with spacing rather than crowding a recurrent feature [20].

The discussion and case report will now focus on an uncommon type of impaction in which the tooth has typically developed with a distinct distal inclination and its eruptive movement is expressed distally, rather than occlusally. In its simpler form, the end result may find its occlusal surface abutting the mesial surface of the mesial root of the first permanent molar. In its more serious form, however, it may be discovered on a periapical or panoramic view superimposed on the roots of the molar, usually on the lingual side. Suffice it to say that the tooth is in an extremely inaccessible location. By and large, its deciduous predecessor is still in place with an unresorbed mesial root, while the degree of resorption of the distal root is dependent on the relative height and angulation of the unerupted premolar successor. Resorption of the roots of the permanent molar is an infrequent finding but, when it does occur and until it reaches a very advanced stage, it is difficult to diagnose because it occurs on the lingual surface of the molar roots. As such, it will escape detection on routine plane film radiographs until much tooth tissue has been lost.

So, the upshot is that it is often to be found in a dentition that is well aligned, with normally related jaws, which may otherwise not require orthodontic treatment. Yet it may be a permanent tooth in a very inaccessible location, on the lingual side of the ridge, at or below the level of the floor of the mouth. Motivation on the part of the patient may therefore be low and there may be an unwillingness to wear visible braces. It may thus be important to devise a partially bracketed system, specifically excluding labial appliances in the aesthetic zone. This presents three essential problems:


(a)


(b)


(c)

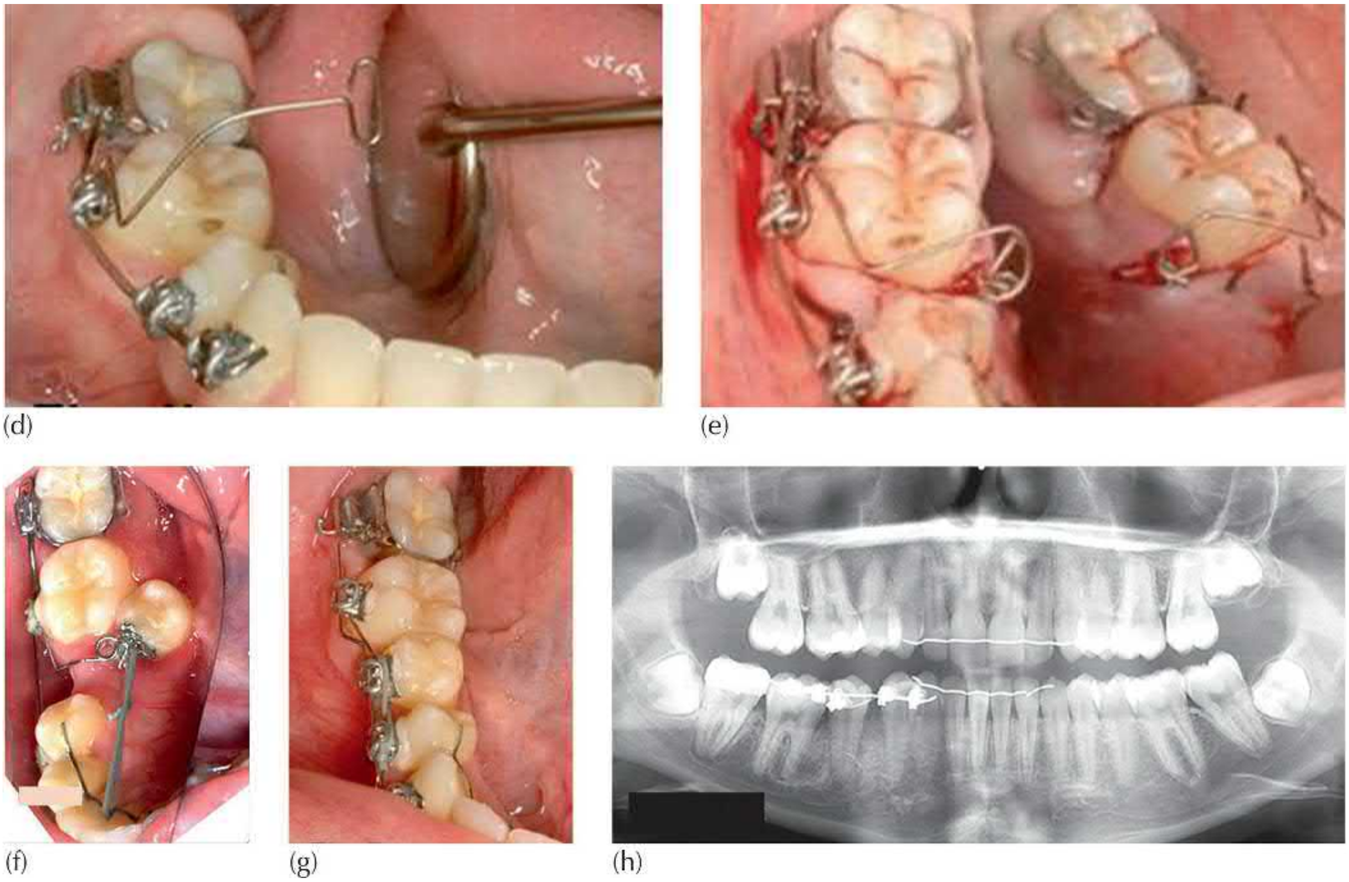


Fig. 12.8 (a) Intra-oral views of the completed case of a 12-year-old child at the time of referral to the author. The yellow arrow indicates a draining sinus tract traced to the deciduous molar. (b) Pre-treatment panoramic radiograph. The right premolar had not yet completed crown formation and it was tipped distally. (c) The panoramic radiograph taken three years post treatment, at age 17 years. (d) The pre-surgical orthodontic set-up. A heavy sectional base arch, fashioned to lie passively, was cinched at the tube and ligated into the three brackets. A light wire auxiliary spring slotted into the second molar tube, proceeded to the mesial of the first molar bracket and was then bent in a double anti-roll bend, before turning vertically upwards and terminating in a helix. (e) Following the surgery, the auxiliary spring was shortened to adapt it to the exiting twisted steel ligature, which then held it in its active mode. The spring is seen from both buccal and mirrored lingual sides, following its adaptation at the chairside. (f) The premolar had erupted through the attached gingiva. Continued extrusion was then augmented with mesial movement using elastic thread, tied to the twistflex splint. (g) Simple ligation of the bracket with elastic thread and a subsequent steel ligature provided the final alignment to bring the premolar into alignment. (h) Panoramic view of the condition before debonding, showing the aligned premolar.

- Establishing a sufficiently resistant anchor base that will not compromise the existing alignment.
- Offering strategic sites on this anchor base from which traction may be applied to resolve the impaction and then to align the impacted tooth.
- Developing a spring device or system that will resolve the impaction, erupt the tooth and bring it close enough to its intended location in the arch for routine orthodontic treatment to finish the job.

This type of single-tooth orthodontic movement is very demanding on anchorage and the anchor units should certainly involve a large number of teeth, including some on the opposite side of the arch, as well as teeth in the incisor/canine area. But how can one do this without placing unsightly brackets on the anterior teeth? Case 12.1 will be used as an illustration of how this may be achieved successfully.

Case 12.1: The ignored impacted mandibular premolar

Five years before being first seen by the author, this 17-year-old female had endured two years of orthodontic treatment, but was unaware that an impacted and migrated right second premolar had been left untreated and that a deciduous second molar was over-retained (Figure 12.8a). Referring back to her pre-treatment panoramic radiograph (Figure 12.8b), taken at age 12 years, the distally tipped second premolar was present and had still not completed the calcification of its crown.

She had recently complained of pain and discharge, which her dentist had traced to the non-vital deciduous molar. When a new radiograph was taken, the unerupted premolar was revealed, having migrated lingually and distally, to reach a location in line with the midpoint of the first permanent molar, opposite the furca (Figure 12.8c).

Extraction of the deciduous tooth was inevitable, with the recommendation that orthodontic treatment be recommenced with the aim of treating the errant second premolar. The patient was unhappy about the prospect of renewed treatment and she conditioned her acceptance on there being no appliances in the maxilla and no visible appliances on the anterior teeth in the mandible.

From careful palpation of the lingual side of the ridge and together with the information from newly commissioned radiographs (cone beam computed tomography was considered unnecessary), the premolar was diagnosed as being lingual to the molar. Its crown was situated between the two molar roots and tucked into the bifurcation, such that a hypothetical direct line between the tooth and its place in the arch was through the mesial root and the mesial cusps of the molar. This meant that alignment of the molar required the premolar to initially be moved superiorly with the inclusion of a lingual vector to the force, to clear it from the obstructing lingual side of the molar. It then needed to be drawn mesially and occlusally to bring it opposite the extraction site of the deciduous second molar and subsequently buccally into its place. Finally, it would also be necessary to perform fine tuning in the form of minor rotation, uprighting and torqueing.

Following the earlier orthodontic treatment, the anterior alignment of the teeth had remained stable due to the bonded splints. Nevertheless, it became clear that limiting the anchor unit solely to the teeth adjacent to the impacted tooth would be inadequate. An anchor unit was designed to incorporate all the teeth from the left-side first premolar to the second molar on the right of the mandible. The twistflex retainer wire had been bonded from the occlusal fissure of the first premolar of each side and included the lingual aspects of the mandibular canines and incisors, to make an eight-tooth stabilizing unit.

Brackets were placed on the canine, first premolar and both permanent molars on the right side and these were rigidly held by an 0.215 in. ×a 0.028 in. rectangular sectional arch. This created a total anchor unit that comprised 10 teeth, reinforced by a stationary anchorage. The right-side canine and first premolar were linked on their buccal and lingual sides.

An active 0.016 in. round steel spring was formed into a modified ballista spring, slotted into the second tube on the second molar band and ligated into the bracket of the first molar (Figure 12.8d). The spring was cinched at the second molar. It exited the mesial of the first molar bracket and was fashioned into a tight loop pressing on the buccal aspect of the tooth, above the bracket, to prevent the wire rotating in the slot. The anterior portion of the spring was taken lingually across the occlusal plane through the space of the extracted deciduous tooth. The lingual end of the spring was formed into a loop, whose passive mode saw this portion of the wire standing above the occlusal plane.

Given that the impacted tooth lay below the level of the floor of the mouth, bound by highly mobile and delicate oral mucosa, any form of open surgical exposure would be expected to be extremely uncomfortable for the patient for a very long time [21].

A closed surgical exposure was employed and it was a most difficult task to perform, largely due to the poor accessibility of this area. It cannot be sufficiently emphasized how important it is for the orthodontist to take an active part in this procedure – to help the surgeon and to be helped by the surgeon to successfully place an attachment on the tooth and to apply immediate traction, while the anaesthetic is still effective. In these technically difficult scenarios, interdisciplinary cooperation is likely to make the difference between success and failure.

The surgeon reflected a full lingual flap from the sulcus gingiva of the second molar, forward to the first molar, crest of the edentulous ridge and first premolar, followed by blunt dissection down on the lingual side, until the crown of the second premolar was reached. No attempt was made to dissect out the follicle of the tooth, but a small area of crown enamel was exposed and the area isolated with good use of high-power suction and pressure packs. Once haemostasis was achieved, the orthodontist was on hand to bond a small eyelet on the exposed, etched and dried area of exposed crown, while the surgeon and assistant maintained visual access and the dry field.

A soft steel 0.012 in. ligature wire had been inserted into the eyelet prior to placement and twisted to form a long tight pigtail. A fresh package of light-cure bonding material was used to ensure the reliability of the bond and, once completed, the surgeon fully closed the flap to its former place, with only the twisted pigtail ligature projecting superiorly. The surgeon was requested to draw the ligature through a small vertical slit in the flap and to suture it securely in a position slightly lingual to the line of the dental arch.

At this point, the orthodontist re-inserted and ligated the prepared ballista spring device in the buccal tube with its free end in its passive position high above the occlusal surface (Figure 12.8c). With light finger pressure, the terminal loop was pushed gently downwards and lingually, over the occlusal plane and close to the tissues in the recently vacated second deciduous molar gap. The terminal loop was then ensnared on the lingual side by the twisted ligature, which was hooked over it to ensure a secure but easily adjustable connection (Figure 12.8d).

The ballista spring had been designed to provide traction in an occlusal but also in a lingual direction. The ballista was left for a month or so to do its work without the need for adjustments, during the highly sensitive period of post-surgical discomfort, while the entire area was healing. The range of action of this type of spring is extremely wide and the only thing that was needed for the subsequent two or three visits was to roll the twisted ligature over the terminal loop, to keep it battened down, close to the tissues in the extraction space and lingual alveolar mucosa.

Within a few short weeks, the premolar was seen to bulge the lingual mucosal surface of the mandible at the level of the floor of the mouth and this indicated that it was clear of the roots of the molar. Given the continuous light occlusal force and its wide range, a more mesial component of traction became necessary to replace the lingual vector within a relatively short time. As the premolar extruded in the occlusal direction, an elastic ligature was tied between the hooked end of the pigtail ligature (and eventually the eyelet itself) and one of the interproximal adhesive-free areas of the bonded twistflex splint on the lingual side of the anterior teeth (Figure 12.8e, f).

Directional control of occlusal and mesial traction was very easy to manage and it continued until the premolar tooth stood on the lingual side of its final target site in the arch. At this point, the ballista was discarded and a light elastic tie to the buccal sectional wire provided the third dimension of traction control to bring the tooth into alignment (Figure 12.8g, h).

Maxillary second premolars

The most common reason that maxillary second premolar teeth become impacted is similar to the case with the mandibular second premolar. It is related to space loss in the dental arch following the early extraction of the deciduous second molar, with the consequential drifting of the two adjacent teeth, particularly the first permanent molar. It is also to be noted that mesial movement of the first permanent molar in the maxilla is more rapid than occurs in the mandible. It more completely closes off the space and it does so, even in the late mixed-dentition stage, by mesial tipping and a mesio-lingual 'rolling'. Accordingly, when space has been lost, the maxillary second premolar will often be seen to be developing with its root apex in the line of the arch and its crown deflected palatally and palpable on the palatal side of the alveolar process. As with both the mandibular second premolar and the lateral incisors of both jaws, the developmental position of the maxillary second premolar is lingual to the line of the arch, and any physical limitation in the mesio-distal width of its normal eruption path will tend to deflect the tooth in a more palatal direction.

Palatal displacement can occur due to over-retention of the deciduous second molar. It can also occur when there has been a more palatal orientation of the tooth bud of the unerupted premolar in its early development. The outcome may be premolar eruption or partial eruption at the palatal aspect of the cervical margin of the over-retained deciduous tooth. Alternatively, it may become more horizontally oriented and remain unerupted, occasionally being very palpable close to the mid-palatal raphe.

Because of the oblique angle of the X-ray tube in the vertical plane for periapical radiography of this area, the depiction of this more horizontally oriented premolar will give the appearance of a short and under-developed root. Indeed, if there is a more exaggerated palatal tip, the tooth will appear on the film as a small cross-sectional circle. This being the case, it is probable that further radiographs will not be necessary, particularly if the tooth is palpable in the palatal area. The conventional (oblique) occlusal film or a second, laterally shifted periapical film will offer the opportunity to add recordable 3D information. Both a postero-anterior cephalogram view and the true vertex view would in fact be more decisive. However, the relatively high dose of radiation that would be involved is excessive considering the limited additional information that this may provide. Nevertheless, if these views are available, they should be studied for any relevant information.

In Chapter 4, we illustrated and emphasized that a panoramic view of the maxillary second premolar area is recorded with the X-ray beam originating from the other side of the patient and behind the ear. This means that a palatally displaced second premolar will be imaged further mesially in relation to its erupted neighbours. If, at the same time, the lateral cephalometric view contrastingly shows the tooth to be in its normal antero-posterior location, then the diagnosis of palatal displacement will have been confirmed by a method that is essentially another form of the tube-shift parallax method (buccal object rule).

Infra-occlusion of deciduous teeth and its influence on premolar successors

Infra-occlusion of deciduous molars in either jaw is a relatively common phenomenon and in most cases the affected teeth are shed quite normally, with only a relatively minor delay in their exfoliation time [22–25]. The cause of the phenomenon is a local ankylosis at some point or area of the root of the tooth. In this situation, the tooth will not alter its position and, lacking vertical development, its height will remain constant while the adjacent teeth continue their passive eruption as vertical growth of the alveolus progresses. The result is that the affected tooth becomes relatively submerged (infra-occluded).

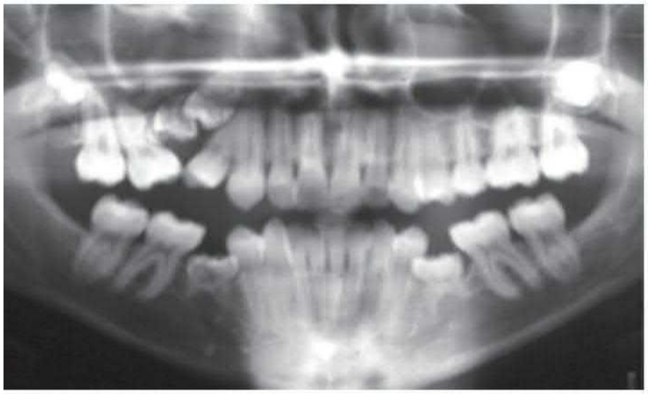
Attempts to move the affected tooth and to overcome the infra-occlusion by orthodontic means have little chance of success, since it is largely impossible to identify the site or extent of the ankylotic connection. Indeed, it is a task that the orthodontist will rarely be called upon to perform, so long as an unerupted permanent premolar is present. On the other hand, an infra-occluded tooth may actually be used for anchorage purposes to achieve movement of other teeth, without the risk of unwanted movement to the infra-occluded tooth itself, since it behaves very much like a temporary anchorage device.

In a situation where the infra-occlusion is very substantial, an extreme vertical displacement of the apically placed successor will also occur (as has been discussed earlier in this chapter). Indeed, the apex of the root of the developing premolar may even cause a palpable prominence in the otherwise smooth profile of the lower border of the mandible [24]. In the maxilla, an infra-occluded tooth may be so severely displaced that its permanent successor will be developing in close proximity to the floor and pushing up the lining of the maxillary sinus. With such extreme vertical displacement, there will be a lack of alveolar bone in the immediate area, compared to that accompanying the normal adjacent teeth. In these latter cases, extraction of the infra-occluded tooth should be carried out to enable the proper development of the root of the permanent successor. If the location of the premolar is also abnormal, the extraction should be made at a very early stage, since the deciduous tooth may become the cause of an eventual ectopic location.

It is often quite impractical to attempt to bond an attachment to many of these grossly displaced premolar teeth. For the most part it is also unnecessary, due to the fact that, once the affected deciduous tooth has been removed, the position of the premolars will generally spontaneously and dramatically improve within a short space of time. Few studies or even case series have appeared in the literature relating to these extreme cases and opinions are strongly influenced by single published case reports or clinical experience of the individual practitioner. There seems to be much merit to a 'wait-and-see' policy and there is a fairly reliable basis for optimism for spontaneous premolar eruption, following space opening and extraction of the infra-occluded deciduous tooth (Figure 12.9).

Fortunately, with infra-occluded teeth actual space loss within the mandibular dental arch is very minimal, despite the obvious fact that the teeth adjacent to an infra-occluded tooth are often severely tipped towards them. The reason for this is that there is a displacement of the roots of the teeth immediately adjacent to the infra-occluded tooth, away from the affected tooth, with little or no change in the distance between their crowns [25–27].


(a)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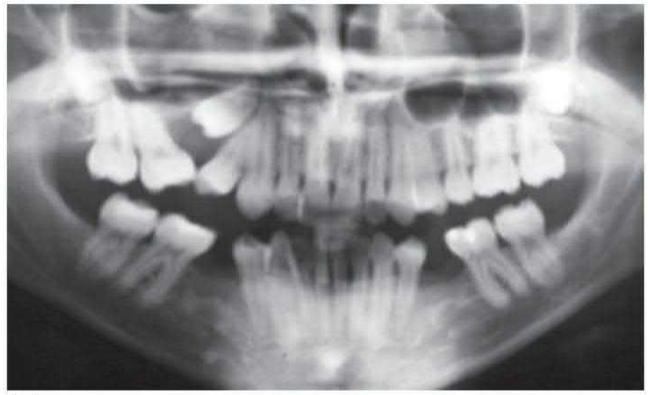
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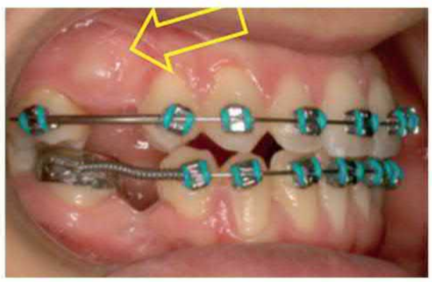
(d)


(e)


(f)


(g)


(h)


(i)


(j)

Fig. 12.9 (a) The pre-treatment panoramic view of a 17-year-old female with missing mandibular second premolars and third molars, with severe infra-occlusion of two mandibular deciduous second molars. (b) The initial panoramic radiograph. (c) The follow-up radiograph after extraction of the deciduous molars. (d) Appliance therapy. The brackets are aligned parallel to the axial inclinations of the long axes of the teeth. Note the first molar and first premolar angulation. (e) Space has been gained and the teeth uprighted. (f) The premolar has been aligned and orthodontics nears completion. (g, h) Occlusal views of the two arches. Note the hourglass form of the edentulous areas of the mandibular second premolar teeth. (i) Post-treatment panoramic view of the completed case. (j) The completed treatment prior to retention.

A space maintainer should be placed when the infra-occluded tooth is removed, or even before the extraction is made, because space loss is frequently rapid. In the first instance one should avoid any attempt to surgically uncover the very deeply placed premolar. Following the removal of the deciduous tooth, the patient should be monitored over a long period of time, with an occasional periapical radiograph taken to check for eruption progress, as indicated.

Case 12.2: Infra-occluded deciduous molars, impacted and missing premolars

The patient was a 17-year-old female. The malocclusion was class I, with a mild skeletal class III tendency (Figure 12.9a). The mandibular incisors were retroclined and deciduous second molars were severely infra-occluded to gum level. The first permanent molars and first premolars in the mandible were tipped towards one another, closing off the space for the second premolars to a large degree on each side.

In the maxilla, all the permanent teeth to the second molar on the left side were present, but there was no space for the second premolar on the right side. Its space was fully closed by severe tipping of the first premolar and first molar teeth.

A study of the initial panoramic film revealed congenital absence of the two second mandibular premolars and the third molars. In the maxilla, the second premolar of the right side was present and severely dislocated very high up, with its apex clearly protruding into the maxillary sinus. This tooth was blocked by an over-retained, infra-occluded and almost totally resorbed deciduous second molar (Figure 12.9b).

The aim of treatment was to remove the remaining deciduous teeth, erupt the maxillary second premolar and create adequate space for eventual implant-supported prosthodontics to rehabilitate the missing teeth in the mandible. The patient was seen by an oral and maxillofacial surgeon for removal of the three deciduous molars, with the express instruction not to expose the impacted second premolar of the right side of the maxilla (Figure 12.9c).

As soon as healing was well under way, the patient was seen again and fixed orthodontic appliances were placed, to undertake the task of uprighting the first premolar and first molar of the mandible and of the right side of the maxilla. The placement jigs on the maxillary brackets underline the extreme 90° angulation difference between the long axes of the maxillary molar and premolar (Figure 12.9d). At the same time, second premolar spaces were prepared to accommodate the unerupted second premolar and the eventual implants (Figure 12.9e, f).

Five months after the extraction of the infra-occluded deciduous molar, the unerupted second premolar could be seen and palpated, and its spontaneous eruption was clearly imminent (arrow). Considering its initial location, the tooth had moved with impressive speed, together with its accompanying rim of new alveolar bone. In contrast, the edentulous areas in the mandible showed a distinct lack of bone and an hourglass ridge (Figure 12.9h).

Seven months later and without surgical exposure, treatment completed, the appliances were removed and fixed retaining devices placed.

Following removal of the appliances (Figure 12.9g–j), fixed canine-to-canine twistflex bonded splints were placed, together with a more rigid and heavier wire bonded to the first molar and the first premolar, to hold the space for the future implant-supported crown restorations.

Infra-occluded teeth cause arrest of vertical bone growth

Infra-occluded deciduous teeth are associated with a lack of alveolar bone height in the immediate area. The height from the inferior border of the mandible to the occlusal table is significantly reduced when compared with a normal, unaffected antimere. The height of the teeth immediately adjacent to a severely infra-occluded deciduous molar is also reduced compared with the height of unaffected contralateral teeth. This phenomenon has been blamed on the inclusion of a vertical component in the normally horizontal trans-septal fibres of the infra-occluded tooth, which inhibits the vertical development of the adjacent teeth [26].

Extraction of the infra-occluded deciduous tooth initially leads to healing and bone reorganization, which, in the absence of permanent teeth, will not increase the vertical height of the body of the mandible or the maxilla in that area. However, if a permanent tooth is present and begins to erupt, alveolar bone development will accompany the eruption and the vertical bony deficiency will eventually be rehabilitated. This may be only partial and a lateral open bite may sometimes persist.

Case 12.3: Infra-occluded deciduous molars and arrested bone growth

Second premolars in either jaw occasionally become impacted in a situation that is further complicated by severe infra-occlusion of the second primary molar (Figure 12.10). When infra-occlusion occurs in the very young child, the relative submergence of the tooth will occur rapidly, in direct contrast with the vertical growth of the alveolar ridges, until the deciduous tooth is lost from sight beneath the overgrowing gingiva. The erupting first permanent molar will then migrate mesially to an excessive degree and will tip in an exaggerated manner, greater than that which would normally be seen after the early extraction of a deciduous tooth. This appears to be due to the influence of the infra-occluded tooth in the vertical plane [25–27]. Similarly, the deciduous or permanent tooth immediately mesial to the affected tooth will tip strongly distally, to the extent that the long axes of the two adjacent teeth, instead of being parallel to one another, will converge coronally at an angle of almost 90°. When, at the first clinical examination, the orthodontist comes across this type of unusually severe convergence, an infra-occluded deciduous tooth should always be suspected.

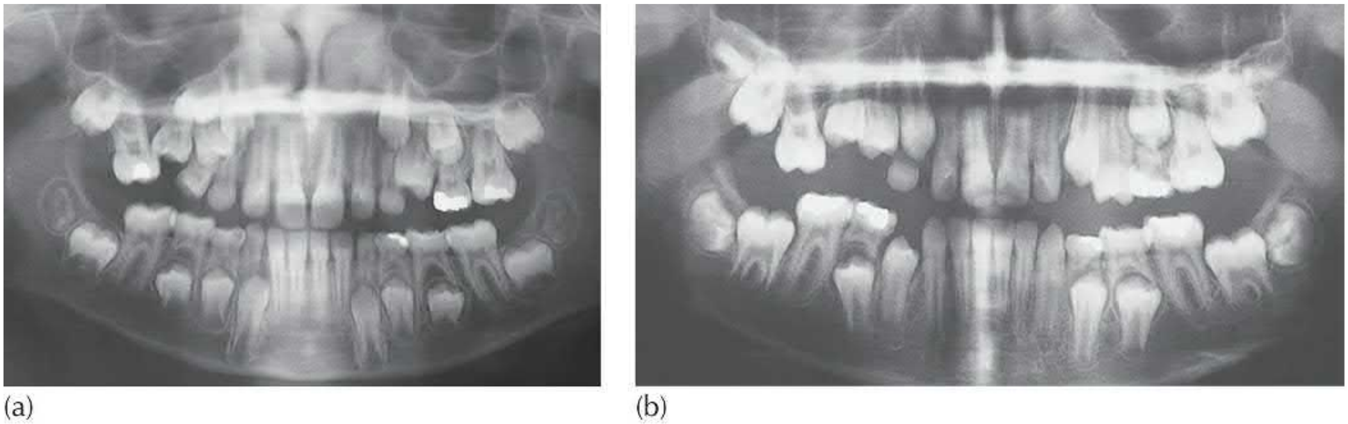


Fig. 12.10 (a) Characteristic extreme tipping of the right permanent first molar, adjacent to an infra-occluded maxillary deciduous second molar. (b) Space maintainers were not placed, but nine months later the canine and premolars had advanced towards eruption and the first molar had autonomously uprighted, without assistance.

The infra-occluded deciduous tooth will now have been firmly locked in by the reduced space in the arch and will remain there during the entire period of the resorption of its root. After the resorption is complete, the tooth will likely be shed. Sometimes, the entire dentinal contents of the crown become resorbed and the empty enamel shell will remain sequestrated *in situ*. In the maxilla, the unerupted second premolar will develop in these cramped circumstances and, during the continuation of the growth of the root, will become displaced, usually mesio-palatally, and its root oriented mesially. It may eventually side-step the empty enamel crown and erupt into the palate, but usually it will remain high up in the maxilla and close to the floor of the maxillary sinus.

In a panoramic radiograph, the tooth may frequently be seen to superimpose on the unerupted maxillary canine of the opposite side. Since it is further from the film than the canine of the other side, its imaging is consequently much enlarged and blurred and may be mistaken for an odontoma located on the opposite side.

Case 12.4: All you need is space, patience and a good surgeon

Treatment of the orthodontic problem presented in Figure 12.11(a, b) is surprisingly simple. The molar must be moved distally to its ideal location in order to reopen the space in the arch. Since the tooth has a strong mesial tip, a removable appliance, carrying a finger spring to distalize the molar (Figure 12.11d), is probably the most efficient appliance available for this task, particularly in the mixed-dentition stage. It will usually take no more than three or four months to achieve its goal.

The patient is then referred to the surgeon for removal of the unresorbed remains of the deciduous second molar. For this, the acrylic base of the removable appliance must be trimmed in order for it to avoid pressure on the healing post-surgical soreness and swelling and, at the conclusion of the surgical procedure, re-inserted into the mouth to retain the molar position. The removable appliance itself is perfectly adequate as a space maintainer, but compliance may be a problem, particularly in the immediate post-surgical period. In the longer term, it is preferable to place a soldered lingual arch in the maxillary arch, constructed on two molar bands.

With the adolescent patient, in the permanent dentition stage, a fully bracketed fixed appliance should be used in order to combine this local problem with the treatment of the overall malocclusion.

Following the removal of the remains of the infra-occluded tooth, the second premolar will respond as soon as it is free of these physical constraints. Within a period of several months to a year or so, it generally erupts unaided into the location prepared for it in the arch. For this reason, the second premolar does not need to have an attachment placed on it, nor is it usually necessary to surgically expose it. In contrast to other impacted teeth, there appears to be little benefit in going through the elaborate orthodontic and surgical preparations that we have described in relation to incisor and canine teeth. Much surgical damage would be inflicted by the effort and difficulty involved in exposing and bonding an attachment to a tooth in this location and the exercise would most often be entirely superfluous.

Case 12.5: Severely infra-occluded deciduous teeth: Think biology, not mechano-therapy

To illustrate many of the features that we have described, we present here the case of a healthy 6-year-old boy affected by multiple severely infra-occluded posterior teeth.

When all the deciduous teeth in all four quadrants of the mouth are severely infra-occluded, one may best observe the transformation that takes place naturally over the period of the treatment using panoramic radiographs. One may also trace the changes brought about by the 'token orthodontic treatment' adopted to correct any residual minor malalignments. The monitoring of this case was followed through over the 10-year period between ages 6 and 16. This represented the period during which the complete deciduous dentition metamorphosed in recognized stages, subsequently transitioning into the complete permanent dentition (Figure 12.12).

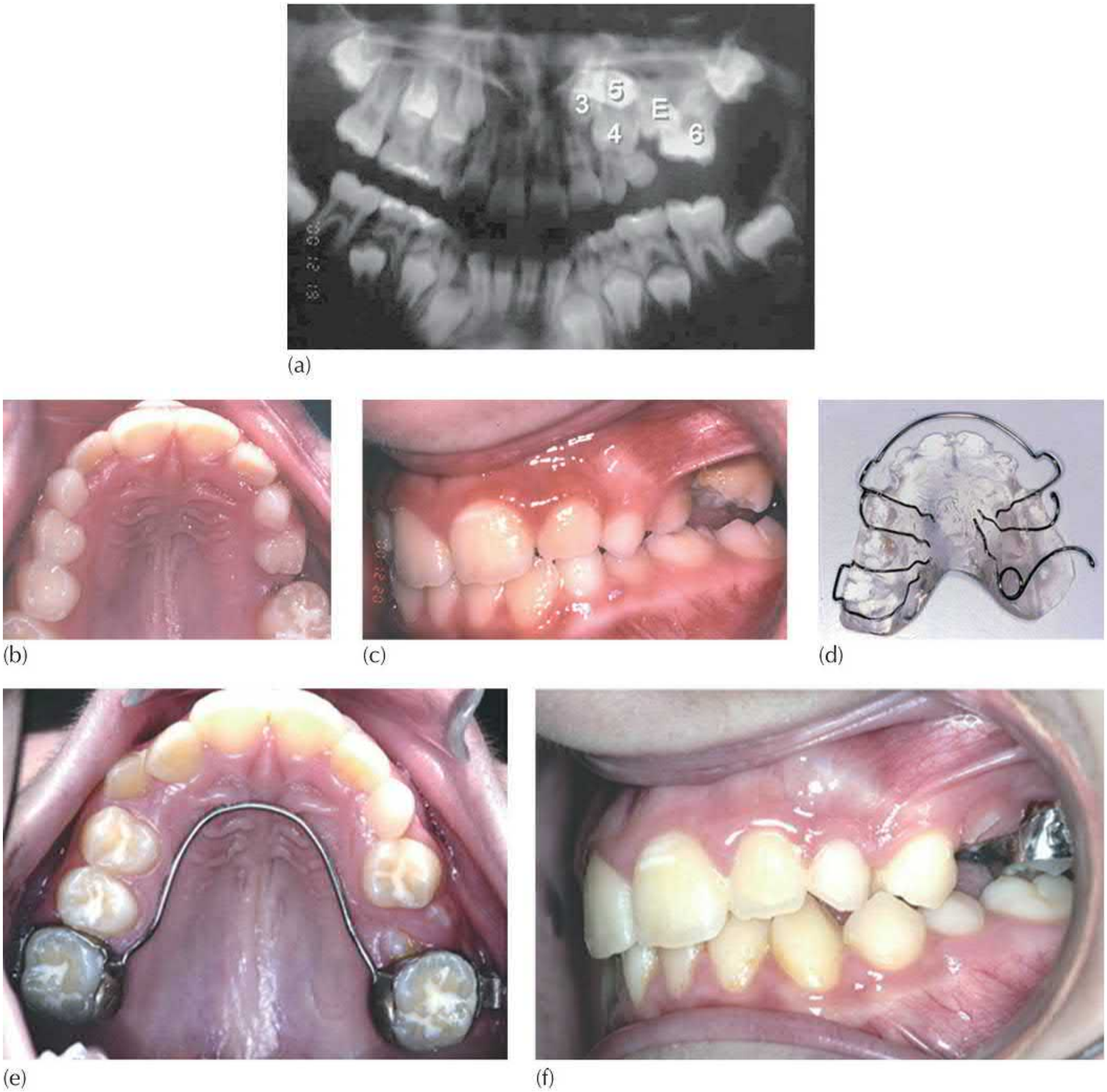
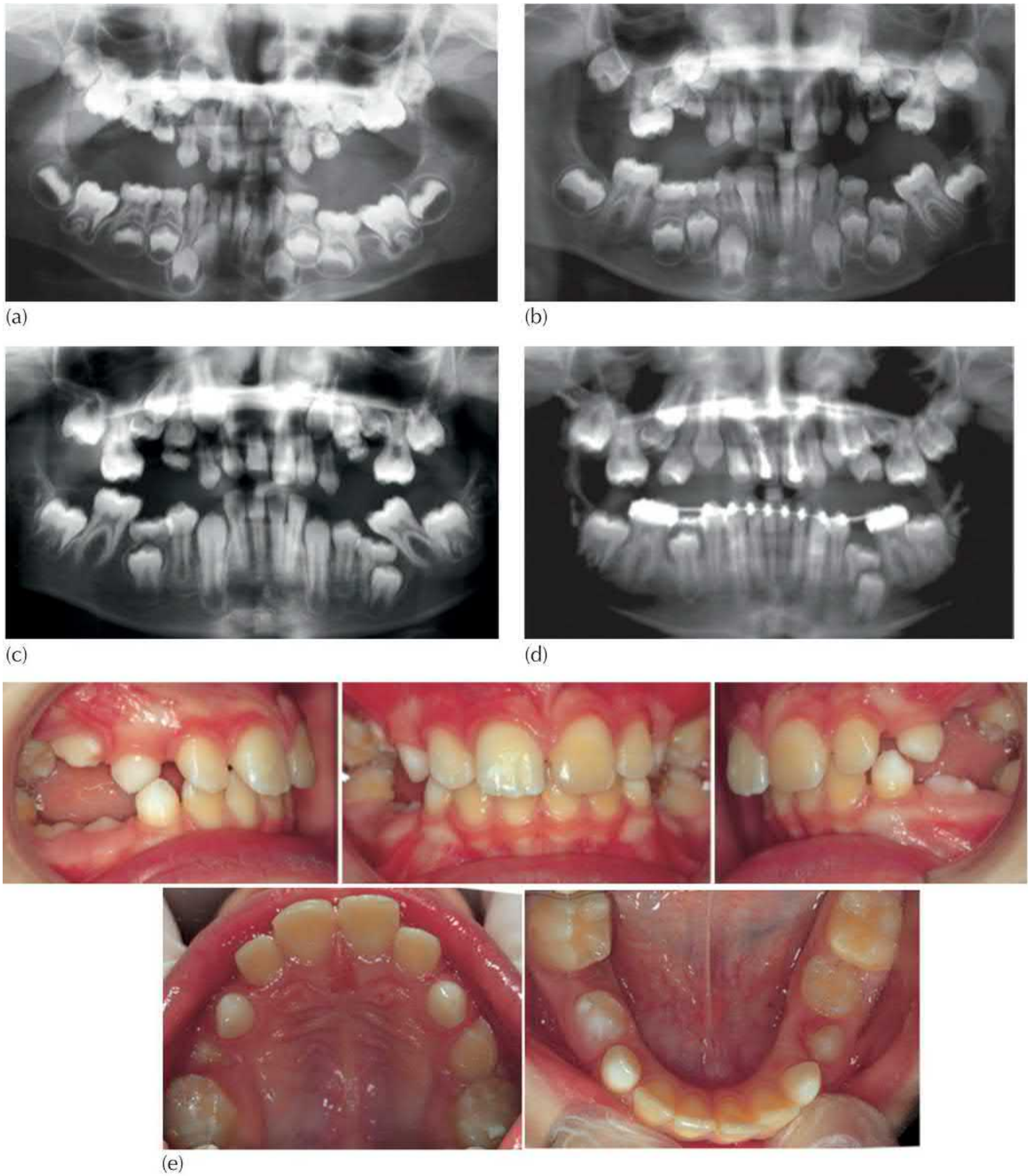


Fig. 12.11 (a) The complex interrelations between the first permanent molar (6), the infra-occluded second deciduous molar, the unerupted second premolar (5), first premolar (4) and permanent canine (3). Note the almost 90° angle described by the long axes of the first permanent and deciduous molars. (b) The occlusal view shows some distal drift of the deciduous first molar, canine and permanent lateral incisor. (c) The left first molar is strongly tipped mesially into the place of the second deciduous molar and out of occlusion. The first deciduous molar is distally tipped. (d) A simple removable appliance that is retained by clasps on the right permanent molar, both deciduous first molars and a labial arch. The spring is designed to move the molar distally. (e) A soldered lingual arch holds the molar in its place in this occlusal view, taken 18 months later. The second premolar is now erupting into its place. No other orthodontic treatment was performed in this case up to this point. (f) The view from the left side on the same day. The tip of the buccal cusp of the second premolar is discernible.

At the time the child was first seen, no deciduous teeth had yet shed and neither had any permanent teeth erupted. The parents' complaint was the absence of many posterior teeth and that only his deciduous front teeth were in occlusal contact (Figure 12.12a). On examination, the deciduous second molars in both jaws were very significantly infra-occluded and the deciduous first molars only slightly less so. The posterior open bite on the left side was more marked than on the right. The initial panoramic radiograph showed the presence of all the permanent teeth (with the exception of the third molars), with no apparent abnormality. There appeared to be an overall mild degree of lateness in their root development, suggesting a delayed dental age. No treatment was undertaken at that time. No diagnosis was established at that time either, although the incorrect possibility of primary failure of eruption had been mooted and was ascertained by the fact of a successful outcome.



(a) (b) (c) (d) (e)

Fig. 12.12 Panoramic radiographic follow-up over a 10-year period. (a) At age 6 years, with full deciduous dentition and infra-occluded deciduous and unerupted permanent posterior teeth. (b) At age 8 years, with increased infra-occlusion deciduous molars, erupted and severely tipped permanent molars. (c) At age 10 years, with extreme deciduous infra-occlusion and vertical displacement of second premolars. (d) At age 10.9 years, biomechanical interceptive reclamation of lost space to facilitate natural eruption. (e) Intra-oral photographic views at age 10.6 years prior to commencement of space regaining. (f) At age 13 years, all teeth erupted without recourse to extrusive traction, following which orthodontic alignment treatment began. (g) Panoramic view two years post treatment, at age 16 years. (h) Full multi-bracketed appliance therapy set-up. (i) Intra-oral view two years post treatment, at age 16 years. Note incisor crown discoloration pursuant to root canal therapy.

Two years later, at age 8, at a follow-up clinical intra-oral examination, a new panoramic film was taken (Figure 12.12b). At this point the patient had fully erupted incisors with an adequate alignment for that stage of his dental development. More importantly, it was noted that the first permanent molars had erupted in both jaws, but that they exhibited a pronounced mesial tip. At the same time, the deciduous molars had become much further infra-occluded. The radiograph showed only the earliest signs of root growth in the premolar and second molar teeth.

Two further years later, at age 10, the mandibular deciduous first molars had exfoliated naturally and the first premolars had begun to erupt (Figure 12.12c–e). In the maxilla, the deciduous first molars had become mobile, with total resorption of the intra-coronal dentine resorption, and were clearly about to be shed. It was also evident from the new panoramic film that the unerupted maxillary second premolar teeth were mesially displaced and had caused total intra-coronal resorption of the maxillary second deciduous molars. Root development of the permanent teeth, as seen on that film, confirmed a dental age one year less than the boy's chronological age.

Shortly thereafter, the child suffered a traumatic episode that affected the face and teeth. As a consequence, the maxillary central incisors lost their vitality and root canal treatments were performed. A new panoramic film (Figure 12.12d) was taken at 10.9 years when orthodontic treatment began, with the express and sole purpose of re-opening lost posterior space. In the mandible, a fixed appliance had been placed with the intention of distally correcting the mesially tipped first molars, to provide space for the surgeon to extract the deciduous second molars and to free the premolars to erupt autonomously. Considerable spontaneous resorption of the roots of the second deciduous molars had already occurred and the right premolar appeared close to spontaneously erupting.

At the outset, this patient had been suffering from a major vertical dento-alveolar problem, yet the treatment that was required involved a simple approach. Initially (and in part due to the lateness of dental development), the diagnosis was unclear and no treatment was advised for over four years until the child was 10 years old. At that point, many of the deciduous teeth had exfoliated and permanent teeth were erupting. In fact, some had reached occlusion with their antagonists.

In the maxilla, when the first premolars had erupted, a removable acrylic appliance, supported by an integral (i.e. cured into the acrylic) high-pull headgear, was placed with the sole purpose of distalizing the first molars using simple distal tipping springs. In a straightforward and short phase I treatment, the orthodontist was successful in applying orthodontic forces to successfully move the permanent molars distally.

The panoramic view gave the first indication that the roots of the premolars were in an adequately developed state to expect them to erupt rapidly, if the infra-occluded deciduous teeth were to be extracted. Accordingly, they were finally extracted a few months later, when adequate space had been made. All the premolar teeth then erupted spontaneously over a two-year period, without the need for surgical exposure of the unerupted teeth and simply by holding the space.

Following extraction of the severely infra-occluded second deciduous molars, the only orthodontic procedure that was performed was post-treatment retention of reopened spaces. The resolution of the remainder of the vertical problems that had produced the lateral open bite occurred physiologically, as a direct result of the elimination of the infra-occluded deciduous molars. The spontaneous and full eruption of the premolars was accompanied by new alveolar bone and a rebuilding of the height of the alveolar ridges, which, too, had taken place without biomechanical assistance. At age 13 years, all teeth had erupted and full bony regeneration with alveolar ridge height had been rehabilitated. Orthodontic treatment was initiated to address the residual minor malocclusion, involving the routine use of an orthodontic multi-bracketed system (Figure 12.12f–

i).

In the final analysis, the treatment of this patient was based on an understanding of the adverse characteristics of infra-occluded deciduous teeth, the expectations following their timely loss and the biological principles involved. In this context it was important to decide which permanent teeth should be left to erupt without assistance rather than be subjected to extrusive traction, and when and in what circumstances orthodontic traction should be applied.

It is perhaps pertinent to ask how many of us would have begun treatment of this case at age 6 years; how many of us would have considered this to have been an orthodontic/surgical case for extraction, exposure and traction; and how many would have misdiagnosed this as a case of primary failure of eruption, with its few (if any) treatment options?

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13
The Root Form of Impacted Teeth

Adrian Becker

Normal root development

The aetiology of hooked root apices

The 'hooked root' theory of tooth impaction

Abnormal root form

Fake causes

In this chapter we will examine whether there is any connection between the phenomenon of curled roots and impacted teeth. Is there truth in the notion that not all abnormally configured roots are caused by impacted teeth and not all impacted teeth give rise to an abnormal root configuration?

Normal root development

The initiation of development of the root of a tooth follows on seamlessly from the completion of the development of the crown. Hertwig's root sheath is responsible for root development and it starts as a proliferation of epithelial cells located at the join between the outer and inner enamel epithelia [1–3]. A 3D cervical loop is thus formed as an all-around rim at the edge of the enamel organ. On the outer surface of the tooth, the formation of root dentine begins at the location of the future cemento-enamel junction (CEJ) by differentiating odontoblasts from the dental papilla. However, the dentine so formed is fully continuous with the dentine within the crown, the only difference being that it no longer has external enamel protection.

The direction of normal root growth of a single-root tooth continues along the extension of the long axis of the crown of the tooth. This generally means that it is vertically oriented and continues on this vertical path, and is strongly linked to the eruptive progress of the tooth. The roots of a multi-rooted tooth, on the other hand, tend to diverge to a limited degree, but otherwise continue on their vertically oriented path. During normal dental development, the unerupted tooth unit migrates in an occlusal direction as its root grows, concurrently and cumulatively generating alveolar bone behind it [4]. Although the root elongates considerably, the developing apex of a mandibular tooth becomes more and more distant from the lower border of the mandible.

A similar developmental course occurs in the maxilla, where the roots of the teeth increase in length, yet their apices become more distant from the palatal plane of the maxilla. As the tooth advances along its path of eruption, it vacates a virtual space behind it, into which the root has room to grow and which new alveolar bone will fill in. When the tooth finally erupts into the oral environment and reaches the occlusal plane, it does so with only two-thirds of its root completed. This means that the remaining one-third continues to develop even during the period that the teeth are in occlusion. The development process will take approximately three further years to apexification.

The reason that the tooth becomes propelled occlusally is the snowballing interplay between the innate eruption potential of the tooth and the vertical growth of the alveolar bone, which is inspired by that eruption. These developmental processes are the prime factors in the vertical increase in the height of the lower third of the face.

The aetiology of hooked root apices

A PubMed search using the key words 'impacted teeth' and 'root development' reveals a long list of references to clinical articles and individual case reports. Most of the references relate to case studies of unusual and difficult cases, and some truly remarkable treatment results. However, one does not find published studies of the inter-relationship of tooth impaction and restricted, stunted, redirected or irregular development of the roots of these teeth. Nor until relatively recently had there been any investigations of the question whether, if the impactions were to be resolved, the roots would recover to realize some of their root-forming potential. In some cases corrective or diverted directional root growth has been shown to occur [5–10].

The next pages will discuss this very important issue and why it is considered to be important from the clinical point of view.

What, then, is the evidence available to support the theory that, if the impaction were resolved, the roots would regain and recommence their growth potential? Given the dearth of available clinical studies of this question, one may be permitted to argue the case mainly by deriving information on an individual basis, despite the tendencies towards bias that this entails and despite the limited justification to proclaim valid generalizations.

Normal root development will continue relentlessly for as long as it is uncompleted and unapexified. The roots of all teeth grow vertically upwards in the maxilla and vertically downwards in the mandible and yet, ironically, the more the root grows, the further it moves away from the apical base. Any impediment to the innate eruptive potential will bring the newly developing apical portion of the root to reduce its distance from the 'apical base' – that imaginary line that separates alveolar bone from basal (skeletal) bone. Thus, an active dental papilla at the root end of the tooth will continue to lengthen the root until either it apexifies or it eventually reaches an anatomical barrier, such as the compact bone of the lower border of the mandible or the periosteum that lies beneath the epithelium that lines the maxillary sinus or the floor of the nose. Because it can go no further in the vertical direction, any additional growth potential will be realized in a diverted (horizontal) direction and a hooked apex will likely result.

From the discussion in Chapter 1, we know that an impacted tooth is a tooth that has been prevented from erupting for any of a wide variety of possible reasons. However, its innate capacity for root development and for eruption remains – albeit on a progressively reducing basis.

In some cases, root development, which normally has the potential for excellent growth, may be impaired by the restricted space available to it. In most cases, wisdom teeth are extracted because they are impacted to some extent and have grown in physically restricted conditions. If one were to rummage through the biological waste disposal receptacle in the operatory of any self-respecting oral and maxillofacial surgeon, one would undoubtedly discover a very large number of extracted third molars. A majority of these will feature bizarre root configurations. It is well recognized that the abnormal root development of these commonly impacted teeth occurs due to the confined circumstances in which they grow.

I well remember my first teacher of orthodontics, who was perhaps the most important influence on my choice of profession. He was a proponent of the extraction of second permanent molars, in extraction cases, in preference to premolars. Among the many arguments that he put forward for its efficacy, he maintained that the third molar would eventually erupt into the place of the extracted tooth and would develop a more improved root form and length than would otherwise have been the case [11, 12]. This was an opinion based purely on anecdotal evidence, born out of years of logical, but biased, experience. This does not mean that his conclusions were wrong – just scientifically unsubstantiated. In the course of time, many of his erudite observations and conclusions were indeed proven correct, but in those heady days evidence-based treatment protocols were not yet in style.

The 'hooked root' theory of tooth impaction

At an initial clinical examination, tooth impaction is suspected when the tooth is absent from an otherwise fully erupted dentition, in a patient whose eruption age is already well past the time that the tooth would normally be present. The absence of the tooth can have several explanations. It may indeed be congenitally absent, but it may also be impacted. The tooth (perhaps a maxillary lateral incisor or mandibular second premolar) may be present but developmentally late, in which case a radiograph will show a short root with an open apex. The diagnosis of impaction can only be confirmed by the inclusion of radiographic evidence, which would reveal the tooth's unerupted presence, with root development in excess of two-thirds of its expected final root length.

When an impaction is diagnosed, practitioners will normally examine the radiograph and follow a logical thread of investigation. They look for a possible reason for the impaction and their gaze alights on the existence of a hooked root on the impacted tooth. To many of us, this will immediately seem to be the logical, rational (and convenient) answer. It would seem obvious that an antagonistic hooked root will not permit normal eruption and, probably, will not submit to orthodontically driven extrusive traction either. They rationalize that this abnormally shaped root (which they may liken to a ship's anchor) is resisting the innate eruptive potential or a biomechanically applied orthodontic force and must surely be the reason for the failure of the tooth to respond. Indeed, the story certainly appears to fit the explanation from a purely *technical*, static point of view.

What the practitioner has not considered, however, is an answer based on *biology*, namely the dynamic biological scenario that leads *a priori* to the materialization of the abnormal root form. In the preceding chapters, we have learned that there are several causal factors for why an impacted tooth does not respond to its innate eruptive potential nor to extrusive orthodontic force. By itself, a hook-shaped apex is almost certainly *not* one of those factors.

Abnormal root form

The real aetiology of the abnormal root form phenomenon will be revisited in the following pages and exemplified through the cases presented under the headings of a number of anatomical anomalies and pathological entities. These may be listed as follows:

- Infra-occluded deciduous molar obstructing a maxillary or mandibular premolar.
- Odontoma.
- Permanent tooth obstruction.
- Dentigerous cyst.
- Invasive cervical root resorption (ICRR).
- Pre-eruptive intra-coronal resorption (PEIR).
- Benign tumours and other soft tissue lesions.

- Trauma.
- Cleidocranial dysplasia (CCD).
- Idiopathic causes.

Infra-occluded deciduous molar obstructing a mandibular premolar

In an early case report that we published in the *American Journal of Orthodontics* in 1982 [13], we described a patient whose left mandibular second deciduous molar was severely infra-occluded (submerged), with its crown completely buried beneath the gingival tissues. Whether or not this tooth had ever erupted into the oral cavity was not known, but considered unlikely. The adjacent first molar and first premolar were strongly tipped towards one another, almost completely closing off what gave the appearance of being an extraction space, despite the presence there of two buried teeth. What was interesting was that the second premolar was located apical to the infra-occluded deciduous second molar and its stunted, very broad, but incompletely developed root could be seen on the lateral oblique radiograph (panoramic films were not in general use at the time the patient was treated). The developing premolar root apex was in close contact with the compact bone of the lower border of the mandible and had altered the bony profile of its outer inferior surface.

Treatment consisted of extraction of the infra-occluded deciduous molar, together with the second permanent molar, with no active orthodontic therapy. Space between first molar and first premolar re-created spontaneously under the influence of the erupting premolar, which went on to grow a very long and much narrowed root, when compared with its unaffected antimere. Photographs of the case are no longer available, but may be seen in the original article [13].

Odontoma

An odontoma is a space-occupying body, composed of a melee of enamel and dentine tissues in no particular order and with no specific size, shape or arrangement. They occur in two types, namely the composite odontoma, which is a single amorphous mass of mixed dental tissues (Figure 13.1), and the complex odontoma, which comprises a number of denticles lumped together. In some cases, their presence is associated with the congenital absence of an adjacent tooth, as if it actually is the missing tooth in anomalous form. They are no harmful or pathological aspects to odontomata, other than the effects on the other teeth of the large space that they may occasionally occupy.

In the case illustrated in Figure 13.2, the mandibular composite odontoma is extremely large and it has displaced the single permanent molar down to the lower border of the mandible. The effect of its size has been to envelop the molar completely, in such a way that its roots were growing horizontally in the compact bone, along the lower border.

Fig. 13.1 A vertically impacted second mandibular molar, prevented from erupting by the dentigerous cyst encompassing its crown. The diverted root apex was caused by its development in close proximity to the lower border of the mandible (i.e. an anatomical barrier).

Courtesy of Dr V. Heister.

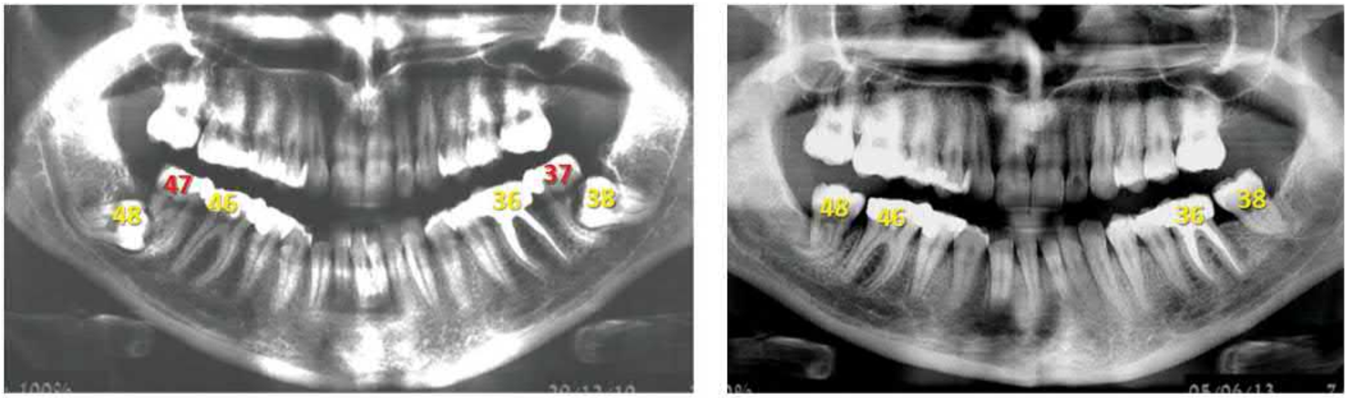
Fig. 13.2 A very large composite odontoma has limited the space in which the normal molar tooth has developed. The roots of the molar tooth have grown horizontally, guided by the inferior border of the mandible and altering its surface anatomy.

Permanent tooth obstruction

A 34-year-old female patient was referred because the second mandibular molar on each side was in the process of undergoing severe resorption of its distal root (Figure 13.3a). On the right side, there was a horizontally impacted third molar apparently actively burrowing into a very large resorption crater within the root area of the second molar, which had once been the apical two-thirds area of the distal root. On the left side, a similar impacted third molar had eliminated the entire distal root of the second molar. The resorption process could be seen on the panoramic film to have proceeded to the mesial root and was already into the distal half of the crown.

On each side, the root apices of both third molars were closed and they were in close proximity to the mandibular canal. On the right side, the roots of the tooth crossed over each other, because the distally curved mesial root had clearly been influenced by the presence of the canal and could be seen to conform to its longitudinal profile.

Clearly, the third molars were attempting to advance their eruptive potential in a mesial direction, which was resisted by the second molars. At the other end, the intrinsic eruption urge was resisted by the anatomical limitation provided by the mandibular canal, which had diverted the root-forming Hertwig's sheath in an altered, more horizontal direction. The valiant resistance of the second molars to the aggressive advance of the third molars had cost severe resorption of the distal roots of the second molars. The problem has a number of different aspects, none of which make a treatment decision easy:



(a) (b)

Fig. 13.3 (a) Bilaterally impacted mandibular third molars associated with resorption of the roots of the adjacent second molars in an adult. (b) Extraction of the resorbed second molars and orthodontic resolution of the third molar impaction.

- On the one hand, leaving the third molars in place would permit the fullest expression of their continued resorptive potential, thus hastening the already certain demise of the second molars.
- Orthodontic treatment to distance the third molars, aimed at their uprighting and alignment, would, in the context of this specific case, be completely impractical and counterproductive – not to mention technically impossible to achieve.
- It is difficult to see how the third molars can be extracted without incurring further damage to the second molars and/or to the inferior alveolar nerve bundle.
- Extracting the third molar would leave in place a highly compromised second molar with a very poor prognosis in the long term.
- Extracting the second molars was not considered technically difficult, but it too posed several questions:
  - The patient would effectively be left without both the second and third molars from the dentition.
  - The maxillary second molars would be deprived of their occlusal antagonist and no doubt in due course would over-erupt.
  - The panoramic radiograph of the case shows large restorations present in both first molars, with the left one additionally exhibiting a complex root canal filling. These two teeth could hardly be relied upon in the long term.
  - With a patient at the age of 34 years and given the angle at which the third molars presented, there was no possibility that these teeth would autonomously upright and erupt into the mouth.
  - Was active orthodontic intervention, at the age of 34 years [13] and given the angle at

which the third molars presented, a practical line of treatment? Perhaps the third molars were ankylosed?

- Given the proximity of the roots of the third molars to the inferior alveolar canal bundle, was there a high risk of collateral damage from the surgical exposure or the orthodontic treatment that was being considered?

Would the angulated roots resist the challenge of orthodontic resolution? The patient had everything to gain if this highly optimistic line of treatment were to be successful, but was there any positive indication of the likelihood of success, or a clue that could justify embarking upon this ambitious treatment plan?

The third molars had grown in restricted space due to the anatomical limitation provided by the mandibular canal and their roots had grown and altered their form in a more horizontal direction. Yet at the same time, the third molars were attempting to express their intrinsic eruption urge and already the valiant resistance of the second molars to the aggressive advances of the third molars had cost the second molars severe resorption of their distal roots.

It was judged that the third molars and their periodontal supporting tissues were healthy, as evidenced by the fact of their ongoing resorption and very impressive and progressive migration into the resorption craters of the distal side of the second molars.

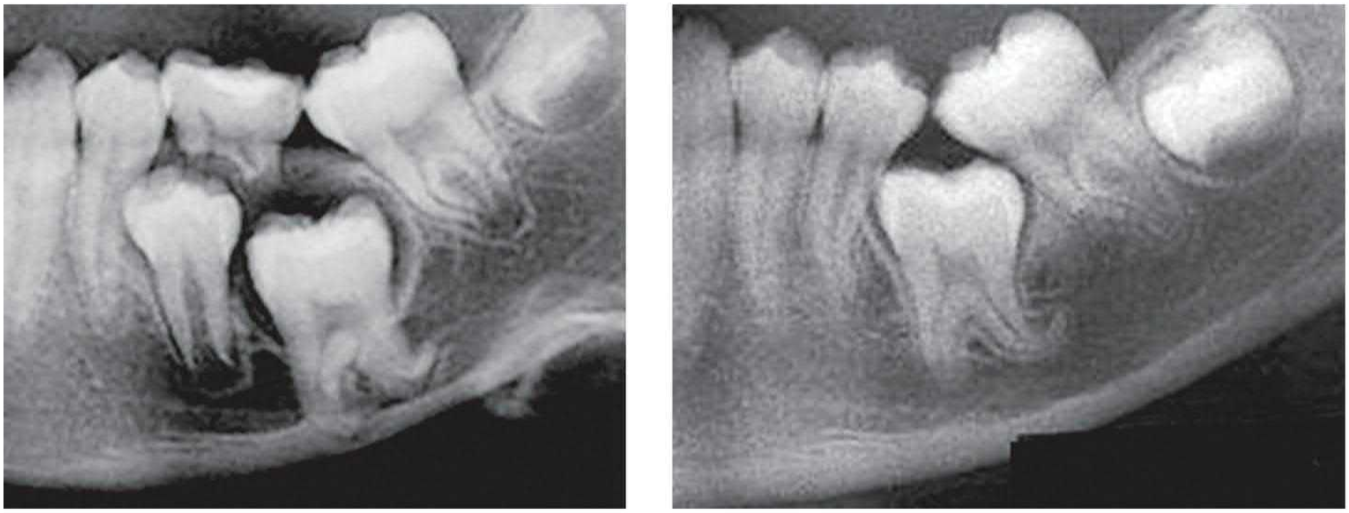
In the event, extraction of the second molars was performed and, simultaneously, attachments were placed on the exposed superior surfaces of the third molars, by the orthodontist at the time of their exposure. Active traction was applied to a prepared fixed mandibular orthodontic appliance, before the patient was transferred to the recovery area.

The third molars responded well to the orthodontic treatment and were uprighted and erupted using intra-arch orthodontic forces only, in a one-arch treatment (Figure 13.3b). The patient had lost two severely damaged molars. She had gained two functional molars that were completely healthy, with excellent prognoses, and she suffered no damage to the innervation of the lower jaw, despite the angulated roots of the teeth.

Many of us will look at these wisdom teeth on the initial panoramic film – with their severe horizontal orientation and their vertical height discrepancy to the occlusal plane, the long 90° distal curvature of their mesial roots (which significantly/ominously follow the line of the inferior alveolar canal) and their relationship to the anterior border of the ramus on each side – and conclude that the chances of success were slim. However, there was one positive factor that hinted at optimism in this case. Both third molars were causing resorption of the roots of the second molars and, as the resorption proceeded, the third molars were actively migrating mesially into the void created by the resorption. In other words, these teeth were neither arrested nor ankylosed, but 'successfully' exercising a dynamic eruptive potential in a futile direction and with devastating effect. They were 'on the move'! These teeth were therefore considered suitable candidates for orthodontic resolution, which was subsequently undertaken, leading to a successful outcome (Figure 13.3).

Dentigerous cyst

The crown of each tooth develops within its follicle and, when the time comes for the tooth to erupt, the follicle fuses with a concentration of cells from the oral epithelium and a pathway opens up for the tooth to emerge into the oral cavity. A dentigerous cyst originates from the normal follicle of a developing tooth. The follicle may sometimes enlarge due to an excess of fluid within it, causing the hydrostatic pressure within it to increase. The follicle may continue to increase in size until the pressure within reaches a level where it exceeds the eruptive force of the tooth. This causes eruption to stop, but it does not prevent the further build-up of hydrostatic pressure within the follicle. It continues to expand, at the expense of the surrounding bone, which resorbs due to the pressure being exerted upon it. If the follicle remains within the bone, the pressure will mount to such a degree that it may sometimes cause the tooth, which had started its eruption process, to back up along its eruption path. There is no histological difference between the epithelial linings of a dental follicle and a cyst. According to convention, a dental follicle attains the status of a 'dentigerous cyst' when a routine periapical X-ray discloses a 2–2.5 mm gap between the enamel of the tooth and the follicle.



(a) (b)

Fig. 13.4 (a) A section of a panoramic film showing a first permanent molar impacted due to a dentigerous cyst encompassing its crown. (b) The repeat panoramic film taken approximately two years after extraction of the deciduous molar. Note that the second premolar tooth erupted ahead of the molar. It adopted an approximately 20° alteration in the orientation of its long axis. Nevertheless, the apical section of the root continued to grow and complete its growth in its original and unprejudiced vertical direction.

Courtesy of Dr Immanuel Gillis.

In Chapter 14 we present a lengthy discussion of dentigerous cysts and their relationship to impacted teeth. Several of the cases presented there demonstrate clearly how teeth that develop in the walls of particularly large dentigerous/radicular cysts will often develop anomalous root forms.

The case of an impacted mandibular permanent first molar is illustrated in Figure 13.4. It was impacted deep into basal bone due to the dentigerous cyst encompassing its crown. Its root growth had continued and had met the lower border of the mandible. This had obstructed further longitudinal growth and had caused its root apices to divert and double back and thus to produce the hooked end. The inferior profile of the mandible became altered by a small bump precisely opposite the point where the mesial root of the molar was located.

Judging by the extent of closure of the root apices of the infra-occluded permanent molar (which are fully closed in the picture), the child was at least 9 years of age at the time that the film was taken (Figure 13.4a). The film also shows the root of the first premolar to be fully closed and the apices of the permanent second molar almost fully developed. Accordingly, the evidence that is available from this film is provided by the developmental status of the first premolar and second molar, which together point to the dental age of the child as being 13 years. As emphasized in Chapter 1 and elsewhere in this book, we must ignore the fact that the root of the second premolar was only two-thirds developed. This does not contribute to the age assessment of the child, since second premolars are frequently late in their development.

The beginning of the bend on the root of the first molar can be seen on these two films, located approximately one-half to two-thirds of the way down the root, which corresponds to shortly before the tooth was due to erupt. A first molar erupts at age 6 years and it is therefore logical to conclude that the cyst was already active in preventing eruption at an approximate dental age of 5 years.

Extraction of the deciduous second molar defused the cyst and freed the second premolar, which then rapidly erupted, ahead of the first molar and into mesiodistal contact with the second molar. The extraction also eliminated the cyst itself, which had been responsible for holding the permanent molar down into the compact bone of the lower border of the mandible. The repeat panoramic film taken two years later (Figure 13.4b) shows the situation some time after the deciduous second molar had been extracted and the area had healed. Despite the hooked root ends and with no orthodontic assistance, the tooth had spontaneously surged upwards until it became lodged between the two adjacent teeth.

The clear conclusions that can be derived from this process are as follows:

- The cyst was the cause of the infra-occlusion.
- The infra-occlusion was the cause of the hooked apices.
- The hooked apices were the result of the infra-occlusion/non-eruption/impaction and not the cause.

Invasive cervical root resorption

ICRR has been discussed at length in Chapter 10 and, as its name implies, is almost always initiated at the CEJ area of the tooth. However, there are exceptions like the case presented in Figure 13.5(a, b), in which a maxillary permanent first molar in a young person was affected and where the portal of entry of the lesion was in the furca between the three roots. The ICRR lesion was directly associated with the infra-occlusion and with the failure of the orthodontic traction to move the tooth. The molar had partially erupted and traction had been applied in a failed attempt to bring the tooth down to the occlusal plane. As the result of the failure, the roots of the molar began their vertically elongating development from a higher level than normal in the maxilla. Since there was now a reduced width of bone above the tooth, the developing apices reached the periosteum and epithelial lining of the floor of the maxillary sinus *after only partial* root growth. In order to complete the expression of their full length, the direction of development of the final part of each of the roots was deflected horizontally, thereby forming a terminal hook.

The tooth was carefully extracted, removed whole, cleaned up and subsequently examined in its dry state. The mesio-buccal and disto-buccal roots and much of that part of the dentine within the crown had been replaced by resorptive mush.

It was concluded that the ICRR had prevented the tooth from erupting [14, 15], thereby limiting its developing roots to growing within the reduced height of skeletal bone, too close to the floor of the sinus. The hooked root was the direct result of the roots growing against the obstructing anatomical barrier of the sinus floor, leading to a reduced maxillary height in the immediate area.

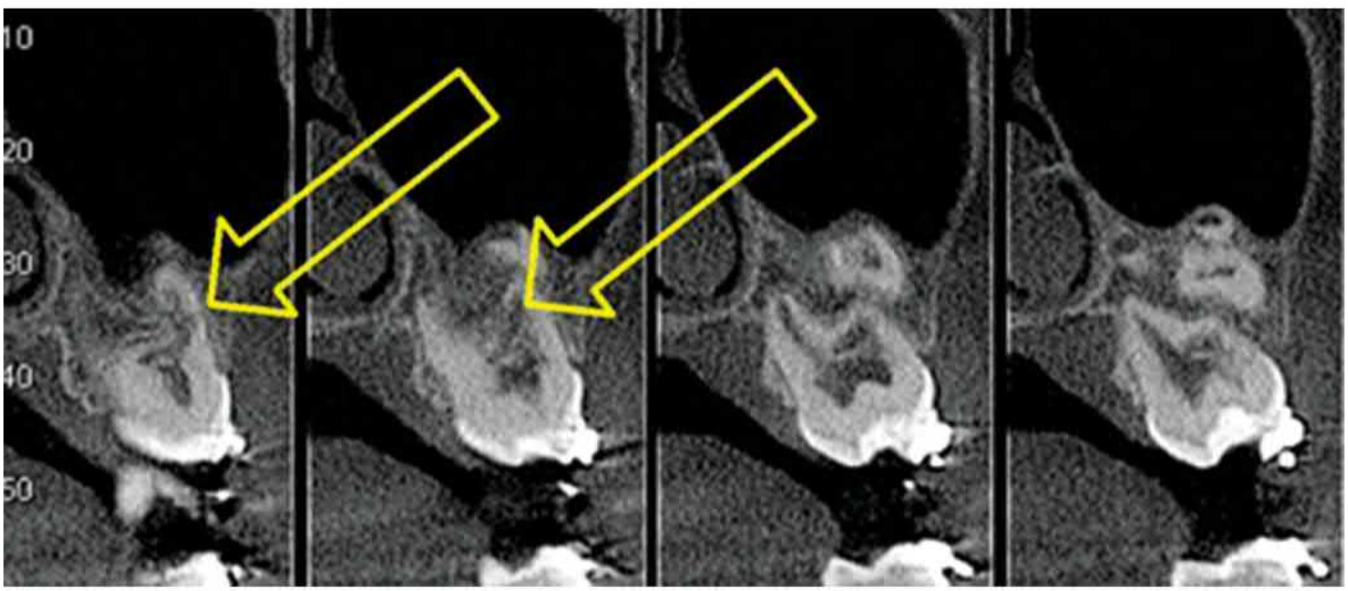
Pre-eruptive intra-coronal resorption

PEIR is a pathological resorptive process that is in many ways similar to ICRR and is discussed fully in Chapter 10. It is a process that occurs within the follicle of an unerupted tooth and attacks the dentine of the crown of the tooth, through a defect in its enamel layer [16]. The most frequent locations for this to occur, therefore, are where the enamel layer is more likely to incorporate microscopic faults or imperfections, namely in the depths of occlusal and buccal fissures, incisal edges, cusp tips, buccal pits and *dens in dente*. These lesions are completely asymptomatic and are often mistaken for caries. Paediatric dentists will often examine a 7–8-year-old child who has recently erupted a maxillary lateral incisor and may have diagnosed the existence of a *dens in dente* in its cingulum area. Subsequent simple cavity preparation may then easily lead to pulp exposure. This will be due to the soft mush within a PEIR lesion, which is commonly found in this location in a tooth that had erupted into the mouth only a short while previously.

The patient in Figure 13.6 was a 16-year-old male with an unerupted and asymptomatic left mandibular canine tooth. His panoramic radiograph was of poor quality and the lesion was initially missed (Figure 13.6a, b). When the tooth did not respond to space opening and alignment, the panoramic radiograph was examined a second time, this time adjusting the contrast and light. The tip of the crown of the tooth lacked its sharp and distinct appearance and it was subjected to a cone beam computed tomography (CBCT) examination. The portal of entry of the PEIR lesion could then be seen at the tip of the cusp, which, as has been referred to above, is one of the typical locations for a point fault in the enamel cover of the crown of the teeth. In the longitudinal and cross-sectional slices, the resorbed area may be seen to extend deep into the dentine and to further stream down on either side of the pulp chamber. By combining this information from the longitudinal cuts with that from the cross-sectional cuts, a 3D picture may be constructed that will show that the resorption process was in fact encircling the pulp chamber and the root canal, as it proceeded in an apical direction.

The tooth was located very deep down in the basal or skeletal bone of the mandible, indeed too deep to be in the tooth-bearing alveolar bone (Figure 13.6c, d). This was a much lower position than was to be expected in a simple delayed eruption situation. Something had clearly impeded the eruption of the tooth. The root apex can be seen to have turned to the mesial as it entered the thick cortical plate at the lower border of the mandible. This, then, is an excellent example of arrested eruption, in which there has been arrest of the natural force of the eruption of the tooth and of the normal vertical element of mandibular basal bone. The only possible local aetiological abnormality that was present and could have been the cause was the PEIR lesion.

(a)



(b)

Fig. 13.5 (a) An 11-year-old boy with infra-occluded maxillary left first permanent molar (arrows). (b) Serial cross-sectional cone beam computed tomography slices show the area of root with invasive 'cervical' root resorption, which was initiated in the furca area (arrows).

Courtesy of Dr Gavriel Gal.

Three additional and similar cases, involving different teeth all affected by the PEIR phenomenon, are illustrated in Chapter 10. Most of the teeth with PEIR lesions will erupt normally and once the lesion has erupted in the mouth, the clastic cells will die. The progress of the lesion will then be arrested, having been isolated from their nutritive lifeline, which is the intra-follicular vascular plexus and fluid. However, there is unquestionably relevant anecdotal evidence that an *advanced* PEIR lesion may arrest the eruptive process and cause the last part of the root end to apexify against an anatomical obstacle, such as the lower border of the mandible (Figure 13.6d), thereby diverting the apex in a different direction [16].

Trauma

In Chapter 5, several cases were illustrated in which trauma caused a change in the direction of root growth, particularly of the central incisors in the maxilla. It was shown that the 'classic' form of a dilacerate incisor develops with the root growing in a semi-circular path in a labio-superior direction. It was also demonstrated how these teeth may be treated, quite regardless of their root anomalous form.

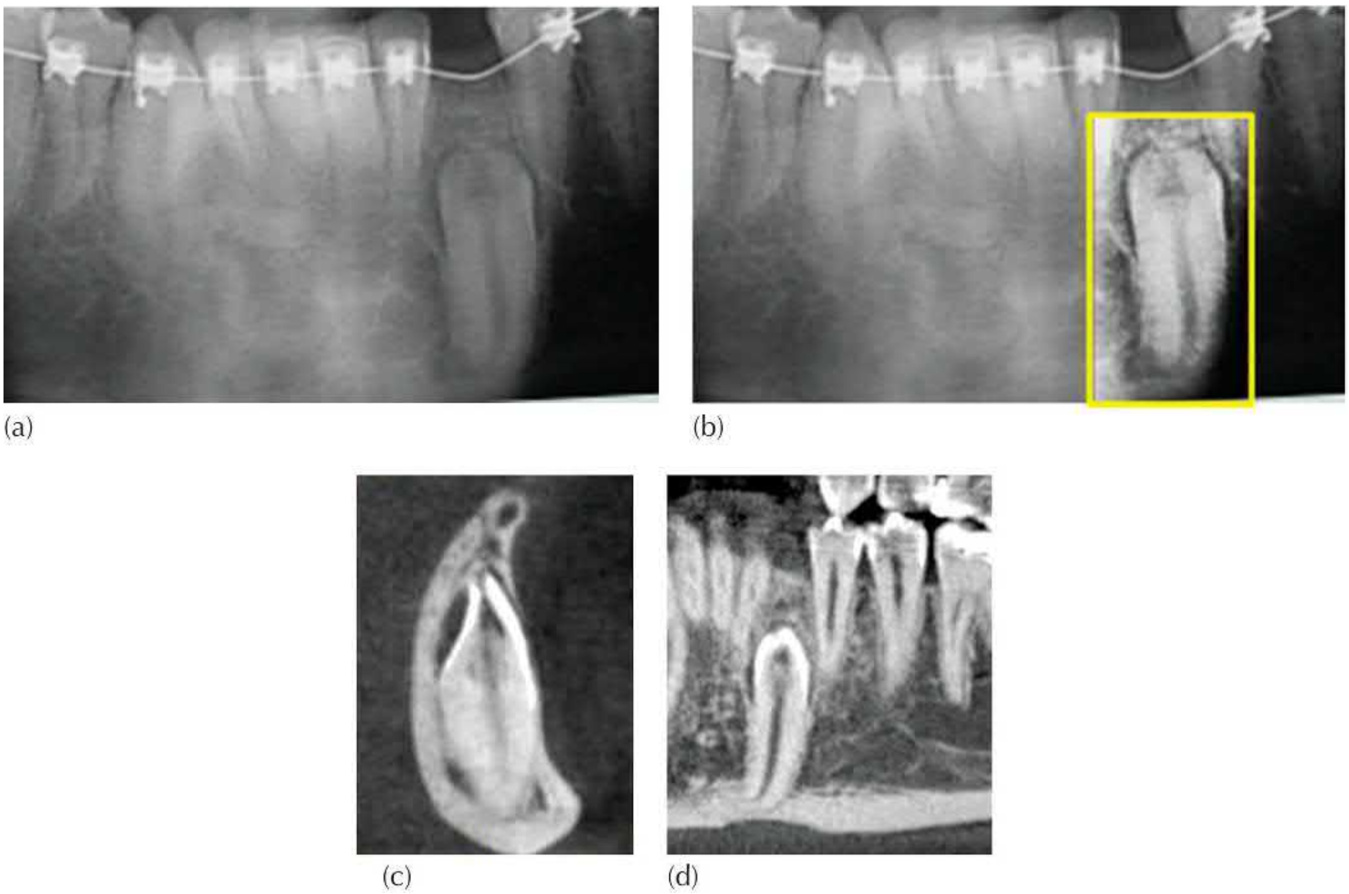


Fig. 13.6 (a) A section of the low-quality panoramic film of a male 18-year-old patient with the mandibular left canine impacted with completed root apex. (b) The image of the tooth has been adjusted for lightness and contrast to reveal pre-eruptive intra-coronary resorption. The apex of the tooth is located close to the lower border of the mandible and is hooked.

Courtesy of Dr Adam Renert.

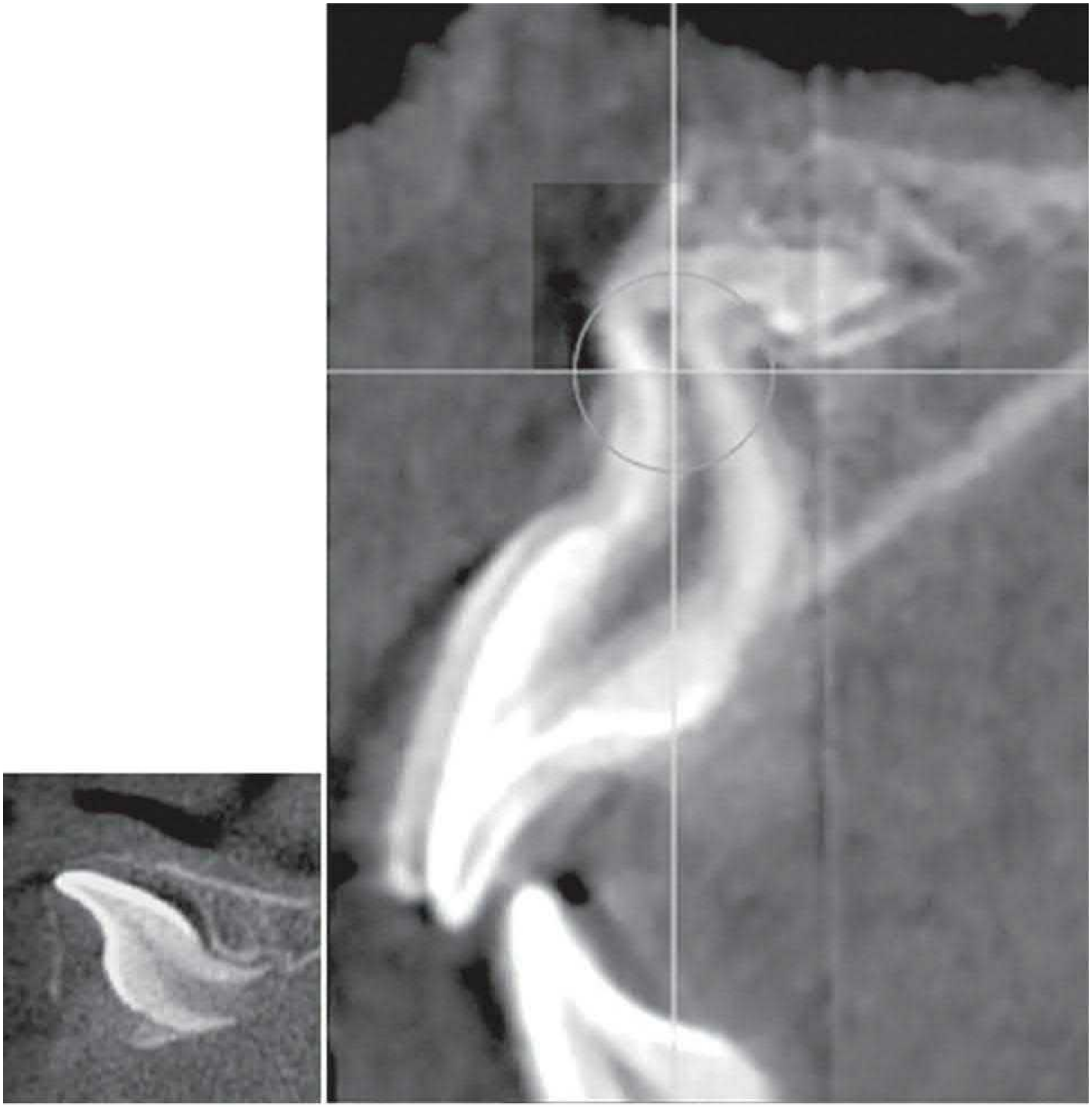
(c) In the cross-sectional view from the cone beam computed tomography (CBCT), the pre-eruptive intra-coronal resorption (PEIR) is clearly seen to infiltrate much of the coronal dentine, with the incisal tip port of entry. The root tip is in close relation to the lower border of the mandible. (d) A longitudinal CBCT cut of the same tooth shows its hooked root end and the advanced resorption process within the crown.

One of the conclusions of the discussion was that if treated very early, not only can the severity of the dilaceration be mitigated, but the redirected growth of the uncalcified and still-developing root apex may even be turned around in the opposite direction (Figure 13.7) [4, 5]. This would eliminate the necessity for apicoectomy and maintain the tooth's vitality for the long term. One may be permitted to wonder whether, as an added bonus, the reversal of the root end, despite its bizarre anatomy, may act as a buttress to retain the final position of the tooth. The initial root curvature had developed only after the original traumatic incident, in infancy. The reverse root angle and apical section only grew and calcified during and after the application of labial root torque. Therefore, apicoectomy with root canal therapy would be strongly contraindicated. Unintended devitalization as the result of renewed trauma or due to deep caries would probably be the only reason to justify an apicoectomy procedure and this solely in order to facilitate root canal therapy.

Three cases were presented in Chapter 6 (Figures 6.17, 6.19 and 6.20), each of which had suffered severe trauma that had caused dilaceration or complete arrest of growth of the roots of all the maxillary incisors, as well as a total lack of downward migration. The maxillary incisors remained very high up in the anterior maxilla and very close to the floor of the nose. The teeth in these three cases were vital, with open but non-developing apices of their almost totally absent roots. The application of extrusive force on these teeth brought about their eruption, which was followed by an impressive, if narrow, growth of elongated roots.

Benign tumours and other soft tissue lesions

When a dentist diagnoses the presence of an impacted tooth, the radiograph on which it is confirmed is usually combed to find the reason for the anomaly. In general, the dentist will be looking for a hard tissue body close by. Soft tissue entities do also exist and, as we have presented above, include enlarged dental follicles/dentigerous cysts. However, benign tumours and other forms of soft tissue lesion will arrest or deflect the eruption path of an erupting tooth. Several illustrations of these entities are presented in Chapter 11 (Figures 11.4 and 11.5). It is also possible that chronic periapical abscesses could be potential causes of arrest or deflection, except for the fact that, in general, these are not present for long enough. Chronic periapical abscesses are usually associated with pain and thus as soon as they occur, the patient will seek treatment to eliminate them, and this will usually be well ahead of the initiation of an anomaly of root form.



(a) (b)

Fig. 13.7 From the case illustrated in Figure 6.17. (a) Inset, early developing dilacerate central incisor with labially directed curvature of the root. (b) Post-treatment cross-sectional cut of the same case, to show the lingually directed alteration of the root form coinciding with the timing of application of labial root torque.

Cleidocranial dysplasia

The characteristic features of CCD are non-exfoliation of the deciduous teeth, non-eruption of the permanent teeth and the unerupted presence of supernumerary teeth. The developing teeth are generally to be found in the deeper reaches of both jaws, which would suggest that their developed roots would have abnormally shaped roots. (For a full discussion of CCD in all its facets, see Chapter 21.)

CCD patients who remain untreated or are treated in their late teens or 20s will invariably present with abnormally shaped roots. However, as is mentioned in Chapter 14, where there is timely surgical exposure and orthodontic traction during the period when the roots have reached their 'normal' stage for eruption in other patients, one should not expect to see abnormally shaped roots. An essential element of timely treatment is the employment of intermaxillary extrusive forces (i.e. vertical up-and-down elastics) that are designed to increase the height of the lower third of the face by artificially supplying forces to erupt the teeth. Upper-versus-lower intermaxillary forces move the root apices away from the skeletal bases in both arches and, as such, eliminate this cause of root abnormality.

Idiopathy

In addition to the list of causes of root anomalies discussed earlier, there are also occasional instances where it is not possible to arrive at a diagnosis of the cause of the impaction. This will be mostly due to the lack of any of the clinical and radiographic signs that one would usually expect to find. The following is a description of such a case, with non-eruption of the teeth in the mandibular right premolar/molar area, whose aetiology and diagnosis were unknown.

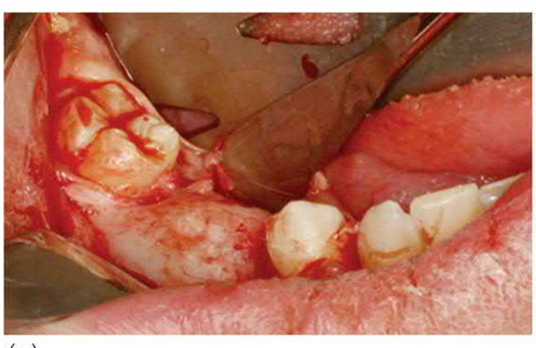
In the absence of a firm diagnosis, the sole approach available to the orthodontist is to treat the case empirically. Essentially, this means amassing the information available and refining it in stages as the effects of each treatment phase are observed and recorded. In a situation of this kind, one will need to start by applying a force and attempting to move the teeth. If two or more teeth share a single traction arm that links them together and one of the teeth refuses to respond, then it will prevent the others from moving. It should be remembered that the unwanted side effect of using a continuous archwire, in order to erupt a single resistant impacted tooth, will be to intrude the adjacent teeth. No assessment can yet be offered to the patient of the chances of success until we have completed the further stages of the empirical analysis over the period of several months of preparatory treatment to align and level, to open space, to insert a full-thickness base archwire and to begin applying traction to the tooth. Only after the extrusive force has been active for several weeks or perhaps a month or two will we learn whether or not the tooth has shown signs of movement. The outcome may be total disappointment, particularly if there was little or no real malocclusion to treat, aside from the impacted tooth.

Case 13.1: Impaction, retarded eruption and consequent over-eruption of posterior permanent teeth

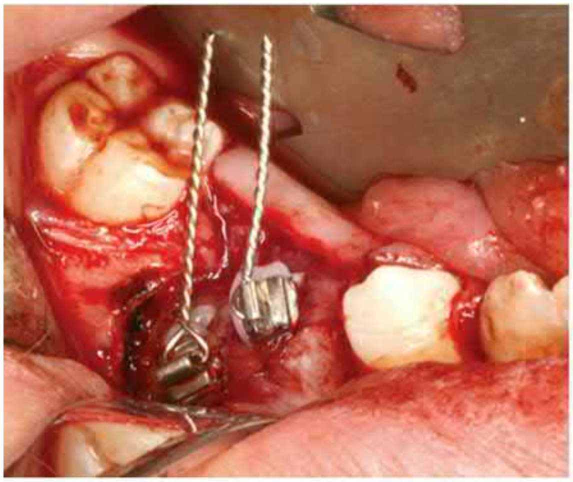
At the first visit of a 10-year-old boy, his father pointed out that the two deciduous molars on the mandibular right side had been extracted, due to caries, five years earlier. There were no erupted permanent teeth distal to the lateral incisor on that side (Figure 13.8a, b). All the unopposed teeth of the same side in the maxillary dental arch had markedly over-erupted, with the first maxillary permanent molar in occlusal contact with the mucosa of the opposite jaw. This had resulted in a distinct cant in the occlusal plane in which the right side was several millimetres lower than the left. The dental age of the child was assessed at 9 years and therefore only the mandibular first molar could be classed as impacted (see Chapter 1).

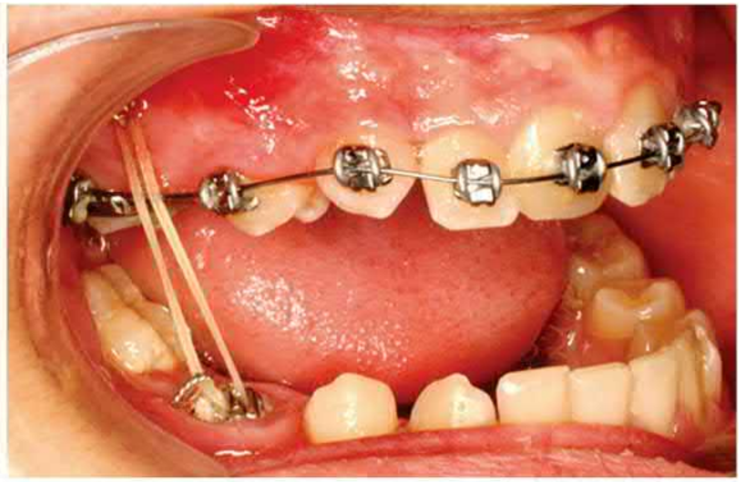

(a)


(b)


(c)


(d)





(e) (f)

(g) (h)

(i)

(j)

Fig. 13.8 (a) Panoramic radiograph at age 10 years. The right mandibular quadrant has no erupted permanent teeth distal to the lateral incisor. (b) Pre-treatment intra-oral views of the dentition seen by the author at age 13 years, in the late mixed-dentition period. The mandibular right side remains edentulous. The cusp tips of #47 are barely discernible. (c) In surgery, a broad occluso-buccal flap was reflected to immediately reveal the canine, first premolar and second molar. The flap was not re-sutured over these teeth (open exposure). (d) The second premolar and the deep first molar were exposed following removal of their bony cover. (e) Simple attachments were bonded with twisted steel ligatures drawn occlusally. (f) The flap was re-sutured back to its former place (closed exposure), with only the two twisted ligatures visible. These were shortened and fashioned into two traction hooks. Note that the canine, first premolar and second molar were left exposed. Traction was then applied with light elastic forces, from a zygomatic temporary attachment device to the hooks and placed by the patient. (g) Panoramic and (h) periapical radiographic views at the completion of active treatment. (i) Intra-oral views to show the final alignment, with corrective levelling of the occlusal plane. (j) The intra-oral photographs of the patient 9.5 years post treatment, with only a bonded lingual retainer holding the alignment of the lower anterior teeth.

The mandibular right first permanent molar was present, but located deep down in the body of the mandible, close to the lower border, despite apexified roots. The tooth exhibited an exaggerated, distally curved root pattern. Its occlusal surface was covered by a thick band of alveolar bone, but its follicle appeared slightly enlarged and it seemed unlikely that this could have provided the aetiological answer to its impaction, nor the reason for the altered root pattern. The unerupted adjacent premolars had only developed one-third to one-half of their roots and were also covered by the thick band of alveolar bone. By definition, therefore, these premolar teeth were not impacted or even delayed in their eruption. In the maxillary left side, a single deciduous second molar had also been extracted and the space was lost by mesial drifting of the first permanent molar on that side.

A further three years passed before the child returned for treatment, at age 13 years. On examination nothing appeared to have changed, although the tips of the two buccal cusps of the mandibular second permanent molar were just visible above the gingiva (Figure 13.8b). Neither the premolars nor the first permanent molar of that side had yet erupted. The premolars and canines of the other quadrants of the mouth were in the early stages of eruption.

The treatment plan was to orthodontically encourage the eruption of the two premolars and two molars. This was most effectively achieved with up-and-down vertical intermaxillary elastics. However, in view of the cant in the maxillary occlusal plane due to over-erupted teeth, intermaxillary dental traction would have aggravated this vertical asymmetry. Accordingly, this entire surgical procedure was performed under a general anaesthetic, a plate was fixed to the zygomatic process of the right side and the premolars and permanent molars were surgically exposed. Simple bonded attachments were placed only to the first molar and second premolar, which were located well down in basal bone of the mandible, and vertical elastic were drawn between them and the zygomatic plate (Figure 13.8c–f).

The teeth responded well and were quickly erupted. Routine orthodontic treatment followed, to achieve a good treatment result (Figure 13.8g–i). The molar, despite its contorted root pattern, had offered no resistance to the orthodontic traction applied to erupt it.

Why the molar had been so severely infra-occluded was never discovered and at the outset the parents of the child had been advised that the prognosis for success in the treatment was therefore unknown. They chose to treat and, in the event, the empirical approach was successful. A satisfactory result was achieved, despite the absence of a defined aetiology.

The patient never attended for post-treatment follow-up but, on an isolated visit accompanying his younger sister for treatment 9.5 years later, he offered the opportunity to be re-examined. His teeth had remained in excellent alignment and occlusal relations, although his non-vital right central incisor had been restored with a post and porcelain crown (Figure 13.8j). A bonded lingual twistflex retainer, placed at the conclusion of the treatment, was still present and successfully maintaining the alignment of the mandibular incisors.

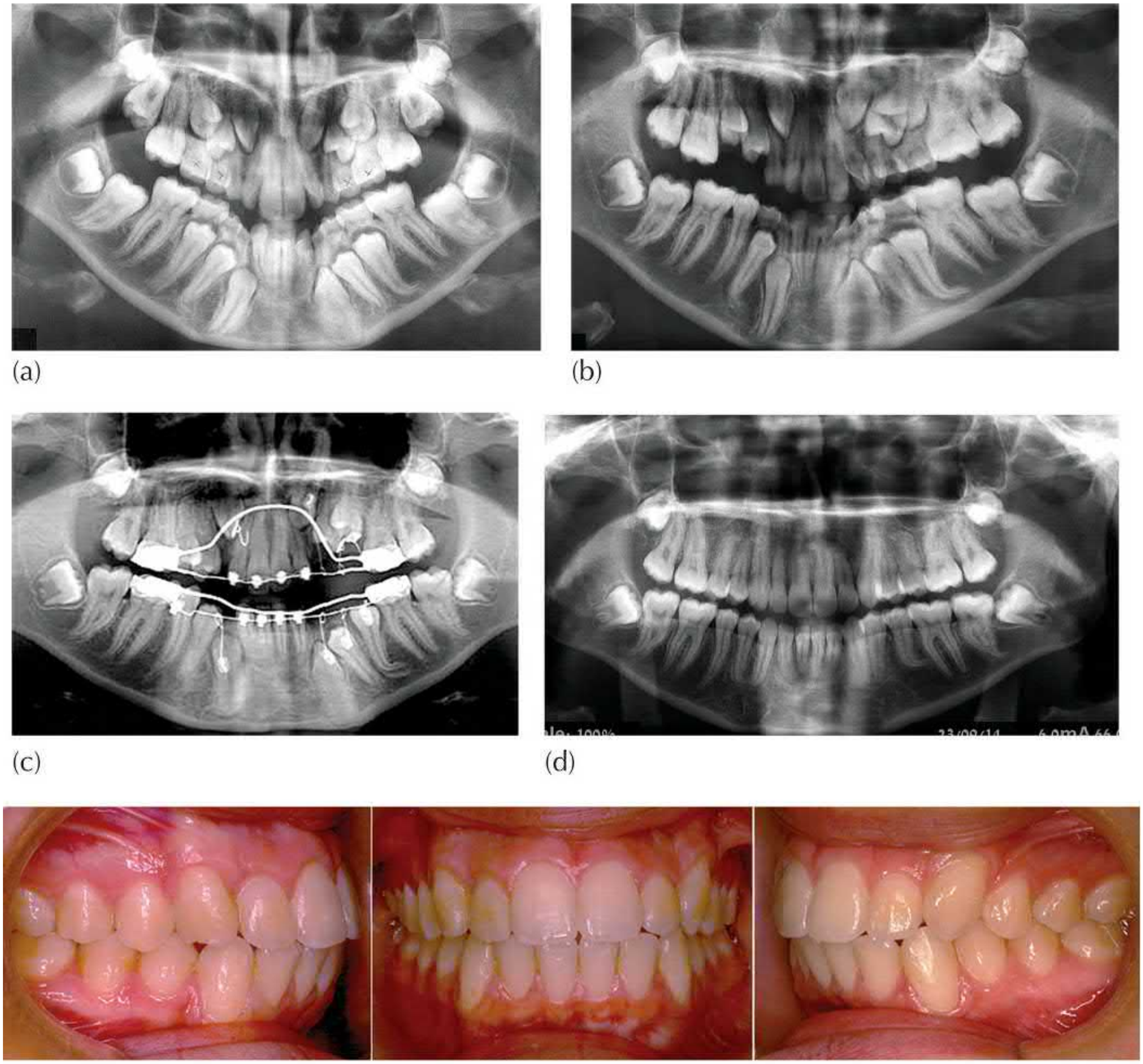
Case 13.2: Twelve deciduous and twenty unerupted permanent teeth at age 16

The second case of impaction concerned a 16-year-old female for whom the aetiology was unknown, with no anamnestic, clinical or radiographic clues to assist in defining the diagnosis. She had been entirely unaware that she still had 12 over-retained deciduous teeth, until her dentist brought it to her attention and discussed the need for treatment. She was normal, healthy and non-syndromic. At the time, this young adult's erupted permanent dentition comprised only the incisors and the first molars, together with the full complement of the remaining deciduous canines and molars.

A panoramic radiograph revealed unerupted permanent canines, premolars and second molars – 16 teeth in all, with complete or advanced closure of the root apices (Figure 13.9a). Moreover, many of the teeth exhibited hooked root apices, located in the compact bone of the lower border of the mandible or adjacent to the floor of the maxillary sinus.

The second permanent molars were unerupted and, with the exception of the right mandibular second molar, their apices were fully closed. The unerupted third molars were at a very early stage of root development. The apices of unerupted canines, premolars and second molar teeth were located deep in the area of the basal bone in both jaws, in contrast to the roots of the erupted teeth. The dental age of this 16-year-old was approximately 15 years. The unerupted teeth should normally have erupted at two-thirds root development, which was between four and six years earlier. The completed development of the roots of the canines, the premolars and the second molars indicated that each of these could be defined as impacted and several of them exhibited hooked apical root development. The deciduous teeth were therefore over-retained, for which three or four years earlier extraction would normally have been the appropriate treatment.

The patient's dentist extracted the maxillary right deciduous molars and the mandibular right second deciduous molar, and scheduled her for further visits for the purpose of extracting the remaining deciduous teeth. The patient only returned 17 months later, because the premolars on the right side had still not erupted, despite the promise that rapid eruption would occur (Figure 13.9b). She then refused to submit to further extractions unless orthodontic treatment was carried out in order to erupt the other permanent teeth.



(a) (b) (c) (d) (e)

Fig. 13.9 (a) The initial panoramic radiograph of a female patient at age 16 years. (b) At age 17.6 years and 17 months after extraction of three deciduous teeth, #54 and #55 and exfoliation of #85. (c) A year later, at the age of 18.5 years. Seen following extraction of all the deciduous teeth, exposure of all the permanent teeth and bonded eyelet attachment, with appliances in place. (d) Panoramic view at completion of 22 months of active treatment. (e) Intra-oral photographs at 19 months post treatment.

The author accepted the patient for treatment. Applianceswere placed on the teeth and the patient was referred to an oral and maxillofacial surgeon for the extractions and for the exposure of the permanent teeth. Extraction of the deciduous teeth and exposure of the impacted teeth was performed by the surgeon under general anaesthetic (upon her insistence). Eyelet attachments were bonded and immediate traction was applied to the teeth by the orthodontist, while the patient was still on the operating table and before she was transferred to the recovery room. A new panoramic film (Figure 13.9c–e) was taken on the same day, which showed the considerable distances these teeth needed to be moved to the labial archwire.

This case indicates that an unknown or undiagnosed entity had prevented the teeth from erupting. Perhaps it was the roots of these deciduous teeth that were peculiarly resistant to resorption, or perhaps it was the follicle of the permanent tooth that had not activated an (as yet) undiscovered and unidentified deciduous tooth resorption factor. The consequence was that the apices of the impacted teeth had been forced to grow in close proximity to the skeletal boundaries; hence the development of hooked roots. At the same time, it is important to learn that hooked roots, in the absence of a complicating additional factor, will not compromise the normal response of the tooth to extrusive mechanics.

Empirically undertaken treatment undoubtedly has its place, as these case reports have indicated, but orthodontists must be prepared for failure because they have not identified the specific cause of the problem. A cause does exist, otherwise the tooth would have erupted.

Fake causes

Maxillofacial surgeons and orthodontists, patients and their parents are justifiably concerned regarding the severely infra-occluded mandibular molar and its relationship to the infra-alveolar nerve and vascular bundle. The ill-considered extraction of a molar whose roots encircle the bundle is certain to cause rupture of the bundle, with copious arterial bleeding, which will be difficult to arrest. It will also cause long-term and probable permanent nerve damage and loss of sensory perception in the lower lip and tongue.

The relevant question in the present context, however, is whether the encirclement of the neurovascular bundle is the primary cause of the failure of the tooth to erupt. In order to answer this question, the reader must consider why the roots of the tooth had actually arrived in a position to grab the bundle. Root encirclement is obviously not normal, but it would be fallacious to consider this as being a primary cause – it is a 'fake' aetiology.

Under normal developmental circumstances, the inferior alveolar blood vessels and the largest (mandibular) division of the trigeminal nerve are located in skeletal bone. They run together in tandem, well below the roots of the teeth. The teeth are normally located in alveolar bone and follow a vertically upward eruption path, in the direction of the occlusal plane, and are also being carried upwards by the general growth. The combination of these two factors ensures distancing of the roots from the nerve bundle. Furthermore, teeth that move in this way grow straight roots. They do not exhibit abnormal root configurations.

There is always *another*, totally different and often evasive factor that was the initiator and primary cause of this potentially complex and unfortunate outcome. For such a scenario to occur, this 'other factor' must be an entity, likely in the immediate vicinity of the nerve bundle, that is able to delay, hinder or impede the vertical development of the tooth concerned and thereby to override its innate potential for eruption.

This other factor is the primary cause of both the impaction and the nerve bundle involvement. The factor will commonly be a dentigerous cyst enveloping the crown of the affected tooth or a radicular cyst of an adjacent tooth. It may perhaps be due to retromolar crowding of unerupted second and third molars, or a locus of ICRR, sometimes exhibiting a portal of entry in the furca of the molar. It is also this other factor that, therefore, forces the root development to be confined to a much reduced space, which is bordered by the roots of other teeth, by the compact bone of the lower border, enclosed and impeded on all sides. It also abuts the neurovascular bundle, around which the developing roots would then be liable to become entangled. Neurovascular bundle involvement is a situation of profound clinical concern. From the aetiologic standpoint it is, nevertheless, a secondary phenomenon, i.e. the outcome of the primary cause.

Case 13.3: Roots of unerupted permanent first molar entangled in inferior alveolar nerve and vascular bundle

This case shows an unerupted mandibular first molar that had apparently been drawn down to the lower border because of the entanglement of its roots with the inferior alveolar canal and its neurovascular bundle. It may be difficult to divorce oneself from acceptance of the populistic aetiological explanation, which superficially appears to fit the 'cause-and-effect' mould so well. However, this explanation is not plausible and the reasoning is also superficial and frivolous. During normal development, the molar could never be so deeply placed in the mandible for its newly forming roots to have been in the position to wrap themselves around the inferior alveolar neurovascular bundle. Whatever it is, the other factor must have been the primary cause responsible for preventing the molar from moving upwards with its own eruptive potential and the vertical alveolar bone growth. Therefore, no – the entanglement of the neurovascular bundle is the result, not the aetiology. It is incumbent on the clinician to identify the primary cause in order to plan appropriate treatment.

The CBCT 3D image of a severely infra-occluded left first permanent molar, showing the 60° curved mesial root of the tooth, actually forming a part of the lower border of the mandible (Figure 13.10a). The development of the roots had clearly followed the horizontally directed anatomical barrier, causing a disturbance of its otherwise smooth continuum. This root was palpable at the clinical examination. The roots can be seen astride the inferior alveolar nerve and vascular bundle, closing in on it inferiorly. The yellow arrow points to the ICRR lesion at the CEJ of the mesial side of the tooth.

When the 3D image was sliced vertically and sagittally (Figure 13.10b), the extent of the lesion was seen to have involved much of the dentine of the coronal part of the root and cervical part of the crown, apparently including the pulp chamber, although the tooth was asymptomatic.

If we are to attempt to trace the course of events that gave rise to this bizarre situation, it would seem that the starting point was the initiation of the ICRR lesion, which must have assailed the first permanent molar very early in the child's infancy and thwarted its upward eruption and, thereby, also the growth of alveolar bone in the immediate area. The roots nevertheless continued to grow. The bend in the roots may be seen to have started shortly after the main root trunk had divided into its mesial and distal branches at its bifurcation, which would normally have been at about the age of 4–5 years. The root development then turned distally, in a line parallel to the horizontal mandibular inferior border on both the lingual and buccal sides of the inferior alveolar canal, joining up again on its underside.

(a) (b)

Fig. 13.10 (a) A 3D screenshot taken from the cone beam computed tomography video clip of a patient with an impacted first mandibular molar whose roots had ensnared the inferior alveolar canal, which is traced and marked here in red. The yellow arrow indicates a lesion of invasive cervical root resorption, on the cervical area of the exterior of the crown. (b) The involvement of the resorption lesion within the tooth may be seen as indicated (arrow). Note the close proximity to the lower mandibular border. See Online PPT & video Fig. 13.10.

Is there an appropriate treatment strategy for this apparent Catch 22?

It is clear that any attempt to extract the tooth is out of the question, yet the adjacent second molar is severely mesially tipped. No doubt, too, the second premolar will also eventually erupt and become distally tipped when its deciduous predecessor exfoliates, thereby completing the closing-in of the affected molar by a tipped tooth from both sides. Although these adjacent teeth may be uprighted orthodontically, the impacted molar cannot be raised, because it cannot be separated from (a) its grip on the contents of the inferior alveolar canal or (b) the lower border of the mandible, all because of (c) the non-responsive ICRR lesion. Neither can the space be closed by drawing the second molar mesially, without its roots clashing with the crown of the unerupted molar.

Perhaps there is a good argument for leaving the unfortunate tooth untreated. After all, the resorptive ICRR process cannot spread to other teeth or damage any other structures, and the fact that ICRR is eating away at this tooth may actually be to the patient's overall benefit in the fullness of time. One drawback is the relative lack of alveolar bone around the tooth, in particular, above it. This may make the area prone to pathological fracture. Arguably, the major drawback is the absence of a functioning occlusion on the left side of the mouth.

The plan must therefore include uprighting and paralleling the second molar and the (as yet unerupted) second premolar, to re-create a molar space. At that point, a conventional fixed bridge may be made using these two uprighted teeth as abutments, while ignoring the retained molar.

A surgical option, with potentially important advantages, also exists. Surgical excision of the infra-occluded first molar must be approached with great caution and it can be made through an intra-oral approach. The second permanent molar needs to be moved posteriorly to create enough space for the surgeon to be able to approach the impacted crown from the occlusal direction.

The aim would be first to identify the occlusal surface of the crown while maintaining the buccal and lingual walls intact. The crown will be cautiously ground away with a bur from the occlusal surface down, horizontally through the walls of the pulp chamber and on to the superior portion of the main trunk of the root of the affected tooth. Height reduction of the crown of the tooth will be taken down to the base of the pulp chamber, leaving the vital pulp bleeding from newly truncated root canals of the tooth. At the same time, an autogenous bone graft, taken from the patient's retromolar, tuberosity or chin area, will be inserted to rebuild the alveolar ridge defect, above the remnant of the impacted molar. This would eventually become the recipient site for an artificial dental implant. Alternatively, the second molar and the presently unerupted third molar could be drawn mesially through the graft to close off the 'extraction' space, as part of the overall orthodontic treatment.

There is no intention to remove the area of root on the mesio-buccal aspect that is affected by ICRR. On the contrary, the outcome of this de-coronation procedure would be the continuance of the ICRR resorptive process eating away at the deeper remaining parts of the retained roots.

The treatment of this young patient is about to begin and it will be following this surgical/orthodontic treatment plan.

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14
Rescuing Teeth Impacted in Dentigerous Cysts

Adrian Becker

Dentigerous cysts

Radicular cysts

Treatment principles

The prognosis of teeth that have been severely displaced by cysts

Eyelets or brackets?

Conclusions

Cysts are found in a variety of tissues and in many sites in the human body. They are fluid-filled, epithelium-lined, balloon-like lesions that, due to hydrostatic pressure from within, generally enlarge progressively and painlessly. If they are developing in a homogeneous medium, the laws of physics dictate that they will be spherical in shape. If the medium is bone, then the bone will resorb in response to pressure from within, thereby progressively permitting the enlargement. Simultaneously, on the outer side of the bone there is a reactive apposition process, which causes the bone to become expanded. This apposition is slower than the resorption from within; accordingly the bony expansion is accompanied by a thinning of the bony walls of the cyst, which may eventually become paper thin. In the final instance, the cyst will resorb the last remnant of the hard tissue and become fluctuant beneath the skin – in the context of this book, the oral mucosa.

There are two main types of benign cyst that the dentist encounters in relation to an impacted tooth: dentigerous cysts and radicular cysts.

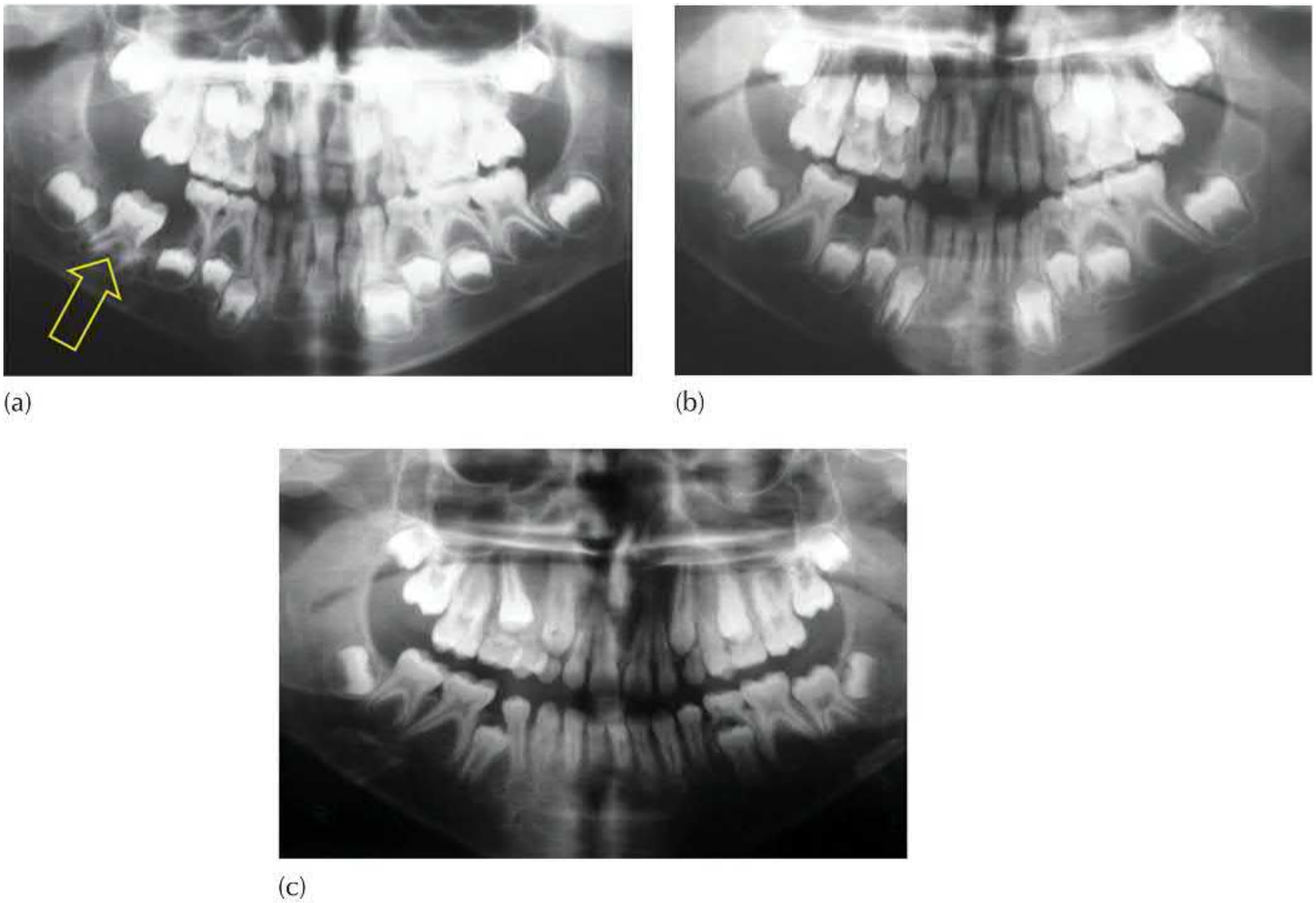


Fig. 14.1 (a) A dentigerous cyst surrounding the crown of the mandibular right first molar has arrested eruption and perhaps slowed down root development, compared with its antonym. Note the reduced height of the surrounding bone and the resorbed distal root of the second deciduous molar (arrow). (b) Follow-up radiograph, taken two years post surgery, show space loss having occurred from both the distal and the mesial, impacting the second premolar. The bizarre root morphology of the molar is similar on both sides. (c) At 5 years post surgery, root growth and bone support have rebounded impressively.

Dentigerous cysts

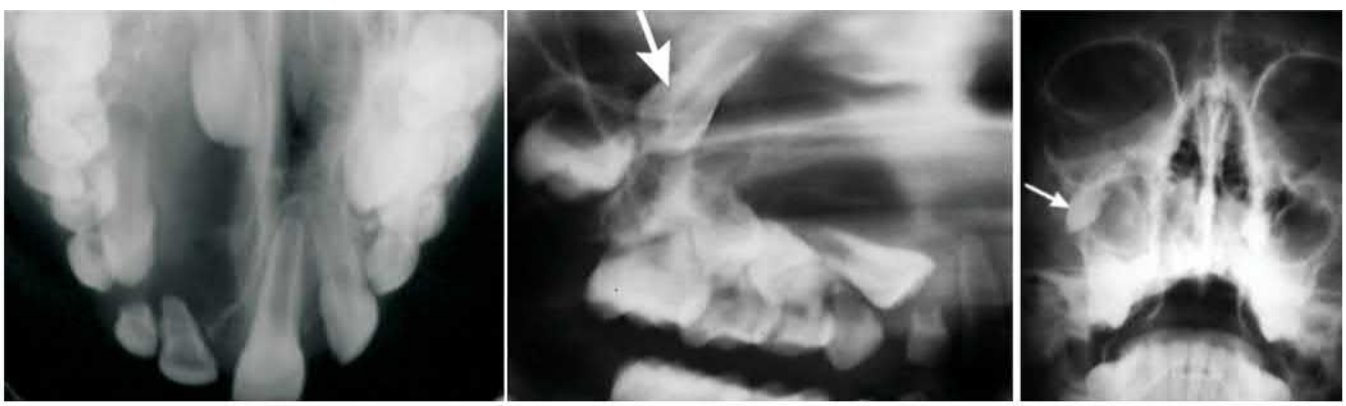
A dentigerous cyst is a specialized type of cyst to be found around the crown of an unerupted tooth. It will develop as an expansion of what is normally the very narrow space between the inner and outer enamel epithelia of the dental follicle, in which the completed crown of the tooth has developed. The inner and outer layers meet at the cemento-enamel junction (CEJ) at the neck of the developing tooth [1–3]. The cystic area increases its size due to the production of fluid by the epithelium, which forces the layers apart into the typical spherical shape. The crown of the associated tooth protrudes into the cyst, with its long axis pointing to the centre of the lesion (Figure 14.1).

There is a sub-type of dentigerous cyst that is also due to a benign enlargement of the normal dental follicle. It occurs when eruptive movements of the tooth bring it through the bone and into close proximity with the oral mucosa, but it does not spontaneously break through. This early dentigerous cyst is fluid filled and fluctuant to palpation, and is termed an eruption cyst. It usually resolves spontaneously by rupture into the oral cavity. The tooth then erupts normally, its gingival attachment becomes normal and no subsequent signs of the earlier pathology remain.

However, should the cyst become larger, the pressure from within overcomes the tooth's inherent eruptive force potential and will stop its normal eruption. Indeed, it may even cause the tooth to 'back up' along its former eruption path, and displace it apically, while remaining in the middle of the cyst (Figure 14.2). It seems, therefore, that the term 'eruption cyst' may denote a state of pressure equilibrium between the force of eruption and the opposing force of intra-cystic pressure. With a smaller eruption cyst, the forces of eruption might prevail, as already pointed out. However, a larger eruption cyst may require surgical incision and drainage to bring about decompression, which will then permit the tooth to erupt spontaneously and, in the younger patient, quite quickly.

The long axis of the affected tooth itself is generally perpendicular to the epithelial outer wall of the cyst at its CEJ (Figure 14.2). A good portion of the apical section of its root remains firmly in bone. The pressure-generated enlargement of the cyst will, by a resorptive squeezing out of the crestal area of bone, cause its lining to circumferentially and progressively outline more and more of the otherwise bared coronal portion of the root (Figure 14.1).

With further expansion of the cyst, its lateral aspects will push against adjacent unerupted teeth. The latter will then be displaced as their supporting bone becomes thinner and as the cyst lining comes into direct contact with their periodontal ligament (PDL). Each of these secondarily involved teeth then becomes profiled in the walls of the cyst, with only a thin epithelial lining to cover one side of the bared tooth along its full length (Figure 14.2b, c). The other side of the displaced adjacent tooth is invested by bone. The PDL will intervene over the root area and its own dental follicle will intervene in the crown area. The degree of displacement of these teeth will depend on the size of the cyst, but they lie in, and are oriented parallel to, the walls of the cyst, in contrast to the perpendicular orientation of the directly involved tooth.



(a) (b) (c)

Fig. 14.2 A large cyst occupies much of the right side of the maxilla. (a) The anterior occlusal film shows the central incisor 'backed up' in line with its long axis. (b) This right half of the maxilla, taken from a panoramic film, shows the lateral incisor and both premolars laid out horizontally in the floor of the cyst. The canine has become displaced posteriorly into the molar region (arrow). The location and orientation of these teeth define the perimeter of the cyst. (c) A Waters' projection radiograph of the skull shows the degree of buccal displacement of the canine (arrow), indicating the lateral boundary of the cyst.

Histologically, the cyst lining is squamous or stratified squamous epithelium and as such is similar to the follicle from which it originated. Thus, the only criterion for distinguishing between an enlarged follicular sac and a dentigerous cyst is its size, as seen on a periapical radiograph. A practical way of defining a dentigerous cyst is when the distance on the film between the crown of the tooth and the dental sac is larger than 2.5–3 mm. This is the definition most frequently used in radiology and surgery. It is possible, however, to refine this definition with more discerning biological criteria, which take into account the implications of the increased hydrostatic pressure within the lesion. A refined definition will assist in deciding whether the eruptive progress of the affected tooth should be halted or reversed. The radiolucent outline of the lesion may appear to connect with the tooth some way down the root, apical to the CEJ; this might be considered a more valid diagnostic sign.

The aetiology of a dentigerous cyst is presently not clear, although it is generally associated with chronic local inflammation. The inflammation may be seen when the deciduous predecessor has become non-vital and an apical granuloma has initiated cystic change in the follicular sac of the unerupted permanent successor. Alternatively, an incomplete root canal treatment may leave the deciduous tooth symptomless, but the chronic periapical lesion may remain unresolved and this may act as the irritant that induces a cyst to develop from the follicle of the permanent successor (Figure 14.3a, b). Unerupted permanent teeth, particularly maxillary canines, often exhibit enlarged follicles, and these may sometimes become further enlarged (Figure 14.4). This seems to occur frequently when there is a close association with the roots of the lateral incisors, although no specific explanation for this is forthcoming.

(a) (b)

Fig. 14.3 (a) An incomplete root canal treatment has been performed in the mandibular left deciduous canine, as seen on this panoramic view. (b) A routine follow-up panoramic radiograph, taken prior to impending orthodontic treatment, reveals the development of a dentigerous cyst around, and displacement of, the left permanent canine.

Courtesy of Dr M. Barzel.

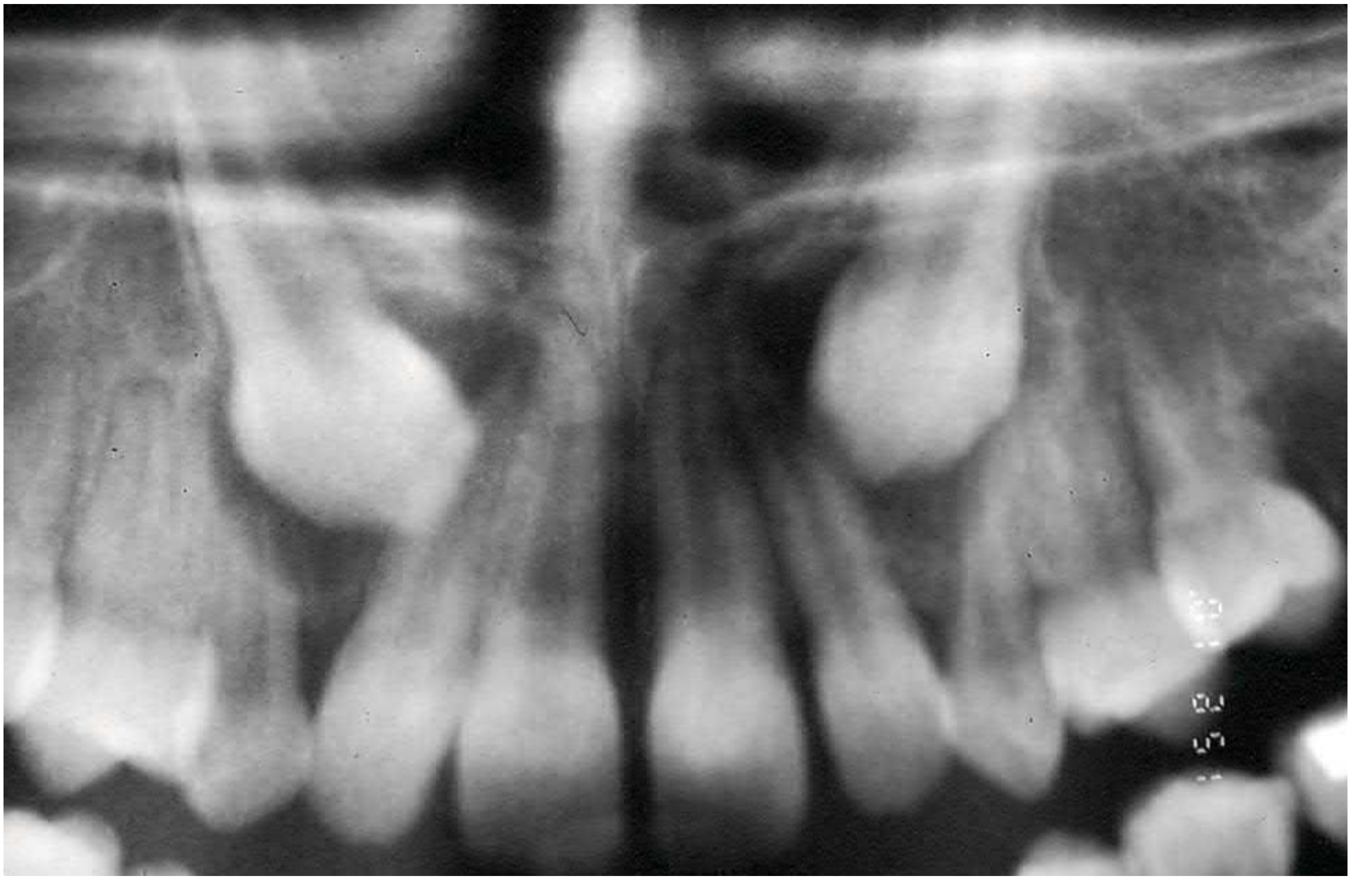


Fig. 14.4 The anterior portion of a panoramic view showing cystic enlargement of the follicles of the two maxillary permanent canines.

Radicular cysts

After root formation of a tooth is completed, Hertwig's root sheath disappears, leaving behind only the epithelial rests of Malassez in the immediate area. These remnants may sometimes be stimulated to become cystic by the presence of a periapical granuloma [4]. The radicular cyst is therefore to be found at the apex of a non-vital tooth and, like the dentigerous cyst, it too may grow at the expense of the surrounding bone. It may then displace, and partly envelop, unerupted adjacent teeth, with the crowns and roots covered by the cyst epithelium. In such a case, all the displaced teeth will be find themselves located in the walls of the cyst and oriented at a tangent to the cyst lining that covers them. However, no tooth will have its entire crown enveloped within the cyst and the cyst lining will not be attached to the cervical area of any one of the teeth involved.

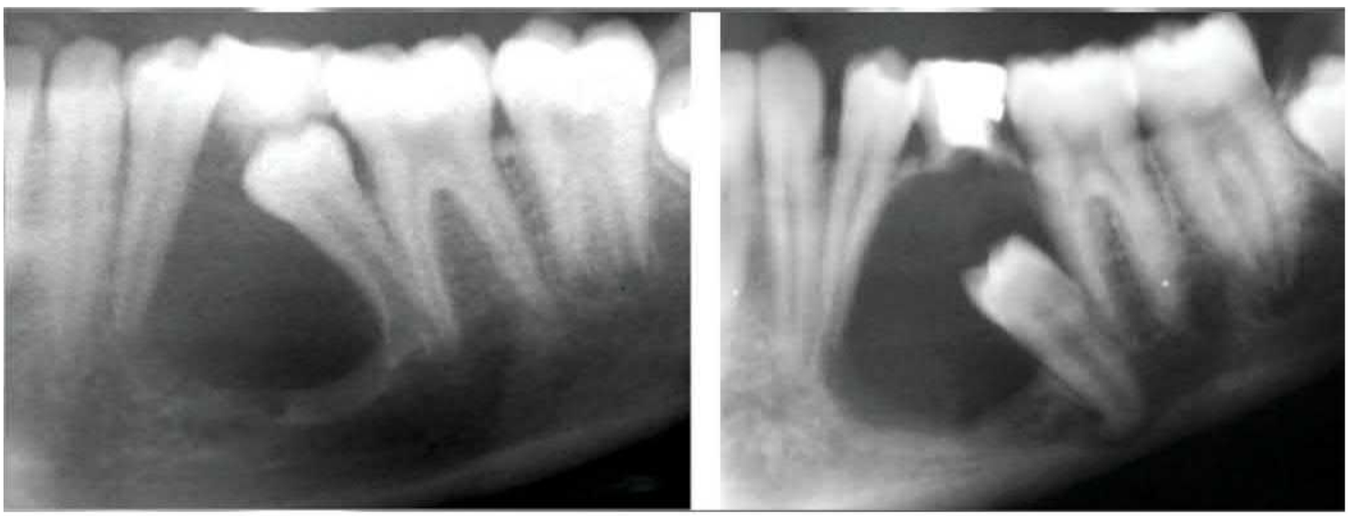
To illustrate the difference between the radicular cyst and the dentigerous cyst, two different individuals are presented in Figure 14.5, each having been diagnosed with what appears to be an identical large cyst associated with the left mandibular second premolar. The cyst shown in Figure 14.5a is a radicular cyst. Here, the second premolar is mesially inclined. The enlarging cyst has primarily displaced the crown and root distally against the mesial side of the first molar, behind the cyst lining. The likely aetiology was a failed and infected root treatment in the second deciduous molar, which has irritated the rests of Malassez in the apical granuloma to become cystic. In Figure 14.5b, the crown and coronal part of the root of the second premolar are encompassed within the cyst and the orientation of the tooth points towards the centre of the cyst. A degree of asymmetry exists, which may be due to the relative ease with which the first premolar root has been moved away from the lesion. The more robust, two-rooted molar, on the other hand, has better withstood the cyst pressure. The loss of crestal alveolar bone has occurred all around the coronal portion of the root. This clearly indicates that it is dentigerous.

Histologically and clinically, the radicular cyst is similar to the dentigerous cyst and the clues to its identity are largely clinical. Accordingly, the following discussion of treatment and outcome will not differentiate between the two in any substantial manner.

Treatment principles

Surgery

Professional intervention may influence the future of the displaced tooth, depending on the type of treatment employed to resolve the cyst. The cyst may be opened and its lining completely shelled out in a procedure called enucleation [5]. The excised tissue is then sent for histological examination to confirm its innocence. The crown of the tooth is left fully exposed within the cystic cavity. The tooth itself exhibits a high degree of mobility, due to its very rudimentary and much reduced supporting periodontal attachment. A complete and hermetic closure of the surgical flap is then usually attempted, thereby sealing the former cyst cavity from the exterior in order to protect the exposed bone and soft tissue from infection. The intention is to encourage the cavity to fill with a blood clot and healing is by primary intention.



(a) (b)

Fig. 14.5 Two similar situations arising from different causes. (a) A radicular cyst. (b) A dentigerous cyst.

If the cyst is very large, the chances of breakdown of the clot and consequent infection become significant. Even in successful cases, the associated unerupted tooth will become deeply buried in the newly forming bone and will need to erupt a considerable distance through this repairing bony tissue. In such circumstances, spontaneous eruptive movement of the tooth may be very slow and if the tooth is grossly displaced by a large cyst, it may remain in an inaccessible position. Its extraction may then be unavoidable [5]. The prognosis for its eruption would appear to be in inverse proportion to its distance from the oral cavity.

In the event that the blood clot breaks down due to infection, the area will be left with a highly undesirable expanse of bare necrotic bone. The entire former cystic area will remain exposed to the exterior and will require some form of protective dressing or pack and long-term antibiotic cover. In this situation, most of the teeth involved will need to be extracted, which, in the final analysis, will leave a large defect of the basal bone and may alter the shape and contour of the patient's face. In the long term, this will have major functional, cosmetic and psychological consequences [5]. There will be a need for artificial replacement of the missing teeth and possibly even a maxillofacial prosthesis, in order to overcome the basal defect.

In view of this possible scenario, enucleation is generally recommended only for relatively small cysts. For larger cysts, a two-stage procedure is often advised. The first stage is aimed at decompression and drainage of the cyst without removing its epithelial lining. Several months later, in the second stage, the cyst has reduced in size, the lesion will be reopened and the remaining epithelium shelled out, in what has been termed the 'curative enucleation of the cyst lining' [5]. There can be little doubt that total removal of the epithelium is not always easy to achieve, since the exercise may threaten the unerupted teeth that are lodged in the walls of the cyst (Figure 14.6). These teeth have a very limited, rudimentary and tenuous periodontal attachment to the adjacent bone. Thus, the teeth themselves may be inadvertently plucked from their places and, conversely, some detached areas of epithelium may remain within the healing tissues, which may later regenerate.

The surgical treatment option that is to be preferred for the larger lesions of this type is called marsupialization [6–9]. This involves opening the cyst into the oral cavity at its most superficial point and maintaining the patency of this orifice over a long period of time. No attempt is made to remove more of the lining than is necessary for a biopsy examination. The cut linings of the cyst and the oral mucosa fuse to become continuous with one another. The teeth directly or indirectly involved, with the lesion, are deliberately left undisturbed and remain covered by the thin epithelial continuum of the cyst lining.

In time, the lined cyst cavity becomes progressively smaller as bony regeneration occurs behind the epithelium and fills in the defect from the bottom up. As it does so, the directly involved tooth and the secondarily involved teeth are generally carried bodily forward, as if on the crest of a wave, in the vanguard of the naturally occurring regeneration.

There is little doubt that it was an understanding of this natural process that provided the stimulus for periodontists to invent the analogous guided tissue regeneration method. While the cyst was growing in size, it will have 'squeezed out' the supporting alveolar bone covering the root surface, leaving it to be invested in only the epithelial cyst lining. With the defusing of the raised hydrostatic pressure, the potential space between the cyst lining and the root will become re-suffused with new bony support. The osteogenesis that lifts the epithelial lining away from the PDL and the root surface will cause the bone levels seen in other unerupted teeth to return to normal values. In this way, teeth that previously appeared to be in hopeless situations may now take on a new lease of life, provided that orthodontic treatment is later instituted in order to provide any final eruptive assistance that may be needed, as well as to align them. However, any attempt to apply orthodontic traction to teeth before complete resolution of the cyst, and before the maximum amount of spontaneous eruption has occurred, will extrude them ahead of the advancing bone, thereby weakening their bony and periodontal support and prejudicing their longevity.

Fig. 14.6 (a) Pre surgery. (b) Immediately post surgery. (c) The same view six months later.

When the cyst is eliminated in the way described above, spontaneous resolution of the impaction may be expected to occur to a significant degree. Several truly remarkable cases have been reported in the literature [7, 8]. From our own experience in Jerusalem, the case reports are by no means exceptional and, with rational and careful management, have been repeated with a high degree of reliability in the most extreme cases that have come under our care [10].

The conclusions to be drawn from this discussion are that, as a first stage, the cyst must be treated and that monitoring of the healing process should be instituted and continued until the bone has completed the reparative fill-in of the bony defect. Only at that point, which will be many months later, should an assessment be made of the extent of the improvement that has occurred naturally; how much more may be expected; and how much orthodontic treatment will still be needed to improve the positions of the teeth. It will therefore be clear that not only is there no value in bonding an attachment to the tooth at the time that the marsupialization is undertaken initially, but that the procedure is likely to be harmful to the natural recuperation and positional improvement of the target teeth and for the health and integrity of the surrounding tissues – not least the cyst lining.

From the point of view of the oral and maxillofacial surgeon, treatment of this cyst is a priority in order to confirm the relatively innocent diagnosis. It must be remembered that, until a biopsy and pathological investigation are performed, the diagnosis is only tentative. The more sinister alternative diagnoses are fortunately rare; nevertheless, the surgeon cannot take the risk involved in delaying the performance of the necessary diagnostic procedures until the patient is ready to accept orthodontic treatment. Therefore, the first stage of surgical treatment, aimed at eliminating the pathological entity, must be regarded as obligatory and must include histopathological examination of biopsy material and careful follow-up.

From the orthodontic point of view, the patient should be prepared for treatment, being given an understanding of the demands of oral hygiene and the need to wear appliances and to expose the impacted teeth. These requirements may often be fulfilled quite quickly, but it is unfair to coerce young patients into a hurried decision before they are ready and it is usually counterproductive in terms of future compliance. Moreover, in view of the obvious benefit for the orthodontist in waiting for the regeneration of bone in the void that was previously occupied by the cyst, there is absolutely no hurry to begin orthodontics. Indeed, the contrary is true for many of these cases and there is usually nothing but benefit to be had by waiting out a delay of as much as two years.

It would be logical to infer from this discussion that, although the orthodontist has much to contribute to the outcome of the treatment, this contribution relates to the later stages and not to the immediate prospects. It would still be wise to include the orthodontist in the decision-making team, but inappropriate for him or her to become actively involved in the early stages of treatment, until much of the bony fill-in has occurred and the tooth has migrated down ahead of this.

The following short series of individual case descriptions is presented with the aim of illustrating a number of the problems that arise with the appearance of these benign cysts of dental origin. We shall discuss how they behave in relation to the included and associated teeth, how much of the morbidity for which they are responsible may be reversible, the timing of orthodontics in relation to the necessary surgery and how they may be treated, with good prognoses.

Case 14.1: Was it necessary to extract the adjacent tooth?

Figure 14.6 shows a series of three panoramic films, following up the surgical treatment of a large mandibular cyst in a 7-year-old boy. The first film shows the initial situation. The cyst was related to a root-treated and crowned deciduous second molar. This had been assumed to be the cause of the cyst, due to unresolved periapical pathology after failure of the root canal treatment. The circumscribed and well-defined cyst occupied the full height of the corpus of the lower jaw, from the crest of the ridge to the lower border of the mandible. In the sagittal plane, it stretched from the mesial aspect of the full length of the molar root to the unerupted first premolar, while in the bucco-lingual plane the film showed no vestige of lingual or buccal plate. The entire area was devoid of bone, which apparently had raised concern for the possibility of this leading to a pathological fracture, during the surgical procedure. A rudimentarily developed second premolar was present in the depth of the lesion, tipping distally, with the beginnings of its root growth located at the lower border of the mandible.

It seemed likely that this was a radicular cyst, which had pushed aside the developing and largely rootless unerupted second premolar, accounting for its long axis being parallel to the wall/floor of the cyst. The surgical procedure had been performed under general anaesthetic and involved extraction of the deciduous tooth, together with complete enucleation of the cyst (Figure 14.6b). The postoperative film shows absence of the premolar and in the referral letter the surgeon had indeed written that he had found it necessary to remove the second premolar.

From the surgeon's perspective, three points are noteworthy in the management of this patient:

- The very under-developed second premolar clearly had a negligeable attachment to its surroundings, as seen on the original film.
- The cyst lining itself was seen as constituting a significant part of the attachment of this tooth.
- During a surgical procedure of this type, visibility inside the cyst cavity would be poor.

The surgeon may have felt it wise to remove the tooth, in view of its orientation, the lack of any significant bony support and the absence of a developed root. All this would have been seen as demonstrating a poor prognosis. Indeed, had the tooth remained in place, there is room to question whether it would have continued to develop a normal root and if it could ever have been expected to upright itself and erupt into the mouth, either spontaneously or with orthodontic help. On the other hand, its root showed the very earliest stages of its development and was wide open and vital, indicating potential for the genesis of a reasonable root.

One remaining possibility was that, under these exceptional circumstances, it is conceivable that this very early developing tooth, with its very tenuous attachment to its surroundings, had been inadvertently dislodged during the removal of the cyst lining.

If, on the other hand, it transpires that the cyst was dentigerous, triggered by the infection from the failed root canal treatment, it should be remembered that the lining of a dentigerous cyst arises from the inner and outer enamel epithelia of the tooth germ. In the long term and under normal circumstances, this epithelial tissue of the follicle eventually fuses with the epithelium of the oral mucosa, opens and everts to form the normal gingival attachment of the healthy tooth (see Chapter 6). During cyst formation the lining usually remains unaltered. Opening it to the oral environment, with a marsupialization procedure, will allow the lining to become contiguous with the oral mucosa. In time, a metaplasia of its epithelium would occur, as is the case with every normally erupting tooth with a normal follicle. The former cyst lining would then become histologically indistinguishable from the remainder of the oral mucosa.

The prognosis of teeth that have been severely displaced by cysts

When faced with a defined pathology and an extreme displacement of the affected tooth or teeth in relation to dentigerous or radicular cysts in general, the orthodontist and the oral surgeon need answers to the following six questions, before being equipped to formulate a treatment protocol:

- Following treatment to eliminate the cyst, how much improvement in the re-alignment of the severely displaced teeth can be expected to occur autonomously?
- Will the tooth continue to grow its root to a reasonable length?
- Can these teeth be subsequently brought into the arch?
- What is the possibility that disturbances or anomalies in the calcification or form of these teeth resulting from the circumstances and the particular site of their development may limit the quality of the treatment outcome?
- Will they be accompanied by a good periodontium and bone support?
- Can this be done in such a way as to make the involved teeth indistinguishable from any other teeth at the end of treatment?

The answers to these questions depend largely on the operator's understanding of the biology of the condition and on the ability to be patient, as the following discussion will attempt to illustrate. Perhaps the most dramatic aspect of the treatment is the incredible potential for spontaneous resolution, with an amazing response of the body to regenerate lost bone and to restore normal anatomy (Figure 14.7).

(a) (b)

Fig. 14.7 Marsupializing a cyst of dental origin. The yellow dotted line represents the long axis of the unerupted canine and the red dotted line the long axis of the first premolar. (a) Both teeth have been markedly displaced by the cyst. (b) The autonomous effect on the positions of the teeth when the cyst was eliminated produced a 60° correction of the canine and considerably more of the premolar.

Case 14.2: Cyst resolution and autonomous alignment

In terms of the aetiology of this case, it would be reasonable to assume that this is a radicular cyst, originating from the non-vital deciduous first molar, which has significantly displaced the first premolar and canine downwards and mesially. It could, however, also be argued that the chronic periapical granuloma of the deciduous tooth has stimulated the follicular sac of the first premolar, which then developed into a dentigerous cyst. Due to the resistance of the erupted deciduous tooth, the premolar and canine have rotated downwards and mesially. Additionally, the long axis of the premolar appears to traverse the middle of the cyst. As already noted, this dispute is academic, since the approach to treatment will be the same in either case.

In the event, treatment was provided in the form of extraction of the deciduous canine and deciduous first molar. This effectively resulted in the surgical marsupialization of the cyst by virtue of the fact that, as expected, the cyst lining was ruptured during the extraction. The remainder of the cyst lining was left undisturbed. A pack had been placed loosely in the wound and the socket margins partially approximated with sutures. A week or so later the sutures and pack were removed and at the same time a lingual arch space maintainer was placed.

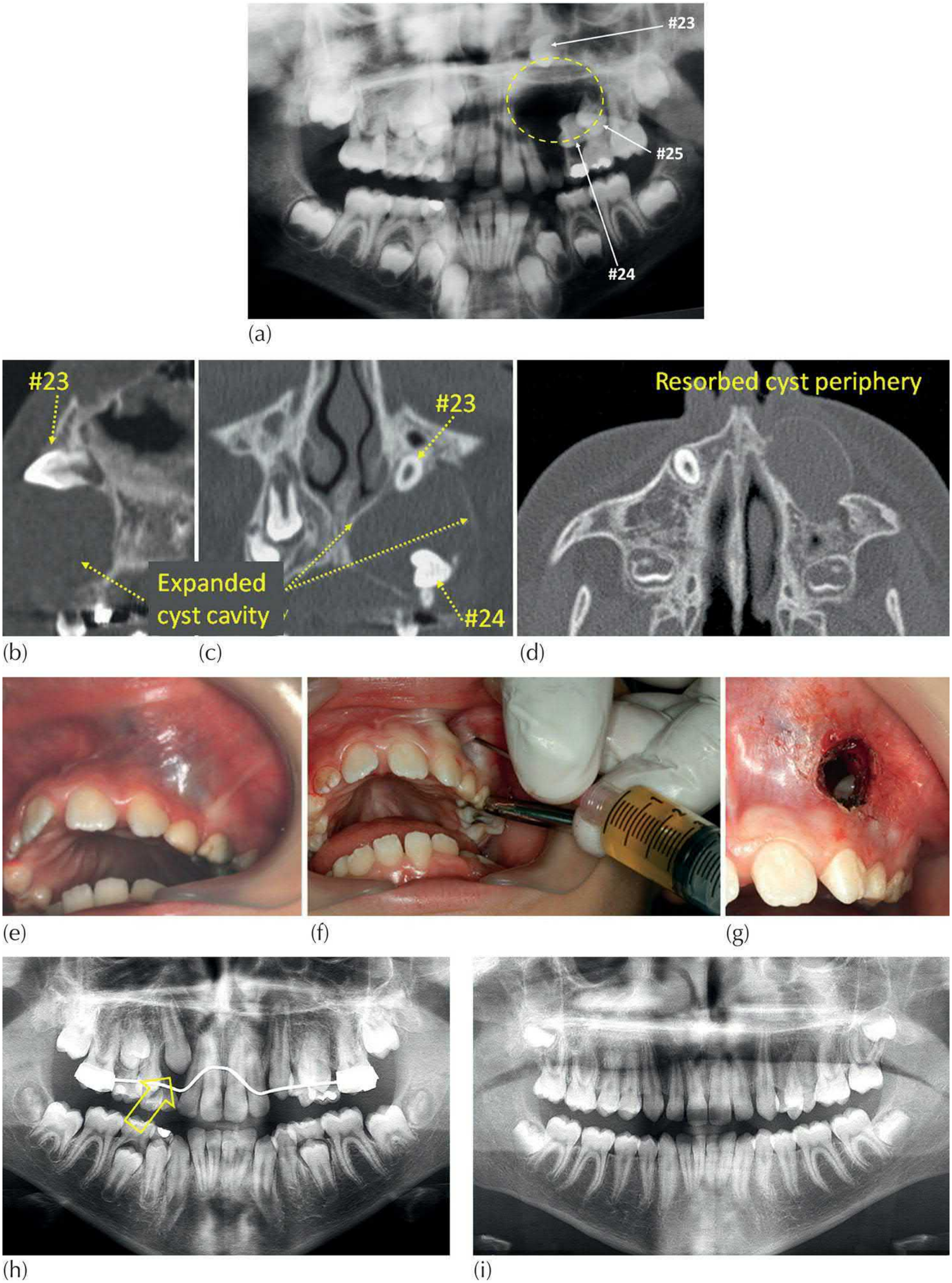
In follow-up visits over the succeeding few months, the two displaced teeth were seen to have improved their positions and erupted into the mouth, without any further assistance. A comparison of the panoramic radiographs taken at the time of surgery and at the 13-month post-surgery follow-up shows the amount of spontaneous correction that occurred, with the regeneration of alveolar bone into the void previously occupied by the cyst. In the pre-surgical film, the canine showed a mesial tipping displacement from the normal axial inclination of about 60° and the first premolar of about 80°. Ten months later, the long axis of the first premolar and that of the canine had fully corrected to exhibit a 5° over-correction with distal tilt. All this had occurred spontaneously, without the need for any orthodontic correction, essentially due to a reversal of the progress of the expanding pathological entity that had caused the initial displacement [8].

As a general principle, the larger the cyst, the greater is the displacement; this, together with the defusing of the lesion, produces a great deal of migration of the affected teeth in a very short space of time. This is directly related to the contraction of the previously cystic area. There can be no question that corrective treatment of these cysts of dental origin depends largely on surgical intervention. The displacement of teeth trapped within the cyst, or adjacent to it, may sometimes be completely reversed. That said, it is important to note that total spontaneous resolution is not always the outcome and it does not always bring the teeth back to their ideal place in the dental arch (see Figure 20.8).

Case 14.3: Cyst resolution and autonomous alignment

An 8-year-old boy was brought by his mother for a first visit to the orthodontist, with the complaint that he had a diffuse and painless swelling on his face and inside the mouth. He had previously been seen by the paediatric dentist, fully expecting to be told that he had a dental abscess on a deciduous tooth and that it would require extraction. The general dentist, who had seen the bite-wing and periapical radiographs, had realized that the diagnosis was not quite so simple and had referred him for a surgical and orthodontic assessment (Figure 14.8).

On examination, the left side of his face was swollen, from the slightly drooped left commissure and almost up to the left eye. Intra-orally, a large fluctuant swelling featured in the entire left vestibular sulcus, displaying a blue hue on the covering oral mucosa. On the palatal side the swelling was present on a much smaller scale. The boy displayed an early mixed dentition, which included the permanent incisors and first permanent molars in both jaws. The remaining teeth were deciduous and a single left primary molar was missing from the mandibular dentition. There were several amalgam fillings present in deciduous teeth. The maxillary left first deciduous molar had a particularly large filling that, according to the referral letter, was placed after a pulpotomy had been performed on that tooth.


#23
#25
#24
(a)
#23
#23
Resorbed cyst periphery
Expanded cyst cavity
#24
(b)
(c)
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(e)
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(g)
(h)
(i)

(j)

Fig. 14.8 (a) Dentigerous cyst radiography – the initial panoramic view showing the extent of the very large cyst (yellow circle), with the canine, premolars and the root of the lateral incisor displaced in the roof, the floor and the walls of the cyst, respectively. (b) The borders of the cyst: cross-sectional slice from the cone beam computed tomography (CBCT) series. (c) A coronal slice from the CBCT series shows the extreme size of the cyst cavity and the thinned outer border. (d) An axial slice showing the breadth of the cyst. (e) Clinical examination and treatment by marsupialization surgery: the typical blue hue of the swollen vestibular sulcus. (f) Draining the cyst with a wide-bore cannula inserted through the mucosa. (g) A stomium was created through which the glistening epithelium-covered enamel of one of the associated teeth could be seen. (Surgery by Prof. J. Lustman.) (h) A follow-up panoramic radiograph taken 26 months postoperatively. (i) The panoramic radiograph following the natural eruption of all the permanent teeth. (j) The fully erupted permanent dentition, achieved by surgical marsupialization of the large dentigerous cyst and a second, smaller one, with no orthodontic appliances other than a passive space maintainer.

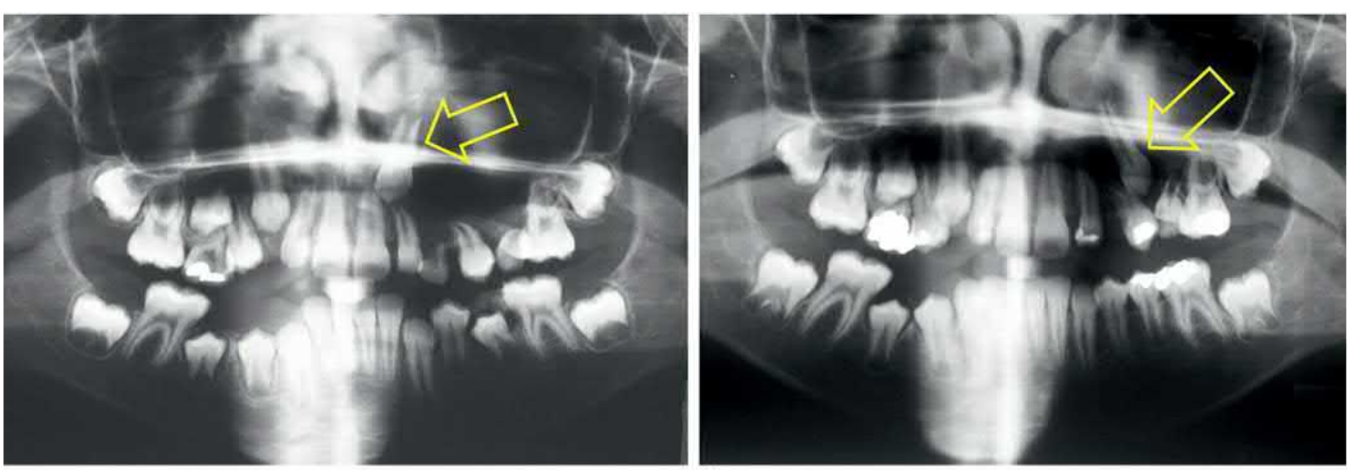
From the initial panoramic view, the tentative diagnosis of a dentigerous/radicular cyst was made (Figure 14.8a). The cross-sectional, coronal and axial slices of the cone beam computed tomography (CBCT) revealed a very large cyst occupying most of the left half of the maxilla. The premolar teeth were lying almost horizontally beneath the floor of the cyst. The canine was pointing horizontally forward above the highest point of the cyst and close to the floor of the orbit. The outer bony wall of the cyst was expanded, paper thin and, judging by the fluctuance on its buccal side, palpably incomplete. On the basis of these clinical signs, it was possible to identify this as a radicular cyst. The distance between the canine and the premolars was approximately 30 mm.

A CBCT imaging scan was prepared and, from the cross-sectional, coronal and axial slices, it was possible to confirm the presence of a very large cyst, whose outer bony profile was almost completely resorbed away (Figure 14.8b–d). Clinically, this caused the swollen alveolar ridge of the vestibular sulcus to be covered only by oral mucosa and alarmingly fluctuant (Figure 14.8e).

The first procedure performed was surgical and was aimed at defusing the cyst itself. To do this, the surgeon inserted a wide-bore needle/cannula through the soft outer wall of the oral mucosa in the vestibular sulcus and drew off about 3.5 mL of straw-coloured fluid (Figure 14.8f). As the fluid filled the syringe, the mucosal wall covering the cyst capsule deflated, exposing the complete resorption of the outer shell of its former bony periphery. The deciduous canine and the non-vital deciduous first molar were extracted and a circular stomium was cut with a scalpel into the mucosal wall, to permit continued draining (Figure 14.8g). The epithelial lining of the cyst was left untouched, so that the only place where bleeding actually occurred was at the cut mucosal edge of the stomium. Therefore, bleeding was very minimal and was easily arrested with electrocautery. The cyst cavity was irrigated and then lightly packed with ribbon gauze soaked in Whitehead varnish. Over the succeeding days and weeks, the oral mucosa and cyst lining merged at the cut edge and healed, to complete the marsupialization. The ribbon gauze was changed and shortened periodically until the former cyst cavity reduced in size.

The only orthodontic procedure that was implemented a few weeks later was the placement of a palatal arch soldered to two molar bands. The sole aim of the device was to prevent mesial drifting and to preserve the arch length following the extractions. The patient was seen periodically, to enable mapping the progress of the teeth and the regeneration of bone in the former cystic area. A follow-up panoramic view, taken 26 months post surgery, showed considerable improvement in the angulation of the long axes of the premolars, which had uprighted themselves (Figure 14.8h). The canine and two premolars had drifted together as a result of the regenerating bone in the former cyst cavity. The canine had moved down into a position that indicated its imminent eruption in its appropriate place in the arch. This radiograph revealed that, in the interim, the dental follicle of the unerupted canine of the unaffected right side had considerably enlarged (now redefined as a dentigerous cyst) and was impeding the canine's eruptive progress. Comparing the two canines, one may discern that the eruption status of the right canine lagged behind that of the formerly severely ectopic canine. Accordingly, the deciduous canine was extracted. The soldered palatal arch was left in place until the last of the deciduous teeth had shed and the maxillary permanent dentition had fully erupted.

The patient had reached the age of 11 years when all the permanent teeth had erupted. The teeth had aligned themselves into a class I molar relationship, with an increased overjet of 5 mm and a complete and deep incisor overbite. The maxillary left first premolar had erupted into a buccal cross-bite (scissors bite) with its opposing premolar and there was a degree of over-eruption of the mandibular and maxillary incisors (Figure 14.8i, j). The patient's periodontal health was characterized by mild generalized inflammation, typical of irregular brushing, with poor brushing technique. However, the previously affected left canine was in much the same state of health as the adjacent teeth, with no hint of the very compromised manner in which it had started life. Routine orthodontic treatment was advised, to deal with the relatively trivial and insignificant discrepancies already mentioned.



(a) (b)

Fig. 14.9 (a) The initial film taken in January 2007, shortly before surgical draining of the cyst was performed. The maxillary left canine is located high on the anterior extremity of the large cyst, directly between the central and lateral incisors. It seems likely that this had developed from apical pathology associated with one of the extracted deciduous molars. (b) The follow-up film, 13 months later, shows the canine to have drifted distally between the two premolars, following the contraction and resolution of the cyst. The development of the roots of the canine and premolars has continued uninterrupted. The contrast and lightness of the film in the area of tooth #23 have been adjusted in the interests of clarity.

Case 14.4: Transposition, three teeth at a time

As in the previous cases discussed, the patient here was a young child, 8 years of age, with a history of widespread dental caries and early extraction of many deciduous teeth. On the left side, the panoramic radiograph disclosed a large cyst extending from the lateral incisor to the first molar, occupying most of the body of the maxilla (Figure 14.9a). The unerupted canine had apparently been displaced forwards, to find itself in the vanguard of the cyst and at the level of the root apices of the central and lateral incisors of the same side. Marsupialization had been the surgical treatment performed in this case, as described earlier.

The follow-up panoramic radiograph was taken just over a year after the defusing procedure (Figure 14.9b). It showed a remarkable reduction of the cystic lesion and had skipped two teeth in its transpositioning manoeuvre. It can be seen to be descending between the two premolars in an apparent effort to erupt into the mouth. It is clear that, during the process of increasing its size, the cyst has apparently displaced the canine, forcing it to circumvent the lateral incisor. However, when the cyst receded, the canine moved a long way distally whence it came. It bypassed the lateral incisor, the deciduous canine and the first premolar. This provides an excellent demonstration of the degree to which the cyst will displace teeth, both as it increases in size and as it recedes – and not always on the same return path.

Case 14.5: From pre-phase 1 surgery to phase 2 orthodontics

Trauma to the anterior teeth is common in the very young and may result in the loss of vitality of a deciduous incisor. This will usually be indicated by a deleterious colour change of the crown of the tooth. If this tooth remains untreated in the long term, the chronic granuloma present may itself foster a radicular cyst. Alternatively, it may stimulate the follicle of the developing central incisor to become cystic, as we have already described.

The case shown in Figure 14.10a is of a 6-year-old child with a history of trauma, which is evidenced by the discoloured deciduous central incisor and its loss of vitality. An extreme degree of expansion of the alveolus is seen both in the buccal vestibule and on one side of the anterior portion of the palatal vault. The vault and the vestibule in their natural state have a concave anatomical form, whereas in this case they are convex.

In the panoramic radiograph (Figure 14.10b) taken at that time, the unerupted left incisors, canine and premolars had re-arranged themselves in the form of a circle, behind the cyst lining. The unerupted central incisor showed a marked height discrepancy, with its long axis remaining in the vertical plane. This tooth was bare of bone on its distal side. On its mesial side, it was in continuous contact with the resorbed surface of the bone, from the crown to the developing root end. This was due to hydrostatic pressure from within the cyst, which had pressed the tooth flat against the bony wall of its perimeter, thereby suggesting the diagnosis of radicular rather than dentigerous cyst.

The dilaceration of the root of the central incisor was also indicative of the fact that it had been lying behind the lining of the cyst. The canine, as seen on the panoramic view, was markedly displaced upwards and backwards with a distal tip. The lateral incisor had adopted a severe horizontal posture inferiorly, under the epithelial floor of the lesion. The unerupted developing premolars were less affected. The marked variation in the long axes of the three anterior teeth and two premolars (as though they were lying in a circle) was indicative of the fact that they were located in the wall of the cyst and, as such, they delineated its extent. Using these indicators, it was possible to estimate the shape and size of the cyst cavity and to define its borders.

In this particular case, all that was needed to produce marsupialization was the extraction of the non-vital deciduous central incisor and opening of the cyst. At the same time, the normal and vital deciduous lateral incisors were also extracted – considered a timely step. The extractions immediately brought about spontaneous drainage of the cyst. The edges of the oral mucosa flaps and the deciduous tooth sockets were approximated after including a small pack and drain to permit continued drainage and the healing of the oral mucosa to the cyst lining. No further treatment was provided at that time and the patient was followed up periodically.

After 26 months, the two permanent incisors of that side began to erupt close to their normal locations (Figure 14.10c). The follow-up radiograph taken at that time shows that the incisors and canine had moved forwards and downwards and had come very close to their normal locations (Figure 14.10d). This, together with the bony trabeculation seen on the film, indicates the elimination of the cystic cavity. At the same time, it was noticed that the very long root of the central incisor was dilacerate at the half-way location and its crown was distally displaced. The left lateral incisor root was palatally and distally displaced.

At the age of 9 years, a simple partially bracketed 2 × 4 appliance (a modified Johnson's twin-arch appliance – see Chapter 6) was placed to draw the teeth to their normal positions and to improve the parallelism of the roots (Figure 14.10e–g). The location of the central incisor was resolved, despite a short clinical crown and an excess of mildly inflamed gingival tissue. The lateral incisor crown had been brought into alignment; the orientation of its long axis indicated a strong palatal displacement, requiring considerable root torque. In a similar case, this might normally have been corrected either at this stage or in the full permanent dentition, when a second-phase treatment would be initiated.

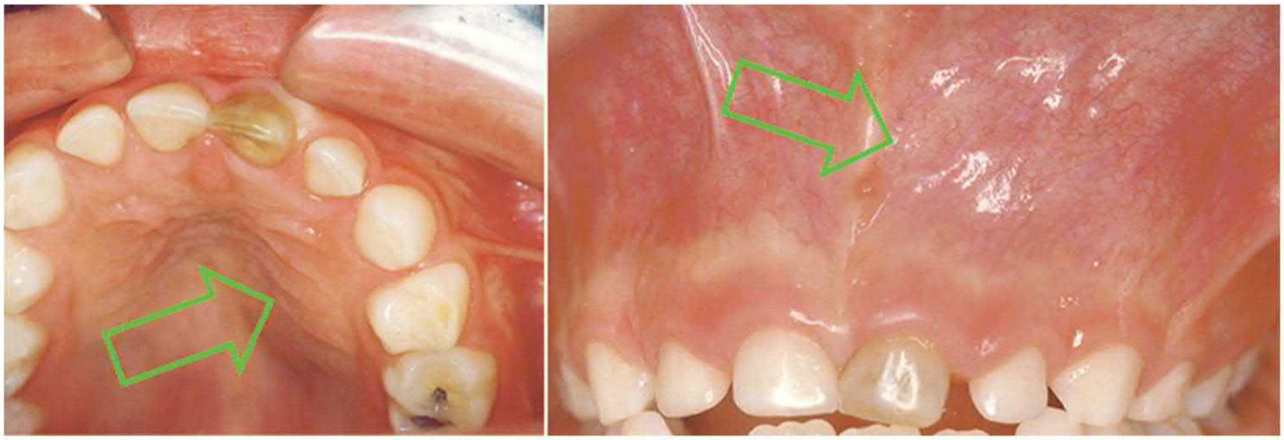
At the outset of this short first phase 1 of treatment, however, it had been noted that labial root torque of the lateral incisor would be very limited due to the labial location of the apical section of the dilacerate root of the central incisor and also to the mesio-labial location of the erupting canine (Figure 14.10f).

It is reasonable to assume that the development of the erupting canine high in the alveolus and its subsequent deliverance from the extreme displacement of the wall of the cyst was a cause for the root dilaceration. Furthermore, the migration of the teeth, squeezed between the cyst wall and the alveolar and/or basal bone under the hydrostatic pressure of the cyst, together with the fact that its root had developed in close relation to the floor of the nasal cavity were the causes of the dilaceration.

Using the tube-shift method, it could be determined from the two periapical films that the orientation of the apical portion of the root was distal and labial to the root of the lateral incisor (Figure 14.10f). This implied that labial root torque of the lateral incisor could not be performed before this anomaly was remedied or circumvented, if this was thought to be possible.

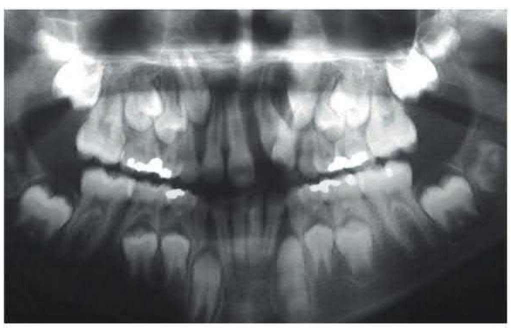
The situation that then presented suggested that the following treatment options were available:

- To leave the situation without further treatment; the lateral incisor would remain in that position.
- To rotate the central incisor disto-labially, which would effectively rotate the abnormally shaped apical portion labially and mesially. However, this would then involve crowning the tooth to achieve a good appearance.


(a)


(b)


(c)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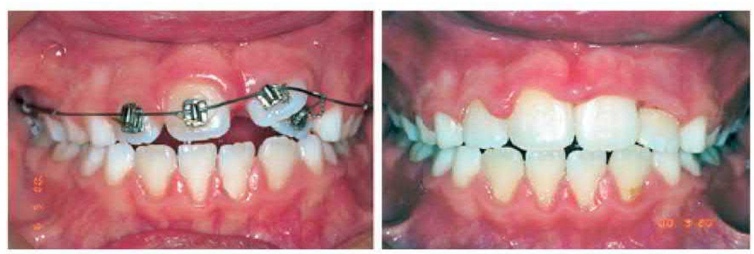
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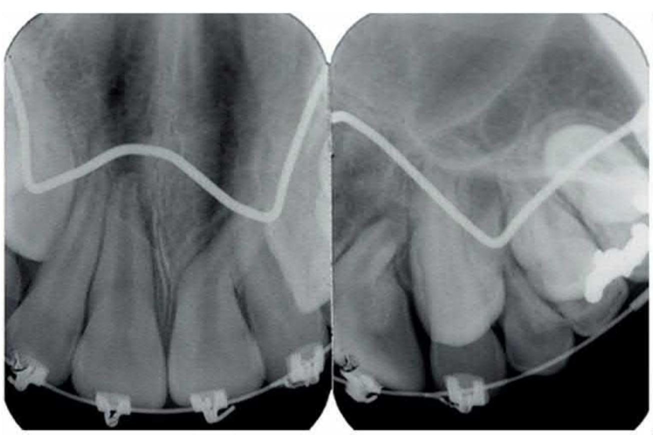
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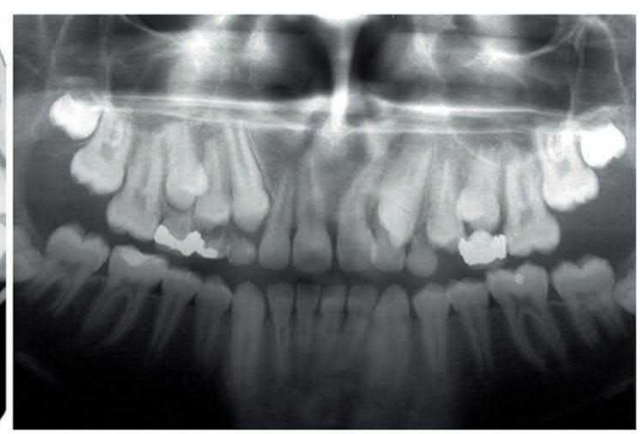
(g)

(h)

(i)

Fig. 14.10 (a) Buccal and palatal swelling indicating a cyst (arrows), due to early trauma with loss of vitality and discoloration of the left maxillary central incisor. (b) Pre-treatment panoramic radiograph. Note how the incisors, the canine and the premolars form a circle in the walls and floor of the (presumably radicular) cyst area, like ‘bees round a honeypot’. (c) The follow-up clinical examination at 26 months post surgery shows the autonomously erupting incisors. (d) The follow-up panoramic view of the dentition in general and the former cystic area in particular. (e) Phase 1 treatment, with partially bonded (modified) Johnson twin-wire arch appliance. (f) A pair of periapical radiographs for a tube-shift evaluation of the relationship of the central incisor root apex vis-à-vis the adjacent lateral incisor and canine. The dilacerate root end was labial and therefore prevented the labial root torque needed to align the lateral incisor. (g) Evaluation of the remainder of the dentition was assisted with this panoramic view. (h) Periapical radiographs of the anterior teeth two years after completion of the case. (i) A partial view of the completed case. The lateral incisor was torqued and uprighted to the maximum possible, in light of interference due to the presence of the dilacerate root.

- Performing root canal treatment and an apicoectomy, thereby eliminating the root apex, but potentially prejudicing the health and colour of the tooth.
- Over-uprighting the central incisor root mesially, thereby moving the apical portion mesially and superiorly. When the lateral incisor had been adequately (or possibly over) torqued, this process would be reversed to permit the root apex of the central incisor to be re-located

palatal to the lateral incisor root.

It was this last option that was the treatment actually attempted, as a phase II procedure in the full permanent dentition. Unfortunately, the degree of dilaceration of both the incisors did not permit the full expression of the torque of the roots of the three teeth involved (Figure 14.10h, i).

The photographic records taken at age 12 years, at the completion of phase 2 of the treated case, showed the two incisors being in an excellent position, crown height and gingival level. The quality of the canine gingival appearance, gingival level and crown height was poorer than for the canine of the unaffected side. The lateral incisor needed further labial root torque and the canine required palatal root torque. This could not be completed adequately because of the clash of root dilacerations.

The radiographs of the former cystic cavity and the immediate area around the roots of the teeth show excellent bony fill-in, resolution and architecture. The only negative element visible in the two-year follow-up periapical radiographs relates to the root entanglement that limits the possible root movement.

Eyelets or brackets?

Over the years, orthodontic brackets have been developed incorporating various highly sophisticated slot angle prescriptions and ligature tie alternatives, which make them as versatile as possible in aligning, rotating, tipping, uprighting and torqueing the teeth. This has allowed the orthodontist to treat well over 90% of cases without having to change attachments, yet being able to achieve excellent alignment, offset, tip, torque and inter-arch relationships. The prerequisites for these brackets to achieve their goal are that they are placed in the mid-buccal position of the teeth and, at the end of the treatment, that a full-sized rectangular archwire is fully ligated into them, enabling them to realize their maximum programmed potential.

When the ideal bonding site of an impacted tooth is not accessible, the route taken by most orthodontic practitioners is to place their regular ‘straight wire’ bracket at a more conveniently accessible site on the tooth – a site where it can be used for extruding the tooth and perhaps to achieve some alignment and levelling. Thus, one may occasionally see the paradox of the much-vaunted Damon™ Q2 bracket, which has been bonded to the lingual aspect of an impacted maxillary canine and tied to an archwire with elastic thread. It doesn’t come more absurd than that! The prescription of any so-called straight wire orthodontic bracket is predicated on the bracket being positioned in the mid-buccal location of the crown and nowhere else. In any location other than that, the bracket cannot realize the full potential of the prescription slot – a prescription that is engineered to perform a very specific type of movement with considerable accuracy and efficiency. Nor would one want it to, unless a series of complicated bends are introduced into the archwire by way of compensation. Beyond a minor degree of rotation, height discrepancy and ectopia, it is difficult to ligate the archwire into the bracket. This stage of the treatment becomes very clumsy and inefficient, slowing down the momentum of the desired correction.

It is obvious that brackets cannot be placed in their ideal positions on teeth that are severely rotated or partially erupted; nor can an archwire be easily and usefully tied into the bracket of a tooth that is grossly tipped or ectopically placed. In these cases, either an initial temporary attachment should be preferred, or the archwire must be modified with a series of offsets and loops.

In Chapter 2, the use of eyelets was discussed in relation to impacted and markedly displaced teeth. Using eyelets as initial attachments on the impacted teeth provides for superior management of the gross movements of the teeth, movements that are needed in the early stages of their resolution. They simplify ligation of teeth in the most extreme positions of displacement and make directional traction much more efficient. Threading a super-elastic auxiliary archwire through one eyelet and sometimes through a pair of eyelets makes large-scale extrusion, tipping, rotation and uprighting movements extremely easy over a broad spectrum of positional dislocation. Within a relatively few short appointments, the impacted teeth may, in this context, be brought into general alignment over large distances. In this way, they rapidly and easily arrive at the final treatment stage, where the detailing and finishing procedures need to be performed. It is only at this juncture that the eyelets should be replaced by the sophisticated prescription brackets that are required to complete the uprighting, rotating and torqueing movements for which they have been designed.

For the patient who is being treated for the resolution of a dentigerous cyst, it is at this stage of replacement of the eyelets by the brackets that new radiographs of the involved teeth should be evaluated, in order to check the form of their roots. As we have noted, teeth that have developed their roots while being displaced by the progressive enlargement of a dentigerous cyst are likely to have an abnormal root form. The discovery of this phenomenon in a particular tooth or teeth will obviously modify the amount and direction of root movement that is indicated for the patient. Once this has been determined, the eyelets should be removed and regular orthodontic brackets, of the type used on the other teeth, should be substituted, in preparation for that final stage of treatment, aimed at the fine-tuning of the alignment and occlusion of the dentition.

In essence, the eyelets are responsible for the resolution of the impaction and for bringing the severely displaced teeth into the ‘orthodontic ball park’. When all that remains to be performed is the final millimetre or two of levelling and crown alignment, root uprighting and torque and the additional few degrees of tooth rotation, these refinements can only be achieved with a sophisticated bracket system and it is only then that these brackets should be substituted for the eyelets.

Alternative surgical approaches to these benign cysts are presently employed in many surgical units, particularly where the orthodontist is not involved in the decision-making process. Perhaps the most common approach has been described by two oral surgeons in a study of 40 dentigerous cyst cases [5]. Apart from one instance, all their cases were treated by enucleation. Their treatment sequence was aspiration, followed by an incisional biopsy for pathological examination. The cystic epithelial linings were subsequently totally enucleated. Extraction of the associated impacted tooth was considered to have been indicated in 34 of their 40 cases. In one isolated case, decompression was performed first and, several months later, excision of the cyst lining was carried out. The histopathological reports had indicated only innocent diagnoses. Postsurgical bone regeneration occurred in all cases within 6–12 months. Grafts were not needed in any of the cases.

In the conclusions of these authors, ‘cyst enucleation … in extensive cysts will lead to loss of several teeth’ and ‘when the teeth involved with the cyst are extracted (especially in children) function, cosmetic and psychological consequences may follow’. While they mention in passing that marsupialization is one of the treatment options, it was not the modality chosen in any of the individuals in their series of cases. Their clear preference was for ‘curative’ enucleation of the lining.

As a general rule, when the lesion is a relatively large one, surgeons prefer not to run the risk of introducing infection, which could track along a stainless steel ligature wire ligated to an attachment on the impacted tooth. Many are uncomfortable with the idea of leaving the cyst lining in place and prefer to shell it out completely, on the premise that it is pathological tissue [6].

These two surgical preferences are more fully debated earlier in this chapter. In the first place, the marsupialization procedure that will have been performed many months earlier will have avoided exposure of the large surface area of bone that would be engendered by a 'curative enucleation of the lining'. Instead, there will be an epithelial-lined cavity of ever-reducing size, with no exposure of the underlying tissues to the exterior. At the later stage, when the teeth themselves are finally exposed and attachment bonded, the exposure is extremely minimal and less than in a routine impacted tooth exposure. There are no large wounds whatsoever in this approach and the risk of infection is likely to be insignificant.

The literature reports only rare incidences of neoplastic change in the lining of a dentigerous cyst. These have been cases in which the histopathological examination has been performed on excisional biopsy material taken at the time of the initial treatment of the cyst. In the present approach, however, a representative portion of the lining is sent for microscopic examination and the patient is followed up clinically over the succeeding months, until full resolution of the cyst cavity has occurred. It would appear that the chances of undiagnosed neoplastic alteration occurring in the former cystic epithelium are extremely small, probably no greater than finding it in another unrelated area of the oral mucosa.

The prevalence with which neoplastic change might occur in a dentigerous cyst has never been investigated. An early histological study of a sample of 52 patients with widened follicles (as distinct from dentigerous cysts) around their impacted maxillary canines showed zero incidence of neoplastic change [6]. However, there are no studies investigating neoplastic change in large samples of patients with clearly defined dentigerous cysts. Accordingly, there can be no foundation for always assuming the worst. Indeed, the very acceptance for publication in the dental literature of occasional, single-individual case reports of neoplasia might be more indicative of typical editorial eye-catching sensationalism and, by definition, extreme rarity. With no other information available, these articles stimulate interest based on emotional appeal and, unfortunately, exert an exaggerated influence on surgical decision-making. There is a great deal of highly emotive, alarmist and even incendiary input of both the patient and the surgeon influencing the decision as to which surgical route to take.

Hence, surgeons will feel much more comfortable if they perform a 'curative enucleation' of the lining of the cyst, together with removing the tooth or teeth involved in the lesion. Technically, this degree of caution cannot be easily faulted. But clinically, in some of these cases this relatively radical surgical procedure may leave a large bony defect, which may adversely affect the patient's facial appearance. The findings of the study by Motamedi and Talesh of extensive dentigerous cysts [5] records extraction of involved teeth in 34 of the 40 cases, following curative excision. It follows that bony regeneration will not occur in these cases when teeth have been removed, and bony reconstruction and implant-borne restorations will be necessary in the long term.

The nature of the work of a surgeon does not normally require the same follow-up as in the case of an orthodontist. Orthodontists will maintain considerable control by virtue of frequent clinic visits. They will place a space maintainer, with the patient on close recall for clinical and regular radiographic examination and later for orthodontic appliance placement and adjustment. A follow-up periapical film, taken a month later, should reveal rapid resolution and healing and a dramatic improvement of the position and orientation of the affected tooth. In the extremely unlikely event [11] that the lesion becomes more sinister, the change will be seen on this film and on one taken three months later. For these reasons, the parents must be told of the importance of follow-up, explaining that marsupialization surgery is simple and minimal and will most likely save teeth; it will generate a normal ridge bony contour and cause no permanent facial disfigurement. It will be important to point out that this proposed treatment will be in direct contrast to enucleation surgery, which is more radical, will likely necessitate the loss of tooth or teeth, will create a large bony defect with possible consequent facial change and will require long-term space maintenance, ridge enhancement bony procedures, implants and crowns.

Conclusions

In regard to the marsupialization of dentigerous and radicular cysts, the anecdotal evidence that has been presented here, and from other cases treated by the author, points to several important, if tentative, conclusions that may be made at this stage. These are as follows:

- Following surgical drainage the cystic area shrinks rapidly as bone fills in behind the cyst lining, to repair the initial bony defect.
- The teeth that have been displaced by the lesion come together within the repairing defect, their orientation improves and there are positive movements in the direction of eruption and, over time, spontaneous eruption may occur in some instances.
- Alveolar bone regenerates around the roots of the teeth.
- The root form of teeth impacted within cysts may be dilacerate.
- Treated according to the following protocol, there is rarely any need to extract the involved teeth and their eventual prognosis is excellent.

The following succinct guide is the suggested protocol for a conservative approach to the resolution of teeth impacted within dentigerous cysts or to teeth impacted in the walls of a radicular cyst:

- Simple decompression surgery – marsupialization and biopsy of the excised epithelial tissue.
- Periodic radiographic monitoring to check for bony fill-in, indicated by the coming together of the teeth within the former cyst location – a year or more after the decompression, depending on the size of the lesion.
- Orthodontic aligning of the erupted teeth, levelling and preparation of the anchor unit.
- Surgery to expose impacted teeth and bond eyelet attachments.
- Traction to the main arch with extrusion, tipping, rotation and some root uprighting movements.
- Checking the root morphology of the involved teeth.
- Substituting standard brackets for the eyelets for controlled root uprighting and torqueing and finishing procedures only when the tooth is in the routine ‘orthodontic ball park’.

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15
Impacted Teeth in the Adult Patient

Adrian Becker and Stella Chaushu

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For many years, it was the popular belief that impacted teeth in adults do not respond to orthodontic forces or that an adult is most unlikely to agree to such treatment. As a consequence, orthodontic treatment was not offered to the patient as a credible and realistic option. Today, the picture has changed and, with the development of more aesthetic orthodontic brackets, lingual brackets and clear aligners, together with the advent of cone beam computerized tomography, an orthodontist's proposal and the patient's acceptance of such treatment are now commonplace. Nevertheless, in the background there remains a degree of wariness, suspicion or circumspection regarding the wisdom and advisability of the undertaking on the part of the orthodontist. As a result, there may be a lack of conviction on the part of the practitioner to propose orthodontics as a solution for the impacted tooth.

Neglect and disguise

A small but significant number of untreated impacted teeth will eventually find some way of autonomously erupting into the mouth without having undergone treatment. This may happen asymptomatically and, indeed, many years after their normal eruption time. Characteristically, it will occur in an ectopic eruption site. The very fact that from time to time these cases do occur is clearly in contradiction to the popular view that eruption potential is lost when the root apex closes [1]. This is particularly true of maxillary canines [2]. Prosthodontists are aware of the occasional patient complaining of the eruption of a tooth under a removable maxillary prosthesis, often many years after the patient had become otherwise edentulous.

There are many and varied reasons why such cases were not dealt with in childhood. Some of these include:

- Advice was probably sought and rejected.
- The patient may have been an orthodontically unmanageable child at the appropriate age.
- The dentist or orthodontist may have been insufficiently convincing in the task of informing the parents of the consequences of non-treatment.
- The parents' level of dental awareness was inadequate.
- The idea that surgery would be needed may have been unacceptable to the parents.
- The cost and duration of the proposed treatment were unacceptable.
- A surgical exposure procedure may have been carried out at the appropriate time, but failed

to elicit eruption and was not then followed up.

- Some impacted teeth, particularly maxillary canines, may simply have never been diagnosed.
- The dentist succumbed to the pleadings of the parents to 'do something temporary to make it look good' until the patient was ready for the definitive treatment – a time that never arrived.

Adults presenting an impacted tooth as an integral part of both minor and major malocclusions need to be evaluated and treated like any younger patient. Their needs are to be properly planned and addressed. Corners should not be cut and a full course of treatment needs to be undertaken, with the most appropriate appliances.

With these basic principles, it is clear that only minimal changes would need to be made to the treatment we have described in the earlier chapters of this book. Such modifications will include using more aesthetic ceramic brackets than in traditional orthodontics, or treatment with lingual braces. However, with lingual braces there are logistical difficulties moving palatally located teeth across a continuous lingual archwire to the buccal side. Similarly, there are concerns in invisibly accessing unerupted teeth that are high on the labial side.

There is an increasingly large number of orthodontists who achieve excellent results with a clear aligner system in routine adult orthodontics. At the time of writing, one commercial aligner company claims that over two million teenagers have been treated with its aligner system and that the system probably can offer the "smile you want" in 70% of that segment of the population. The aligners are inconspicuous or aesthetically pleasing and are worn full time, but need to be removed for eating and for the maintenance of oral hygiene. Because they are removable, the aligners themselves cannot normally be used to apply direct traction to an unerupted tooth. In order for the aligner itself to take an active part in the resolution of the impaction, it would have to possess a specific quick-engage and quick-release mechanism. Such a mechanism would be essential in order to allow the patient to apply the force to the tooth accurately and to release it with ease, for such daily activities as eating and tooth brushing. The optimum effect that can generally be achieved by the aligner is the flexibility to perform all the movements that it normally performs in a non-impaction case, i.e. to open space for the impacted tooth, to align and level, to rotate, to upright and to torque. For the unerupted tooth, however, it can only act as the anchor unit, supporting the action of fixed-spring devices or elastomeric chains, based on palatal arches or soldered to molar bands. May one therefore conclude that patients with impacted teeth belong to the remaining 30% of the same population who cannot be offered the smile that they want? See Chapter 17.

As in all spheres of technology, innovation has effectively changed the scene in orthodontic treatment. Superb results are now regularly produced by using lingual fixed appliances and by aligner therapy, as described in Chapters 16 and 17. However, these two treatment modalities have a number of insurmountable limitations, which, in certain difficult circumstances, may even require extracting the impacted tooth, while a successful outcome might well have been possible with traditional orthodontics.

What does the literature say?

The first question that arises is whether we should expect that treating impacted teeth in adults will produce the same results as in children, in the same period of time and with a similar degree of confidence in achieving a successful outcome. After all, the patient is no longer growing and the root apices closed long ago. The literature published in the orthodontic and surgical journals has been sparse and largely limited to teaching useful techniques, describing novel devices and advice on how to adapt the management of the mature patient compared to the accepted management pattern in a child. Furthermore, since the number of cases is small, most orthodontists have limited experience with coping with impacted teeth in the adult patient and the subject has rarely been aired. Nevertheless, two studies have appeared that have reported somewhat conflicting findings.

According to a study by a German group, the duration of treatment in the over-25 years age range is likely to be significantly longer than that for the child patient [3]. On the other hand, a more recent investigation found just the opposite, namely that treatment was longer in younger patients with impacted canines than in an older group [4]. However, the patients who took part in the latter study were all under the age of 20 years and on average the younger group had more serious impactions than did the older ones. The age difference between the younger and older groups was very small and the complexity of the younger was greater and more involved, making it apparent that little may be concluded from this study regarding the effect of age.

Aside from these two papers, the available articles on adult patients have been anecdotal case presentations, which give no indication regarding the basic questions of whether we can expect that treating impacted teeth in adults will produce the same results as in children.

Accordingly and in order to evaluate the justification for recommending to treat the impaction of teeth in the adult, our group in Jerusalem undertook to investigate the success rate and the duration of treatment for the resolution of canine impaction in a cohort of adult patients (mean age 28.8 ± 8.6 years) whose ages ranged between 20 and 47 years [5]. The control sample for this study was formed by a similar number of adolescent patients (mean age 13.7 ± 1.3 years; range 12–16 years). There were 19 patients in each group, and the control group subjects were individually matched for treatment difficulty with those of the adults in the three planes of space, in accordance with the classification of canine impaction described in Chapter 7 of this volume.


(a) (b)

Fig. 15.1 (a) Anterior and (b) occlusal views of a non-vital and discoloured deciduous central incisor in a crowded dentition, with an impacted permanent central incisor.

Although the duration of the overall orthodontic treatment did not materially differ between the two groups, the adults showed significant increases in the duration and number of treatment visits required to solve the impaction, in both the simpler and the more difficult cases. In the adults, the success rate was 69.5% for the 23 treated canines (4 bilateral and 15 unilateral). The failures occurred solely in the over-30 age group, where 5 canines had failed to erupt and 2 canines had initially responded and then arrested without completing their alignment. This compared with 100% successful resolution for the younger group, in which there were also 4 bilateral and 15 unilateral impacted cases.

The impacted maxillary central incisor

It may be difficult for the orthodontist to imagine a situation where a patient has reached adulthood and still presents an impacted central incisor (Figure 15.1a, b). Clearly, this will have been quite obvious from around the age of 7 years, yet the patient has only sought treatment in their 20s or even later. This situation is indeed unusual and its manifestation varies from country to country, probably in inverse relation to the level of dental awareness in the population. A country that offers its citizens some form of national dental insurance may be expected to have a lower frequency of occurrence among its adults, since it is far more likely that the condition will have been diagnosed during childhood in a community dental clinic and treatment will have been carried out at the appropriate time. Relative freedom from financial constraints in a welfare state would also have encouraged early treatment, although cost is not the only factor and probably not even the most significant one.

Whatever the reason for the tardiness in seeking treatment, the adult patient may have adopted a self-conscious, non-smiling, withdrawn and introverted manner over the years, as a form of concealment. Others will often present with an incisor anomaly that has been unsuccessfully disguised in one of three ways.

First, an over-retained deciduous tooth may have been enlarged by the addition of composite material, although this would probably only have improved the length of its crown. Any increase in the width of the tooth would be limited by the reduced mesio-distal space available, a space that itself has been due to the marked mesial tipping of the adjacent lateral incisor and the central incisor of the opposite side.

Second, this reduced space may have been maintained with a 'flipper' (spoon) partial denture, carrying a single and poorly matched small tooth (Figure 15.2a, b).

Management

It is quite clear that in these circumstances the first and most important prerequisite to any form of treatment for the missing tooth is to provide the maxillary dental arch with an ideal shape in each of the three planes of space. In practical terms, this means:

- Levelling and aligning the entire dental arch. All ectopically placed teeth will need to be brought into an ideal archform, teeth will need to be aligned in a single, uniform occlusal plane and all rotations dealt with.
- Re-opening a space of suitable mesio-distal width in order to accommodate the impacted tooth in the arch. Correcting the palatal inclination of the canine and tipping the lateral incisor of the same side and the central and lateral incisor of the opposite side will usually provide adequate space, although distal movement, extraction or interproximal enamel stripping may need to be considered.
- Correcting the dental midline to be continuous with the lower and with the midline of the face. This is normally achieved as a result of the re-opening of space, but it may require the use of coil springs or anterior, oblique, intermaxillary elastics as part of a more comprehensive orthodontic appliance programme. The use of anterior intermaxillary elastics in the adult is often a difficult request to put before the patient for obvious social reasons. The judicious placement of temporary anchorage devices to permit forces to be applied unilaterally within the same arch is clearly to be preferred.
- Closing down an anterior open bite and bringing the teeth into occlusion. This may

sometimes be achieved by properly aligning the molar tubes and by altering bracket height on the anterior teeth, thereby bringing about the desired extrusion of the teeth – and unpopular anterior vertical elastics are of material help in this situation. Often, however, an increased height of the lower third of the face and excessive vertical exposure of the maxillary anterior teeth and gingivae (gummy smile) may dictate the intrusion of the posterior teeth rather than extruding the anteriors. This may be achieved using zygomatic plates screwed into the inferior aspect of the zygomatic process of the maxilla, opposite the molar teeth. In this scenario, it should be understood that a force applied from a zygomatic plate, high in the sulcus, to the buccal tube on the molar will produce a rolling-out of the molar. It is therefore mandatory to use a transpalatal bar, preferably soldered from molar to molar. This bar should be prepared in such a manner as to be positioned a couple of millimetres away from the palatal mucosa to permit molar intrusion without palatal impingement.

Once these aims have been achieved, the patient is ready for that stage in treatment when all resources will need to be concentrated on the impacted tooth. The entire dental arch must be consolidated into a compound and united anchorage unit, to which the unerupted tooth will be drawn. We have illustrated in Chapter 10 that teeth that have been impacted for many years sometimes undergo pathological change that prevents their eruption, even when all other factors are favourable. It is by no means always possible to diagnose pathological change from a radiograph, unless there is a loss of the follicular sac and actual enamel resorption has become evident over wide areas of the surface of the unerupted tooth. It is therefore true to say that, whenever an adult patient presents for the treatment of an impacted tooth, a calculated risk is taken in offering this kind of treatment to resolve the impaction.

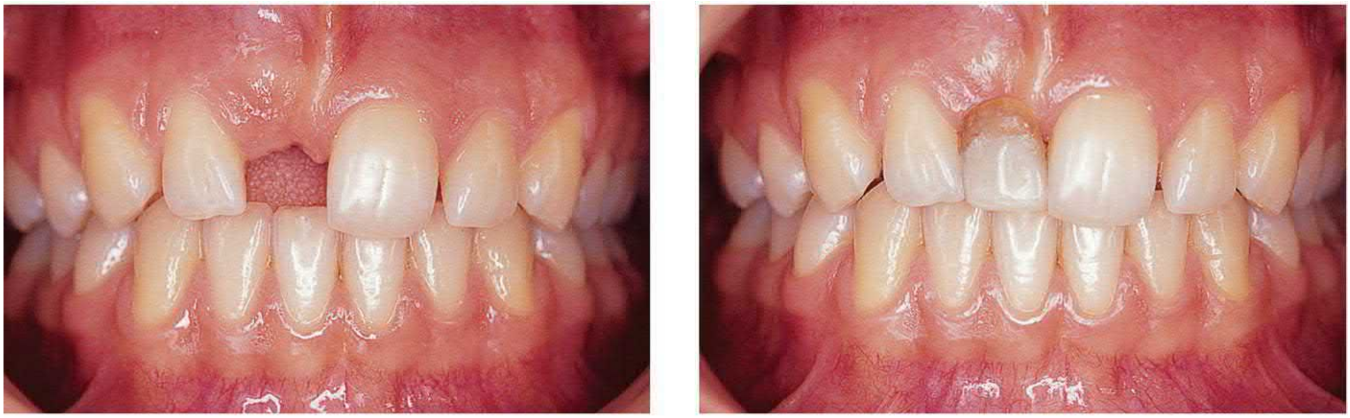
In the most adverse of circumstances, a central incisor or canine tooth will have to be extracted and, perhaps, replaced with an implant-borne restoration. In that event, the orthodontic alignment and space preparation of the dental arch described above will have provided optimal clinical conditions to accept the implant or other form of artificial restoration of the space. An ideal pontic width is present, the roots of the adjacent teeth have been uprighted to make sufficient inter-radicular space for implant placement, all other teeth are aligned and the occlusion is good. However, the surgical removal of a grossly displaced impacted tooth, high above its normal position, will leave a considerable and unsightly bony defect. This will be difficult to conceal in the gingival area around a fixed prosthesis and will not lend itself to the placing of an implant without suitable and prior osseous ridge reconstruction.

The patient must be brought into the decision-making process from the outset and should be informed of the potential advantages of each of the stages of treatment. This is best done using a computerized simulation of the scanned dentition, to show a scheme of the proposed treatment result. Prognosis for the success of the pre-surgical stages of the treatment is excellent, but for the alignment of the impacted tooth it is not so certain. Offering the treatment plan to the patient is therefore probably best accomplished if it is based on explaining the benefits of the limited objectives, i.e. aligning the teeth for the purposes of achieving improved conditions for the construction of a conventional prosthodontic or implant-borne replacement. The added bonus, which will be derived from success in the resolution of the impaction, may then be properly brought into perspective to provide the desirable further incentive. By whatever means the value of the treatment is explained, care should be taken to fully inform the patient that the possibility of failure to bring the impacted tooth into the arch is real, but that contingency plans are available in this disappointing eventuality.

The need for temporary prosthesis during the treatment

Replacing a missing incisor

For the adult patient, planned orthodontic space opening for an unerupted anterior tooth is a daunting prospect. All central and lateral incisors and maxillary canines require some form of immediate temporary prosthetic replacement until such time as the permanent tooth comes into its place. With some patients, particularly those more concerned with their appearance or those who have a broad smile or a wide dental display that is evident in facial expression and social intercourse, there may be a need to artificially replace even premolar teeth.



(a) (b)

Fig. 15.2 (a) Impacted right maxillary central incisor, replaced (b) by poorly matched artificial tooth on 'flipper' (spoon) denture.

Perhaps the most popular solution for an impacted incisor is to trim an artificial acrylic tooth to a suitable shape and size, bond a bracket to it and ligate it into the archwire of the appliance. In the early stages, the archwire is probably nickel–titanium (NiTi) and of round cross-section, which means that the new artificial pontic is very unstable and will rotate around or slide along the archwire. Placing a V-bend in the wire or welding a small piece of wire in the vertical position will prevent the rotation but complicate use of the archwire. It will also need to be copied into each of the subsequent archwires until a rectangular cross-section wire is used.

An artificial acrylic tooth may be bonded to the mesial surface of the contralateral central or ipsilateral lateral incisor, although this assumes that the archwire is absolutely passive when ligated into the bracket on these teeth. A minor rotatory movement will cause a major lateral or medial swing of the pontic, while an uprighting component will markedly intrude or extrude it at its opposite end.

Alternatively, the artificial restoration may take the form of a removable plate carrying a single tooth – a 'flipper' (spoon) denture. The average adult patient may have considerable difficulty becoming accustomed to it, even if its retention is adequate initially. Of greater concern, however, is the fact that the adjacent teeth and many other teeth need to be moved during the orthodontic treatment, which will rapidly make this artificial denture ill-fitting. Furthermore, the close adaptation of the acrylic base to the contour of the other teeth in the jaw may actually interfere with the planned orthodontic movement. For this type of artificial replacement to be successful, Adams clasps may have to be used on the second molars; alternatively, a modified circumferential clasp may hook over the buccal tubes of the first molars. These teeth are often excluded from the planned dental movements and may sometimes be helpful in retaining such a plate, although the distance between the clasps and an incisor pontic may be the cause of an unacceptable degree of instability.

Clearly, more satisfactory alternative methods of artificial replacement are essential to the successful pursuit of treatment for the adult patient, and these must provide an answer to the several shortcomings of the 'flipper' denture. Given a little thought in their design, and rather than their playing the role of villain of the piece, assistance in the application of force to the impacted tooth may be derived from the method of artificial replacement, which may actually contribute to the smooth running of the active orthodontic appliance.

The soldered palatal arch

In the adult patient, the scope of orthodontic correction that is planned tends to be more localized and less comprehensive, particularly when a single and grossly displaced tooth is present. The first maxillary molar teeth are most commonly used as anchor teeth for the fixed appliance, and their orthodontic movement is not usually required. This being so, the buccal aspects of these teeth and buccal/labial aspects of the teeth more anteriorly placed will be used to carry the orthodontic attachments, archwires and auxiliaries. This leaves the palatal side of the teeth and the palate area free, and available to serve the interests of the patient's appearance.

A soldered palatal arch, based on the molar bands, can provide the orthodontic appliance with an excellent anchorage base, at the same time as acting as the vehicle for a satisfactory prosthetic replacement. Several approaches are available. They depend on the adaptation of well-fitting preformed orthodontic bands to the molar teeth and their accurate transference to a plaster working model of the jaw.

On the working model, a palatal arch is fabricated and soldered on the palatal side of the molar bands. A small wire extension may then be soldered or bent into the anterior portion of the palatal arch, extending towards the space in the arch and terminating immediately palatal to the position of the missing tooth, with a configuration that will mechanically retain an artificial acrylic tooth. The exact location of the artificial tooth should be decided in accordance with the projected treatment goals of the case and not necessarily in line with the adjacent natural teeth. Thus, if an overjet is to be closed or a cross-bite treated, the siting of the artificial tooth should be made according to the intended final (or possibly semi-final and staged), post-treatment position of the adjacent teeth. An occluded plaster cast of the opposite jaw is therefore necessary to assist in its accurate placement.

This is the simplest approach of this type and offers the patient a good artificial replacement, which is well tolerated. It also allows the adjacent teeth to be aligned without hindrance, while actually enhancing the anchorage value of the molars during retraction of a procumbent labial segment. The anchor molars cannot be rotated or tipped easily when using horizontal, intra-maxillary elastics, due to the stabilizing effect of the rigid soldered palatal arch.

A significant and valuable refinement of this approach involves bonding a conventional bracket to the artificial tooth, as with the other teeth. This makes the artificial tooth aesthetically compromised to a similar degree as the other teeth and therefore less recognizable as other than a part of the natural dentition. Since this tooth is rigidly attached to the molar teeth and at a fixed distance from them, this method has much more to offer. Its integration into the appliance system makes alignment and levelling more accurate and more rapid. Additionally, the need for elastic traction to reduce the overjet will be eliminated, since the use of the initial fine-gauge levelling and aligning wires in the early weeks of treatment will perform this without any further modification. The distance and relationship between molars and the artificial incisor are fixed to the ideal length and position by the palatal arch. Thus, a progression of ideal wire archforms will align all other teeth within that arch. Essentially, by linking the archwire to the fixed pontic in its normal overjet and overbite location, the first stage of mechano-therapy, which generally deals with initial levelling and alignment only, now comes to include automatic overjet and overbite reduction. The overall length of the heavy palatal arch provides it with a degree of elasticity despite its heavy gauge. Thus, while carrying a temporary prosthetic replacement, it may be used to widen or constrict the dental arch. In the present context, however, it has one other possible function that is less obvious, but most helpful. The palatal arch has the potential to provide the vertical component of force that is needed to close an anterior open bite and, subsequently, the vertical traction needed to resolve the incisor impaction.

The impacted maxillary canine

Aside from third molars, and in common with the younger patient, the tooth most frequently found to be impacted in the adult is the maxillary canine. The principles of diagnosis, treatment planning and appliance therapy in the adult are no different from those in the child, although certain demands are made by the adult patient that may make treatment methods less routine and more individualized.

Palatally impacted canines are frequently associated with only minor malocclusions and, as we have already pointed out in Chapter 7, in dentitions in which the dental age is often very late. Therefore, we may occasionally see a case of impaction that has eluded diagnosis until a much later age, and the circumstance that led to the discovery was the exfoliation of the deciduous canine or sometimes a routine examination by the general dentist, which revealed the buried tooth. Additionally, the increase in demand for orthodontic treatment among adults in recent years may change the attitude of some patients who had strongly opposed orthodontic treatment in adolescence and who may be more inclined to reconsider it later.

To camouflage the absence in the arch of an impacted canine, an artificial acrylic tooth may be bonded to the mesial surface of the first premolar, although this assumes that the archwire is passively ligated into the premolar bracket. A minor rotatory movement will cause a major lateral or medial swing of the pontic, while an uprighting component will markedly intrude it into the gingival tissues or extrude it into premature occlusion at its opposite end.

In a case with impacted incisor teeth, the presence of a palatal arch does not encroach on the area where surgical exposure will be performed and where post-surgical swelling is likely to occur, provided the anterior portion of the palatal arch is not brought too far forward. A cut-back design is usually most appropriate. For the surgical episode involved in the exposure of a palatally displaced maxillary canine, a wide area of palatal mucosa may need to be reflected back, and this, together with the possible sequel of even a minimal degree of postsurgical oedema, effectively disqualifies the use of a rigid palatal arc. A transpalatal soldered bar is usually sufficiently posteriorly located from the surgical site to be used in these circumstances. It cannot be used for prosthetic replacement and its only functions are to enhance the anchorage and to maintain arch width. However, in combination with a buccal arm, it may be very useful and have definite indications.

Limited treatment goals

This discussion has dealt with the more complete and optimized treatment plan that the adult patient may accept, with the view of treating the entire malocclusion, of which the impacted tooth is one entity, in a long list of alignment and occlusal imperfections. Largely in contrast to children, adult patients and their dentitions need the services of periodontists, prosthodontists, oral surgeons, endodontists and other branches of our profession. One or more of these practitioners may have included the orthodontist in the interdisciplinary team needed for this patient, with the specific task of resolving the problem of the impacted tooth. Accordingly, there must be a place for limited scope orthodontics for the adult that we would probably not consider for a much younger patient.

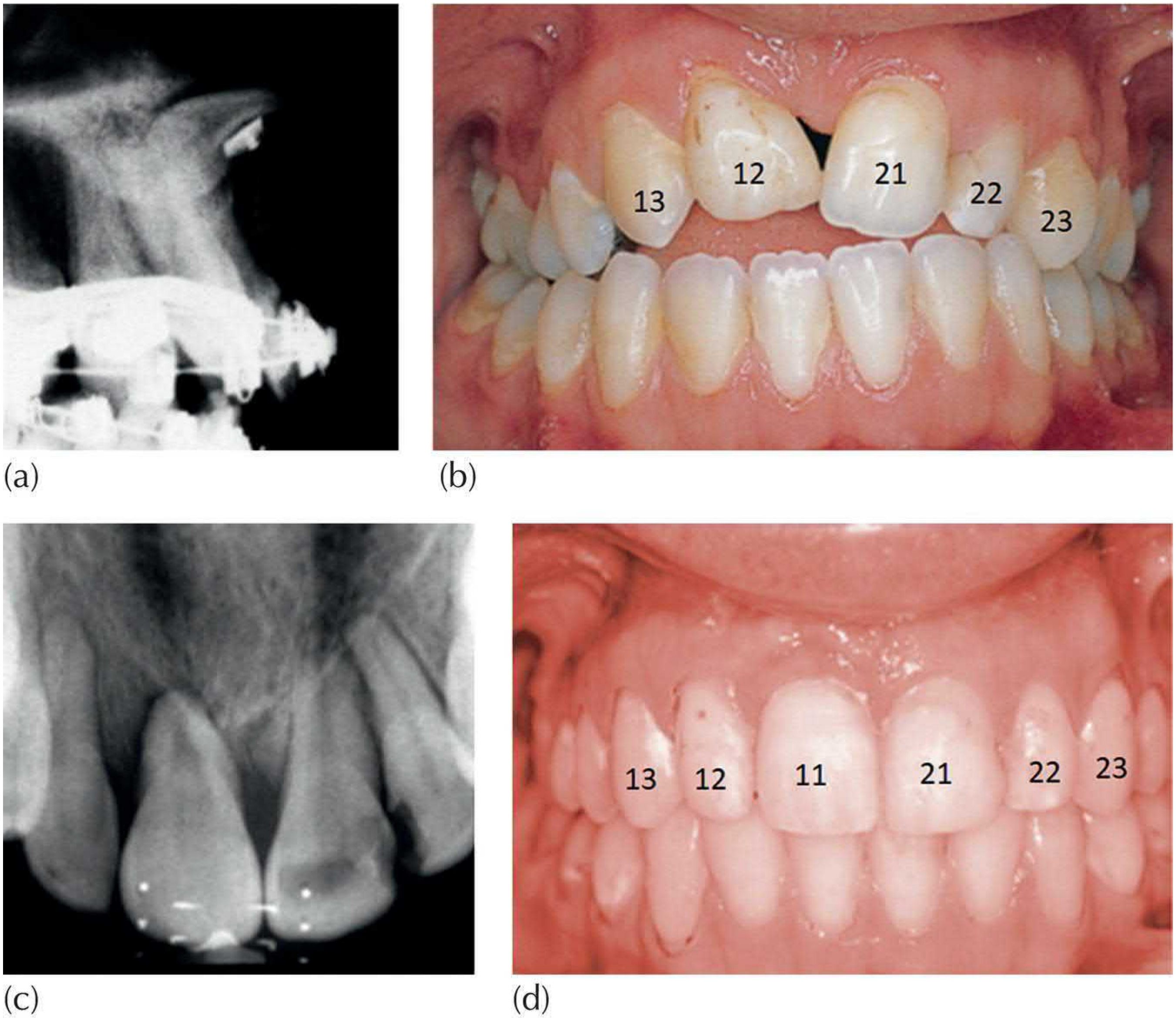


Fig. 15.3 The location of the dilacerate central incisor in a 24-year-old patient. (a) Tangential radiographic view of the dilacerate incisor. (b) The attempt at treating the lateral incisor by prosthodontic enlargement and reshaping. (c) The periapical radiograph of the dilacerate incisor, re-aligned by orthodontic treatment. (d) Intra-oral view of the resolved incisor impaction following orthodontic treatment and surgical exposure.

Case 15.1: Dilacerate incisor impaction and total space loss

The third form of disguise is that the lateral incisor may have been enlarged, with the use of composite material, in an attempt to simulate the shape of the impacted central incisor (Figure 15.3a).

The most significant drawback with each of these lesser treatment alternatives is that the results will not have produced a satisfactory appearance. The absence or reduction in size of a central incisor is always obvious, even to the casual observer, as it is with regard to any significant shift in a maxillary dental midline. The tipping of the two teeth adjacent to the impacted incisor is too severe for this to escape notice and the angle of the lateral incisor is too acute for its long axis to be visually 're-aligned' by composite additions or by reshaping. The narrowness of the neck of the tooth makes it difficult to achieve an aesthetically convincing reconstruction.

Maximizing the anchor unit with fewer teeth

Case 15.2: Simple, effective and bracketless intermaxillary anchorage

In Chapters 6 and 7 we have already dealt with methods of coping with the problem of anchorage by incorporating most of the teeth in both jaws. In many cases, impaction of a single tooth is the sole problem for which the patient has requested treatment. In many adult cases, there are associated benefits to be achieved by the resolution of an impaction, in addition to simply gaining a tooth and, in particular, by providing support for a more comprehensive prosthodontic oral rehabilitation of the dentition as a whole. However, the requisite extrusion, rotation, alignment, uprighting and torque of an impacted tooth, particularly a molar, will generate reactive forces that will undoubtedly undermine an inadequately robust anchor unit.

Nevertheless, for the resolution of a single impacted tooth in an adult who is not happy about wearing orthodontic brackets on the anterior teeth, the construction of a minimally involved but adequately buttressed anchor unit becomes critical in terms of the patient's acceptance of the treatment.

A case of an adult male in the sixth decade of life with an unerupted maxillary third molar is an example of how one may achieve resolution of the impaction with simplified mechanics.

The patient had consulted a dentist with regard to a very localized problem created by the presence of a disintegrating, root-treated, maxillary, second permanent molar. In order for the dentist to restore this tooth, it would normally have required a renewed root canal treatment, a post and a crown. However, in this case, one side of the tooth was fractured to a degree that would have left the shoulder of the crown preparation apical to the crestal bone. The prognosis of the tooth with this infra-bony pocket was thus considered to be very poor.


(a)


(b)


(c)


(d)


(e)


(f)

Fig. 15.4 Impacted maxillary right third molar, following loss of second molar. (a) The occlusion from the right side, illustrating an excellent alignment and occlusion of the teeth. (b) The occlusal aspect of the mesially tipped and partially erupted third molar is seen. (c) The bracketless, direct-bonded anchor unit prepared on a plaster model. (d) Active movement: the L-shaped elastic drawing the third molar downwards and lingually. (e) The bracketed set-up for uprighting the third molar and (f) drawing the molar forwards.

The dentist had identified an unerupted third molar adjacent to the condemned tooth and had calculated that this valuable and perfect virgin tooth would erupt into the space provided by the extraction of the second molar. The tooth was accordingly extracted and, despite the two-year period that followed the extraction, the third molar had still not erupted. At that point the patient, then aged 53 years, was referred to a surgeon who removed the thick mucosa covering the occlusal surface and extended the exposure to the broadest diameter of the crown, again in the expectation that the tooth would erupt. However, in the following 18 months the third molar had hardly moved (Figure 15.4a, b). The patient was finally referred to the orthodontist.

The orthodontist noted a complete mandibular dentition from second molar to second molar and, in the maxilla, from left second molar to the right first molar. The teeth in both jaws were well aligned, the occlusion was ideal and the anterior overbite and overjet were perfect. The third molar was buccally displaced and strongly mesially tipped, vertically separated by 7–8 mm from occlusal contact with the mandibular second molar and 3–4 mm horizontally separated from the adjacent first molar (Figure 15.4a, b).

In order to bring this tooth into its final and desired location, it would be necessary to extrude it, lingually tip it, upright its roots mesially and then translate the tooth mesially to contact the first molar. Such a treatment pattern, particularly if intermaxillary elastics were used, would normally place considerable strain on the anchorage. This, in turn, would need reinforcement in order to avoid reactive over-eruption of the mandibular second molar. In addition, if only maxillary anchorage were to be used, reactive intrusion and space-opening movements on the anchor teeth would be likely to occur.

The treatment commenced by rigid stationary anchorage being devised using a length of round stainless steel wire of heavy gauge (0.024 in.), which was adapted, using a plaster model, to the buccal aspects of the premolars and molars of the opposite jaw. The device was bonded direct to these teeth without using brackets (Figure 15.4c). At each end of the bonded unit, the wire was formed into a small loop for elastic attachment. The rationale behind the rigid device was that archwires ligated into brackets have more freedom of movement or ‘play’ than rigid, directly bonded wire and mesh pads. Brackets and archwires would offer a lesser anchorage value, would be more involved to set up and would be vulnerable to the possibility of breakage, all of which were important elements in this particular situation.

The next stage of treatment involved placing an intermaxillary elastic from a directly bonded hook on the maxillary third molar to the mesial loop of the bonded mandibular anchor unit, as is normally done in relation to a class III intermaxillary elastic. However, by additionally hooking the middle of the stretched elastic over the distal end of the bonded device, an L-shaped elastic configuration was created (Figure 15.4d). The elastic thus applied vertical traction to the maxillary third molar, with a secondary component tipping it lingually. The length of the elastic ensured that the traction exhibited an easily controlled light force with a long range of action. At the same time, the reactive load on the anchor unit was shared between the two premolars and the two molars, which were rigidly bonded together and in tight occlusion, serving to resist the extrusive loss of anchorage and to maintain the level occlusal table.

When the tooth had fully erupted, a band was placed on each maxillary first molar, joined by a soldered transpalatal bar, in order to further brace the anchor molar against the uprighting and space-closing mechanics. Brackets were placed on the maxillary right premolars and the targeted third molar, together with a customized sectional archwire, in order to upright the roots of the third molar and translate it forwards (Figure 15.4e, f). In this second stage, the elastic was employed as and when needed, as a normal class III elastic, from third molar direct to the mesial end hook on the bonded mandibular device, in order to bring the third molar to its intended location and into occlusion.

Case 15.3: An impacted central incisor due to a midline supernumerary 'tooth'

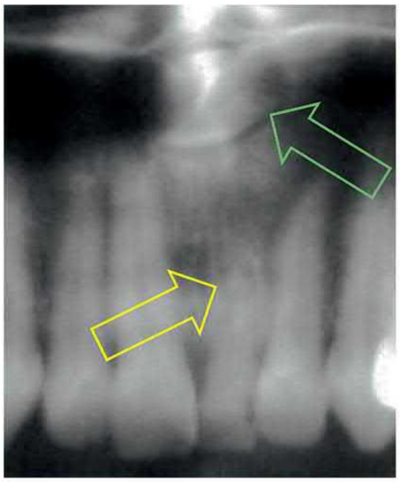
The female patient whose clinical intra-oral photographs are shown at the beginning of this chapter (Figure 15.1) was 24 years of age and was employed as a security officer in one of the European international airport hubs. She rarely came home to Israel during her three-year period of employment and decided to consult a local orthodontist in the country she was working in for treatment of her impacted central incisor tooth.

The treatment records were sparse and of poor quality, but much valuable information may nevertheless be gleaned from viewing the radiographs. Figure 15.5(a) illustrates the anterior section of the pre-treatment panoramic view and includes both permanent canines, both permanent lateral incisors and the right permanent central incisor. The erupted left central incisor was not the permanent incisor, but an over-retained deciduous central incisor. The green arrow points to the horizontally displaced and severely rotated left permanent central incisor, which was located high above the apices of the other teeth.

Since the X-ray beam in a panoramic view is very close to the horizontal (−7°), the height of the tooth (green arrow) that is depicted here above the root apices is a true representation of the vertical height discrepancy (i.e. 4–5 mm) between this tooth and the apices of the erupted incisors. By adding the average length of a central incisor (23–24 mm) to this discrepancy, we may conclude that the impacted incisor is approximately 28 mm from the occlusal plane [6].

If we now look at the anterior oblique occlusal film (Figure 15.5b), we note that the impacted central incisor (green arrow) has apparently 'moved' down over the region of the apical third of the roots of the other incisors. As distinct from the panoramic view, the anterior oblique occlusal view is taken at an angle of 60° above the horizontal. This, then, gave the investigative orthodontist a vertical shift (parallax) pair of views from which to ascertain that the crown of the central incisor was labial to the line of the dental arch, in the incisor midline region. Additionally, there was a small, circumscribed hard tissue entity, of unknown origin or character, between the root end of the over-retained deciduous tooth and the crown of the impacted incisor. It is possible that this small hard tissue entity was the obstruction that had caused the path of the permanent incisor to be deflected and the deciduous tooth to remain in place. From these films, it was also clear that the impacted incisor was severely rotated.

Treatment had begun with the placement of a fixed orthodontic appliance to level and align and to create the needed space for the unerupted incisor. At that point, a surgeon was commissioned with the task of extracting the deciduous incisor and the small hard tissue entity and to expose the crown of the incisor. A button attachment was bonded to the permanent incisor and force applied with elastic thread tied to the main archwire (Figure 15.5c) in a closed surgical exposure procedure. At the same time, a prepared and bracket-bonded temporary artificial tooth was ligated to the archwire to provide the patient with an enhanced appearance.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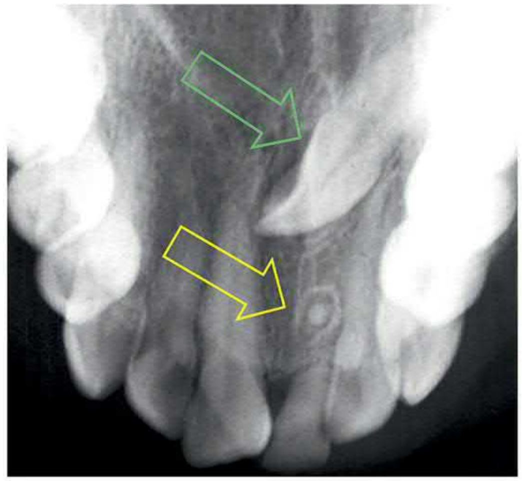
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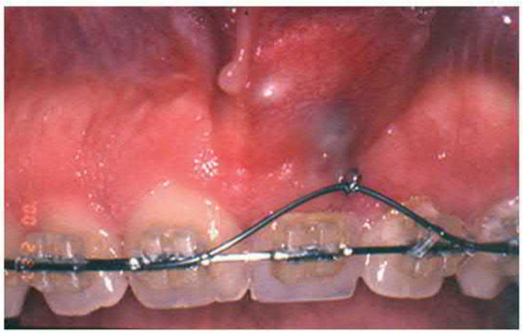
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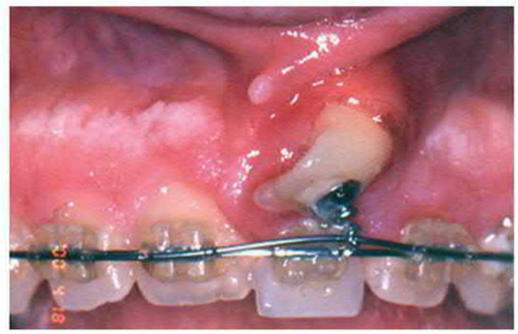
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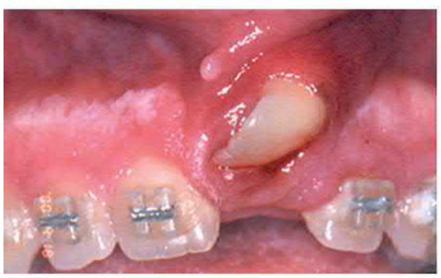
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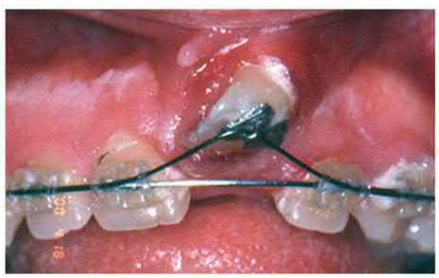
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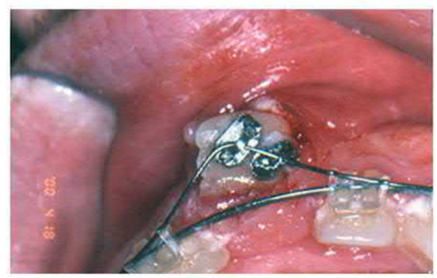

(h)


(i)


(j)


(k)


(l)


(m)

Fig. 15.5 Radiographic views of the anterior maxilla (a) in the panoramic view and (b) in the anterior (oblique) view, indicating the impacted right central incisor (green arrows). There is also a small circumscribed hard tissue entity, indicated by the yellow arrows. (c) Periapical radiograph showing the bonded button and twisted wire connector. (d) The nickel–titanium (NiTi) auxiliary archwire was drawn through the rolled-up circular end of the connector. (e) The button impinged on the archwire and artificial tooth, which, together with the horizontal posture of the impacted tooth, nullified continued extrusion. (f) Customizing the attachment: the button was removed and the artificial tooth eliminated. (g) Two eyelets were bonded at different heights on the labial face of the crown (April 2000). (h) Occlusal view of the same. (i) Much rotation and uprighting have been achieved (May 2000). (j) Re-locating the distal eyelet further disto-incisally and re-threading the NiTi auxiliary, before re-emplacement of the heavy base arch. (k) The uprighted tooth after bracket substitution, with base arch in place, an overlaid torqueing auxiliary and passive (retaining) uprighting spring (October 2000). (l) The appearance at bracket removal (March 2001). (m) Periodontal surgical modification (October 2001).

Several subsequent visits were made to the orthodontist to renew extrusive force activation, before the patient returned to Israel to commence a course of study at one of the state universities, a move that compelled her to transfer to a new orthodontist.

At the first visit to the senior author, the incisor was seen to bulge the oral mucosa, immediately above the artificial tooth, which obviously indicated positive movement of the impacted tooth. A small 'rolled-up' circular end of the twisted wire connector was threaded with an auxiliary 0.012 in. NiTi wire, placed 'piggyback' over the main arch and drawn down to be ligated with elastomeric modules to the bracket slots (Figure 15.5d). The patient was then referred to a surgeon, who raised a flap from the attached gingiva of the crest of the arch and apically repositioned it above the re-exposed tooth, leaving the crown and bonded button visible, but still largely inaccessible (Figure 15.5e).

The long axis of the tooth could now be estimated, from the angulation of the exposed crown, to be lying at an almost 90° angle to the vertical. In the bucco-lingual plane its root was marginally less, which meant that the apex was strongly displaced in a palatal direction. The tooth was rotated approximately 75° around its central axis.

It became evident that the multiple elements that were contributing to the displacement of the tooth in each of the three planes of space were way beyond the usual fine, single-figure discrepancies seen in the over-riding majority of orthodontic cases. This tooth was a very long way from the orthodontic 'ball park' [6]. The tooth required the following approximate correctional movements:

- 90° of mesial root uprighting.
- 75° of de-rotation.
- 90° of labial root torque.
- 28 mm of vertical extrusion to the height of the incisal edges of the adjacent teeth.

For these movements to be initiated the artificial tooth needed to be removed, since it impeded access to the labial surface of the tooth for bracket placement. It will be appreciated that these multi-planar elements (first-, second- and third-order movements) cannot usually be combined but, by and large, must be dealt with individually, with the first being completed before moving on to the next. It would therefore be advantageous to devise an efficient means of performing these very broad-range movements as expeditiously as possible, by customizing the attachments on the tooth so as to reduce to a minimum the period that a patient is without a front tooth.

Placing a regular bracket in its proper location after the button is removed is not easy, but attempting to ligate an archwire into the slot of that bracket, whether by steel ligature or elastomeric rings, is exceptionally difficult, impractical, and indeed ineffective. Attempting this manoeuvre is more likely to dislodge the bracket. On the other hand, the placement of two eyelets would avoid the necessity of ligation of any sort. The NiTi wire is fed through the eyelet and guided with an explorer away from the gingival tissues. In this way, much greater first-, second- and third-order distortions occur naturally in the NiTi archwire and provide a greater range of movement, while the force range may be lessened or increased by the size of the wire. Positive, physiological (force level) and long-lasting (range) forces may be brought to bear on the tooth concerned and it may be assumed that this idyllic set-up will create the micro-environment for the greatest efficacy in the movement of a single (formerly impacted) tooth. The laws of physics (Newton's third law of motion) inform us that there will be counter-effects on the adjacent teeth. It would accordingly make sense to hold the other teeth as rigidly as possible in a heavy base arch (Figure 15.5g, h) in order to spread the load, while the fine NiTi wire does the hard work.

As the tooth uprighted and rotated, the distal eyelet was re-bonded to a new location, closer to the incisor edge and at the disto-labial corner of the crown. Renewal of activation occurred when the same or a new plain auxiliary NiTi archwire was once again threaded into the system.

The uprighting force on the tooth itself was directed from the anatomical lingual to the anatomical labial sides, across its root. However, because the tooth was so strongly mesio-labially rotated, this resulted in labial torque of its root. This may be seen in the series of illustrations in Figure 15.5(f–j) to have been progressively occurring at the same time as the tooth was de-rotating and its root was uprighting. The final effect of this unorthodox biomechanical set-up was to over-torque the root of the incisor labially.

In general, when labially impacted maxillary incisors are orthodontically erupted, control in the labio-lingual dimension cannot usually be achieved until their ideally located brackets are fully engaged in the main archwire. Accordingly, the tooth initially comes down and into alignment with an apex-to-crown lingual tip of its long axis. It must be expected, therefore, that the finally aligned and torqued incisor will usually feature a long clinical crown.

In the present case, we had converted the lingually displaced root of an impacted tooth into a labially displaced root. Accordingly, it became necessary to apply lingual root torque to achieve an acceptable outcome (Figure 15.5k) and to initiate a corrective periodontic procedure to attempt to level the gingival line (Figure 15.5l, m). Retention of the treated result was served by a bonded, stainless steel braided wire.

Implant anchorage

Case 15.4: Erupting an impacted molar and intruding its over-erupted antagonist: Defying Newton

An impacted tooth is always 'vertically challenged'; accordingly, the principal force vector that is needed to erupt an impacted tooth is a vertical force. In order for such a force to be effective, it requires to be at a certain force level and to have a broad range of action. For a tooth that is located at a distance from its normal location, the further the platform from which the force exerted on it originates, the wider will be the range of its activity. Implants inserted in the jaw adjacent to an impacted tooth cannot enable the required range to be achieved, and for this reason the use of implants for the eruption of impacted teeth is usually not very efficient. Furthermore, the temporary anchorage device (TAD) cannot be placed too close to the vertical eruption path of the tooth, since it will become an obstacle preventing its resolution.

Nevertheless, useful alternative approaches present themselves, such as the mid-palatal onplant [7] and the placement of a TAD in the opposing jaw, in a direct vertical line to the impacted tooth, with vertical intermaxillary elastic forces applied by the patient him- or herself. In the case shown in Figure 15.6, a mini-screw TAD placed on the buccal side of the mandibular alveolus, just distal to the second molar tooth, may be used as the source of anchorage for the vertical elastic, in place of the bonded anchor unit.

However, it is not often possible for the patient to place an elastic on the impacted tooth. A second approach, therefore, has the orthodontist applying the force from the impacted tooth directly to the main archwire. In order to overcome the tendency for the two or three adjacent teeth to intrude (anchorage loss), the patient draws vertical up-and-down elastics from the easily accessible hooks on brackets placed on these adjacent teeth to the implant TAD in the opposite jaw. In this way, the likelihood of the anchor tooth becoming intruded will be averted. This is referred to as 'indirect anchorage', an example of which may be seen in a failed case described in Chapter 2 (Figure 2.8).

The presenting symptom for the case of a 19-year-old male patient was ulceration of the thick mucosa covering the alveolar ridge, over an impacted second mandibular permanent molar. In the absence of its antagonist, the maxillary second molar had considerably over-erupted and its mesio-palatal cusp was occluding with the ulcerated mucosa. The reason for the non-eruption of the mandibular molar was the presence of a large dentigerous cyst encompassing its crown (Figure 15.6a, b).

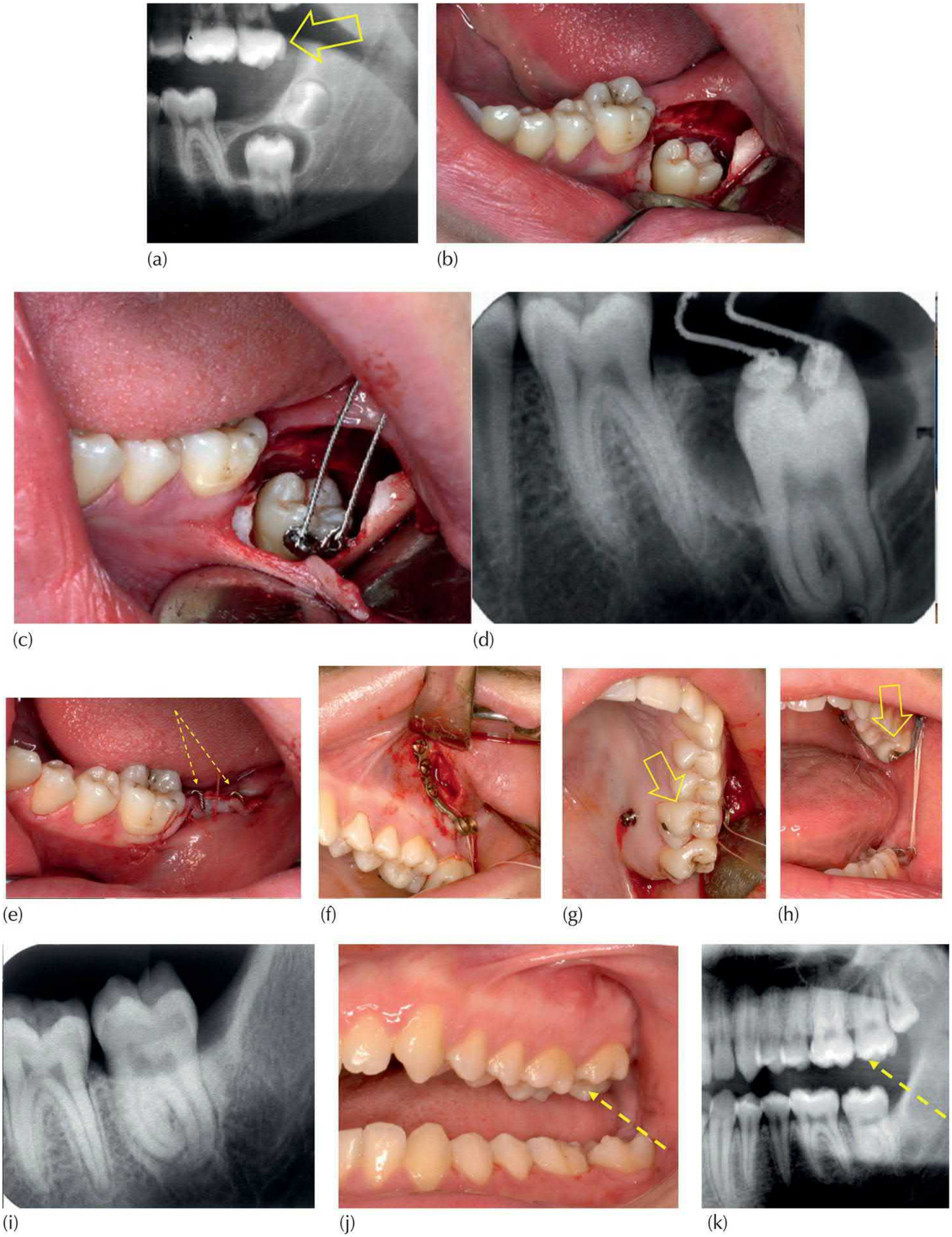
In cases such as this, the anchorage requirement for raising the impacted mandibular second molar is minimal, although the biomechanics is sometimes difficult. Occasionally the condition may resolve itself following surgical treatment of the cyst and the tooth may eventually erupt without assistance. However, when the impacted second mandibular is deeply located in the mandible (Figure 15.6a), maintenance of the patency of an open exposure is likely to be problematic and the process of re-healing of the tissues may delay or arrest progress. It is advisable at the time of exposure to place two attachments on the buccal surface of the tooth (Figure 15.6c, d) – two, because bonded attachments may occasionally fail. The surface of the tooth is broad enough to accommodate both. The twisted wire ligatures were drawn upwards to permit the complete sutured closure of the buccal and lingual sides of the gingival tissue surrounding the extraction site. These ligatures were then cut short at their exit from the wound and turned into small hooks (Figure 15.6e).

There is a corollary to the problem in this case: it was also necessary to intrude the over-erupted maxillary second molar and to establish a distance from the maxillary molar to the lower arch, in order to provide vertical space for the full eruption of the impacted tooth. The intrusion aspect in the maxilla was more challenging than the extrusion aspect in the mandible and it required the use of a pair of TADs in the maxilla on either side of the ridge (Figure 15.6f–h).

A simple screw TAD was placed on the palatal side of the tooth (Figure 15.6g) at a point where there was adequate bone, specifically between the palatal roots of the two molars. A similar screw could also have been used on the buccal side. However, with two buccal roots for each molar and a narrow rim of buccal bone, failure of the TAD was considered likely to occur on that side. The use of a zygomatic plate was preferred in this case (Figure 15.6f), despite the greater difficulty with its placement and, later, with its eventual removal.

The zygomatic plate was placed with three screws on the underside of the zygomatic process of the maxilla, with its free-end hook protruding through the attached gingiva on the buccal side, above the second molar (Figure 15.6h). At the subsequent monthly visits, the orthodontist stretched an elastic chain from the palatal TAD across the occlusal surface of the upper molar to the zygomatic plate hook (Figure 15.6g). This supplied an intrusive force to the upper molar. A button was bonded to the occlusal surface of the molar in order to prevent the elastic from slipping inter-proximally and traumatizing the gingiva.

The patient was instructed in the placement of the up-and-down vertical intermaxillary elastics between the twisted ligature hooks, which were ligated to the eyelet attachments on the mandibular molar, and the zygomatic plate hook. This activated extrusive force to the lower molar. The implants and buttons were finally removed, when the two opposing second molar teeth had successfully arrived at the occlusal plane from opposite directions, with molar marginal ridges levelled in each (Figure 15.6i–k). Treatment duration was eight months, with no other appliance or retention required.



(a) (b) (c) (d) (e) (f) (g) (h) (i) (j) (k)

Fig. 15.6 (a) Left side of panoramic film, showing an unerupted second molar with a dentigerous cyst and an over-erupted maxillary second molar (arrow). (b) Exposure of the mandibular second premolar illustrates the size of the cyst cavity. The third molar was removed at the same visit. (c) Two attachments bonded, since access was good and a large surface was available. (d) Post-surgical periapical radiograph. (e) The exposure site was fully sutured closed, with the two pigtail ligatures fashioned into hooks for elastic traction (arrows). (f) The zygomatic plate and a palatal screw temporary adjustment device (TAD) were inserted under local anaesthetic cover. (g, h) An elastic chain was drawn between the palatal TAD and the zygomatic plate, across the occlusal surface of the over-erupted tooth (arrows), and secured against accidental slippage by a bonded button on the occlusal surface. A single up-and-down intermaxillary elastic was placed by the patient between the hooked end of the zygomatic plate and the molar pigtail ligature hooks and worn full time. (i) Periapical view of the mandibular second molar post treatment. (j) At the end of treatment, the maxillary second molar is well intruded (arrow) and the mandibular second molar had been erupted to the occlusal plane. (k) Section of the post-treatment panoramic view to show maxillary and mandibular molars at the completion of treatment.

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16
Lingual Appliances, Implants and Impacted Teeth

Stella Chaushu

The context of impacted canines vis-à-vis the lingual appliance

Differences in treatment approach engendered by the use of lingual appliances

Canine traction, eruption and alignment

Finishing procedures

Anchorage considerations

Integrating implants with lingual appliances

Conclusion

The context of impacted canines vis-à-vis the lingual appliance

There are four major drawbacks to the ortho-surgical approach for resolution of impacted teeth in adults, namely prognosis, duration of treatment, the need to wear orthodontic appliances and anchorage.

In the last chapter it has been pointed out that the prognosis for the success of the orthodontic resolution of the impacted canine in an adult is lower than in the young patient and that it worsens with advancing age. Furthermore, when such treatment is undertaken, its successful completion should be expected to take considerably longer than in younger patients [1]. For this reason, it is important to find creative ways to shorten the whole treatment, especially that part of it related to the canine impaction. While the objective treatment difficulties are considerable, the adult patient may reject the whole plan of treatment because of the need for wearing unaesthetic fixed orthodontic appliances for long periods of time. Among the 'invisible' appliances used in adults, the lingual orthodontic appliance is, at present, the only viable alternative to the traditional labial appliance that may be efficiently used to treat such complex conditions in adults. Clear aligners can be used as anchorage systems, but they cannot create forces for erupting and dragging an impacted canine into the arch, therefore buttons/attachments fixed to adjacent teeth must still be used.

Only a few articles have been found in the English-language orthodontic literature describing the use of lingual appliances in treatment of impacted teeth in adults [2, 3]. This is rather surprising in the light of the growing demand for facial and dental aesthetics from adult patients and in the light of the fact that lingual orthodontics has become established as a well-recognized and widely accepted discipline. It is nevertheless understandable because, in the treatment of the cases under discussion, an orthodontic appliance may need to execute as many as five different types of movement on the impacted tooth, involving vertical extrusion, tipping to the line of the arch, rotation, mesio-distal root uprighting and buccal root torque (see Chapter 7). Achieving these movements with a lingual appliance is more difficult, and clinicians undoubtedly prefer to treat cases requiring these complex manipulations with the more familiar labial appliances.

Differences in treatment approach engendered by the use of

lingual appliances

Changes and adaptations need to be made to the protocols for the treatment of impacted teeth that have been suggested in earlier chapters of this book, in line with the demands of each of the various stages of treatment. Several problematic areas arise, and it is necessary to show how these may be overcome using the lingual appliance.

Following accurate positional diagnosis, placement of the lingual appliance will initially be aimed at levelling, alignment and space opening for the impacted tooth. These goals may be realized in the present context with the help of copper nickel–titanium (NiTi) archwires initially (Figure 16.1), then a heavier steel archwire, an open-coil spring and sliding mechanics.

The space achieved must then be maintained until the impacted tooth has been initially aligned in the arch. With labial appliances, we have recommended the use of a gently curved stainless steel tube threaded on the wire to act as the space maintainer (see Chapter 6). However, this is not feasible in lingual appliances because of the premolar offset. Therefore, in lingual treatment space is usually maintained with a closed-coiled spring (Figure 16.2), or with a pair of offsets distal to the lateral incisor and mesial to the first premolar, or by 'figure-of-eight' ligation of the teeth on either side of the space.

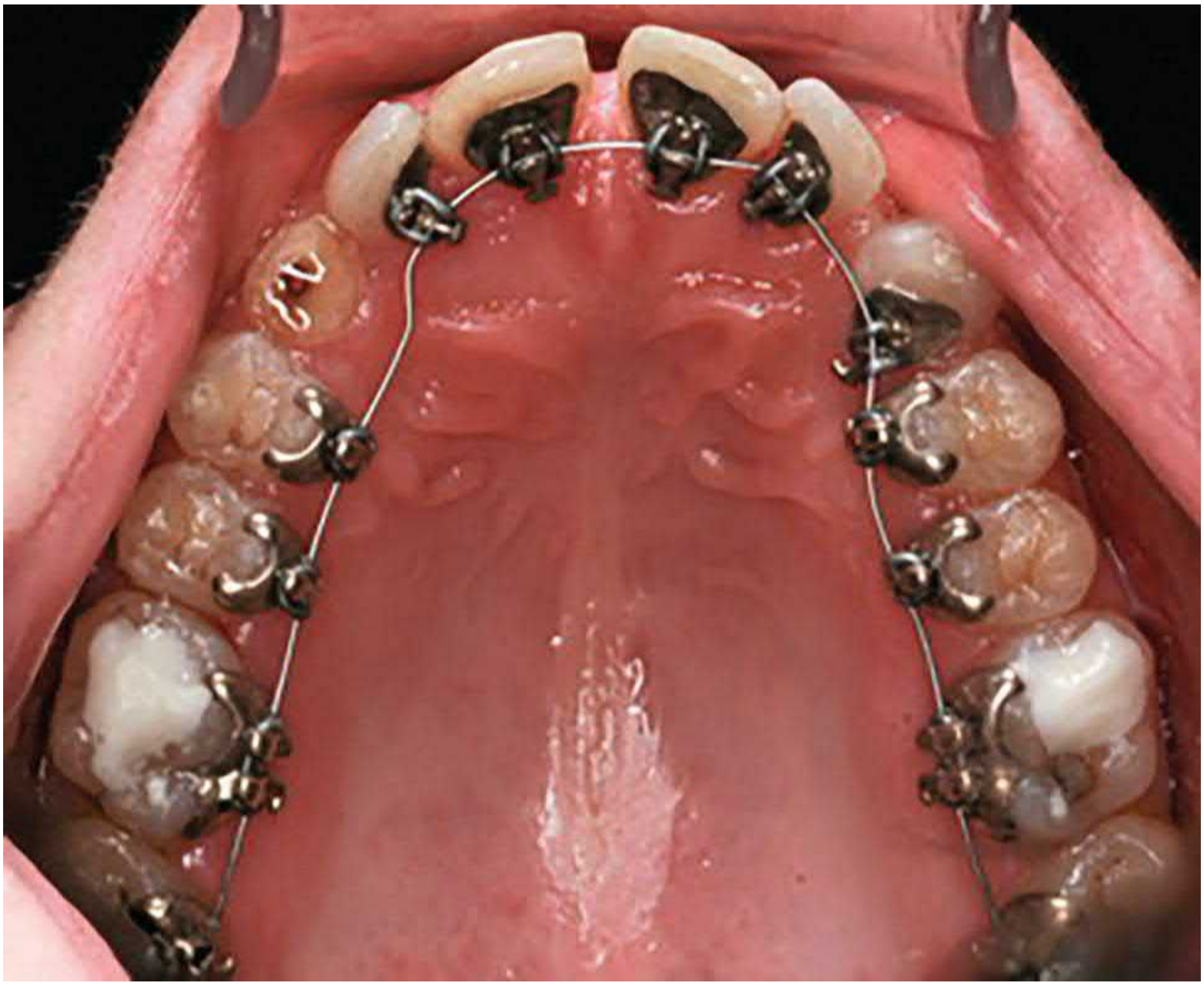


Fig. 16.1 Lingual appliance (Incognito) in case of palatally impacted #13.

Fig. 16.2 Space maintenance with a closed-coil spring.

In Chapter 3, we have discussed the advantages of a closed eruption technique and shown that it provides a better periodontal and aesthetic result when compared to the open eruption technique [4, 5]. The closed eruption technique also results in less postoperative patient discomfort for exposures in the palate [6]. However, a closed eruption procedure for a palatal canine generally requires an intra-sulcular incision along the cervical margins on the palatal side of all the teeth, with the flap raised from first molar forwards. In the presence of a lingual appliance this procedure is clearly difficult to perform, since the brackets and their hook attachments are adjacent to and extend deeper than the cervical margins, obstructing access. Removing the archwire is mandatory prior to surgery, which complicates its post-surgical replacement and the application of traction.

The alternative approaches are:

- To perform closed surgery before appliance placement, leaving the ligature unattached and free in the palate until traction can be initiated, several weeks or months later.
- To perform an open surgical exposure, accepting the disadvantages of its post-surgical discomfort and post-treatment outcome (Figure 16.3).

Canine traction, eruption and alignment

In cases in which traditional labial orthodontic appliances are employed, direct traction to the archwire is often the most efficient line of treatment, and this is best achieved using elastic ties from the impacted tooth across the line of the arch, to the labial side. However, with lingual appliances the distance to the lingual archwire is noticeably short and direct traction is rarely appropriate, except in the early eruption phase of the traction (Figure 16.4).

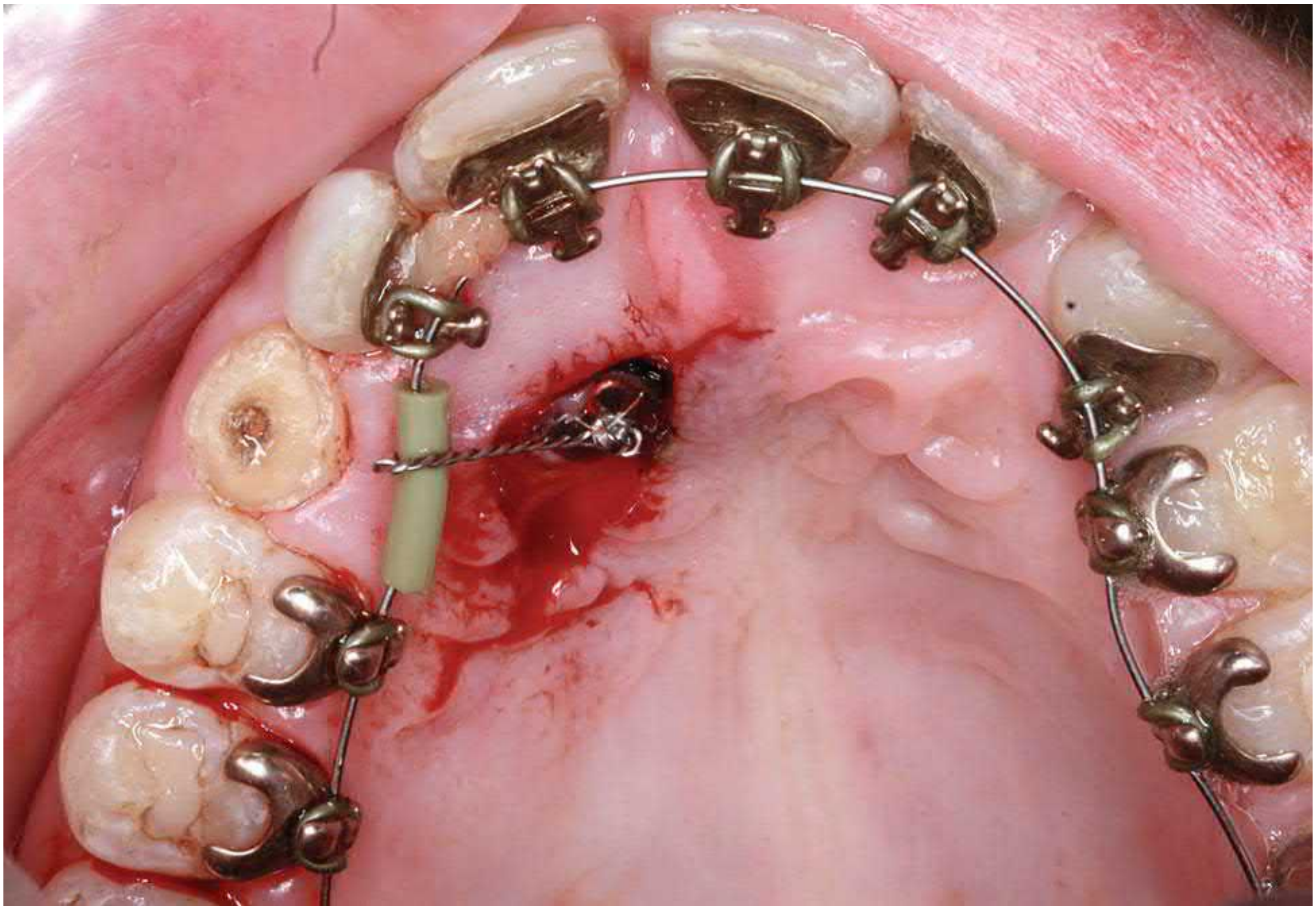


Fig. 16.3 Open surgical exposure of the canine.

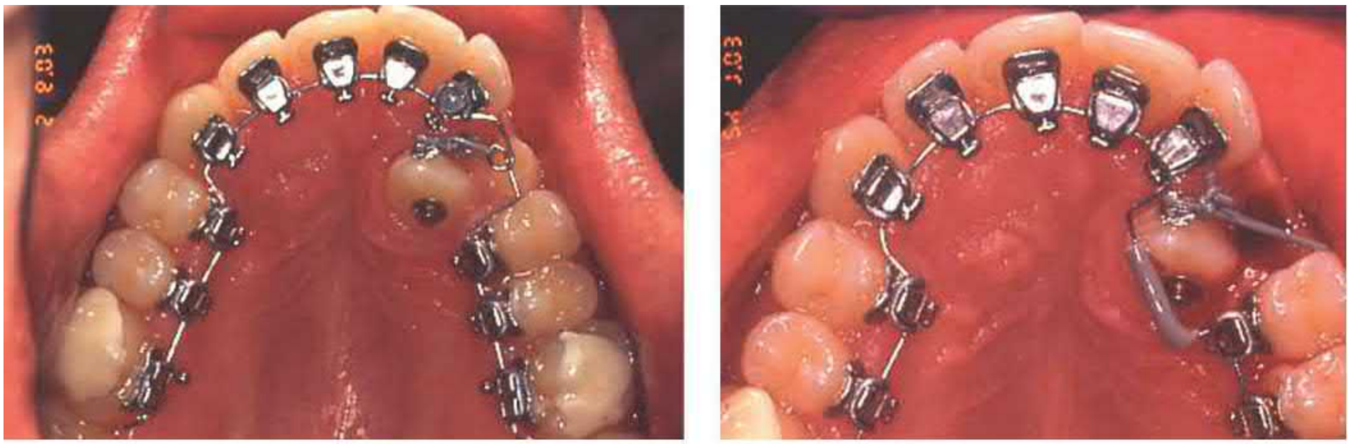
Fig. 16.4 Small distance between palatal canine and lingual archwire.

Following eruption, the lingual wire becomes an obstacle in the way of further progress of the canine. A buccal offset with a helix may be incorporated in the canine area of the lingual archwire to increase this distance and the range of the elastic (Figure 16.5a). A palatal offset may also be used, in which the archwire is designed to circumnavigate the canine on its medial side and close to the palatal midline raphe, while labial/buccal traction will need to be made to a small buccal attachment on a posterior tooth (Figure 16.5b).

In group 2 canine cases, the intimate relation between the canine crown and lateral incisor root will block the canine movement if direct traction is applied, while in group 3 canines the height of the tooth may contra-indicate the use of direct buccal traction. Therefore, the canine must be erupted first in a vertically downward and somewhat palatal movement in order to free it from its entanglement with the incisor roots, as has been amply demonstrated in earlier chapters. An appropriate canine auxiliary should be prepared to be placed at the time of surgery as in a labial approach, such as a suitably modified full auxiliary arch [7]. Again, due to the considerably shorter distance between the impacted tooth and the lingual archwire, the range of action will be significantly decreased and there is a risk of inadvertently applying excessive extrusive forces (Figure 16.6).

Therefore, the auxiliary should be made from lighter wires or its activation range should be decreased. This spring is inserted piggyback under a lingual heavy rectangular base arch, the latter having been placed to consolidate the anchor unit, while the spring provides a light extrusive force to the canine. In this way, unwanted movement on the adjacent teeth will be avoided.

Alternatively, a light active palatal arch (see Chapter 6) may also be used in combination with lingual appliances, although it requires additional molar tubes. Preferably these should be welded to pre-formed orthodontic bands, although the bands themselves may not be acceptable by the patient, for aesthetic reasons and despite the fact that they are so distally sited in the mouth. Once the canine has erupted in the palate, it must be moved buccally towards its place in the arch and the same means may be used as described above. Vertical offsets, designed to erupt the tooth, are limited by the likelihood of impingement by the occlusion of the lower teeth. However, during movement towards the buccal, occlusal interferences with the opposing teeth, which are sometimes encountered when a labial appliance is used, are obviated by the bite-opening effect of the lingual appliances, which eliminates these interferences and facilitates canine migration at this stage.



(a) (b)

Fig. 16.5 (a) Elastic thread tied between the buccal eyelet of the impacted canine and a loop in the buccal offset of the lingual archwire. (b) Elastic thread tied between the buccal eyelet of the impacted canine and an attachment bonded on the buccal aspect of the first molar (unseen). A palatal offset is inserted in the lingual archwire.

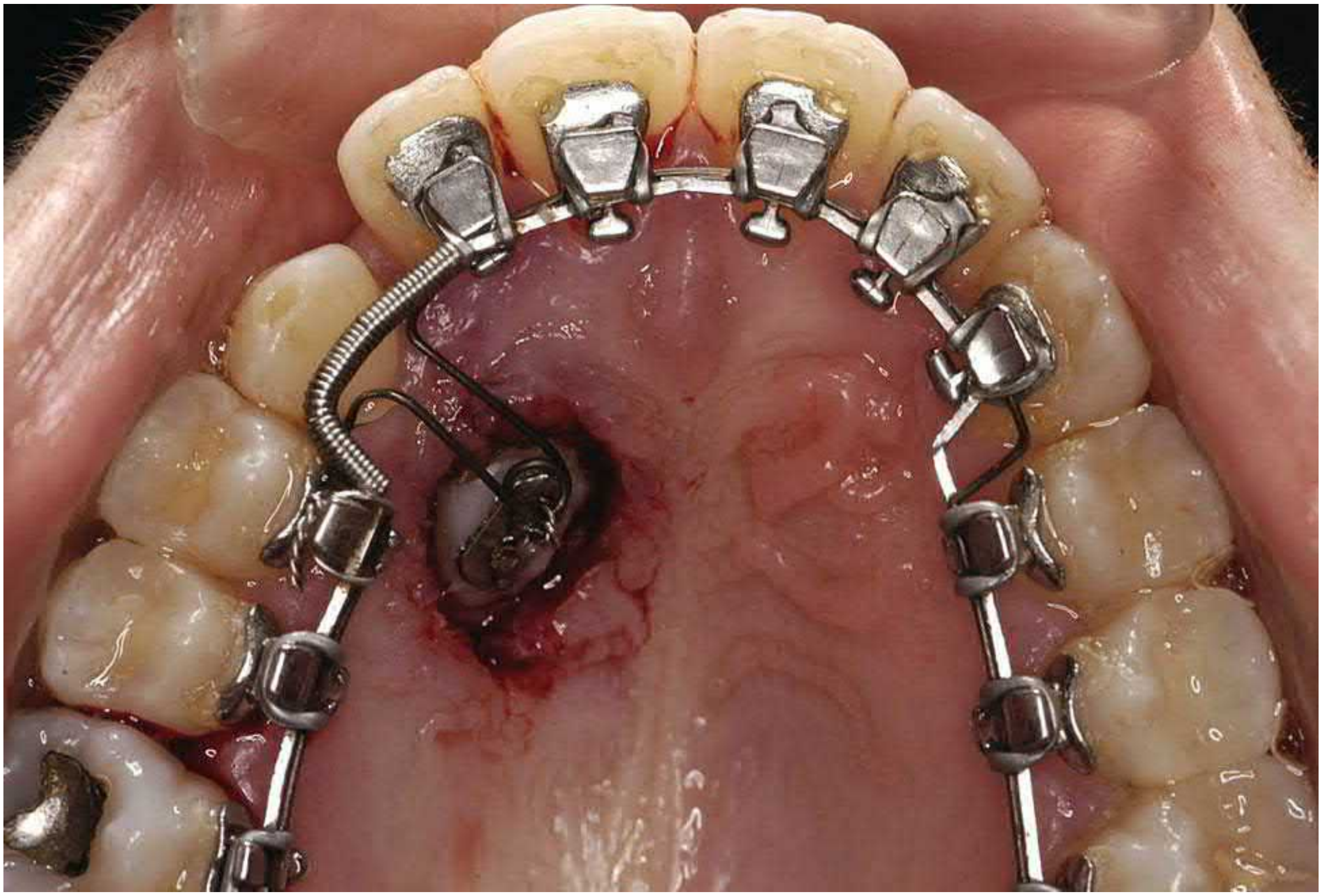


Fig. 16.6 Canine auxiliary ligated under main lingual arch and to canine eyelet.

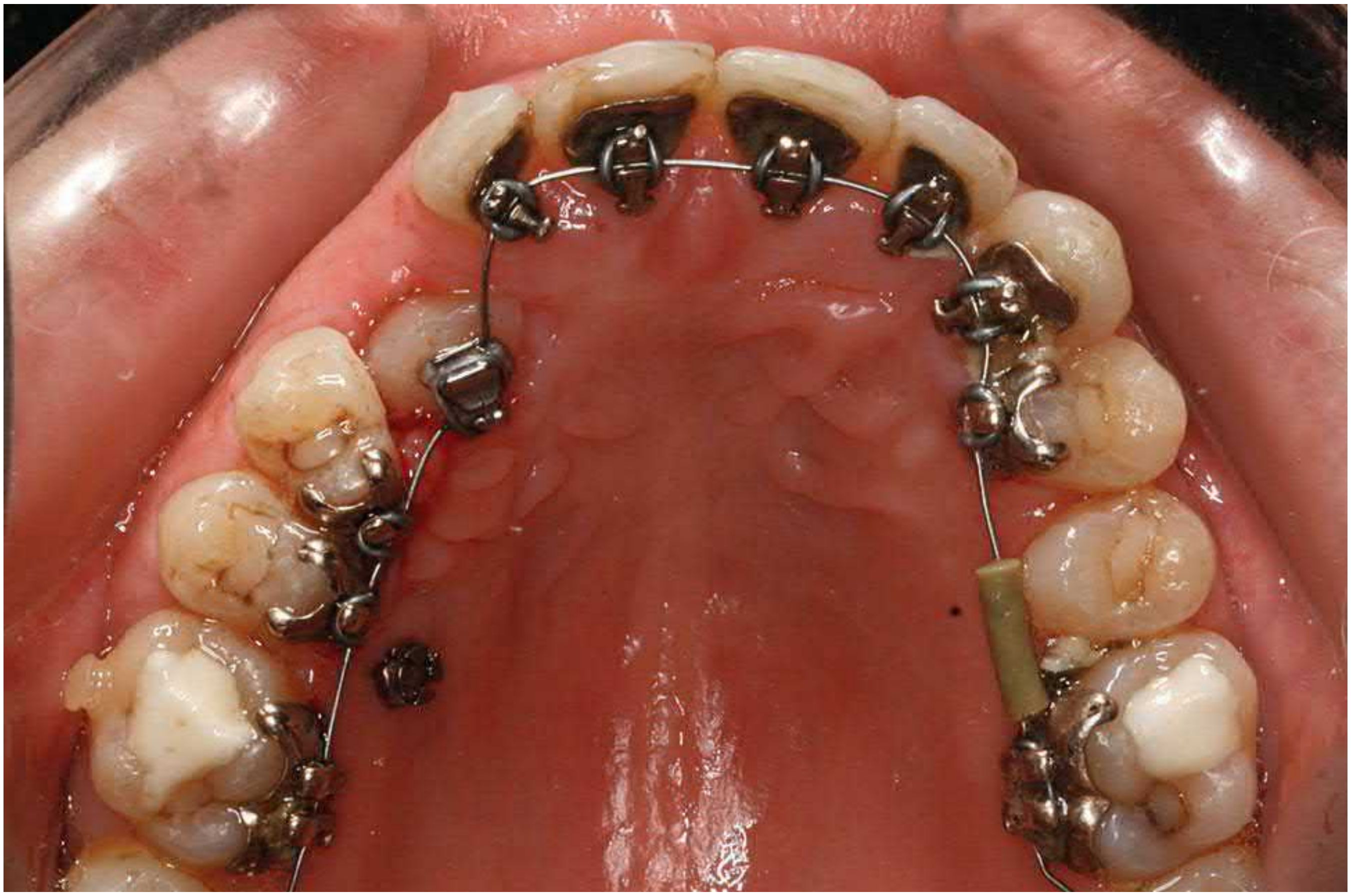


Fig. 16.7 Nickel–titanium archwire inserted through the palatal eyelet.

The short inter-bracket characteristic of lingual appliances is another difference that has clinical implications and will demand the much wider use of super-elastic archwires. With such short inter-bracket spans, even these wires are sometimes too stiff to be fully engaged in the bracket slots and may often be tied tightly into the initial canine attachment only when this tooth has reached a position that is relatively close to its place in the arch. This is done to avoid the application of excessive force on the resolving impacted tooth and to minimize the reactive forces on the adjacent teeth.

When the canine reaches its place in the arch, a bracket has to be bonded (Figure 16.7).

In traditional labial orthodontics, bonding of a bracket at its ideal height on the buccal aspect of the canine is usually impeded at this stage by exuberant gingival tissue, which accumulates on the buccal aspect during the canine's migration towards the buccal, even with good oral hygiene. In contrast, bonding of a lingual bracket is much easier since the clinical crown on the palatal side is usually long, particularly if an open exposure was performed for this tooth.

Finishing procedures

Finishing procedures with lingual appliances are like those with labial appliances. However, since torqueing auxiliaries are largely unsuitable and certainly difficult to design and insert, torque must be introduced in the rectangular archwire or in the bracket base. As with the labial appliance, torqueing a canine with a rectangular archwire might take a long time, because of the small range of deflection possible with the wire and the need for several progressive activations. It should be clearly understood that these torqueing deflections will generate small, but undesirable, reciprocal torqueing moments of the adjacent anchor teeth at each activation, which correct themselves as each activation works itself out. This is generally referred to as 'round-tripping' the anchor teeth, a phenomenon that has been blamed as a cause of root resorption generally. So while torqueing auxiliaries are highly recommended in labial appliances to avoid this potentially harmful side effect, their use with lingual appliances is presently limited.

An additional aspect of lingual treatment, already referred to, is the fact that many of the patients concerned have remarkably high aesthetic demands and will not tolerate the extraction space of the deciduous canine, without some form of temporary pontic placement. For these reasons, the extraction of the deciduous canine needs to be delayed until a late stage of the treatment. If it is necessary to remove the deciduous tooth at an earlier stage, an artificial tooth must be bonded to the adjacent teeth during the intervening period. This may also be a problem with an adult undergoing any form of orthodontic treatment, although the likelihood is much less when the patient has agreed to wear labial appliances, particularly if these are all metal.

Anchorage considerations

One of the most important principles of the mechano-therapy in the treatment of cases with impacted canines is to build up a reliable anchorage unit. This is obviously true for both labial and lingual techniques. Because impacted teeth are much more resistant to movement in adults than in children, the effort to bring them into alignment will be reflected in greater loss of anchorage (Figure 16.8). This may be further undermined, and the problem further compounded, if in addition the anchor teeth are periodontally involved, with loss of bone support.

Fig. 16.8 Loss of anchorage in treatment of a palatally impacted canine in an adult patient. (a) Frontal view. (b) Asymmetrical overjet.

The use of most traditional means of enhancing the anchorage in children, such as palatal arches, consolidation of anchor units with heavy rectangular arches and intermaxillary traction, are appropriate for adults, while others, such as extra-oral appliances or lip bumpers, are taboo for adults in general – and more so for the patient who wants the appliance to be completely invisible and who is averse to anyone knowing that treatment is being performed at all. New opportunities have been opened for adults with the introduction of temporary and osseo-integrated anchorage devices, which have been developed and used especially in cases in which a large amount of tooth movement is required in the absence of adequate alternative anchorage. Mini/micro screws have many advantages. They are inexpensive, small, simple to place, immediately loadable and well tolerated by patients [8–12]. Their main disadvantage is their proximity to the roots, which may be damaged during placement of the screws or when the adjacent teeth are displaced [13].

Integrating implants with lingual appliances

A well-thought-out strategy for the placement of implants offers the possibility of facilitating and shortening treatment and, at the same time, decreasing the deleterious effects of anchor loss. This may be achieved in the following ways.

A titanium mini screw may be inserted in the posterior area of one side of the palate, to provide anchorage for erupting a group 2 or group 3 canine (see Chapter 6) into the palate. A power chain can be used to distance the canine away from the lateral incisor (Figure 16.9).

To provide the extrusive forces, a 0.016 in. stainless steel ballista spring with a loop at its end can be inserted through the internal slot of the mini screw (Figure 16.10a) [3].

The spring is activated by bending it down towards the tongue and then tying it to the pigtail ligature wire of the impacted tooth (Figure 16.10b) [3]. The elasticity of the spring exerts pressure for it to return to its more vertical resting shape and position, thereby applying extrusive force to the unerupted tooth. The ballista spring can be loaded immediately after the surgery, while the patient is still anaesthetized.

Secondly, a micro screw may be inserted into the bone on the labial side of the alveolar ridge [2] to provide the necessary anchorage for moving the tooth buccally towards its place in the arch, once it has been erupted into the palate. An elastic thread tied from an attachment bonded on the buccal aspect of the canine to the micro screw will create a buccally directed force and a moment for correcting its rotation (Figure 16.11).

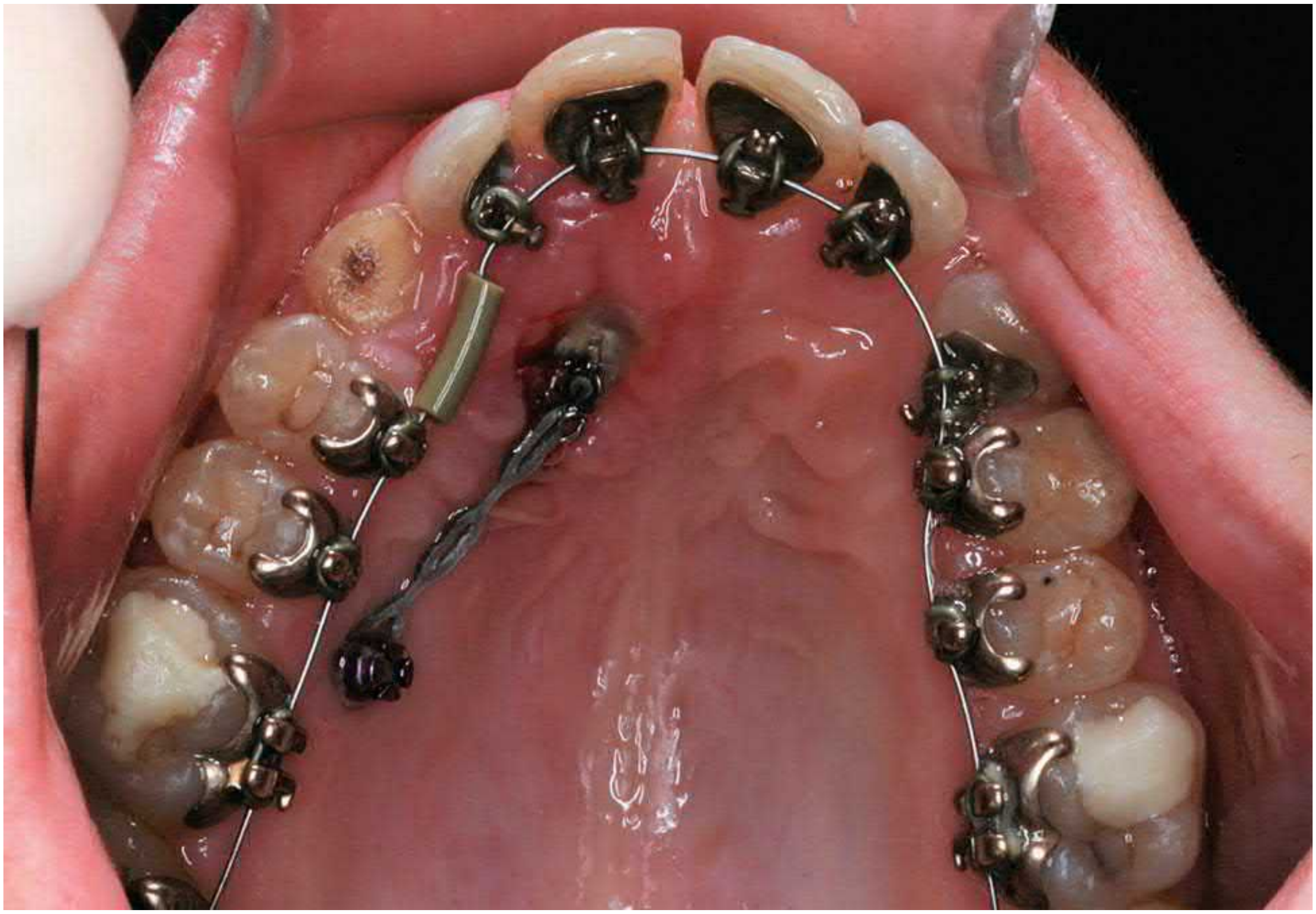


Fig. 16.9 Elastic traction from the eyelet bonded on the palatal aspect of the impacted canine crown to a micro screw inserted between the second premolar and the first molar.

(a) (b)

Fig. 16.10 Ballista spring tied into mini screw. (a) Passive state. (b) Activated by ligation to pigtail ligature, applying traction to the unerupted canine.

The archwire should be offset in the canine area to permit canine movement. Alternatively, the archwire may be cut distal to the lateral incisor and mesial to the first premolar into separate segments, or the canine moved underneath the lingual archwire to attachments placed on the labial side of the anchorage teeth (Figure 16.12). A continuous archwire may be re-inserted after the canine has nearly reached its proper place in the arch, through the palatal eyelet or a newly bonded lingual bracket to perform its aligning and levelling.

In cases where direct traction of the impacted tooth to the archwire is possible from the beginning of treatment, a micro implant may be introduced in the buccal bone in the same appointment at which the surgical exposure is performed (Figure 16.13a). An elastic force from the impacted canine to the micro screw may then be applied immediately, while the patient is still anaesthetized (Figure 16.13b).

If the deciduous canine has to be extracted, an aesthetic pontic needs to be fabricated and the elastic passed under the pontic. In these cases, it is recommended to delay the insertion of the implant until a period of healing of the extraction space has occurred, since the chances of failure are greater when an implant is inserted into a fresh extraction site. Thereafter, the canine may be moved underneath the palatal mucosa towards its place in the arch. In order to move it further buccally and also to extrude it, a beta-titanium (TMA) spring with an artificial tooth may be connected to the implant and activated buccally and vertically, as necessary (Figure 16.14).

It will be seen that a group 2 canine requires two implants, one in the palate to erupt and move the canine away from the lateral incisor root and the other in the buccal alveolar plate for moving the tooth buccally into the dental arch. Cases in which direct traction is possible require only one implant placed in the buccal plate.

The most important advantage of using orthodontic implants is that treatment of the impaction may be initiated before levelling and alignment and opening of adequate space in the arch, and continued in an entirely independent manner. Hence, the clinician has two possible options:

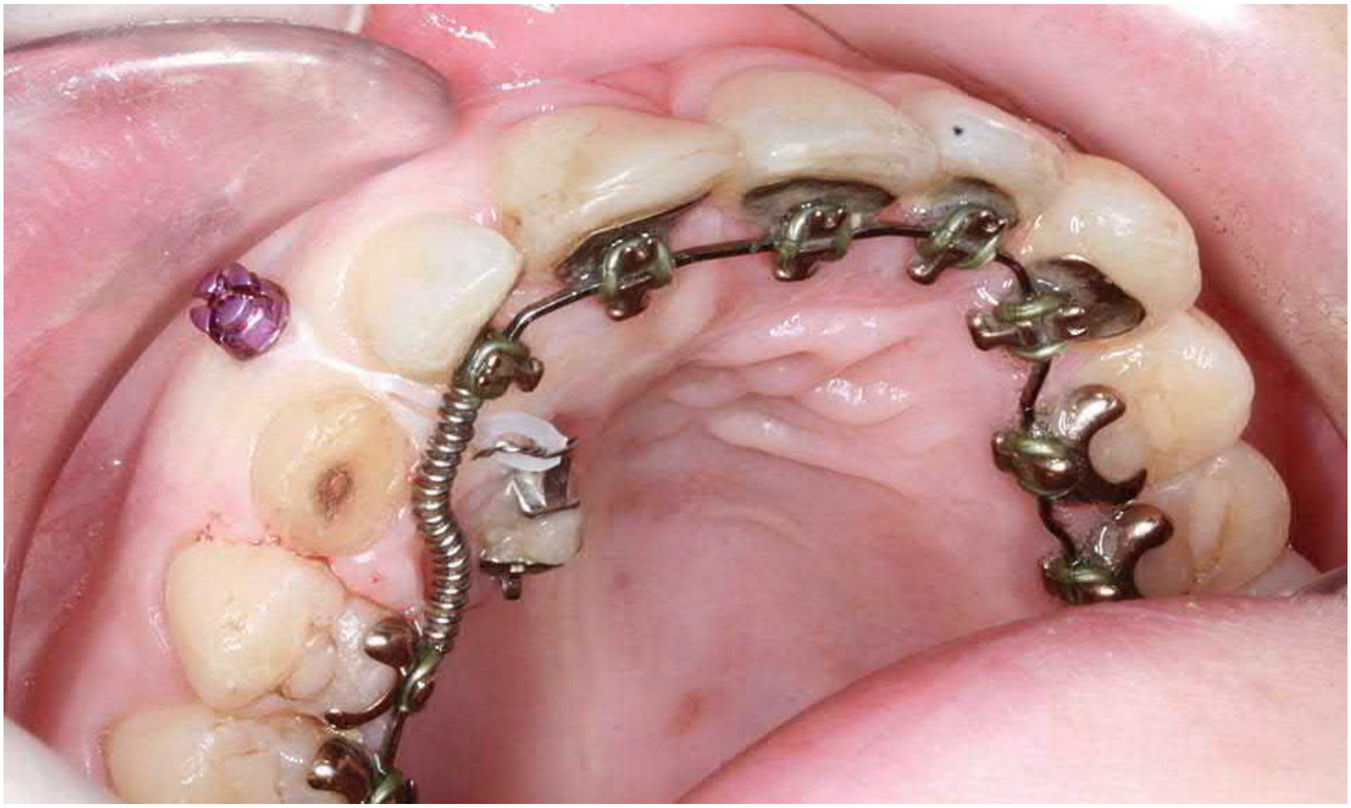


Fig. 16.11 Elastic traction from a secondary labial eyelet to a labially situated micro implant.

Fig. 16.12 Canine moved buccally underneath the lingual archwire.

(a) (b)

Fig. 16.13 (a) Micro implant inserted at the appointment for the canine exposure. (b) A clear chain will be drawn beneath the pontic to the micro implant, to apply buccal traction to the impacted canine.

(a) (b)

Fig. 16.14 (a, b) Beta-titanium spring in its passive mode, bonded to the implant and carrying an artificial tooth. Ligation to the canine will draw the tooth vertically and buccally.

- To erupt the canine concomitantly with and as an integral part of the orthodontic treatment of the other teeth, which is relevant when space opening in the dental arch is needed first. In this case, it would be wiser to erupt the canine only partially (in contrast to what is recommended for labial treatment – see Chapter 6) and then to continue its buccal movement underneath the palatal mucosa, until it passes the lingual archwire on its buccal side. This will avoid archwire interferences and the need to fabricate offsets.
- To perform the entire stage of treatment required for treating the impaction before placing any orthodontic appliance. This approach is suitable in cases in which there is adequate space for the canine in the arch, but also in many other cases, in the interests of reducing the time that orthodontic appliances need to be in the mouth.

The use of implants in this way is equally valid for both labial and lingual treatments and may significantly shorten the period for which the patient has to wear either unaesthetic labial or uncomfortable lingual orthodontic appliances. The idea of treating out the resolution of the impaction before placing appliances is particularly advantageous in lingual treatment, since the problem of interference of canine movement by the archwire is thus circumvented before appliances are placed.

Conclusion

Orthodontic treatment, in general, is a discipline in which a force system is set up to move certain teeth in specifically determined directions and in a particular way, while at the same time preventing the reactive forces that are transferred to the anchor teeth from causing unwanted deterioration in the positions of the anchor teeth. Thus, implant anchorage, which is absolute and not relative anchorage, greatly simplifies the approach, because forces may be applied solely to the impacted tooth, thereby avoiding ill effects on the remainder of the dentition and the need for a cumbersome orthodontic system. Implants may be placed in a wide variety of positions, both within and well outside the dental arch, and as such may be carefully planned and strategically chosen for optimal direction and range of force application.

The combination of lingual appliances and implant anchorage is useful in the ortho-surgical treatment of impacted teeth in adult patients, who would otherwise reject treatment altogether because of the need to wear an unaesthetic labial appliance over a long period of time. This combination can provide answers to three major drawbacks of the ortho-surgical treatment of impacted teeth in the adult patient, namely unimpaired oro-facial appearance, length of time that fixed appliances need to be worn and anchorage.

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17
Clear Aligners in the Treatment of Impacted Teeth

Dror Aizenbud, Tarek El-Bialy and Hagai Hazan Molina

The beginning of an era

Mechanical principles of the aligner

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Clear aligner intra-oral elastics interface

The beginning of an era

A clear aligner system was introduced into the orthodontic armamentarium in 1997 by two graduate students at Stanford University. It has become one of the most highly recommended orthodontic techniques for the treatment of adult patients, and recently even for teenagers and younger children [1], by virtue of its relative invisibility.

Conventional orthodontic treatment with fixed appliances usually takes 20–24 months. As was mentioned in Chapter 4, the complete alignment of an awkwardly placed impacted tooth may add an additional year or even more to this time [2–5]. Due to the long treatment period, teens and adult patients often express reservations about wearing unaesthetic fixed orthodontic appliances.

The 3D computer-aided modelling technique enables the fabrication of removable, clear, semi-elastic polyurethane aligners, which fit over all the tooth's surfaces and are capable of moving teeth with relative precision to a position of improved alignment and occlusion [6]. Not only is the digital orthodontic aspect revolutionary but also its biomechanical basis, insofar as the forces can be exerted simultaneously on the buccal, lingual and interproximal surfaces of the teeth. These have been claimed to contribute to a higher level of tooth movement accuracy due to the pre-treatment planning and, therefore, to a reduced treatment duration. However, a recently published systematic review presents a substantial debate concerning the efficacy of various types of tooth movement achieved with aligners (compared to conventional orthodontic brackets), especially vertical movement, root control, buccolingual inclination and occlusal contacts [7–10]. Several *in vitro* studies [11, 12] have shown that the magnitude of forces and movements generated by aligners is within the range of ordinary orthodontic forces. Hence, there are many clear aligner systems being developed all over the world, which are contributing to the trend of future orthodontics, combining advanced technology with those of other dental disciplines such as maxillofacial surgery and prosthodontics. In the past, clear aligners were considered to have limited use and were recommended only in highly selective cases [6], mainly class I malocclusions with little or no dental crowding, resolved primarily by interproximal reduction in adult patients. Indeed, a PubMed search of the orthodontic literature revealed only one case report describing the use of clear aligners for the treatment of impacted teeth [13].

The treatment of an impacted tooth demands most types of orthodontic movement (extrusion, rotation, tipping, uprighting and torque), with an emphasis on root control. In order to erupt an impacted tooth there is a need for a properly designed spring, always auxiliary to a heavy base arch or fixed soldered banded anchorage appliance due to its ability to deliver a measured and controlled force with low force decay, in a predetermined direction. Clear aligners were disparagingly referred to as 'a simple piece of plastic' and thus might have been considered inadequate for the task of properly managing impacted teeth. However, recent advances in the field of digital orthodontics have led to a quick and dramatic change. Extensive research and development has been invested over the past two decades in different directions simultaneously. Improvement has been achieved in the evolution of the software used for imaging, scanning, planning and executing the treatment; in the development of a suitable polymer from which the aligners are formed; and in the use of a variety of attachments (conventional and optimized), each of which has contributed to enhanced clear aligner capability. The cases described in this chapter illustrate the advances made in the treatment of impacted teeth with clear aligners, and their efficacy and suitability for use in this specialized field.

Case 17.1: Bilateral palatal impacted canines with constricted maxilla and functional shift

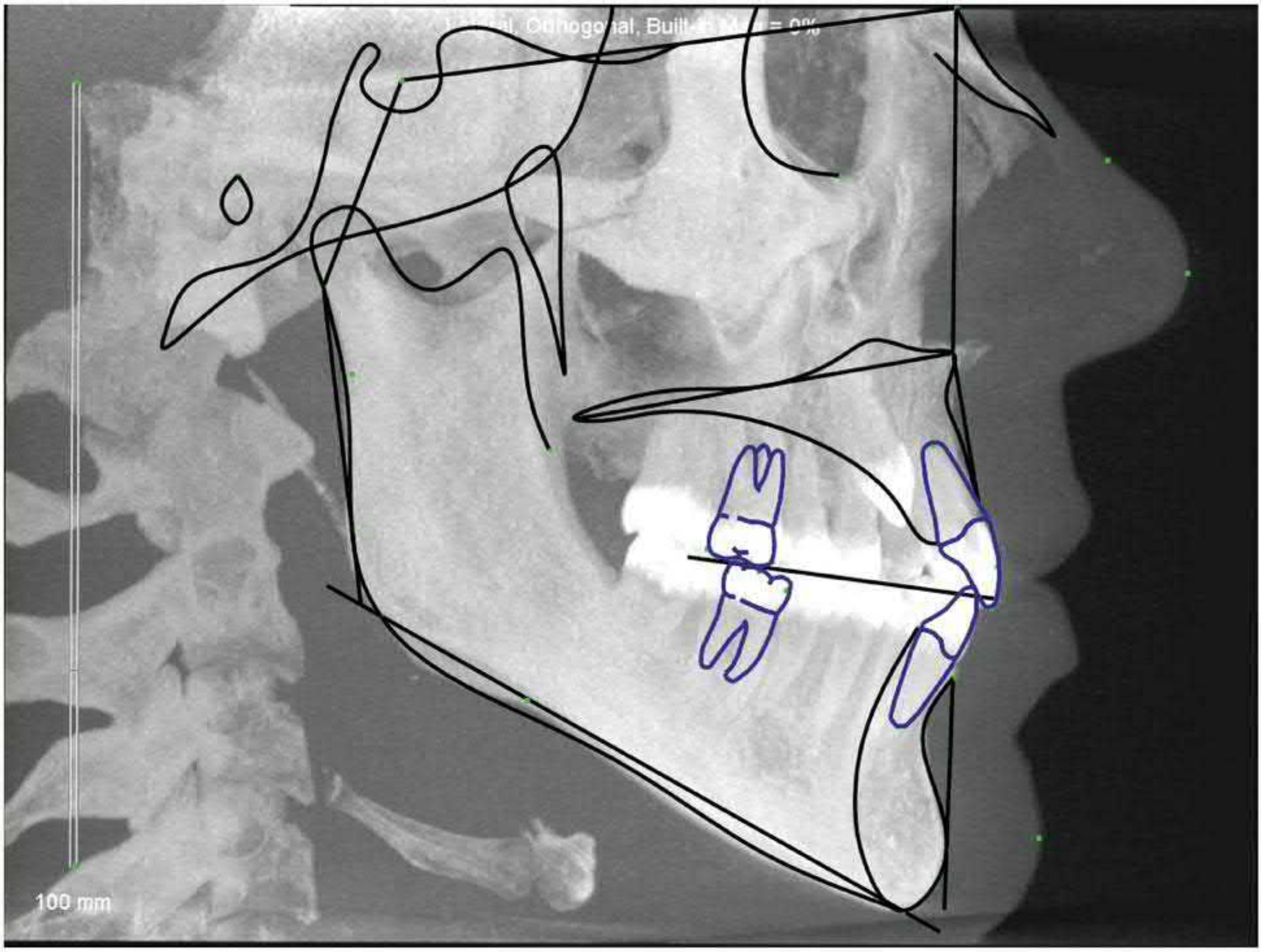
A 30-year-old female presented with the chief complaint of spacing and malalignment of the upper front teeth with impacted upper permanent canines. Pre-treatment clinical photos of the patient (Figure 17.1a) demonstrate a balanced profile with a narrow smile and good initial buccal occlusion on the right side and a class III occlusion on the left, and with a 3 mm dental midline shift of the maxilla to the left and the mandible to the right. A pre-treatment cephalometric radiograph (Figure 17.1b) showed normal apical bases of the maxilla and mandible as well as normal inclination of both upper and lower incisors (Figure 17.1c). Cone beam computed tomography (CBCT) demonstrated palatally impacted upper right and left permanent canines. Initially, a Wilson multi-action palatal appliance was used as anchorage to help with the preliminary eruption of the impacted permanent canines into the oral cavity using elastic thread traction for seven months (Figure 17.1d). After removal of the Wilson multi-action palatal appliance, Invisalign® attachments were placed on the incisors and premolars to help with anchorage and root control while the Invisalign aligners move the palatally positioned permanent canines into normal buccal positions (Figure 17.1e).

After 2 years and 5 months, the treatment ended. The patient was finally fitted with Vivera Invisalign retainers (four sets for upper and lower retainers) to be worn full time (20–22 hours/day) for one year and thereafter at night-time indefinitely (Figure 17.1f).

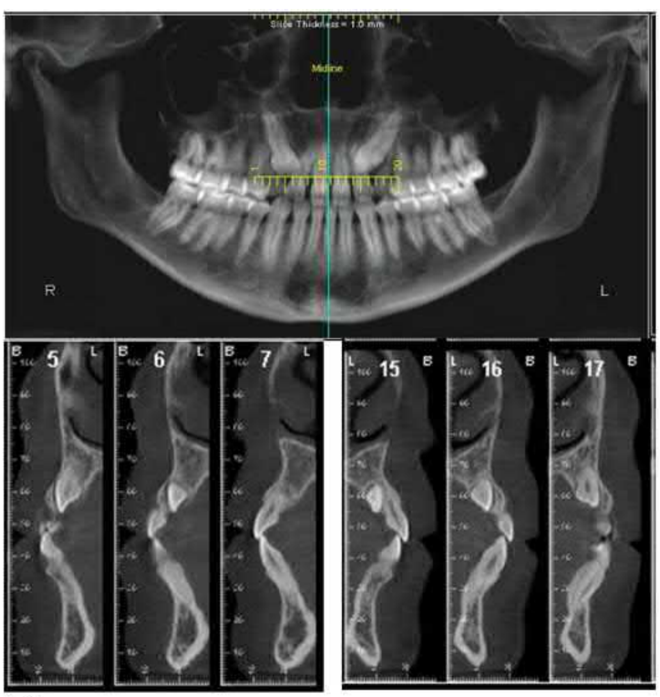
Case 17.2: Skeletal and dental class III with anterior and posterior cross-bite and palatal impacted upper right canine

The main complaints presented by this 19-year-old male included anterior and posterior cross-bites and crowding, complicated by an impacted upper right permanent canine. Initial pre-treatment photos and cephalometric radiograph showed skeletal class III pattern due to a prognathic mandible and a normally positioned maxilla. Upper incisors were slightly retroclined, but lower incisors were severely retroclined (Figure 17.2a, b).

(a)



(b)



(c)

(d)

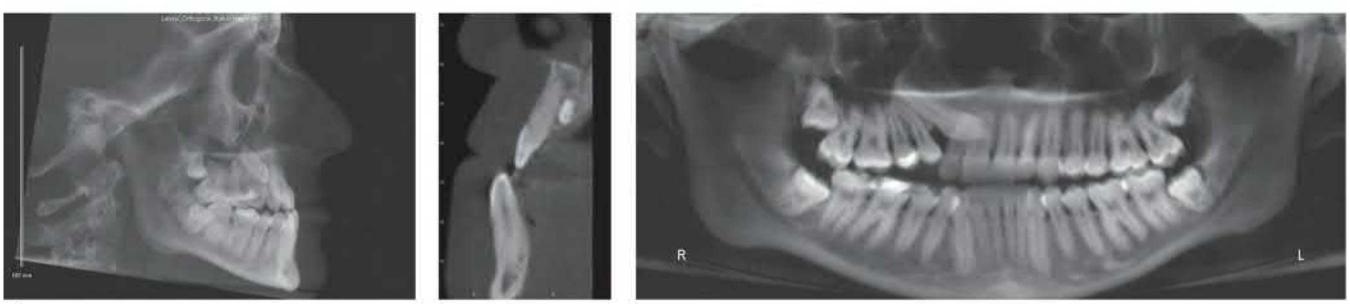
(e)

(f)

Fig. 17.1 (a) Initial extra- and intra-oral photographic records. (b) Pre-treatment cephalometric radiograph. (c) Cone beam computed tomography–driven panoramic view. (d) Wilson multi-action palatal appliance. (e) Intra-oral pictures after removal of the Wilson multi-action palatal appliance and the commencement of clear aligner treatment. (f) Final extra- and intra-oral photos.

The treatment plan included stage 1 of monitoring mandibular growth by serial cephalometric radiographs, with surgical exposure and the application of a multi-action palatal appliance in an attempt to move the impacted upper right canine using an elastic thread, as in Case 17.1. After five months, the upper right canine was visible. The patient indicated that he would prefer the compromised treatment with the non-surgical option to solve the skeletal class III relationship and the treatment option of the Invisalign system. The digital treatment planning of stage 2 included expansion of the upper arch combined with slight proclination of the upper incisors to reduce the anterior cross-bite and provide space for the full eruption of the upper right canine. In addition, sequential lower-arch distalization was programmed in order to correct class III buccal occlusion, the anterior cross-bite and lower dental crowding.

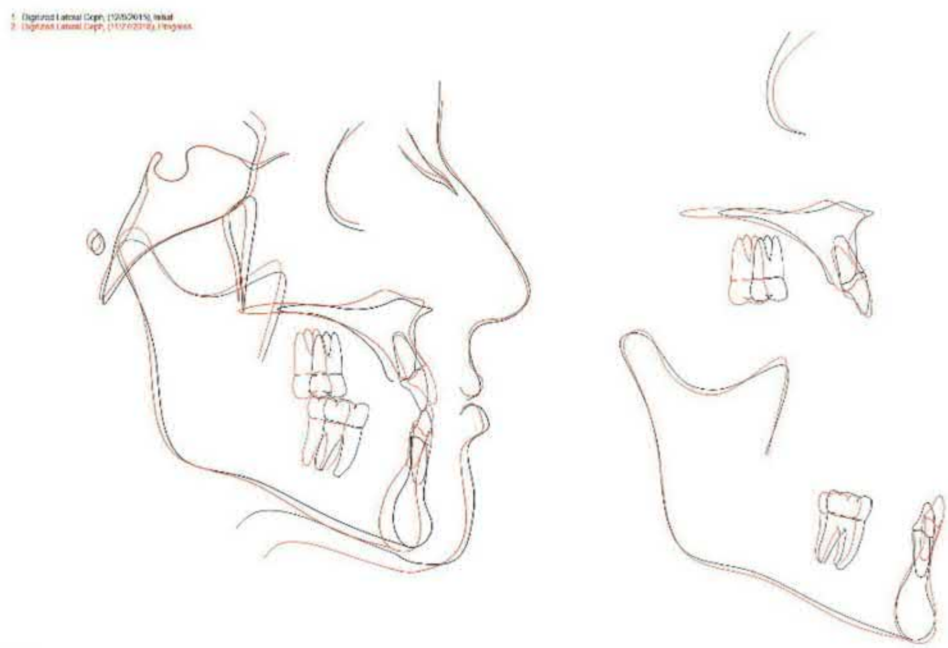
(a)



(b)

(c)

(d)



(e)

Fig. 17.2 (a) Pre-treatment extra- and intra-oral photographs. (b) Pre-treatment cephalometric and panoramic radiographs. (c) Expansion of the upper arch achieved by means of Invisalign clear aligners and normal positioning of the impacted upper right canine. (d) Post-treatment extra- and intra-oral photographs. (e) Cephalometric progress analysis/superimposition (initial – black, progress – red) shows improvement in the class III malocclusion and the accompanying dento-alveolar compensation.

The expansion of the upper arch achieved by means of the Invisalign clear aligners and normal positioning of the impacted upper right canine are shown in Figure 17.2c.

After four years, due to the pre-existing complex pattern of his skeletal and dental conditions, the treatment ended. Post-treatment photographs show improved facial profile and dental occlusion (Figure 17.2d, e).

Mechanical principles of the aligner

Clear aligners move teeth by exerting a push force. When an aligner is placed over the teeth, the semi-elastic polyurethane goes through an elastic deformation, causing the aligner to behave like a spring. Thus, the exerted force is transmitted to the teeth directly through their buccal and lingual surfaces or through the use of a variety of attachments, pushing them into the desired and digitally pre-planned positions. The placement of attachments over the tooth surface increases the tooth's surface area and the tightness of engagement of the aligner.

By using the entire lingual and buccal tooth surface contact areas, clear aligners can provide excellent anchorage control. This may be digitally predetermined and easily changed during the different stages of treatment. This is perhaps best illustrated in the assisted eruption of a single tooth. Thus, extrusion of an impacted canine will generate reciprocal intrusion and tipping forces on the adjacent incisor and premolar teeth. In the conventional orthodontic system these are prevented and balanced by using stabilizing rectangular stainless steel wire in a full-arch braces slot, temporary anchorage devices (TADs) or soldered lingual arches. Hence, with the placement of a clear aligner, all buccal and palatal/lingual surfaces of the teeth in the same arch are intimately entrapped and the reciprocal forces are dissipated over a large contact area with many other teeth. This minimizes the movement possibilities of the anchorage units, and the development of a temporary cant of the occlusal plane. In addition, the digital planning application of the system (for example, ClinCheck® by Invisalign) includes an attachment on these teeth in order to intensify crown and root movement control and minimize their unwanted movements resulting from the reactive force.

Furthermore, clear aligners offer the power-ridge feature for root buccal/lingual torque control, which is essential especially for palatally and buccally impacted upper and lower canines. With this feature, extra torque can be additionally predetermined for individual teeth, depending on the initial malocclusion, the final occlusion desired and soft tissue lip support. On the aligner, the power ridge is a small bump that appears at the gumline on the labial and at the incisal edge on the lingual of the upper and lower front teeth for palatal/lingual root torque, or at the incisal edge on the labial and at the gumline on the lingual of the upper and lower front teeth for buccal root torque. The net effect of applying pressure simultaneously at these two high and low points on opposite sides of the same tooth is the regeneration of a coupled force system that controls the incisors' bucco-lingual root movements, as presented in Figure 17.3.

In a manner similar to that described for anchorage, the power ridge may be changed by digital pre-planning, at various stages during the course of treatment. Since there is some freedom (play) between the aligner and the tooth surface (the power ridge), the actual torque is not fully expressed clinically, and therefore additional torque can be and should be built into the final occlusion in the software in much the same way as with fixed appliances.

With traditional fixed orthodontic appliances, a series of adjustments are made during each appointment until the final occlusion is achieved through a system of trial and error. In the case of clear aligners, all the required adjustments are planned and performed in advance by 3D computer-aided modelling software. Using the system's simulation application, the amount of tooth movement and the magnitude of the orthodontic force created by aligner adjustment may be accurately determined and controlled. This may deliver a precise incremental orthodontic force, with less pain and discomfort [14] and fewer emergencies, which may contribute to less root resorption [15].

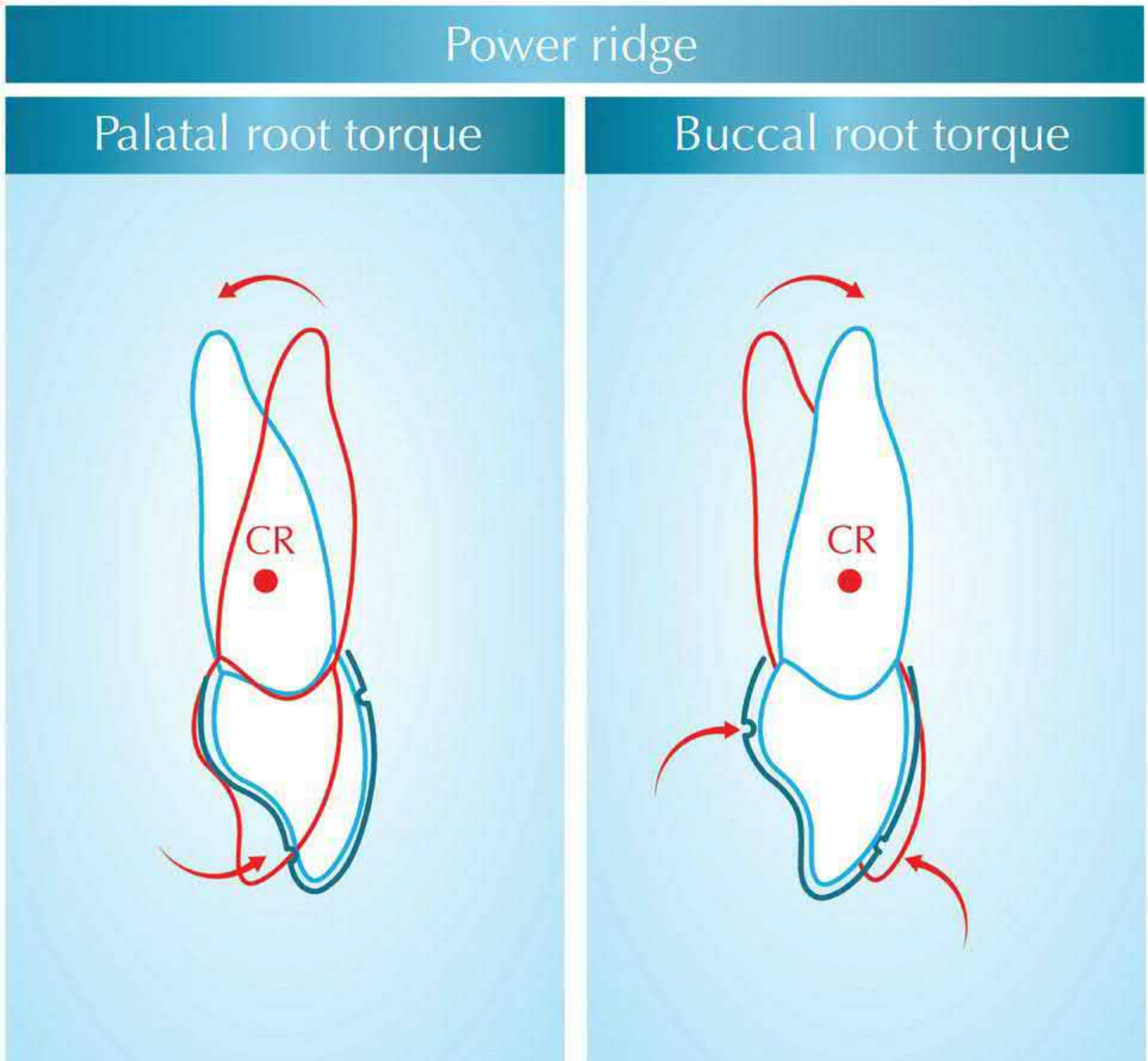


Fig. 17.3 Root movement control and torque in the buccal/lingual direction that are regenerated by means of the power ridge. The dark blue line illustrates the contour of the clear aligner, the red line illustrates the tooth in its original position, and the light blue line illustrates the tooth after buccal–lingual root torque. CR, centre of resistance.

Digital planning software

In clear aligner therapy, a software program is used that simulates the sequence of orthodontic tooth movement from an existing malocclusion towards the final planned occlusion. Thus, the clinician can specifically study the patient's malocclusion and a variety of personalized orthodontic treatment plans can be created, evaluated and presented. Routine use of this software creates a mindset shift in the clinician that could be summarized by the statement 'to begin with the end in mind'. While planning the orthodontic treatment according to the patient's diagnosis, fundamental orthodontic principles and better understanding of the treatment results may be achieved. The simulation obtains pre-treatment visualization of the accurate tooth movement steps and the occlusal relationships. The integral superimposition feature, reflecting continuous animation, compares the simulation of the suggested treatment plan option and the starting point occlusion and tooth position. Thus, the pre- and post-treatment teeth positions may be assessed during different treatment stages and different plan strategies.

Final occlusion, tooth inclination and torque, jaw relationship and soft tissue appearance can be predicted before a single tooth is actually moved. Today's advanced digital planning software enables the clinician to adjust the individualized 3D position of each tooth (crown and root) in the dental arch and reach conclusions on the occlusal consequences by studying the simulation. Tightness as well as interferences of the occlusal contacts may be visualized from different angles and perspectives, including from the lingual side of the teeth for study purposes. Both dental arch form and architecture may be prescribed and modified. In addition, the software enables the use of a conventional attachment to a selected buccal and/or lingual tooth aspect and to design its specific position and dimensions. For example, ClinCheck software provides a wide array of optimized attachments for different teeth according to the degree of 3D positional change for each individual tooth. The attachments are incorporated into the aligners and create specific surface bulges through which the applied force helps to achieve the desired tooth position. Interproximal reduction (IPR) may be advised and modified by simultaneous visualization of its influence on dental crowding alleviation, dental arch form and the effects of occlusal contact. Interdental spaces can be closed and opened between adjacent teeth, for future prosthodontic planning. Specific precision cuts or buttons can be designed for the incorporation of intra-oral elastics in case of additional force or anchorage requirements.

In the case of a missing tooth in the arch (congenitally or due to impaction or extraction), a pontic can be incorporated in the aligners. The dimensions of the pontic are digitally changed throughout the treatment when space is regained, as in the case of the eruption of an impacted tooth. The pontic is continuously present until the tooth is restored or is aligned in the arch. The addition of a pontic in the aligner is important for functional simulation of the arch dimensions, inter-arch relationship and contacts and for aesthetic consideration. For further improved aesthetics, the pontic can be filled with composite material for each aligner.

Managing impacted teeth with clear aligners

Impacted teeth are usually presented with space loss in the area of the impaction due to a missing permanent tooth and/or an over-retained primary tooth. With the possible exception of the second deciduous molar, the deciduous tooth is smaller in the mesio-distal dimension, compared to its permanent successor. In addition, a mild to moderate collapse of the arch dimension is often seen in the arch segment of the impaction, with asymmetry between the two sides of the dental arch.

Therefore, the treatment of impacted teeth includes the need for space preparation before or during the eruption of the impacted tooth, surgical exposure and attachment cementation. This must be followed by orthodontic guidance for the autonomous eruption of the impacted tooth or by active mechano-therapeutic traction. Severe deficiency of dental arch space for the eruption dictates the need for regaining space by distal movement of the posterior teeth and/or mesial movement of the anterior teeth in the arch. This may also include rectifying a collapsed dental arch segment and expansion to regain more space.

Managing impacted teeth with clear aligners may include a combined approach: a preliminary phase of space creation performed by traditional orthodontic appliances while impacted tooth orthodontic traction and final tooth alignment are performed by clear aligners. After the initial space-gaining stage is complete, a digital scan or impression may be taken for fabrication of the aligners for future treatment.

Alternately, by using digital planning software, the clinician may design and plan the arch preparation solely with clear aligners. In the case of unilateral impaction, the final occlusion and the arch segment reconstruction can be visualized based on the intact side of the arch employed to serve as a mirror image. With bilateral impactions, the opposite jaw may be used as a template to provide suitable form and dimensions for arch collapse reconstruction, thus achieving the ideal occlusal relationship. In this way, arch dimension reconstruction and the required space may be digitally planned during the pre-eruptive stage of the clear aligner treatment and even simultaneously during the active impacted tooth orthodontic traction, thus eliminating the preliminary arch preparation stage. Consequently, the duration of the treatment may be reduced.

Methods of regaining space with clear aligners

Space regaining using clear aligners may be performed in the sagittal direction by sequential distalization, sequential mesialization or proclination, and in the transverse direction by dental arch expansion. A combination of expansion with one of the sagittal forms of movement is also possible.

Sequential distalization/mesialization

In the sequential distalization protocol, the kind of tooth movement staging scheme reveals a V-shaped diagram (or 'V-pattern' staging; Figure 17.4). The dental arch from first molar to first molar acts as an anchorage segment to push the second molars distally. When the second molar has been moved halfway, the first molar starts to distalize (Figure 17.4, A). When the second molar stops moving, the first molar has moved halfway and the second premolar starts to distalize (Figure 17.4, B). When the first molar stops moving, the second premolar has moved halfway, and the first premolar starts to move (Figure 17.4, C). This staging of 2 mm tooth movement distally from each side of the dental arch is predictable for both space regaining and the correction of the antero-posterior relationship between the dental arches (Figure 17.4, D). A similar diagram is expected accordingly for the incremental mesialization protocol, but in the reverse direction.

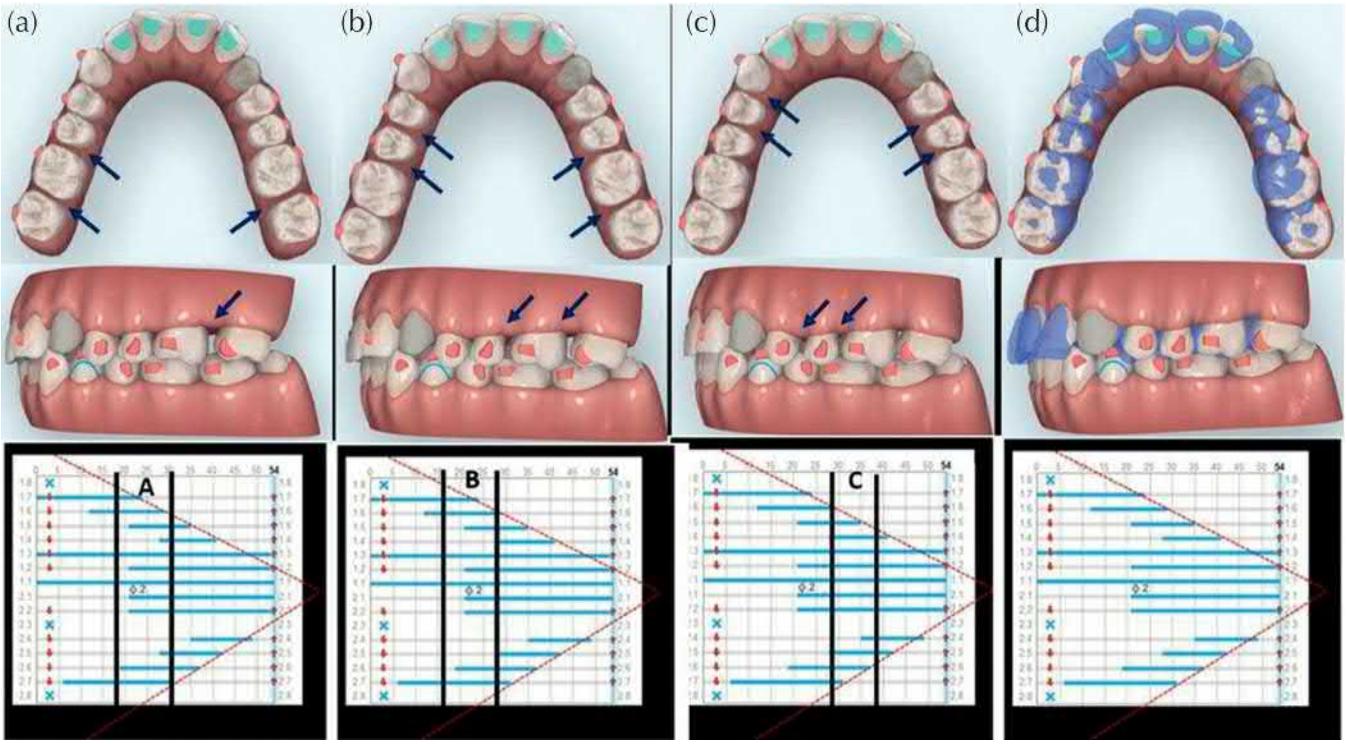


Fig. 17.4 Digital sequential distalization planning to create space for the upper left impacted canine. Blue arrows indicate spaces that were opened during the distalization progress. Upper row: Maxillary occlusal view. Middle row: Lateral left view. Lower row: V-shaped diagrammatic staging view. A. Second molar has been moved halfway and the first molar starts to distalize. B. First molar has moved halfway and the second premolar starts to distalize. C. Second premolar has moved halfway and the first premolar starts to move. D. Posterior teeth movement simulation using superimposition of 2 mm sequential distalization creating space for the impacted upper left canine to erupt.

Expansion

In the expansion protocol of clear aligners, the dental arch diameter grows, the dental arch collapse is corrected and regaining of space is achieved (Figure 17.5). In the digital planning software, the clinician may specify the exact amount (up to 2 mm per quadrant) and location of arch expansion between canines, premolars and molars, canines and premolars only, or premolars and molars only. There is also an option to digitally establish and maintain the required archforms without expansion. Molar expansion of 2 mm is a predictable tooth movement with aligners [16, 17].

The clinical pictures, digital planning software superimposition and treatment progress in a 50-year-old patient with a buccally impacted upper left canine are presented in Figure 17.6). Arch expansion and de-rotation of the upper left first premolar by using aligners provided adequate space regaining for the impacted canine and the active orthodontic eruption was performed simultaneously.

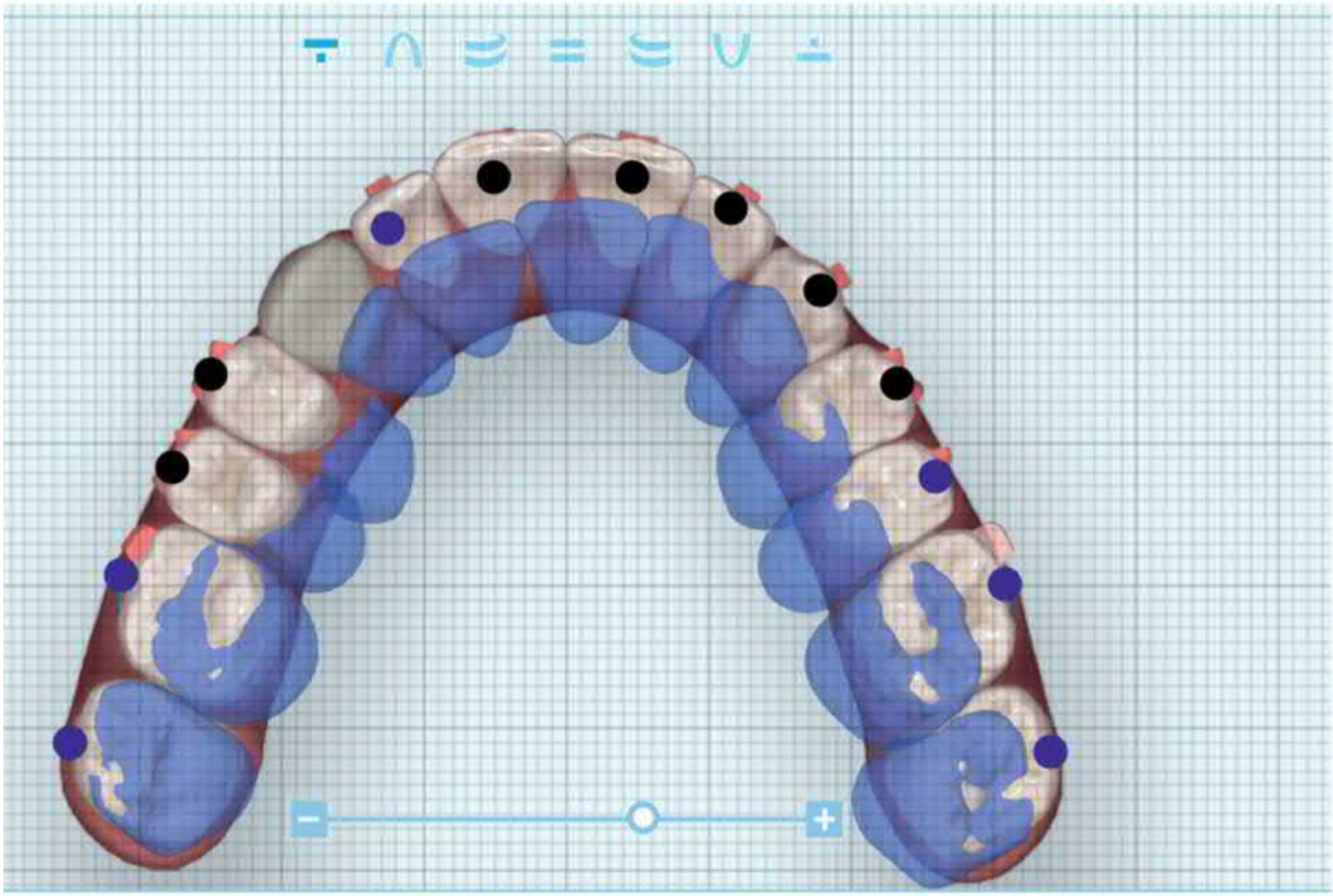


Fig. 17.5 Digital planning software superimposition after upper incisor proclination and upper-arch expansion creating mesial and distal spaces for the erupting canines.

However, clear aligners are not capable of skeletal expansion. When orthopaedic expansion is needed, the combined approach should be taken: a rapid maxillary expansion appliance should be used prior to clear aligner therapy. After the initial expansion phase is completed, a digital scan or impression may be taken for digital planning and fabrication of the set of aligners. The maxillary arch may be retained with a clear vacuum-formed retainer with palatal coverage or by the expander itself, until the aligners are inserted.

Fig. 17.6 (a) Digital planning software superimposition of maxillary expansion. (b–d) Clinical pictures illustrating the treatment progress in the maxillary occlusal view, (e–h) frontal view and (i–l) lateral left buccal view, respectively. (m–p) Treatment progress in the digital planning software.

Sequential distalization and arch expansion may be successive or simultaneous in one arch or both. However, if conducted in both arches they should be successive for anchorage reasons. Inter-arch class II/class III elastics are required for anchorage augmentation during upper-arch/lower-arch sequential distalization, respectively. Because of the contradiction of anchorage between force array elements needed for upper- and lower-arch distalization, the only way to predictably accomplish the required distalization movement is to perform it in a successive manner with upper distalization after lower or the opposite.

Proclination

Proclination of maxillary and/or mandibular incisors may be considered to alleviate crowding, mainly in cases of deep bite and upright or retroclined incisors. This kind of movement may increase the arch diameter and the simulation exercise may show an important contribution in order to regain space for the impacted tooth.

Interproximal enamel reduction

IPR is considered an accepted treatment modality to resolve crowding. It was re-popularized by Sheridan [18, 19] and adopted in the use of clear aligners, to enable tooth alignment and space regaining without excessive proclination (i.e. alteration in the labiolingual position of the anterior teeth) [20]. Under the influence of the aligners, the incisors often move towards the required proximal contact until adequate access is achieved to perform IPR safely. IPR should be performed with a specific set of burs, discs or IPR strips. The amount of IPR is between 0.2 mm and 0.5 mm per tooth contact point. The overall space gained by IPR can be simulated and visualized.

Root movement

Root movement of adjacent teeth is often needed as part of dental arch preparation for impacted tooth eruption, as presented in Figure 17.7. Adjacent root movement may release eruption pathways and prevent impacted tooth-eruption interferences, including unwanted root resorption (the most common is in lateral incisors adjacent to impacted maxillary canines). Thus, an impacted tooth traction orthodontic vector should be precisely pre-planned, combined with adjacent root clearance. The clear aligners' intimate contact with buccal and lingual crown surfaces may affect root movement to a limited extent. However, from the biomechanical perspective, a coupled force system is required to achieve predictable control of the root movement by the aligner.

(a) (b)

Fig. 17.7 (a) Mesial–distal root uprighting redirection control achieved by the application of vertical rectangular conventional attachments applied to the buccal and lingual crowns' surfaces, generating a moment to control root tipping. (b) A variety of optimized attachments may contribute to the aligners' coupled force system, generating a movement in order to control root movement and augment anchorage in the mesio-distal uprighting direction.

Impacted tooth traction while using clear aligners

Once the required space has been gained in the arch and the eruption pathway is free for impacted tooth eruption, surgical exposure of the impacted tooth and its guided eruption (mechano-therapeutic traction) may commence.

Timing and staging

Using digital planning software, it is possible to calculate the amount of regained space needed and the rate of its production, and to predict and simulate arch form reconstruction and occlusal relationships. This information is achievable even before a given tooth starts to move. With this assessment, clinicians may decide to alter the sequence of treatment. They may then start with the surgical exposure and the eyelet bonding to the impacted tooth, even before the commencement of the orthodontic treatment. Thus, the orthodontic guidance of the impacted tooth will be performed together with the space-regaining phase.

A 15-year-old male patient has a labially impacted lower right canine with disto-angular inclination towards the opposite side (left side; Figure 17.8). The canine was surgically exposed and a button was cemented before orthodontic tooth movement had actually begun. Space regaining was performed upon commencement of the orthodontic treatment (by extraction of the lower right deciduous canine and lower left canine distalization) in parallel to continuous impacted canine traction, first towards the left side to enhance eruption of the impacted canine crown and then towards the right side using heavy 3 mm intra-oral elastics (4 oz). The attachments on the lower incisors control the root tip during space closure and impacted tooth traction and increase the aligners' retention.

Accelerated tooth movement

Indirectly, accelerated orthodontic tooth movement is achieved during the space-regaining phase in parallel to tooth traction using clear aligners. The accelerated tooth movement is due to the surgical exposure intervention of the impacted tooth, which includes a full-thickness periodontal flap elevation (including the periosteum) and a corticotomy manipulation. The rationale of periodontally accelerated osteogenic orthodontics is based on alveolar bone decortication, which induces bone turnover in the area of orthodontic tooth movement. The biological response to iatrogenic injury with corticotomy results in inflammation adjunct to the wound-healing process. This is characterized by transient functional osteopenia followed by accelerated bone turnover regulated by the RANK-RANKL/OPG axis, where osteoclast accumulation takes place in the direction of the movement of the tooth [21–23].

Fig. 17.8 (a) Mandibular occlusal view revealed over-retained lower right deciduous canine and interdental spaces between the incisors and the lower left canine. (b, c) Cone beam computed tomography 3D buccal and occlusal images presenting buccally impacted lower right canine in a disto-angular inclination, towards the opposite side (left side). (d) Surgical exposure and button cementation on the impacted canine as a preliminary step before orthodontic tooth movement begins. (e) Intra-arch impacted canine traction, first towards the right side to enable quick emergence, (f) then towards its final position on the right side. Impacted tooth traction was performed using 6 oz (1/8 in. H) intra-oral elastics along with space gaining, which included closure of anterior inter-incisor spaces and lower left canine distalization. (g) Nine months after surgical exposure and elastic traction using Invisalign, the tooth erupted. (h) Combined inter- and intra-arch traction was continued to guide the impacted canine from the opposite side of the arch. (i) Inter-arch elastic traction (open-mouth picture). (j) Intra-arch elastic traction may cause gingival tissue decubitus. (k) Intra-arch elastic traction wrapping around the aligner aimed to prevent pressure ulcer.

Contrary to the traditional treatment approach, where the impacted tooth protocol advances one stage after the other (preparatory stage of levelling and alignment with space regaining followed by impacted tooth exposure, cementation and finally impacted tooth traction), with clear aligners the clinician is able to work simultaneously on different aspects of the treatment. Active impacted tooth eruption can be accomplished along with expansion or sequential distalization and so on, and can indirectly benefit from accelerated tooth movement.

Biomechanics aspects

During surgical exposure of the impacted tooth, a button with a twisted double 0.012 in. stainless steel ligature or an eyelet with a traction chain is bonded and used for the patient to connect intra-arch or inter-arch elastics to buttons cemented over the lingual or buccal surfaces to direct the impacted tooth-eruption path. This treatment concept provides several advantages:

- A wide variety of pulling directions and combinations are easily and immediately obtained by means of elastics connected to the buttons. The location of these buttons is varied using milled windows cut out on different teeth under the aligners. These teeth serve as the anchor teeth for traction of the impacted tooth. The aligners firmly hold the abutment teeth serving as anchorage, pushing them together in the opposite direction to the traction vector exerted on the impacted tooth. Selection of the abutment teeth and positioning of the buttons depend on the specific preliminary position and angle of the impacted tooth, diagnosed by using CBCT and other radiographs, the adjacent roots' proximity and the surgical approach. Additional buttons can be added whenever needed to alter the traction vector direction as the treatment progresses. Accordingly, the new button cut-outs are prepared in the aligners using a punch plier (Figure 17.9).
- A variety of force magnitude according to the size of the intra-oral elastics can be applied and constantly changed. Traction forces do not decay and are even enhanced, since patients replace the elastics at least once per day and can wear them during routine oral functions of speech and mastication.
- The traction force can be modularly built up in the aligner system. Initially, the impacted tooth can be erupted using anchor teeth within the same arch (intra-arch anchorage). As the eruption progresses and the distance towards the dental arch is shortened, anchor teeth may be changed to the opposite arch (inter-arch anchorage), thus the pulling distance is re-elongated and the orthodontic traction force is increased.

Two cases provide clinical examples of these advantages. A 17-year-old male with bilateral mandibular impaction of horizontally oriented (in a mesio-angular inclination) second molars showed delayed eruption of the upper right second molar and missing lower right second premolar, with an over-retained and submerged lower right primary second molar (Figure 17.10). The treatment plan included extraction of the impacted lower left second molar with a spontaneous drift of lower left third molar and re-directing it to replace the second molar to achieve a class I left molar relationship. On the right side, extraction of the upper right third molar and primary second molar, mesialization of the first molar and orthodontic traction of the upper and lower second molars using Invisalign and inter-arch elastic traction were performed to achieve a class III right molar relationship. Future extraction of the upper left third molar was planned as well. After 14 months of treatment and weekly replacement of aligners, the bilateral lower extraction space was completely closed by bodily mesialization of the lower right first molar and spontaneous mesial drift, and active traction of the lower left third molar was accomplished. The horizontally impacted lower right second molar was uprighted after space regaining was achieved by the first molar mesialization and inter-arch orthodontic traction using 3 mm (4 oz) intra-oral elastics.

(a) (b) (c)

Fig. 17.9 Punch pliers for self-incorporation of button cut-outs into clear aligners' margin. (a) Punch pliers. (b) Activation of the pliers. (c) Incorporated cut-out for a button.

The second case was a 13-year-old female with unfavourable impacted lower second premolars, as well as retained deciduous lower second molars (Figure 17.11). The surgeon took the decision to extract the apically erupted lower left second premolar and maintain the lower left deciduous second molar, while extracting the lower right deciduous second molar and bond a gold chain to the lower right second premolar that was initially lingually impacted. Three months after surgical exposure, the lower right second premolar erupted and moved into a more favourable position that can be easily moved to full occlusion. The occlusal and buccal vector of extrusion force directed through two buttons on the right lower first premolar and the first molar enabled extrusion and movement of the lower right second premolar buccally into its normal position.

(a) (b) (c) (d) (e) (f) (g) (h) (i) (j) (k) (l) (m) (n) (o) (p) (q) (r)

Fig. 17.10 (a) Pre-treatment panoramic view. (b) Pre-treatment 3D cone beam computed tomography right and left lateral views. (c) Post-extraction panoramic view. (d–f) Lateral right views of digital planning of eruption of upper and lower second molars. (g, h) Lateral right clinical views of treatment progress and second molar eruption after 14 months of treatment. (i) Lateral right view of intermaxillary elastic traction of the upper and lower impacted second molars. (j–l) Radiographic X-rays describing the mesialization of the right lower first molar and the eruption along with uprighting of the lower right second molar. (m–o) Lateral left views of digital planning of lower third molar eruption. (p, q) Lateral left clinical view of treatment progress and third molar eruption after 14 months of treatment. (r) Frontal view of the clear aligners combined with the bilateral intermaxillary elastics for traction of impacted upper and lower molars.

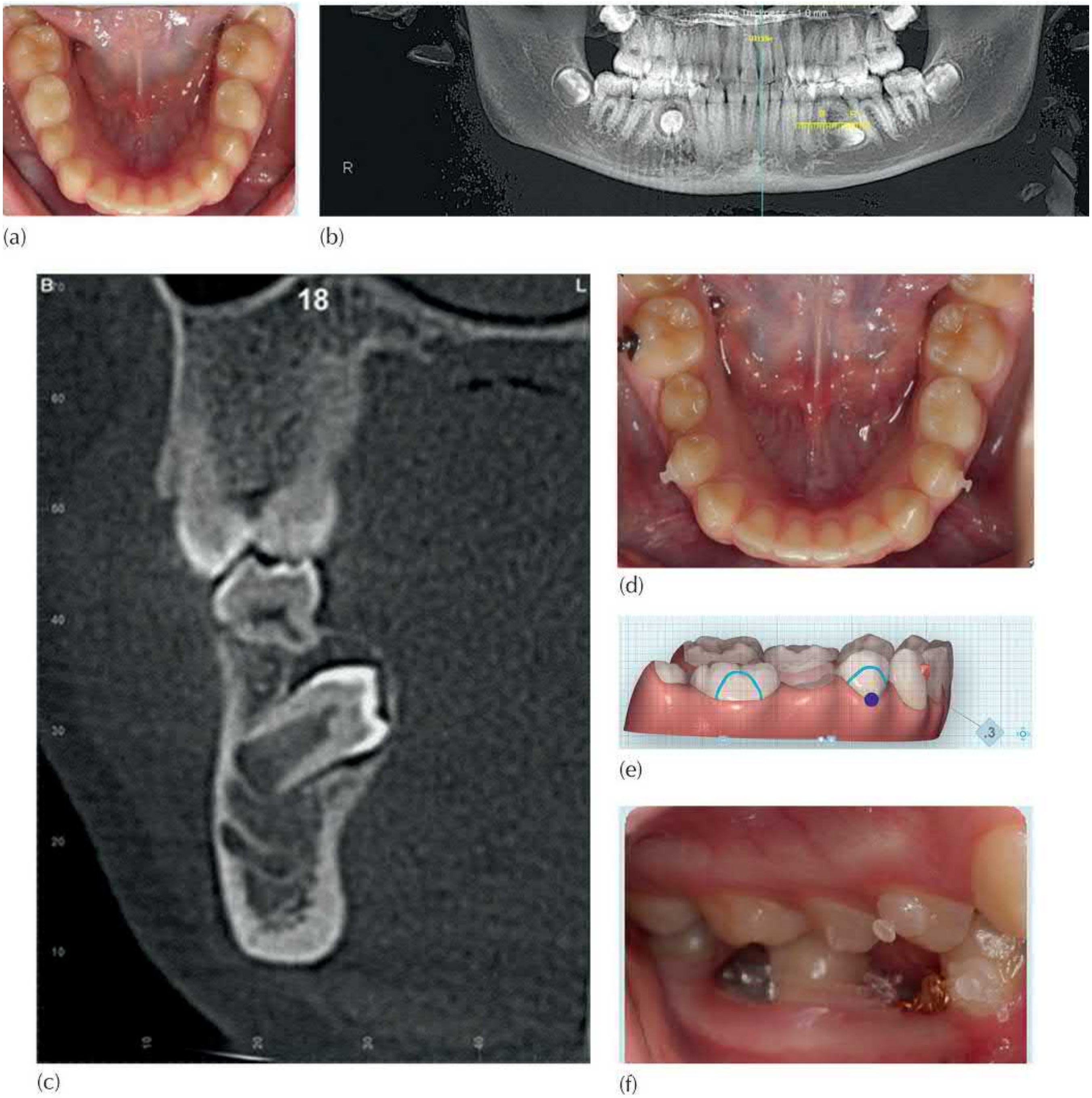


Fig. 17.11 (a) Lower occlusal view. (b) Cone beam computed tomography (CBCT)-driven panoramic radiograph showing retained deciduous lower second molars and impacted lower second premolars. (c) Sagittal screen–driven CBCT of impacted lower right second premolar, showing its lingual position and immature root formation. (d) Lower-arch occlusal view three

months post surgical exposure. (e) ClinCheck showing the space maintained for the erupting lower right second premolar while utilizing the button cut-outs for anchorage to help occlusally pull it. (f) Occlusally and buccally directed vector of extrusion of the lower right second premolar.

Clear aligner intra-oral elastics interface

Different elastics are connected to the aligner by means of cut-out hooks or buttons bonded to abutment teeth. The cut-out hooks are milled into the aligners by the manufacturer, with no additional chair-time requirements. Alternatively they can be self-incorporated at the gingival margin of clear aligners by using the tear-drop pliers (Figure 17.12a), in a manner similar to the addition of buttons cemented to buccal/lingual crown surfaces and the use of punch pliers.

Fig. 17.12 Elastic cut-out hook milled into the aligner. (a) Tear-drop pliers. (b) Activation of the pliers. (c) Incorporated cut-out hook.

The major drawback of cut-out hooks, however, is dislodging the aligners from their firm hold on tooth surfaces by elastics loading. The addition of conventional rectangular attachments to increase aligner retention is often recommended. Buttons require more chair-time for bonding on the teeth in the same arch or in the opposite one. Furthermore, they are prone to bond failure and breakage due to elastic tension or masticatory function. In the posterior area metal buttons are preferred, as metal mesh is considered to result in stronger bond durability. Recently, mushroom-shaped metal buttons were introduced for the use of elastics associated with clear aligners [24] (Figure 17.13). This type of button increases the surface area and the shape of the base, which is precisely fit to the aligner cut-out window. In addition, the base is specially contoured to fit the cervical third of the tooth instead of the centre of the crown, as in the case of regular orthodontic buttons. The edges of the button base are bevelled to avoid interference with aligner seating. These may assist in minimizing breakage and emergency visits. However, in anterior regions, the clinician can choose to bond clear buttons or use a mini mould to prepare composite resin buttons on the spot.

The greatest virtue clear aligner therapy presents, in comparison to fixed appliances, is the ability to design and simulate treatment results before and after the eruption of impacted teeth, while constantly examining occlusal relations. Aligners' design and treatment course adjustment can be periodically altered according to the resultant changes in the inter-arch and intra-arch tooth relationship. Furthermore, clear aligners have superior aesthetics, cause less discomfort and pain [14] and allow improved oral hygiene compared to traditional orthodontic appliances [25]. These increase patients' cooperation and motivation along this complex treatment course. On the other hand, the digital orthodontic surgical treatment planning process in the case of an impacted tooth is often time-consuming both within and outside the dental office. Multiple modifications of the complex procedure planning may be required before it is finally accepted. Additional aligners are common in cases in which the treatment does not progress as planned (i.e. loss of tracking or loss of aligners) or treatment modification is indicated. Furthermore, the ability of clear aligners to achieve precise tooth movement and furthermore to control root movement, which are essential throughout the eruption process of impacted teeth, is under debate in the literature. Drake et al. [26] stated that bodily movement is not achievable with clear aligners. However, Simon et al. [27] reported high accuracy (88%) of the bodily movement of upper molars when a distalization movement of at least 1.5 mm was prescribed. Rossini et al. [28] suggested that these contrasting results might be due to the difficulties related to the application of force coupled with this kind of appliance.

Fig. 17.13 Mushroom-shaped metal button bonded to the upper first molar. The shape of the base precisely fits in the aligner cut-out window.

Torque control with clear aligners has a mean accuracy rate of 50% of the planned movement, but presents a wide variation between 25% and 70% [27, 29, 30]. Sfondrini et al. [31] did not find a statistically significant difference between conventional multi-bracket appliances and clear aligners regarding torque expression in upper central incisors. Nonetheless, Hahn et al. [32] stated that in relation to the intended amount of root movement during torqueing, aligners tend to 'lift up' and therefore no effective force couple can be established for further root control.

Patient compliance is the single most important factor in the success of treatment with clear aligners [33]. Therefore, similar to any other removable appliance, the absolute dependence on children's and teens' cooperation is the major concern. Furthermore, there are instances where the surgically exposed tooth is not sufficiently accessible for placement of elastics. As opposed to nickel–titanium springs, the force is not continuous but intermittent and decays with time, thus there is a need to constantly juggle the elastics and replace them each day or even several times a day. Nonetheless, technological advances in computer-aided design (CAD)/computer-aided manufacturing (CAM) software are revolutionary for clear aligners. Therefore, clear aligners form a quickly growing appliance sector of orthodontic treatment. In this climate of dramatic changes and developments, clear aligners' shortcomings and limitations are expected to be overcome, leading to improvements in their application in the field of impacted teeth.

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18
The Anatomy of Failure

Adrian Becker

Why is it important to know the cause of the failure of the tooth or teeth to erupt?
Patient-dependent factors
Radiologist-dependent factors
Orthodontist-dependent factors
Surgeon-dependent factors
Mid-treatment alternate consultations – second opinions

Why is it important to know the cause of the failure of the tooth or teeth to erupt?

As in most fields of innovative medicine, there are, and always will be, occasions when the treatment plan will fail to achieve its desired results. In this chapter, we will provide a survey of cases and conditions where the initial treatment failed. We will attempt thereby to show how the very fact of failure should be leveraged to lead to investigation, retrospective analysis and prospective trial, and a consequent empirical approach to find the treatment method that would have been appropriate to do the job.

There are many factors complicating the treatment of impacted teeth, factors that are not present in routine general orthodontics. In the first place, the affected tooth is not visible and is only imaged, using clinical and radiographic aids. Consequently, it cannot be examined for abnormality in the same manner or with the same degree of thoroughness as with a normally erupted tooth. The precise, 3D location of a *normally erupted tooth* is obvious from a clinical examination. So too are its degree of rotation, the orientation of its long axis and its relation to the erupted adjacent teeth. Minor flaws in the morphological features of its crown will be recordable, as will surface imperfections in the smooth outline or colour of the enamel. One can see clearly exactly what types of corrective movement and orthodontic treatment will be demanded. Biomechanical planning is straightforward.

These luxuries are not available when dealing with an impacted tooth.

One of the most constant features of the normally growing child is the natural and spontaneous eruption of teeth. In the deciduous dentition, this occurs between the ages of 6 months and 2.5 years. These teeth shed normally between six and ten years later, to be replaced within just a few months, and in rapid succession, by the permanent teeth. This innate attribute is so universal that a single tooth failing to erupt, when all other conditions are apparently favourable, should raise the suspicions of the discerning orthodontist. The very fact of its non-eruption raises the initial question as to why this should be. The many answers range from the common and the obvious to the unusual and least expected.

Determining aetiology must not be considered a mere theoretical exercise, but rather an essential prerequisite that provides the basis for the treatment plan for each individual case. Perhaps the tooth is quite normal, but there is some local impediment blocking its path (Figures 18.1 and

18.2), or perhaps the location of the tooth germ is ectopic. Alternatively, the cause may lie in a local abnormality of the tooth follicle itself, or perhaps the patient suffers from a general pathological condition that, among other features, adversely affects tooth eruption. Accurate positional diagnosis is often fraught with difficulty and mistakes may be made in locating the tooth – even by experts [1, 2].

As a result, a tooth in an intractable position may be granted a good, but false, treatment prognosis and an inappropriate, ill-advised and ill-fated course of treatment may be prescribed.

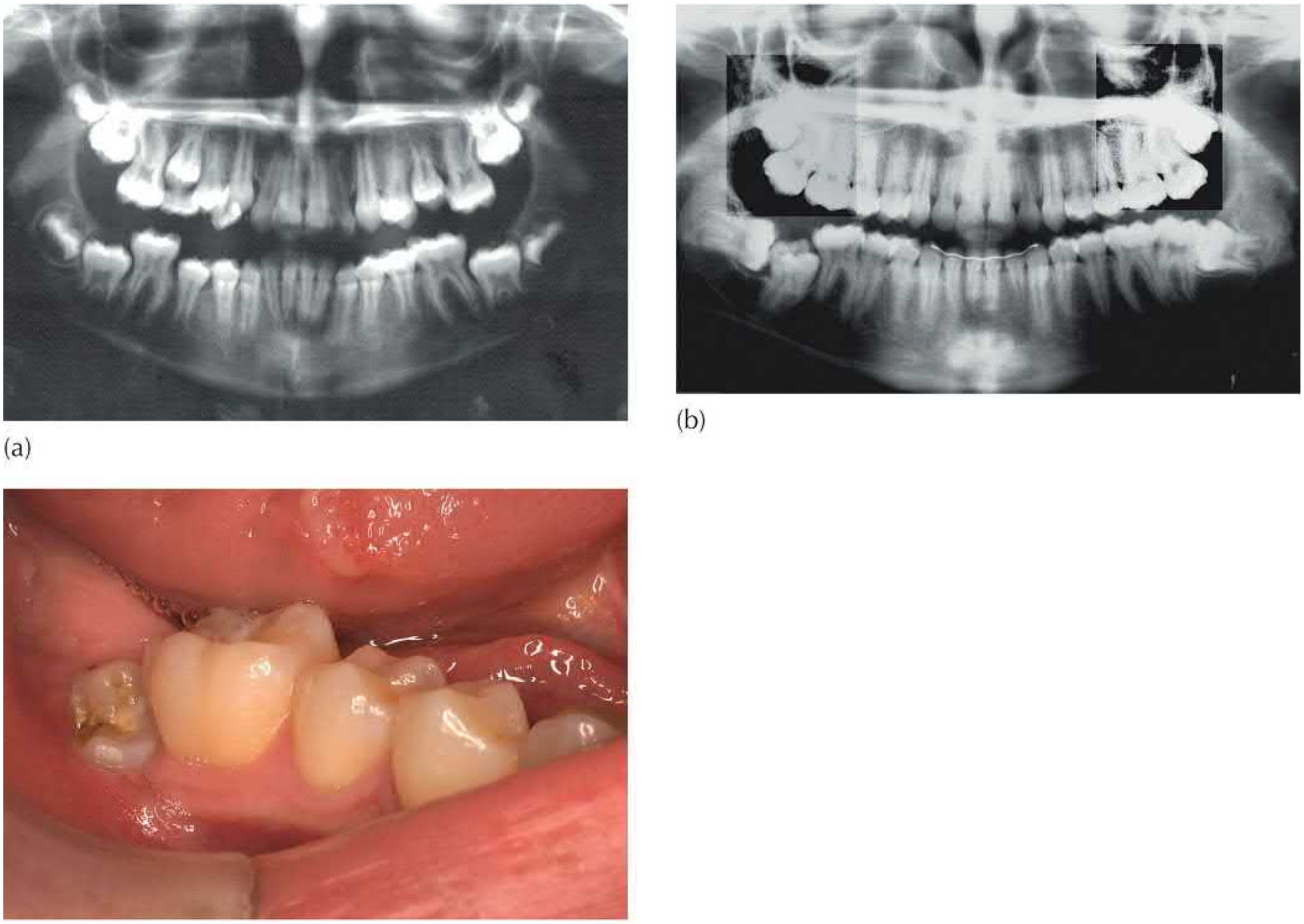
In many cases all that may be required to bring about natural eruption is for space to be made for it, which by itself may re-awaken dormant eruptive movements in the tooth. The tooth may then respond by improving its position and even, with the passage of time, may spontaneously erupt [3]. At the other end of the scale, a complicated directional traction strategy may be needed to bring the tooth into its place in the arch, while avoiding the roots of adjacent teeth. This we have seen in Chapters 6 and 7 in relation to maxillary canines, which are located mesial to the root of adjacent incisors or where the impaction of the tooth is associated with the resorption of those roots.

An open surgical exposure of the impacted tooth may close over in the succeeding days and weeks and make later attachment bonding unreliable or impossible to achieve. When bonding is performed by the surgeon (as opposed to the orthodontist) as an integral task during an open or closed exposure, an attachment may be placed in an inappropriate position on the tooth surface, or the pigtail ligature wire or gold chain may have been drawn through the tissues in a direction inappropriate for traction to resolve the impaction. Alternatively, the bond may fail and, without further surgery, suitable conditions for rebonding may be limited or unattainable (see Figure 8.10).

In the preceding chapters we have seen that, from the orthodontic and surgical points of view, the successful outcome of treatment of a difficult impaction may regress in the long term due to a lack of periodontal support. This is indeed unfortunate and is a situation that could have turned out very differently had certain precautions been taken in diagnosis, treatment planning, surgical exposure or biomechanics.

It is abundantly clear from all the above that there are many different areas where opinions regarding attitudes to treatment may vary among the three principal specialists involved with treatment: orthodontist, oral radiologist and oral and maxillofacial surgeon. In addition, the actual levels of expertise of these professionals may vary widely. Taken from the standpoint of the best interests of our patients, it will be understood that communication, coordination and rapport between these specialists are of paramount importance.

Given the broad spectrum of concerns that are so intimately bound up with the whole approach to the relatively limited phenomenon of impacted teeth, it should not be surprising that the chances of error are legion and, with them, there is a distinct likelihood of embarrassing failure. The purpose of the present chapter, therefore, is to analyse the possible causes of failure that occur from time to time in clinical practice and to group them in relation to the various aspects involved in each scenario. In a recently published study [4], the Jerusalem group collected a sample of 28 young patients for whom treatment for the resolution of their impacted canines had failed. These patients had been referred to the study authors on an individual basis by a large number of orthodontists over a period of several years, with the intention and hope that the cases could be salvaged.



(a) (b) (c)

Fig. 18.1 (a) The pre-treatment panoramic view of a patient whose mandibular right second molar had not erupted at the completion of treatment. (b) A panoramic view of the same patient seven years later and five years after the completion of the treatment shows the mandibular right second molar impacted between the two adjacent molars. (c) A month after the surgical removal of the unerupted third molar and exposure of the impacted second molar, the second molar is erupting spontaneously. The impaction is due to the obstruction created by the distal anatomy of the first molar and the large and horizontal third molar.

Fig. 18.2 A cause of incisor crowding?

Courtesy of Prof. Nardy Caspi-Casap.

In the sample of 28 patients, a total of 37 impacted canines had not been resolved and had been in treatment for an average of 26 months (with a range of 7–72 months) prior to referral. Surgical exposure had been performed three times for 10 of these canines. The referring orthodontists were requested to evaluate why *they thought* the case had failed. The majority had assumed it to be due to ankylosis, while most of the others had missed diagnosing root resorption of the adjacent teeth. A few had blamed their lack of success on bond failure, or on an intractable location of the tooth, or even on failure to adequately surgically expose the impacted tooth.

The Jerusalem group then carried out a re-evaluation of the individual cases, often needing to prescribe a cone beam computed tomography (CBCT) examination. The cases were then re-treated in accordance with the new findings. The result was that 28 of the original 37 impacted canines were successfully aligned in the dental arch. Two of the remaining cases had refused the revised treatment. Of the seven canines with confirmed ankylosis, three were successfully re-aligned following surgical luxation.

In their conclusions to the study, the authors noted that there are many aspects and minutiae in the treatment of an impacted maxillary canine, each of which may cause the treatment to founder. They specifically had the following comments to make:

- Diagnosis of the location of the tooth and its immediate relationship with the roots of the adjacent teeth had generally been treated with cavalier and often negligent simplicity, even though modern technology has provided the tools to achieve this diagnosis with great accuracy in all three dimensions.
- With inappropriate positional diagnosis, it follows that traction will be applied in the wrong direction.

- A lack of appreciation of the considerable anchorage requirements of the case and the need to exploit all available means of enhancing those requirements will inevitably lead to inefficient mechano-therapy and unnecessarily lengthy treatment.
- Ankylosis might have afflicted the impacted tooth either *a priori* or as the result of the earlier surgical or orthodontic manoeuvres.

A summary of the principles guiding the orthodontist in analysis of the causes of failure and in planning the ultimate resolution of impacted teeth may be seen in the following points:

- Patient-dependent factors:
  - Age
  - Medication
  - Abnormal morphology of impacted and adjacent teeth
  - Pathology affecting the impacted tooth
  - Grossly ectopic teeth
  - Lack of compliance
- Radiologist-dependent factors:
  - Incorrect positional diagnosis
  - Root resorption of impacted or adjacent tooth
  - Supernumerary teeth/odontoma
  - Pathology
- Orthodontist-dependent factors:
  - Incorrect positional diagnosis
  - Negligent examination of clinical and/or radiographic features
  - Resorption of the root of an adjacent tooth
  - Poor anchorage
  - Inefficient and poorly designed appliances
  - Iatrogenic causes of failure
- Surgeon-dependent factors:
  - Poor surgical planning and mistaken positional diagnosis
  - Surgical exposure without prior orthodontic planning
  - Unnecessarily excessive/botched surgery

It is paradoxical that on the one hand, in the treatment of a routine malocclusion, orthodontics has reached the pinnacle of excellence with the highest level of predictability and confidence and has become the envy of virtually every other specialty within dentistry or medicine. With the continuing evolution of more efficient appliances, the wide spectrum of malocclusions that can be treated well and within a fairly short space of time is truly impressive. On the other hand, however, when an impacted tooth is found to be one of the elements of this malocclusion, the confidence of orthodontists is often shaken to the core. They may experience no small degree of apprehension and uncertainty as to whether a successful result may be achieved. The unfortunate fact is that 'impacted teeth are not for everyone'! The faint-hearted clinician, or perhaps the responsible clinician, faced with an impacted tooth situation may decide not to accept the patient for treatment at all and may suggest that the parent seek treatment with another practitioner, who may be more experienced and have greater expertise in this specific area of orthodontics. Where the orthodontist does decide to treat the case, treatment is often conditioned on some form of let-out clause or warning that this particular element of the treatment may not be successful.

Readers will have noticed that the above list was preceded by the statement 'the principles guiding the *orthodontist*'. This is because it is orthodontists whose responsibility it is to assess the case. It will be their responsibility also to apply all the strictly orthodontic principles, consider each of the items mentioned in these four categories and decide on a working solution for the problem. Orthodontists must occasionally refer to information and clinical treatment that may not be in their sphere of expertise, specifically from the radiologist and the oral and maxillofacial surgeon. In the final analysis, however, the orthodontist must be the leader of this small group of professionals and make the operative decisions.

The ensuing discussion will reveal some of the reasons why, without proper liaison between the parties involved, failure may occur, and will discuss how good pre-planned and carefully supervised leadership may help to avoid failure.

Patient-dependent factors

Age

In Chapter 6, we referred to the fact that the chances of orthodontic traction having a positive effect on an impacted tooth are extremely high in the young patient, but that with advancing age, notably in the over-30s, the risk of non-movement becomes quite significant [5]. The level of compliance among adult patients is usually better than among children. The relatively undemanding day-to-day care (maintaining a high level of oral hygiene, attending pre-arranged treatment visits, taking proper care of the appliances, placing elastics, etc.) that is within the patient's realm of responsibility is usually managed considerably better by adults. Thus, while tissue response to orthodontic forces in the child is very positive, the endeavour may be more likely to founder due to a lack of compliance. The reverse is true in the adult, where the patient is highly motivated, but the tooth may move more slowly or not move at all.

In the adult, the ravages of time will often be evidenced by a loss of periodontal attachment and bone support, which have been due in large measure to chronic inflammation. Once these factors have been brought under control by appropriate periodontal treatment, routine orthodontic treatment may be recommended with considerable confidence and with a high degree of predictability. This is only true, however, in regard to the *root* of a tooth. For the unerupted *crown* of the tooth the situation may be quite different, since the dental follicle undergoes deterioration over time. Direct contact between tooth enamel and the encroaching bony tissues may occur and this will effectively eliminate the orthodontic therapeutic option. Since this phenomenon is age related, it will rarely be encountered in the young patient, but must be a factor to be considered in planning the treatment of an adult, particularly in the over-30s age group [5].

Medication

Many of our patients, particularly the adults, are on medication of one sort or another on a regular basis and over a long period of time. Part of the history-taking on our patients must therefore be directed at obtaining full details of any form of medication being taken. Orthodontics is probably the least invasive of all dental specialties (after public health dentistry) and orthodontists rarely have the need to prescribe drugs. Indeed, few drugs have properties that directly affect our work. Notwithstanding that, we must be aware of patients needing antibiotic prophylaxis, which is necessary for certain heart conditions, and those taking anticoagulants, particularly in relation to the surgical exposure of impacted teeth.

There is, however, one class of drugs that it is important for the orthodontist to be particularly aware of, since they have a direct influence on orthodontic treatment *per se*. These are the bisphosphonates, a class of drugs that are prescribed to prevent the loss of bone density and the most commonly prescribed drugs used to treat osteoporosis [6]. The drug works by slowing down the osteoclasts, which are the cells that break down bone, and thus it reduces bone loss. Its effect is to tip the balance between the osteoclasts and the osteoblasts, in favour of the latter. Orthodontic treatment is based entirely on this same bone turnover mechanism and it exploits the normal balance between these two antagonistic cells to its advantage. For movement to occur in response to a given orthodontic force, bone must be resorbed (osteoclastic activity) on the wall of the tooth socket where the periodontal ligament (PDL) is compressed and it must be deposited (osteoblastic activity) on the tension side. If the osteoclasts cannot do their job, then the orthodontic treatment will fail, even if the forces are applied for a long time.

From the surgical aspect, too, there is a need to discuss the level of risk of the intended exposure procedure with the patient's physician and the oral and maxillofacial surgeon, particularly if the intended treatment involves the extraction of teeth.

Abnormal morphology of impacted and adjacent teeth

In Chapter 6, we discussed many cases with reference to dilacerate incisors and have shown that the orthodontic/surgical modality of treatment may provide an optimal result in aligning these abnormal teeth. It will assist in carrying the young patient through the years of childhood and adolescent growth, during which prosthetic/implant substitution is generally contra-indicated. Minor restorative modifications in crown or root form may be necessary during this period when the dentition is at its most vulnerable, but with this treatment modality the child will be free of iatrogenic, periodontal disease-producing or caries-generating prosthetic devices. Also significant is the fact that alveolar bone in the area proliferates quite normally with the resolution of the impaction and maintains its height throughout growth, in parallel with the other teeth. It would therefore be a serious mistake to extract these teeth indiscriminately simply because of a diagnosis of morphological abnormality. The practitioner is strongly advised to consider all the alternatives before recommending extraction.

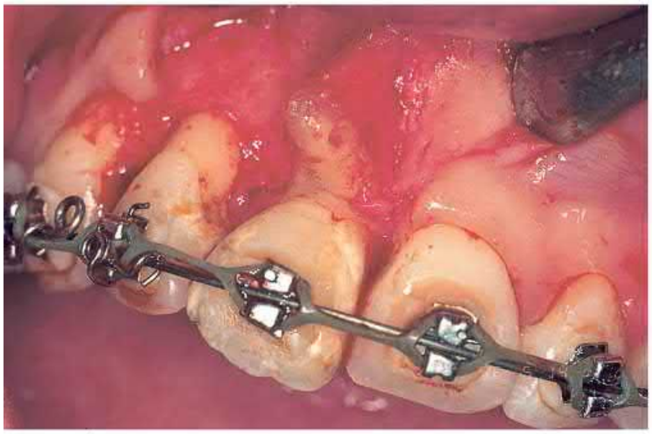
In cases of these abnormalities, fixed bridges and implants have a limited life expectancy and failure may occur much earlier. This, together with the atrophy of alveolar bone in the immediate area that inevitably occurs following an extraction, must be considered to be a failure to fully exploit the natural and available raw material (i.e. the imperfectly formed tooth). Nevertheless, there are cases in which the location of the dilacerations and the degree of the tooth's distortion leave little option but extraction (Figure 18.3).

Rather than an impacted canine itself being resistant to movement, it may be that the root morphology of the first premolar is the hidden impediment. The adjacent first premolar normally erupts before the canine and has a buccal and a palatal root. These roots, particularly the palatal one, may develop in the direct eruption path of the canine. This may happen when the premolar erupts with a distal crown tip or when the tooth is rotated mesio-buccally. The root itself may be deformed and exhibit a mesially directed dilaceration of its root apex, as has been described in

Chapter 7 (see Figure 7.2). In plane film radiography, the individual roots of the premolar are sometimes not possible to distinguish and superimposition on the canine leaves the bucco-lingual interrelation of the two teeth difficult to discern. CBCT imaging of these cases will often clarify the problem and assist in the determination of a suitable direction for the application of traction, by revealing developmental root impediments. In the case illustrated in Figure 7.2, the root orientation of the premolar needs to be over-uprighted in a distal direction and then the tooth should be rotated mesio-palatally to free the canine from interference. Once the canine has been brought into alignment, the first premolar may then be re-uprighted and re-rotated into a more optimal position, taking due care to avoid root contact.


(a)


(b)


(c)


(d)

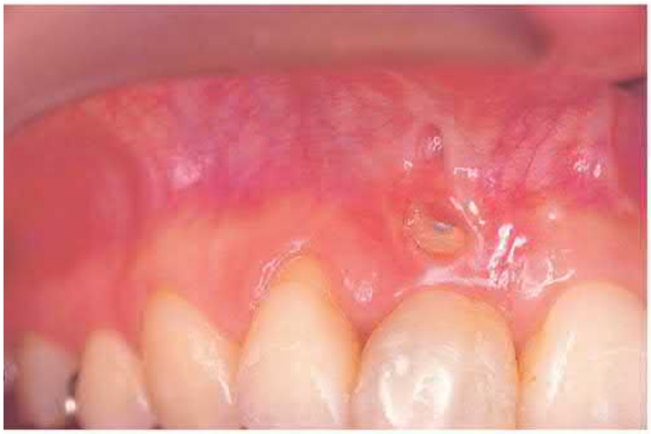
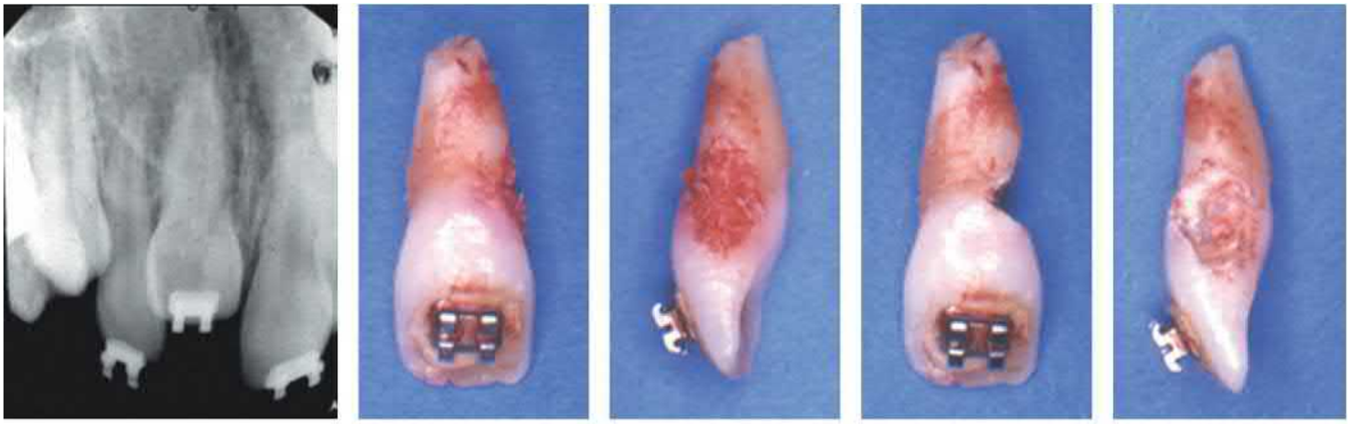

(e)

Fig. 18.3 A 15-year-old female presented with a dilacerate but erupted right maxillary central incisor. (a) The initial malalignment. (b) Following alignment and levelling, the root apex can be seen to be pointing labially under a thin cover of overlying oral mucosa. (c) When the flap was raised over the area, with a view to perform an apicoectomy, it was seen that there was no labial bone covering the short and malformed root. (d) The root apex was trimmed back and a retrograde filling placed. (e) At the two-month follow-up visit, the root apex had fenestrated the oral mucosa and the tooth was extracted.

Pathology affecting the impacted tooth

There are a few pathological entities of the impacted tooth itself that adversely affect eruption. High among them are ankylosis and invasive cervical resorption [7]. Both these conditions are quite rare. They are asymptomatic and thus difficult to diagnose in their early stages, even with good radiographic technique. The presence of either will result in failure of the affected tooth to respond to the applied orthodontic force, due to a loss of integrity of the normal periodontal tissue in one or more, often very small locations on the root surface. This subject is discussed fully in Chapter 10, where several examples of these conditions are described and illustrated in detail.

In the example illustrated in Figure 18.4, invasive cervical resorption had been the diagnosis, which had been blamed for the failure of the right central incisor to fully erupt. A close look at the mesial side of the cervical area of the tooth of the periapical radiograph showed a defective outline (Figure 18.4a). Orthodontic treatment had been instituted in a vain attempt to overcome the problem. The tooth was extracted and a large area of resorption mush, in the cervical area of the extracted tooth, was seen on the mesial side (Figure 18.4b, c). This soft mush was removed with a scaler, revealing the broad extent and depth of the erosive lesion (Figure 18.4d, e) into the body of the root.



(a) (b) (c) (d) (e)

Fig. 18.4 Invasive cervical resorption. (a) Periapical radiograph of the infra-occluded tooth. (b, c) The resorption area seen following extraction of the tooth, with its associated resorption 'mush'. (d, e) The full extent of the erosive lesion can be seen following excavation of the 'mush'.

(a) (b)

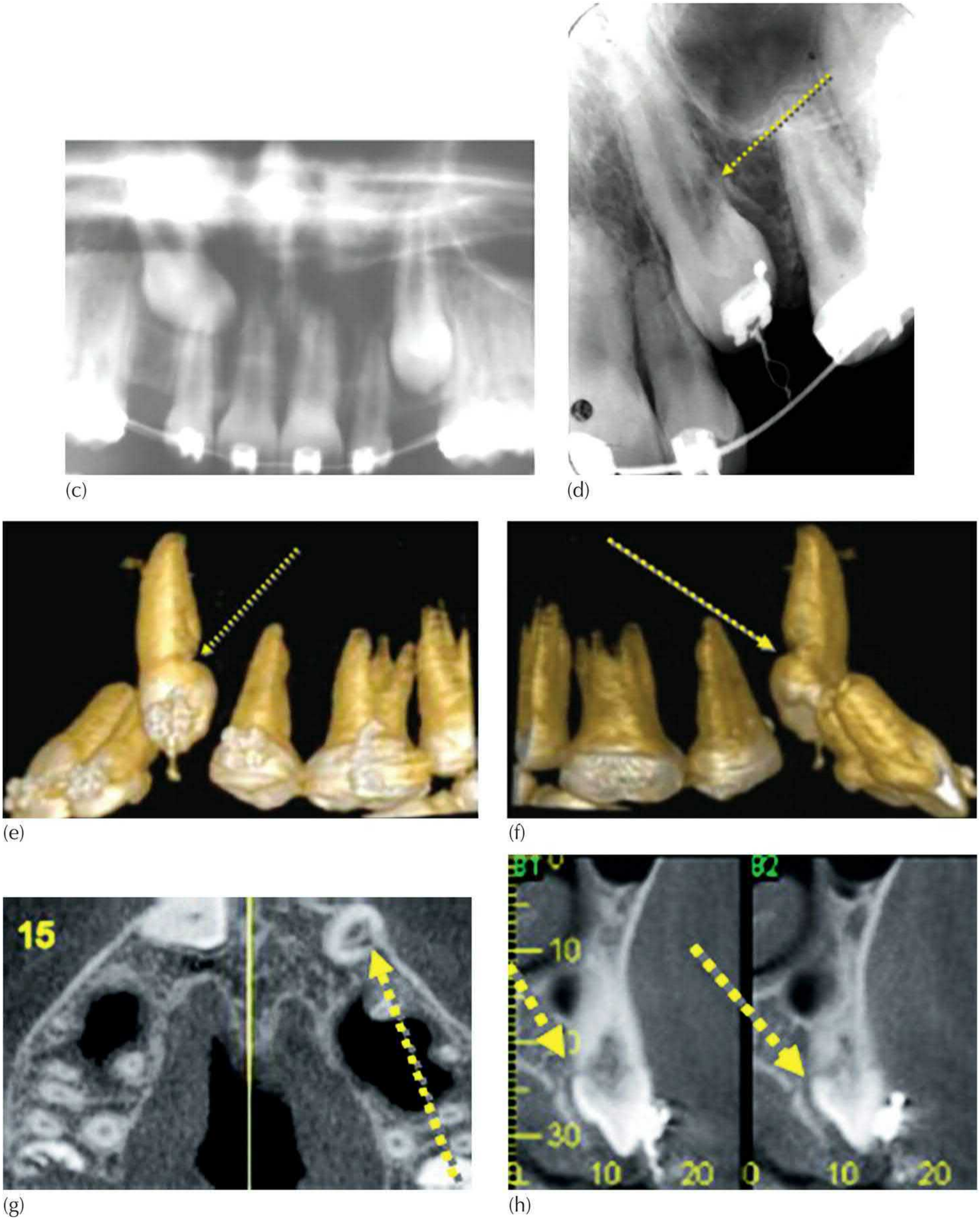


Fig. 18.5 Invasive cervical resorption. (a) Intra-oral view at consultation. (b) Intra-oral view from the initial treatment records, five years earlier. (c) Anterior section of panoramic view taken prior to surgical exposure showing canines with no apparent pathological involvement. (d) Periapical view after five years of treatment, with invasive cervical root resorption lesion on the distal aspect

of the root of the left canine (arrow). (e, f) A buccal and a lingual 3D view from the cone beam computed tomography (CBCT) series shows the lesion extending from the distal to lingual sides of the root (arrows). (g) A single axial (horizontal) slice from the CBCT to show the right canine lying horizontally above the roots of the incisors. The left canine shows a distinct break in the continuity of the root on the distal side (arrow). It is possible to discern the narrow pulp chamber outlined by the more radiolucent pericanalar layer and the resorbed area of root around it. (h) Two cross-sectional (vertical) slices from the CBCT show the palatal portal of entry of the resorption process and its mushrooming extension inwards.

It seems that there is a tendency of many orthodontists to continue orthodontic treatment for many months, even stretching into years in some cases, in an attempt to resolve the impaction of canines, before finally calling for help (or simply giving up).

The case in Figure 18.5 was referred to the author for consultation having been in active orthodontic treatment for five long years. The first two years of this period were spent creating space for the canines and hoping for subsequent spontaneous eruption. When this did not happen, the two canines were surgically exposed and attachment bonded. Traction was then applied for the remaining three years, to no avail.

At the consultation visit, a very significant 10 mm anterior open bite was noted (Figure 18.5a), which had clearly developed during the entire period that extrusive force was being applied to the canines. The initial photographic records, taken five years earlier, showed a 1 mm positive vertical overbite, with incisal edge contact in closure (Figure 18.5b). The anterior section of the pre-surgical panoramic view (Figure 18.5c) showed no apparent pathological involvement that could have explained non-eruption of the canines. However, the periapical view, after three continuous years of extrusive traction, was more than sufficient to highlight the invasive cervical root resorption (ICRR) lesion on the distal aspect of the root of the left canine (Figure 18.5d).

A CBCT series was performed shortly before the consultation appointment, in which the buccal and lingual aspects of the 3D image showed the lesion extending from the distal to lingual sides of the root (Figure 18.5e, f).

A single axial (horizontal) slice from the CBCT indicates that the right canine was lying above the roots of the incisors. The cross-section of the left canine shows a distinct break in the continuity of the root on the distal side. It is possible to discern the narrow pulp chamber, outlined by the more radiopaque pericanalar layer (Figure 18.5g, h), and the resorbed (radiolucent) area of root around it (see Chapter 10). Two juxtaposed cross-sectional (vertical) slices from the CBCT show the palatal portal of entry of the resorption process and its mushrooming extension inwards. It is most likely that the aetiological factor for the ICRR lesion was triggered during the surgical exposure episode. It may have been due to an excessive exposure of the tooth into the cemento-enamel junction (CEJ) and root area, which would have damaged the cementum. It may have been the surgeon ‘making sure’ that the tooth was adequately mobile by ‘rocking’ it. It may have been the unnecessary flooding of the open surgical area with orthophosphoric acid etchant, used in bonding, that had leaked onto the exposed root surface. On the other hand and according to Heithersay [8], it may simply have been the effect of orthodontic movement *per se*.

Despite long-term orthodontic traction being applied to these teeth, they will not respond. However, the reactive force will act on the teeth that comprise the anchor unit and will cause their intrusion. Such is the power of resistance of an ICRR lesion. (This diagnosis is discussed fully in Chapter 10, Figures 10.3 and 10.8).

Grossly ectopic teeth

Figures 18.6–18.10 relate to five different cases in which there is an impacted tooth that has found itself in a location where it is doubtful if any orthodontist would attempt to bring it to its place in the arch, even if this was considered to be possible.

There seems to be no limit to the variety of locations in which ectopic teeth may appear in the jaws. Although rare, extreme ectopy can manifest itself not only within the normal areas of teeth development, but also in remote areas of the jaw and elsewhere, such as among the contents of dermoid cysts. It is only for their curiosity value that we have shown here some examples of this feature. In these illustrated cases it is doubtful whether orthodontic treatment would be offered at all. Due to their significant separation from the remainder of the dentition, imaging of these teeth may be best achieved with the use of straightforward planar radiographs. In many of these cases, there may be little or no added orthodontic value in the use of CBCT.

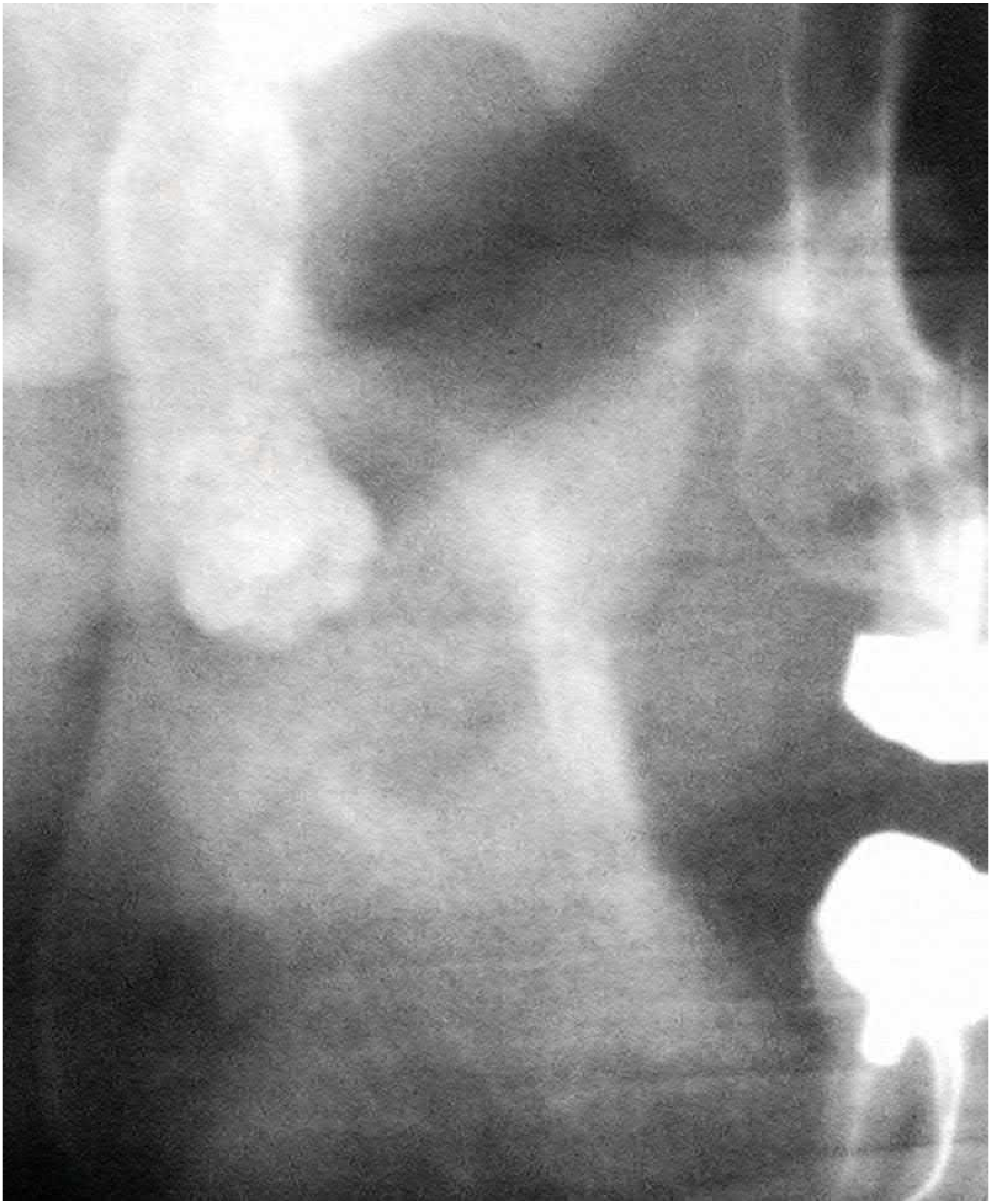


Fig. 18.6 A 'condylar ' third molar complete with dentigerous cyst. Courtesy of Dr Adam Renert.

As with other varieties of abnormal teeth, the surrounding tissues of the ectopic tooth are generally quite normal and the potential that they may have for responding to the application of orthodontic forces may often be excellent. Nevertheless, the question that needs to be answered is whether the estimated length of time needed for their treatment, together with the questionable periodontal prognosis, is sufficiently favourable to render the orthodontic/surgical modality superior to other therapeutic options. The answer will usually incline to the negative, leading to extraction or, occasionally, towards leaving the tooth untreated, because of difficulty and possible complications involved in extraction.

Lack of compliance

In the delivery of orthodontic treatment to any patient, such simple but routine functions as effective oral hygiene, placement of intermaxillary elastics, keeping appointments and other basics are essential – and the patient must accept these responsibilities. Without this self-help, orthodontics therapy may still be administered, but it demands that these functions be reliably and continuously undertaken by a third person, usually a responsible adult and usually a parent, who is prepared to do so for the duration of the treatment [9].

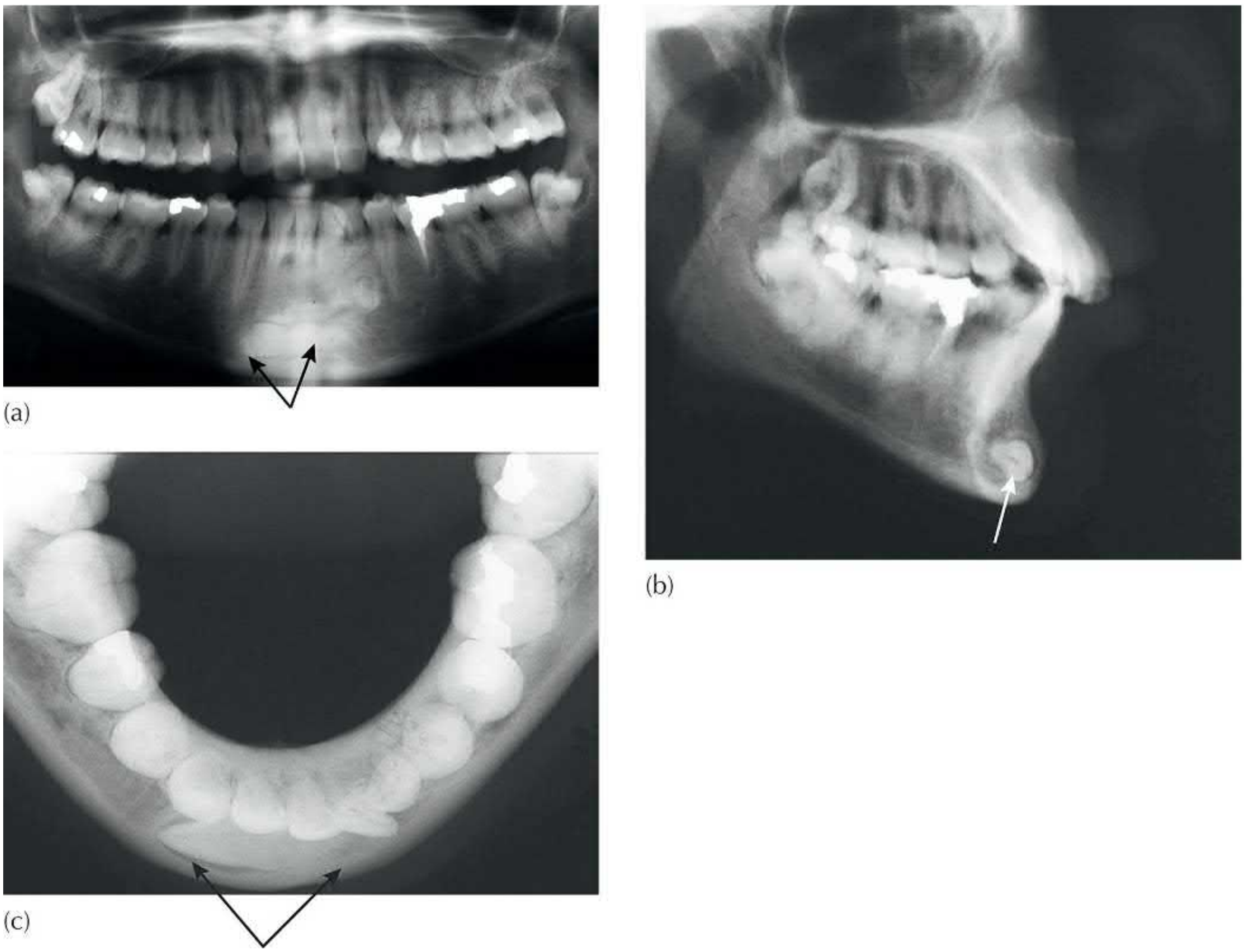
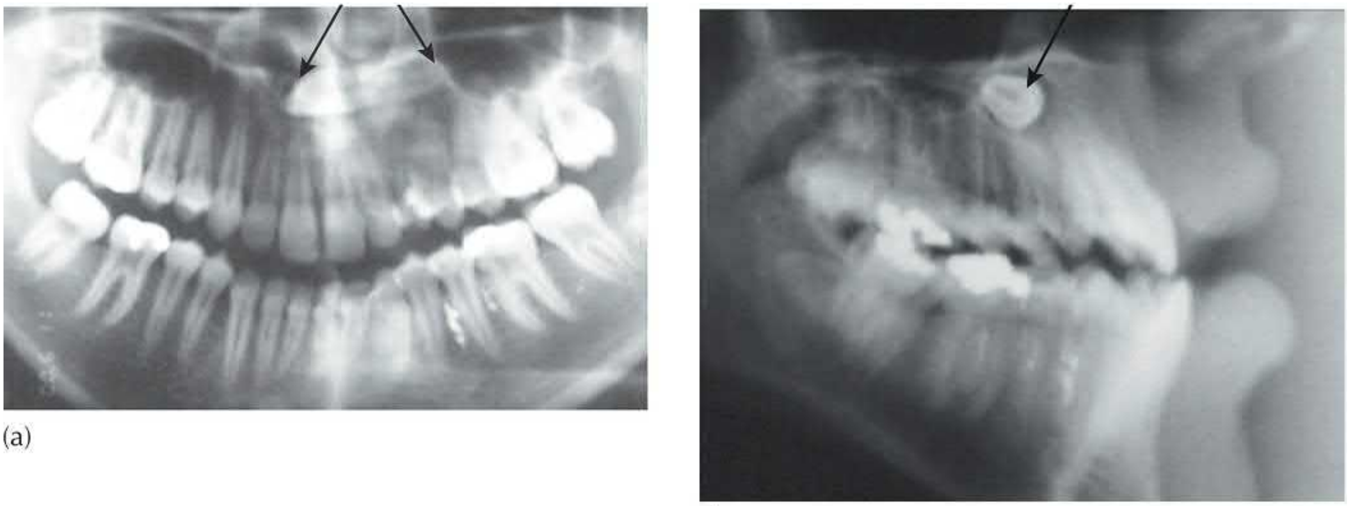


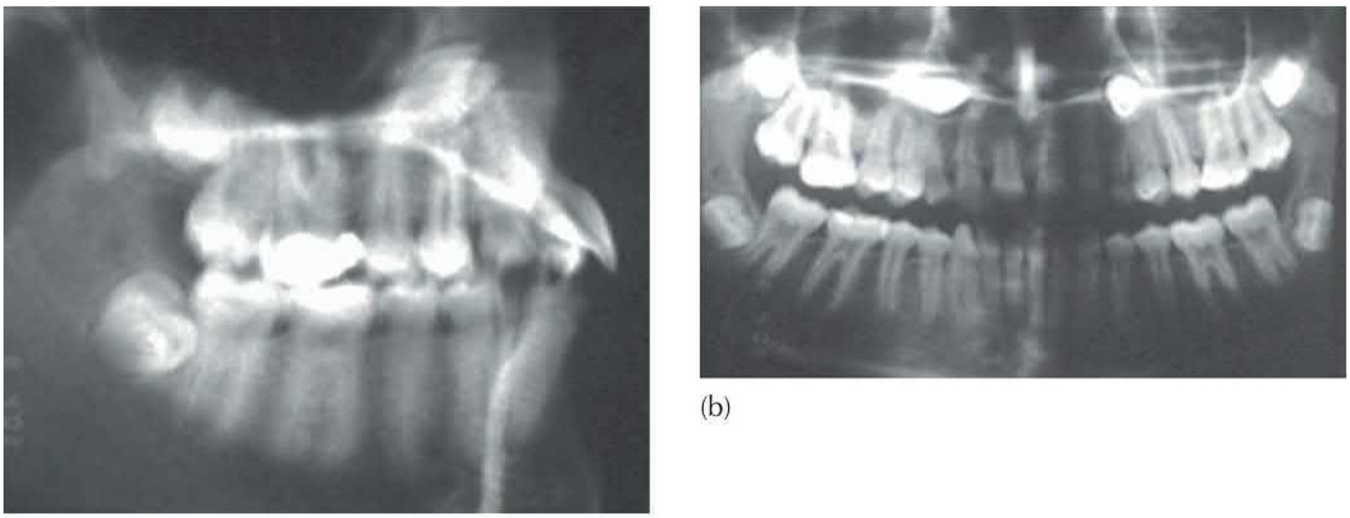
Fig. 18.7 (a–c) Panoramic, lateral cephalometric and occlusal views of a mandibular left impacted canine crossing the midline and exactly at right angles to the mid-palatal and antero-posterior planes (arrows). The direction of the X-ray for the cephalogram is in the long axis of the tooth and it depicts it in cross-section.



(a)

(b)

Fig. 18.8 (a, b) The maxillary parallel to Figure 18.7. Courtesy of Dr Monica Barzel.



(b)

(a)

Fig. 18.9 (a, b) Bilateral 'high-flying' maxillary canines. Courtesy of Dr Penina Teper-Adler.

It is not sufficient that the child has a significant malocclusion with (or without) one or more impacted teeth. Neither is it sufficient if, in such a case, the parent of the child is positively in favour of the suggested treatment, and even if the orthodontist is keen to accept the challenge. If the child is not prepared to accept the treatment and the responsibilities that it imposes upon him or her, then the treatment will most likely fail.

Radiologist-dependent factors

Having a radiologist decide which radiographs should be taken for each routine orthodontic case is obviously 'overkill', because the orthodontist should be sufficiently familiar with what is generally required and what will normally suffice for a specific case. This should also be true of impaction cases. However, an open door to the radiologist's office is an obvious advantage for certain difficult cases. There are distinct advantages in having a second pair of eyes look at the unusual presentation of a possible anomaly or recommend one or other of the lesser-known (or lesser-used) CBCT options. These tools may clarify the picture, towards achieving an accurate positional diagnosis of the unerupted tooth. The ability to distinguish incipient resorption of an adjacent tooth, on the one hand, from ICRR signs of ankylosis of the impacted tooth, on the other hand, will enable the orthodontist to assess the chances of success of a treatment.

Orthodontist-dependent factors

Incorrect positional diagnosis

Inadequate or inappropriate use of imaging techniques may sometimes produce a false impression of the exact location of an unerupted tooth. It often happens that films are available within the patient's records, but are not considered relevant for positional diagnosis, since this was not the original intention for obtaining the particular view concerned. It should be routine for orthodontists to insist that the initial records of all their new patients include a panoramic, lateral cephalogram and sometimes a postero-anterior cephalogram. The panoramic radiographs are important to identify the presence of all the teeth, to register their state of development and to offer a 2D impression of the location of the impacted tooth. The cephalograms are studied and evaluated by the measurement of angles and distances between anatomical and dental structures. It is essential to exploit all available and obtainable information in these radiographs, particularly in regard to 3D diagnosis of impacted tooth position. Failure to search all the evidence thoroughly will result in the patient being subject to further irradiation in the search of information that may well be already available.

We have discussed grossly ectopic teeth as being one of the situations that a patient may present to us for which the orthodontic/surgical modality may not provide the best treatment solution. However, in order to reach a conclusion as to whether orthodontic treatment would be beneficial, a careful analysis of the orientation of the tooth, in its ectopic location, needs to be made, and this must be done by the orthodontist.

One of the most important guiding principles upon which this decision will be based relates to the accurate diagnosis of the location of the root apex of the aberrant tooth. If the apex is in a fairly normal position, the prognosis will generally be good, because the main part of the treatment for that tooth will involve a tipping movement, which is easy to apply and rapid in its response.

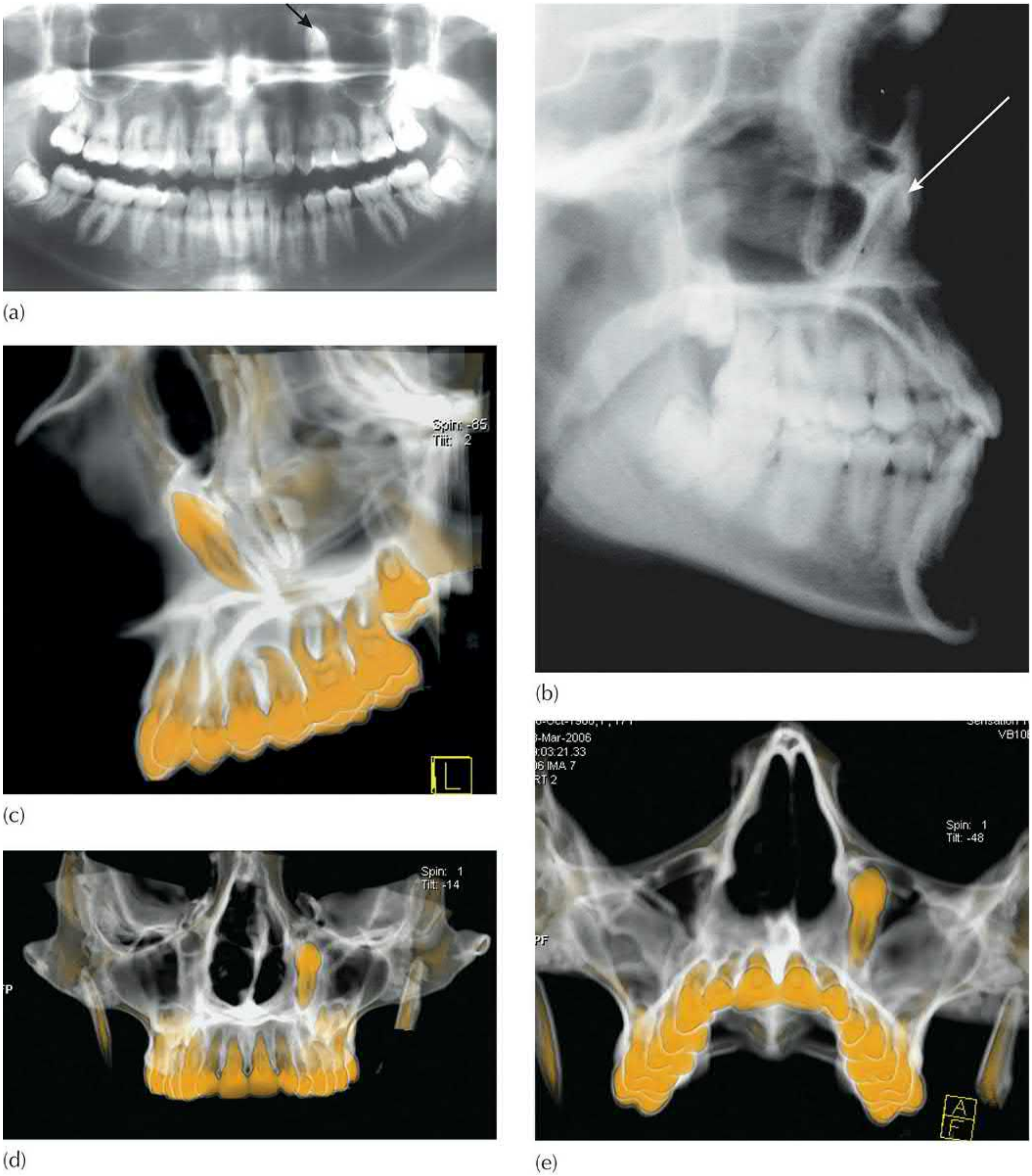
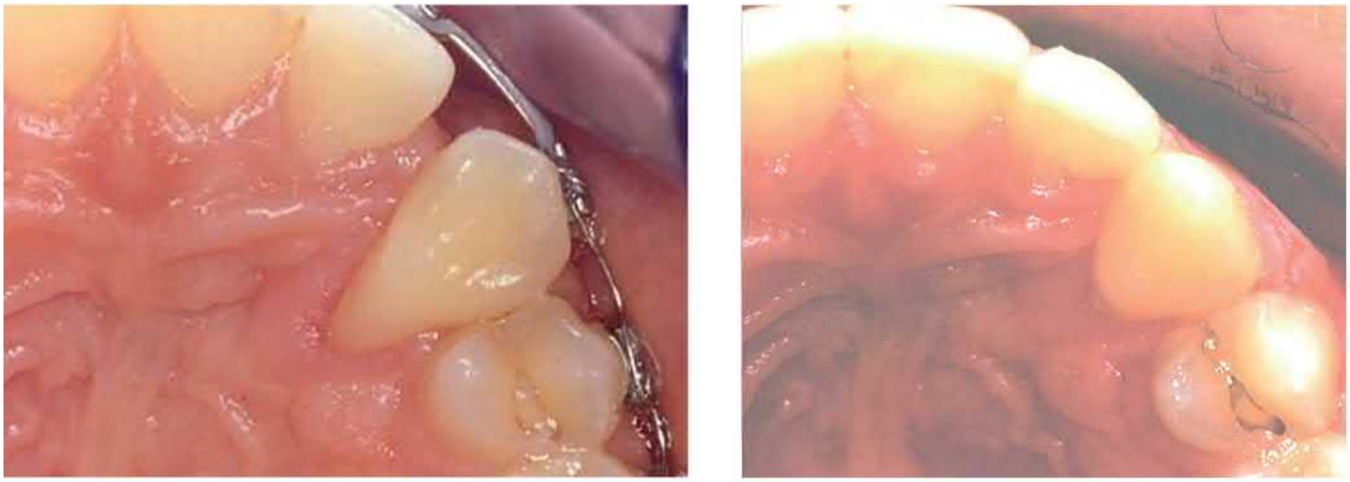


Fig. 18.10 An 'eye-for-an-eye' tooth. (a, b) The panoramic and lateral cephalometric views of this young female patient show the crown of the left maxillary canine (arrows) to be in close relation with the floor of the orbit of that side. It was important to establish its exact location in the three planes of space and whether further 'eruptive' movements in the present direction would threaten the eye. (c–e) 3D computerized tomographic views of the tooth provide accurate positional information with which to consult the ophthalmologist.

Courtesy of Dr M. King.



(a) (b)

Fig. 18.11 (a) A severely displaced (group 4) canine crown has been brought to the line of the arch and needs much labial root torque. Considering the length of the root of a canine, its apex must be moved buccally through approximately 10 mm of alveolar bone. (b) The root torque was achieved using a torqueing auxiliary and took 17 months to complete.

Courtesy of Professor Stella Chaushu.

However, whenever the root apex is displaced, particularly when it is located on the same side of the arch as the displaced crown, very considerable torqueing and/or uprighting movement will be required. Root movements are largely impossible to accomplish before the bonded attachment on the crown of the tooth has reached the main archwire and been ligated to it. Therefore, during the mechano-therapy employed to bring this tooth to the line of the arch, the orientation of the impacted tooth will generally change unfavourably, thereby causing the root to bulge the palatal or buccal mucosa to an exaggerated degree and leading to a dehiscence of its palatal cervical area. The severity of this bulging and the consequential dehiscence will depend on the distance that separates the root apex from the general line of the arch (i.e. its normal place). In the more extreme cases, this will require a disagreeably wide angle of torque correction (Figure 18.11), which will translate into many months or years of treatment, the periodontal implications of which will often leave much to be desired.

In Chapter 8, we analysed the position of the buccally impacted maxillary canine with mesial displacement and discussed the reason why, when using plane film radiography, its positional diagnosis was particularly prone to error. When the mesial displacement is more severe, a periapical or anterior occlusal radiographic view will depict it superimposed on the mesial aspect of the root of the lateral incisor and on the distal aspect of the root of the central incisor. In addition, since this canine is located in the depression between the two roots, using the lateral tube-shift method may not produce an adequate differential overlap of the incisors, which is needed to determine its labio-lingual positional diagnosis.

There are parallel problems with the vertical tube-shift method. Because of the angle of the central ray from the periapical or anterior occlusal vantage points in the vertical plane, this labially displaced tooth will appear to be more occlusal than its true position and will be superimposed on the middle portion of the roots of the adjacent teeth. On the other hand, with a panoramic film, the relative height of the tooth will show it to be more apically superimposed on the roots of the incisors (for a description of vertical tube shift, see Chapter 4). The frequent result of all this is likely to be a misdiagnosis.

The unfortunate but logical result of this problem of 3D geometry is that the surgeon concerned may attempt to surgically expose a labially impacted canine from the palatal side and then report the case as having been a very difficult one or that the tooth was impossible to find (see later Figures 18.19 and 18.20).

Negligent examination of clinical and/or radiographic features

It is the job of the general dentist or paediatric dentist to attend to raising the level of the patient's intra-oral well-being. This specifically refers to the maintenance of a high standard of oral hygiene and the avoidance of diets containing a high intake of refined carbohydrate. Moreover, this includes the performance of daily fluoride rinses before bed, biannual fluoride gel or, preferably, fluoride varnish application, depending on the caries risk assessment of the patient. It must be remembered that the insertion of orthodontic appliances in the mouth immediately raises this risk.

These elementary procedures are essential for the avoidance of caries in general, but white spot lesions in particular, when the patient begins orthodontic treatment. The responsibility for setting up and supervising this basic health care rests firmly on the shoulders of the GP or paediatric dentist, but the orthodontist has the unique opportunity from the initial visit to monitor compliance during the regular visits for treatment that the child must make.

So, too, the responsibility for treating caries devolves on the GP or the paediatric dentist, but it is for the orthodontist to be aware and notice untoward or suspicious carious lesions, and refer the child appropriately to the practitioner.

For orthodontic diagnosis and treatment planning, the orthodontist will need to have radiographs of several types and to study them for what they have to exhibit. Unusual and chance findings, root and crown development or pathology must be sought. Failure to do so could lead to failure, complications or damage caused by the ill-advised implementation of treatment that, in more ideal circumstances, may otherwise be completely suitable. For this, the orthodontist will not be immune from blame and will likely be judged legally complicit.

Resorption of the root of an adjacent tooth

The subject of resorption of the root of an adjacent tooth has been fully discussed in Chapter 9. It is important, however, to emphasize at this point that the occurrence of this phenomenon in the incisor area is much more common (66.7% of adjacent lateral incisors and 11.1% of adjacent central incisors) than was once thought [10]. In its severest form, it develops rapidly and, in a relatively short time, may irretrievably destroy much of the root of an adjacent central or lateral incisor [11]. The young patient with a mixed dentition should be monitored regularly, in order to watch the development of the early malocclusion and to identify the optimum moment at which to commence orthodontic treatment in the full permanent dentition. Nevertheless, even yearly radiographic monitoring of the immediate area will not prevent resorption from causing much root shortening during the intervening months, before it is brought to the attention of the orthodontist.

In these cases, therefore, a potentially threatening position of an unerupted canine, in relation to the lateral incisor root, should encourage the orthodontist to adopt a closer follow-up procedure. A single periapical view (*not* a panoramic view) taken 4–6 months after an initial baseline radiograph should show the presence or absence of downward eruption progress of the canine, as compared with its antimere. If there should be noticeable lack of eruption progress, or a strong overlap of the incisor roots, or an alteration in root form or length, the orthodontist would be advised to consider initiating earlier treatment than otherwise.

When the condition is mild, traction on the impacted tooth will distance it from the resorbing area and the resorption will effectively stop [11]. However, when the resorption has become extensive, accurate relative positional diagnosis of the impacted canine and the affected root end must be established. There are two reasons for this: (a) the exact direction for suitable traction needs to be determined; and (b) based on this, the site of the surgical exposure will be chosen to enable the attachment to be placed on a surface that faces the intended direction of traction. Exposure should be as conservative as possible, sufficient only to accept the full base of a small attachment while haemostasis is maintained. Meticulous closure of the surgical flap is then performed.

Failure to observe these precautions will lead to failure in one or more aspects of the treatment. The application of orthodontic force to the impacted canine, in a direction inappropriate to the resorbing root end, may bring the two into closer contact and thereby encourage further resorption (Figure 18.12). In this situation, it is important to avoid an open surgical exposure and also to avoid the clearance of tissue around the crown of the tooth to free the crown from potential contact with bone. Either of these two procedures will risk exposing the resorption front at the root face to the oral environment. Such exposure will lead to devitalization of the incisor and further endanger its viability, whether or not a surgical pack has been placed.

Case 18.1: Aggravating an inherent resorption tendency by inappropriate directional traction

In the case illustrated in Figure 18.12, the influence of the unerupted canines in producing root resorption of the lateral incisor root was not apparent in the initial panoramic view, taken at 11 years of age (Figure 18.12a). The orthodontist commissioned a repeat film two years later, immediately prior to the commencement of non-surgical treatment for the patient’s class III malocclusion. This second film showed oblique distal resorption of the roots of both lateral incisors, which was clearly associated with the proximity of the unerupted canines (Figure 18.12b). What could not be explained was why the left central incisor had lost almost half its root length due to resorption. The cause of the resorption of this tooth was not apparent, since the unerupted canine was quite distant from it.

Orthodontic treatment began (Figure 18.12c) and, before adequate space was provided in the arch, the left canine was exposed, with traction being applied directly to the labial archwire. The vertical vector of the traction caused the canine to move down, directly towards the root of the lateral incisor. The follow-up radiograph showed the resultant severe resorption of the lateral incisor root (Figure 18.12d).

It was at this point that the patient was referred to the author for continuation of treatment. On the first visit, an auxiliary labial arch was placed in such a way as to change the direction of the traction from vertical to labial (Figure 18.12e).

The rest of the treatment was completed with the erstwhile palatally displaced canine remaining ‘in limbo’ until space became available for its alignment. Orthodontic forces were not placed on the lateral incisor until the canine was well clear. Root uprighting and torqueing procedures on the lateral incisor were avoided and the treatment was completed in a very short time period, with just a simple levelling and aligning movement of the endangered lateral incisor (Figure 18.12f).

(a)

(b)

(c)

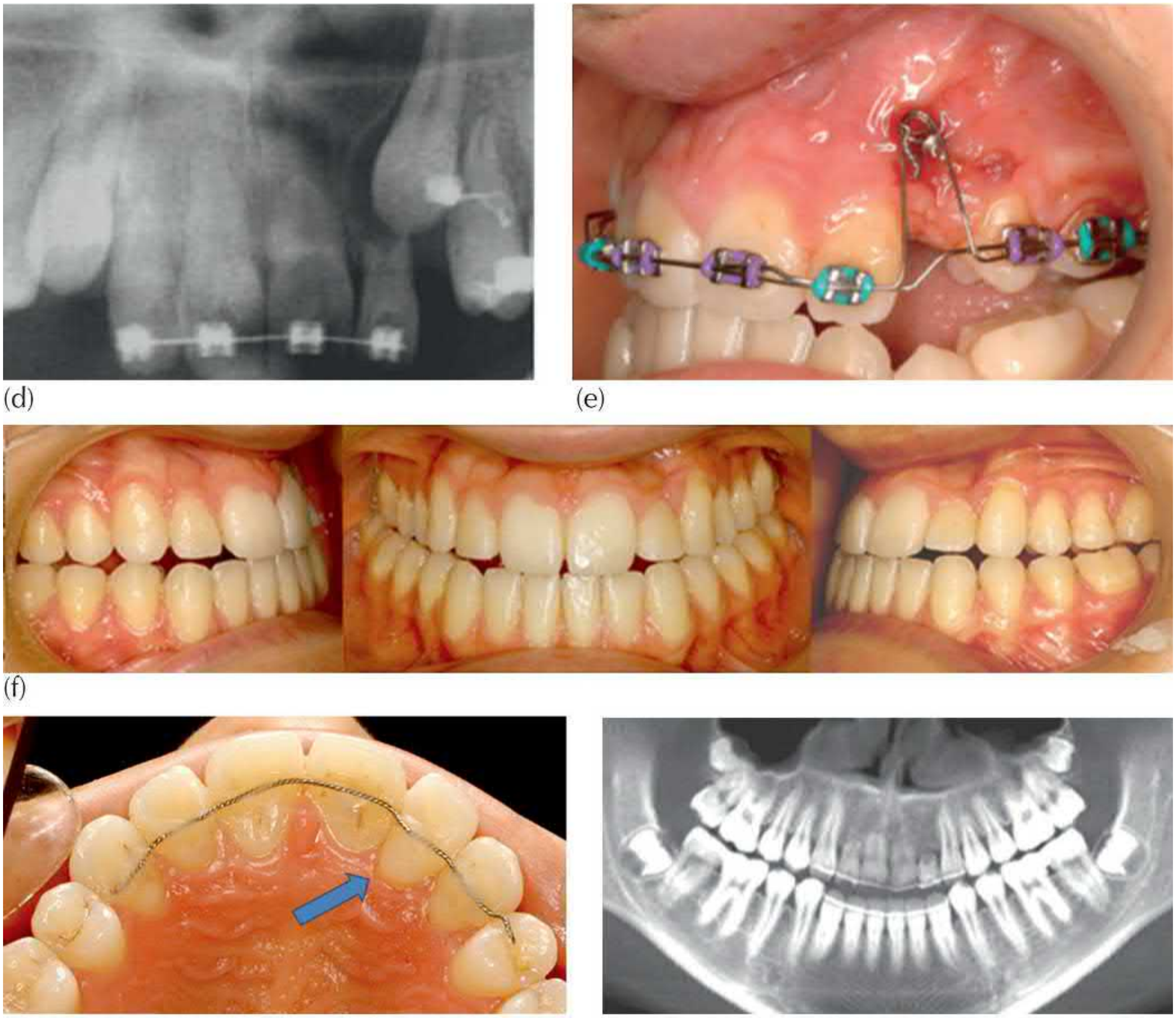


Fig. 18.12 (a) Panoramic view at age 11 years showing no abnormality. (b) Panoramic view at age 13, with considerable resorption of the roots of all four incisors. (c) Due to the urgency of the situation, brackets had been placed by the first orthodontist, the canines were exposed, and traction applied before levelling, alignment and space opening had been achieved. (d) Vertical traction from the bonded button to the archwire had increased the resorption alarmingly. (e) A passive main arch was placed, with a labial auxiliary arch to apply labial force to the canine. (f) Alignment and finishing with cusp-to-cusp and incisal edge-to-incisal edge occlusion. The lateral incisor was tipped to its place as the last function of the appliance, before bonded twistflex lingual retainers were placed in both jaws. (g) At six years post treatment, the occlusal view shows the exposed enamel edge of the crown of the left lateral incisor (arrow). (h) A panoramic radiograph was also taken six years post treatment, showing severe resorption on all four maxillary permanent incisors – but nowhere else.

The follow-up radiograph, taken at 17 years of age, one year after bonded twistflex wire splints had been placed, revealed severe resorption of the roots of the other three maxillary incisors, which had lost two-thirds of their initial root length or more. The left lateral incisor had lost almost its entire root but, with the splint in place, there was no obvious mobility. With the cessation of orthodontic movement, it was estimated that further resorption would not occur and it was hoped that the patient might look forward to a few years of stability before artificial replacements become necessary [11]. No other teeth were affected by root resorption.

At age 22 years and almost six years post treatment, the follow-up clinical examination (Figure 18.12g) revealed that the sharp lingual edge of the crown of the most severely resorbed tooth (the left lateral incisor) could be detected with an explorer (arrow). The tooth was completely asymptomatic, but a careful examination showed that this enamel knife edge was unsupported by dentine within the crown. The tooth was extracted and replaced by an implant-supported artificial crown.

The treatment procedure described in this case raises an interesting point. On the one hand, resorption of the root of the tooth immediately adjacent to an impacted canine is a well-known phenomenon and the effect is clearly a local one. On the other hand, there are many cases in which there may be general resorption of the roots of all the anterior teeth, with or without orthodontic treatment. This has been extensively documented and its aetiology has been variously ascribed to genetic, humoral, hormonal or idiopathic factors. It is therefore an enigma, as seen in the case illustrated here (Figure 18.12h), that three incisor teeth, with no obvious proximity to the impacted canine, were resorbed to more or less the same degree as the immediately adjacent lateral incisor, while the remainder of the dentition was totally unaffected.

Iatrogenic damage may also be inflicted by inadequate attention to detail; specifically to an incomplete examination of the diagnostic radiographic material. As was pointed out in Chapter 7, a displaced lateral incisor is usually due to the proximity and angulation of an adjacent impacted canine. Reopening space with simple mechanics brings the root of the incisor into direct contact with the unerupted crown of the canine, unless the movement achieved is bodily movement with no tipping. If the angle between the long axes of the lateral incisor and the canine is small, it will often encourage improvement in the angulation of the impacted tooth and subsequent spontaneous eruption, as has been pointed out by other researchers [12–14]. However, when the angle of orientation of the teeth approaches 90°, uprighting the incisor will bring its root apex into contact with the crown tip of the canine and develop a force that attempts to coerce the canine to ‘back up’ along its long axis. This will be a very potent cause of resorption of the incisor root apex.

Poor anchorage

Anchorage is an important consideration in all forms of orthodontic treatment where forces are to be applied to teeth. The reactive force is distributed between all the teeth that will be serving as the anchorage required for any fixed or removable appliance. In a case where only one tooth is required to be moved, which may only need levelling and tipping, there may be no perceivable counter-movements on the anchor teeth. However, this is not always so for a single impacted tooth. In such a case the tooth needs to be drawn over a long distance, from its initial location to its place in the arch, and then be subjected to significant root uprighting and torqueing movements. Consequently, the detrimental effect of loss of anchorage may be significant. It may cause the alteration of intermaxillary relations and create premature occlusal contacts and functional mandibular shifts. Since extrusion is one of the main force vectors needed in the treatment of impacted teeth, open bites may often be the unfortunate result. This will be due to the reactive intrusive forces brought to bear over quite a long period on the teeth that make up the anchor unit in the same jaw. Many practitioners will initially employ ‘up-and-down’ intermaxillary elastics as a means of reinforcing the anchorage of the affected arch. However, a mandibular dentition is not immune to adverse movement from consistently applied intermaxillary forces. The long-term use of these vertical elastics will cause an over-eruption of the teeth in the opposing arch and a consequent cant in the occlusal plane, with similar occlusal disturbances. The way to avoid these unfortunate sequelae is to use anchorage elements that are not dependent on other teeth, such as extra-oral headgear and temporary or osseo-integrated implants (as we have described in earlier chapters).

When vertical loss of anchorage occurs as a side effect of this treatment, the consequence will be the establishment of an open bite. An 'up-and-down' elastic placed on a mini-implant in the opposing jaw will be most useful in controlling this undesirable consequence. On the other hand, there will be some occasions when it would be more appropriate to ignore the problem created by vertical loss of anchorage, provided that vertical traction is successfully extruding the impacted tooth. The degree of intrusion that may occur is not without limit and, once the impacted tooth has been aligned in its place in the dental arch, the adverse intrusive consequences are easily reversible. In this way (and strictly in the final stages of treatment only), the use of vertical elastics against two heavy base arches of slightly exaggerated, corrective archform will rapidly achieve this goal. Nevertheless, this is a form of 'round-tripping' that may be unacceptable to many because of its toll on resorption.

Case 18.2: Loss of anchorage due to resistance of the palatal mucosa to re-eruption of the tooth

In Chapter 7, we showed that, following a closed eruption exposure in the palate, vertical traction of the tooth will cause the thick palatal mucosa to bulge more and more occlusally, with the shape of the tooth clearly outlined beneath (Figure 18.13a). Yet the tissue is sometimes too resistant to permit eruption. In this situation, a small window of palatal mucosa needs to be opened, after which the tooth will respond very quickly (Figure 18.13b, c). Failure to do this will give rise to unwanted reactive movement of the anchor unit (loss of anchorage) and palatal arches may become buried in the palatal tissue (Figure 18.13).

Case 18.3: Acute mucosal/periodontal inflammation in a high-vaulted palate, due to inadequate vertical extrusion of a palatally impacted canine before applying horizontal traction to the labial archwire

A corollary to use of the labial auxiliary arch in the treatment of a palatal canine is the lack of an appreciation of the 3D picture. A group 2 or group 3 canine usually needs to be brought down on the palatal side of the arch and erupted through the palatal mucosa (as we have seen above and in the several instances illustrated in Chapter 7). This movement is essential in order to take the canine on a vertically circuitous route around the roots of the neighbouring incisors, to provide an obstacle-free path to its place in the arch. However, there is also a height factor, since the tooth may often have been erupted in a high-vaulted palate on the palatal side of the alveolar ridge.

Drawing this tooth labially with traction applied from the main archwire, before it has been adequately erupted vertically, may cause the tooth to become re-buried in the palatal mucosa of the medial wall of the alveolar ridge. This will cause an acute inflammation of these tissues, including swelling and excrutiating pain. The mucosal tissue will frequently enlarge to obscure the tooth, as well as the bonded attachment and the elastic thread (Figure 18.14a, b). By so doing, it creates a similar environment to that which produces a third molar pericoronitis.

In this situation, it is essential to eliminate the lateral traction element, which will mean cutting the elastic tie to the labial archwire, together with irrigation of the area with an atomized water spray and prescribing antiseptic mouthwashes. The acute symptoms will disappear almost immediately and the inflammation will subside within a few days.

In the longer term, traction should be renewed within a week or so of the acute episode, by reinstating the auxiliary labial arch in order to reapply vertically extrusive traction for a further period until the canine reaches the level of the occlusal plane (Figure 18.4c, d). At that point, traction towards the labial archwire will not usually cause any further problems.

Case 18.4: Rapid eruption of the canine following re-exposure of the canine crown causing over-eruption

A second corollary to the use of the labial auxiliary arch in the treatment of a palatal canine may demonstrate the opposite effect to that just described, due to a lack of appreciation of the efficacy and range of a well-activated auxiliary labial arch. The initial panoramic view showing the maxillary left canine impacted high in the palate due to an adjacent supernumerary tooth (Figure 18.15a, b). It was pointed out earlier that when the buried canine bulges the palatal tissue and does not succeed in breaking through this thick tissue, it will become essential to cut a small window in the mucosa (Figure 18.15c, d), in order to free the tooth and allow it to erupt under the influence of this auxiliary labial arch. Much of the substantial bulge comprises palatal mucosa and the tooth itself will therefore still need considerable extrusion. Accordingly, the auxiliary arch is to be left in place for a short period of further activity, to overcome this vertical discrepancy. In some cases, such as when the patient misses appointments, the speed and extent of the extrusion may be so exaggerated as to markedly over-erupt the aberrant tooth, until it actually interferes with the patient's occlusion (Figure 18.15e–g). An auxiliary nickel–titanium wire was placed in the brackets under the main arch, to apply a corrective rotational, labial and intrusive force to the tooth (Figure 18.15h).

Inefficient and poorly designed appliances

The various orthodontic techniques in general use today are extremely efficient in moving erupted teeth around the dental arches and are very useful in correcting abnormal intermaxillary dental relations and in aligning crowded teeth to a high standard of finish. The individual brackets have been specifically engineered to achieve these objectives and, given proper professional attention and good patient compliance, most treatment plans can be easily completed within a two-year period. These same fixed appliances are, however, not so efficient when it comes to focusing all one's energies on the singular effort to resolve the impaction of a severely displaced tooth. Indeed, it may take considerable time and planning to bring the tooth from its ectopic location to an advantageous position close to the main archwire. Only when this has been achieved may the tooth be reckoned to be in the orthodontic 'ball park'. This is the vaguely defined point at which further treatment of the erstwhile severely ectopic tooth may be combined with that of all the other teeth, and where the practitioner may be permitted the luxury of relating to the patient and the malocclusion like 'any other routine case'.

A most unfortunate practice has developed among orthodontists: tying elastic thread to the most gingival link of a gold chain and stretching it to a rigid archwire as the means to apply traction to the impacted tooth. As we have explained in Chapter 2, this is a very ill-conceived way to try to achieve good and efficient results, due mostly to the small distances across which the elastic thread is drawn. Much clinic time is wasted in the very short intervals that are necessary between appointments in order to change the elastic thread and to maintain the momentum of the traction. The practitioner's ability is very limited when attempting to control the force delivered by a knotted elastic tie, which produces a high force that decays rapidly, from one that generates no force at all. Patients are quite likely to become disconcerted by the constant demands on their time and their cooperation may dissipate, with the consequential risk of failure 'by default'. On the other hand, the use of a spring with a wide range of activity and a measurable force level will produce much more rapid results, with excellent control of the force levels being applied and the freedom to allow several weeks between visits, without risk of relaxation of tension in the spring.

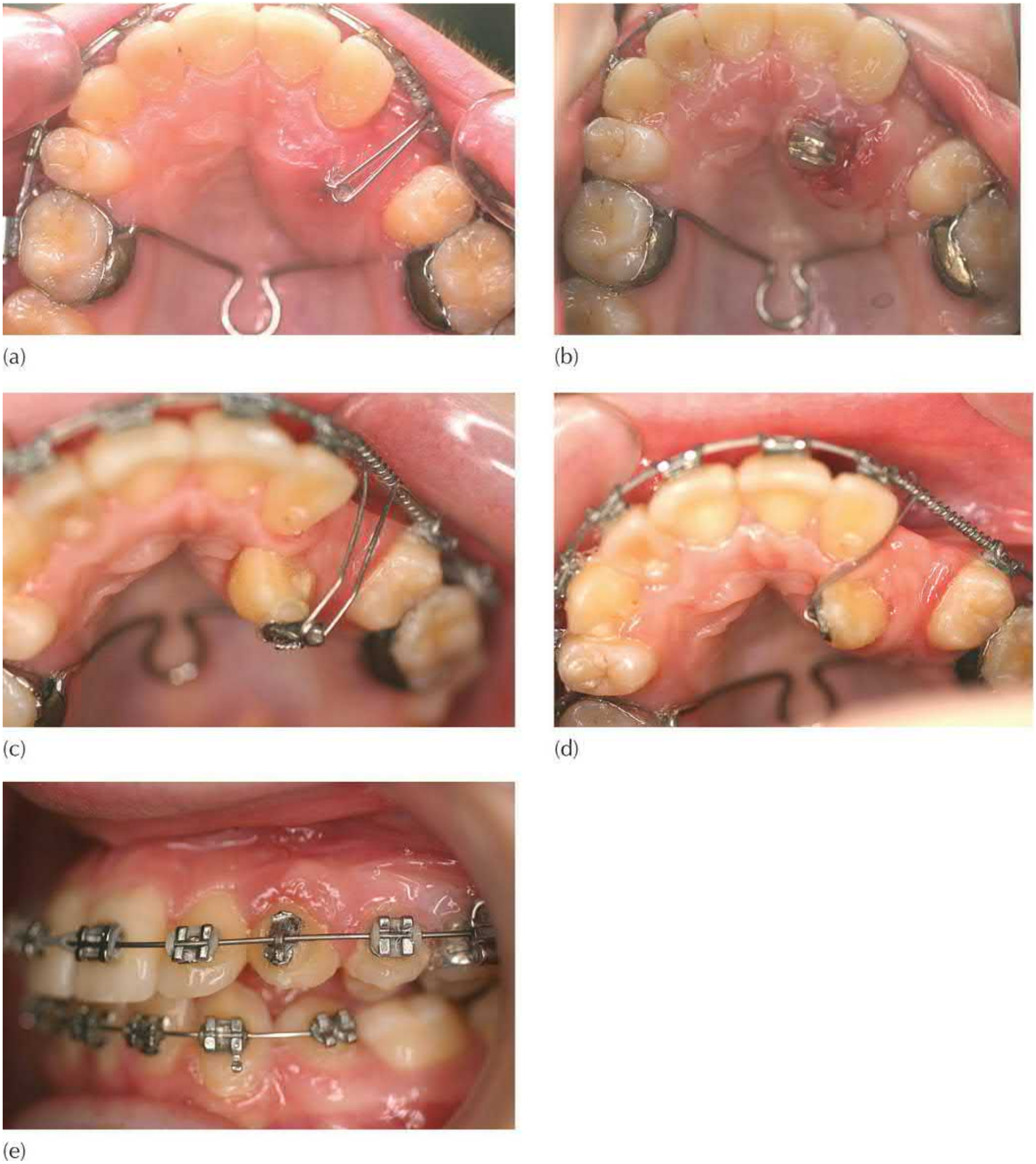
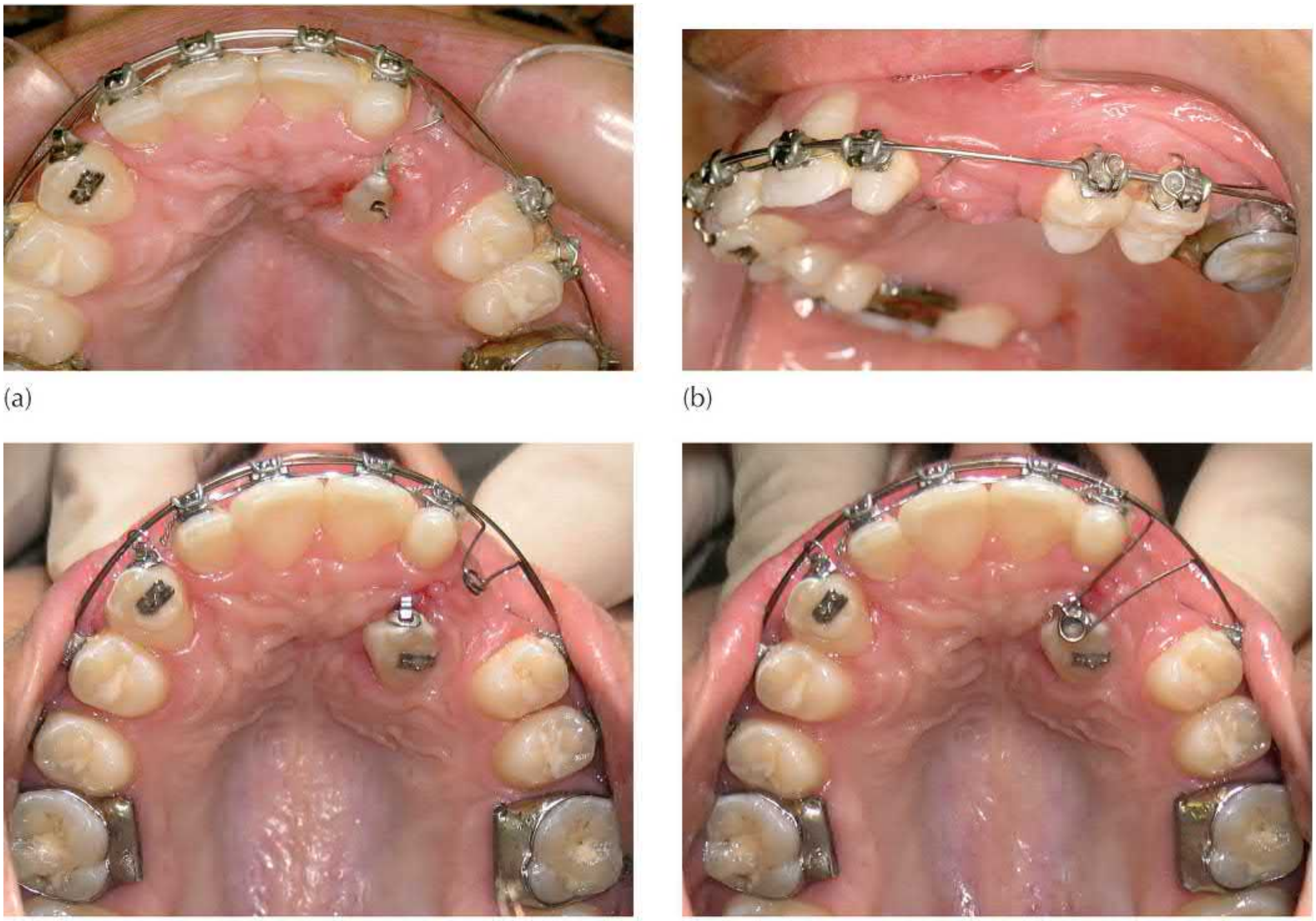


Fig. 18.13 Lost anchorage. (a) Following a closed surgical exposure of this palatal (group 2) canine, traction was applied and the tooth quickly became palpably evident beneath the palatal mucosa. Despite many months of further traction, the tooth did not break through the mucosa, but instead the soldered palatal arch became buried in the palate, indicating loss of anchorage. (b) A simple incision and removal of palatal tissue over the crown tip revealed the original bonded attachment. (c) A month after the re-application of light occlusally directed force, the tooth had erupted well. (d) A new eyelet was placed in a more advantageous position and elastic traction

direct to the archwire incorporated a rotatory component. (e) Six months later, the archwire was engaged through the eyelet, as the tooth completed its rotation and was brought to its place in the arch.



(a) (b) (c) (d)

Fig. 18.14 Inadequate vertical extrusion and iatrogenic damage. (a, b) Viewed from the occlusal aspect and from the left side, the left maxillary canine was mechanically erupted into the palate. It was prematurely drawn labially and became buried in the medial side of the alveolar ridges to produce acute pain, inflammation and swelling. The tooth, the attachment and the traction elastic were buried in the inflammatory tissue. (c) Ten days later, the inflammation and swelling had receded to reveal the formerly impacted canine. An auxiliary labial arch was tied into the brackets piggyback fashion and the position of its active loop section may be seen in its unligated passive mode. (d) In its active extrusive mode, the ligated active loop was now drawing the canine vertically downwards towards the occlusal plane.

Iatrogenic causes of failure

It may come as a surprise, but many of the worst failures in the orthodontic treatment of impacted teeth come from well-trained and experienced orthodontists. The failure does not occur because they have not followed the classic treatment guidelines that they were taught in graduate school. It is because they did faithfully and rigidly follow those treatment protocols. They put the treatment planning stage on 'automatic pilot', without considering the fact that certain clinical and radiographic findings in some individuals might require some original thought, in relation to certain obstacles 'on the ground'.

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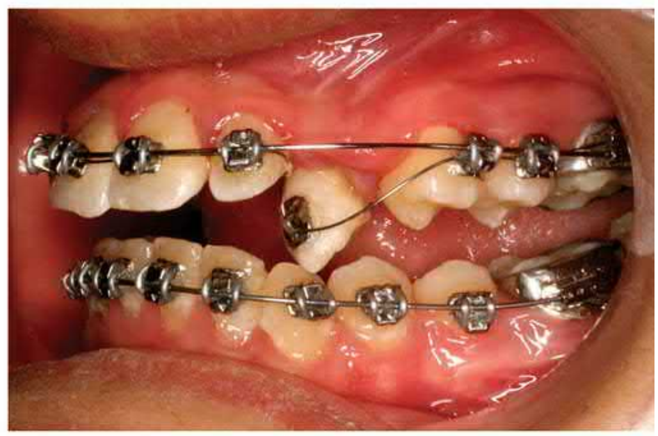

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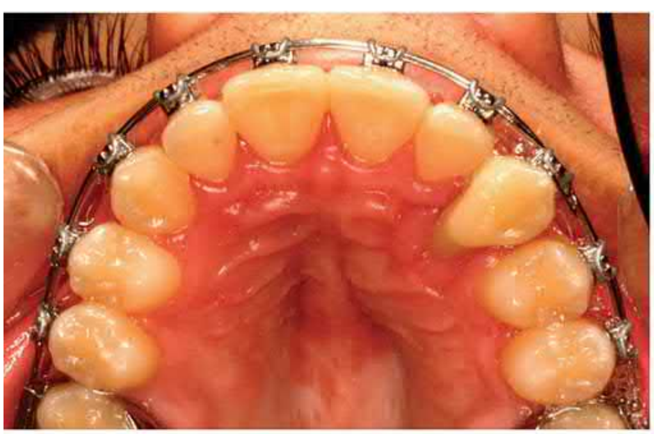


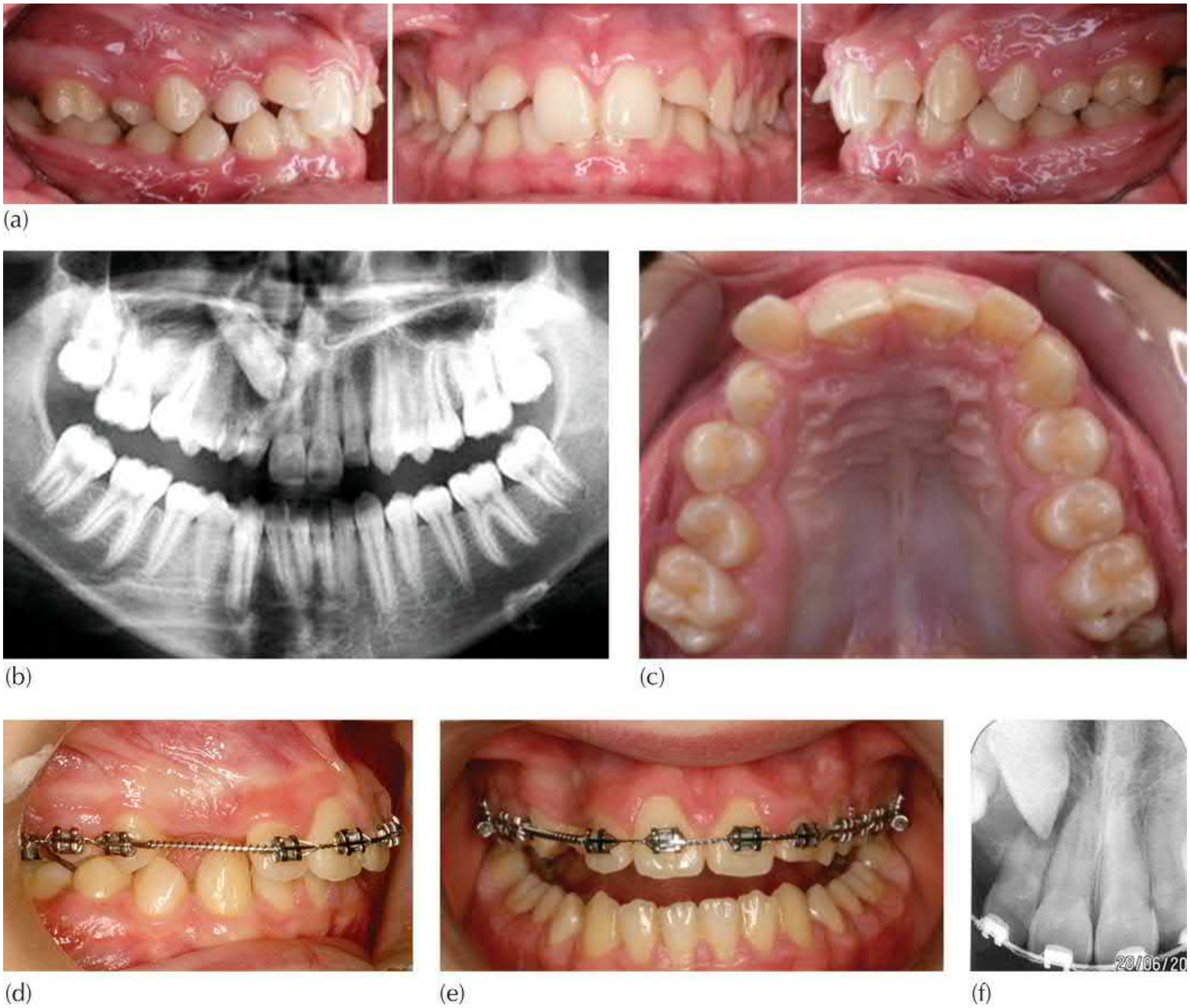
(g)

(h)

Fig. 18.15 Excessive vertical extrusion and iatrogenic damage. (a) The initial panoramic view. The deciduous canine had an unresorbed root. (b) Following a closed surgical exposure, eyelet bonding and immediate traction with a labial auxiliary arch, the tooth had come down and was bulging the thick palatal mucosa, but unable to penetrate it. The auxiliary arch is seen with its loop in the passive mode (i.e. lying vertically), freed from the twisted steel ligature. (c) A simple minimal re-exposure of the cusp tip was performed. (d) The loop of the auxiliary arch was re-ligated in its active mode (i.e. horizontal) to erupt the crown of the tooth. (e) Three weeks later, an unexpected, highly unusual and rapid over-eruption had occurred, bringing the tooth down below the occlusal level. (f) The view from the left side to show severe occlusal interference. (g) The tooth developed a long clinical crown, with root exposure on the palatal side, and required considerable labial root torque. Both of these handicaps were due to the excessive extrusion. (h) The final stage of treatment to effect the labial root torque is best achieved using a Begg-type torqueing auxiliary.

Case 18.5: Hidden dangers of space opening for impacted canines

The patient was a 15-year-old male, referred to the author after he had been in treatment elsewhere for a little under two years. His initial photographic records (Figure 18.16a) revealed a class I malocclusion with retroclined upper central and all four lower incisors, in addition to over-eruption of these teeth into a deep anterior overbite relation. The deciduous right canine was not mobile, in an otherwise complete permanent dentition, and the unerupted right permanent canine was not palpable. The left lateral incisor had a fractured crown and a minor labial proclination, while the maxillary right lateral incisor crown was labially proclined and distally flared. This arrangement suggested pressure from a suspected but invisible impacted canine on the distal and labial corner of the root of the incisor (Figure 18.16c) [15].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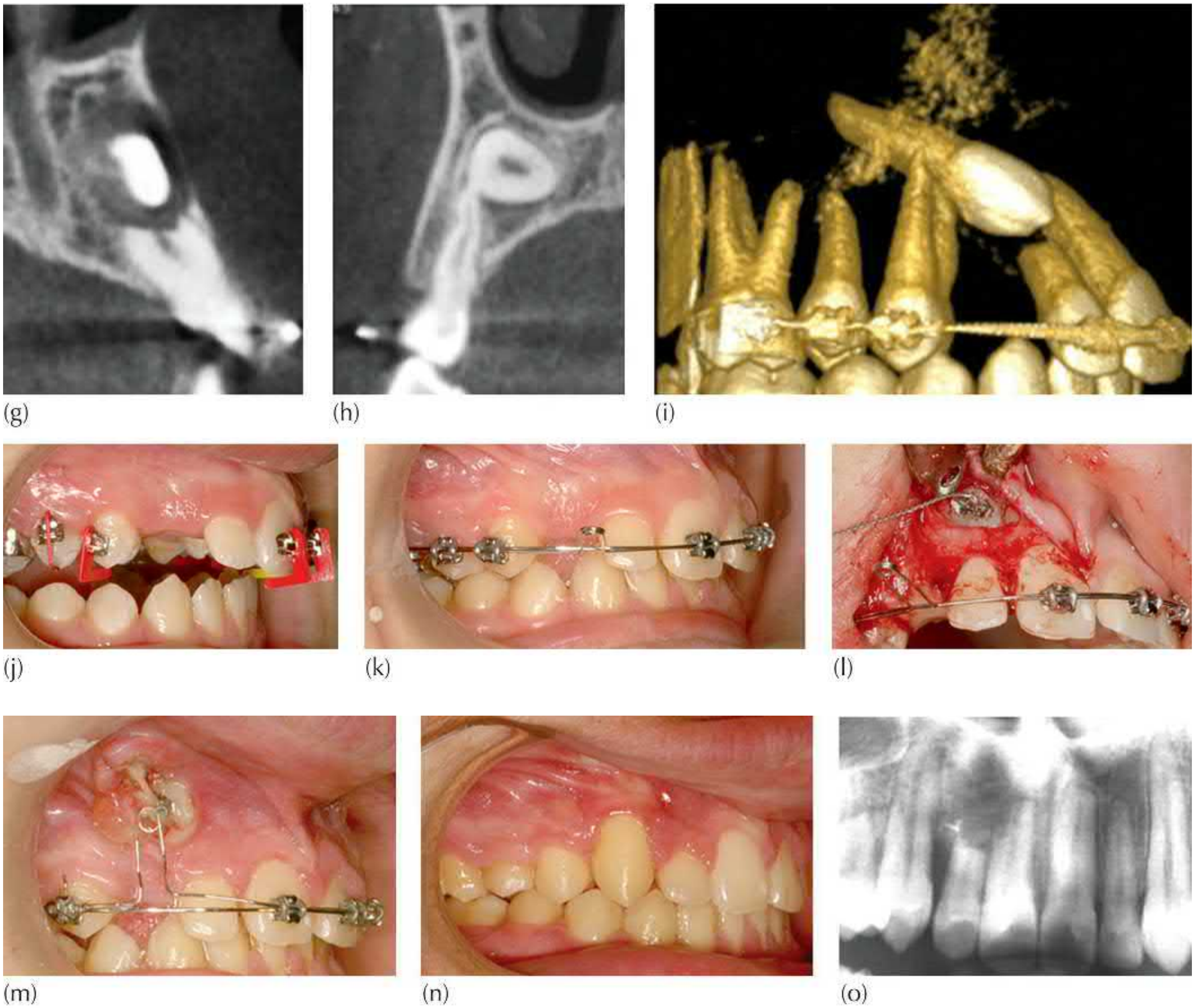


Fig. 18.16 (a) The initial condition. (b) The panoramic showing the canine crown jammed against the root of the lateral incisor. (c) The occlusal view of the maxilla, showing the labial and distal flaring of the lateral incisor. (d, e) Preparation of space for the canine: simultaneous alignment and uprighting of the lateral incisor. (f) Loss in excess of 50% of the lateral incisor root. (g) CBCT imaging: cross-sectional slice across the lateral incisor, showing the resorption crater. (h) Cross-sectional slice across the lateral incisor, illustrating contact between the buccal root of the premolar and the root of the impacted canine. (i) 3D view of the intimate relationship between the canine and the two adjacent teeth. (j) Changing the treatment approach, with no bracket on the resorbed lateral incisor: bracket position altered to bring about de-rotation and distal over-uprighting of the premolar. (k) Auxiliary labial archwire with long horizontal loop. (l) Exposure and eyelet attachment bonding. Note that the canine is located in the direct long axis of the incisor. (m) Traction and alignment: one month post surgery sees the canine exiting the labial oral mucosa. (n) Debonding without attempting root uprighting and torque. (o) Anterior portion of the panoramic view, taken immediately following debonding.

The panoramic radiograph (Figure 18.16b) showed the presence of all the permanent teeth, with the exception of three of the third molars. A mesio-angular impacted right permanent canine was found to be in obvious contact with (and arguably responsible for) the laterally flared lateral incisor, at a point halfway down its root. Early signs of root resorption of the lateral incisor at that area of contact had not been noticed at the outset. The long axes of the premolars of that side were normally oriented.

Orthodontic treatment had begun with the placement of brackets on all the maxillary teeth, with a series of aligning archwires and an open-coil spring for space opening. This stage is normally very short, but it took a full 18 months of treatment before adequate space was provided.

There was no clinical sign of eruption on the part of the buried canine, despite very generous space opening (Figure 18.16d–g). A periapical radiograph was taken to follow up on the progress and it showed two-thirds of the lateral incisor root having been lost to resorption. The tip of the crown of the impacted canine was located within the resorption crater and, with its enlarged follicle, the canine was pointing threateningly at the likelihood of further damage. The lost two-thirds of the root of the incisor, both mesio-distally and bucco-lingually, were the result of space opening. The reason for the abnormally long duration of this early stage of the treatment was unmistakably due to the resistance of the canine to the uprighting of the incisor. It had taken 18 months for the canine to resorb two-thirds of the incisor root.

The patient was sent for CBCT imaging, which also illustrated a number of small but crucial mistakes (Figure 18.16g–i). Space opening had indeed been generous at the occlusal level, but it was inadequate at the apical level. The apex-to-crown long axis of the canine was oriented mesially and at an angle approximately 25° below the horizontal. The crown tip was located disto-labial to the incisor root. Due to the misplaced bracket on the first premolar (Figure 18.16i) and the action of the coil spring, the crown had been tipped distally and rotated mesio-buccally. This had tipped the roots mesially and in particular had rotated the lingual root into direct contact with the underside of the canine root. The cross-sectional CBCT slice of the lateral incisor (Figure 18.16g) shows the canine and its enlarged follicle nestling within the broad resorption crater, directly above and slightly labially located. The cross-sectional slice of the premolar (Figure 18.16h) clearly indicates direct contact between the apex of its buccal root and the coronal third area of the root of the canine.

The existing appliance was removed and new brackets were substituted, in such a way that their bonded locations would reflect the movements needed to optimally re-align the teeth. The resorbed lateral incisor was left without a bracket, until the canine could be distanced from the immediate area. The canine was exposed with a buccal approach and a closed exposure procedure (Figure 18.16j–m), in the (ultimately successful) endeavour to retain the vitality of the incisor. The auxiliary labial archwire needed to be made with a fairly long loop, in order to raise the canine buccally over the root apices of the premolar, and as such caused some irritation of the mobile vestibular mucosa (Figure 18.16m) as the tooth responded and the loop correspondingly moved away from the alveolar mucosa.

Once the canine had erupted through the oral mucosa, the auxiliary arch was discarded and direct vertical elastic traction to the arch wire was substituted. A new bracket was placed on the lateral incisor and further treatment brought the orthodontic procedure to a close (Figure 18.16m–o). Despite the fact that the lateral incisor suffered virtually no further resorption of its root, it was decided not to attempt to apply torque to the incisor and the debonding appointment was made with a partly compromised result. The patient was then referred to a periodontist for gingival surgery, in order to apically reposition a pedicle graft of attached gingiva from the crestal area of the ridge.

The core of the problem

The core of the problem is related to the developmental dynamic of the orientation of the long axes of the maxillary permanent lateral incisors. This dynamic is described fully in Chapter 7, in relation to the aetiology of canine impaction (see Figure 7.7). If orthodontists ignore this physiological process in a phase 1 treatment, they risk being complicit in spawning a serious and iatrogenic malocclusion that would not otherwise have developed. Two cases are presented here as illustrations, but first, a short synopsis of the developmental dynamic involved.

For a 14-year-old patient in the *full permanent dentition stage*, the ideal crown-to-apex axial inclination of the four maxillary incisors, and of the lateral incisors in particular, is mildly apically *divergent* [16, 17]. In effect, this means that, in the final desired alignment of the incisors, the right-to-left distance between the root apices of the lateral incisor teeth is greater than the distance between the mesio-distal midpoints of their crowns (see Fig. 7.7a). In the *early mixed and developing dentition*, on the other hand, the initial normal alignment of the long axes of the incisors is apically *convergent*. This in turn means that the inter-apical distance of the lateral incisor teeth is less than the distance between the mesio-distal midpoints of their crowns. This latter situation is essential for the normal autonomous eruption of the canines (Figure 7.7b). Accordingly, it is potentially harmful to aim, prior to the eruption of the canines, to achieve that same 'ideal' final incisor alignment in the 7–10-year-old child that is so necessary and so attractive in the 14-year-old, at the age when the canines are in their place.

This principle potentially creates confusion at the commencement of orthodontic treatment in the younger group, because it is the 'accepted norm' that levelling and alignment constitute the first stage of most orthodontic treatment plans.

Case 18.6: Bilateral developmental disturbance in the eruption path of maxillary canines

The series of panoramic radiographs shown in Figure 18.17 accompanied a 17-year-old female patient to the orthodontic office of the author for an initial appointment in the latter part of 2014. The first panoramic radiograph (Figure 18.17a) had been taken in June 2006 when she was 9 years old, when she had been seen by an orthodontist and had been advised that treatment was not appropriate at that time. The overall malocclusion, although interesting, is not the relevant point at issue in this discussion and is not described here.

Both permanent canines could be seen high in the maxilla and appeared to be following a more mesial and horizontal path than normal. The left canine was in the process of mesially bypassing the lateral incisor root apex. The right canine was closely related to the wide open apex of the lateral incisor, while the adjacent and unerupted right first premolar had a mild but abnormal distal crown tip, with its root apices displaced mesially towards the root apex of the lateral incisor.

The December 2008 panoramic view (Figure 18.17b) showed both canines still very high up, with the left canine demonstrating a greater degree of vertical development than the right, but at this point both were in close proximity to the distal side of the roots of the central incisors, apparently bypassing the lateral incisors and displaying enlarged follicles.

A CBCT performed in 2011 contributed the additional information that the crowns of both canines were labially displaced and that the root of the left lateral incisor was significantly displaced both palatally and distally. Both these features might have been discovered by palpation and in the clinic by viewing the maxillary dentition from the palatal aspect – but apparently they were not noticed. Orthodontic treatment was initiated in early 2011.

The May 2013 panoramic film (Figure 18.17c) shows the maxillary orthodontic appliance still in place, more than two years after commencement of treatment. Space had been regained at the occlusal level between the crowns of the lateral incisor and first premolar on each side. However, presumably due to misjudged bracket placement on the lateral incisors, the roots of these teeth had become further distally angulated than normal, so that their apices were in close proximity to the roots of the first premolars. The right unerupted canine had not been surgically exposed and its location was largely unchanged, although its relationship to the distally moved apex of the lateral incisor had now severely worsened into a transposition. The left canine, on the other hand, had been surgically exposed and a button attachment placed. The subsequent traction, using a steel ligature to the premolar, had brought the tooth down to only a minimal degree, and could now be seen to be wedged and similarly transposed between central and lateral incisor.

From the panoramic film taken in November 2013 (Figure 18.17d), there appeared to have been little significant change in the positions of either impacted canine. This was indeed not surprising, since the right canine was still untreated and the left canine was being submitted to traction towards the premolar region, but was blocked by the root of the intervening lateral incisor and trapped between lateral and central incisors.

Looking at the patient’s intra-oral photographs (Figure 18.16e, f), there appears to be nothing wrong with the orthodontist’s intention to align the teeth and create space for the canines. However, the lateral incisors appear to be labially tipped, with their apices palatally and distally displaced, particularly on the left side. The first premolars had been mesio-buccally rotated and distally tipped.

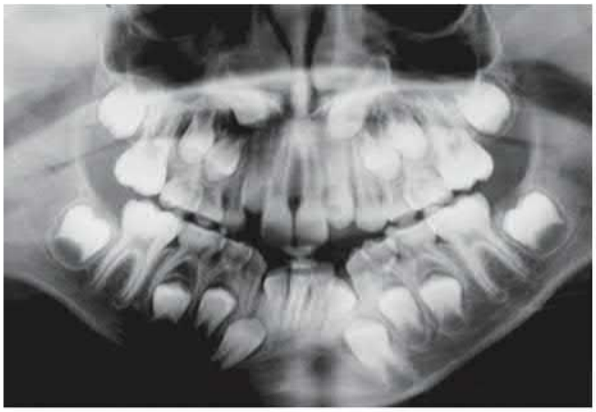
A CBCT had been taken in February 2014 and the axial slices (Figure 18.17g–j) showed how the apex–crown orientation of the right canine straddled the alveolar ridge from lingual to labial, between the roots of the lateral and central incisors. The canine was lying labio-lingually across the dental arch, at the level of the incisor apices, and demonstrated a strong mesial tip. Its root apex was palatal and its crown was labial to the lateral incisor root. The mesial aspect of the canine was located lateral to the central incisor apex, while the extreme tip of the crown was on the labial side of the alveolar ridge. The canine was still unerupted and located high in the sulcus. Its relationship to the lateral incisor had been reversed and a transposition had been created by the iatrogenic, appliance-generated, distal displacement of the root of the right lateral incisor (Figure 18.17g, h).

On the left side, the canine/lateral incisor relation (Figure 18.17i, j) showed the root of the lateral incisor to have been palatally displaced, clearly due to the influence of the labially adjacent location of the unerupted buccal canine.

The CBCT confirms that labial surgery and labially applied traction should resolve the two canine impactions. Mesial root uprighting and labial root torque would need to be postponed until after the canines are in their place. In the event, however, traction had been applied vertically downwards, direct to the labial archwire.

At the same time, a strong labial torqueing moment on both lateral incisors had been created by the rectangular archwire ligated into the brackets of the maxillary dentition. This had added to the clash between the root end of the left lateral incisor and the canine and had been the most likely cause of lack of progress in moving the unerupted left canine distally (Figure 18.17g). Similarly, on the right side, the same torqueing moment had been acting on the right lateral incisor and had clearly contributed in preventing the right canine from autonomously migrating in a downward direction.

To complicate matters still further, the axial (horizontal) cuts of the CBCT had confirmed that the root apex of the right canine had been lying on the medial aspect of the maxillary sinus, on the partition wall between the sinus and the nasal cavity. In this situation, it would appear that the only remedy for the mistaken treatment would be to labially torque the lateral incisor roots, after tipping its crown distally into the canine location and then to relocate the canine in a fully transposed relationship with the incisor.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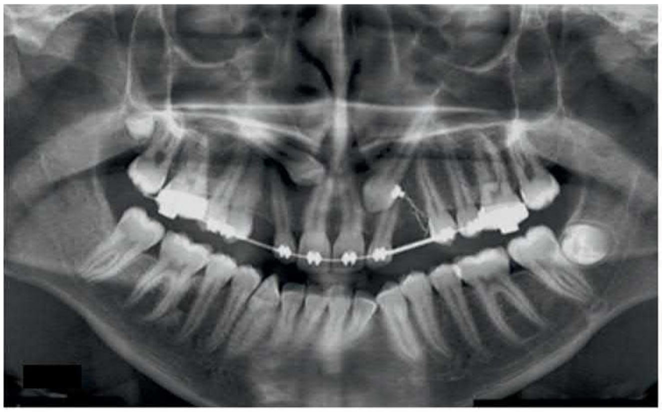

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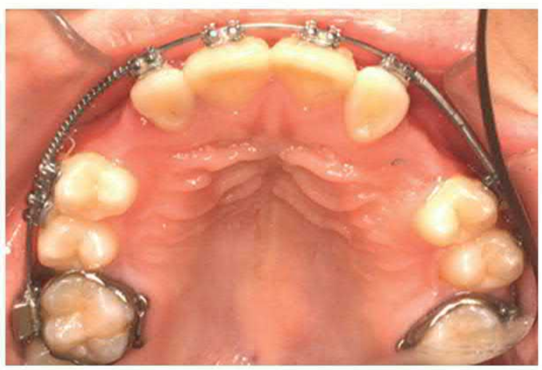

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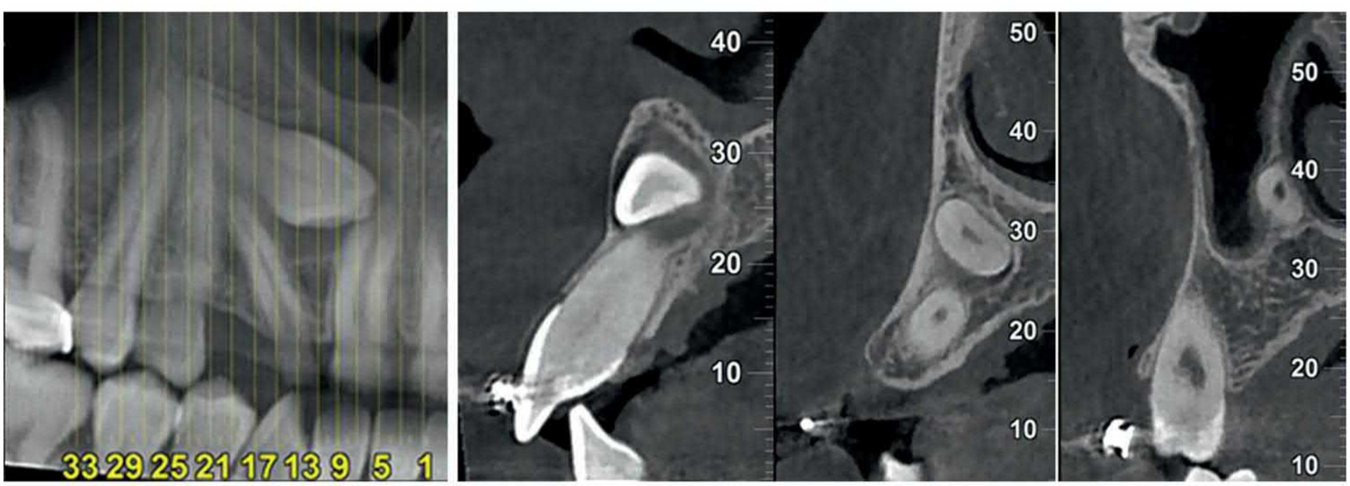

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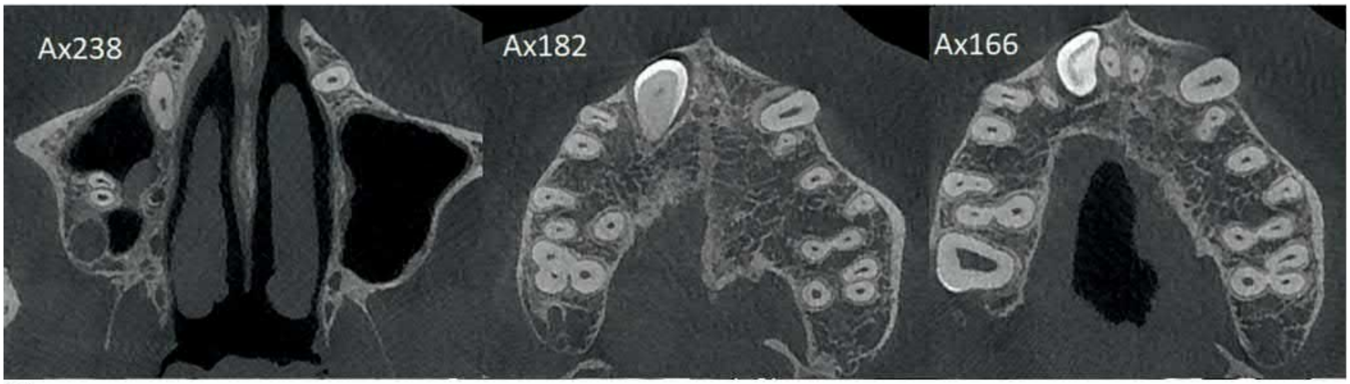

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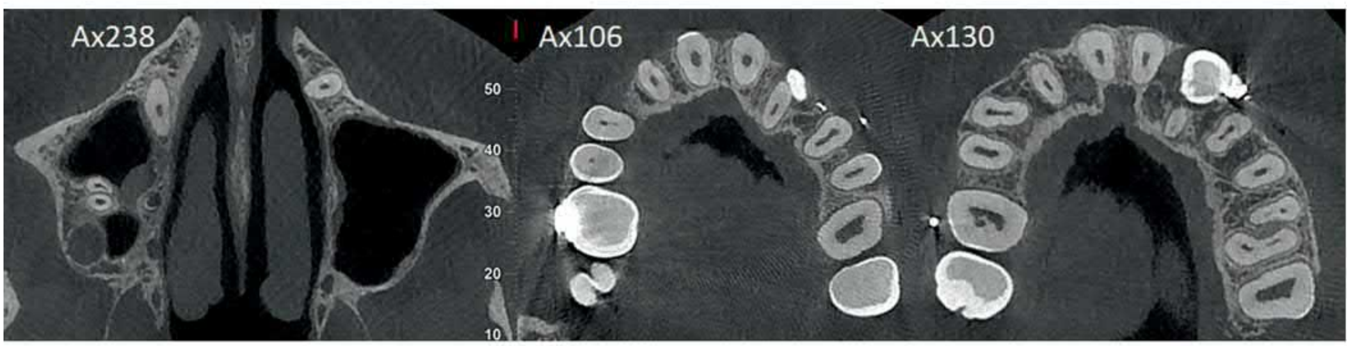

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Fig. 18.17 (a) The 2006 panoramic radiograph of the early mixed dentition. (b) The 2008 panoramic view of the late mixed dentition. (c) The May 2013 film shows how the bonded appliance had tipped the roots of the lateral incisors distally, creating a partial transposition with the mesially directed canines. (d) The November 2013 panoramic view showing no appreciable progress. (e) Intra-oral views of the teeth in occlusion. (f) Occlusal view of the maxilla. Note the lingual orientation of the long axis of both lateral incisors, particularly on the left side. (g) Cross-sectional cuts at differing sagittal locations to show the lateral incisor/canine relation of the right side. (h) Axial cuts at differing heights to show the lateral incisor/canine relation of the right side. (i) Cross-sectional cuts at differing sagittal locations to show the lateral incisor/canine relation of the left side. (j) Axial cuts at differing heights to show the lateral incisor/canine relation of the left side.

What often goes unnoticed in these situations (and has already been noted above) is the orientation of the premolar teeth. In this case and due to the space-opening stage, the premolar crowns on both sides of the jaw had been tipped distally and their roots mesially. This had brought the premolar roots into close proximity to the roots of the canines and could have contributed to the resistance to canine movement.

Case 18.7: Interceptive uprighting of incisor root to avert maxillary canine impaction

An 8-year-old girl was referred by her paediatric dentist, who was concerned regarding the possibility of bilateral eruption disturbance of her maxillary canines. He had identified the potential problem from the way they appeared on a panoramic radiograph and how they were reflected in the incisor arrangement. Apart from this, her dentition exhibited totally normal clinical features, with class I occlusal relationships in the early mixed-dentition stage and widely spaced maxillary incisors. Deciduous canines and molars were present, as were all four permanent first molars. As the result of a trauma episode a year or so earlier, the left central incisor had fractured off its mesial incisal corner, but the tooth was still vital with a normal response to the pulp tester.

The child arrived for her first visit with the panoramic radiograph (Figure 18.18a) that had been taken in February 2012. This was the radiograph upon which the abnormal relationship between the unerupted permanent canine crowns and the lateral incisor apices was diagnosed and could be clearly seen. The canines were not palpable on either side of the ridge.

As in Case 18.1, it is once again pertinent to refer to the development of the maxillary incisor teeth and their relationship to the maxillary canines [16, 17], comparing the similarity of the case of this child to that case and also to the normal development (Figure 7.7a) that is described in Chapter 7.

In the present case, the four maxillary incisor teeth were erupted, but their long axes were apically *divergent* and the unerupted permanent canines were in close relation with the open apices of the roots of the lateral incisors. This abnormal presentation of the incisors should have been a red warning light, being a harbinger of eruption disturbance of the canines. Divergent roots signified that the apices of the lateral incisor were located too far distally and were actually encroaching on canine space. The concern was that the canines would need only a minimum mesial migration for them to become transposed with the lateral incisors. As was seen in Case 18.1, this would have seriously compromised the patient’s treatment in terms of difficulty, duration and prognosis.

Phase 1 orthodontic treatment was advised, with the sole aim of correcting the alignment of the long axes of the roots of the four incisors from being apically divergent to apically *convergent*. By so doing, it was considered that the treatment would provide the canines with a more normal environment, in the expectation that autonomous eruption would occur and would lead to a normal alignment of the teeth. Accordingly, a bonded multi-bracketed appliance was placed, with slot angulation adjusted to slightly over-treat the alignment of the long axes of the four incisors mesially towards the midline (Figure 18.18b–e). This would thereby better replicate the ‘ugly duckling’ stage and offer the unerupted canines the distal guiding slope of the lateral incisor roots to encourage their eruption [16, 17].

Treatment lasted just six months (Figure 18.18f, g), at the end of which a removable Hawley retainer was substituted for the fixed appliance. At this time, too, the deciduous canines and first deciduous molars were extracted, in order to further encourage canine eruption. This rationale for the extraction of the deciduous canines is well known and has become an established interceptive measure in the mixed-dentition stage in situations when canine impaction is suspected. However, the concurrent extraction of the deciduous first molar is a lesser-known remedy [18]. Its extraction has been shown to encourage the rapid eruption of the first premolar. When the premolar erupts, its bulky crown becomes vertically distanced from its close proximity to the canine. Due to the mesio-distally narrower cervical and bifurcation areas of the premolar root, this provides a residual space permitting the canine ideally to drift sufficiently distally for it to improve its eruption path and its chances of normal eruption.

At a follow-up appointment two years later, it was noted that the full dentition from second molar to second molar, including the canine and premolar teeth, had erupted without further treatment and into excellent alignment (Figure 18.18h, i).

The clear conclusion of the treatment was that, in order to alter the environment and thus to persuade the permanent canines to self-correct their aberrant eruption paths, three distinct elements had been used:

- Moving the roots of the incisor apices mesially towards the midline, to bring them mesial to the crowns of the unerupted permanent canines, thus re-creating the normal incisor arrangement in the mixed-dentition stage.
- Extracting the deciduous first molars, in order to generate a rapid eruption of the premolars and provide a modicum of space, distal to the permanent canines, to encourage them to adopt a normal eruption path.
- Extracting the deciduous canines, in order to influence the permanent canines to re-direct the long axes of the incisors from apically divergent to apically convergent.

Surgeon-dependent factors

Poor surgical planning and mistaken positional diagnosis

Case 18.8: The surgeon could not find the canine

A patient had been in orthodontic treatment for one year before he was transferred to the author for continuation of treatment (Figure 18.19a). The reason for the transfer was concerned with the surgeon's having failed in her attempt to expose the canine from the palatal side of the maxilla using an open exposure technique. She had been unable to find the impacted canine and had re-closed the surgical wound.

Despite a reasonably long healing period, the residual soft tissue and bony defects remained, indicating where the approach had been made (Figure 18.19b). It was noted that good orthodontic alignment of the erupted teeth had indeed been achieved by the previous orthodontist. However, in the process the treatment had eradicated all potential clinical signs of canine location.

The intra-oral photographic views taken from the original pre-treatment records (Figure 18.19c) show labial tipping of the crown of the left maxillary central incisor and palatal tipping of its root. This was the distinct clue that the canine was on the labial side of the incisor root.

Both the anterior section of the original panoramic view and an anterior occlusal film project their images of the teeth at differing angles and, as such, there will be differing degrees of superimposition of the canine crown over the incisor root. The vertical tube-shift method could have been used for this case, because it would have confirmed the diagnosis of a labially displaced canine (Figure 18.19d, e).

A cross-sectional cut and a 3D view from the newly ordered CBCT were also on hand to confirm the labial position of the canine (Figure 18.19f, g).

Surgical access to the canine was thus rendered simple and pin-pointed the canine crown sited between the roots of the two central incisors. The full flap was sutured back to its place in a closed exposure procedure. The pigtail ligature exited through the oral mucosa flap opposite the tooth

(Figure 18.19h–j). An auxiliary labial arch was ligated in piggyback style, with the horizontal loop of the auxiliary arch in its passive mode. The horizontal loop of the auxiliary arch was flexed vertically upwards with a small mesial vector included, to be engaged by the pigtail ligature (Figure 18.19j). This imparted a labially directed force with a distal component in order to circumvent the central incisor root.

The clinical crown of the central incisor was notably elongated on the palatal side, due to severe gingival recession resulting from the earlier surgery. The healed surgical defect could still be seen (Figure 18.19l). There was a minor post-treatment difference in crown lengths between the appearance and clinical condition of the right and left canines, although the gingivae were completely healthy. The anterior portion of a panoramic film and a periapical view, taken 2.3 years post treatment, is presented here (Figure 18.19m).

The conclusions that are to be drawn from this case teach us that when orthodontists attempt to diagnose a location, their interest should be directed first to the root apex and the orientation of the long axis of the tooth. If the apex is in the line of the arch, the chances of aligning a deviant angulation of the long axis are very favourable, since the tooth merely requires to be tipped into its place. If the apex is buccal or lingual to the line of the arch, then the tooth will require a considerable degree of root torque; it is cases like this that are the difficult ones from an orthodontic point of view.

The surgeon is the second person who must make an assessment of the location of the crown of the tooth for surgical exposure, but this purely for surgical needs. Strictly, the surgeon has no interest either in the angulation of the crown in relation to the other teeth, or in the location of the apex of the tooth, or even in the orientation of its long axis. These features are all irrelevant for surgical exposure of the crown of the tooth. The task of the surgeon here is to present an exposed surface of the crown of the tooth for the bonding of an attachment, followed by re-suturing the surgical flap back to its former position (closed exposure), with only a gold chain or steel ligature remaining exposed thereafter. Alternatively, the task is to expose the tooth and leave it open, with or without a periodontal pack to maintain the opening. For this, the surgeon needs only to determine the location of the crown of the tooth.

(a)

(b)

(c)

(d)

(e)

(f)

(g)

(h)

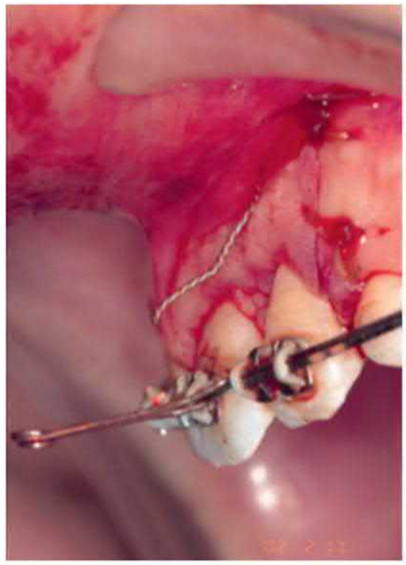
(i)

Fig. 18.18 (a) Initial panoramic radiograph (February 2012). (b) Bracket placement on permanent incisors and deciduous canines and molar teeth, with locating jigs indicating divergent long axes (January 2014). (c) Initial nickel–titanium archwire (January 2014). (d, e) Completion of phase 1 treatment immediately before and after debonding (July 2014). (f) Panoramic radiograph at completion of phase 1 treatment, before debonding (July 2014). (g) Intra-oral views of the case six months after completion of phase 1 treatment and extraction of deciduous canines and first deciduous molars (January 2015). Note the permanent canines palpable on the labial side of the alveolar ridge, beginning to erupt (arrows). (h) Intra-oral photographs of the patient 18 months after completion of phase 1, with no further treatment having been performed. (i) Panoramic view of the patient at that time.

An independent repetition ('a second opinion') of the positional diagnosis is a form of insurance against the damage caused by misdiagnosis. Between the two practitioners an agreement can be reached on which surface of the tooth is to be exposed, using what type of surgical procedure and from which side of the alveolus. The location of a bonded attachment and the direction that the gold chain or steel ligature connecter must be drawn for appropriate direction of traction must be decided before the procedure begins. These decisions are best made on the spot, with both practitioners taking an active part in the procedure. This has been our strong recommendation throughout this book. Failure occurs when one or more of these elements is not performed as explained here. Teamwork is everything!


(a)
(b)
(c)
(d)
(e)
Left side canine
Left side incisor
(f)
Left side canine
Left side incisor
(g)


(h)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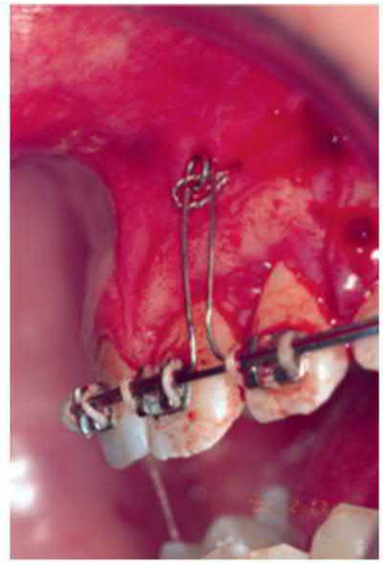
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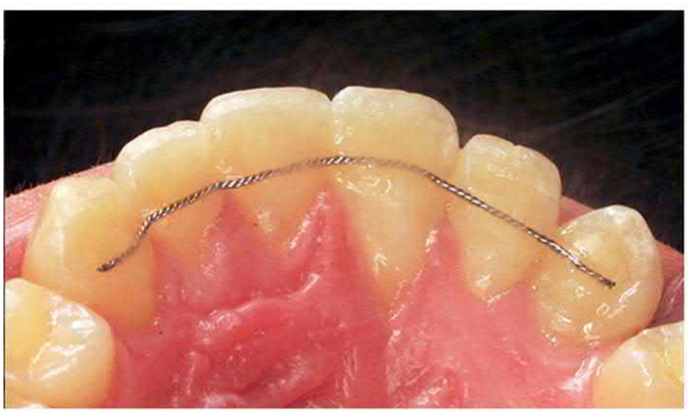
(k)


(l)


(m)


(n)


(o)

Fig. 18.19 The records of the patient taken at the time of transfer from the first orthodontist. (a) The achieved alignment. All potential clinical signs of canine location have been eradicated. (b) The palatal view showing soft tissue damage, bony defects and severe recession of the gingiva. (c) Intra-oral photographic views from the original pre-treatment records, indicating labial canine displacement. (d, e). The anterior section of the original panoramic view and an anterior occlusal view used for vertical tube-shift diagnosis (see Chapter 4). The canine is labial to the root of the central incisor and would also have been clinically palpable. (f) An early cone beam computed tomography (circa 2001): cross-sectional cut and (g) 3D view confirm the labial position of the canine. At surgery, the passive mode of the auxiliary labial archwire takes the long loop well out of the way of the surgeon's work and is usefully placed before surgery begins. (h) The canine was exposed on the labial side of the ridge and a small eyelet is bonded to the canine crown, with a twisted ligature wire connector hanging from it. (i) The twisted ligature wire pierces through the flap during suturing of the flap. (j) The loop of the auxiliary archwire is raised and engaged by the ligature, as close as possible to the oral mucosa covering the ridge. (k–m) Completion of traction and final alignment, seen 2.3 years post treatment. (n) Post-treatment evaluation: the palatal view of the tooth shows improvement in the gingival condition following the mistaken palatal surgical approach to the canine, but the recession is still obvious. (o) The labial side of the canine shows a minor degree of gingival recession. Post-treatment panoramic and periapical radiographic evaluation, performed 2.3 years later, shows a good result.

Case 18.9: A dilacerate central incisor, for which the surgeon bonded a bracket to the palatal root apex

As the result of early trauma to the front of the mouth, damage may be indirectly caused to the developing and unerupted central incisor, as we have demonstrated in Chapter 6. A 'classic' dilaceration may be the long-term result and this will typically be located high in the anterior maxilla, with its developed root describing a posteriorly and superiorly curved course. The root apex is usually palpable as a bump on the palatal side of the alveolar ridge. The crown, on the other hand, can be located high in the labial vestibulum, close to the midline, where it will be palpable under the nose and adjacent to the anterior nasal spine.

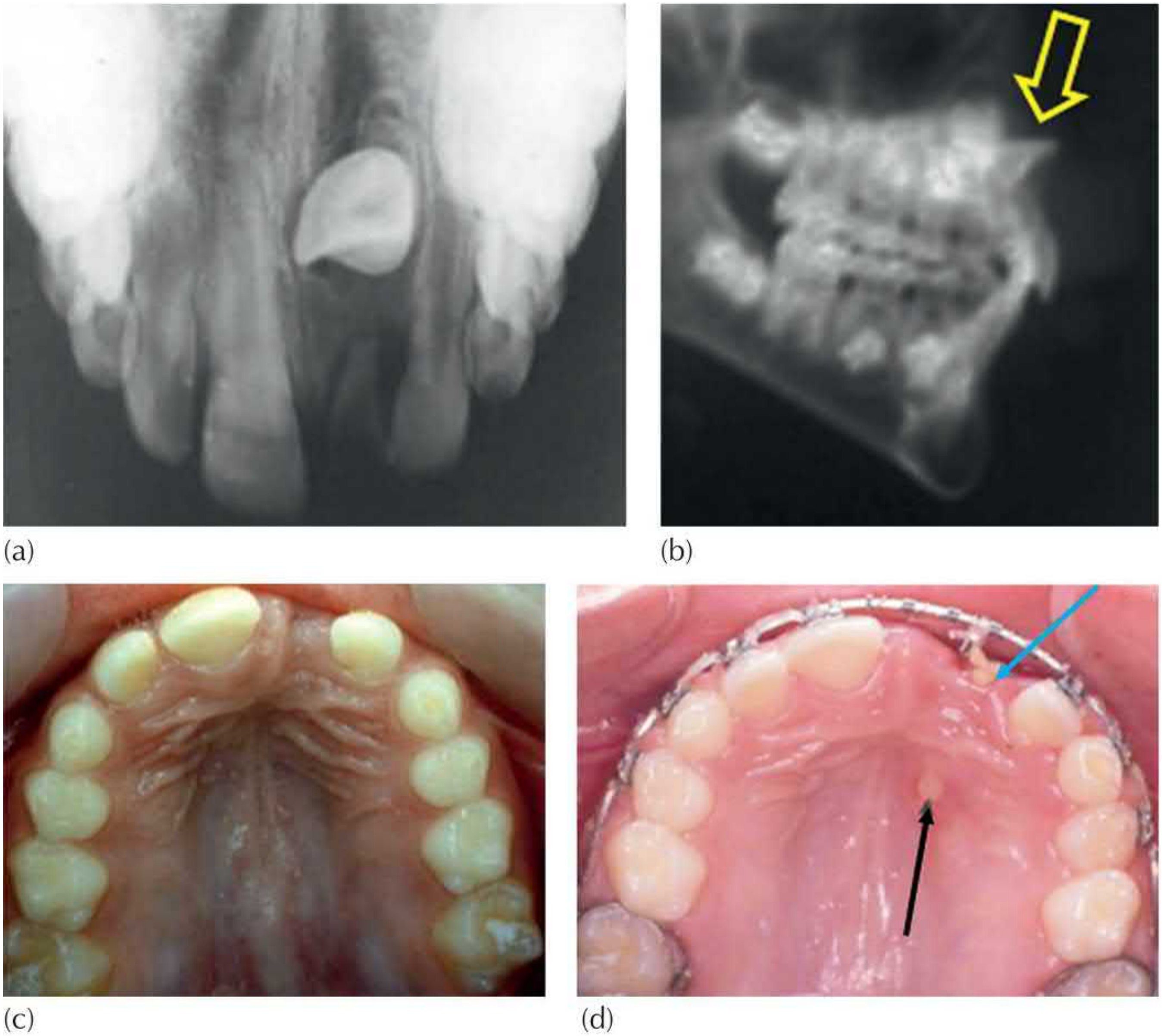


Fig. 18.20 A case of mistaken identity. (a) The radiographic anterior occlusal view of the maxilla shows the typical appearance of a classic dilacerate central incisor. (b) The cephalogram confirms the position of the crown high up and labial, adjacent to the root of the nose. Courtesy of Prof. N. Shpack. (c) An occlusal view of a patient with an unerupted maxillary left central incisor. (d) Intra-oral occlusal view of the maxillary dentition immediately prior to the third surgical episode. The exposed root apex of the tooth (arrow) can be clearly seen in the mid-palate.

In the patient illustrated in Figure 18.20, the radiographic anterior occlusal view of the maxilla shows the typical appearance of a classic dilacerate central incisor, with the crown viewed in its long axis and the apical portion of the root pointing superiorly (Figure 18.20a). The cephalogram, which is a standardized true lateral view across the maxilla from the side, confirms the position of the crown high up and labial, adjacent to the root of the nose (Figure 18.20b). Unfortunately, the patient was sent to the surgeon for surgical exposure of the crown and attachment bonding with a short letter of referral and the anterior occlusal radiograph, unaccompanied by the orthodontist.

The surgeon mistakenly exposed the root apex in the palate (Figure 18.20c, d) and attempted to bond an attachment to it. In the second surgical attempt, he exposed the crown, bonded the attachment and ligated it to the labial archwire with elastic thread. The tooth was extracted at a third surgical episode, a short time later. It is hard to imagine this scenario occurring when two separate professional evaluations of the positional diagnosis of the tooth are carried out, with the orthodontist in attendance.

Problems also occur when either the orthodontist or the surgeon dismissively considers that the possibilities for the location of the canine are very limited. For some, a single panoramic view or a tube-shift pair of intra-oral radiographs is all that they may deem necessary. They seem to give little credence to the location of its crown, its root, its rotation and the orientation of its long axis. They may totally ignore the significance of its proximity to the roots of other teeth and its 3D relation to them and the presence of resorption of their roots – not forgetting the possibility of pathology of the impacted tooth itself.

In the absence of adequate imaging, positional diagnosis is approximate at best and there begins a misconceived search for the tooth in question. This involves rummaging through the open surgical field, macerating the soft tissues, clearing away alveolar bone excessively and unnecessarily, with the distinct possibility of damaging the area of the CEJ or the root surface of the impacted tooth or of its immediate neighbours.

Surgical exposure without prior orthodontic planning

As we have seen from the preceding chapters of this book, there are many situations and instances in which the appropriate treatment of impacted teeth will require the cooperation and involvement of other specialists and, in particular, the oral and maxillofacial surgeon. We have tried to define the optimum balance of the roles of the orthodontist and the surgeon and to present a logical treatment protocol in this, albeit lopsided, arrangement. We have shown that for the orthodontist, the impacted tooth is just one aspect of a malocclusion, which usually affects the rest of the dentition. Accordingly, the treatment designed to bring the tooth to its proper location in the mouth is presented as an integral part of an overall malocclusion.

The basic role of the surgeon is a one-time surgical episode, designed to eliminate abnormalities, such as hard tissue obstacles and pathological entities, and to provide clinical access to a tooth, whose destiny the orthodontist cannot otherwise control.

There are, of course, cases where initial orthodontic alignment, levelling and space preparation will have succeeded in causing the tooth to erupt autonomously and thereby eliminated the need for surgery. It is, however, a rare case that does not require the services of an orthodontist, because even autonomously erupting, formerly impacted teeth do not usually erupt into their ideal final location.

The initial choice facing the orthodontic clinician, when taking on a case of impaction of a canine, is a difficult one. In order to reduce mechano-therapy to a minimum, it is usually wise to wait for the eruption of the full permanent dentition and avoid early intervention (phase 1) of active orthodontics, by substituting it with an extended minor surgical alternative. The aim is to encourage a spontaneous eruption of the impacted canine, for example by extracting deciduous teeth and exposing the tooth to the oral environment. At the same time, we must not forget that an integral part of this decision is the risk that the tooth will still not respond. Indeed, for most patients, the discovery of the impaction at a later age will have come as an unwelcome surprise. Rather than wear orthodontic appliances, they may beg to undergo surgery, even when the chance of success is low.

Published figures are available that may justify the routine use of surgery, with its moderate degree of reliability to generate spontaneous eruption (under certain circumstances), but there will always be a natural and healthy reserve regarding its efficacy. By contrast, the use of an orthodontic force applied from a suitable auxiliary, with an appropriate direction, range of activity and energy level, will overwhelmingly accord the treatment a much greater level of reliability. It will also be helpful in limiting the damage caused by surgical exposure to the surrounding structures, both directly and indirectly. By taking this early proactive stance and with proper management, therefore, the chances of success in bringing about spontaneous eruption will be much improved. However, if an orthodontist is permitted to exploit the clinical know-how acquired from a good number of years' experience in orthodontic practice, a policy of smart case selection could introduce a bias that may improve the success rate significantly.

Case 18.10: Iatrogenic damage due to radical repeated surgical exposure without orthodontic involvement

In one particular case, a 21-year-old male had, over a period of a number of years, been seen irregularly by an oral and maxillofacial surgeon, to whom he was referred by his dentist for the treatment of his bilaterally impacted maxillary canines. The surgeon had encouraged him to have the deciduous canine extracted and the two teeth surgically exposed, even though there was insufficient space in the crowded maxilla to accommodate them. The rationale was that, since the canines were also likely to be displaced buccally or palatally, they would probably erupt to one or other side of the line of the erupted teeth. The patient would only then, the logic went, require the services of an orthodontist to align them. Open surgery was performed and he was followed up for a year or so by the surgeon. The palatal and interproximal soft tissue grew again over the area and there was no positive change in the fortunes of the canines. The surgeon thereafter repeated the exposures on two additional occasions, each more 'surgically adventurous' than the previous one.

When the author eventually saw this patient for the first time (Figure 18.21a, b), he diagnosed generalized crowding on skeletally normally related jaws, a mild class II molar relation and increased overbite and overjet. Following the three 'open-and-pack' surgical interventions over a three-year period, soft tissue defects and bony defects were present on the palatal and distal sides of the denuded lateral incisor roots, and the periodontal condition of both lateral incisors was very poor. Neither canine had shown any signs of erupting. A periapical radiographic view (Figure 18.21c) showed the canines to be associated with resorption of the incisor roots.

This was treated by the author as an extraction case, sacrificing the periodontally and root resorption involved lateral incisors, compensated by first premolars in the lower jaw. Before the canines were surgically exposed, the teeth were aligned in both jaws and the overbite and overjet fully reduced. At that point, heavy base arches were placed in both jaws, the canines exposed and eyelet attachments bonded. Direct traction was applied to each from the main archwire and they erupted easily and quickly, with the regeneration of new alveolar bone, to fill the large defects caused by the three earlier surgical interventions and now by the extraction of the maxillary lateral incisors. The canines were carefully brought into alignment in the former location of the extracted lateral incisors and the treatment taken to completion (Figure 18.21d). The gingival height and architecture on the palatal side were returned to normal and the prognosis of the result was excellent (Figure 18.21e).

Case 18.11: Botched surgery

For the oral and maxillofacial surgeon, exposure of an impacted tooth is considered a trivial procedure and it is occasionally treated with a cavalier attitude and scant regard for background preparation, positional diagnosis or treatment planning. There are a number of aspects of the surgeon's involvement that may lead to failure, and these are mainly due to mistaken diagnosis of the exact 3D location of the impacted tooth. As already discussed in several places in this book and elsewhere, we believe that the surgical episode is far too crucial and important a stage for the orthodontist to absent him- or herself from active participation [19]. A significant number of legal cases brought against orthodontists are initiated based on the botched exposure of the surgeon, which often is the cause of the loss of the impacted tooth. This most particularly occurs in the aesthetic zone of the mouth, i.e. with maxillary canines. One glaring example of such a case is presented here.

A 12-year-old female was diagnosed by her orthodontist with a skeletal class II jaw relationship with a typical Angle's class II division 2 malocclusion (Figure 18.22a, b). The radiographs also revealed the presence of an impacted right maxillary canine high in the anterior maxilla, intimately involved with the incisor apices of that side (Figure 18.22c, d). She was next seen only 18 months later with a view to treating the malocclusion, and appropriate records were taken. The lateral cephalogram and the initial panoramic view clearly showed the impacted canine to be lying almost horizontally, with its crown tip in the midline. It was palpable in the labial vestibule.

The orthodontist evaluated the relationship between the canine and the incisor roots and considered, wisely, that this was an extremely difficult case to solve. The proposed treatment plan was to extract this canine and the deciduous canine on the same side, together with the first premolar on the left side. The aim was to bring the right first premolar into interproximal contact with the lateral incisor, in place of the extracted canine. The intention was to close the maxillary extraction spaces and to torque the maxillary incisors to a more acceptable inter-incisal angle and appearance. The mandibular dentition was to be treated without extraction, so that the final occlusion would be completed with a class II molar relation.

The patient was referred to an oral and maxillofacial surgeon to carry out the extraction of the very problematically located impacted canine. The surgeon attempted to approach the canine through a buccal flap over the first premolar tooth. However, he totally failed to locate and expose the canine, and during the ill-fated procedure damage was caused to the premolar. Both roots of the first premolar were unintentionally amputated just above the CEJ.

A panoramic radiograph (Figure 18.22e) was commissioned at the conclusion of the surgery, which revealed that the location of the canine had been completely missed, although there was some concern that perhaps the roots of the canine and of the second premolar had suffered some collateral damage at the time. The surgeon informed the parents of the unfortunate outcome of the surgery.

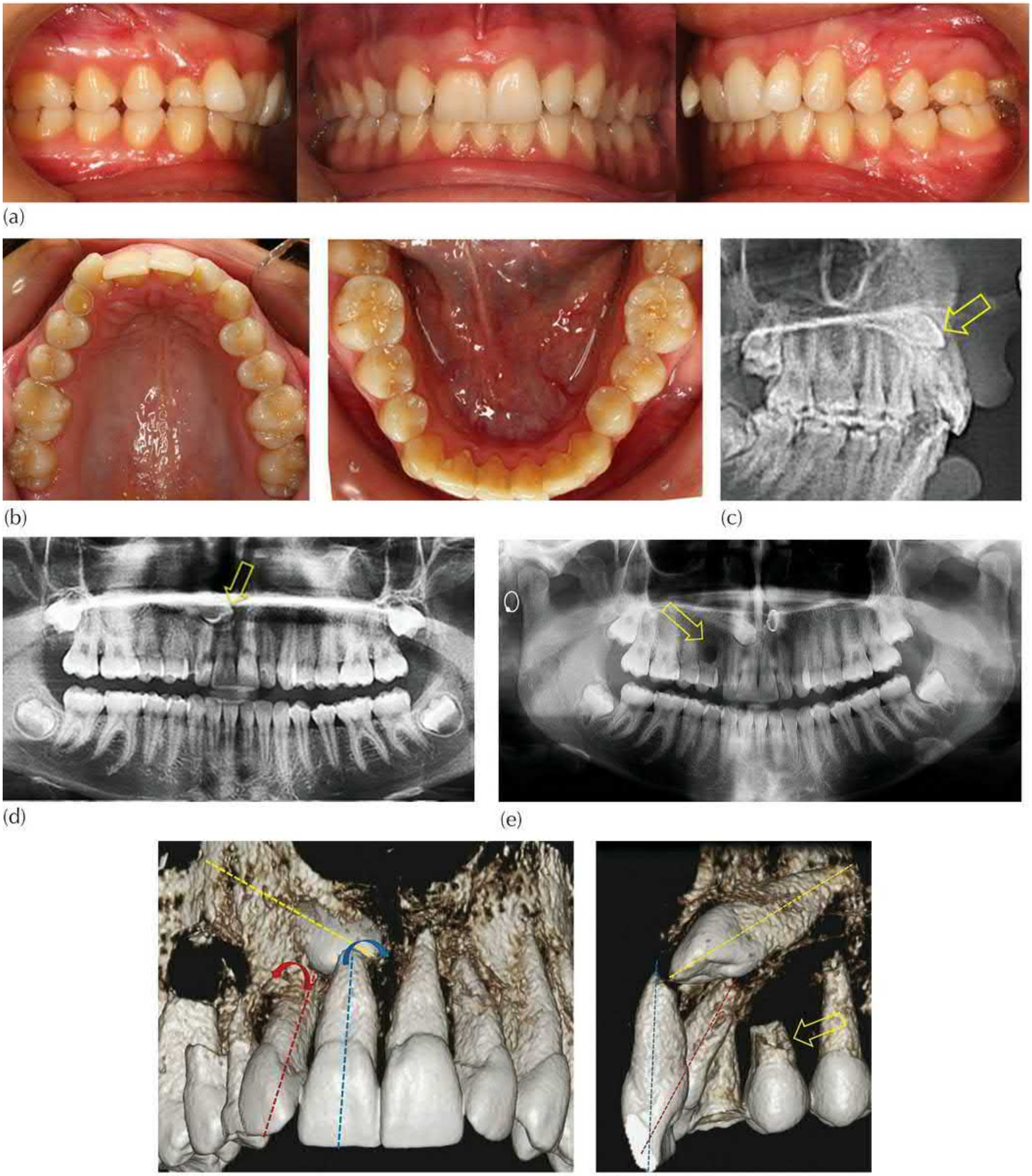
Notwithstanding this, the patient subsequently returned to the orthodontist, who had not been present at the surgical episode and who decided that the case was now too complicated and preferred that the patient be treated elsewhere.

The patient was referred for CBCT imaging in order to review the surgical damage and to diagnose the exact 3D location and relationship to the adjacent teeth, in order to determine whether it would be possible to adopt a conservative approach to resolving the impaction and bring the canine after all to its place in the dental arch. The aim would be to extract the severely damaged right first premolar and the deciduous canine, together with the first premolar on the left side. In this way a similar result could be expected, albeit with an increased treatment duration, provided the canine could be brought to its place. Considering its complicated relationships to the central and lateral incisor root apices (Figure 18.22f, g), this was a tall order.

The inter-relationship of the teeth adjacent to the impacted canine could be most advantageously determined using a number of 3D screenshots of the area from different angles (Figure 18.22f, g), in addition to using axial, cross-section, coronal and longitudinal slices. From the 3D screenshots, it was easy to perceive that the tip of the crown of the canine was locked between the palatal side of the apex of the central incisor and the labial side of the apex of the lateral incisor. The root apex of the canine was high in the alveolar bone, immediately above its mesio-distally ideal location in the line of the arch. Resorption of the central incisor root apex was identified (Figure 18.22g) at the closest point of the follicle that separated the tip of the canine crown from the incisor root apex.

(a) (b) (c) (d) (e)

Fig. 18.21 After three failed surgical interventions. (a) The intra-oral photographic records on the first visit to the orthodontist's office. (b) The occlusal view of the maxillary dentition. Note the severe post-surgical bony defects and denuding of the root of the lateral incisors. (c) A periapical view of the incisor area on the same date. (d) Intra-oral views of the completed treatment after the extraction of the damaged lateral incisors, together with the mandibular first premolars. The canines were brought into alignment in place of the extracted lateral incisors. (e) The occlusal view shows how eruption of the canine has regenerated alveolar bone into the area, to completely rehabilitate the form and appearance of the palatal anatomy and the gingiva.



(a) (b) (c) (d) (e) (f) (g)

Fig. 18.22 (a) Intra-oral photographs of the teeth in occlusion in a class II division 2 malocclusion, on a skeletal class II base, with over-retained right maxillary deciduous canine. (b) The class II division 2 malocclusion: the occlusal view. In the radiographic presentation, (c) the lateral cephalometric and (d) panoramic views clearly show the height and labial impaction of the right permanent canine, above the apices of the adjacent incisors (arrows). (e) A new panoramic radiograph was taken the day after the surgery and clearly shows the amputated premolar (arrow). The patient had meanwhile acquired right ear and left nostril rings. (f) Cone beam computed tomography 3D screenshots from the anterior view and (g) viewed from the palatal side of the dental arch. The long axes of the three involved teeth are depicted with dotted lines, blue for the central incisor, red for the lateral incisor and yellow for the canine. Note that the tip of the canine crown is palatal to the root of the central incisor and labial to the lateral incisor root. The yellow arrow indicates the amputated premolar. This case is currently under treatment, in its early stages. See Online PPT & video Fig. 18.22.

Above the deciduous canine and first premolar there was a large cylindrical tunnel, stretching from the buccal to the palatal sides of the alveolus. This corresponded to the section of bone that had been ground away during the surgical procedure. The remnant of the premolar comprised only its crown and the very short stumps of its truncated roots.

The proposed amended treatment plan that was adopted, in the light of these adverse circumstances, now had to carry with it the obligation to tackle the difficult impaction of the canine, while minimizing the chances of causing further collateral damage to the two incisors. The treatment plan was as follows:

- Extraction of the maxillary deciduous canine (#53).
- Placement of a maxillary fixed orthodontic appliance for alignment and levelling of the teeth, initially including the first premolars, for stability during levelling.
- Over-uprighting the root of the maxillary right central incisor deliberately towards the midline and the root of the maxillary right lateral incisor distally (note the blue and red curved arrows in Figure 18.22f). These movements would normally have contradicted an orthodontist's normal alignment and levelling routine, but were intended to temporarily divert the root apices away from interference with the proposed movement of the crown of the impacted canine.
- Surgical exposure of the impacted canine (#13) from the labial side, under the lip, and bonding an attachment.
- Extraction of both maxillary first premolars (#14, #24) and the deciduous canine (#53), when the impacted canine had reached to within close proximity of the deciduous canine.
- Applying distal and labial movement of the right canine to clear the central incisor root, circumventing the lateral incisor and then distally and vertically downwards, to align it in its place.
- Placement of a mandibular fixed orthodontic appliance to align and disperse the crowding without extracting teeth. Class III intermaxillary elastics and maxillary space-closing elastic chain.
- Relocating the brackets on the right-side incisors to their ideal angulation, with appropriate corrective re-uprighting.
- Torqueing the maxillary central incisor roots lingually.
- Finishing procedures as needed.

- Retention.

The approach described here was, however, not without its risks. The most significant of these included the possibility of failure to bring the canine into its place, or, by so doing, causing the loss of vitality of the adjacent incisors. The treatment of the case began a few months before this book went to press. (Suffice it to say that the surgeon has taken upon himself the cost of this treatment.)

Mid-treatment alternate consultations – second opinions

There are a number of reasons why a patient would want to consult another orthodontist for a second opinion. These include where the patient has the impression that the treatment has, after a long period, not shown the expected resolution, or that the treatment is leading nowhere or is failing. Unfortunately, there are also cases where the request for a second opinion may come from a lawyer representing a patient, who feels aggrieved at what he or she perceives to be failure and the assumed negligence that must have caused it. Regardless of the source of the referral, the principal aim of suggesting and, indeed, giving a second opinion must be the well-being of the patient and a satisfactory resolution of the orthodontic problem. It is the patient's right to seek a second opinion, but the treating orthodontist should be informed by the patient and, ideally, by the second orthodontist that the opinion is being sought.

Let us consider how the second orthodontist should act.

The patient will normally arrive for the consultation appointment with a parent, bringing the initial pre-treatment photographic and radiographic records, as well as updated and follow-up records that will have been acquired during the period of treatment. The orthodontist should perform a meticulous examination and take note of every detail of the records that may appear relevant. The clinical examination will usually reveal fixed appliances that had been placed on the teeth by the first orthodontist and will probably have achieved some levelling and alignment of the teeth.

If the exposure had been performed using the closed approach, then careful palpation of the expected location of the impacted tooth should be made, to try to assess its position. It is particularly important to observe any traction mechanism that may be ligated to a gold chain or wire ligature, thereby indicating the direction in which force has been applied to the buried tooth. Next, the amount of space prepared in the dental arch for this tooth should be measured, to see if this is adequate to accommodate the impacted tooth, although this will only be considered as the cause of non-eruption if the tooth is close to the line of the arch. The existing radiographs should be reviewed to determine whether they are adequate for the task of accurately locating the tooth in three planes of space. Note should be made of the dates on which they were taken. If these films were taken more than a year previously, then progress radiographs should be done, and any supplementary views should be taken that may assist in accurately determining the positional diagnosis.

If the diagnosis is not completely clear, or if the tooth is in a position and orientation in which 3D relations are difficult to mentally reconstruct, or there is a suspicion of a pathological entity such as ICRR, then in such events a CBCT examination may need to be commissioned. At the same time, clinical photographs should be taken of the case, without disturbing the appliances.

If the patient has not brought the original records to the first appointment, every effort should be made to obtain them from the treating orthodontist, despite the fact that they may be old records. We have already emphasized that clinical signs seen (or missed) in the original malocclusion models or intra-oral photographs may show displacement of the crown or root of an adjacent tooth, which itself may help in diagnosing the initial position of the tooth concerned. These signs will have been largely eradicated by the initial levelling and aligning procedures that will have been completed well before the second orthodontist sees the patient (Figures 18.16 and 18.19).

One of the factors initiating renewed eruption activity of an impacted tooth is the active orthodontic movement of teeth adjacent to that impacted tooth, whether in order to bring about alignment and levelling or to re-open space. Although this may finally be successful in generating eruption, it may, conversely, direct the tooth further along the wrong path.

Accordingly, it is clear that comparing the old films and photographs with new radiographs and with a clinical examination will often lead to a better understanding of the dynamics surrounding the impaction and to the chance of a more successful resolution of the problem.

Before a new treatment plan can be formulated, new scans or casts of the teeth may be needed. This should be carried out when all the ordered radiographs have been assembled and after the archwires have been removed. The archwires should then be replaced without renewed activation until a definitive line of treatment is devised and reported to the patient and to the first orthodontist. It will then require a decision as to whether the original practitioner will continue with the case or, for whatever reason, the case will transfer to the new orthodontist, or indeed elsewhere. This is a decision that the patient must make, which will undoubtedly have a significant influence on the method of treatment and on the assessment of whether the original treatment has been confirmed as justified.

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19
Traumatic Impaction

Adrian Becker and Stella Chaushu

Acute traumatic intrusion (intrusive luxation)
Spontaneous re-eruption
Manipulative/surgical repositioning and splinting
Orthodontic reduction
Orthodontic treatment considerations
Indications for the different types of orthodontic appliance
Conclusion

Acute traumatic intrusion (intrusive luxation)

One of the most common sights in the waiting rooms of dental offices, emergency rooms of general hospitals and departments of paediatric dentistry of dental schools is parents waiting with young children who have quite obviously suffered trauma to the lower part of the face and jaws. Often the event that has caused the trauma had actually occurred only a matter of hours prior to their arrival at the medical facility. The trauma will typically have been caused as the result of an accidental blow to the mouth during innocent play, a fall or sporting activity and will have resulted in fracture or avulsion of the front teeth. (Having said this, one must be watchful and alert to the possibility of child abuse.)

The effects of traumatic injury on the teeth are varied and can be as minor as a transitory pulp hyperaemia, or a more serious fracture of the crown of the tooth or of its root, or, in the severest cases, avulsion of the entire tooth. Intrusion of one or more of the incisor teeth is often associated with a fracture or comminution of the labial plate of bone and tearing of the periodontal fibres. The child may present at the emergency clinic with what appears to be a total avulsion. The tooth is not visible in its former place, the gingivae are lacerated and there is a considerable fresh blood clot.

A periapical radiograph of the area will reveal a superior displacement of the tooth into the alveolar bone. This will not necessarily have produced a fracture of either the crown or the root. The labial plate, on the other hand, will be fractured and displaced labially. The injured but uninterrupted band of labial attached gingiva and oral mucosa will frequently hold the labial plate closed, while the integrity of the blood supply to the soft tissues will usually have remained intact, thereby providing the means for good and rapid healing of the soft tissue.

Although technically this tooth has been totally avulsed, it has happened in an atypical manner. It is completely displaced from its socket, its attachment apparatus has been totally severed and its vital supply lines have been disrupted. It has, however, one enormous advantage over the typical avulsed case: the tooth has not been allowed to dry. It will not usually have been in contact with any form of contaminated material and it will not normally be necessary to store it in saliva or milk or another recommended isotonic medium before restoring it to its rightful place. It will be situated in an area initially surrounded by a coagulating haematoma and later by an organizing blood clot. In these circumstances it must be assumed that the damaged periodontal fibres will fare considerably better than do those of a replanted tooth that has spent some time out of the mouth.

The treatment for the several dental conditions described above and of any soft tissue lacerations will require the considerable skills of the paediatric dentist, the endodontist and the oral surgeon, and is not within the scope and context of this book. Nevertheless, there is one small corner of the field of traumatic injury in which emergency adjunctive orthodontic treatment may be of value. This relates to those injuries in which there has been displacement of the damaged teeth coupled with particularly intrusive luxation.

This may be alternatively referred to as the acute, traumatically induced impaction of a previously erupted tooth, and it requires the special attention and skill of the orthodontist. However successful endodontic and restorative treatments may be in providing for a renewed healthy retention of the tooth in its surroundings, the final outcome will be judged by the degree of success in re-aligning the tooth (or a reasonable surviving portion of it) to its former place in the dental arch.

This type of injury will have occurred as the result of a severe blow in the general orientation of the long axis of the tooth, which has driven the tooth upwards into the alveolar process. This will have had the effect of causing injury to the periodontal ligament (PDL), involving a severance of the gingival and periodontal fibres. This may or may not be accompanied by varying degrees of crown and/or root fracture and comminution of the bone lining the socket. The long-term prognosis would be root resorption [1]. The insult to the pulp will cause pulp necrosis in virtually every case where the apex is closed and in about half of cases when the root apex is still open [2]. In the latter, there will often be arrest in further root development [1].

Intrusive luxation may find its resolution in one of three ways:

- Spontaneous re-eruption.
- Manipulative/surgical repositioning and splinting.
- Orthodontic reduction.

Spontaneous re-eruption

Following vertical displacement, an affected tooth may re-erupt with no external encouragement and eventually return to its original position [3]. This will be particularly the case if its root apex is still open [1] (Figure 19.1), although some teeth may re-erupt even after root closure. Should the teeth remain intruded after several weeks of follow-up, corrective relocation will be needed. Some emergency treatment and initial restorative procedures will already have been carried out by the paediatric dentist, endodontist or oral surgeon, so the patient will not be in pain at the time that the corrective relocation is required. However, whether the relocation of the intruded tooth is achieved by orthodontic movement or by surgical manipulation, additional insult will be caused to the tooth, which would be avoided if the potential for spontaneous re-eruption could be realized [1].

Fig. 19.1 An 8-year-old female following trauma to the lower face. (a, b) Seen four days post trauma, there is an intrusive displacement of both central and right lateral incisors. (c, d) At seven weeks post trauma, the teeth have partially re-erupted without orthodontic treatment.

Manipulative/surgical repositioning and splinting

For immediate repositioning of the tooth to be successful, the tooth needs to be gently manoeuvred into its former place and splinted there, in the hope that the severed gingival and periodontal fibres will heal to a sufficient degree to maintain the tooth in its place for the long term. Three main elements will determine the future of the tooth:

- Restoration of the periodontal attachment, assuring re-establishment of the integrity between the tooth and its supporting tissues.
- Healing of the pulp tissues or of the periapical environment, after pulp extirpation and root canal therapy (the reader is referred to appropriate texts in paediatric dentistry, endodontics and oral surgery for details of these procedures).
- The degree of root resorption that is an inevitable consequence.

Orthodontic reduction

If, immediately following the traumatic episode, extrusive forces are applied to an intruded tooth that has few intact periodontal fibres, it is highly likely that the tooth will be exfoliated within a very short time. Accordingly, before initiating traction, it is advisable to wait for at least a couple of weeks to allow for healing and for the re-establishment of some measure of periodontal support. With the organization of the blood clot and reattachment of the periodontal fibres, such support will hopefully be provided.

In order to enable the intruded tooth to successfully ‘take root’, i.e. to achieve the union of tooth to the surrounding bone, it needs to be through periodontal fibre healing, either alone or together with surface resorption. According to Andreasen and Andreasen [4], in the clinical situation healing without surface resorption is probably not a possibility, since it needs to be completed without causing any injury to the innermost layer of the PDL. Healing with surface resorption, on the other hand, will leave the luxated tooth attached to the socket with a normal PDL and new cementum. This will enable the tooth to respond to orthodontic forces.

The situation is completely different if healing occurs by replacement resorption. This would create a direct union between the root and the surrounding bone and the repair would be considered successful, but as a result the tooth would never be amenable to orthodontic forces.

There are occasions when a transient replacement resorption will occur and the tooth may subsequently regain a normal attachment unaided. There is no certainty that this will actually occur and it is more likely that areas of ankylosis will occur over the root surface, with the consequence that the tooth will remain intruded permanently. In this condition, the tooth would constitute a liability to the dentition and would not even be useful as a foundation for a lasting prosthodontic restoration. In a growing child an intruded and ankylotic tooth will become progressively more infra-occluded in relation to the adjacent teeth. Its accompanying bone will also be lacking compared to the normal vertical development of the alveolar bone that is surrounding the unaffected teeth. Taking all these factors into consideration, it is clear that there is only limited value in maintaining the tooth as a means of preserving alveolar bone, and therefore its extraction may often be preferred.

Orthodontic intervention undertaken immediately after the traumatic episode may thus offer the only viable treatment option that, together with certain relatively minor restorative procedures, has the potential of producing a good result, with a fair prognosis. If the tooth is still completely sub-gingival, then the labial gingival soft tissue will need to be pared back or apically repositioned to a point where 2 mm of the incisal edge of the tooth is revealed. Once the periodontal fibres have begun to reunite, light extrusive force are applied. This will be in the earlier stages of organization of the blood clot, but before the deposition of bone (i.e. 10–28 days post trauma).

A meta-analysis was undertaken that was designed to evaluate the orthodontic modality of treatment of these cases [2]. The analysis included material taken from other published studies of individual cases and case series reports. It found that there was a 90% rate of successful repositioning of the intruded teeth. The analysis also emphasized the point we made earlier in this chapter, that all those teeth with closed apices lost their vitality, as did approximately half those with an open apex. External root resorption was diagnosed in 54.8% of the involved teeth. Marginal bone loss was rarely seen in the patient sample, which is in sharp contrast to the findings of other studies [1]. Inflammatory root resorption was found to occur as a late complication in teeth with closed apices, and pulp obliteration was seen in those teeth that had remained vital. The conclusion of that study was that orthodontic reduction was the most reliable of the three alternatives and was found to be kinder than the surgical option to both hard and soft tissues. Orthodontic reduction was shown as providing the opportunity for a superior outcome in terms of fewer teeth lost and potential complications.

The conclusions of this meta-analysis have not been universally accepted and other studies have found little difference in long-term results between the orthodontic and surgical options. It has been argued that the extra clinic time and attention needed for orthodontic reduction of the traumatic intrusion do not justify any potential minor difference in the long-term results [1].

Orthodontic treatment considerations

There are significant factors to be considered when entering into a course of orthodontic treatment of intruded teeth and particular care must be exercised when using fixed appliances in this situation [1].

First, for any extrusive movement of a single tooth or group of teeth, some kind of resistant framework needs to be bonded to the adjacent teeth to act as a multiple anchor unit from which force would be applied to the intruded tooth or teeth. This may take the form of a few brackets and an archwire. However, the composite bonding of a customized rigid wire directly to the labial enamel of these teeth (illustrated below) would be more satisfactory from many points of view. Unfortunately, these adjacent teeth will themselves have almost certainly been traumatized at the time of the accident and using them for anchorage may lead to further damage, even at the light force levels involved.

Secondly, if the intended extrusion is initiated more than two months post trauma, ankylosis is likely to have affected the intruded tooth [4]. Active extrusive forces generated by the appliance will then be futile. The reactive forces will be absorbed by the anchor teeth and these will themselves become intruded.

It very often happens that children who present themselves for routine comprehensive orthodontic treatment have a history of non-displacement trauma to the maxillary incisor teeth. This is indeed more prevalent in children who have an enlarged overjet. In addition, many of them will have already undergone root canal therapy. In such a case the appropriate routine advice given by the orthodontist is to delay commencement of treatment until there is some radiographic evidence of repair. However, where a child presents for treatment and displays *intrusive trauma*, the reaction of the orthodontist must be different. The possibility of the occurrence of ankylosis (replacement resorption) is significant and will become evident within two months of the trauma episode. In addition, teeth that had completed root development at the time of the accident are generally scheduled for root treatment in the first week after the traumatic incident. Faced with this situation, it is clear that the orthodontic extrusion of these teeth must begin at the latest within six weeks of the traumatic episode. Indeed, a time-frame of between 10 and 28 days would be the optimum [2], since the risk of failure of extrusion due to replacement resorption is very high. On the other hand, the risk of an orthodontically induced complication of the root treatment is much lower and of little therapeutic significance.

Once the tooth is brought into alignment it may, for a few weeks only, be retained and splinted to its immediate neighbours, using a short length of multi-strand wire, bonded to the labial surface of the three teeth. It is important not to cover the wire completely with composite material, but to place a small quantity of composite material across the wire over each tooth and to leave broad interproximal areas of exposed and flexible wire. Rigid bonding for long periods is contra-indicated, since it appears to lead to a greater incidence of pulp necrosis and pulp obliteration [5, 6]. The use of a multi-strand wire splint allows a degree of movement that is similar in extent to that seen in physiological mobility [7–10] and thus it may be safely used for a considerably longer period if so desired. However, newer evidence appears to negate any difference in outcome between rigid and flexible splinting, and does not find that the length of time that stabilization is present alters the prognosis [1].

Indications for the different types of orthodontic appliance

Modified Hawley appliance

The Hawley appliance has been perhaps the best-known and most widely used removable appliance in orthodontic practice for over a century. In the distant past, it was used as a mainstay appliance for the reduction of an enlarged overjet in a spaced anterior dentition. Today it is almost solely used as a night-time device to passively retain the results of treatment by other, more sophisticated treatment methods. It typically comprises a labial bow, which wraps around the six anterior teeth and usually crosses the occlusion interproximally, between the canine and first premolar on each side, where it is cured into an acrylic palatal plate that closely fits the palatal mucosa.

(a) (b) (c) (d)

Fig. 19.2 (a) A fractured and intruded incisor, seen one day after acute trauma. (b) A steel button was bonded to the fractured left central incisor and the hemi-sectioned labial bow adjusted by the parent and/or child in a downward activated movement to extrude the tooth. Note that a provisional pinch band is placed on the fractured right central incisor. (c, d) Root canal treatment of both incisors was performed, followed by semi-permanent incisor crown restoration and rehabilitation of their crowns.

The simple Hawley appliance, however, is extremely well suited for an active role in the resolution of the violent impaction of incisor teeth that was the culmination of trauma [11–12] (Figure 19.2). It is constructed from an alginate impression that is taken at the initial visit of the child to the office and is generally ready for insertion into the mouth at the child's second visit, within days. It is retained passively in the mouth through the agency of molar clasps and the labial bow and, by itself, it applies no forces to the teeth.

At this second visit, a small button attachment is bonded on the labial side of the intruded tooth. The labial bow is cut at its mid-labial point and, for an intruded right central incisor, the left half of the cut labial bow is removed with cutters. The free-ended right half of the labial bow is then adjusted so that its cut end lies passively above the bonded labial button, while being free from contact with any other teeth.

The patient is taught to place and remove the appliance accurately and easily and instructed in appropriate oral hygiene. Once the child is familiar and comfortable with it, the extrusive function must be initiated.

The appliance is removed from the mouth and the half labial bow is deliberately bent downwards. If the child now replaces the appliance in the mouth, the molar clasps and palatal acrylic will be easily relocated in their places, but the half labial arch will be lying passively below the labial button. The child is then taught to simply raise the labial wire with the fingers and place it over the labially bonded button. This will apply a very light, secure and easily measurable extrusive force to the traumatically impacted incisor, with a broad range of action.

This method is simple and additionally has the advantage that it does not exploit the adjacent teeth to provide stability for the appliance, particularly since they are most likely to have also been damaged during the traumatic episode (Figure 19.2). Treatment generally proceeds rapidly, with the tooth appearing in the mouth and at the level of its neighbours within a few weeks, depending on the amount of extrusion required. On the other hand and since the activation depends on the patient placing the activated labial bow over the labial button attachment, clumsiness or lack of care may result in the tooth being displaced labially or palatally or the activation being neutralized.

It is essential that this treatment be planned and executed in close liaison with the paediatric dentist, and that neither specialist loses sight of the role of the other in their joint attempt to save this important tooth. There will be points along the treatment path where several therapeutic and restorative functions may need to be implemented to encourage the survival of an ailing pulp, or in the several stages that may lead to a successful root canal treatment, or the provisional rehabilitation of the broken crown.

Bonded wire frame

Fractured incisors are very common in special needs children [13–18], particularly in those afflicted by cerebral palsy. Depending on the area of the brain affected, these children may be unable to walk or may do so only with great difficulty and will consequently be more prone to accidental falling. With similarly affected upper limbs and slower reactions, they may be unable to protect themselves with their hands and the result will often be that the nose, lips and teeth – particularly protruding teeth – will absorb the brunt of the trauma as they hit the ground. Most young children, healthy or disabled, will need sedation or general anaesthesia to enable the successful performance of the variety of different treatments that are likely to be required in the emergency session that may follow a traumatic incident.

If, at examination, it becomes clear that sedation or general anaesthetic will be needed in order to perform surgical, endodontic and/or orthodontic treatment, it is obvious that this should, as far as possible, be performed in the same sedation/anaesthetic session.

In the case in Figure 19.3, an 8-year-old female patient with cerebral palsy was seen by the paediatric dentist 10 days after a traumatic episode. The maxillary incisor tooth had almost completely disappeared under the oedematous gingiva, with only 1–2 mm of its disto-incisal corner visible. The child was totally uncooperative, with involuntary limb movements, body contortions, biting and other uncontrolled behaviour. Intravenous sedation (propofol) was arranged for the purposes of debriding the gingiva in the immediate area, initiating root canal therapy and commencing the process of reducing the displacement with orthodontic traction.

An alginate impression of the upper jaw was made immediately the child became still and before other work was commenced. The model was poured while the minor surgery and root treatment got underway. The technician prepared a wire frame on the plaster model from a length of 0.020 in. hardened stainless steel wire. It was fashioned to lie passively over the labial surfaces of the left central and lateral incisors and left deciduous canine, and on the right lateral incisor and deciduous canine of the right side, across the area of the intruded incisor. The wire incorporated a small retention loop at each of these teeth for the purpose of bonding retention. In the area of the damaged incisor, the wire was turned incisally into a vertically offset section, incorporating a small circle.

Returning to the operatory, the wire frame was bonded to the five adjacent teeth and a small button was similarly bonded to the exposed disto-incisal corner of the incisor. A light elastic tie was made between the button and the circle, in order to extrude the incisor and distribute the reactive vertically intrusive force to the other five anterior teeth, as the source of the anchorage (Figure 19.3b). This method has the advantage that it may be constructed, bonded and activated in a single analgesia/anaesthesia session. It is simple and requires neither sophisticated orthodontic brackets nor any great orthodontic skill.

In the subsequent visits, the elastic tie was renewed several times until the tooth had reached its desired vertical height. At that point the wire frame was removed. The case was completed a few months later, when root canal therapy for the previously intruded incisor was completed. The periapical radiograph of the incisors, taken at that time, showed signs of root resorption and the parents were advised to return for endodontic follow-up in due course (Figure 19.3c, d).

Self-supported labial arch on fixed molar bands

Let us now consider a case where all four maxillary permanent incisors in a young child have suffered acute traumatic intrusion and there are no anterior teeth on which to mount an appliance to extrude them. In such cases a very different appliance will be needed.

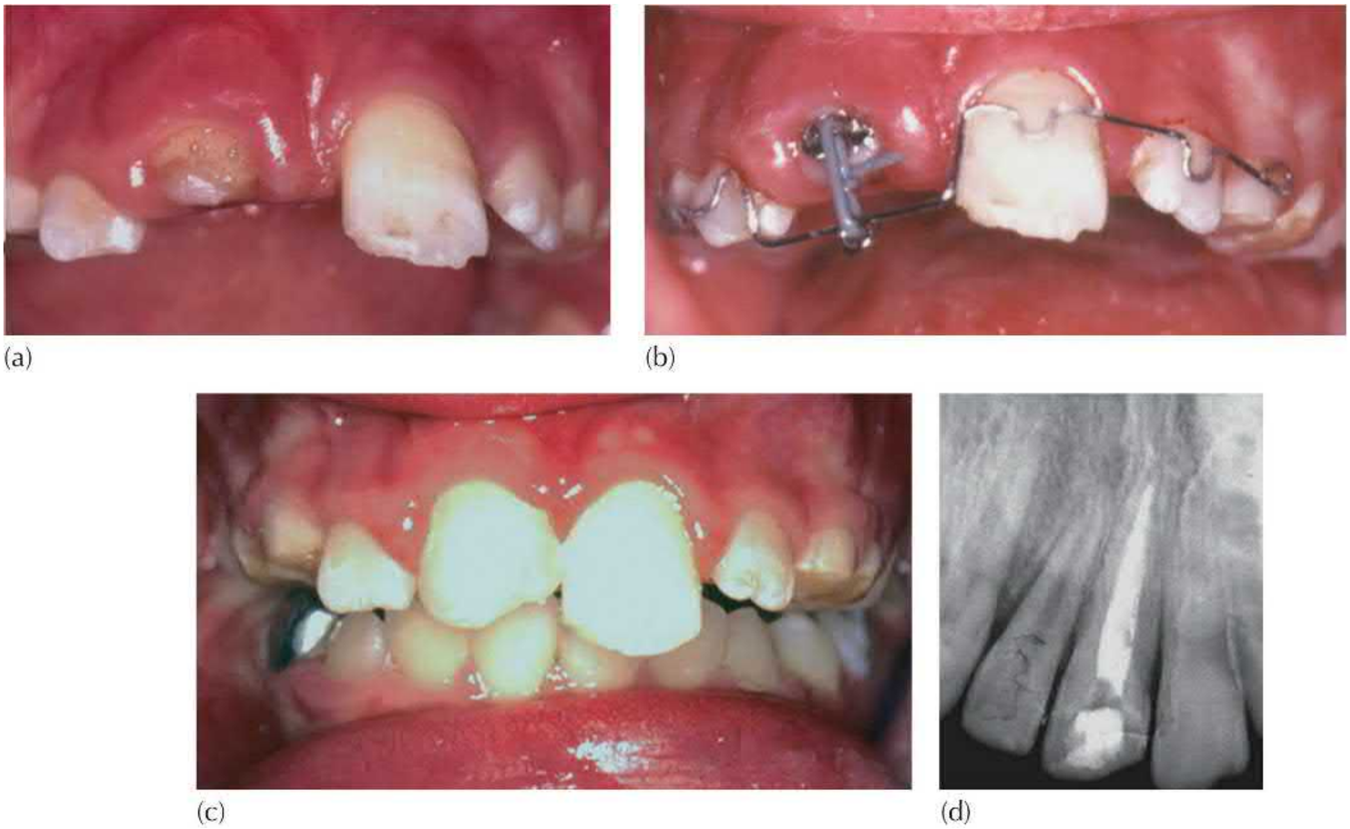


Fig. 19.3 (a) Traumatic intrusion in a special needs child at one month post trauma, (b) with bonded wire unit and a button bonded to the exposed crown surface of the affected tooth and elastic extrusion tie in place. (c) A clinical and radiographic view one month later, following extrusion. (d) Root canal therapy was executed in an attempt to arrest the apparent root resorption.

The female child in question here was 9 years of age and suffered from cerebral palsy. She had fallen forwards out of her stroller the day before, and the fall had caused the intrusion and enamel fractures to the incisors (Figure 19.4a, b). The periapical and tangential radiographs demonstrated the degree of upward and labial displacement of the teeth and labial displacement of the alveolar bone of the tooth sockets. They also showed that the roots of the teeth were not fractured (Figure 19.4c, d).

This scenario obliges the orthodontist to look to a third possible appliance design, which involves the placement of molar bands with a soldered palatal arch. Ideally this should include an acrylic Nance button in the palate. Round 0.036 in. (0.9 mm) tubes are soldered to the buccal side of the bands and a heavy self-supporting 0.036 in. labial archwire is fashioned to include adjustment loops immediately mesial to the tubes to act as stops.

The patient was seen on the day following the traumatic episode and, under propofol intravenous sedation, received the professional attention of the paediatric dentist, the oral surgeon and the orthodontist. The gingival tissues were debrided and trimmed to give access to the incisor teeth. Initial root canal procedures were performed on the damaged incisors (Figure 19.4e, f). The orthodontist adapted plain molar bands, carefully removed them and replaced them in an alginate pick-up impression and transferred them to the technician. At the same visit, eyelets were bonded to the labial aspects of the incisor teeth.

A week later, the molar bands, carrying a soldered palatal arch unit and soldered 0.036 in. round buccal tubes, was cemented into place (Figure 19.4g). The loop stops of the 0.036 in. self-supporting archwire were adjusted to distance the archwire a millimetre or two labial to the anterior region, with its passive position slightly below the level of the incisal edges. With light finger pressure, the anterior portion of this stopped arch was raised and tied with steel ligature wires to each of the eyelet attachments (Figure 19.4h, i). This generated extrusive traction, the force of which was measurable and controllable and its range adjustable to the desired force level. A full description of this in relation to impacted maxillary incisors can be found in Chapter 6, but also in Chapter 21, where stage 1 of the Jerusalem approach to the treatment of patients with cleidocranial dysplasia (CCD) is described.

The use of eyelets is to be preferred over brackets, for several reasons. In the first place, one or more of the four damaged teeth may already have developed a resistance to extrusion due to ankylosis that will have taken place during the interval between the trauma and the appliance construction. With a special needs child, as in the case in discussion, the likelihood was that this was not the first accident of this kind the child had suffered and it is possible that ankylosis was already present from an earlier trauma. Accordingly, even though only one of the four teeth may be ankylosed, the use of a continuous archwire connected to each of the incisor teeth would undermine the response of all four.

(a)

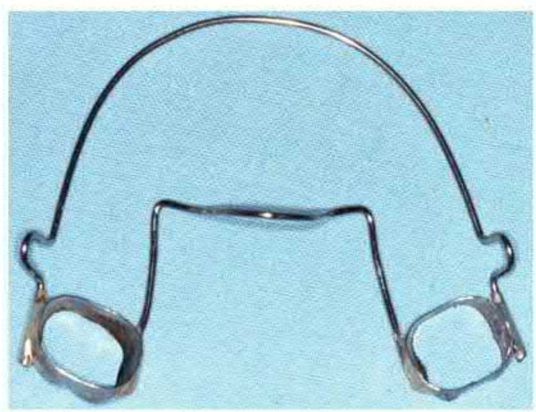
(b)

(c)

(d)

(e)

(f)



(g)

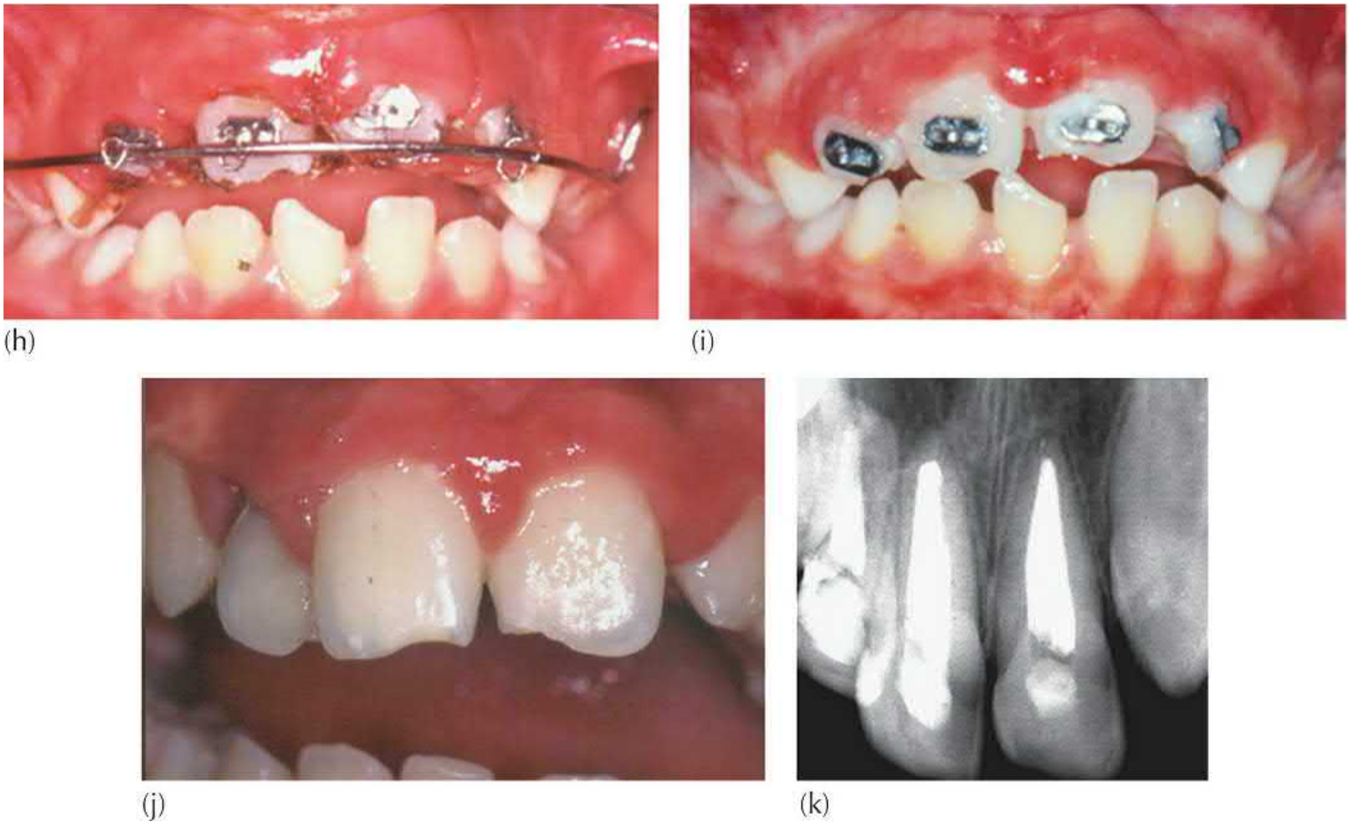


Fig. 19.4 (a, b) Intra-oral appearance of the periodontal damage surrounding the severe intrusion of the maxillary incisor. (c, d) Periapical and tangential views of the anterior teeth and maxilla. (e, f) Anterior view after gingival reduction and debridement were undertaken to permit convenient access for initial endodontic procedures. (g) The incisor extrusion appliance is based on molar bands, to which is soldered a rigid palatal arch. The detachable labial arch slots into a soldered 0.036 in. horizontal round buccal tube on each side. (h) The self-supporting labial arch has been raised with light extrusive finger pressure and ligated to the eyelets. (i) The response of the teeth to initial extrusive force. (j, k) The completion of the emergency interdisciplinary phase 1 treatment.

The use of a self-supporting arch method with individual eyelet attachments is to be preferred over the use of a regular fixed orthodontic appliance. Initially all the incisor eyelets were ligated to the archwire with steel ties under extrusive tension. Results are normally to be expected to gradually start to appear within days or weeks and, if so, the method should be continued until the teeth are brought to the appropriate height (Figure 19.4h, i).

In the present case, however, the teeth did not respond initially until the left lateral incisor had been released from its ligature tie. The other three incisors then moved rapidly in response to the unleashed extrusive force. The lateral incisor was then luxated and re-attached under tension. Happily, this proved to be successful (Figure 19.4i).

During this short period, the patient was seen by the paediatric dentist in order to continue the necessary stages towards completion of the root canal treatment. The left lateral incisor suffered severe inflammatory root resorption and was finally extracted, while invasive cervical root resorption of the right lateral incisor was diagnosed and appeared certain to lead its demise, too.

One of the ‘social’ problems that may be encountered is that parents of very young children who have recently experienced this type of acute trauma are often confused by the need for multi-disciplinary treatment. One of their concerns is the inevitable increase in cost and who should pay for it. They may waste critically valuable time seeking financial recompense from insurance companies and frequently ankylosis will likely have begun even before the orthodontist steps into the picture. The treatment of acute traumatic intrusion is among the very few orthodontic procedures that should be ranked as urgent, where the time factor will make all the difference between success and failure (Figure 19.4j, k).

Palato-labial partial avulsion

The patient in Figure 19.5 was a healthy 7.4-year-old boy with an early mixed dentition. The child had been brought to a dentist because of trauma to his anterior maxilla, with much consequent bleeding and pain. The mandibular incisors and all four first molars were the only erupted permanent teeth. The maxillary left central incisor was in the early stages of eruption. The dentist diagnosed that this incisor had undergone palato-labial avulsion (lateral avulsion) and noted that it had elongated and its crown had turned inwards. The child could not occlude the teeth because the displaced incisor was now prematurely contacting the lower incisor.

The treatment provided by the dentist was to grind the labial side of the incisor to reduce the occlusal interference (Figure 19.5a–d) and to give the child a bite plate to disarticulate the teeth. It was only after several days had elapsed that the child was referred to a trained paediatric dentist. The paediatric dentist referred the patient on to an oral surgeon, with the request that manipulative reduction of the displacement be attempted, to be followed by immediate splinting. The oral surgeon was of the opinion that it was no longer appropriate to consider reduction without first evacuating the several days-old blood clot that had obviously filled the socket. However, evacuation of the blood clot would have dictated an open-flap procedure, which, in turn, was likely to consign the prognosis of the incisor to an unacceptably low level. And so finally, the child was referred to the orthodontist with the request that reduction be performed using an orthodontic appliance and that this be achieved by applying labial tipping and then palatal root torque, with accompanying intrusion.

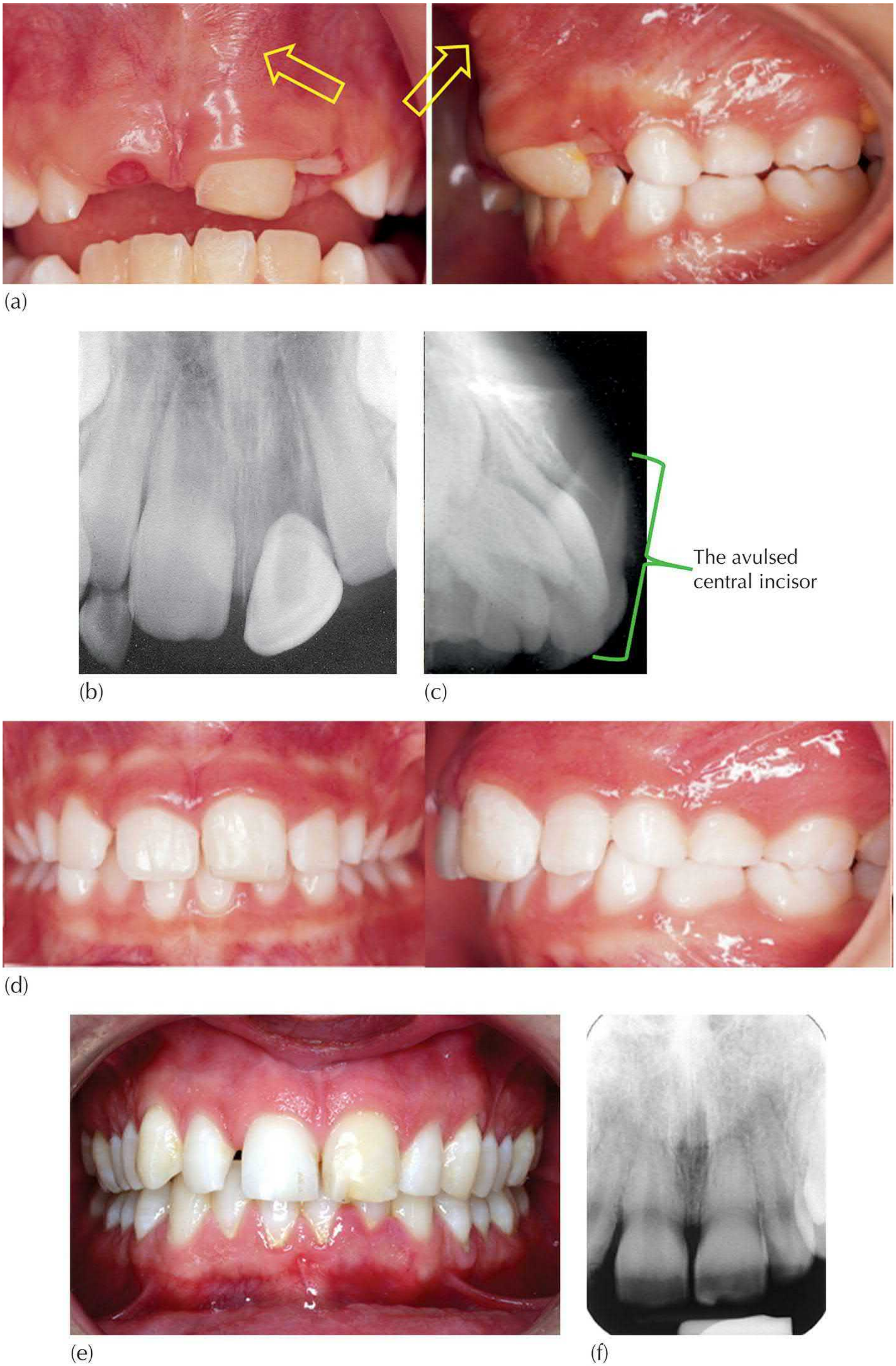

(a)
(b)
(c)
The avulsed central incisor
(d)
(e)
(f)

Fig. 19.5 (a) The arrows point to the bulging root apex of the palatal-labial partially avulsed central incisor. (b, c) Periapical and tangential views of the severely displaced incisor, showing labial displacement of the open root apex. (d) At removal of orthodontic appliances. (e) Five-year follow-up: the anterior teeth in occlusion. (f) The periapical radiograph shows pulp obliteration of the treated tooth and a good periodontal picture.

A modified Johnson twin-arch appliance was constructed with a soldered palatal arch, as demonstrated in Chapter 6 of this book. This appliance is popularly called a 2 × 4 appliance, since it comprises two molar bands and four incisor brackets, side-stepping the deciduous teeth in between. However, in the present case it would have been more appropriately described as a 2 × 1 appliance, since there was only the dislocated single maxillary incisor and no other anterior teeth on which to place an orthodontic attachment. For this reason, the anterior portion of the composite archwire of the appliance needed to be a 0.018 in. stainless steel round wire, engaged in the single bracket and friction-fitted into the 0.020 in. side tubes. These side tubes, in turn, could free-slide accurately in the round 0.036 in. molar tubes. Open buccal coil springs were placed on the 0.020 in. side tubes and compressed between their mesially soldered hooks and the molar band tubes. The planned, slight upward-tipped orientation of the soldered molar tubes and the springs quickly intruded and advanced the incisor labially, bringing it free of occlusal contact.

This first appliance function was completed only 10 days later, at the next visit of the child to the office. At that visit, a Begg torqueing auxiliary was fashioned from 0.014 in. hard, round stainless steel wire, ligated into the bracket and activated by lacing it back to the molar tubes. The treatment proceeded with great speed, since this involved moving the tooth through a freshly organizing blood clot and the appliance was removed two weeks later. The total treatment time was 3½ weeks (Figure 19.5d). Following removal of the appliance, the ground-down crown was restored with composite material and follow-up periapical radiography revealed minor signs of root resorption.

The patient was seen over five years later and was offered phase 2 orthodontic treatment for his relatively minor malocclusion. Radiographically, the pulp had been completely obliterated, from which it must be assumed that the tooth had maintained its vitality, despite the very serious avulsion that had occurred so many years earlier (Figure 19.5e, f).

Conclusion

Where the patient has suffered intrusive luxation or gross displacement of a maxillary incisor tooth, it is the paediatric dentist, rather than the orthodontist, who has to face the challenges and accept responsibility for the conduct of the treatment. He must be the ‘main contractor’ in the care of the injured child, bringing in surgical, endodontic or orthodontic ‘subcontractors’ to perform specific parts of the multi-disciplinary treatment, as and when necessary. However, there appears to be a challenging over-enthusiasm among paediatric dentists to undertake the limited orthodontic procedures described here, which may sometimes be quite complicated. There is a complementary and contrasting reticence on the part of orthodontists to accept these patients for treatment because of the very real risk that the injured tooth may become resorbed, ankylosed or otherwise lost during treatment. These outcomes are rarely encountered in routine orthodontic treatment and, when they occur, they come as an unwelcome surprise to the orthodontist. Orthodontists see them as signs of treatment failure or neglectfully performed treatment. Many will thus prefer to shy away from undertaking orthodontic treatment on traumatized teeth when the chances of these phenomena occurring may be high. This represents an unfortunate and unpardonable evasion of responsibility on the part of the orthodontist towards the patient.

Experienced orthodontists are very skilled professionals, trained and able to apply appropriate directional forces to resolve intruded and other displaced teeth and to do so with speed, with suitable force levels and with the least discomfort to the patient. In this respect, they will often have an important role to play as an integral member of the multi-disciplinary dental trauma team – particularly so in the early stages of the emergency treatment in cases of acute traumatic impaction.

One further point leads on from this specific issue. Judging by what we see in our orthodontic practices, there appears to be a significant number of children who show signs of greater or lesser past trauma to their anterior teeth, which had obviously occurred over the few years between eruption of the teeth and the age at which orthodontic treatment is advised. Nevertheless, other children, apparently the silent majority, may show no outward nor radiographic signs of trauma. Among them there is an unknown number who will have suffered a relatively minor blow at one time or another and woken up the following morning with neither pain nor discomfort.

Most of these children will have no memory of the traumatic incident, but nevertheless it may be the cause of degenerating health of the pulp and even, possibly, its slow and asymptomatic demise. There is reason to believe that this may be a more prevalent sequence of events than is commonly thought. Suffice it to say that when orthodontic treatment is initiated and even minimal force is applied to the (hitherto unknown to be affected) tooth, the hyperaemia that normally affects the pulp in the first few days merely serves to re-awaken the vital remnants of degenerated pulp tissue. From there, a cycle of events occurs that may lead to discoloration of the crown, pain and swelling and thence to a need for endodontic therapy [19, 20]. An unfounded accusation against the orthodontist by the general dentist or by the endodontist may then follow that the orthodontist has applied excessive force with an appliance and that this was the cause of the pulp pathology. From these rash, unfounded and irresponsible comments, which merely demonstrate the accuser's lack of knowledge, the path to the law courts may be exceedingly short.

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20
Extreme Impactions, Unusual Phenomena, Difficult Decisions

Adrian Becker

Case 20.1: Monster tooth, supernumerary tooth, impacted central incisor and the maxillary midline

Case 20.2: Bilaterally impacted maxillary canines in a patient suffering with aggressive juvenile periodontitis

Case 20.3: Labially impacted maxillary canine at the level of the nasal floor

Case 20.4: The inaccessible canine

Case 20.5: Severe trauma in infancy: repairing the damage with orthodontics

Case 20.6: Labial to the lateral incisor and lingual to the central incisor

Case 20.7: Three adjacent impacted molars

Case 20.8: Five unerupted teeth in the walls of a dentigerous cyst

In this chapter, the intention is to present a few cases featuring impacted teeth in a variety of difficult, inter-disciplinary or extreme situations. For these cases there are no hard-and-fast rules, the literature offers the practitioner little assistance and, despite all the advice that may be sought and received, the orthodontist largely remains alone in a diagnostic or treatment planning wilderness without a compass. Options may be few, but they also may be so many that each potential scenario must be acted out in the fertile imagination of the orthodontist to find the direction that will offer relative success, cause the least collateral damage and carry with it the least risk of failure. Some may require the active participation of specialists in fields other than orthodontics, particularly the oral and maxillofacial surgeon, the paediatric dentist, the endodontist and the periodontist. By their very nature, these cases are frequently one of a kind and thus determining the diagnosis, the treatment options, the chosen treatment approach and the prognosis may never be evidence based, but largely dependent on the logic acquired from the collected clinical experience of the operators.

This is both the strength and the weakness of published single-case reports. There is often much to learn from them individually but, whatever that may be, it cannot be used to draw conclusions in relation to other apparently or arguably similar cases in the future. Without doubt, legitimate criticism may be levelled by any dentist regarding the treatment decisions that were made in the following individual presentations. Moreover, an alternative approach to the same case might be preferred, a choice that will be influenced or biased by that orthodontist's positive or negative experience with the same or contrary modalities of treatment.

The clinical cases shown here are mostly finished cases with long-term post-treatment follow-up and they are offered specifically as they relate to impacted teeth. Others are in the final stages of their overall active treatment as this book goes to print but, in all cases, the principal issue under discussion (i.e. resolution of the impaction) will have been fully and successfully addressed.

Case 20.1: Monster tooth, supernumerary tooth, impacted central incisor and the maxillary midline

The existence of an unusually large maxillary central incisor with talon cusp or cusps, otherwise known as dens evaginatus, is rare and usually published in the literature as a single-case report [1–3]. Since it takes up more than the space of a normal central incisor and its location is at the front of the mouth, the dens evaginatus is unsightly and disfiguring. To reduce it in size with the view to reshaping it to more normal proportions is difficult or impossible, because of a large pulp chamber and/or a very broad cross-section in the cervical region. In such circumstances, it is often extracted and replaced prosthetically, or it may be enlarged and reshaped to make it resemble two teeth, a central and a lateral incisor, while sacrificing the adjacent normal and healthy lateral incisor.

In the case of a healthy 7-year-old girl (Figure 20.1a–d), the right central incisor was much enlarged with a Y-shaped crown cross-section, due to the talon cusp and a much enlarged pulp chamber and root cross-section at the cemento-enamel junction (CEJ). The dentition comprised the four erupted first molars, mandibular central incisors and rotated erupting mandibular lateral incisors, associated with mild dental crowding. On the maxillary left side there was an atypical incisiform 'central incisor', which was assumed to be a supernumerary tooth. The dens evaginatus occupied most of the space for both central and lateral incisors of that side. The remainder of the dentition comprised healthy and restored deciduous teeth in normal intermaxillary occlusal relations.

Periapical and panoramic radiographs revealed the unerupted teeth superimposed on one another with inadequate differentiation for appropriate diagnosis. Accordingly, cone beam computed tomography (CBCT) was performed (Figure 20.1e, f) from which it was concluded that the unerupted teeth in the maxillary incisor region included two normal lateral incisors and an unerupted, normally shaped, left maxillary central incisor. This lent credence to the assertion that the erupted 'central incisor' was indeed a supernumerary tooth and that the dens evaginatus possibly represented a fusion between a right central incisor and an additional supernumerary tooth.

The shape and size of the dens evaginatus, together with its pulp chamber dimension and cross-sectional breadth at the CEJ, determined that the limited alteration of crown shape possible would not provide a satisfactory answer to the overall space problem, nor would it contribute to improving the patient's appearance. Thus, its extraction was unavoidable. This created the unbalanced situation in which an incisor would be missing on the right side while an 'extra incisor' was present on the other.

The treatment proposed, therefore, was to move the erupted and presumed supernumerary tooth across from the left to fill the place of the extracted dens evaginatus on the right side and thus to permit the eruption of the impacted normal left central incisor tooth into its designated place. Once this was completed, the deciduous canines in both jaws would be extracted to provide space temporarily to permit the alignment of the four incisors in both jaws.

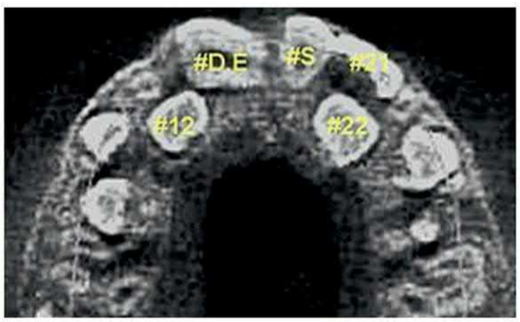
A modified form of the 2 × 4 appliance (in fact a 2 × 1 appliance) was placed, with a palatal arch soldered to two molar bands and the typical modified Johnson twin-arch set-up described in Chapter 6. A Tip-Edge® bracket was placed on the single erupted permanent supernumerary incisiform tooth and an archwire of 0.016 in. round steel wire inserted into the buccal arms of the composite archwire, which in turn would be inserted into the molar tubes (Figure 20.1g).


(a)

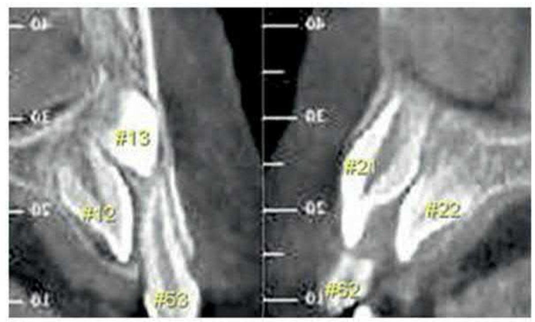

(b)


(c)


(d)



(e)



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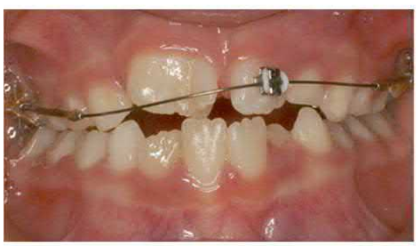
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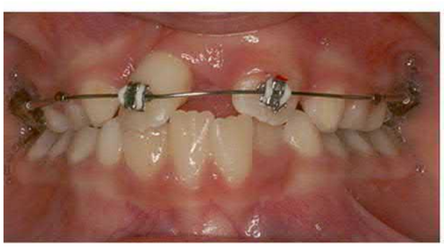
(i)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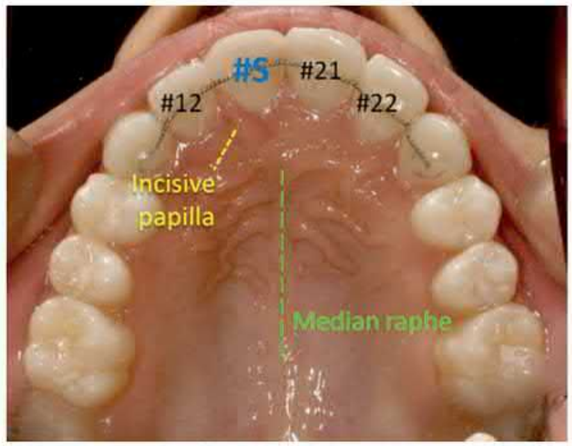

(o)

(p)

Fig. 20.1 The dens evaginatus. (a) Extra-oral view of the patient's smile. (b) Occlusal view showing the enlarged dens evaginatus and Y-shaped incisal edge. (c) Intra-oral views of the teeth in occlusion. (d) Periapical view shows enlarged pulp chamber. (e) Axial view from the cone beam computed tomography identifies the unerupted lateral incisor (#12 and #22), the left central incisor (#21), the presumed and erupted supernumerary tooth (#S) and the dens evaginatus (#D.E.). (f) The patient's right side cross-sectional slice shows the relationship between the unerupted lateral incisor (#12) and canine (#13) and the deciduous right canine (#53), while the inter-relations between the left side central incisor (#21), the lateral incisor #22 and the deciduous canine (#63) are clear. (g) Intra-oral views of the teeth in occlusion in the phase 1 treatment stages in September 2007, the 2 × 1 appliance in place. (h) In November 2007, immediately following the extraction of the dens evaginatus and activation of the coil spring to tip the supernumerary tooth mesially and top the right side. (i) In January 2008, the tooth has been deliberately over-tipped. (j) Intra-oral views of the teeth in occlusion: in April 2008 a bracket was placed following eruption of the left central incisor and the patient was referred for extraction of the mandibular deciduous canines. (k) In May 2008, the supernumerary incisor and the left central incisor are uprighted with uprighting springs. (l) In July 2009, the end of the phase 1 treatment. (m) In September 2014, intra-oral views of the teeth 17 months after completion of phase 2 treatment and following prosthodontic enhancement of the supernumerary tooth, to simulate a normal right central incisor (#11). (n) Case completion: harmonious relation between the lips at rest and the presentation of the incisor teeth. (o) Occlusal view to show the diversion of the anterior portion of the median raphe and the large discrepancy in the location of the incisive papilla. (p) Periapical view immediately prior to bracket removal clearly shows the diversion of the midline suture. The raphe is a midline anatomical structure and resists further uprighting of the supernumerary tooth (#S).

The orientation of the soldered molar tubes and these buccal arms was tipped slightly downwards on each side to encourage incisor eruption and bite closure, and a welded stop was placed on the buccal arms of each side mesial to the molar tubes to maintain the initial arch length and to prevent unwanted sliding of the buccal arms through the tubes.

The 'monster' right dens evaginitus central incisor was extracted at the next visit and, on the same day, a coil spring was compressed between the soldered stop at the mesial end of the left buccal arm and the bracket on the left erupted incisiform supernumerary tooth (Figure 20.1h). Six weeks later, the tooth was seen to have tipped across the midline and into proximal contact with the deciduous canine of the opposite side (Figure 20.1i, j). The impacted left central incisor erupted rapidly and autonomously five months after placement of the coil spring, driven by the sudden provision of space in the arch. This tooth was bracketed (Figure 20.1k) and a coil spring again placed on the arch to move it to the midline. An auxiliary spring was placed in the vertical slot of the Tip-Edge brackets of the supernumerary tooth and left central incisor, to upright their roots across the facial midline (Figure 20.1l, m).

During the subsequent 21 months of treatment, the four deciduous canines were extracted and the lateral incisors erupted without further assistance. Brackets were placed on them and the teeth were aligned and moved towards and slightly across the midline. Phase 1 treatment was completed seven months later, with adequate alignment of the teeth (Figure 20.1l).

The orthodontic treatment was recommenced when the permanent teeth had erupted and was completed within a few months, with standard fixed orthodontic appliances and retained with lingually bonded, canine-to-canine, twistflex splints. The supernumerary incisor tooth was subsequently rehabilitated to a more idealized form by the prosthodontist (Figure 20.1m).

It should be clearly understood that moving a tooth from the left side of the maxilla to the right, across the midline, does not infer that the tooth actually traverses the midline palatal suture, although a symmetrical and harmonious appearance and dental midline were achieved (Figure 20.1n). What happens is that the bone on each side of the suture is remodelled and moves together with the tooth, taking with it the incisive papilla (Figure 20.1o, p), so that the suture remains on the mesial side of the left incisor, as can be seen on the photographs and the radiograph. Any attempt to force the issue of uprighting the supernumerary tooth against the fibrous median raphe will likely cause the root to resorb.

Case 20.2: Bilaterally impacted maxillary canines in a patient suffering with aggressive juvenile periodontitis

The patient was a 15-year-old girl, who had been referred to the author for the treatment of her bilaterally impacted maxillary canine teeth. Clinically, there was a close to normal occlusion with excellent alignment in both jaws, good inter-cuspation and a normal overbite and overjet (Figure 20.2a). An examination of the initial panoramic view (Figure 20.2b) indicated a routine palatal impaction of both maxillary canines, both classified as group 1 type (see Chapter 7) and the deciduous canines were over-retained, with long unresorbed roots.

The complicating factor here was that the patient suffered from aggressive juvenile periodontitis, with the loss of much alveolar bone in the molar and incisor regions of both jaws. No mention was made in the referral letter to the effect that the patient suffered from periodontal disease and there were no symptoms that might have indicated this. The clinical signs of the condition were recognized at the initial examination and were confirmed on the panoramic film. The patient was sent for appropriate treatment by a specialist periodontist [4, 5].


(a) (b) (c) (d) (e) (f) (g)

(h)

Fig. 20.2 (a) Intra-oral appearance of the dentition and gingivae after successful completion of the periodontic treatment. (b) Initial panoramic view with bilateral maxillary palatal canine impaction. The typical picture of aggressive juvenile periodontitis is seen, with deep vertical periodontal defects and severe bone loss in the four molar and maxillary incisor regions. (c) A new panoramic film taken after the successful completion of periodontal treatment shows the radio-opaque areas where bovine bone was used to regenerate bone in the defective areas. Periodontic treatment by Professor Ayala Stabholz. (d) Closed surgical exposure of the right impacted canine. Note the presence of a tube threaded on the archwire, as a space maintainer between the brackets of the adjacent teeth, the eyelet attached to the canine and a long twisted connector extending occlusally. (e) An elastic chain was stretched between the brackets on the lateral incisor and first premolar. (f) The elastic chain was stretched upwards to be ensnared by the twisted connector, which had been formed into a terminal hook. Surgery by Dr H.P. Samen. (g) The completed case seen at eight years post-treatment follow-up. (h) Periapical radiographs, as seen at eight years post-treatment follow-up.

The patient returned 18 months later having completed her periodontal treatment, which included the grafting and integration of bovine bone in the more severely affected locations mesial to the first molars. These may be clearly seen as small radio-opacities on the new film after a long period of post-treatment follow-up (Figure 20.2c). Note also the spontaneous closure of the spaces between the second premolars and the first molars that had been present before treatment began.

Pre-surgical orthodontic preparation for this almost normal occlusion involved levelling, aligning and space opening and lasted just four months, before closed exposures were performed on both canines (Figure 20.2d–f). A measured length of steel tube was threaded over the base arch, with the purpose of holding the distance between the premolar and lateral incisor brackets. The right side is shown here, to illustrate the use of an elastic chain stretched between the occlusally inserted T-pins into the vertical slots of the Tip-Edge brackets of the lateral incisor and first premolar, which was then raised and engaged in the pigtail ligature close to the sutured flap. In this way, renewable vertical traction was applied to the impacted teeth to bring about their eruption. The final result, shown here eight years after completion of the orthodontic treatment (Figure 20.2g, h), shows excellent alignment and inter-arch relations.

The clinical and radiographic appearance of the teeth offered no signs or clues that would indicate that the canines had previously been palatally impacted and the overall periodontal condition was excellent [4, 5].

The bone grafts, while still discernible in the radiographs, have become progressively more integrated into the trabecular picture and their incompletely resorbed remnants are still visible in the periapical radiographs. The orthodontic treatment duration for this case was 18 months and the patient is still (eight years post treatment, as this book goes to press) followed up by the periodontist on a regular basis.

Case 20.3: Labially impacted maxillary canine at the level of the nasal floor

The patient, a girl aged 11 years in the late mixed-dentition stage, was referred to the author with accompanying radiographs from which bilateral labially impacted upper canines had been diagnosed, one of which was extremely high in the maxilla. The existing occlusion was almost ideal, with good general dental alignment, a class I occlusal relationship of the molars and normal incisor overbite and overjet (Figure 20.3a).

The panoramic radiograph and the lateral cephalogram (Figure 20.3b, c) showed the presence of a lingual arch space maintainer, which had been placed following the extraction of deciduous teeth. They showed the presence of all the permanent teeth, together with the about-to-be-shed maxillary left first and second deciduous molars and the mandibular left second deciduous molar. The two maxillary deciduous canines were also present with virtually complete and unresorbed roots. The maxillary left first premolar root was mesially displaced and in partial transposition with the left canine, which was extremely high and lying horizontally in the palatal plane on a line shared by the floor of the nose and the floor of the maxillary sinus. The right canine was also very high, in comparison with any ‘regular’ impacted canine, although not reaching the severity of the left canine. The a–p and vertical orientation of the two canines were clearly depicted in the lateral cephalogram, as well as the mesial displacement of the root of the first premolar (Figure 20.3c). In the CBCT 3D views and the cross-sectional slice shown here, the relative difficulty of the impactions will be clearly appreciated (Figure 20.3d–f).

(a)

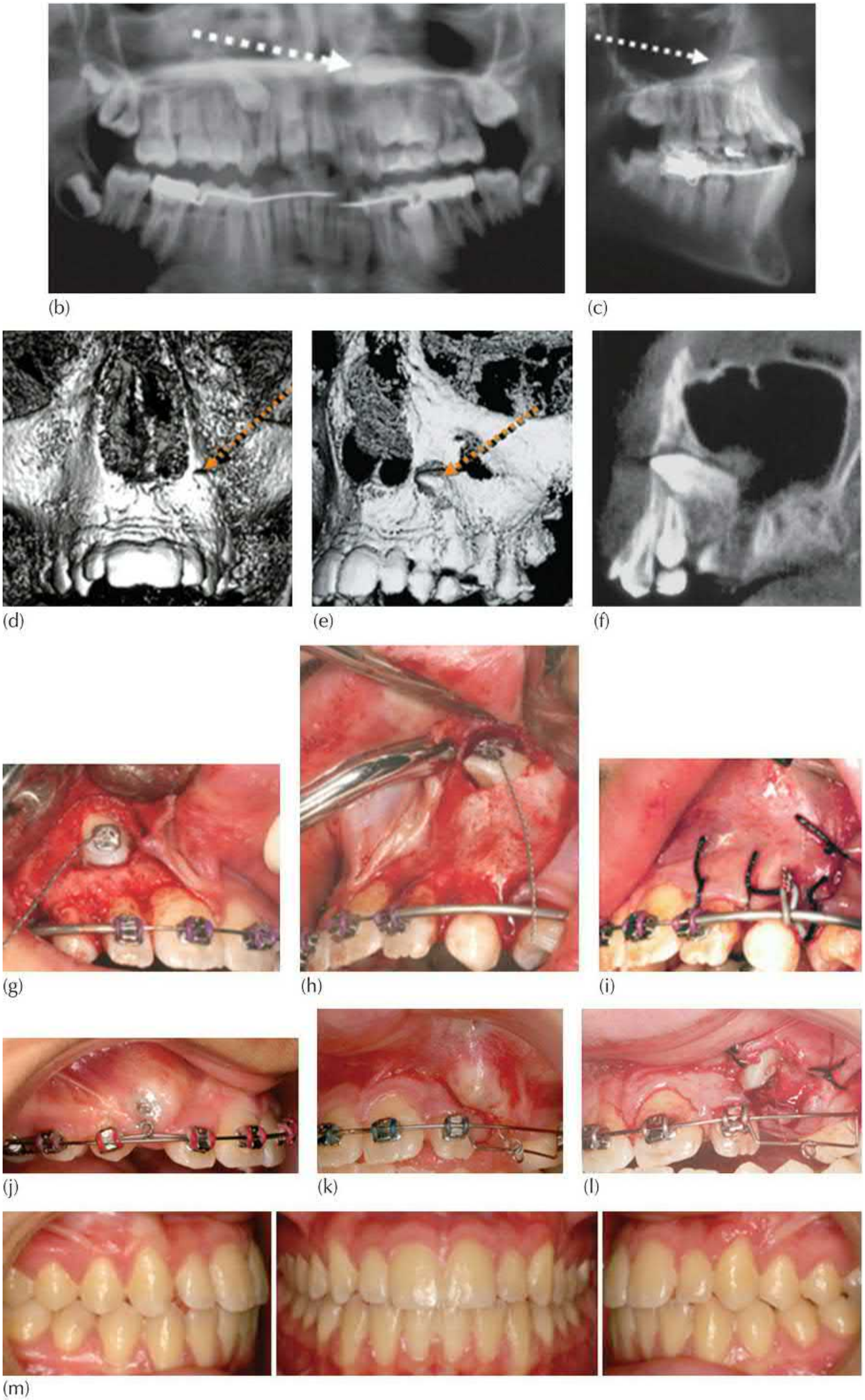
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Fig. 20.3 (a) Pre-treatment intra-oral photographs of the teeth in occlusion. (b) Panoramic radiograph shows the extreme height of the left canine, lying horizontally in the floor of the nose and maxillary sinus. (c) Cropped cephalogram showing the upward and forward eruption trajectory of the canine, in line with the anterior nasal spine. (d, e) Cone beam computed tomography imaging 3D screenshots of the facial skeletal showing the location of the left-side permanent canine, high above the floor of the nose (arrow). (f) Cross-sectional slice of anterior maxilla, depicting the angle of the long axis of the tooth and its relation to the anterior nasal spine. Source: First published in *Seminars in Orthodontics*, reprinted with permission of Elsevier. (g, h) Clinical views of both canines at the time of surgical exposure to show their differing heights. The left-side canine is located adjacent to the nasal cavity and maxillary sinus, above the height of the vestibular sulcus. Each canine has a bonded eyelet with a twisted steel ligature. (i) Closed exposure technique used to expose the canines on both sides, with eyelet bonding. On each side the ligature exits the lower edge of the fully replaced and re-sutured flap. Initial elastic ligation is made to the archwire. Surgery by Dr E. Regev. (j) Orthodontic traction brings the palpable right canine through attached gingiva. (k) The left canine bulges the highly mobile oral mucosa and threatens to erupt through it. (l) Apical repositioned flap to place attached gingiva on the crown of the left canine. (m) Treatment completion. Note recession of gingivae, signs of aggressive tooth brushing. (n) Post-treatment radiographs show significant root resorption of all the maxillary anterior teeth. (o) Panoramic radiograph of the completed case.

Orthodontic alignment, levelling and space opening were completed very quickly and measured stainless steel tube lengths were threaded onto the heavy 0.020 in. main arch to maintain canine spaces and add rigidity to the anchor unit.

Labial surgical flaps were raised from the attached gingiva around the deciduous canines on each side of the maxilla under local anaesthetic cover (Figure 20.3g–i). These were reflected high into the depth of the sulcus area on both sides, but on the left side exposure of the canine was only achieved about 10 mm above the height of the vestibular sulcus. Small eyelet attachments were bonded, with the twisted pigtail ligature drawn vertically downwards, closely adapted to and lying over the exposed alveolar bone. The surgical flaps were then fully replaced and sutured, with the terminal hook of the pigtail ligatures emanating from the sutured edges on each side. The deciduous canines were not extracted until a few months later. Orthodontic traction was provided immediately following the suturing of the flaps with elastic thread ties (Figure 20.3i).

Subsequently, traction was variously applied with nickel–titanium (NiTi) auxiliary wires and with offset light wire auxiliary arches. On the right side, it was found possible to erupt the canine through the attached gingiva and directly into its designated location (Figure 20.3j). On the left side, the canine bulged the oral mucosa above the attached gingiva (Figure 20.3k) and a secondary surgical procedure was undertaken to apically reposition attached gingiva over the crown of the tooth (Figure 20.3l).

At the end of treatment, the alignment of the teeth was excellent and, due to the compulsive aggressive tooth brushing, there was a general displacement of the gingival tissues in an apical direction. This was more noticeable over the two canines, which is largely to be expected with labially displaced canines (Figure 20.3m).

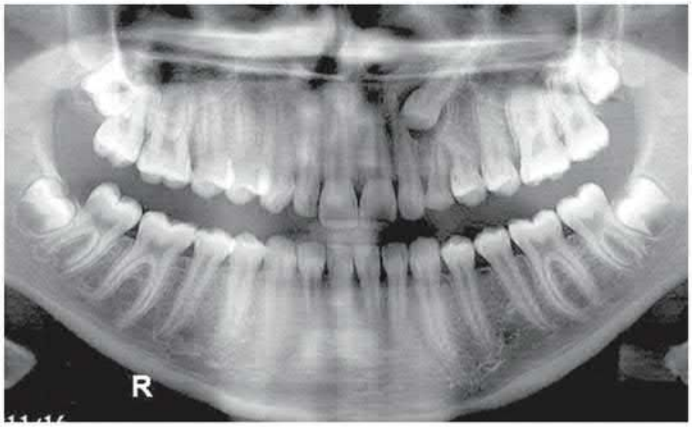
Post-treatment radiographs (Figure 20.3n, o) show significant root resorption of the lateral incisors on both sides and of the central incisors and the left canine to a lesser degree.

Case 20.4: The inaccessible canine

First seen in November 2016, a girl aged 13.6 years exhibited a mild skeletal II profile (Figure 20.4a). There was significant lip incompetence, with the lips fairly wide apart at rest, due largely to a short upper lip. The maxillary anterior gingiva was visible at rest with an accompanying minor chronic inflammation. The permanent dentition was erupted to the second molars in both jaws, with the exception of an over-retained deciduous maxillary left canine.

The molar relation on each side was slightly in excess of a half cusp class II. The incisor overjet was 5 mm and the overbite 5 mm, with contact high on the cingulae of the maxillary incisors. The canine–canine segment of the mandibular dentition was over-erupted by approximately 3 mm above the molar/premolar occlusal plane, while the maxillary incisors were similarly elongated, due to the antero-posterior discrepancy and poor lip control. The mandibular dental arch was generally in excellent alignment, with two very slightly slipped contacts at the left central incisors. The maxillary dentition was similarly well ordered.

(a)



(b)

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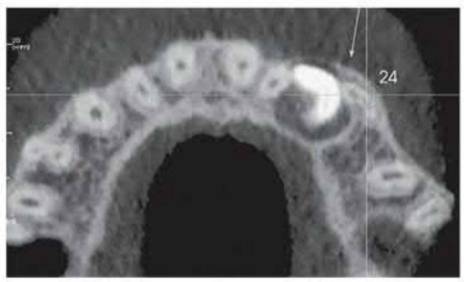

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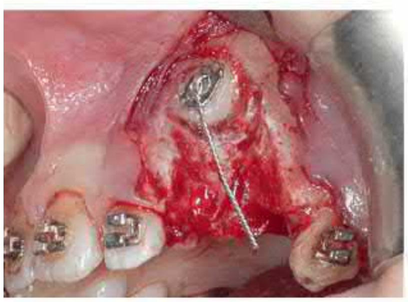
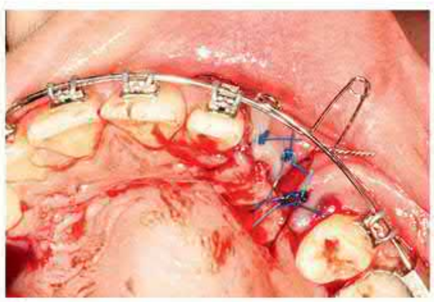


(g)



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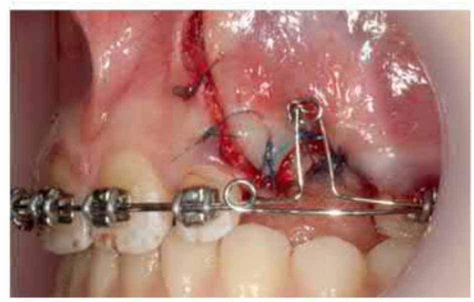


(i)

(j)

(k)

Fig. 20.4 (a) Intra-oral photographs of the teeth in occlusion. The over-retained deciduous canine is seen on the left side of the maxilla. (b) Planar 2D radiography: the panoramic radiograph illustrates the full complement of teeth, including unerupted third molars. The maxillary left canine is impacted high in the maxilla, surrounded by an enlarged dental follicle; the root of the left deciduous canine is only partially resorbed. A root of the first left maxillary premolar appears shortened and curved to the mesial. (c) A periapical view of the canine area indicates superimposition of the canine with the root of the lateral incisor. The curved root of the premolar appears shortened. (d) Cross-sectional, axial and coronal slices from the cone beam computed tomography reconstruction in the three planes of space show the canine crown surrounded by the enlarged follicle and locked between the roots of the lateral incisor and first premolar. The premolar clearly has an elongated root, not discernible from the planar radiographs. The more anterior cross-sectional slice focuses on the direct contact of the canine crown with the labial aspect of the lateral incisor root. (e) The axial slice shows the restricting influence of the roots of the incisor and premolar on the canine crown, making the tooth inaccessible from the buccal side. (f) A coronal slice shows the mesial extension of the elongated palatal root of the premolar on the lingual side of the canine crown, thereby completing the inaccessibility of the canine. (g) Surgical exposure: the deciduous canine and first premolar were extracted and the canine exposed, using a closed exposure procedure, with attachment bonding. (h) Full-flap replacement followed by re-ligation of the main archwire, together with a full-arch auxiliary archwire in passive (horizontal) mode. (i) Loop raised in the activated (vertical) mode and ensnared in the hooked end of the twisted ligature wire. (j) Panoramic view of completed case. (k) Post-treatment orthodontic result. See Online PPT & video Fig. 20.4.

The panoramic and periapical radiographs (Figure 20.4b, c) showed that all the permanent teeth were present, with the crowns of the unerupted third molars at the completion of calcification and no root development yet. The maxillary left deciduous canine still had most of its root intact and the permanent canine was unerupted and located high in apparent contact with the mildly shortened root apex of the adjacent lateral incisor. The permanent canine was encompassed by an enlarged follicle/dentigerous cyst. Additionally, a root of the adjacent first premolar exhibited a mesial curvature in its long axis.

Essentially, the case may be presented as a dental class II on a skeletal class II base with little to no crowding in either jaw and a vertical excess of the anterior segments of both arches. The lip cover was poor. All this was complicated by the presence of an impacted maxillary left canine.

If we were to ignore the impacted tooth, the remaining malocclusion would need to be treated by normalizing the antero-posterior relationship between the two dental arches in one of the following ways:

- *With a non-extraction approach*: to correct the class II dental relationship by *en bloc* movement of the teeth in one jaw versus the teeth in the other, taking care to level the occlusal plane before or during this process. This could be achieved using one of a number of methods, including the so-called functional appliances, such as twin blocks, bionators, Fraenkels, etc. It could probably be equally well served with the use of fixed multi-bracketed appliances with the addition of extra-oral and/or intermaxillary traction – fixed (Carriere, Herbst, Forsus, etc.) or removable (headgear and class II elastics).
- *By extracting a tooth on either side of the maxillary arch*: usually a premolar and normalizing the incisor relation by retracting the anterior teeth into the space, while calculating to 'burn' intra-arch anchorage by drawing the maxillary molars mesially and into a full class II dental relation.
- *A four-unit premolar extraction*: premolar extractions in the maxillary and mandibular dentitions to achieve both a normal incisor relation and a normal molar occlusion.

Concerns with the impacted canine

The following is a list of concerns that an orthodontist might have in relation to the canine in this case:

- The canine was surrounded by an enlarged follicle/dentigerous cyst, which must be considered as a possible contributory cause of the lack of eruptive progress of the canine. Was this a reason to prefer an extraction protocol that unilaterally sacrifices the canine, in preference to a premolar?
- The tip of the canine crown was in close proximity to the apex of the lateral incisor, which had a shorter root than its antimere. This was likely to have been due to root resorption related to the futile eruptive efforts of the canine. Will resorption continue after aligning the canine, thereby undermining the longevity of the incisor? Is this also a reason to prefer an extraction protocol to eliminate the canine, rather than a premolar?
- The canine was located high in the maxillary alveolus, far from its place in the arch, and perhaps the orthodontic treatment would be unnecessarily long or its prognosis poor. Was this a reason to prefer an extraction protocol to include the canine, rather than a premolar?
- The first premolar has a strange dilaceration of one of its roots, which also appears shorter on the panoramic film. For preference, perhaps that should be extracted rather than the canine.

Extracting the permanent canine itself because there is the suspicion of its having caused a minor degree of resorption of the lateral incisor root, or because it is involved with pathology (the dentigerous cyst), is a harsh and unfounded operative decision. In earlier studies, our clinical research group in Jerusalem has provided strong evidence that root resorption that is associated with an unerupted canine will arrest when the canine is distanced from the area [6, 7]. Similarly, teeth impacted within dentigerous cysts have been shown to be eminently orthodontically/surgically salvageable with an excellent post-treatment prognosis [8] (illustrated in Chapter 14).

Perhaps, too, the root curvature and the unusual length of the roots of the premolar tooth may have been a predetermining aetiological factor in the canine impaction and their continued presence may have effectively thwarted its eruption.

Accurate positional diagnosis

It became clear that the initial radiographic examination, which included two periapical views, a panoramic view and a cephalogram, was far from adequate for the purpose of accurate 3D positional diagnosis of the canine. There was a lack of information regarding the existence, extent and location of the assumed incisor root resorption. It was also essential to know the length and proximity of the dilacerate root of the premolar to the canine and whether it is on the buccal or lingual side. This information had an important bearing on operative decisions that were about to be made. Accordingly, a CBCT was performed and a few slices of the secondary constructions are presented herewith (Figure 20.4d–f).

From these comprehensive views, particularly the 3D video clips (see https://vimeo.com/231505687 and https://vimeo.com/231505198) that have been expertly animated by the CBCT technician, it can be seen that the palatal root apex was curled around and in contact with the labial side of the canine, while the palatal root was on the palatal side of the canine. The mesial surface of the canine was in contact with the disto-labial surface of the apical portion of the incisor root, where it had resulted in some resorption of the incisor root apex. The canine was, therefore, trapped on all sides and unable to be moved in any direction.

Treatment planning in light of the inaccessible canine

The treatment plan adopted for the case involved extraction of the deciduous canine and the maxillary first premolars. This was the only way to free the canine from the clutches of the tangled premolar roots.

Treatment

Treatment commenced in March 2017. By June 2017, alignment had been achieved and a rigid stainless steel main arch was placed, and the patient was introduced to the oral and maxillofacial surgeon. At the surgeon's insistence, the archwire was removed (by the orthodontist) and the teeth were extracted as directed, although there was considerable difficulty in freeing the canine of the premolar roots without damaging the former. This required raising an attached gingival flap on the labial side, from the crest of the ridge and in a closed exposure procedure, and locating the canine high up on the labial side of the ridge. The premolar and deciduous canine were extracted and the impacted canine was exposed. The orthodontist bonded an eyelet attachment with a light cure composite (Figure 20.4g), while the surgeon maintained the area free from blood and saliva.

At the same surgical visit, the orthodontist replaced the main 0.020 in. base arch, together with a piggyback auxiliary archwire of 0.016 in. stainless round wire and carrying the active horizontal loop for drawing the impacted canine (Figure 20.4h, i), which had been prepared ahead of time. Since the tip of the canine was located on the labial side of the resorbed apex of the lateral incisor, the auxiliary archwire was designed to apply traction in an initial labial and distal direction (Figure 20.4i). The surgical flap was sutured fully to its former place, with the twisted ligature from the eyelet piercing through the oral mucosa of the flap higher up.

Treatment proceeded to align the canine and fulfil the remaining aims of the treatment plan. It was completed in June 2019, for a treatment duration of 27 months.

The postoperative records showed a good periodontal result and, importantly, no further resorption of the left lateral incisor (Figure 20.4j, k).

Case 20.5: Severe trauma in infancy: repairing the damage with orthodontics

The patient was a 10-year-old female who attended with the complaint that she had missing maxillary anterior permanent teeth. She had suffered the ravages of caries in the deciduous dentition, the restorative and preventive treatment for which had been grossly neglected. From the patient's history it was learned that the child had suffered severe trauma from a fall at the age of 4 years, when the four deciduous maxillary incisors had been lost. Since that time, she had been without her front teeth.

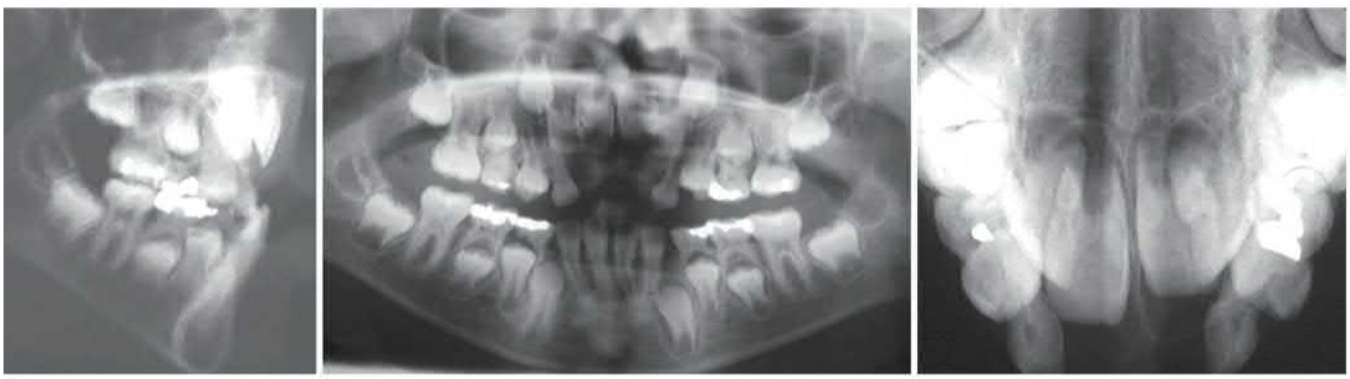
At examination, the mandibular counterparts of the missing incisors were over-erupted and retroclined, the maxillary arch was narrowed and a left-side unilateral cross-bite was present, with accompanying functional shift into full closure. The dental arches were restricted, with obvious potential crowding. The anterior maxillary bony ridge was very thin and under-developed, as is to be expected in the absence of teeth (Figure 20.5a).

The radiographic records that accompanied the child included periapical, panoramic and cephalometric films (Figure 20.5b) and a CBCT scan (Figure 20.5c). These showed the presence of all permanent teeth, with anomalous development of the maxillary incisors and canines. The roots of the incisor teeth were very rudimentary, of a length to be expected at 3–4 years and with wide, open apices. These teeth were of abnormal form and they were located very high in the anterior maxilla close to the nasal floor. From the point of view of the child's chronological age, the eruption time of these teeth was long overdue, but from the length of their roots and their height in the alveolus, normal eruption could not be expected for 4–5 years, although the likelihood of this occurring at all was zero. By contrast, the developmental status of her unaffected teeth, erupted and unerupted, was closely identified with the child's chronological age [9, 10].

She had been taken to several orthodontists for treatment of the unerupted incisors, each of whom had been at a loss to prescribe appropriate treatment.

When she was finally seen by the author, the conclusions drawn in relation to these teeth were that their development had been seriously hindered by the trauma that had occurred so many years earlier, root development seemed to be adversely influenced by their proximity to the nasal floor and it could not be assumed that further root length development would occur, particularly given the apparent lack of eruptive potential of these teeth. To extract them, with the view to temporary prosthodontic replacement and, subsequently, implant-supported crowns, would have caused very much more alveolar bone resorption and a large anterior bony defect. In light of the age of the child and her dental history, long-term wear of artificial prostheses would likely seriously reduce the prognosis for the survival of the other teeth. The prostheses would need to be present for 10 or more years, for the majority of which she would only be seen periodically by her dentist and therefore would be at considerable risk of developing further caries and gingival inflammation.

(a)



(b)

(c)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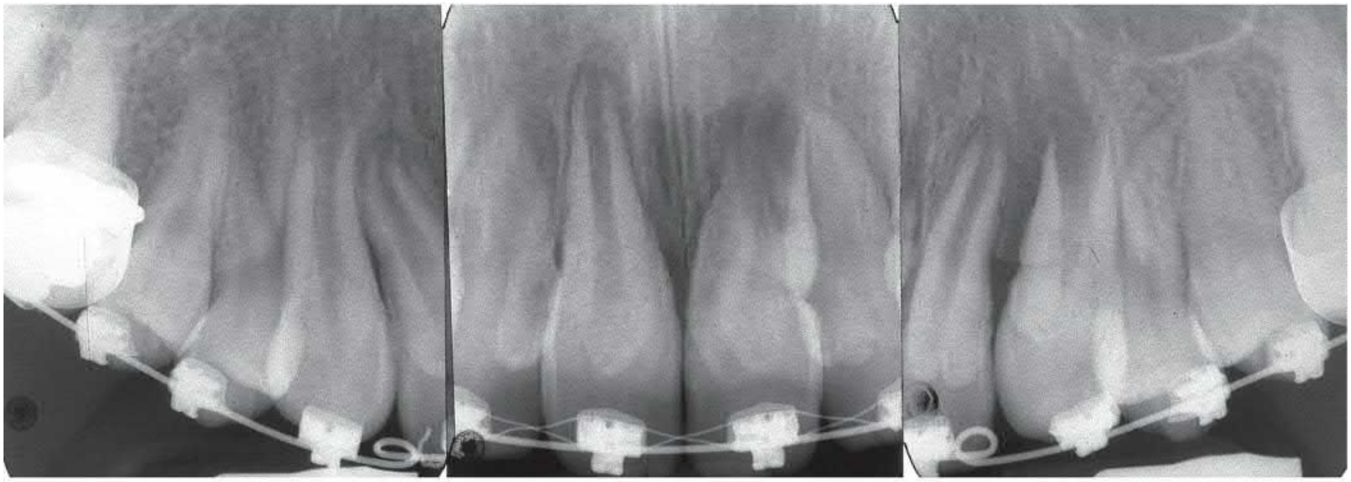


(n)

(o)

(p)

(q)

Fig. 20.5 (a) Intra-oral photographs transferred with the patient to the author, showing the initial condition. Note missing incisors and defective alveolar ridge, marked potential crowding, left side cross-bite, active caries and poor overall dental status. (b) Initial cephalometric, panoramic and maxillary anterior occlusal radiographs. (c) Cross-sectional and anterior coronal 'slices' from the cone beam computed tomography to show incisor crown anomaly, very early root development and location of the teeth in relation to the nasal floor. (d, e) The maxillary incisor crowns were exposed and eyelet attachments bonded with the eyelet in the same vertical line as the long axis of the teeth. (f) The surgical flap was fully sutured, with only the twisted steel pigtail ligatures engaging the raised self-supporting labial arch. (g) The radiographic occlusal view, showing the appliance and the ligature. (h) Regular orthodontic (Tip-Edge PLUS) brackets were placed on the newly erupted teeth. (i) The teeth were aligned and brought forwards with buccal coil springs, to provide space for the canines. (j, k) The canines were exposed and bonded. (l) The canines were torqued lingually. (m) Completed orthodontic treatment. Note the enamel hypoplasia adjacent to the gingival area of the incisor crowns and the unusual acute crown–root angle of the two maxillary canines, as seen in their profiles. (n) Periapical radiographs at the time of debonding the appliances. Note the growth of the incisor roots, with open apices still present. (o) Similar periapical views at four years post treatment show closure of the four incisor apices, including the left central incisor, which subsequently required root canal treatment. (p) At four years post treatment the normal appearance of the patient's smile and the excellent smile line, despite the marred hypoplastic area at the labial cervico-gingival junction. (q) Panoramic radiographs clearly exhibit the remarkable growth of the incisor roots.

On the other hand, a successful plan that attempted to enhance the attenuated innate eruptive force of these teeth would bring with it the benefits of providing the child with her own natural and adequate, if temporary, anterior dental rehabilitation. Furthermore, this would be accompanied by excellent natural regeneration, contributing materially to the replacement and reconstitution of the defective alveolar bone height. True, the prognosis of these teeth was unknown and the presence of orthodontic appliances in the mouth was also a risk factor for caries and gingival inflammation. Nevertheless, the expected treatment duration would be relatively short and the child would be under frequent and routine professional supervision, thereby reducing potential collateral damage to a minimum.

Molar bands with a soldered palatal arch were cemented and a removable self-supporting labial arch slotted into the round buccal tubes on the bands, as with the first phase of cleidocranial dysplasia (CCD) treatment (see Chapter 21).

At surgery, the four maxillary incisors were exposed, bonded with small eyelet attachments and the full flap sutured back to its former place, with the twisted steel pigtail ligatures emanating from the sutured edge (Figure 20.5d–g). In subsequent visits, the pigtail ligatures were rolled up higher as the teeth responded and a mandibular Johnson modified appliance was placed with the intention of intruding and proclining the lower incisors.

Once the incisors had erupted, orthodontic brackets were substituted for the eyelets on the incisors, which were then aligned and proclined labially (Figure 20.5h, i).

This provided sufficient space for the maxillary canine teeth, which were impacted in the line of the arch but had also suffered anomalous development as the result of the trauma, represented by an abnormal bucco-lingual crown–root angle, as may be seen in the completed case (Figure 20.5m).

A second surgical procedure was performed to expose and bond attachments to both maxillary canines (Figure 20.5j, k) and this was followed by full alignment of the remaining teeth (Figure 20.5l). In this final stage, mandibular second premolars were extracted to provide space to eliminate the lower crowding and to permit the necessary anchorage for class II traction to control the overjet.

Thus, in the final occlusion, the molars were brought to a full unit class III intercuspation, while the canines were normally related. In this manner, the orthodontic treatment was completed with a good smile line relationship between the lower lip and the incisal edges (Figure 20.5m). Treatment duration was 26 months, with bonded 3-3 twistflex retainers in place in both arches.

The immediate post-treatment radiographs (Figure 20.5n) show considerable root growth, which was believed to have been a most unlikely outcome in the pre-treatment location of these severely damaged teeth. It is reasonable to speculate that this length of root may have been the reward generated by the extrusion of the teeth away from the anatomically limiting nasal floor.

The follow-up records taken four years later, at age 17 years (Figure 20.5o–q), show further improvement in the root length, including the left central incisor, which required root canal treatment about nine months after the completion of the orthodontic treatment and after its root had apexified. The health of the teeth and surrounding tissues was good and the prognosis of the teeth appeared to be fairly good in the medium term. Nevertheless, there was a mildly marred appearance due to enamel hypoplasia and long clinical crowns of the affected teeth, despite the reshaping that was performed at that time. The patient was referred to a prosthodontist to rehabilitate the crowns of these teeth, while relying on the roots, which did not exist just a few short years earlier.

Case 20.6: Labial to the lateral incisor and lingual to the central incisor

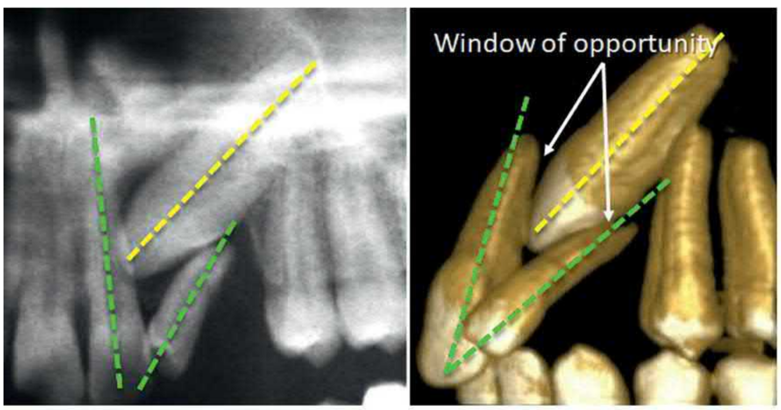
This 14-year-old male patient attended with what seemed a very minor problem. The dental arches in both jaws were well aligned and the occlusion textbook perfect. The posterior teeth met in a fully interdigitated class I occlusion, the incisor relations were ideal and there was a modicum of spacing generally in the dentition. The unerupted right maxillary canine was palpably in its ideal location, about to erupt and take its place in the dental arch. The only flaw was to be found in the left anterior maxilla, where the canine had not erupted. The long axis of the lateral incisor appeared to be proceeding apically, close to the horizontal, in a slowly rising distal and palatal direction, such that the root could be envisaged low down on the palatal surface, lingual to the line of the arch in the canine location (Figure 20.6a–e). Additionally, the tooth was rotated 30° mesio-labially, overlapping the adjacent central incisor.

In a situation like this, the clinician should always suspect a labial canine, with the strong possibility of a canine–lateral incisor transposition [11]. The scenario indicates a labially placed space-occupying body within the alveolus, the presence of which displaces the lateral incisor root palatally and distally. The displacing factor is usually an unerupted labial canine, which may be palpated on the labial side of the ridge, above the lateral incisor. However, on occasion, futile and vertically downward eruptive movement of a relatively high labial canine brings it more mesially and on the lingual side of a vertical root of the central incisor. Thus, the canine may end up straddling the ridge labial to the lateral incisor and lingual to the central incisor, in partial or complete transposition with the lateral incisor. Under these circumstances, the canine will not be palpable labially or lingually.


(a)


(b)


(c)



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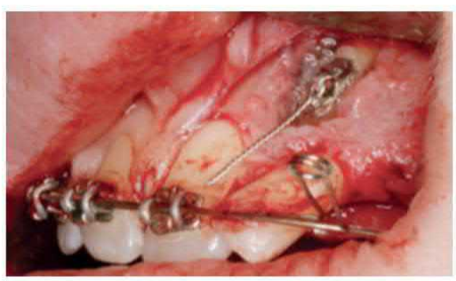
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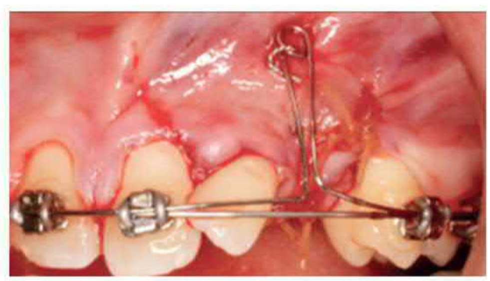
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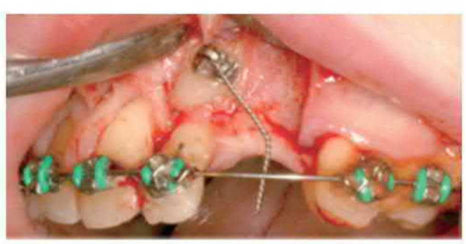
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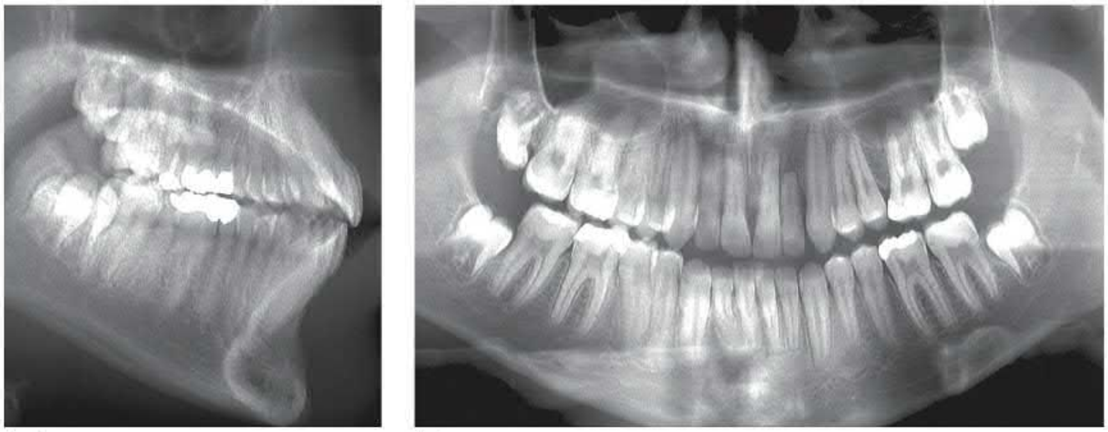


(m) (n)

Fig. 20.6 (a) Intra-oral views of the teeth in occlusion at the start of orthodontic treatment. (b) Planar radiograph: the anterior sector of the panoramic view shows the partial transposition of the canine vis-à-vis the lateral incisor. (c) The dentition as seen on the cephalogram shows the palatal location of the canine. The root of the lateral incisor and its labio-lingual relation to the adjacent teeth are not seen. (d) This is repeated from Figure 8.8, to illustrate the only logical 'escape route' for resolution of the transposed canine. (e) The auxiliary 0.016 in. labial arch in place, ligated piggyback over the 0.020 in. round main arch, in its passive (horizontal) mode. (f) At surgery, the canine was exposed only enough to present a small bonding surface on its labial side, without exposing further coronally towards the tip of the crown. (g) A small eyelet attachment was bonded and the labial flap was sutured back to its initial location, with only the twisted steel ligature emerging through the mid-flap, in the oral mucosa. (h) The loop of the auxiliary labial arch was flexed upwards in a quarter circle and held there by ensnaring it with the twisted ligature as close as possible to the oral mucosa–covered alveolar process. There was no bracket placed on the left lateral incisor at this point. Surgery by Dr Harvey D. Samen. (i, j) The second exposure of the canine, following its palpable labial movement and its distancing from the root of the lateral incisor. A broad flap was raised to the distal, which was the direction that further movement of the canine would be drawn. A bracket was bonded to the incisor and a root uprighting spring was placed. (k) The flap was fully sutured back over the canine, while further distally and inferiorly directed traction was applied to the pigtail twisted ligature. (l) Seen on the day the fixed appliances were debonded. (m, n) Immediate post-treatment radiographs: lateral cephalogram and panoramic views, which clearly show the root resorption of the lateral incisor.

The radiographs of this patient showed a full complement of teeth, including the unerupted third molars (not shown). The left maxillary canine was noted on the panoramic view to have migrated mesially and its crown tip was superimposed on the middle root area of the central incisor. On this film, the lateral incisor was tipped in the mesio-distal plane at an angle of 45°, with its partially resorbed apex displaced into the area of the alveolar ridge reserved for the canine.

From the CBCT, it was confirmed that the body of the canine was labial to the lateral incisor and its crown tip was palatal to the root of the central incisor (Figure 20.6h, i). Furthermore, root resorption of the lateral incisor root was identified as an oblique defect in the integrity of the normal root outline.

A maxillary orthodontic appliance was placed on all the erupted teeth from the first molars forwards on each side, with the exception of the ectopically oriented left lateral incisor. Immediately prior to the surgical exposure, a prepared auxiliary arch of 0.016 in. gauge was tied into the brackets with elastic modules, in piggyback fashion over the 0.020 in. steel base arch, with its active loop lying horizontally in its passive mode (Figure 20.6e).

Surgical exposure was undertaken from the labial side of the ridge under local anaesthetic and an eyelet attachment was bonded by the author at the time (Figure 20.6f, g). Access to the canine had to be carefully performed, since coincidental exposure of the apically and widely diverging roots of the two incisors needed to be explicitly avoided. It was for this reason that the left lateral incisor was left without a bracket. Any levelling, aligning or space-opening movement at this time would have immediately closed off the 'window of opportunity' and precluded labial movement of the canine.

The pigtail ligature from the bonded attachment was directed labially and slightly distally, to pierce the oral mucosa area of the surgical flap at the height of the canine. Once the attached gingival flap was fully sutured to its former place, the pigtail ligature was all that was visible intra-orally, high up in the sulcus, and was the only means of communication with the impacted tooth. The loop of the auxiliary archwire was then raised, turned towards the pigtail ligature and ensnared by turning the pigtail around its terminal loop, as close as possible to the oral mucosa (Figure 20.6h). This had the effect of applying traction to the canine, high up and in a labial direction, through the 'window of opportunity' provided by the widely divergent roots of the two incisors in the mesio-distal and bucco-lingual planes (Figure 20.6d).

In the subsequent 2–3 months the patient had considerable discomfort due to ulceration of the highly mobile oral mucosa from a slightly excessive length of the loop of the auxiliary archwire (Figure 20.6h), particularly as the canine moved labially and the active loop moved away from the alveolar ridge.

Once the canine had become labially palpable above the root of the lateral incisor (Figure 20.6i), it was time to begin the alignment of the incisor. This meant that the crown of the canine had become labially located to the almost horizontal incisor root. A bracket was placed on the incisor, whose aim was to de-rotate it and then to upright its root mesially, towards the central incisor. By doing this at this stage in the canine movement, the incisor root would cease to be an impediment and the canine would be presented with a clear vertical path directly to the main archwire.

There remained one further snag that still needed to be overcome. As mentioned, there had been no alternative to initially drawing the canine with a connector exiting the surgical field through the oral mucosa. To continue to draw the tooth down to the archwire would have resulted in the same sensitive, fragile and mobile mucosa supplying the canine with a gingival cuff, which would be highly vulnerable to damage from simple gustatory and other oral functions.

Accordingly, a periodontal procedure was used to re-expose the canine by raising a periodontal flap that included attached gingiva from the firm and stippled gingiva above the crest of the ridge (Figure 20.6j). The same twisted steel wire connector was then re-directed downwards and distally, to exit at the inferior edge of the re-sutured flap, using an elastic thread tie. The tooth could thus be drawn in the right direction, while still remaining unerupted and unexposed to the oral environment (Figure 20.6k), until it had emerged close to the crest of the ridge and, of greatest importance, through the attached gingiva.

With the eruption of the canine into its appropriate location, a bracket was substituted for the eyelet attachment and, as expected in the finishing stage, much labial root torque of the lateral incisor and lingual root torque of the canine were then applied.

After 25 months of treatment, the fixed appliances were removed (Figure 20.6l) and removable finishing and retaining appliances were placed. The radiographs show good root parallelism and good intra- and intermaxillary relationships of the teeth in the immediate area of concern (Figure 20.6m, n).

The lateral incisor, which had suffered pre-treatment root resorption, remained with a similar degree of root shortening, while some minimal and clinically insignificant resorptive blunting was noted of the apices of the maxillary central incisors. However, this case was treated in 2002, before the body of published studies on resorption in relation to the prevalence and treatment of impacted canines [6, 7]. At the time, it was not known whether confirmed root resorption would continue to threaten the tooth after completion of treatment. For this reason, the labial root torqueing mechanics of the lateral incisor were prematurely halted, for fear of losing the tooth.

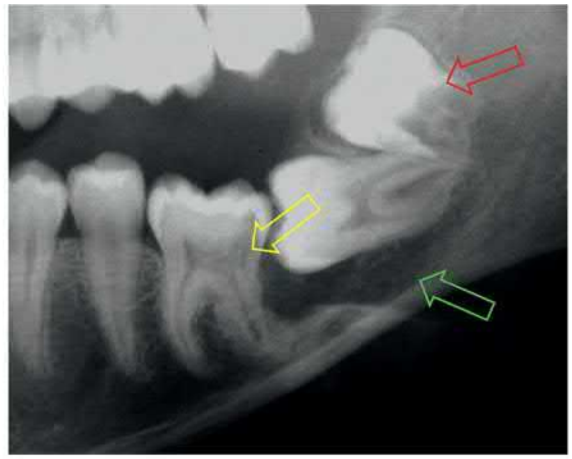
Case 20.7: Three adjacent impacted molars

This 13-year-old boy had an extraordinarily complicated eruption status and inter-relationship of the three adjacent left mandibular permanent molar teeth, each impacted in its own unusual way (Figure 20.7a). It was for this reason that the patient was referred to the author, both by the patient's dentist and from the office of an oral and maxillofacial surgeon. There was room only for two of those three molars. One molar needed to be extracted and two aligned, if this was possible. If not possible, then two needed to be extracted, assuming that only the third could be manoeuvred into a satisfactory location, in alignment and occlusion.

The first molar was significantly infra-occluded and only partially visible in its mesial occlusal surface. It was tipped slightly distally and both roots exhibited a distal curvature. The apex of its distal root was additionally hooked and was located close to the lower border of the mandible, but also uncomfortably close to the neurovascular bundle within the inferior alveolar canal.

The second molar was mesially tipped at a 105° angle to its normal vertical position, i.e. 15° below the horizonal, and it was lying on what appeared to be a cystic lesion, since it was totally asymptomatic (Figure 20.7b). The possibility of its being a chronic inflammatory lesion was also considered, but the absence of pain or discharge made this diagnosis less likely. Together with the horizontal width of the tooth itself, the lesion occupied almost the entire height of the mandibular body. The lesion had exposed the distal root of the first molar to its apex and also the entire mesial side of the root of the second molar, up to and including its apices, while extending downwards to resorb a significant area of the compact bone of the mandibular lower border. The periodontal prognosis of this tooth was very much in doubt.

(a)



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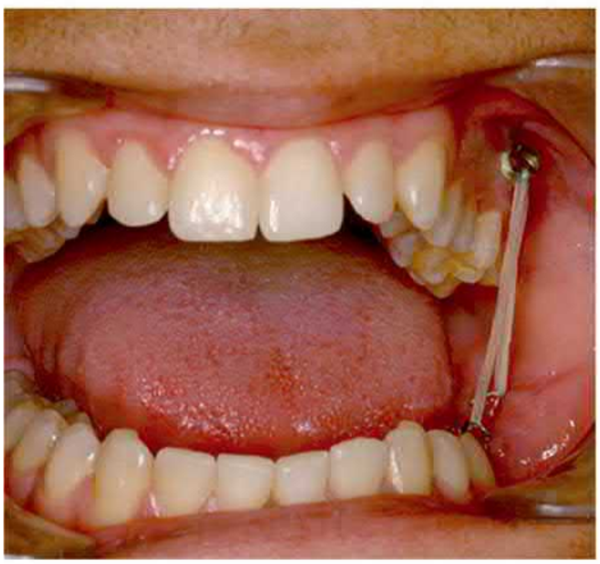
(c)



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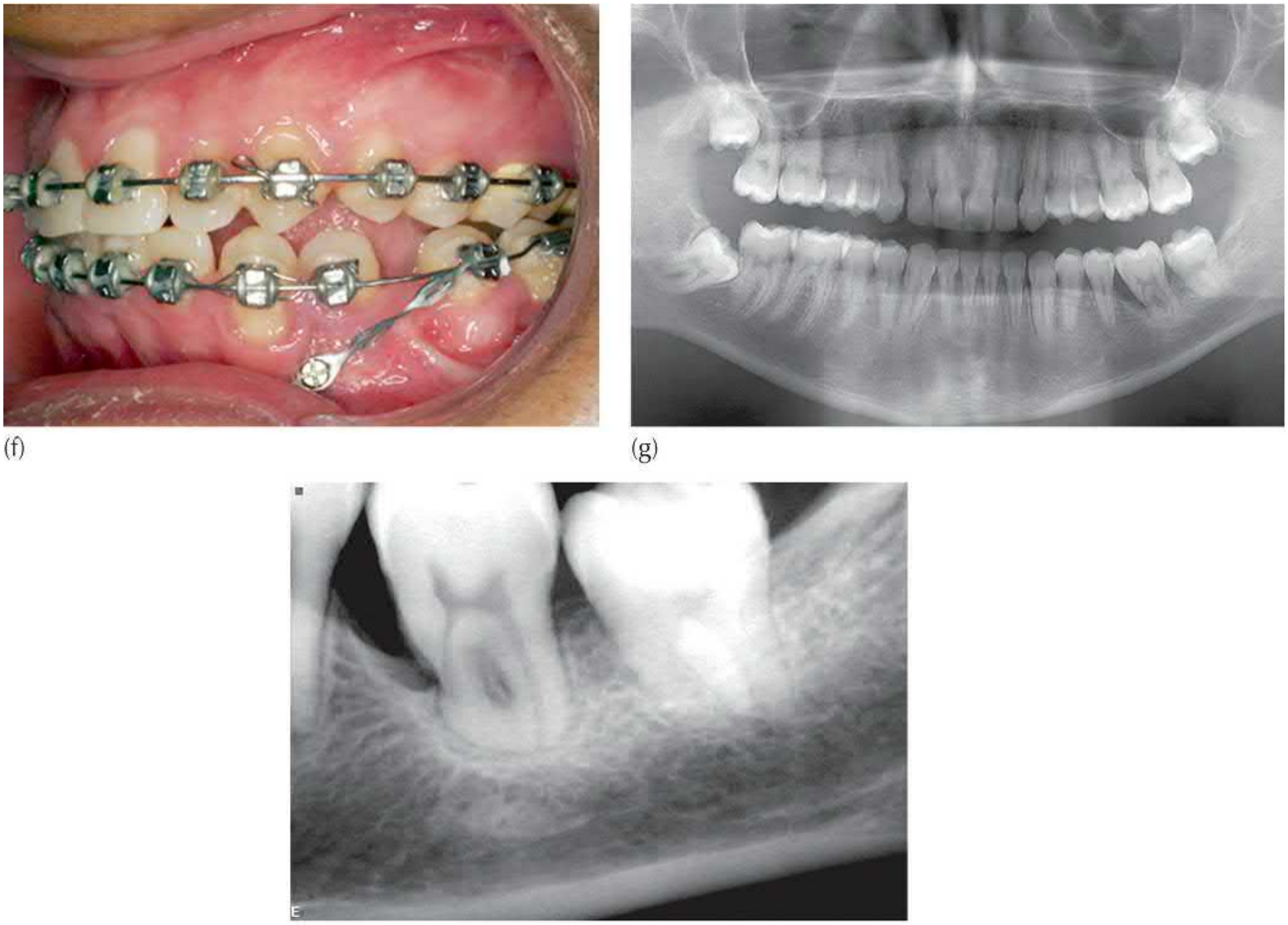


(f) (g) (h)

Fig. 20.7 (a) Initial panoramic view of the dentition at the commencement of treatment to solve the impasse of the three impacted mandibular molars of the left side. (b) The third molar was located in the anterior part of the ramus (red arrow), totally above the occlusal plane and at 45° to the horizontal. The second molar lay 105° to the vertical, with a large cystic area beneath it, having resorbed the bone down to the lower border (green arrow). The first molar, with a slight distal angulation, was infra-occluded, due to an invasive cervical root resorption lesion resorbing the distal half of the crown, from the cemento-enamel junction and extending inwards towards the pulp chamber (yellow arrow). (c) Surgical exposure and traction: the wound was packed to ensure access to the exposed second molar, following the open surgical exposure. (d) Elastic up-and-down traction drawn from the zygomatic plate to the twisted wire hook of one or other of the eyelets. (e) Full multi-bracketed appliances: the second molar was fully uprighted before an attachment was placed on the newly exposed third molar. (f) A screw temporary attachment device was used as anchorage for further space-closing and uprighting movements of the molars. (g) Post-treatment radiographic follow-up: the panoramic view shows the two molars in their place with slightly relapsed mesial tip. (h) Excellent bony regeneration has occurred and there is a significantly increased mandibular height. Despite the reduced level of alveolar bone around the roots of the molars, bony trabeculation is impressive, in support of the two molars.

The third molar lay above and distal to the second molar, in the anterior part of the ramus, and was mesially tipped 45° to the horizontal at a level that was considerably higher than the mandibular occlusal plane.

Treatment options

In the referral letter, the dentist had suggested that the third molar be extracted, the soft tissue lesion curetted, the second molar orthodontically uprighted and the first molar orthodontically raised into occlusion. The surgeon, on the other hand, had suggested extraction of the second molar, followed by orthodontic uprighting, intrusion and space closure by the third molar and active eruption of the first molar into occlusion. He had noted that extreme care would need to be exercised because of the possible danger of mandibular fracture during an extraction, because the pathological bone resorption caused by the lesion had obviously weakened the mandible. The third treatment possibility was extraction of the first molar and then undertaking a very difficult series of orthodontic acrobatics to erupt and upright the two remaining molars.

The orthodontist, while cognizant of each of these relevant clinical and radiographic observations, was committed to asking the key question: 'Why?' Why was the molar infra-occluded? After all, the first molar would normally have been present in the mouth approximately six years prior to the second molar and four years prior to the second premolar. It would reach the occlusal level within a few weeks or months of eruption. Why should it subsequently infra-occlude?

We are therefore left with the question: Is each of these treatment options equally viable? The missing element in this conundrum is the diagnosis.

Diagnosis and treatment plan

A careful examination of the radiograph revealed that the distal root of the first molar had a 'woolly' appearance and there was a distinct degree of radiolucency of that root and within the distal part of the crown of the tooth. The diagnosis was extensive invasive cervical root resorption (ICRR) [12], which characteristically prevents further eruption and commonly affects the configuration of the roots (see Chapters 7 and 16). Its initiation was probably due to the long-term presence of the chronic inflammatory lesion.

With the diagnosis of ICRR, this meant that neither natural nor appliance-generated eruption could be expected to succeed. Additionally, because so much of the distal portion of the root and crown of the tooth had been destroyed by the resorption process, its prognosis of ever becoming a restored tooth was considered to be close to zero. Accordingly, the choice for extraction fell to this first molar. The orthodontic treatment *per se* was based on an otherwise non-extraction approach, which meant that considerable thought needed to be given to the provision of adequate anchorage for the uprighting and mesial movement of the second and third molar teeth. A maxillary zygomatic plate was used for the purpose of uprighting the second molar, followed by a screw temporary attachment device (TAD) placed in the premolar region of the left side of the mandible for subsequent mesial space-closing mechanics.

Treatment

The first molar was very carefully extracted in pieces, which were found to have been hollowed out with resorption mush, as expected. At the same time, the cystic lesion beneath the second molar was treated conservatively with curettage. An open procedure was used to expose the second molar and place two eyelets, to each of which was tied a twisted steel ligature hook, and the surgical wound was packed during the healing period (Figure 20.7c). In the maxilla, a zygomatic plate was placed, direct elastic intermaxillary (up-and-down) traction was subsequently applied by the patient (Figure 20.7d) and the elastic rings were then renewed daily.

Once the second molar tooth had uprighted sufficiently (Figure 20.7e), the eyelets were removed, a routine horizontal molar tube was substituted and full upper and lower fixed orthodontic appliances were fitted to address the overall class II malocclusion, as well as the local molar problem. A screw TAD was then placed between the premolars of that side, so that uprighting and mesial movement could be performed together, with both intermaxillary and molar-to-TAD horizontal elastic traction simultaneously (Figure 20.7f).

Subsequently, the third molar was surgically exposed and similar mechanics applied to upright it and draw it mesially. For the final space closure, the TAD was relocated to the canine–first premolar interproximal bone.

Treatment duration and outcome

In the final instance treatment lasted six years, because of the biomechanical difficulty and the amount of orthodontic movement that was needed for each of these two molar teeth. It should be appreciated that the resolution of the third molar could only be initiated after the second molar had been brought to its place.

The first 1½ years of treatment were devoted solely to raising the second molar, without the placement of appliances on the other teeth. The appliances were only placed when the time came to effect mesial movement of the second and then the third molars.

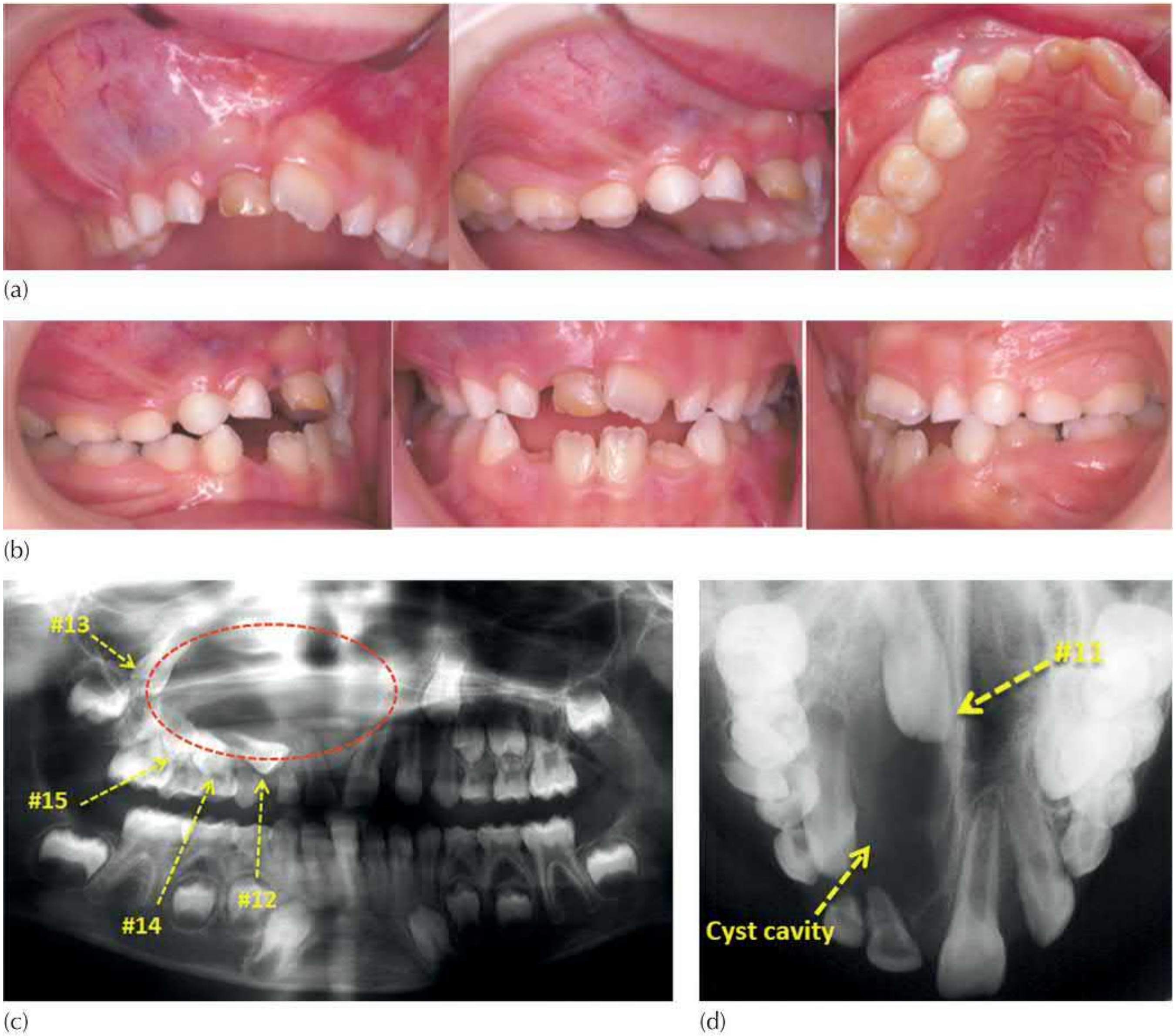
The follow-up radiographic views of the area showed excellent bony regeneration, with the production of well-calcified and trabeculated bone around the apices of the two molars (Figure 20.7g, h). However, while much regeneration of bone had also occurred in the area of the extracted infra-occluded first molar, the mesial side of the second molar root was bounded by an infra-bony pocket that required a specific oral hygiene regimen for the maintenance of its periodontal health. A comparison of the pre-treatment and post-treatment panoramic films indicates a marked increase in the height of the mandibular body between the apices of the molars and the lower border of the mandible.

Case 20.8: Five unerupted teeth in the walls of a dentigerous cyst

In Chapter 14 we saw how teeth that have been dispersed from their normal locations by an expanding dentigerous cyst will characteristically improve their positions when the pathological entity has been eliminated. Some appear to return to their original or improved locations with amazing precision, provided that the orthodontist is prepared to be very patient and not intervene too early with orthodontic procedures. In the case offered here, however, the phase 2 biomechanics were very involved and required the practitioner to consider some extraordinary measures to achieve the correction of grossly displaced teeth, particularly in relation to root movements.

In the case of this 7.6-year-old boy, there was marked swelling on the inner and outer aspects of the alveolar processes, which was reflected by swelling of the right side of his face. Intra-orally, there was over-retention of the deciduous teeth in the area and non-eruption of the permanent teeth, which would normally have been close to spontaneously erupting at this time (Figure 20.8a, b).

The maxillary right deciduous central incisor was discoloured and non-vital. Radiographs (Figure 20.8b) indicated severe displacement of all the permanent teeth on that side of the maxilla, extending from the anterior midline to the molar region, as well as an upward extension of the cyst, raising the floor of the maxillary sinus.


(a)
(b)
#13
#15
#14
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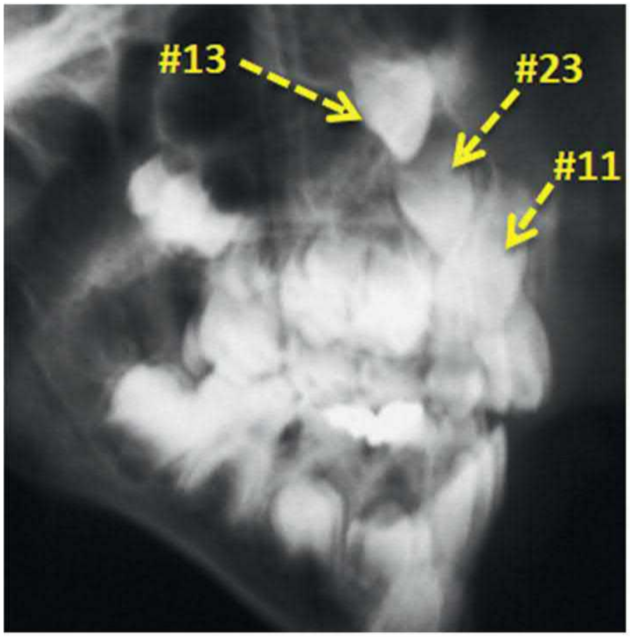
#11
Cyst cavity
(d)



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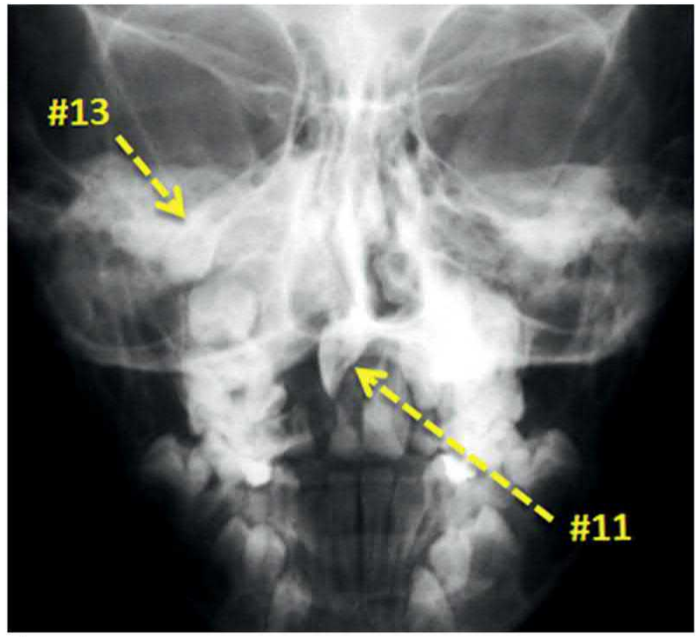

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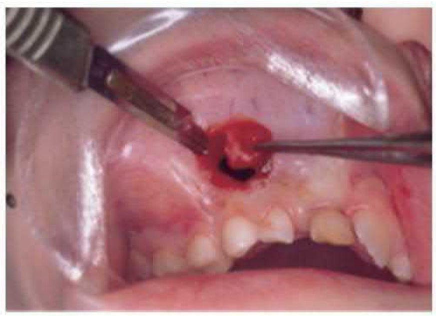
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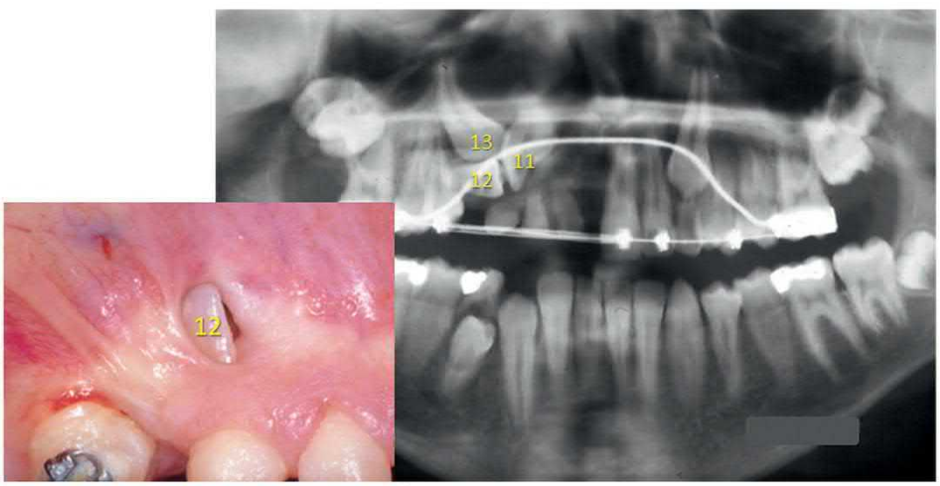
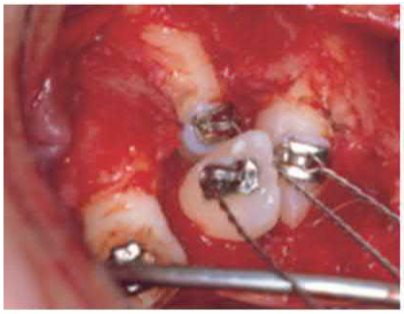
(i)



(j) (k)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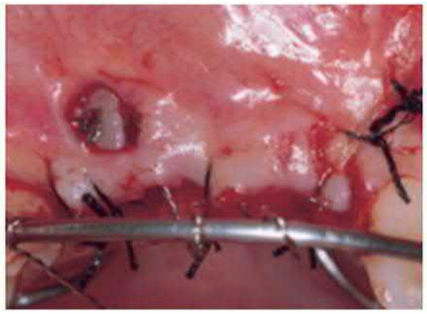
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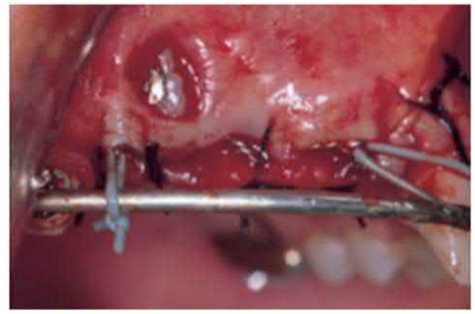
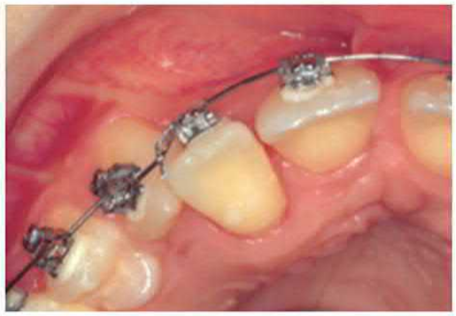
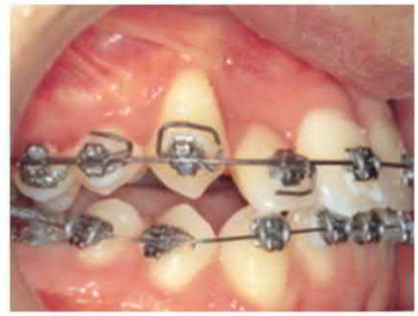

(n)


(o)


(p)


(q)


(r)


(s)


(t)

Fig. 20.8 (a) Intra-oral views of the considerable expansion of the maxilla on both sides of the alveolar ridge, on the right side. (b) Intra-oral photographs of the teeth in occlusion. (c) Panoramic radiograph defines the extent of the cyst according to the dispersion of the teeth in its lining. The central incisor is not visible, since it is beyond the focal trough. (d) In the anterior occlusal view, the central incisor is seen very high in the maxilla. (e) Lateral cephalogram and (f) postero-anterior cephalogram added further information in the a–p and coronal planes. (g) Draining the cyst with a syringe, followed (h) by enlargement of the opening into a stomium, to encourage re-healing of the cyst lining with the oral mucosa and thus to maintain the opening in the long term. (i) Lightly packed with ribbon gauze soaked in Whitehead's varnish. Courtesy of Prof. A. Shteyer. (j) Ready for phase 2 orthodontics after 39 months of follow-up, seeing the teeth coming together within the cyst cavity: the appearance of the lateral incisor at the stomium. (k) Panoramic radiograph with the new orthodontic appliance in place, following levelling, alignment and space opening for the remaining three unerupted teeth. (l) Surgical exposure of the impacted teeth: eyelet bonding on the three teeth, of which the canine and the lateral incisor are transposed and the canine is palatal. (m) The flap was sutured back and the twisted ligature connector temporarily turned over the customized tube that had been placed over the archwire. (n) Initial directional traction to the two incisors was applied to the two incisors, but the connector belonging to the canine left without traction until a later date, when the obstructive lateral incisor was distanced. (o) 'Ball park' orthodontics: the transposition has been corrected, but (p) the degree of divergence of the bucco-lingual axial relation of the canine and lateral incisor roots can be seen to be of the order of 90°, which (q) was treated using individual reciprocal torqueing springs. (r) The results of the use of these individual torqueing springs. (s) The final alignment and occlusion of the teeth in this case. The right lateral incisor and canine both have a minor degree of crown elongation. (t) The right central incisor is significantly dilacerated and the right canine exhibits both minor dilaceration and an obliterated pulp.

The radiographic pattern of the displacement clearly demarcated the extent of the cyst (Figure 20.8c–f). The maxillary central incisor of that side had been pushed superiorly and mesially across the midline. The root apices of the lateral incisor and, to a lesser extent, the two premolars were pushed inferiorly and distally, causing these teeth to recline almost horizontally above their deciduous predecessors in the floor of the cyst. At the same time, the canine had been displaced superiorly and laterally in close relation to the floor of the orbit.

Given the orientation of these teeth, together with the presence of a non-vital deciduous incisor, it seemed likely that the cyst was radicular, although this was by no means certain. With much of the right side of the patient's maxilla virtually devoid of bone, there had been the distinct risk that a minor blow to the face could cause a pathological fracture of the facial skeleton. Since the condition was almost entirely symptomless, it is likely that this could have been the presenting symptom.

Under the influence of infiltration local anaesthesia, the fluid was first drained from the cyst using a syringe and wide-bore needle, which easily passed directly through the buccal sulcus area of what was the bony alveolar ridge. The ridge had become expanded and extremely thin due to the size of the cyst. A relatively large quantity of brownish liquid was withdrawn from the cyst into the syringe. A circular incision was made in the immediate area over the cyst, to produce a hole in the oral mucosa about 10 mm in diameter, communicating directly with the cyst (Figure 20.8g–i). The oral mucosa and cyst lining were left to heal and become contiguous, while the hole itself remained patent. The excised tissue was sent for pathological examination and found to be innocent and consistent with benign cystic epithelium.

The patient was seen periodically during the following months, in order to change and reduce the size of the dressing as the cyst became progressively smaller. In the accompanying radiographic follow-up, the teeth were seen to be coming together in the wake of the reduction of the volume of the cavity, until the lateral incisor could be seen peeking through the stomium.

In the 39-month follow-up period, the widely dispersed teeth in the walls of the cyst were seen to improve their positions and to come together. This was a clear indication that the cyst had disappeared and that there had been a considerable filling-in of the bony defect, with eruption of the lateral incisor through the stomium (Figure 20.8j, k) [8].

At this point, a fixed orthodontic bonded appliance, with a soldered transpalatal bar, was placed on the erupted teeth. This would act as a composite anchorage unit (Figure 20.08k) for the extrusion and alignment of the teeth within the former cyst cavity. The central incisor of the healthy left side of the maxilla had traversed the midline and the first premolar on the affected right side had partially erupted, mesio-lingually rotated and mesially displaced. A simple coil spring was placed between the two teeth and, after initial levelling, was activated to move the premolar distally and correct its rotation, while reciprocally moving the left central incisor back to the midline. This effectively opened more than adequate space to accommodate the three impacted teeth. A heavy archwire was then placed in the brackets of the maxillary teeth, with a customized cut length of over-sized steel tube, suitably curved to correspond to the archform. This was aimed at stabilizing and maintaining the long span of unattached archwire between the midline and the first premolar (Figure 20.8l–n).

In the Department of Oral and Maxillofacial Surgery of the Hadassah-Hebrew University Dental School, the relatively simple and minor surgical exposure of the now very superficial crowns of the three teeth was then undertaken on an ambulatory basis, under local anaesthetic. A full labial attached gingival flap was raised from the crest of the ridge in order to expose the three teeth. Small eyelets were bonded in strategic positions, with twisted steel pigtail ligatures threaded into the lumen. The periphery of the stomium had originally been cut within the free and mobile oral mucosa. Accordingly, the edges of the stomium were freshened before being sutured together, in order for them to heal over and avoid becoming a part of the gingival cuff of the newly erupted teeth. The surgical area was then fully closed and the pigtail ligatures were taken through the sutured attached gingival edges of the flap (Figure 20.8m, n).

Before the patient was released from the operatory, directional elastic traction was applied between these steel ligatures and the main archwire. The elastic traction was renewed periodically, until the teeth had fully erupted and been brought into approximate alignment. At that stage, sophisticated brackets of the same type as were used on the other teeth were substituted for the eyelets. The treatment was continued until full alignment was achieved and, it should particularly be noted, until the extreme amount of root uprighting and root torque was completed (Figure 20.8o–q).

As already pointed out in Chapter 14, teeth that are displaced and lie in the walls of a dentigerous or radicular cyst often seem to exhibit root dilaceration. This is clearly due to the fact that they developed in reduced circumstances of space and pressure. This particular case had proven to be no exception.

Orthodontic brackets have been developed over the years to incorporate various highly sophisticated slot angle prescriptions and ligature tie alternatives. This has rendered them versatile in aligning, rotating, tipping, uprighting and torqueing the teeth. The new brackets have enabled the orthodontist to treat well over 90% of cases without having to change attachments. It is now possible to achieve excellent alignment, offsets, tip, torque and inter-arch relationships of the teeth (Figure 20.8r, s). The prerequisites for these brackets to achieve their goal are that they be placed in the mid-buccal position of the teeth and, at the end of the treatment, that a full-sized archwire be fully tied into them to allow them to realize their maximum programmed potential.

When the ideal bonding site of a tooth is not accessible, the method adopted by most orthodontic practitioners is to place their regular 'straight wire' bracket at a different site on the tooth, where it can be used to achieve some alignment and levelling. In this position, however, it cannot be used to realize the full potential of the prescription slot (a prescription that is able to perform any other type of movement with considerable accuracy and efficiency), nor would one want it to, unless a series of complicated bends are introduced into the archwire by way of compensation. For these and other cases of significant displacement, it is difficult to ligate the archwire into the bracket. This stage of the treatment accordingly becomes very clumsy and inefficient, slowing down the momentum of the desired correction. The use of an initial temporary and non-specific attachment is to be preferred, or, alternatively, the archwire must be modified with a series of offsets and loops.

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21
Cleidocranial Dysplasia

Adrian Becker

Clinical features and dental characteristics

Diagnosis

Treatment modalities

Recognition of the clinical features

What about the skeletal class III relationship in cleidocranial dysplasia patients?

What management protocol can be used to achieve this level of compliance?

Erupting the permanent teeth

Surgical therapeutic measures

Orthodontic strategy

Preparing the patient

The Jerusalem approach in clinical practice

Extreme tooth movement

Retention of the treated result

Orthognathic surgery

Clinical features and dental characteristics

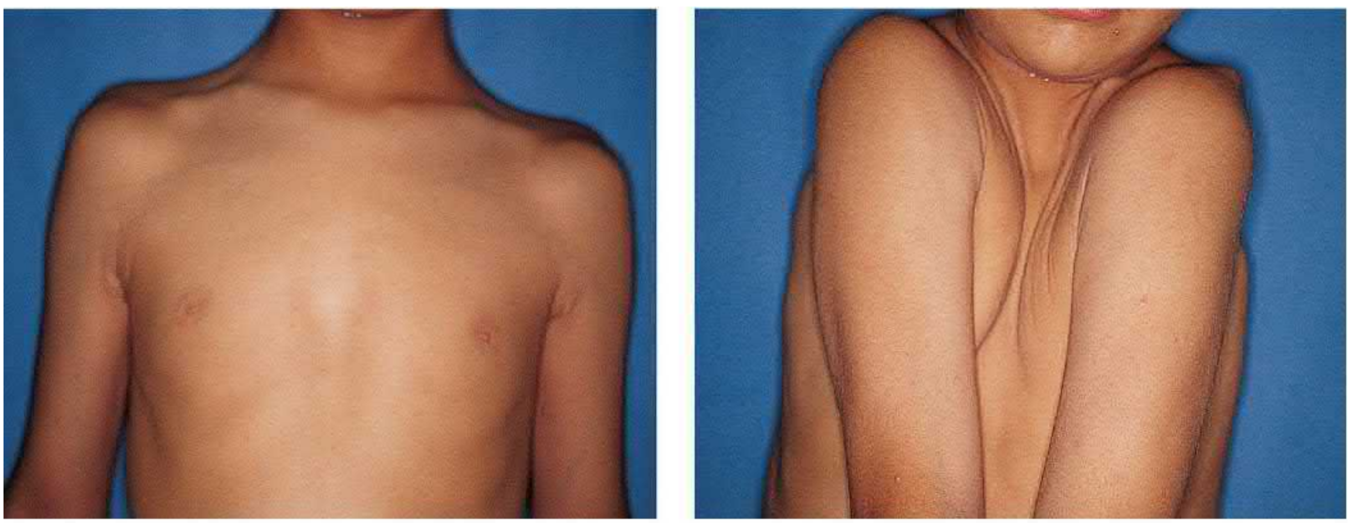
The cleidocranial dysplasia (CCD; previously referred to as cleidocranial dysostosis) patient is typically of short stature, with a brachycephalic skull and bossing of the parietal and frontal bones. There is hypoplasia of the mid-face, giving the (misleading) appearance of mandibular prognathism. The skull sutures and fontanelles exhibit delayed closure and, with the formation of wormian bones, secondary centres of ossification occur in these areas. The development of the clavicles is defective and ranges from a small medial gap to total absence in severe cases []. The patient usually has a narrow chest and sloping shoulders.

According to Stewart and Prescott [8], more than 100 other anomalies have been associated with these major clinical features of the condition. CCD does not affect sufferers mentally or intellectually and, from this limited aspect, they are completely normal. The palate is narrow and occasionally high, and there is a marked degree of lateness in the development of the deciduous dentition, while eruption is generally normal. There is rarely any alteration in the number of the deciduous teeth, although on occasion erupted supernumerary/supplemental deciduous teeth may be found in the incisor area. The permanent molars usually erupt late, although spontaneously, while the remainder of the permanent dentition (i.e. the successional teeth – incisor, canines and premolars) exhibit very delayed eruption and even complete non-eruption. Additionally, supernumerary teeth typically develop in the successional teeth areas and much less frequently in the molar areas in numbers that may even reach double figures. While higher numbers are uncommon in these cases, the highest recorded number of supernumerary teeth that has been reported in the literature was 63 [9]. Apart from barrel-shaped teeth and the rare occurrence of peg-shaped teeth in the maxillary incisor area, the supernumerary teeth take the form of premolars in the premolar area, canines in the canine area and incisors in the incisor area. They may therefore be more accurately called 'supplemental teeth'.

At the other end of the scale, the author's experience with a large number of CCD patients has revealed two patients with the correct number of teeth, another with congenitally missing maxillary lateral incisors and yet another with a missing third molar.

Equally affecting males and females, CCD is an autosomal dominant inherited disease [4] with a high incidence of new mutations at around 20–40% of all cases [5]. Part of the RUNX family of transcription factors, RUNX2 (Runt-related transcription factor 2) is known to be the gene directly involved. It encodes a nuclear protein, 521 amino acids (56648 Da), with a Runt DNA-binding domain. RUNX2 is essential for osteoblastic differentiation and skeletal morphogenesis, acting as a scaffold for nucleic acids and regulatory factors involved in skeletal gene expression.

RUNX2 is the only gene specific to the aetiology of CCD, with sequence analysis showing 60–70% of CCD patients who present with a missense or nonsense mutations, small insertions or deletions and exon skipping. Among the remaining 30–40% of patients with mutations, 13% may, by other means of testing (karyotype for visible deletions, insertions and rearrangements involving the RUNX2 locus in chromosome 6p21, quantitative polymerase chain reaction [qPCR], real-time PCR, fluorescence *in situ* hybridization [FISH], etc.), be found to have large deletions of this specific gene and of the genes following. Mutations in the RUNX2 gene span the whole gene and are highly penetrant.



(a) (b)

Fig. 21.1 (a, b) The approximated shoulders of a cleidocranial dysplasia patient.

There is no clear genotype/phenotype correlation in CCD. When mutations of RUNX2 are found, they are pathognomonic of the disease and phenotypes of other diseases are not associated with them [10].

Approximately one-third of the cases that we have seen have been random occurrences, with no family history of the condition. Most of the cases that have been under our care come from families where one parent was affected and diagnosis was usually (but not always) made at birth. For most of the other cases, a tentative or initial diagnosis was suspected by the child's paediatrician or orthopaedist only several years into the child's life. The discovery may sometimes be made at a routine paediatric dental examination. Corroborative evidence from a clinical examination and a wider radiological examination would then be obtained to establish the definitive diagnosis. During this physical examination, the clinician should attempt to confirm as many of the features described above as possible. In particular, the patient should be asked to approximate the shoulders to confirm the clavicle anomaly (Figure 21.1).

Palpation should then be done of the areas between the parietal bones on the crown of the skull, as well as between the frontal bones at the upper forehead/hairline region. In both of these midline areas, a smooth and wide hollow, concavity or furrow (Figure 21.2) may be clearly felt, in contrast to the convex contour of the skull of a normal child.

A radiological examination is the next to be performed, to include views of the clavicles (Figure 21.3), the fontanelles, which may be seen on lateral and postero-anterior cephalometric films (Figure 21.4a, b), and an initial panoramic film of the jaws (Figure 21.5).

In addition to the principal bony defects of the cranium and clavicles, a significant proportion of CCD individuals suffer other skeletal and orthopaedic anomalies. According to a study by Cooper et al. in 2001, 57% suffer from flat feet, 28% from knock knees and 18% from scoliosis, while joint dislocation of the shoulder and elbow may also occur [11]. Additionally, infections of the upper respiratory tract are common, specifically the sinuses and the ears, where conductive hearing loss occurs in 39% of cases. Treatment for these associated conditions is indicated and should be performed by the paediatric specialist concerned. For the most part, the signs and symptoms of the condition are very distinct and, these predispositions aside, entirely benign. They are in no way progressive, the patient is not physically or mentally disabled and, in general, other body systems are not adversely affected.

Fig. 21.2 Frontal midline furrow passing through the hairline.

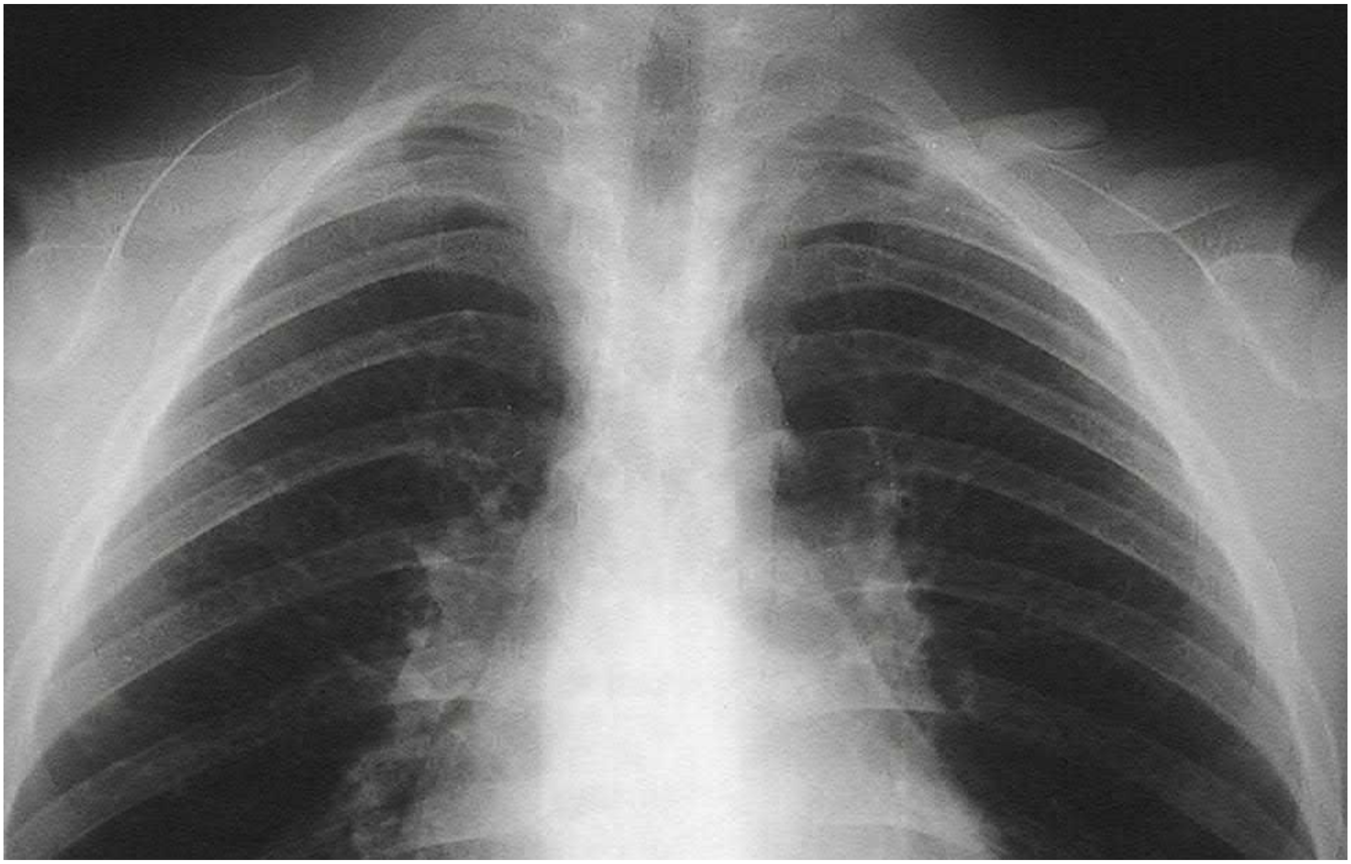
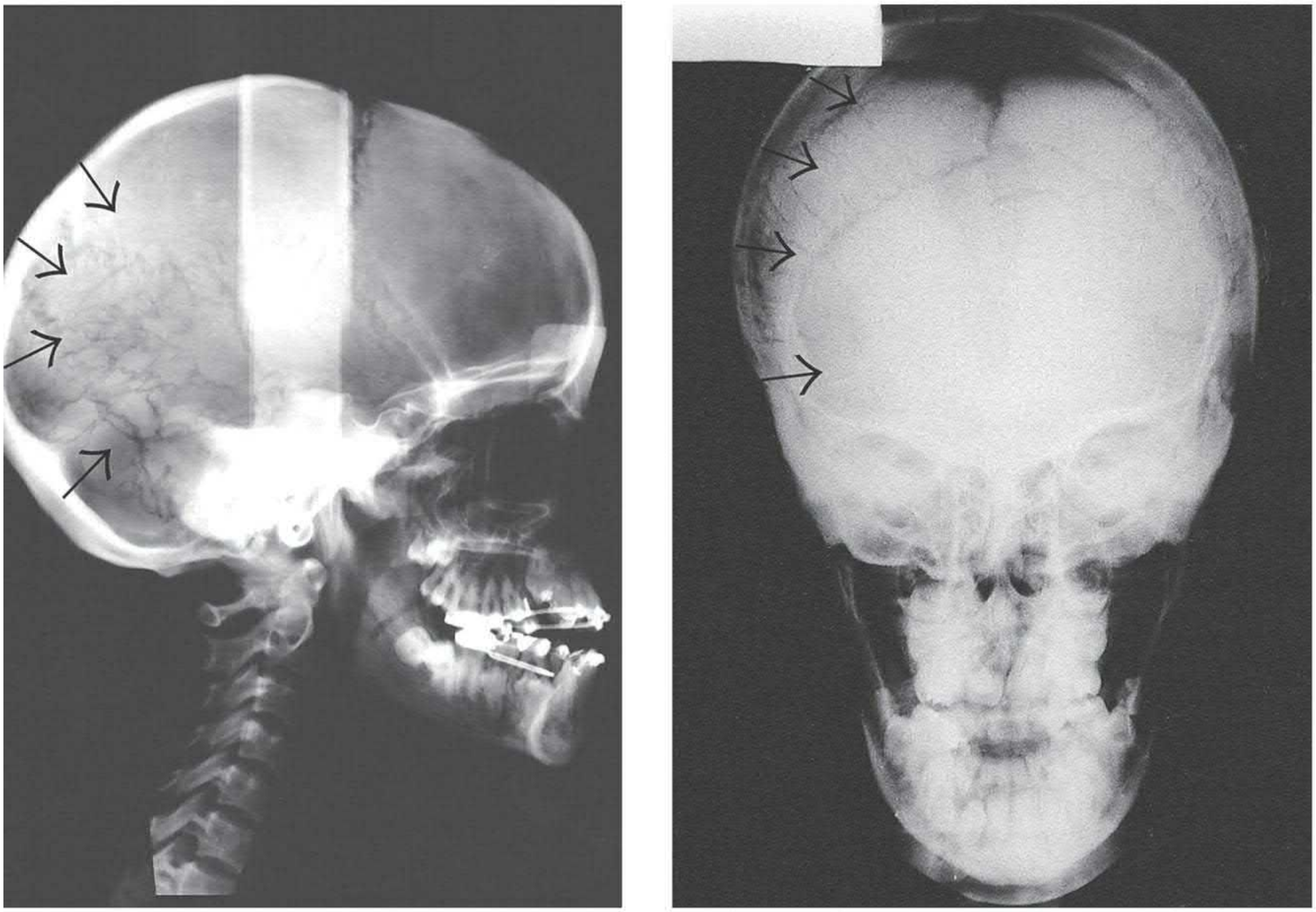


Fig. 21.3 Chest radiograph to show incomplete clavicles.

At present, there is no way to change the underlying inherited condition. Treatment cannot therefore be advised for the primary condition [5, 6] and its diagnosis does little more than label the child as an oddity. The only situation where treatment is needed is when one or more of the associated conditions becomes burdensome. Indeed, it is the often associated oral and dental disability that undoubtedly presents CCD's most serious ramifications. This disability affects the vertical and horizontal growth of the face and oral structures, including alveolar bone and teeth. These clinical features are surprisingly well known to students and to experienced practitioners in the dental profession, quite out of all proportion to the rarity of the condition. This mainly reflects the curiosity value rather than any demonstration of ability on the part of the profession to bring about change and correction in the past. For many decades, the profession has stood in awe of the overwhelming number of dental problems that these cases present, quite unable to offer satisfactory answers. The CCD patient presents with a potentially overwhelming list of dental disabilities.

The dental characteristics of the typical CCD patient will include over-retention of the deciduous dentition, non-eruption of the permanent dentition and the presence of many supernumerary teeth (Figure 21.5). Nevertheless, there is no dental discomfort or disturbance, unless the deciduous teeth become decayed. The deciduous teeth are small relative to the growing face and are not visible below the upper lip, particularly when an anterior open bite is present, which itself seems to be quite prevalent in CCD. In many cases in the rest position, it is the forward-postured tongue that is visible between the lips (Figure 21.6). The horizontal growth pattern generally produces a mandible of normal length and an under-developed maxilla, which therefore produces a skeletal and dental class III relationship. However, this relationship is not always initially present in the younger patient, but may gather momentum, to a greater or lesser degree, during the adolescent growth spurt [12] (Figure 21.7). This trend is by no means certain and, as they complete the development of their facial pattern at the end of the adolescent growth period, there are cases of good class 1 relationships and even the occasional class 2 case may be diagnosed. The vertical growth of the alveolar processes is generally deficient, which leaves the patient with very shallow labial and lingual sulci in both jaws. Taken together, these features give the patient an edentulous appearance, which may often be the presenting symptom.



(a) (b)

Fig. 21.4 (a, b) The postero-anterior and lateral cephalograms show abnormal cranial form, open fontanelles and numerous wormian bones (arrows).

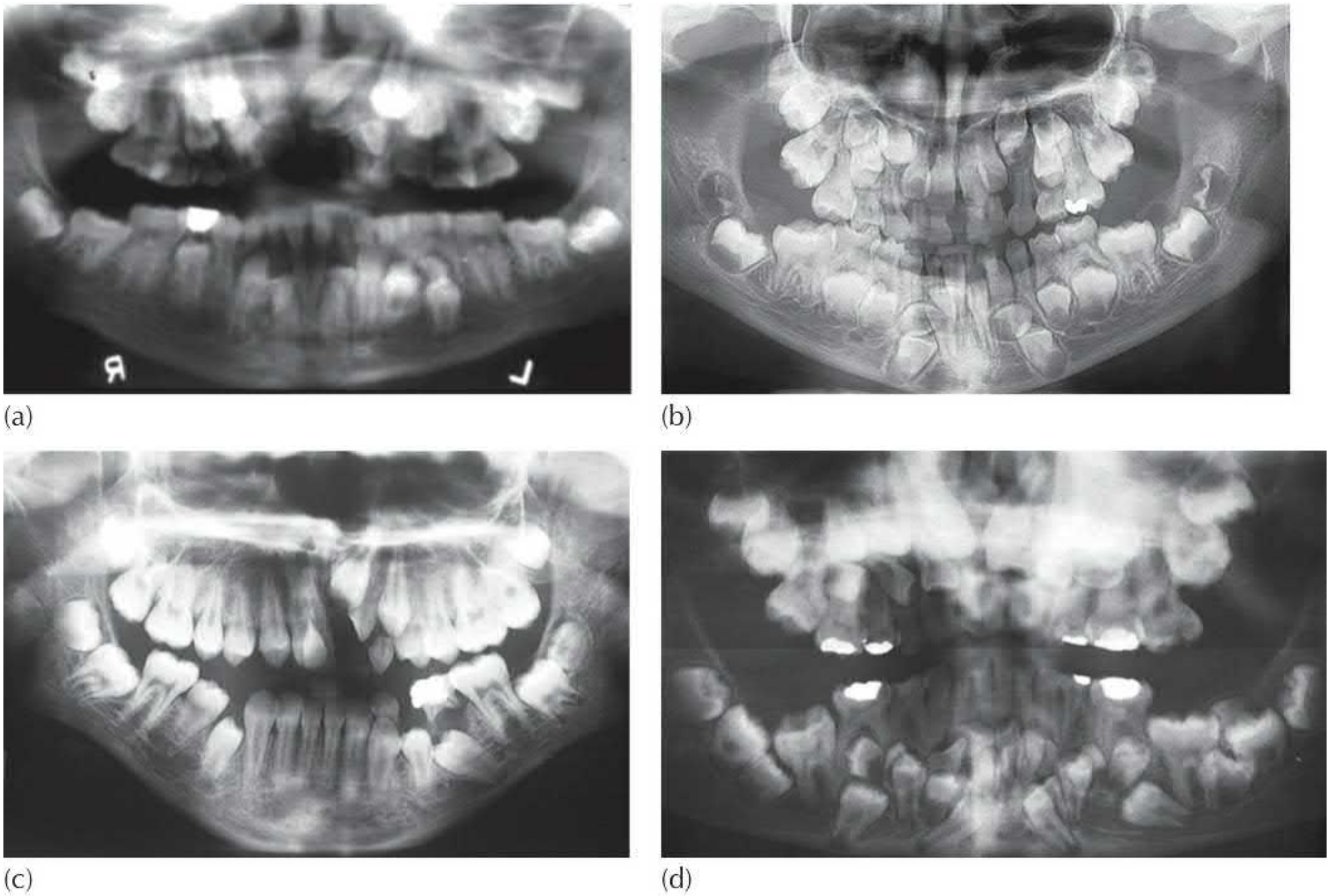


Fig. 21.5 Variation in number of supernumerary teeth in cleidocranial dysplasia patients. (a) A 14-year-old female with eight extra teeth. (b) A 13-year-old female with six extra teeth. (c) A 13-year-old male with one mesiodens. (d) A 15-year-old female with a full deciduous dentition and two erupted supernumerary deciduous maxillary lateral incisors (22 in total). Only one erupted (deeply carious) permanent molar is present. There are 27 supernumerary teeth, in addition to the 31 unerupted permanent teeth – a total of 81 teeth. Note the presence of supplemental molar teeth.

Fig. 21.6 The tongue is visible at rest, postured forward between the anterior teeth and the lips.

Some light has been shed in these cases on a possible reason for the non-resorption and over-retention of the deciduous teeth and the non-eruption of the permanent teeth [13]. It has been proposed that decreased root surface resorption occurs in the deciduous teeth due to a thin, uniform layer of resorption-resistant acellular cementum covering virtually the entire root. In the permanent teeth, very little cellular cementum is seen on the roots of the teeth. However, secondary deposition of reparative cementum is found in areas of focal resorptive defects and this may be blamed for the non-eruption of the permanent teeth.

In view of these facts, the following circumstances will be of relevance:

- The child with CCD has little by way of a tangible complaint involving general or local pathology (no pain, no swelling, no difficulty in day-to-day functioning), yet the dentist has diagnosed a benign condition requiring treatment of extraordinarily comprehensive therapeutic magnitude.
- The dentist has few available guidelines on how to even begin to approach the resolution of the overall problem.
- A practitioner seeing a case for the first time is unable to predict treatment results.
- The degree of facial deformity is usually of insufficient consequence to demand surgical modification, at least in the younger patient.

It therefore follows that it is entirely understandable that responsible dentists will hesitate before undertaking treatment. They will be faced with the following options:

- Not to offer treatment at all.
- To suggest the more radical approach of extraction of many teeth, followed by implant-borne prosthodontic replacement and rehabilitation.
- To advise an orthodontic–surgical treatment procedure, with an unknown level of confidence in their own ability to achieve the desired outcome, namely to provide an efficient

masticatory apparatus and improvements in the dental appearance and the facial proportions.

Non-treatment becomes less of an option as the patient becomes a teenager. Due to considerable occlusal attrition and caries, there will be progressive morbidity of the deciduous dentition, which will start in the early teens and gather pace over just a few years. Root canal treatment may often be needed and restoration becomes difficult. The patient's appearance may suffer further, with a reduced lower face height [14], impaired masticatory function and continuing facial growth contributing to the increasing over-closed appearance. Non-treatment is not therefore a viable option.

Diagnosis

Most cases of CCD will have been diagnosed by the paediatrician in the first years of an infant's life. Others are diagnosed by the orthodontist after the child has been referred by various agencies, including medical specialties and general dental practitioners or dental specialists, who suspect that the child is suffering from CCD. Those with a family history of the condition will obviously be diagnosed earliest, because this fact will have given the parent and doctor advanced warning of this possibility.

Among those without a family history, diagnosis may not be made until much later, since there are relatively few signs and symptoms that will indicate abnormality and the need for a more focused examination. These children's physical development may be noticeably slower and their stature will be relatively shorter, although characteristic facial features may be relatively less pronounced. On the other hand, they are usually bright children, quick learners, with no behavioural problems and socially well adjusted – and it is these attributes that may tend to mislead even the enquiring mind away from the possible existence of a pathological entity. Of course, there are occasions when some parents will present themselves at the orthodontist's office on their own initiative, requesting advice and help in the search for a solution to the worrying presence of 'very small teeth' or to a 'toothless' appearance. CCD individuals vary widely in the degree of manifestation of the phenotypical features, with some exhibiting a broad spectrum of the associated characteristics and others with relatively few. Some may even escape detection and diagnosis until early adolescence. Sexual development is generally quite normal.

Fig. 21.7 Typical skeletal growth pattern in the cleidocranial dysplasia patient. (a, b) At age 10 years, the facial soft tissue profile is orthognathic, although the intra-oral dental and dental base relations are class III. (c, d) At age 17 years, there is a clear under-development of the mid-face, with an accompanying mandibular prognathism and a marked worsening of the class III dental and skeletal relations. The patient is being prepared for orthognathic surgery.

Courtesy of Dr D. Harary. (e, f) At age 17.5 years and following surgical correction.

As we have stated, a small proportion of patients will be diagnosed with CCD much later. This may sometimes occur as the follow-up to a dental examination to investigate the complaint of failure of the deciduous incisors to shed and of the permanent incisors to erupt. This would normally occur at approximately 8 years of age, at which time these children find themselves the only one in the class at school who do not have new and large anterior teeth. The children are now becoming more and more different from their contemporaries. What in infancy were minor differences in stature and facial development now become more pronounced, as none of the expected physical changes that should have occurred by this time have occurred. The deciduous teeth are likely worn down by attrition and will have very short clinical crowns. They are almost completely invisible in normal facial expression and inter-personal dialogue, giving the child an edentulous appearance, akin to the visage of old age.

In order to confirm that the patient does indeed suffer from CCD, our diagnostic routine has come to include:

- A family history to check for parents or other relatives who may have been diagnosed with CCD.
- A clinical examination in search of the general characteristics of the condition, which takes in the cranium, face and clavicles, including the mobility of the shoulders.
- An intra-oral examination to relate the eruption status of the dentition to the patient's chronological age.
- A radiographic evaluation, which plays a critical role in the confirmation of the clinical diagnosis and will include a chest X-ray and antero-posterior and lateral skull radiographs, which are performed in a cephalostat. At the same time, a panoramic radiograph will be studied and supplemented with periapical and occlusal views, as required.

Following establishment of the tentative diagnosis, a genetic analysis should be undertaken. It is recommended that a small blood sample be taken and forwarded to a laboratory specializing in dealing with the gene specific to CCD, namely RUNX2. The laboratory will extract the DNA from the blood sample and then perform the sequencing. There is a 60–70% likelihood of identifying the gene although, as has been pointed out at the beginning of this chapter, its absence does not mean that the disease is not present.

An important part of the geneticist's examination will include gathering information about relatives and the possibility that other, more distant family members may be similarly affected. Once the diagnosis has been confirmed, genetic counselling is offered to the parents regarding their own future offspring, but more particularly regarding future offspring of the affected child. CCD is an autosomal dominant genetic condition or syndrome, which means that the inheritance pattern is determined by the transmission of the chromosomes when the gene is located on just one of the autosomal chromosomes. Dominant means that a single copy of the disease-associated mutation is enough to cause the disease. Thus, the chances for offspring to be affected are high.

Treatment of the oro-facial characteristics of the condition will involve the talents of a team of three dental specialists: the child's dentist, the orthodontist and the oral and maxillofacial surgeon. They will need to work in close collaboration and the first stage may often begin immediately.

Treatment modalities

Before the development of superior dental adhesives and other dental and orthodontic materials, the approach to the treatment of CCD patients by dentists in the past left much to be desired. In many cases the dentist would use wholesale extractions of the erupted deciduous teeth, the impacted teeth of the normal series and the supernumerary teeth. They would place removable and fixed prostheses, which were supported on unerupted or partially erupted abutment teeth. The results provided a 'quick fix', but were highly unsatisfactory, even into the short to medium-term future. The oral rehabilitation that was later required was extensive and needed to be performed on relatively young patients. More often than not, treatment had to be backed up in the years that followed with more comprehensive prosthodontics, due to further deterioration of the health of the existing natural teeth and the loss of alveolar bone.

Today, many of the aims of treatment may be realized with several different approaches and, not surprisingly, these differing methods have most often reflected the particular discipline within dentistry in which the treating dentist specializes. Furthermore, the advances of specialization, sophistication and the level of excellence practised within each of the specialties compared with yesteryear have widened the spectrum of clinical proficiency within each sphere of expertise. To a certain degree, therefore, the mode of treatment offered to a CCD patient may depend upon whose door the patient knocks first, as we shall see from the following alternative types of treatment.

Prosthodontics

The most popular approach by the prosthodontist has been to provide removable partial or full prostheses, which fulfil all the patient's immediate needs. This approach has been suggested by many, although only after the removal of all the deciduous teeth and the unerupted supernumerary and most of the permanent teeth [9, 15, 16]. Given that the alveolar bone height in CCD cases is very limited, with shallow vestibular sulci, the dentist is invited to ponder the implications of the construction of replacement tissue-borne, tooth-borne and implant-borne prostheses 7–10 years post treatment, after additional, iatrogenic ridge resorption and dental caries will surely have occurred.

Others have advised retaining the standing teeth and constructing prostheses around them [8,16–18]. A further refinement recommends the exploitation of any standing teeth and surgically exposing the more superficial unerupted teeth, to serve as supports for an over-denture [18–20]. By making the denture 'tooth borne', it is less likely to cause further ridge resorption. The supporting teeth, however, will under these circumstances deteriorate quickly, both from caries of their crowns and root surfaces and from loss of their periodontal attachment.

Implant-based prosthodontics is ill advised since implants cannot be placed in a jaw that is full of unerupted teeth, without the prior removal of a very large number of these teeth. Extensive extraction will then take its toll in the shape of considerable post-surgical resorption of additional alveolar bone from the already severely reduced bony ridge. Unfortunately, the relative absence of suitable implant sites and the thinness of the mandible itself will usually rule out the use of implants.

Surgical relocation

In the search for a non-prosthetic method that utilizes the existing teeth, careful dissection of the unerupted teeth and their repositioning or transplantation into artificially prepared sockets has been advocated [5, 21, 22], but this too demands the prior surgical removal of the supernumerary teeth. However, the long-term results of this method of treatment of CCD patients have not yet undergone sufficient investigation, particularly in view of the presence of multiple impactions and deficient alveolar bone width. (This presents an important area for study and would give the profession some information and insight regarding the fate of these teeth in later years.) Accordingly, the practitioner who employs the surgical approach may be left with the open question as to whether the transplanted teeth can be relied upon to erupt autonomously and behave like normal teeth, or perhaps undergo ankylosis and root resorption in common with other transplanted teeth.

There are many advantages of prosthetic/prosthodontic replacement with removable and/or fixed devices and expedients, particularly when combined with orthognathic surgery. The most important advantages of these devices are that they offer rapid and dramatic results in terms of function, appearance and psychological support. The method offers the possibility of rehabilitation of artificial teeth in the appropriate places in the mouth in lieu of the impacted teeth, thereby providing the patient with a façade of 'straight teeth' and the will to smile. It is also used to enhance a reduced vertical height of the lower third of the face, which is often present in any patient with multiple unerupted or extracted teeth or anodontia, not just CCD.

However, these non-orthodontic methods all suffer one serious drawback, namely that the results thus achieved deteriorate fairly rapidly and their prognoses are relatively poor. When one considers that treatment for the condition needs to be carried out in the first and second decades of the patient's life, these modalities must be considered to be of limited value and essentially inadequate to achieve the aim of lasting more than a few short years, at best. Skeletal growth, tooth eruption (however partial this may be) and heightened tooth morbidity will demand renewal and replacement of these prosthodontic restorations at regular and relatively short intervals, prior to and during the adolescent period.

Orthodontics and surgery

Prior to the early 1960s, the idea of treating CCD patients using orthodontic methods was considered to be fanciful and impractical, and was widely derided. However, in the mid-1960s some limited positive results were first obtained. This caught the imagination of a small number of clinicians and, in the late 1970s and early 1980s, several journal articles appeared advocating a number of surgical and orthodontic treatment protocols. Methods were designed to bring about the eruption of the teeth by extracting the deciduous teeth, surgically removing the unerupted supernumerary teeth and exposing the buried permanent teeth. This was done both with and without the use of a surgical pack, depending on the depth of the individual teeth within the tissues [1423–25].

The patient was then seen in routine follow-up visits, until the teeth erupted or had reached a sufficiently accessible position (occlusal to the healed gingival tissues) for the application of orthodontic bands or bonded attachments. In other words, reliance was placed on the expectation of a degree of natural tooth eruption, while assisted eruption was provided only for those teeth that had already partially erupted. As we have noted, CCD patients are characterized by a lessened power of eruption; accordingly, many months will pass before teeth appear and most of the more deeply sited teeth will most probably never erupt at all. Additional surgical exposure will be needed for some of these teeth, but still with no guarantee of success.

Immediate bonding and ligation at the time of surgery in these cases were introduced in the literature in the 1980s, when Trimble et al. [26] and Davies et al. [27] each showed a single case in which this was done. The advantage of being able to apply forces to the most intractably impacted teeth is well illustrated in these two case reports. These studies emphasized the need for further examination of the results and prognosis that may be achieved by a method involving surgical removal of the unwanted deciduous and supernumerary teeth, followed by the orthodontically assisted eruption and alignment of the natural permanent teeth. What, after all, could be better than to restore the dentition with the patient's own teeth and with normal alveolar bone support, through the medium of a healthy periodontal ligament?

Beyond these and many recent single-case reports, there have been few references in the literature describing attempts to standardize orthodontic treatment strategy. It must therefore be concluded that the orthodontic option has not been exercised in many cases and that there are few centres anywhere in the world where a significant number of patients have been thus treated. For these reasons, it is difficult to assess accurately the present state of opinion regarding recommended or appropriate procedures.

Only to a limited extent can success in achieving normalcy be reached through treatment of the non-dental features of CCD. This is particularly so in relation to orthopaedic and otorhinolaryngological problems. In total contrast, the orthodontic and surgical modality is capable of producing excellent dental and maxillofacial results, which may often be life changing. Indeed, the level of excellence available to many CCD-affected patients by the orthodontic and surgical modality is perhaps surprisingly good when viewing their initial presenting signs and symptoms. This has only been apparent relatively recently and requires careful planning. It is best divided into several logical stages or phases, each of which addresses its own clear goals and direction. However, the treatment is long and arduous and, for this reason alone, it may not suit every orthodontist or, indeed, every patient.

Within this modality, three treatment different approaches have been suggested over the years, each based on the experience gained from the treatment of several cases and each with its own relative merits. These will be referred to as:

- The Toronto–Melbourne approach.
- The Belfast–Hamburg approach.
- The Jerusalem approach.

The Toronto–Melbourne approach

This method was originated by a team from Toronto, Canada [14], and was further developed in Melbourne, Australia [24]. The method involves surgical procedures being performed in a stage-by-stage series under endotracheal general anaesthesia. The timing of each stage is dictated by the normal eruption times of the permanent teeth. Accordingly, the deciduous incisor teeth are extracted in the first stage at 6 years of age, followed by the deciduous canines and molars at 9–11 years. Following this, supernumerary teeth overlying the crypts of the unerupted permanent teeth are removed, together with substantial amounts of bone in order to uncover the crowns of the permanent teeth to their maximum diameter. The teeth are left widely exposed. The Melbourne team prefers to expose the incisors at a separate and additional surgical episode. This is done after the late eruption of the first molar teeth and placement of bands, which may reach full expression only at about the age of 10–11 years. Surgical packs are used to maintain the patency of the surgical exposure and to safeguard access for eventual bonding of the teeth.

The expectation is that, following the removal of the obstructive elements (i.e. the deciduous and supernumerary teeth, together with a liberal amount of bone and soft tissue), the teeth will then erupt of their own accord to a varying degree and over an extended time-frame. When convenient, orthodontic brackets are bonded to individual teeth and these are drawn to a light archwire, which spans the unsupported premolar/canine areas, from the banded molars to one or more anteriorly erupted incisors. Teeth are then drawn to the archwire, insofar as there is accessibility to bracket bonding.

Smylski et al. [14] and Hall and Hyland [24] do not propose any special or purpose-designed appliances to deal with the vertical traction that is needed in every area of the mouth. They appear to rely on conventional methods used in routine orthodontic treatment.

Limitations

There are several caveats in relation to this method, as follows:

- The patient is under active treatment for many years, starting from a very early age and requiring several recommended and fairly extensive surgical interventions, as well as several smaller ones for individual teeth. The age of the patient in the early stages and the scope of the surgery are the major factors that need to be taken into consideration in deciding whether all these interventions should be carried out under general anaesthesia.
- Notwithstanding the removal of the deciduous anterior teeth at an early stage, in order to encourage the eruption of permanent incisors, spontaneous eruption does not always occur. This was recognized by Smylski et al. [14] and Hall and Hyland [24] in their subsequent recommendation to fully expose the permanent incisor teeth in a distinct and separate surgical stage. This means that the patient is anteriorly edentulous for some considerable time, which would seem a high price to pay for what may be undue optimism regarding the potential for normal eruption in CCD cases. In two of the three cases described by Smylski et al. [14], unerupted supernumerary teeth were not present in the anterior segments and the permanent incisor teeth responded to simple exposure and packing. However, there are many cases where spontaneous eruption does not occur. After all, this feature is one of the diagnostic criteria of the condition, which may be associated specifically with the frequent presence of supernumerary teeth in this region.
- The placement of attachments to the deeply sited permanent teeth is not performed at the time of surgery but some time later, only after full healing (by secondary intention) has occurred and after the surgical packs have been removed. Accordingly, at each surgical stage, valuable time is lost between the exposure and the application of force needed to encourage the eruption of the teeth.

The Belfast–Hamburg approach

Simultaneous to the introduction of the Toronto–Melbourne method, but quite independently from it, Richardson and Swinson [28] of Belfast, Northern Ireland, and Behlfelt [29] of Hamburg, Germany, proposed a diametrically opposite method of treatment of the teeth in CCD. They recognized that, while there is a need for extensive surgery in these cases, all such surgery could be completed at one and the same time, including the extraction of all deciduous and supernumerary teeth and the exposure of all unerupted permanent teeth. This would be carried out under general anaesthesia, in operating theatre conditions, and with surgical packs placed over the remaining teeth to encourage epithelialization of the exposed tissue, which is the essence of healing by secondary intention.

During the succeeding weeks, these surgical packs remain in place and may be changed from time to time over a further short period, until it is convenient to bond the brackets to the exposed teeth. The concept of this method is that bonding can then be done under more reliable conditions than those pertaining during the surgical procedure.

Whether or not eruption of these teeth will occur without assistance is the subject of some debate.

One opinion maintains that, while there is apparent improvement, this is due to the radical loss of surrounding soft and hard tissue during the surgical procedure, rather than to actual vertical dental change [30].

Nevertheless, even with the most favourable and optimistic assessment, there can be no doubt that the predicted eruption will be neither sufficient nor reliable enough to eliminate the need for extrusive mechanics. As with the Toronto–Melbourne approach, the appliances consist of molar bands and bonded brackets, with long spans of unsupported and relatively fine archwire, which are used to vertically develop the partially erupted teeth.

Limitations

By recommending all extractions and exposures at one time, the Belfast–Hamburg surgical policy has clear advantages from the patient's point of view, although a balance has to be struck in terms of timing. The earlier-developing permanent teeth, particularly the incisors, should not be exposed too late in their development and thereby lose any eruptive potential that they may have. On the other hand, the later-developing teeth should not be exposed too early, at a stage when their roots are insufficiently developed. Accordingly, the Belfast team [28] recommended that the one-time, comprehensive surgical intervention be performed at age 12–14 years.

The immediate advantage of this policy is very clear and encouraging. Its shortcomings are, however, of considerable consequence, although not so obvious. By delaying treatment until this late age, the teeth of the normal series will have been held, for an extended period of time, deep down in basal bone by the supernumerary teeth, particularly in the lateral incisor/canine/premolar area. Their roots will have reached an advanced stage of development within the confines of these cramped circumstances, which is likely to exaggerate the tendency for a stunted, tortuous and distorted root morphology [31, 32]. Removal of the unwanted extra teeth at this late stage will relieve the impaction of the permanent teeth of the normal series, but it will do so at a time when they exhibit even less potential for spontaneous eruption, particularly in the incisor region, since the root apices will have already been completed.

During growth of a normal child, with the eruption of permanent teeth, the vertical development of the alveolar processes that then occurs makes a significant contribution to the height of the lower face. It also leads to the establishment of deep vestibular and lingual sulci, with a clear differentiation of wide zones of oral mucosa and attached gingiva. In the untreated CCD patient, on the other hand, vertical growth of the alveolar bone appears to be markedly diminished. This is what causes the reduced height of the lower third of the face, which is a characteristic feature of the condition.

Thus, with the late removal of the unwanted deciduous and supernumerary teeth, at a time when most of the patient's growth has already occurred, the ultimate vertical alveolar growth that accompanies the erupting permanent teeth will be reduced and will leave a shallower sulcus, an absence or reduced width of attached gingiva. The overall result will undoubtedly be an incompletely, vertically developed lower third of the face.

An additional flaw in this method of treatment is that, in addition to removing the unwanted supernumerary teeth, it will be necessary to gain access to the canine and premolar teeth of the normal series and to expose them widely. However, because of the delay in extracting the supernumerary teeth, the target teeth will be very deeply situated; indeed, their developing root apices may even be relatively close to the lower border of the mandible or the floor of the nose and maxillary sinus. In such a case, there will be a necessity to remove considerable quantities of bone [14]. In turn, as recommended by several authors, one will need to place a surgical pack over and around the crowns and necks of the teeth in order to prevent bony healing-over and encourage spontaneous eruption. The purpose of the packing procedure is to prevent the reparative filling-in of bone, which will incur marked delay in healing. Furthermore, pushing the pack into the area of the cemento-enamel junction (CEJ) will inevitably lead to a poor periodontal prognosis for the finally erupted tooth, due to an exposed CEJ and lessened bone support [33].

An additional problem is also to be foreseen with this method. The frequent need to change packs over a long period incurs pain, discomfort and nuisance. There will be a consequent difficulty in maintaining oral hygiene and a limitation of normal function, with a prolonged bad taste and odour in the mouth. From the surgeon's point of view, this will entail seeing the patient for many time-consuming appointments. Until brackets may be successfully bonded and traction applied, there will be no active encouragement of eruption, and that in a case characteristically afflicted by slow or non-eruption.

In summary, at an age when facial appearance is very important, the patient will spend an unacceptably long time without teeth. Furthermore, bone regeneration will have been retarded by the use of a method that involves liberal removal of gingival soft tissue and alveolar bone, with healing by secondary intention [33]. Eruption will be delayed, and overgrowth of the soft tissues, to re-cover the deeper and newly exposed teeth, may still occur.

Understanding the problem

From the discussion of these two approaches, it becomes clear that treatment could be vastly improved if the placement of attachments and the initial application of extrusive traction could be included and addressed during the surgical procedure itself. This, however, creates several formidable obstacles, the largest of which is the skill and ability of the surgeon to create a series of micro-environments whereby, in order to permit the delicate attachment bonding procedure, a small area of the crown of each of the teeth is exposed and conditions of haemostasis and isolation guaranteed.

There can be no question that the skills needed to achieve this type of complicated treatment protocol require more than one pair of hands and more than one qualified operator in the operating theatre. The ideal situation at this critical time is the interdisciplinary cooperation of the surgeon with the orthodontist. As pointed out in Chapter 5 and in several subsequent chapters, there are enormous advantages to be gained by the presence of the orthodontist, which will have a long-term bearing on the efficacy of later orthodontic resolution of impacted teeth in general. Indeed, if this is true in the case of the treatment of a single impacted tooth, then its benefit is exponentially more valuable in relation to multiple impactions, particularly for those that are located deep in basal bone.

Without the placement of attachments at the time of surgery, access to the unerupted teeth will need to be guaranteed by the surgeon performing wide opening and radical bone resection and the placement of surgical packs. However, with attachment placement a conservative surgical policy will be possible, whereby only enough bone is removed to allow access for the placement of a small eyelet attachment on the minimally exposed tooth surface. The surgery may then be aimed at preserving rather than removing bone. The presence of bone in the eruption path will not hinder mechanically encouraged eruption of the teeth, either in these cases or in general. The absence of bone would be a greater drawback in terms of the eventual degree of bone support and the consequent periodontal prognosis of the erupted teeth [33].

Despite the fact that it has been reported [14] that in CCD cases the alveolar bone is denser, we have not found abnormal bone in any of the cases in our care. While the observer may understandably be misled by the fact that cortical bone is indeed found, to the relative exclusion of spongiosum, it should be remembered that the impaction of many teeth within the jaws will take up much of the volume within the body of the mandible where spongiosum would normally be present. Thus, while cortical bone encompasses all these teeth and is present in normal amounts, nevertheless spongiosum is sparse.

The parent of a CCD child will normally seek professional advice when the child is about 8 years old. Action may need to be initiated and it is strongly recommended that this be considered *after* evaluation by a competent and knowledgeable orthodontist. Unfortunately, the child's first port of call is often the office of another dental professional, whose (seemingly logical) approach to the problem may well be that described in the flow chart in Figure 21.8. If this directive is carried out, the child will be dentally maimed for a long period of time – just as long as it takes for the parents and the proactive practitioner to arrive at the conclusion that the expected improvement has not materialized and, in all probability, will not occur in the foreseeable future. (Where ignorance rules supreme, maiming a child can result, despite the best of intentions.)

There is no logical basis to presume that this extraction protocol of treatment will succeed, because it does not take into consideration three important factors that are characteristic of CCD [34–36], namely:

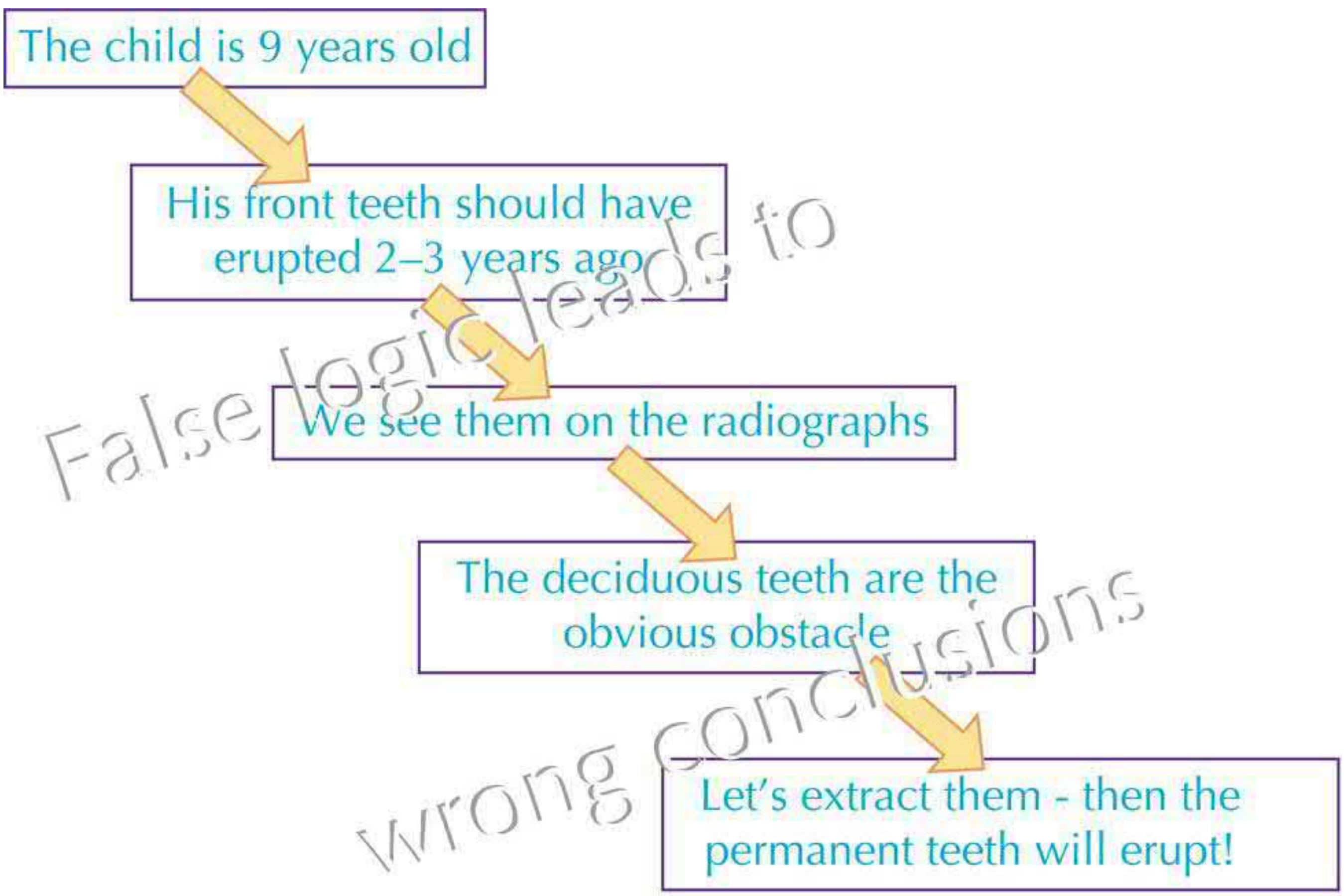


Fig. 21.8 A flow chart based on false logic leads to the wrong conclusions.

- The dental age of CCD children is approximately three years delayed in relation to their chronological age and that of their contemporaries, which means that the permanent incisor successors are too under-developed to expect them to erupt.
- The eruptive potential of the permanent teeth is greatly reduced and, while some teeth do

erupt spontaneously, they take a very long time in coming through and their eruption is rarely complete. Most of the teeth, however, do not erupt at all.

- CCD patients develop supernumerary teeth at a very early stage, particularly in the incisor region. These constitute physical obstructions that prevent the teeth of the permanent dentition from erupting.

Furthermore, because dental development is so late, it means that active treatment aimed at erupting the front teeth must be delayed until the child's *dental age* reaches 7 years (see Chapter 1). This is the time that we would normally want to see signs of incisor eruption. In the CCD child celebrating the 10th birthday, the dental age characteristically corresponds to age 7. To determine dental age, it is necessary to study the radiographs to look for root development of approximately two-thirds of the final expected root length of the incisors. This will be the developmental stage at which the tooth – any tooth – should be erupting into the mouth. It is this stage of tooth development that is to be found in the recently (naturally) erupted teeth in the normal child unaffected by CCD. This is the developmental stage at which the innate potential for eruption is at its most potent. Biomechanically erupting a tooth much earlier will risk damage to the tooth itself and to the surrounding tissues.

The first permanent teeth that are scheduled to erupt in any child are the incisors and first molars. These teeth are therefore those that determine the timing of the commencement of orthodontic treatment and, until these teeth have developed one-half to two-thirds of their final root length, no treatment aimed at encouraging eruption should be performed.

The Jerusalem approach

The Jerusalem method [34–36] was presented for the first time at the same forum as the Belfast–Hamburg approach. However, the *modus operandi* of the Jerusalem method is quite different from both the Belfast–Hamburg and the Toronto–Melbourne methods. The Jerusalem approach is based on a rationale that is related to the abnormal dental development of the patient and the factors that produce it.

This comprehensive approach to treatment addresses the following points:

- Recognition of the clinical features of the facial, oral and dento-alveolar structures in the disease.
- The surgical measures that are required to provide access to the areas concerned.
- The need for an orthodontic strategy to enable the application of extrusive mechanics to the buried teeth in an efficient and reliable manner.
- Attending to the patient's psychological well-being by focusing on the earliest stages of treatment on the resolution of the incisor impactions.

Recognition of the clinical features

CCD patients exhibit all the following features to varying degrees:

- Class III skeletal and dental relationship.
- Non-resorption of the roots of deciduous teeth.
- The presence of supernumerary teeth, manifestly displacing the developing permanent teeth and providing a physical barrier to their eruption.

- Reduced eruptive force, notwithstanding that eruptive movements are often evident.
- Poor vertical development of alveolar bone, as witnessed by a shallow sulcus, a reduced height of the lower face and a class III skeletal tendency, due to an under-developed maxilla and to a counter-clockwise mandibular rotation.
- Late but normal and unhindered eruption of first and, much later, second permanent molars in both arches.
- Late dental development, as evidenced by the root development of the permanent teeth, whether erupted or unerupted [24, 34–36].
- Severe crowding due to the increased number of teeth, both permanent and supernumerary, developing deep in skeletal bone in both jaws, close to the lower mandibular border and the floors of the nasal and maxillary sinuses.

What about the skeletal class III relationship in cleidocranial dysplasia patients?

The basic problems that we have detailed are not merely multiple eruption disturbances, they also include skeletal disparity in the development of the two jaws, as well as associated psychological problems related to the poor appearance, which itself is due to long-term missing teeth. Most of these factors are not present in the routine orthodontic case.

The treatment for some of these problems is age related. One example is the need for orthopaedic maxillary protraction, which is probably best treated when the child is between 4 and 7 years old. If not so treated, the alternative would be orthognathic surgery after all the teeth have been brought into alignment in the class III relation, and that would be in young adulthood. Neither of these two modalities can be attempted while treatment of the unerupted teeth is progressing, since they will seriously interfere with the efficacy of the treatment with eruption biomechanics.

There is a much higher prevalence of a skeletal class III jaw relation in CCD patients than in the general population. This is due, in general, to under-development of the maxilla, which causes mid-face hypoplasia. The class III relation is not always evident in the younger CCD individual, but a negative differential growth pattern seems to accelerate at or around puberty. Not all CCD cases are affected and one may occasionally see a skeletal class II case, which has become more severe during subsequent adolescent growth.

At the age of 4–7 years, a distraction face mask will help to overcome the reverse relation of the dental arches, but only if there is appropriate management on the part of a parent and a kindergarten teacher to encourage full-time wear. An 8–10-year-old child would need to have strong motivation, understanding and a resilient character to wear the appliance at school. This appliance, if worn full time, has the capacity to achieve amazing results. From bitter experience, however, if the orthodontist compromises by agreeing to the appliance being worn half the day for twice the duration, there will be little positive and no lasting effect.

In order to treat the skeletal class III by protraction of the maxilla, an *en masse* orthopaedic force is essential. This can be usefully achieved without reference to the state of development of the permanent teeth. Therefore, in the interim and while awaiting adequate root development of the unerupted permanent incisors, protraction of the maxilla can be performed and followed through; this, with the intention of significantly over-correcting the negative overjet and the class III dental and skeletal relationships in the full deciduous dentition.

While this may often reduce the child’s class III growth pattern, later growth and a mandibulardominated pubertal growth spurt or relative growth cessation in the maxilla may still occur. In that event, it will need to be treated later with class III mechanics, but it will demand ortho-surgical treatment when the discrepancy is large.

For speed and effectiveness, the use of face mask protraction therapy should follow a 24/7 regimen. When wearing the face mask full time, an *in toto* advancement of the maxilla of 5 mm on each side, can be achieved in about five or six months in children of this age. This will be quite apparent by the obvious positive change seen in the patient's facial profile. It will also be seen in the alteration of the relationship between the upper and lower deciduous molar teeth and in the reversal of the negative deciduous incisor overjet to a positive one. Without question, much of this change will be pure dental movement, but there will also be a significant skeletal change – the younger the better.

What management protocol can be used to achieve this level of compliance?

To influence the patient and the parent to achieve a sufficiently high degree of cooperation is far from easy, but it can be achieved in a good proportion of instances – whether with CCD patients or with non-CCD pure skeletal III cases. The most important factor in the process is first to convince the parents of the efficacy of the appliance and the need for full-time wear. If the orthodontist is able to achieve this, it will generally pay handsome dividends in terms of clinical results in the long run.

There will be a significant number of parents who might not be prepared to require the child to wear the appliance, for fear of harassment at school. Most parents will ask that the appliance be worn at night. They will refer to it as a 'night brace' and will say that they do not mind if the treatment takes longer. Either way, if a compromise agreement is reached with a parental 'guarantee' that it will be worn 16–18 hours per day, in practice the best that will realistically be achieved is less than 10 hours per night – and that assumes that the family remembers each night.

It should be realistically and clearly understood, however, that a part-time compromise agreement *does not work*. In effect, its purpose is to avoid embarrassment either of the parents or of the child in the face of outsiders, such as friends and relatives. When there is a knock on the front door, the appliance is removed. For a 7–9-year-old child, the achievable maximum may never even reach 10 hours per 24-hour period. Moreover, the child who only wears it from 8 or 9 in the evening until waking up in the morning will generally find the face mask under the bed the next morning, simply because it will have been unconsciously removed during sleep. Such children do not become accustomed to it because they do not wear it during waking hours. It takes daytime wear for the child to become accustomed to the appliance.

The initial discussion with the parents and the child is not an easy one and no attempt should be made to force the issue, certainly not on the first visit in which it is discussed. The explanation should deal specifically with the aims of this treatment and the known fact that, even with a totally compliant patient, a significant proportion of the improvement will be lost in the year or so when the protraction treatment ceases. A wide margin of over-treatment of the jaw relation will therefore be necessary for a recordable net gain to be seen after the relapse has occurred. At this point, it is a valuable asset to be able to show photographs of successful treatment of another child to demonstrate what it is possible to achieve (Figure 21.9a–c).

Finally and before they leave the office, the parents will usually ask what alternatives there are. Here, many will fall into line when they realize that the alternative will be orthognathic surgery, which would only be appropriate some 12–15 years later.

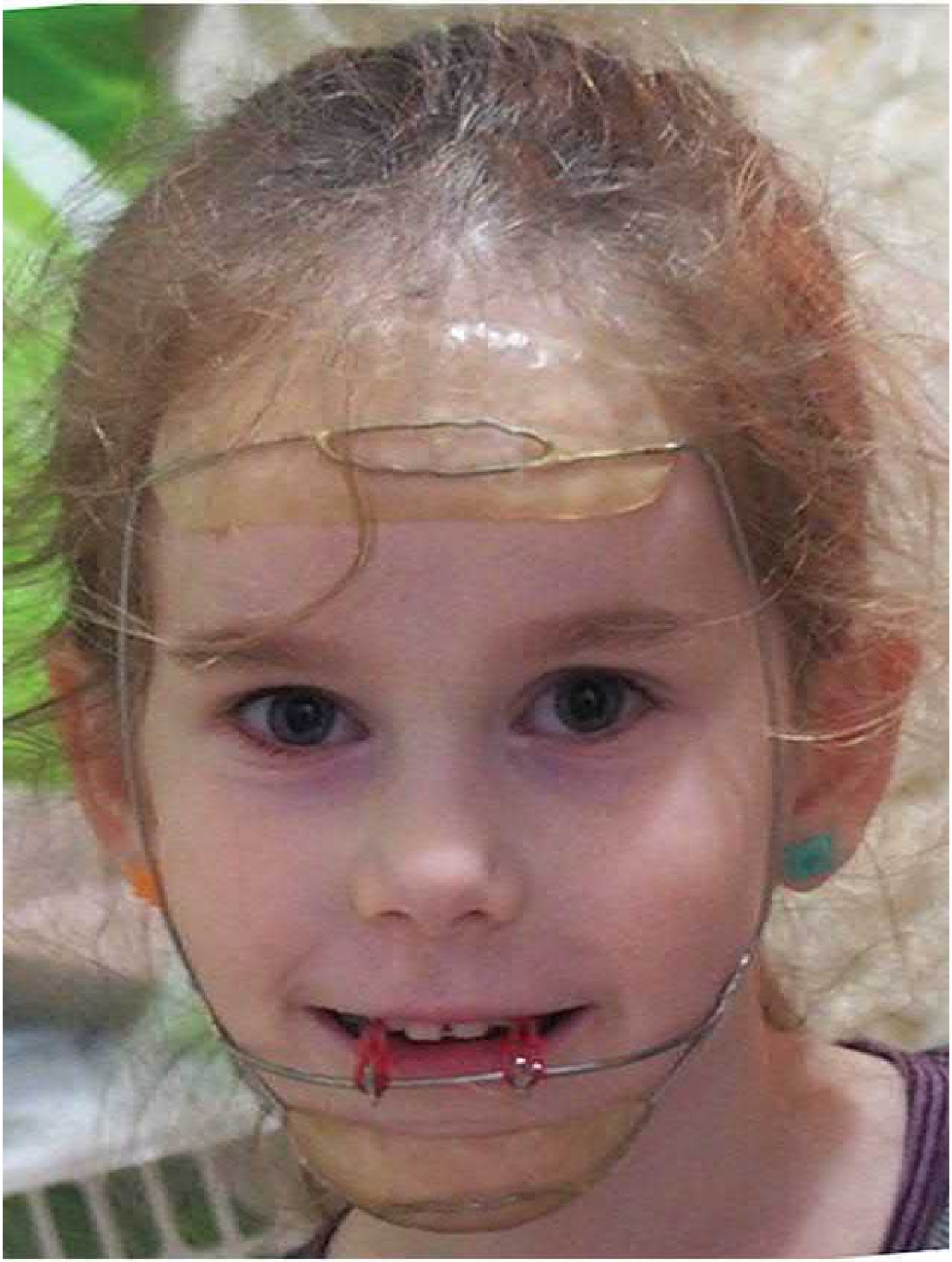
By the second visit, the parents will have come to a decision. If they are not prepared to commit to 24/7 cooperation with the appliance, the orthodontist would best be advised to abandon the idea of maxillary protraction, because the chances of a good *and over-treated* result will be strongly compromised. Any other ‘offer’ on the parents’ part should be rejected. By agreeing, the orthodontist will have relinquished control of promoting a treatment, for the success of which the orthodontist will be held responsible. This pre-phase I treatment stage should therefore be abandoned and treatment delayed until the root development of the incisors indicates that the child is ready to commence stage I.


Before treatment
Completion of treatment
1 year post-treatment

(a)


Before treatment
Completion of treatment
1 year post-treatment
October 2017
January 2019
January 2020

(b)



(c)

Fig. 21.9 (a) A composite photograph of intra-oral views taken prior to treatment (in the top row) and showing a severe class III malocclusion of the complete deciduous dentition, at age 4 years. The middle row, taken 14 months later, shows the dentition on the day treatment was completed and the protraction appliances were removed. The lower row illustrated conclusively the degree of relapse that had occurred in the 12-month period since treatment was stopped. No retention appliances were placed. (b) Photographs of the same patient in profile on the same days, to show treatment and post-treatment changes in the lip profile of the patient at rest. (c) The face mask being used (with permission) on the same non-cleidocranial dysplasia child. Note the minimalist dimensions and the clear acrylic caps and their excellent adaptation to the chin and forehead. Alteration in force direction can be made by bending the cross-piece up or down or re-soldering at the desired level. The patient was recorded here on the last day of treatment, immediately prior to appliance removal, to show the relatively inobtrusive customized face mask.

Younger patients are generally less self-conscious about the unnatural appearance of the face mask than are older children. Children in the kindergarten/pre-school framework and even in the first and second grades of school certainly do notice, but are less critical than their older peers and do not ridicule these patients or make them feel uncomfortable. Convincing the parents of a 4–7-year-old is therefore much easier. Their resistance is much less and more easily overcome. Most children of this age have no problem facing other children in the kindergarten and play group.

It is also essential to recruit the kindergarten or school teacher to play a key supportive role in relation to generating a positive attitude in the other children. In this age range, the child spends a lot of time at home and goes to bed early, which increases the possibility of more wear than in the older child, when full-time wear is not completely achievable. Accordingly, there is much to be gained by treating children at the pre-school stage, if they are diagnosed sufficiently early. A child can usually be encouraged to wear the appliance if it is simple to place and connect up with elastics to the intra-oral bonded splint. Once connected up, a child can be very receptive to understanding its purpose.

Extra-oral appliances and the face mask, in particular, are arguably the most disliked and consequently insufficiently used appliances in orthodontics, specifically because of their appearance. However, if we want the appliance to be worn full time, it is our solemn duty to make the face mask as unobtrusive and non-restrictive as possible. This presents a problem if a pre-formed face mask (as advertised in the catalogues of the various orthodontic manufacturing companies) is to be provided. Since they are ‘one size fits all’, they are of necessity very ungainly and awkward, because of the adjustments that need to be made to render them comfortable and effective. In the effort to make the chin and forehead caps comfortable, they are lined with thick padding, which takes up considerable space. The distance between the chin and the forehead varies from patient to patient and so it is necessary to include an adjustable screw fitting to permit alteration of the distance between the two cup pads. The plastic caps require the placement of a hinge on each to allow adjustability of the angle of the cup to the form of the face. In some designs, there is a thick supporting rod that mimics the midline along the full length of the face to join the chin and forehead caps. Mounted on this are another couple of adjustable screw stops from which the traction elastic will be drawn. In the vain effort to make the appliance attractive to the child, the plastic parts are made in bright colours and one company links the appliance to a football crash helmet, in the hope that children will be fooled into believing that they will make the New York Giants team one day!

It is our contention that it is essential to make the face mask as simple and as inconspicuous as possible, yet strong and comfortable enough to provide the means to the desired end. This demands eliminating the padding in the chin and forehead caps and making them from clear transparent acrylic. It means avoiding adjustable screws to enable varying of the facial height, eliminating cap hinges, discarding adjustable screw stops and using a narrow wire frame that does not cover the face. What is needed is a custom face mask and it is easy to make, using basic dental/orthopaedic low-tech expertise, as we will attempt to show in the following section [37, 38].

Constructing a custom orthodontic/orthopaedic face mask

The only ingredients needed in the clinic are (after Turley [37]):

- A broad length of very thin plastic (also known as saran wrap or clingfoil), usually available from home stores in rolls (and intended to cover the salad bowl to prevent the contents from drying out before the guests arrive).
- A plaster bandage, i.e. a roll of gauze impregnated with plaster of Paris and used in the plaster room of any hospital orthopaedic department or office.
- An indelible pencil or felt-tipped pen.

The patient is seated in the slightly reclined dental chair and clothing protected with a large bib. The thin plastic sheet is carefully wrapped around the head, to completely cover the face – having first cut a hole in it, to be placed over the nose and mouth. It is important to use a large piece of plastic sheeting to fully encircle the head so that the ends overlap each other and thereby retain it tightly in place. The child's head is positioned in the headrest of the chair, which is now tipped back to almost horizontal. Throughout the procedure, the office should be devoid of all other people, with the possible exception of a parent, who is sworn to silence and good behaviour. There should be no background disturbances.

The roll of plaster bandage is soaked in a bowl of cold water for a few seconds, until it is thoroughly wet. Its free end is placed on the child's face and it is laid down in a series of wide circles on the plastic, successively over the chin, the face and the forehead as the plaster bandage is rapidly unrolled. This is continued in a circular movement until the outer regions of the face are covered, up to but excluding the ears, superiorly to include the forehead and a few centimetres above the hairline, then inferiorly to fully enclose the chin. A narrow strip of plaster bandage should also be taken carefully from one side to the other, across the upper lip, making sure that it does not interfere with the patient's nasal airway (Figure 21.10a, b). The purpose of the several layers around the face is to give the final plaster cast adequate bulk for strength, in the absence of any other form of support. Do not cut the plaster bandage, but continue laying it down until the roll is finished.

The patient should not be left alone while the plaster is drying, but should be spoken to softly, ensuring that there is no movement to disturb the rapid set of the plaster. Before removing the cast, the anatomic midline of the face is clearly marked on the plaster. The extent of the chin cap and forehead cap may also be drawn on if desired (Figure 21.10c), although this is easy to define, later on, on the casting itself. Once set, the plastic sheeting should be carefully freed from behind the head and brought forward on both sides, permitting removal of the cast, which should come clear together with its plastic lining.

The whole operation can be performed in a light-hearted manner and will be remembered by the child as having been a fun activity – so it is worth photographing. It should be remembered that young children, male or female, have facial hair that is very fine and difficult to see. If this procedure were to be performed directly on the skin of the face, removal of the cast would be very difficult and extremely painful for the patient.

The plaster cast provides a sufficiently accurate impression of the face for the purposes of the technician, to whom it is sent. The technician casts the plaster impression while the saran plastic wrap is still in place and will act as a separating medium. Alternatively, a liquid separating medium may be used. The technician then constructs a wire frame of 1.5 mm wire joining the forehead area with the chin area, taking it posteriorly to just in front of the ears, so that it is not too obvious. He solders a cross-piece 10–15 mm labial to the upper lip, with a small soldered hook on each side of the midline. The chin and forehead caps are then fabricated in clear acrylic, into which are cured the ends of the wire frame.

The intra-oral appliance

Although pre-formed bands could be cemented to the second deciduous molar, the teeth usually have very short clinical crowns and brackets would need to be placed on the other teeth, together with the construction of a palatal arch. In the present context, it is advantageous to use acrylic cap splints on the posterior teeth and a metal skeleton framework across the palate, to join the two sides. Should expansion be required, a hyrax screw can be substituted as the connector between the two sides, by curing its extension arms into the acrylic covering the teeth (Figure 21.10d, e). Wire hooks or bondable buttons, cured into the acrylic on the buccal side in the deciduous canine area, may then be used as the points of application for the elastic traction to the face mask.

The acrylic cap splints should be bonded to the posterior teeth with glass ionomer cement, after sandblasting and/or etching the buccal and lingual surfaces of the teeth as necessary. If the occlusal surfaces are also included in this preparation, it is likely that subsequent removal will be excessively difficult. When the time comes to remove the appliance from the teeth, at the end of the protraction procedure, a bracket-removing pliers may be used to crush the acrylic side pieces and separate the cement from the tooth and from the splint. The acrylic that is bonded to the occlusal surfaces is likely to need to be drilled off the teeth. This 'clean-up process' will take a great deal of time and effort and regrettably may be a traumatic experience for young children. However, the knowledge that they are finally ridding themselves of the appliance will generally help to carry them through.

Connecting it all together

A small elastic is placed on each of the hooks on the buccal side of the intra-oral appliance and, with the face mask held in place, it is stretched to engage the soldered hooks on the cross-piece. With an elastic on each side, the face mask is held against the face quite securely and does not require other forms of retention (Figure 21.10f, g). The amount of traction force used may be controlled using smaller, heavier and/or multiple elastics.

The custom face mask requires no padding, since the thin acrylic cups are an accurate fit on the chin and forehead. The use of forehead and chin cups made of relatively thin, clear acrylic and a wire frame just in front of the ears on the face makes it fairly inconspicuous (Figure 21.9a). There are no knobs, hinges or screws. As a result, the child is much more prepared to wear the appliance and the parent much more positive in encouraging the child to cooperate.

Even with the best bonded cap splints and good oral hygiene, there is always a degree of gingival inflammation and sometimes the appearance of an area of enamel decalcification, due to voids unintentionally created during the cementation procedure. These may not be detected until the cap splints are finally removed. It is therefore essential to complete this pre-eruption phase of the treatment of CCD as quickly and efficiently as possible, in order to reduce the occurrence of undesirable side effects. In addition, slow completion of the aims of the pre-phase I treatment may extend the treatment to the time when the eruption phase is ready to begin. Streamlining the treatment with a compliant patient will help to achieve these goals in a reasonable time.

Bringing the teeth to a class I molar relation with a normal overjet will not be a sufficient result of the pre-phase I stage, and both these gains will quickly be lost, due to relapse of the inter-arch relation to class III. However, with good cooperation (i.e. full-time wear of the face mask), a full cusp class III relation and large negative overjet may be transformed into an over-treated full class II molar relation and increased overjet within 6–8 months. Following the discontinuation of protraction forces and removal of the bonded splint, one should expect to see a significant reduction in both the class II related molars and in the overjet. This is likely to bring the two dental arches to much more normal inter-arch relations within a further 3–4 months.

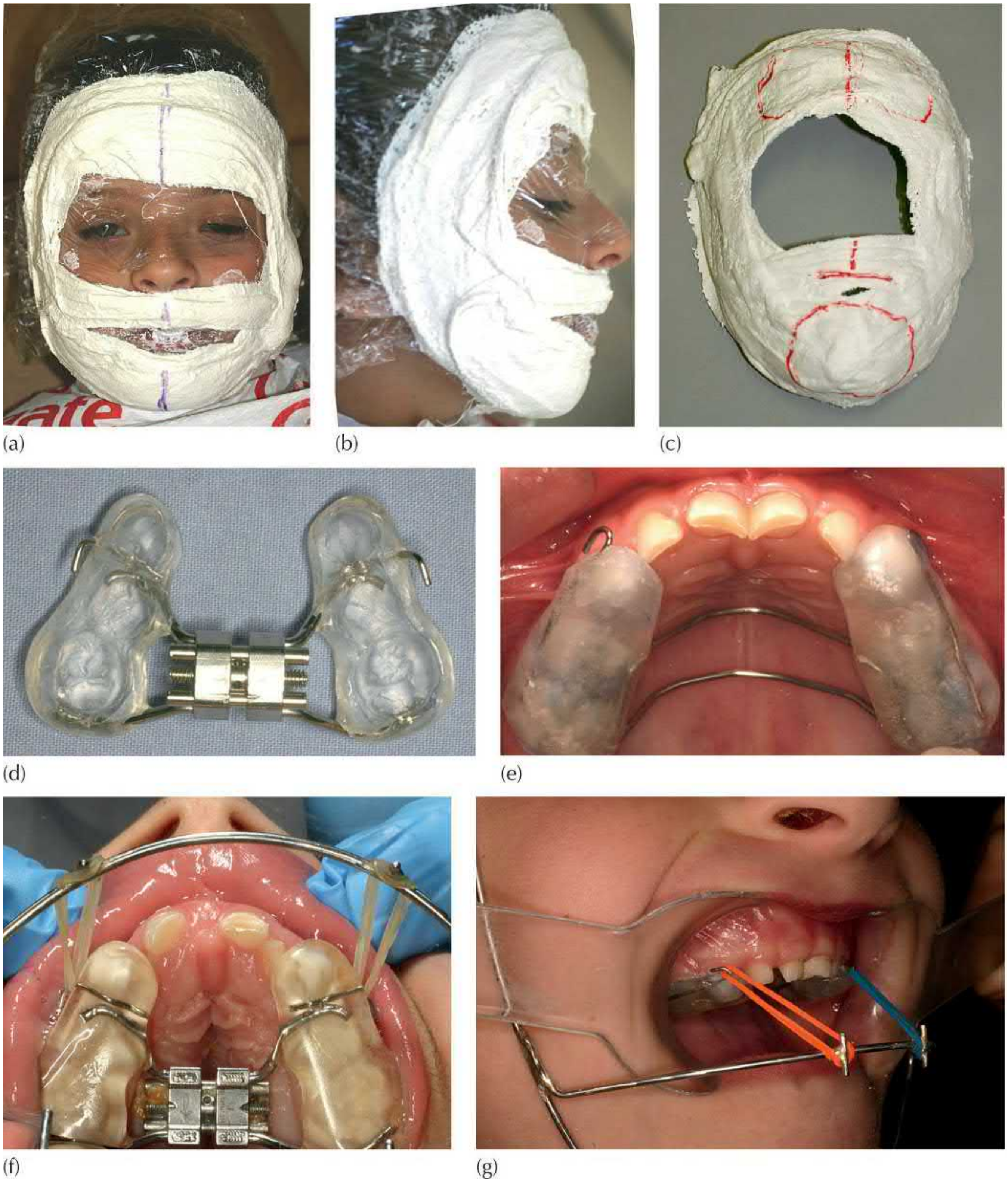


Fig. 21.10 (a, b) A plastic bib covers the patient's clothing and a thin plastic sheeting (saran wrap or clingfoil) has been stretched tightly round the head, with a large hole for unimpeded nasal breathing. Wet plaster bandage has been laid down over the face in a series of circular movements to cover the chin and forehead. A portion of the bandage has been laid over the upper lip. The midline is clearly marked on the plaster. (c) The separated plaster cast of another patient. Note the chin and forehead cap markings. An outline of the forehead and chin elements, together with a midline, were drawn on the cast before its removal. (d) Acrylic cap splint with an expansion screw

cured into the acrylic, prior to cementation. Note the buccal hooks in the canine region, in a 9-year-old male cleidocranial dysplasia (CCD) patient. (e) A similar acrylic cap splint with transpalatal wire supports, in an 8.5-year-old female CCD patient. Expansion not required. (f) An occlusal view of the acrylic splint showing the traction elastics in place. There are two heavy 3/16 in. elastics on each side. (g) The mouth is opened wide to permit photography of the intra-oral traction hooks. At rest, the direction of traction is in the horizontal plane.

If the promised cooperation of the patient is not fulfilled or not renewed in the follow-up visits, then it is preferable to terminate the procedure immediately, to avoid disappointment and later patient recriminations.

Erupting the permanent teeth

In general, at about the age of 7–8 years and whether or not a pre-phase I protraction procedure has been carried out, the parents will seek professional advice because they will be concerned that the deciduous incisors are still present and there is no sign of the permanent incisors. Remedial treatment needs to be initiated and it is strongly recommended that this be considered after evaluation by a knowledgeable and competent orthodontist. Unfortunately, the orthodontist's office will not tend to be the first port of call, but rather the office of a general or paediatric dentist. The advice given there may well be along the seemingly logical line of thought described in the flow chart in Figure 21.8. The result of this protocol will be that the child will be missing front teeth for a long period of time – just as long as it takes for the parents and the proactive practitioner to arrive at the realization that the expected improvement has not materialized and, in all probability, will not occur in the foreseeable future.

In Chapter 1, we pointed out that the developmental stage at which teeth normally erupt is when the roots of the teeth have reached approximately two-thirds of their final expected length. We have also seen, in the earlier part of this chapter, that the dentition in most CCD children characteristically develops approximately three years later than in the normal child. Succinctly put: the dental age of the affected child is three years behind the chronological age. Thus, in the CCD patient, mandibular incisors typically exhibit two-thirds root growth at the age of 9–10 years, maxillary incisors at age 10–11, mandibular premolars at the age of 13–14, maxillary canines at 14 years, and so on.

As with normal dental development in an unaffected child, it is equally desirable that the teeth in the CCD patient erupt into the mouth at the time when there is an open apex and one-half to three-quarters of the eventual expected root length. At the age of 10 years, with CCD patients the only permanent teeth answering these criteria will be the four incisors in each jaw and the four first molars. The premolar teeth are not expected to reach this level of development for a further three or four years. Thus, any attempt to surgically expose and orthodontically erupt all incisors, canines and premolars in a single surgical episode would be strongly contra-indicated. However, on the other side of the equation, there will be the following problems:

- To delay treatment for three or four years, in order to achieve a single combined surgical procedure for all these teeth, would mean delaying the incisors and their associated supernumerary teeth developing their roots in extremely cramped circumstances.
- With their root apices then becoming fully closed, the teeth would lose any of the already reduced eruptive potential that they may have initially possessed.
- A more serious result of complete elimination of all the deciduous teeth and all the buried supernumerary teeth in one surgical episode is the fact that the patient would be almost

totally edentulous for a lengthy period of time. This would leave only the permanent molars available to support an orthodontic appliance.

- There will be a serious strain on the resources available to devise a biomechanical system needed to vertically erupt the permanent teeth.
- And finally, there are debilitating, functional and social aspects of such a drastic line of treatment.

Surgical therapeutic measures

The Jerusalem method of treatment [34–36] requires that surgery be performed in two distinct stages. The timing of these surgical episodes is directly related to the dental age at which the different groups of teeth reach the point in time when they normally should be erupting, i.e. one-half to three-quarters of their eventual root development. Thus, the first surgical episode is planned for *dental age* 7 years, which translates into the CCD patient's *chronological age* of 10 years, and in most cases will involve the incisor teeth of both jaws only.

After the first stage (referred to below as intervention 1), the first permanent molars and deciduous molars will remain in place to await the further development of the permanent canines and premolars and to provide the patient with the means to function. This will also provide the orthodontist with several available teeth to use in later stages, as support and anchorage for the orthodontic appliances. Mechanically efficient application of vertically directed force may then be brought to bear on the unerupted incisors. It will be noted, however, that if this involves leaving unerupted supernumerary teeth in place, this may interfere with the modicum of spontaneous improvement in premolar eruption, however minimal that might otherwise be.

Intervention 1

At the *dental (not chronological) age* of 7 years, the deciduous canines and incisor teeth are extracted, together with the supernumerary teeth that are in the immediate area. At the same time and in the same surgical episode, the crowns of permanent incisor teeth are surgically exposed and eyelet attachments are immediately placed. The surgical flaps should be fully closed over the deeply located unerupted teeth and traction will be applied to the twisted steel connectors that exit the sutured edges.

At this time, the canine and premolar teeth are at an early stage of development, with their roots less than half their expected final length. Accordingly, the surgical intervention in the posterior region is limited as far as conveniently possible to removal of supernumerary teeth. Actual exposure of the developmentally immature posterior teeth of the permanent series should not be undertaken and, most importantly, their dental follicles must be left intact until much later. If there are no supernumerary teeth in the canine/premolar areas, the deciduous teeth should be left in place.

From clinical experience gained from the treatment of many CCD patients, it seems that the prognosis for bringing the teeth into alignment and function is better in those individuals who have fewer supernumerary teeth. It is reasonable to assume that this is because the presence of a large number of supernumerary teeth will be associated with greater displacement of permanent teeth, particularly in terms of their depth in the basal, rather than alveolar, bone.

On the basis of this observation, it would seem logical to remove the supernumerary teeth early, even if the permanent teeth in the canine/premolar areas are still under-developed. In such an event, and provided that the integrity of the dental follicles of these permanent teeth is maintained, one may sometimes see a modicum of positive and autonomous eruptive movement in the 3–4-year gap between the first and second surgical interventions.

Intervention 2

The dental age of 10–11 years (chronological age 13–15 years) is the most appropriate time for the second intervention. The root development of the posterior successional teeth will by then be sufficiently well advanced. This second-stage intervention involves the exposure of the crowns of the canines and premolars in both dental arches, as well as the placement of eyelet attachments on these teeth and the immediate application of traction. The particular requirements of the surgical procedure relate to the conservation of bone in general and of the cortical part of the bone in particular. Removal of any remaining unerupted supernumerary teeth, with a minimum of buccal plate of bone, will create enough space around the crowns of the impacted permanent teeth of the normal series to allow the immediate bonding of small eyelet attachments. The lingual plate should be left intact and at its original height. Maxillary second premolars may require a palatal approach, in which case the buccal plate should be left intact. Bone that covers the occlusal surface of the crowns of deeply impacted teeth should not necessarily be removed. The dental follicle will be left intact, except for the small window opening on the crown at the site chosen for attachment bonding.

The second surgical episode will be planned when the canines and premolars realize the same root development requirement, i.e. 3–4 years after the first. By that time, the incisor teeth will have been fully erupted and aligned and will have provided the patient with much-improved function and appearance. They will also have allowed the inclusion of these teeth into the support and anchor unit of the orthodontic appliance, in readiness for the imminent, biomechanically driven eruption and alignment of the posterior teeth.

A wide soft tissue flap exposing the surgical field is advised in order to enable good vision and access and to help in maintaining the conservative attitude to the removal of bone. Finally, the partial-thickness muco-gingival flaps will be returned to their original places and sutured without the use of packs, in the manner of primary soft tissue closure [3339–43].

Orthodontic strategy

At the consultation that takes place immediately before commencement of the phase I treatment, most CCD patients present with a variety of over-retained deciduous teeth. In general, the first permanent molars in all four quadrants will have erupted. Additionally, there may be one or more of the permanent incisors in a state of partial eruption. Indeed, it is not even unusual to find an intact and complete deciduous dentition (Figure 21.11a, b). The posterior deciduous teeth are frequently found to be affected by caries. A panoramic and lateral cephalogram radiograph will show all the unerupted permanent teeth, while a careful examination will usually permit the identification of several supernumerary teeth, both in the maxillary midline area and often elsewhere (Figure 21.11c). In many instances, new supernumerary teeth, which may not have been discernible on original records, may appear on the radiographs taken at this later stage.

In the broad overview of the treatment appropriate to this group of patients, the provision of space within the arch is made by antero-posterior horizontal expansion of the dental arches, which is appliance generated, while the extraction of deciduous and supernumerary teeth will provide space in the vertical plane. Furthermore, this intervention has been timed for this to occur at the stage in the development of the teeth at which the eruptive potential is at its peak, namely when the apical third of the root is developing.

This offers the opportunity for the unerupted permanent teeth to migrate towards the occlusal plane. Even though the teeth in the CCD patient have a reduced natural eruptive potential, they may sometimes benefit from this encouragement to take up a more normal developmental position within the alveolus. Improvement will be limited and may still not be sufficient to allow the roots to develop freely enough to acquire a more normal root morphology [34, 35].

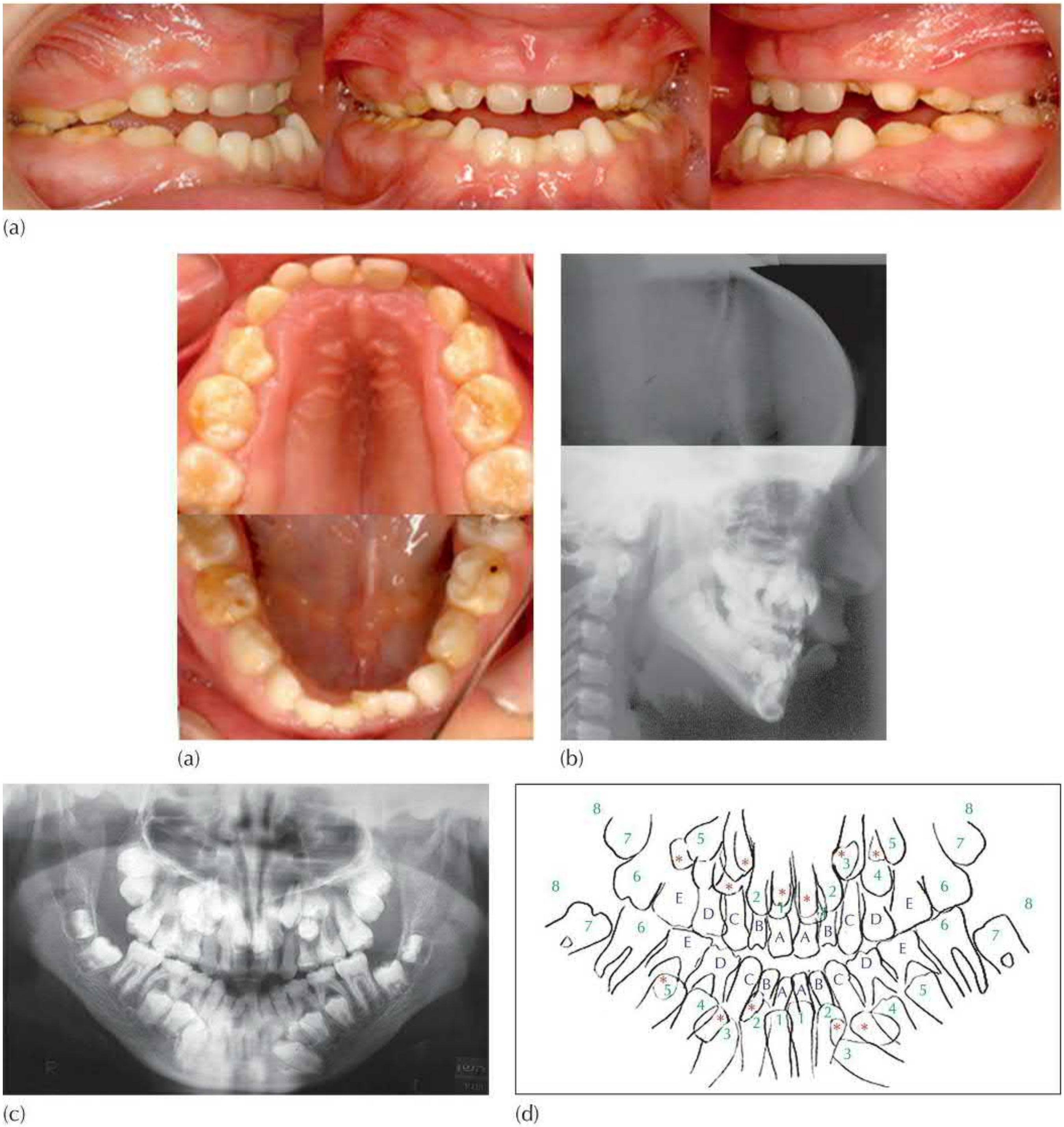


Fig. 21.11 (a) Intra-oral views of the dentition of a 13-year-old male cleidocranial dysplasia patient, showing an almost complete deciduous dentition and significant potential crowding of the permanent teeth, with only the erupted first molars of the permanent dentition. The clinical condition indicates a severe skeletal class III inter-arch relation. (b) A poor-quality cephalogram at 12 years of age shows a steep mandibular plane and vertical growth direction. The top part of the

film has been deliberately Photoshopped to illustrate the open anterior fontanelle and coronal suture. (c) The initial panoramic view. The mass of superimposed, unerupted teeth can be clearly seen to be at considerable distances from the occlusal plane, particularly in the maxilla. (d) A tracing of the panoramic view in (b) with the deciduous teeth labelled A–E, the permanent teeth labelled 1–8 and the supernumerary teeth asterisked.

There are many instances of spontaneous eruption after space preparation and after extraction of the deciduous teeth, but this is not to be relied upon. If it does indeed occur, it will simplify the treatment plan. However, the Jerusalem approach has been formulated to confront the worst eventuality, i.e. across-the-board non-eruption. From the point of view of the orthodontic mechano-therapy, efficient force application in a specific direction for each tooth, requires evaluation of the following points:

- There must be a sufficient number of erupted teeth in the mouth to act as an anchorage base from which forces may be generated. As we have already pointed out, the permanent molars usually erupt without assistance, and one or two incisors may also be visible.
- A rigid appliance base or frame must be designed in order for it to withstand chewing and other functional and para-functional movements that may be expected to occur during daily oral function. Long spans of free unattached and unprotected archwire may exist between the first molar and the lateral incisor on each side, which makes this requirement difficult to achieve.
- Individual and groups of unerupted teeth must be subjected to light continuous extrusive forces that are effective over a wide range of movement.
- Appliance design has to be sufficiently versatile to enable it to:
  - Apply vertical extrusive forces to rapidly erupt the impacted teeth.
  - Open spaces between recently erupted teeth, to provide room for other unerupted teeth and to establish interproximal contacts and archform.
  - Bring these teeth into occlusion and upright their roots.
  - And all this with only minor alterations to the basic design.

Based on clinical experience with more than 40 CCD-affected individuals, we have observed that there are few cases where the first permanent molars do not erupt into the mouth autonomously. The lack of an anchor molar will cause technical difficulties in generating occlusally directed forces on the unerupted teeth. It will also create difficulty in raising an unerupted molar itself into the occlusion. These cases require special consideration on an individual basis, but many of the answers to the exceptional situation may often be found by transferring the onus of the anchor molar onto an orthodontic band on the terminally located second deciduous molar. However, the lack of an anchor molar undoubtedly makes for the most severe complications in the treatment planning of CCD.

For the purposes of illustrating the Jerusalem method, we will describe the treatment plan in the case of a dentition exhibiting an ultimate worst-case scenario, by which we mean that, aside from erupted first permanent molars, the only other erupted teeth in the mouth are the deciduous incisors, canines and molars, 20 in all, i.e. the full complement of deciduous teeth.

An initial examination with the paediatric dentist needs to be arranged at which the permanent molars *and* deciduous molars are examined for caries and treated restoratively in the normal way. At this session, reinforcement of the aspects of oral hygiene and any other necessary preventive measures will be dealt with. It should be remembered that the deciduous molar teeth will need to be maintained in a healthy state for at least a further 3–4 years. The orthodontist will require a panoramic radiograph, although it is more than likely that this will already be available from visits to other dental practitioners (Figure 21.11c). During the years ahead, the CCD patient will need to have many radiographs and cone beam computed tomography (CBCT) imaging, both for diagnosis and for follow-up of the treatment, so that careful monitoring of the number and type of films that are needed should be carried out. Care will need to be exercised in commissioning new films, in order to reduce the considerable aggregated dosage of ionizing radiation to which the patient will inevitably be exposed.

The initial films need to be carefully studied to identify the teeth of the normal series and the supernumerary teeth. The individual teeth on the film should be carefully identified and then marked and labelled on a tracing, because the case will need to be discussed with the surgeon in regard to the upcoming first surgical phase (Figure 21.11d). A decision needs to be made regarding which teeth will be extracted, which will be surgically exposed and which will be equipped with a bonded attachment. A CBCT will often be an essential diagnostic aid at this stage and for most cases should be considered mandatory.

Preparing the patient

In Chapter 6, we pointed out that it is unacceptable to leave even the youngest patient without front teeth for an extended period of time and that it is important to make the child aware that efforts are being made to speedily rectify such a situation. The physical obstacles to eruption (i.e. the deciduous and supernumerary teeth) must be removed in order to facilitate the eruption of the anterior teeth. Proper timing is critical and extraction should only be done at the age when the permanent incisor teeth indicate root development that is adequate for eruption, and only when an appliance is in place to actively supplement their limited eruption potential.

The Jerusalem approach in clinical practice

Stage 1: Ensuring the health of the dentition

Treatment of the CCD patient will necessitate the wearing of orthodontic appliances for several years. Therefore, an essential requirement in all cases is that the health of the dentition be guaranteed by proper oral hygiene instruction, with follow-up to monitor adequate level of compliance. Appropriate use of fissure sealants and fluoride applications is recommended. At the beginning of the treatment, it is essential to determine in advance the timing of the extraction of the remaining deciduous teeth. This will enable the paediatric dentist to decide on the type of restoration indicated, in the event of the need to treat carious teeth.

Stage 2: Vertical correction in the incisor region

As has been pointed out, there is a delay of about three years in the dental development of a CCD child, compared with the actual chronological age. Thus, for most CCD cases, it will not be until about the child's *10th birthday* that the spontaneous and unimpaired eruption of all first permanent molars will occur, to demonstrate a *dental age of 7 years*. Sometimes, one or more of the permanent incisors will also have erupted but, in the following description of the technique, we shall assume the least favourable initial scenario, i.e. that no permanent anterior teeth are present.

The initial orthodontic set-up

Surgery for the extraction of the remaining deciduous teeth is to be conditioned upon the patient going into the operating theatre with the constructed appliance in place, in order to apply immediate extrusive forces to the impacted teeth. The appliance should be placed a week or so prior to the date for surgery, to ensure that it is comfortable and not producing any sores or other unnecessary pain or distress. The intention is to activate vertical traction contemporaneously with the latter part of the actual surgical procedure itself and before the patient is aroused from the general anaesthetic. If this is attempted later, there is a significant risk of failure, because the patient is fully conscious. It should be appreciated that the soft tissues tend to close over any partially erupted teeth and there is considerable sensitivity and tenderness of the recently surgically traumatized oral soft tissues – even several weeks later.

Following the placement of elastic separators in the interproximal contact of the first permanent/second deciduous molars, plain orthodontic bands will be fitted on the erupted first molars and an impression taken of each dental arch. The bands are then carefully removed from the teeth, re-seated in the impressions and a model is cast. Soldered 0.036 in. gauge stainless steel lingual stabilizing arches are prepared on the models of the two dental arches (Figure 21.12a). Care must be taken to design the form of the lingual arches so that they will not interfere with the surgeon's access to the individual impacted permanent teeth that will be exposed.

On the buccal side, single round cross-section tubes of 0.036 in. gauge need to be placed on the molars in such a way that they are oriented to run mesially, in a direct line, close to the buccal side of the deciduous teeth and parallel to the occlusal plane. This is exceptionally difficult to achieve with individual pre-welded or weldable manufactured tubes. Accordingly, it will be better and far more accurate to use straight lengths of stainless steel tubing and to solder them to the bands on the plaster model. The excess lengths of tube are then cut short to leave only a 6–8 mm soldered tube on each molar. In order to be able to align the buccal tubes accurately, it may be necessary first to align a lingually displaced first permanent molar with a simple removable appliance. The efficient working of the appliance will depend on this.

An 'incisor-erupting' archwire is prepared in advance for each jaw (Figure 21.12a), whose function is to achieve a correction in the vertical plane. In other words, this archwire is entirely responsible for the application of extrusive force on the four incisors and to bring them to the occlusal level. This archwire is made of 0.036 in. stainless steel round wire, which slots into the buccal molar tubes up to a predetermined bayonet bend on each side. Since this is an 0.036 in. wire that slides into a 0.036 in. tube, there will be no 'play' in its precise fit, it will be held rigidly and it will be self-supporting. In this way, the wire is held 2–3 mm labial to the anterior teeth and 2–3 mm gingival to the occlusal plane. In the canine area, an S-shaped hook is soldered, with its mesially pointing extremity on the occlusal side and the distally pointing extremity gingival. In the midline area, a small wire frame is also soldered and points upwards towards the height of the oral mucosal reflection in the maxilla and the reverse in the mandible. The only flexibility that exists in this archwire is the up-and-down deflection that may be effected in the incisor area, with its fulcrum at the molar itself. At that distance (approximately 5 cm) and with an appropriate deflection, its range of action is ideal for imparting light, continuous extrusive force.

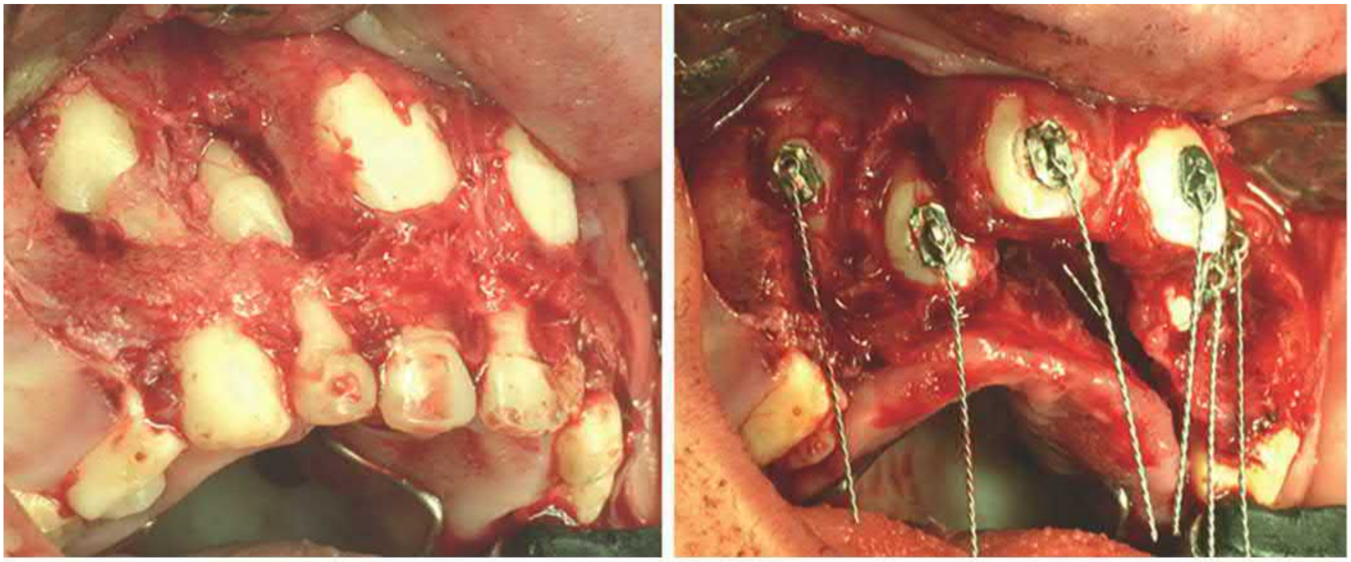
The two-part appliance therefore comprises a cemented base unit with a lingual arch and buccal tubes soldered to the molar bands in both jaws. This unit is placed in the mouth and checked for accuracy and comfort. The second part, the prepared and removable labial arch, is then slotted into the molar tubes and it, too, is checked. If all is well, the maxillary and mandibular base units are cemented into place a week or two before the surgery. The archwires with eyelet attachments and a small kit of instruments that will be used to facilitate the bonding and ligation will be autoclaved and stored in readiness for use at the time of surgery.

Surgery in stage 2

The patient is now ready for the first surgical intervention, which must be performed in the environment of a hospital operating theatre, under endotracheal general anaesthesia.

As noted above, in CCD patients many impacted teeth are to be found very deep in the basal bone. To follow an open exposure policy would entail removing the supernumerary teeth and all the bone around the impacted teeth of the normal series down to the CEJ. It would also mean maintaining the patency of the exposure by reducing the soft tissue and placing surgical packs. There will be a need to suture the surgical flaps more apically, to prevent the gingival tissues from re-covering the exposed teeth. To do this for a series of deeply impacted teeth would mean paring the height of the alveolar bone down to the level of the necks of these teeth. This would result in a very radical removal of bone and, particularly, a potentially dangerous weakening of the body of the mandible.

(a)



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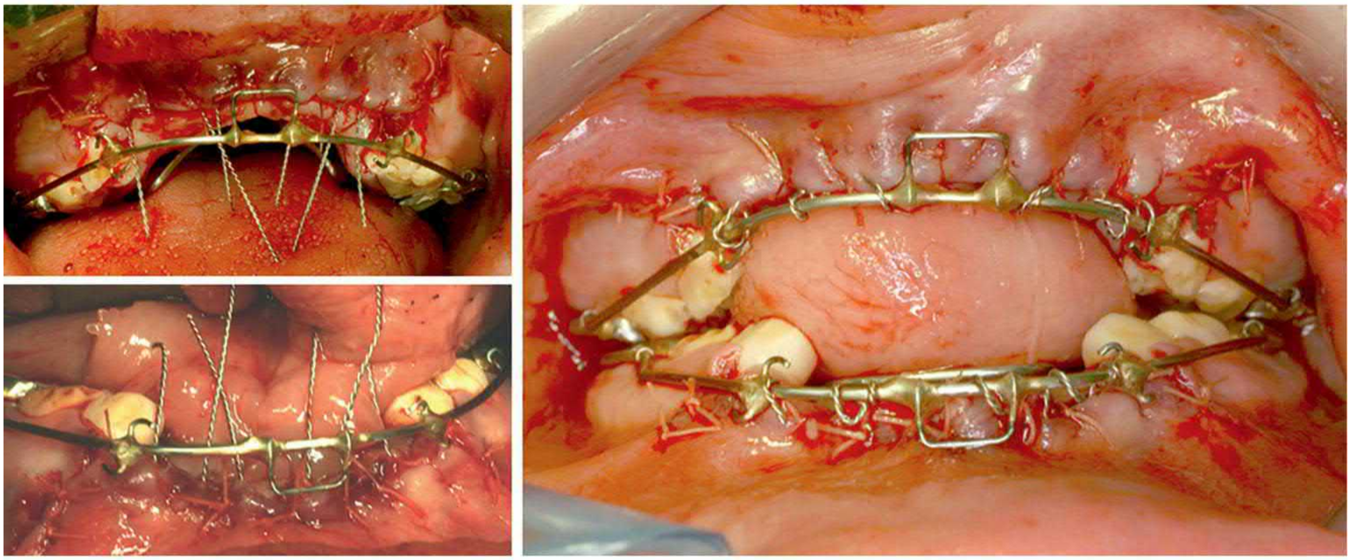

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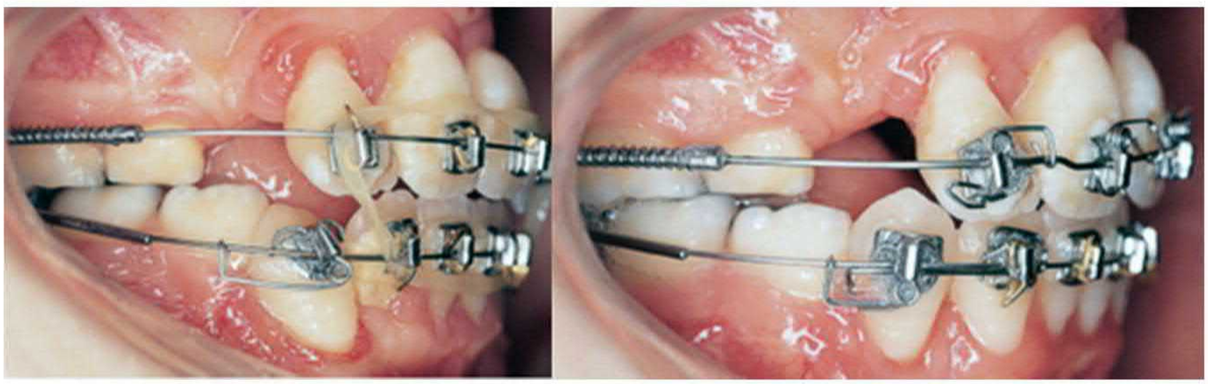

(h)

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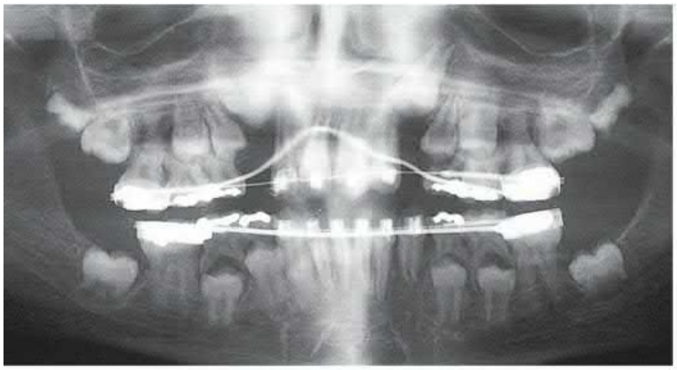

(k)

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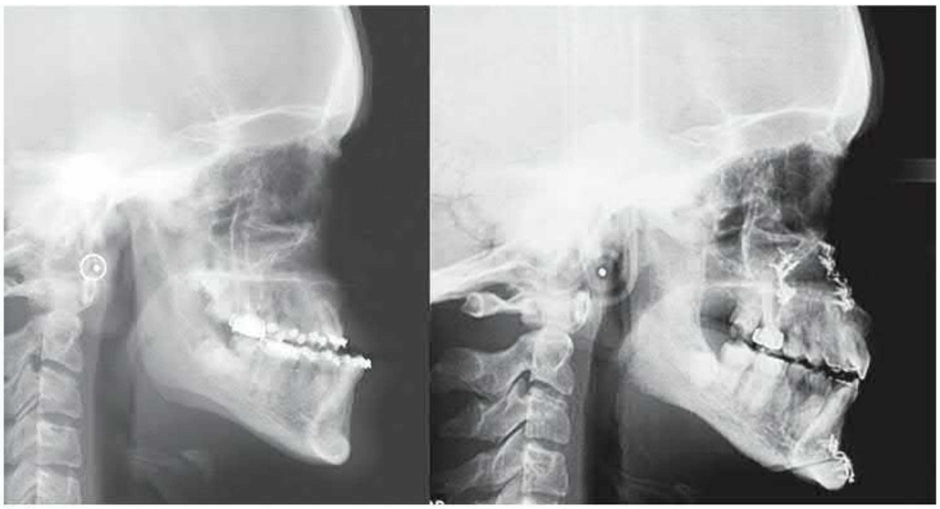

(p)

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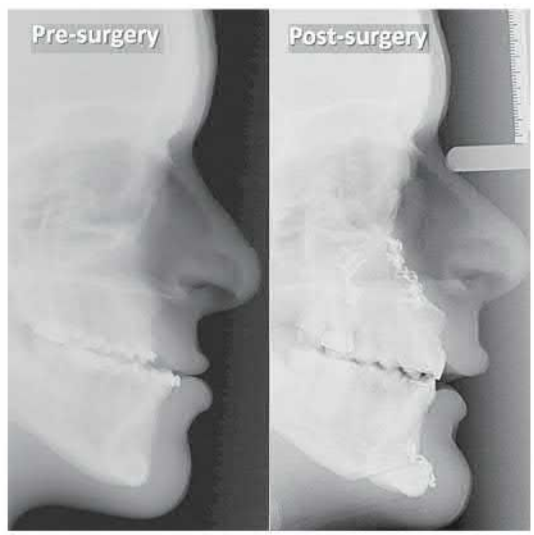

(r)

(s)

(t)

(v)

(u)

Fig. 21.12 (a) The initial appliance, with a lingual arch on molar bands in each jaw and soldered 0.036 in. round buccal tubes. Removable labial incisor-erupting archwires of 0.036 in. round archwires, with S-hooks in the canine region and anterior midline area frame. (b) At surgery. The exposed labial surfaces of the maxillary incisors (and canines in this case), with the deciduous incisors and supernumerary teeth still in place to show the height of the permanent teeth. The same view after extraction of the supernumerary and deciduous teeth, with eyelets vertically oriented. (c) Similar views of the mandibular anterior teeth. (d) At surgery. The surgical flaps were replaced, with only the twisted wire connectors exiting at the sutured edges. The prepared self-supporting archwire was re-inserted and ligated with the shortened connectors under light tension. (e) The six extracted anterior deciduous teeth in each jaw, together with the single anterior maxillary supernumerary and the six supernumerary mandibular teeth herewith displayed. (f) At five weeks post surgery, a very light anterior 'up-and-down' elastic is placed on the distally pointing element of the S-hooks in the canine areas to enhance the anchorage. Note the use of the midline frames to prevent tissue impingement. At nine weeks post surgery, five incisors have erupted and the archwires have been disengaged to increase their deflection. Re-engaging the archwires illustrates their range of effectiveness. (g) At 6.5 months post surgery, all incisors have erupted. Conventional brackets have been substituted for the eyelet attachments and the 'incisor-aligning' archwires are tied in. At this juncture, extrusive forces were applied to the mandibular canines for the first time and up-and-down elastic were still in use. (h) Before and after correction of the bilateral mesial displacement of the root of the mandibular canine. Note the continued use of up-and-down elastics and the active coil springs on the side tubes of the maxillary appliance. (i) Before and after correction of the buccal displacement of both mandibular canines and the lingual displacement of the lateral incisors. (j) Preparation for vertical correction of the posterior teeth. The Tip-Edge brackets were substituted for the earlier Begg brackets, simply for convenience rather than necessity. The same molar bands and transpalatal arch were still in place. (k) The new panoramic radiograph, taken a few months before exposing the unerupted teeth. (l) The post-surgical panoramic view shows a heavy and very minimally activated 0.020 in. round stainless steel archwire, ligated into the maxillary six anterior teeth. The connectors from the bonded eyelets on the premolars are turned over the archwire before suturing the surgical flap. In the mandible, the archwire has yet to be placed in the same manner. (m) The fully erupted first molar to first molar dentition, in class III occlusal relation. (n) The dentition seen at the completion of orthodontic treatment, after the eruption of all the permanent premolars and canine. Note the unerupted presence of three of the four permanent molars on each side of the maxilla and the development of an additional and unerupted mandibular right premolar. (o) The pre-surgical orthodontic set-up for intermaxillary fixation, seen here with the teeth in occlusion and in the occlusal views. (p) Comparative cephalograms seen before and after the surgical procedure. (q) The postsurgical panoramic view. (r) Radiographic profile of the soft and hard tissues, as seen on the lateral cephalograms, pre- and post treatment. (s) Clinical intra-oral views, as seen post treatment. (t) The degree of exposure of the maxillary incisors was good and the incisal edges correctly related to the crest of the lower lip at rest. (u) The posterior teeth were well 'socked in' in their ideal occlusal relations, at six years post treatment. (v) Panoramic radiograph taken six years post treatment. Note the alteration in position of the right-side mandibular third molar and that the third and fourth maxillary molars have been extracted.

A *closed surgical exposure* policy is strongly recommended for these teeth. This will entail opening an attached gingival flap from the gingival crevice of the deciduous teeth and identifying the crypts of the teeth deep in the vestibular and lingual sulci, after the extraction. The supernumeraries need to be clearly identified and extracted. At the same time, only the thin shell of bone covering the dental follicle should be carefully removed from the buccal aspect of the permanent teeth. The follicle is opened on this aspect only and just enough to provide an enamel surface large enough to accept a small bonded eyelet attachment. Bone is not removed occlusally or interproximally and bone channelling in the intended direction of tooth movement is to be avoided. Every effort must be made to conserve as much bone as possible, in the interests of maintaining and, eventually, enhancing alveolar bone height.

Experience has shown that overlying bone is not an impediment to the movement of the impacted teeth. It resorbs in response to the vertical extrusive forces in the same way as forces acting on erupted teeth in routine orthodontic practice [41–43]. When bone is arbitrarily cleared away by the surgeon in order to encourage eruption, it is always done more radically, as some might say to be sure that it will not need to be repeated later.

We have already discussed the value and importance of the orthodontist being present at the surgical exposure of teeth. It is quite unfair to expect an oral and maxillofacial surgeon to place attachments on impacted teeth at the time of surgery. Such surgeons are not familiar either with the desirable site of the attachment on the crown of the tooth concerned or with where traction of the tooth is to be directed. The orthodontist should be on hand to bond simple eyelets to the exposed and bonded incisor teeth, with the eyelets oriented parallel to the long axes of the teeth concerned (Figure 21.12b, c) [43].

The pigtail ligature connectors are drawn vertically towards the opposite arch, while the pre-surgically fabricated archwires are re-inserted into the horizontal buccal tubes (Figure 21.12d). The pigtail ligatures in the maxilla are then bent over to ensnare the heavy labial archwire, which will have been raised under light finger pressure, towards the sutured surgical flaps and unseen impacted teeth (Figure 21.12d). The archwire in each jaw is then loaded with an extrusive force against the four unerupted incisors, through the agency of the twisted pigtail ligatures that exit the occlusal edge of the flap. The surgeon then closes and sutures back the full flap to cover the entire exposed surgical field.

In these last two paragraphs, the reader should be able to count six different but important tasks that need to be performed at the time of surgery. The orthodontist is the only person familiar with the importance of each of these and the only person competent to perform these six tasks and to do so to best advantage in terms of streamlining the subsequent orthodontic treatment [39].

At the completion of this episode the patient will have lost all the anterior deciduous teeth, from deciduous canine to deciduous canine inclusive, and will also have had the anteriorly placed unerupted supernumerary teeth removed in both arches. Fine pigtail ligatures will have been placed in the eyelet attachments bonded to the incisor teeth and, following suturing of the flaps back to their original place, these ligatures will be the only link between the invisible unerupted permanent teeth and the exterior (Figure 21.12e). Deciduous teeth that are not associated with supernumerary teeth are generally left until the next surgical stage.

Under these circumstances, this surgical procedure, with the placement of attachments and the activation of traction, will generally take between three and five hours, depending on the number of supernumerary teeth removed and the number of unerupted permanent teeth that need to be exposed.

In the fullness of time, the permanent canines in both jaws will grow longer roots than the premolars. At the first surgical intervention aimed at the incisors, the radiographs may often show that the canines have already developed much of their long roots. This may sometimes be considered adequate to allow for exposure of the canines at the same time as the incisors. This step is also favoured by many surgeons, both for immediate convenience and to reduce the number of teeth to be exposed in the second intervention. However, in this eventuality, extrusive traction needs to be applied to the canines, but only after the eruption and alignment of the incisors has been completed. All six upper and lower incisors and canines (12 in all) were exposed and bonded in the first surgical intervention in the case illustrated in Figure 21.12. Much time elapsed and more root growth occurred before the incisors had completed their appliance-aided eruption, their alignment and their needed proclination. Thus, extrusive forces were only aimed at more mature canines after some considerable time.

Orthodontics in stage 2

After the initial surgical procedure, the patient will be seen by the surgeon in a post-surgical visit prior to release. A further visit will generally be scheduled for follow-up of healing a week or so later, and thereafter the patient will be referred back to the orthodontist for continuation of the orthodontic stage of the treatment.

The visit to the orthodontist will usually be 3–4 weeks later, when the patient will be apprehensive and the tissues will be tender. It is consequently wise to limit the treatment provided at this appointment to cleaning the general surgical area with atomized water from a triple syringe. If one or more of the pigtail ligatures is causing ulceration of the lips or tongue, it should be carefully rolled up with a pliers or ligature director. Light-curing a small droplet of 'flow' composite bonding material over the sharp end is also sometimes a useful and rapid remedy.

If the patient is relaxed and cooperative at this preliminary orthodontic visit, it will be the appropriate opportunity to raise the anterior portion of the archwire and re-adjust the pigtail ligatures to increase the extrusive activation. The orthodontist may use surface anaesthetic spray to limit the discomfort engendered by these manipulations.

The light force from the archwire deflection generates a rapid response of the teeth. This will be evident from the elongation of the pigtail ligatures over a period of a just few weeks. Over subsequent visits, extrusive pressure may be simply and efficiently re-applied by displacing the archwire apically with light finger pressure and then rolling up the pigtail around it, until eruption finally occurs. This procedure should be performed simultaneously in both arches in order that they may subsequently be treated more efficiently.

The extrusive forces and their range are very easily measured and will therefore be easily controlled to within appropriate levels. The anchorage employed in the initial activation of the heavy archwire is from the molar teeth and from the lingual and palatal arches. If this is not reinforced with effective supplemental resistance, the permanent molars will tip mesially and, in the maxilla, the palatal arch will impinge on the palatal tissue and may sometimes become buried in it, as seen in Chapter 18 (Figure 18.14). This adverse effect will usually have occurred in both jaws and will illustrate failure of anchorage.

The application of vertical "up-and-down" elastics to the labial arches is extremely effective (Figure 21.12f). Aside from anchorage considerations, intermaxillary vertical elastics also have a very positive effect on the extrusive forces that have been applied to the teeth. For this reason, the second or third post-surgical visit is probably the first real opportunity to teach the child how to place these elastics. The distal-facing element of the S-shaped hooks on the heavy archwires was designed with this in mind. A single 3/8 in. or 5/16 in. medium elastic is stretched from the right to left hooks in the maxilla and then vertically down to engage the parallel hooks on the mandibular archwire. In order to keep the middle part of the elastic clear of the healing gingiva, it is stretched labially over the small soldered wire frame in the midline. The archwire itself may need to be secured into the molar tubes by drawing an elastic chain between the distal of the buccal tubes to the mesially pointing extremity of the S-hook, although this is rarely necessary. This anterior vertical elastic provides an intermaxillary vertical force to each archwire. At the same time, the forces employed to erupt teeth in one jaw are anchored by the reactive force that is producing the eruption of the teeth in the opposite jaw. This is called reciprocal anchorage.

Further activation should be done every 3–4 weeks, in accordance with the progress towards eruption of the teeth. As the pigtail ligatures become longer and the initial activation becomes exhausted, the ligatures require to be rolled up to raise the archwire and thus to maintain the momentum of the extrusive force (Figure 21.12e). The teeth will come through fairly quickly, depending upon their initial degree of displacement and ectopy, the range and magnitude of the force and the frequency with which adjustments are made. The teeth will erupt with a markedly lingual inclination, because extrusive force is vertical and the point of application of the extrusive force is to a labial attachment.

The vertically oriented eyelets, which were bonded to the teeth at the surgical procedure, will become fully visible supra-gingivally as the incisor teeth are erupting. At this point the heavy archwire should be discarded and orthodontic brackets placed on the newly erupted incisors.

However, there is much to be said for leaving the vertically oriented eyelet attachments in place for just one further visit, since the anterior teeth are still very far from being aligned. Lighter nickel–titanium (NiTi) and then stainless steel archwires will efficiently complete the levelling and alignment of the newly erupted teeth if they are threaded directly through the lumen of the vertically oriented eyelets, rather than being tied in with steel ligatures. If the deciduous molars are still present and were not extracted in Stage 2, then brackets should also be placed on the deciduous molars. If, on the other hand, the deciduous molars were extracted in Stage 2 of the treatment, in order to permit surgical access to eliminate supernumerary teeth in the premolar area, then a very different type of archwire will be needed. It will be appreciated that aligning and levelling the anterior teeth require the use of NiTi and lighter stainless steel archwires. Archwires of this type would be totally inappropriate when there is a very long bilateral edentulous span between the molar and lateral incisor teeth, as is apparent here, when deciduous molars have been extracted. Light and flexible archwires are still needed for incisor alignment, but the long edentulous spans require the presence of a heavier and more rigid archwire. The solution to this can be found in the composite archwire used in the modified Johnson's 2 × 4 twin-wire appliance described in Chapter 6. As in the case where the deciduous molars have not been removed, so here, too, the final visit prior to removing the eyelets (in favour of regular orthodontic brackets) should be devoted to the threading of the 2 × 4 flexible anterior part of the composite archwire directly through the lumen of the vertically oriented eyelets.

Stage 3: Horizontal (a–p) correction in the incisor region

Orthodontics in stage 3

The procedure described above will now have reached the stage where the incisor teeth will be fairly well aligned but lingually inclined. The eyelets should now be replaced by an orthodontic bracket of the orthodontist's choice, which should be sited in the routine manner (Figure 21.12g).

NiTi or light stainless steel archwire should be placed in the 2 × 4 side tubes, to improve the alignment of the incisors and the performance of mesio-distal uprighting. The progressive adjusting of the archwires will then proceed until a medium (0.016 in. or 0.018 in.) plain stainless steel round wire may be comfortably placed in the middle portion, using the same side pieces.

Two remaining points still need to be addressed at this stage where the premolar and, to a lesser degree, the canine teeth are still relatively under-developed. First, it would be preferable if the next stage were to be delayed a further 2–3 years to allow the premolar teeth to develop longer roots, before exposing them and attempting to raise them to the occlusal level. However, space should be prepared for them as early as possible, in the hope of seeing some eruptive progress during this waiting period. The second point relates to the incisor teeth, which have been erupted into a very vertical or even slightly lingually slanted posture.

Only one procedure is needed to treat both these situations, namely to increase the length of the span between the lateral incisor and the first molar on each side of both jaws. This is an antero-posterior expansion that lengthens the potential tooth-bearing area and, in so doing, creates space for the unerupted canines and premolars. The reactive force will also procline the incisors. All of this is highly desirable and will be achieved with the use of open-coil springs, threaded onto the long buccal arms of the 2 × 4 appliances used in the first eruption stage (Figure 21.12h).

In the case illustrated here, the expanded coil springs were placed on the side pieces after a 'stop' was soldered or welded to their mesial end. When the side pieces were replaced in the buccal tubes, the coil spring was compressed between the buccal tube and the mesial stop, thereby displacing the archwire forwards. When the archwire was subsequently ligated into the anterior brackets, it created an antero-posterior expansion force, acting between the first molars and the incisors. This rapidly tipped the incisors to a more normal labial inclination and, at the same time, lengthened the arch in the buccal region, thus enabling the eventual 'acceptance' of the unerupted canine and premolar teeth into the arch.

Once completed and in order to retain the resulting situation, a heavy base arch of 0.018 in. or 0.020 in. stainless steel was placed, incorporating closed and passive coil springs on the archwires, between molar tube and incisor bracket or between deciduous molar and incisor brackets. Archform was greatly enhanced and, with large aligned incisor teeth suddenly visible between the lips in speech and facial expression, the patient became aware of a vastly improved appearance for the first time.

At 15 months post surgery, the archform had been normalized and eruption of the mandibular canines was included as the last item in this stage of treatment. Because the rigid retaining base arch was present, it was considered appropriate and advantageous to undertake the correction of the labio-lingual displacement of both the mandibular canine and the adjacent lateral incisor (Figure 21.12i) and the severe mesial displacement of the root of the mandibular canine (Figure 21.12j). The occlusal view of the mandibular anterior teeth indicates conflicting labio-lingual displacement of the roots of the lateral incisors and canines, prior to and following the correction. These harsh root displacements required 4–5 months of further treatment to correct. This was done during a waiting period for adequate premolar root development, before moving on to initiation of the second surgical intervention.

In general, the treatment up to this point (Stages 2 and 3) should normally take between 18 and 24 months to complete. The teeth were in the mixed-dentition stage and in good alignment, with adequate space prepared for the eruption of premolars and canines. The appliances were stable and rigid, merely holding this situation pending the second surgical procedure, which was scheduled for 2–3 years later. Oral hygiene was good and the patient was followed up periodically during this long period.

It was during this period of follow-up, when no active treatment was performed, that the patient had clearly entered a significant growth spurt. This brought out the dominance of the mandibular growth in relation to the maxillary growth and the skeletal class III relationship was firmly established.

Stage 4: Vertical correction in the posterior region

The next stage opened with a study of a new panoramic radiograph to check the developmental status of the unerupted canines and premolars (Figure 21.12k) in order to assess the degree of their root development and re-assess their vertical location within the alveolus. A minor improvement in the positions of these teeth appeared to have occurred in the meantime, either due to absence or earlier removal of supernumerary teeth in this area or, simply, to an increase of space in the immediate proximity.

Surgery in stage 4

The main aim of surgery at this stage is to expose the permanent canines and premolars. The new radiograph confirmed development of a single maxillary left supernumerary tooth that had been identified on the initial radiographs. Signs pointing to the development of additional extra teeth may often be seen at this stage in the development of the dentition. The fundamental question of whether or not to perform a CBCT at all is very much a decision that must be taken jointly by the orthodontist and surgeon involved. In their deliberations they must bear in mind the number, frequency and dosage of past and future exposure to ionizing radiation to which these patients have been or will be subjected in the future (and not just from the present episode of treatment).

A second basic question to be determined is whether or not to conduct the surgery under local anaesthesia on a conscious patient. In discussion of this question, one must carefully consider the orthodontist's previous clinical experience with that particular patient. The discussion should include opinions from the orthodontist, oral and maxillofacial surgeon and indeed the patient. While there are advantages to working on a cooperative conscious patient, doing so may involve more than one surgical session, since all four quadrants of the mouth are implicated and the patient's own tolerance and forbearance for these long sessions is likely to be overtaxed. For the most part, a repetition of endotracheal anaesthesia and operating theatre conditions is warranted.

Prior to the surgery in this case, a new bracketed system was placed and the teeth quickly brought to full alignment for the placement of a heavy base arch in each jaw.

If there are remaining deciduous teeth, as seen in this case, these should be extracted and a buccal flap raised in each quadrant in turn. The permanent canines and premolars of the normal series and the supernumerary teeth need to be identified and the latter carefully removed. The individual permanent canine and premolar teeth are minimally exposed on their buccal surfaces (in the same way as with the incisors in the second stage; Fig. 21.12b, c). In the event that there are lingually located supernumerary teeth, the molar bands and soldered lingual arch will need to be removed and re-cemented after completion of the surgery for that jaw. Bone is not removed over the occlusal or interproximal aspects of the exposed teeth, even if these teeth are deeply embedded in the basal bone. The surgeon should isolate the teeth using retractors and sterile swabs, together with the use of a fine suction tip. The area is rinsed with sterile saline and dried, using suction rather than compressed air. The individual enamel surfaces of the teeth are etched using gel etchant to avoid spillage, drawn off in the suction tip before rinsing the enamel surface. The area is dried off again with the suction tip. An eyelet is attached to each tooth, using light-cure bonding material, and oriented in line with the long axis of the tooth.

It is important that eyelets should be bonded to the two premolars on each side of the same jaw. The same 2 × 4 or heavy stainless steel archwire is re-inserted and re-ligated to the incisor brackets. Several extrusive force options for the impacted teeth are available and whichever is chosen should ideally be applied before the surgical flaps are re-sutured to their former places. This will close off the surgical area as completely as the tissue will allow, while leaving only the twisted soft steel ligature wire vertically exiting the sutured edges of the flaps.

Manipulation of the pigtail ligatures and application of extrusive forces are functions that may often act to transfer considerable force to the newly bonded eyelets and may thereby cause one or more to fail, under the conditions prevailing in the operating theatre. Our own experience has shown that, with the excellent cooperation that we have developed with our collaborating surgeons, such failure is a rare occurrence [39]. Nevertheless, it is often preferable to apply the extrusive forces before suturing is done. One must always remember that in the event of eyelet detachment, sutured flaps will need to be re-opened before bonding may be repeated.

Once again, the orthodontist has the same crucial role in the operating theatre and will need to be consulted constantly regarding the aspect of each tooth that is to be exposed and the degree of exposed tooth surface needed for bonding. Bonding of the attachment to the designated site is best performed by the orthodontist, who will have planned the location and direction in which the pigtail ligature needs to exit the re-sutured flap. One of the greatest benefits of the presence of the orthodontist is the availability to apply immediate traction to the impacted tooth through the agency of the twisted steel wire connectors, as described in Chapter 5. Attempting to do this even 1–2 months later is much more difficult for the child and a first-time application of traction, with healing and haemorrhagic gingivae, is usually very sensitive and uncomfortable. It is also delicate, thorny and fiddly for the orthodontist to accomplish, without at least applying surface anaesthetic spray, to avoid an understandably wriggling child.

Stage 5: Correction of the root orientation

Orthodontics – eruption mechanics

The scope for designing an extrusion mechanism in the premolar region of the mouth is very limited. Essentially there are just two principal options:

- The twisted steel pigtail ligatures exiting through the sutured edges of the replaced flap are turned over into small loops, as close as possible to the gingival tissues. Elastic thread can then be tied between the rigid side tubes of the 2 × 4 labial arch and these small loops, and will generate an extrusion force of small range and with limited control, the extent of which will be dependent on the distance between the two.
- If the archwire used is a stainless steel round wire of 0.020 in., this will offer a minimal degree of flexibility in the long span between lateral incisor bracket and molar tube. The twisted steel pigtail ligature is left fairly long in order to be used directly to entrap the long span of unsupported archwire that has been deflected under finger pressure towards the replaced flap. The pigtail is turned over the archwire in the form of a hook, to hold it in its now activated extrusive mode. This simple move will avoid the necessity of an additional tie, while providing a wider range of action.

Extrusive traction should be applied to the premolars by ligating a flexible mechanism (such as a spring auxiliary or elastic thread) to a rigid archwire or temporary anchorage device. Tying a non-elastic steel ligature from the eyelets of the premolars (or their connectors) to a super-elastic NiTi archwire is *not* an alternative. Such action would cause bowing of the unsupported archwire span, with very minimal extrusive force on each of the premolars. The reactive force will cause the incisors to collapse in lingually, to tip the molars mesially and, by so doing, lose the space that had been gained earlier

Once exposure and attachment bonding in the canine/premolar area were completed (Figure 21.12l), archwires were slotted into the molar tubes and re-ligated in the anterior brackets. The application of extrusive forces to the premolars and canines were completed before the patient was wheeled out of the operating theatre. As has already been noted, activation of the extrusive mechanism at the time of surgery will allow a month or so for healing to occur and for pain and discomfort to disperse before a new activation is needed. In some cases this single activation alone will bring a more superficial tooth to the surface.

It is important for the future orthodontic resolution of any impacted tooth that it is the orthodontist who must decide upon the manner of completion of the surgical procedure. There must be good access to the tooth/teeth after the flaps are re-sutured back to their former places and before the patient exits the operating theatre. When the patient subsequently returns to the orthodontic clinic a few weeks later, there should be no reason for delay in proceeding directly with the planned orthodontic treatment strategy of renewing the extrusive force. In many cases, a marked improvement in the position of the impacted tooth will already be evident.

Progress will be measured at the next visit by the degree with which the twisted steel ligature has lengthened supra-gingivally. At that visit, the hooked end of the ligature, which was positioned as the point of application of the elastic thread, is to be rolled up on itself with spring-former pliers, until it is once again in tight contact with the healing soft tissue flap. It is then re-ligated with elastic thread in the same manner as before. In the second method, the hooked end is shortened and again turned over the deflected archwire, under light finger pressure, to reactivate its force. In both cases, the presence of the soldered lingual arch helps to prevent any mesial tipping of the molars that would otherwise occur.

Once the teeth have erupted sufficiently for the eyelets to become fully visible supra-gingivally, the distance between the attachments and the archwire will have become markedly reduced and, with that, the extrusive potential of the system will become significantly less. Elastic thread will no longer be useful and pigtail ligatures will no longer displace the archwire vertically. The existing archwires are only then discarded and substituted by round NiTi archwires of 0.014 in. or 0.016 in. gauge, which are threaded directly through the vertically oriented eyelets on the canines and premolars.

Within a matter of 4–6 weeks, the teeth will have come close to their intended final locations. They will no longer require individually customized elastic or spring devices to move them from their positions of remote ectopy into the general line of the archform of the other teeth. Henceforth, the fine movements of the formerly impacted teeth will be controllable by a continuous plain archwire, in what we have referred to here as the orthodontic ‘ball park’.

This ball park may be loosely defined as ‘the status reached that permits a continuous archwire to be ligated into sophisticated, precision-engineered, orthodontic attachments on all the teeth, including the formerly impacted tooth’. In essence, the patient has now become an average, conventional orthodontic patient, like any other. The remaining treatment will be to level and align, rotate, upright and torque the teeth in the manner normally carried out for any other orthodontic patient. The orthodontic ball park is therefore the ‘recreation ground’ where orthodontists are clinically comfortable and where the various orthodontic systems or ‘philosophies’ are able to offer therapeutically complete and exquisitely sculpted outcomes.

Within the scope of the routine treatment, the eyelets should be removed and replaced by regular orthodontic brackets of the type favoured by the orthodontist (Figure 21.12m). The molar bands with the round tubes and soldered lingual arches are also removed and replaced by bonded tubes or bands with the tubes and attachments that complement the bracket system chosen. Any required molar expansion or rotation may now be performed, together with the uprighting and torqueing movement needed to produce optimal alignment. Standard finishing procedures that are protocol in any routine orthodontic case now become possible and are carried out in the usual way. Within approximately six months, the teeth will have erupted those last couple of millimetres and existing rotations and root movements will have been corrected.

In the illustrated case, the panoramic radiograph shows the unerupted presence of the second, third and fourth permanent molars, crowded into the maxillary tuberosity, and unerupted mandibular third molars. In the mandibular right side, a supernumerary premolar is seen to superimpose on the lateral incisor, canine and first premolar.

Extreme tooth movement

In many cases of CCD that one sees, the teeth will have been severely displaced by the physical space-occupying presence of supernumerary teeth, which are scheduled to be extracted as an integral part of the treatment protocol. Accordingly, the appropriate treatment will involve the very challenging task of uprighting and torqueing to an extent not seen in non-CCD patients. The treatment takes considerable time to achieve satisfactory results, even when a particularly efficient root-moving mechanism is used. This is due to the distances that displaced root apices have to travel through alveolar bone in order for the tooth to be brought to a vertical axial orientation. For optimum effect, the orthodontist is encouraged to use auxiliary springs on rigid base arches. Springs possess a greater range of action and flexibility of forces, while the base arch maintains the overall archform.

Retention of the treated result

After a short period of time with conventional removable retainers, the protocol in Jerusalem has been to prepare and apply fixed multi-stranded bonded retainers to the maxillary and mandibular six or eight anterior teeth [43–47]. These will then hold the labio-lingual positions of all the anterior teeth, as well as prevent rotational relapse. The removable retainers are then discarded.

With the CCD patient, there is no scientific way to judge the 'biologically correct', and therefore stable, position of the incisors. Nor are there any published cephalometric data on a large group of treated and post-retention CCD patients to help establish such norms. It is wrong to compare the cephalometric values of these patients to the average values found in the various growth studies that have been carried out on normal patients.

Consequently, the use of well-recognized orthodontic analyses and growth predictions, as proposed elsewhere [24], would appear to be invalid and misleading. The orthodontist can never be sure of the stability of the final result of this aspect of the treatment, and some form of long-term retention will usually be advisable. Accordingly, we have adopted the view that the incisors should be brought well forward and extruded below the upper lip. In this manner, 2 or 3 mm of their incisal edges will be clearly visible when the lips are at rest and slightly parted. We also agree with the recommendations of Zachrisson regarding the so-called 'smile line' [48] and the need to compensate to some degree for the years for which the patient has lived with very short and largely unseen teeth.

Prior to commencement of treatment and even during the initial stages of treatment, only deciduous teeth have been present, with the result that these patients' social interaction with others would have been controlled by a constant and over-riding desire to mask the missing or diminutive anterior teeth. Indeed, they may have adopted unnatural, unwelcoming, unsmiling facial expressions and a reserved attitude. However, once dental alignment is complete and appliances removed, a positive and dramatic psychological change takes place in these patients' attitude to life. From that point on, many treated CCD patients have a permanent smile on their faces, consciously and deliberately displaying their new-found teeth. They adopt an optimistic outlook on life and become much more open in their day-to-day contact with others.

Orthognathic surgery

A significant proportion of CCD patients will develop skeletal class III relationships, as seen in the patient in Figure 21.12, and in these cases it is inevitable that orthognathic surgery will be the best answer. To all intents and purposes, the appropriate timing for this treatment is predicated on two factors:

- It should only be commenced when all the teeth have been erupted and brought into an occlusion, in order to provide a stable base for the fixation of the surgically mobilized jaws in their desired locations and skeletal relations.
- It should only be undertaken when the patient's growth has stopped. It should be remembered that the mandible is one of the last bones in the body to complete its ossification.

For the patient illustrated in Figure 21.12, treatment began in July 2006, with the incisor-erupting stage, when he was aged 13.11 years. In a departure from protocol in this particular patient, the four permanent canines were included, together with the incisors, in this first stage. As a result, this phase of the treatment was longer than usual and was only completed 34 months later, in April 2009. At its conclusion, the six maxillary and mandibular anterior teeth had been brought to their place and into good alignment, with a minimal but positive overjet situation. In time and particularly during the adolescent growth period, this deteriorated into a marked cross-bite relation and severe class III malocclusion, due to the exaggerated realization of the growth potential of the mandible (Figure 21.12o, p). The remaining orthodontic procedures in this phase were completed in December 2011, when he was 19.5 years of age, with the angulation of the incisor teeth having been decompensated in line with the planned post-surgical outcome, thereby producing a large pre-surgical negative overjet.

Shortly after completion of the orthodontic preparation, the patient was drafted into the military, where he spent the next three years. Plans for the orthognathic treatment stage could not be put into effect during his service and the treatment was delayed until his release, in February 2015. However, the maxillary third and newly developed fourth permanent molars (Figure 21.12n) were extracted in October 2014, in readiness for the jaw surgery.

In conference with the surgical team, led by Prof. Nardi Casap Caspi, a two-jaw procedure was planned, not least in view of the very large discrepancy between the jaws. This involved a LeFort 1 osteotomy in the maxilla to create a 6 mm advancement and four 1.5 mm AO plates (DePuy Synthes) were used for fixation. A bilateral vertical ramus osteotomy was employed to set back the mandible by 4 mm, followed by intermaxillary fixation. A 6 mm advancement genioplasty with fixation using two 1.5 mm AO plates was carried out in the mandible. The patient was discharged from hospital seven days after surgery, having been intubated for two days in the intensive care unit following respiratory complications during the recovery period.

The surgery was performed in June 2015. The patient was seen subsequently on several occasions until December 2015 for some minor orthodontic adjustments, before the appliances were removed (Figure 21.12q). Fixed 3-3 twistflex bonded retainers were placed in both jaws on the same day and no other form of retention was used.

The patient's overall facial appearance and profile underwent marked improvement, from the point of view of both the soft tissues and the bony skeleton (Figure 21.12r). The face was harmonious and symmetrical, although for reasons of patient confidentiality this is not shown here. The upper lip was well supported by the dentition and there was a good degree of lip competence. The teeth are well aligned and the jaws now normally related (Figure 21.12s).

The 'smile line' of the incisal edges of the upper teeth in relation to the curvature of the lower lip was excellent (Figure 21.12t). The pre-surgical records were taken in 2013 (when the patient was 21 years of age) and the immediate post-surgical records only in 2015 (following discharge from the military) at age 23 years.

The major clinical benefits that were achieved in the orthognathic surgical phase of the treatment may be summarized as follows:

- Increased lower third of the face.
- Improved chin profile.
- Improved nasal profile.
- Relatively reduced nasal length due to the dentally supported upper lip and a consequent forward displacement of soft tissue A-point.
- Intra-orally, the teeth were well aligned and the occlusal relations feature good class I dental inter-digitation with normal overjet and overbite.

A general overview of the patient after the completion of the treatment showed the following features. The maxillary central incisors displayed long clinical crowns due to a degree of gingival recession (Figure 21.12u) and, while the periodontal tissues were healthy, the panoramic and periapical radiographs showed bone loss around the maxillary incisors. This may be causally related to the fact that supernumerary teeth, at the outset, had been located on the lingual side of the unerupted incisors. A large bony defect had resulted following their surgical removal. A relative lack of fill-in of new bone during the healing stage, together with the forced eruption of the labially and superiorly displaced incisors, did not stimulate a sufficiently positive response on the part of the alveolar bone, enough to follow the dental development. The left maxillary central and lateral incisors also displayed short roots (Figure 21.12v), because of their initial extreme height displacement and close relation with the floor of the nose (see Chapters 6, 13 and 20).

At the 2021 follow-up visit (sixth year of post-surgical follow-up), the results were stable and the tissues healthy, as seen on the panoramic radiograph (Figure 21.12v).

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