ORTHODONTIC TREATMENT OF IMPACTED TEETH

THIRD EDITION

Adrian Becker
Orthodontic Treatment of Impacted Teeth
To my wife Sheila, to our children and grandchildren, and to the memories of our parents and my sister.
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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 orthopedic 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:
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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
# 1

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

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

**Dental age**

A patient’s growth and development may be faster or slower than average and we may assess his age in line with this development [1]. Thus, a child may be tall for his age, so that his morphological age may be considered to be advanced. 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 age, we are in a position to assess the child’s skeletal age. Similarly, there is a sexual age assessment related to the appearance of primary and secondary sexual features, a mental age assessment (intelligence quotient, or IQ, tests), an assessment for behaviour and another to measure the child’s self-concept. These indices are used to complement the chronological age, which is calculated directly from the child’s birth date, to give further information regarding a particular child’s growth and development.

Dental age is another of these parameters, and it is a particularly relevant and important assessment, used in advising proper orthodontic treatment timing. Schour and Massler [2], Moorrees et al. [3, 4], Nolla [5], Demerjian et al. [6] and Koyoumdjisky-Kaye et al. [7] have drawn up tables and diagrammatic charts of stages of development of the teeth, from initiation of the calcification process through to the completion of the root apex of each of the teeth, together with the average chronological ages at which each stage occurs.

Eruption of each of the various groups of teeth is expected at a particular time, but this may be influenced by local factors, which may cause premature or delayed eruption with a wide time-span discrepancy. For this reason, eruption time is an unreliable method of assessing dental age.

With few exceptions, mainly related to frank pathology, root development proceeds in a fairly constant manner usually regardless of tooth eruption or the fate of the deciduous predecessor. It therefore follows that the use of tooth development as the basis for dental age assessment, as determined by an examination of periapical or panoramic X-rays, is a far more accurate tool.

Thus, we may find that a child of 11–12 years of age has four erupted first permanent molars and all the permanent incisors only, with deciduous canines and molars completing the erupted dentition. If the practitioner were merely to run to the eruption chart, he would note that at this age all the permanent canines and premolars should have erupted, and he would conclude that the 12 deciduous teeth have been retained beyond their due time. The treatment that would then appear to be the logical follow-up of this observation requires the extraction of these 12 deciduous teeth! However, there are two possibilities in this situation and, in order to prevent unnecessary harm being inflicted on the child and his parents, the radiographs must be carefully studied to distinguish one context from the other.

In the event that the radiographs show the unerupted permanent canines and premolars having completed most of their expected root length, then the child’s dental age corresponds with his chronological age (Figure 1.1). The deciduous teeth have not shed naturally, due to insufficient resorption of their roots. As such, we have to presume that they are the impediment to the normal eruption of the permanent teeth. Their permanent successors may then strictly be defined as having delayed eruption. Under these circumstances it would be logical to extract the deciduous teeth on the grounds that their continued presence defines them as over-retained.

The second possibility is that the radiographs reveal relatively little root development, more closely corresponding, perhaps, to the picture of the 9-year-old child on the tooth development chart (Figure 1.2). The child's birth certificate...
may indicate that he is 12 years of age, and this may well be supported by his body size and development, and by his intelligence. Nevertheless, his dentition is that of a child three years younger, determining his dental age as 9 years and diagnosing a late-developing dentition. Extraction 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 and early extraction may lead to the undesired sequelae characteristic of early extraction, performed for any other reason.

From this discussion, we are now in a position to define the terms that we shall use throughout this text. The first refers to a retained deciduous tooth, which has a positive connotation and which may be defined as a tooth that remains in place beyond its normal, chronological shedding time due to the absence or retarded development of the permanent successor. By contrast and with a negative connotation, an over-retained deciduous tooth is one whose unerupted permanent successor exhibits a root development in excess of three-quarters of its expected final length (Figure 1.3). Thus, a radiograph of the permanent successor is needed to determine the status of the deciduous tooth and, by implication, its treatment.

A permanent tooth with delayed eruption is an unerupted tooth whose root is developed in excess of this length and whose spontaneous eruption may be expected in time. A tooth which is not expected to erupt in a reasonable time in these circumstances is termed an impacted tooth. Dental age is not assessed with reference to a single tooth only, since some variation is found within the different groups of teeth. An all-round assessment must be made and, only then, can a definitive determination be offered. However, in doing this one should be wary of including the maxillary lateral incisors, the mandibular second premolars and the third molars, the timing of whose development is not always in line with that of the remaining teeth [8, 9]. These are the same teeth that are most frequently congenitally missing in cases of partial anodontia (oligodontia). Indeed, reduced size, poorly contoured crown form and late development of these teeth are all considered microforms of missing teeth [9–11]. It is important to note that this variation in the timing of their development is only ever expressed in lateness, and they are not to be found in a more advanced state of development than the other teeth. If the individual dental ages of any of these variable groups of teeth is advanced, then so too is the entire dentition in which they occur.

### Assessing dental age

When studying full-mouth periapical radiographs or a panoramic film several criteria can be used in the estimation of tooth development. The first radiographic signs of the presence of a tooth are seen shortly after the initiation of calcification of the cusp tips. Thereafter, one may attempt to delineate the completed crown formation and various degrees of root formation (usually expressed in fractions), through to the fully closed root apex. By and large, orthodontic treatment is performed on a relatively older section of the child population and, as such, the stages of root formation are usually the only factors which remain relevant.

The stage of tooth development that is easiest to define is that relating to the closure of the root apex. For as long as the dental papilla is discernible at the root end, the apex is open and still developing. Once fully closed, the papilla disappears and a continuous lamina dura is seen to intimately follow the root outline. The accuracy with which one may assess fractions of an unmeasurable and merely ‘expected’ final root length is far less reliable and much more subject to individual observer variation.

Root development of the permanent teeth is completed approximately 2.5–3 years after normal eruption [5]. This allows us to conclude that, at the age of 9 years, the mandibular incisors (which erupt at age 6) will be the first teeth to exhibit closed apices and that these will usually be closely followed by the four first permanent molars. At 9.5 years, the mandibular lateral incisors will complete, while at 10 years and 11 years, respectively, the roots of the maxillary central and normally developing lateral incisors will be fully formed. This being so, when presented with a set of radiographs, we may proceed to assess dental age by following a simple line of investigation, which uses the dental age of 9 years as its starting point and then progresses forward or traces its steps back, depending on its findings.

If the mandibular central incisor roots are complete, we may presume the patient is at least 9 years old (dental age) and we may then advance, checking for closed apices of first molars (9–9.5 years), mandibular lateral incisors (9.5 years), maxillary central incisors (10 years), normally developing.
maxillary lateral incisors (11 years), mandibular canines and first premolars (12–13 years), maxillary first premolars (13–14 years), normally developing second premolars and maxillary canines (14–15 years) and second molars (15 years).

By this method, we may arrive at a tentative determination for dental age on the basis of the last tooth in this sequence which has a closed apex (Figure 1.4). It is now important to relate the actual development of the remaining teeth in the sequence to their expected development that may be derived from the wall chart or from tables that have been presented in the literature. This may then provide corroborative evidence in support of an overall and definitive dental age determination.

When the dental age is less than 9 years, none of the permanent teeth will have completed their root development and the clinician will have no choice but to rely on an estimation of the degree of root development, degree of crown completion and, in the very young, initiation of crown calcification (Figure 1.5). This is most conveniently done by working backwards from the expected development at age 9 years and comparing the dental development status of the patient to this, beginning with the mandibular central incisors and the first permanent molars. Thus, at dental age 6 years, one would find one-half to two-thirds root length of these teeth and this could be confirmed by studying the development of the other teeth. At the same time, one should expect unerupted maxillary central incisors with half root length, mandibular canines with one-third root length, first premolars with one-quarter root length, and so on.

As pointed out earlier, variation occurs, and this may lead to certain apparent contradictions. In such cases, excluding the affected maxillary lateral incisors, mandibular second premolars or third molars from the calculation will usually simplify the procedure and contribute to its accuracy. As we have noted, early development of these teeth in relation to the development of the remainder of the dentition does not appear to occur. Individual variability is expressed only in terms of degrees of lateness. This means that the developmental status of these teeth may be used as corroborative evidence for the determination of dental age, provided that their own timing is first confirmed as being in line with the remainder of the dentition.

Unusually small teeth, coniform premolars and mandibular incisors, and peg-shaped lateral incisors are most often seen developing very much later than normally shaped and sized teeth of the same series, sometimes as much as three or four years later, and should not be included in the overall estimation. Thus, in diagnosing dental age for a patient with an abnormality of this nature, one may present a determination for the dentition as a whole, with the added notation that this individual tooth may have a much lower dental age. Typically, we may occasionally examine a 14-year-old patient who has a complete permanent dentition, including the second molars, with the exception that a mandibular second deciduous molar is present. The radiographs (Figure 1.6) show the apices of

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

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

Fig. 1.6 Late-developing second mandibular premolars with retained (not over-retained) deciduous second molars in a child with dental age 11–12 years. The contrast and brightness of the picture have been adjusted in the relevant areas to clearly show the stage of development of these tooth buds.
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 development equivalent to about a quarter of its expected eventual length, or less. On the basis of this information, we may assess the dental age of the dentition as a whole to be 14 years. At the same time, we would have to note that the dental age of the unerupted second premolar is approximately 7 years. Having made this determination, we may now confidently say that the second premolar, individually, does not exhibit delayed eruption and the deciduous second molar is not over-retained in the context of the terminology used here. Accordingly, it would not be appropriate to extract the deciduous tooth at this time, but to wait at least a further few years, at which time the tooth may be expected to shed normally. To summarize this discussion, it is essential to differentiate between four different conditions that may exist when we encounter a dentition which includes certain deciduous teeth inconsistent with the patient's chronological age. Because the ensuing classification of these conditions is treatment oriented, the labelling of a patient within one of these groupings indicates the treatment that is required:

1. **A late-developing dentition.** The dental age of the patient lags behind the chronological age, as witnessed radiographically by less root formation than is to be expected at a given age, in the entire dentition. Typically, this will be evident clinically by the continued and symmetrical presence of all the deciduous molars and canines on each side of each jaw. The extraction of deciduous teeth is contraindicated, since the teeth are expected to exfoliate normally when the appropriate dental age is reached.

2. **Over-retained deciduous teeth.** The dental age of the patient may be positively correlated with the chronological age, but the radiograph shows an individual permanent tooth or teeth with well-developed roots, which remain unerupted. This tends to be localized in a single area and 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, but shedding has not occurred due to the persistence of the remaining part of the root or of a second and unresorbed root. Nevertheless, the condition may occasionally be found symmetrically in a single dental arch or in both arches. Extraction of the over-retained tooth or teeth is indicated.

3. **A normal dental age, 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, and extraction of the deciduous predecessor is to be avoided. Normal shedding of the tooth is to be expected when the root of the permanent tooth reaches two-thirds to three-quarters of its expected length.

4. **A combination of the above.** Sometimes one may see features of each of the above three alternatives in a single dentition.

The importance of interpreting the differential diagnosis for a given patient cannot be over-emphasized, since it has far-reaching effects on all the aspects of diagnosis, treatment planning and treatment timing for cases with impacted teeth.

**When is a tooth considered to be impacted?**

From the work of Grøn [12] we learn that, under normal circumstances, a tooth erupts with a developing root and with approximately three-quarters of its final root length. The mandibular central incisors and first molars have marginally less root development and the mandibular canines and second molars marginally more when they erupt. We may therefore take this as a diagnostic baseline from which to assess the eruption of teeth in general. Thus, should an erupted tooth have less root development (Figure 1.7), it would be appropriate to label this tooth as prematurely erupted. This will usually be the consequence of the early loss of a deciduous tooth, particularly one whose excision was dictated by deep caries with resultant periodontal pathology.

At the opposite end of the scale, we find the unerupted tooth which exhibits a more completely developed root. The normal eruption process of this tooth must be presumed to have been impeded by one of several aetiological possibilities. These include such factors as a failure of resorption of the roots of a deciduous tooth, an abnormal eruptive path, a supernumerary tooth, dental crowding, a much enlarged dental follicle/dentigerous cyst, other forms of soft tissue pathology or a disturbance in the eruption mechanism of the tooth. However, a thickened...
Orthodontic Treatment of Impacted Teeth

eruption of the impacted tooth into its place in the dental arch. The extent of this timespan is dependent on several factors, such as 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. During this period, therefore, local changes in the erupted dentition may occur as the result of the break in integrity of the dental arch caused by the surgical procedure, such as space loss and tipping of the adjacent erupted teeth. This intervention is no less susceptible to the drifting of neighbouring teeth than is any other factor that may produce interproximal loss of dental tissue.

With an odontome or supernumerary tooth in the path of an unerupted permanent tooth, vertical (and sometimes mesial, distal, buccal or lingual) displacement of the permanent tooth is likely to be considerable. It would be convenient if removal of the space-occupying body could be performed leaving the deciduous teeth intact, since the deciduous tooth would maintain arch integrity during the extended period needed for the permanent tooth to erupt normally. Unfortunately, in order to gain access to perform the desired surgery, one or more deciduous teeth often need to be extracted. This being so, and having regard for the long distance that a displaced permanent tooth may have to travel before it erupts into the mouth, space maintenance should be regarded as essential in most cases, particularly in the posterior area. It should be the first orthodontic procedure to be considered, preferably in advance of the surgical procedure, and it should be retained until full eruption of the permanent tooth has occurred.

Impacted teeth are often associated with a lack of space in the immediate area. This is frequently due to the drifting of adjacent teeth, although crowding of the dentition in general may be the prime cause. In such cases, the spontaneous eruption of an impacted tooth is unlikely to occur unless adequate or, preferably, excessive space is provided. It would be convenient if excision of the associated pathological entity could be comfortably delayed until this time to bring about the desired eruption and permit this corrective treatment to be attempted when the root development of the unerupted tooth is adequate. However, the surgeon will 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. Odontomes and supernumerary teeth are generally considered to be exceptions to this rule and the timing of their removal may be considered more leisurely.

**Fig. 1.8** (a) The right mandibular second premolar was extracted at age 8.5 years. (b) Seen at age 11, the root of the unerupted first premolar is almost completed.

post-extraction or post-trauma repair of the mucosa (Figure 1.8) should not be overlooked as a potent cause of non-eruption.

Not infrequently, and particularly in the mandibular premolar region, there may be a history of very early extraction of one or both deciduous molars. Delayed or non-eruption of the premolars will occur due to a thickened mucosa overlying the teeth. It is usually possible to palpate these teeth, their distinct outline clearly seen bulging the gum for a period of a year or more, although eruption may not occur.

**Impacted teeth and local space loss**

A time lapse exists between the performance of a surgical procedure to remove the cause of an impaction and the full eruption of the impacted tooth into its place in the dental arch. The extent of this timespan is dependent on several factors, such as 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. During this period, therefore, local changes in the erupted dentition may occur as the result of the break in integrity of the dental arch caused by the surgical procedure, such as space loss and tipping of the adjacent erupted teeth. This intervention is no less susceptible to the drifting of neighbouring teeth than is any other factor that may produce interproximal loss of dental tissue.

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**Whose problem?**

Patients do not go to their dentist complaining of an impacted tooth. They are frequently unaware that this abnormality exists, since there is no pain, discomfort or swelling. Nor is it obvious to the layman that there is a
missing tooth, since the deciduous predecessor may not shed naturally in these circumstances. The vast majority of impacted teeth come to light by chance, in routine dental examination, and are not the result of a patient’s direct complaint. As a general rule, it is the paedodontist or general dental practitioner who, during a routine dental examination, discovers and records the existence of an over-retained deciduous tooth. A periapical radiograph will then confirm the diagnosis.

There are two principal exceptions whereby an abnormal appearance may motivate the patient to seek professional advice. The first of these usually brings the patient to the office at the age of 8–10 years, when a single maxillary central incisor will have erupted a year or so earlier and the parent points out that the erupting lateral incisor of the opposite side has not left enough space for the expected eruption of the second central incisor (Figure 1.9). Often, the deciduous central incisor is over-retained. In this situation, the parent has recognized the abnormality, but will not generally have the technical understanding to suggest the possibility of impaction of the unerupted central incisor.

The second exception occurs with a 14–15-year-old patient who requests the restoration of an unsightly carious lesion on an over-retained maxillary deciduous canine. Generally speaking, the patient will be unaware that this is not a permanent tooth and it will require suitable professional advice to point out that restoration is probably not the appropriate line of treatment, but rather extraction and resolution of the impaction of the permanent canine.

A very small percentage of cases may initially be seen by their general dental practitioner because of symptoms related to relatively rare complications of impacted teeth. Among these symptoms are mobility or migration of adjacent teeth (due to extensive root resorption), painless bony expansion (dentigerous or radicular cyst) or perhaps pain and/or discharge (non-vital over-retained deciduous tooth or infected cyst, with communication to the oral cavity) [13].

Initially, the practitioner should ascertain whether there is a good chance that resolution will be spontaneous once the aetiological factor has been removed or whether active appliance therapy will be needed. To be able to do this, the exact position, long-axis angulation and rotational status of the tooth have to be accurately visualized and an assessment of space in the arch needs to be made. Following this initial assessment, the paedodontist or general dental practitioner now has to decide who should treat the problem.

Many dentists will prefer not to accept responsibility for the case and will refer the patient to an oral and maxillofacial surgeon on the premise that surgery will be needed. Many surgeons will agree that the problem is essentially surgical in nature and will proceed to remove over-retained deciduous teeth, clear away other possible aetiological factors, such as supernumerary teeth, odontomes, cysts and tumours, and will 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 occurred. This will have the effect of encouraging eruption in many cases. 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, over a period of a few weeks. Careful placement and wedging of the pack between an impacted tooth and its neighbour is used by surgeons to help free the tooth to erupt naturally when the pack is later removed. Often, in the more difficult impactions, wider surgical exposure is undertaken, which includes 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.

Following a period of many months and (for some of the more awkwardly positioned teeth) sometimes extending into years, the surgeon, family dentist or paedodontist will usually then follow up the spontaneous eruption of the impacted tooth until it reaches the occlusal level. If, at that time, alignment is poor or the tooth still has not erupted, the patient will be referred to the orthodontist.

They may alternatively and preferably refer the patient directly to an orthodontist in the first place. Certainly, the orthodontist cannot directly influence the position of the impacted tooth until appropriate access has been provided surgically and 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 level of quality care may be provided and in a very much shorter timeframe. This will be discussed in the ensuing chapters of this book.
The timing of the surgical intervention

From the above discussion, we see that the timing and nature of the surgical procedure are determined by the degree of development of the teeth concerned, at the time of the initial diagnosis. At an early stage, a radiographic survey of a very young child may reveal pathology, such as a supernumerary tooth, an odontome, a cyst or benign tumour, which appears likely to prevent the normal and spontaneous eruption of a neighbouring tooth.

At this stage, it would be inappropriate to expose the crown of an immature tooth from every point of view. In the first place, one would not want to encourage the tooth to erupt before an adequate (half to two-thirds) root length has been produced. Second, at that early stage of its development, the tooth cannot be considered as impacted and, given time and freedom to manoeuvre, will probably erupt by itself. Early exposure risks the possibility of damage to the crown and to the subsequent root development of the tooth.

Nevertheless, with the discovery of the pathological condition (Figure 1.10), the potential for impaction exists and leaving the condition untreated will worsen the prognosis. Accordingly, removal of the pathological entity, without disturbing the adjacent permanent teeth or their follicular crypts, should be the aim of any treatment at that time. It may then reasonably be expected that normal development and eruption will eventually occur. Whilst this is an obviously desirable course of action, access to the targeted area may be thwarted by the presence and closeness of adjacent developing structures and delay may still be advised.

The second scenario occurs when the condition is only discovered much later. In this case (Figure 1.11), it may be seen that the superiorly displaced central incisors have fully developed, if angulated, roots and the adjacent lateral incisors have erupted with almost the full length of their roots completed. The central incisors may justifiably be defined as impacted, and the aims of surgical treatment become two-fold: first, to eliminate the pathology, and then to create optimal conditions for the eruption of the permanent tooth, which is already late. This will usually involve exposure of the crown of the tooth. For many teeth, given adequate space in the dental arch and little or no displacement of the impacted tooth, spontaneous eruption may be expected [14, 15]. As we shall see in subsequent chapters, there are several situations and tooth types where this may not occur, or may not occur in a reasonable time-frame, often due to severe displacement of the affected tooth. For these cases, the natural eruptive potential of the tooth is supplemented and, if necessary, diverted mechanically, with the use of an orthodontic appliance.

Patient motivation and the orthodontic option

Angle’s class 2 malocclusion is present in between one-fifth and one-quarter of the child population in most countries of the western world [16, 17]. However, even a cursory analysis of the patient load of any given orthodontic practice will reveal that around three-quarters of the patients are being treated for this malocclusion. The reason for this has to do with the fact that a patient’s appearance is adversely affected to a greater extent by this condition than by most others. In other words, appearance plays an extremely large part in the initiative and motivation on the part of the parent of this young patient to seek treatment.

A significant section of the remaining quarter of the patients in this hypothetical orthodontic practice are being treated for various less unsightly conditions (crowding, single ectopic teeth, open bites or class 3 relationships). This leaves only a few patients in this practice sample who have been referred for strictly health reasons, which may not be obvious to the patient.

Appearance is not a problem for this small group of patients, who will have agreed to orthodontic treatment only after they have been motivated by the careful and
persuasive explanations of a dentist, orthodontist, periodontist, prosthodontist or oral surgeon, regarding the ills that are otherwise likely to befall them and their dentition.

Most impactions are symptomless and, aside from maxillary central incisors, do not usually present an obviously abnormal appearance. Accordingly, motivation for treatment in these cases is minimal, and much time has to be spent with the patient before he/she agrees to treatment. The story does not end there, since these patients may often require periodic ‘pep talks’ to maintain their cooperation and the resolve to complete the treatment. Many of them will not maintain the required standard of oral hygiene, and, while it is difficult to justify continuing treatment in these circumstances, 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 present in the dental arch. For these reasons, while ambitious and innovative treatment plans may be suggested, it is essential to take motivation into account before advising lengthy and complicated treatment, since the risk of non-completion may be high.

References
2

Radiographic Methods Related to the Diagnosis of Impacted Teeth

(In Collaboration with Stella Chaushu)

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Three-dimensional diagnosis of tooth position 14
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 it pertains 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, the different ways of radiologically displaying and recognizing pathological entities, such as supernumerary teeth, enlarged eruption follicles, odontomes, root resorption and other pathological entities, are discussed and compared. 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.

Qualitative radiography

Periapical radiographs

The first, simplest and most informative X-ray film 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. It is generally aimed to be perpendicular to an imaginary plane which bisects the angle between the long axis of an erupted tooth and the plane of the film, to produce the minimum of distortion. The periapical film is designed to view the tooth itself from the angle of best advantage, unrelated to its position in space.

From this 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, and odontomes of the complex or compound composite type. Similarly, it 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 film of a suspected impacted tooth in a radiographic examination. As with any radiographic film, however, 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 film as to which is lingual and which buccal.

For this film 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 is oblique, and will vary between 20° and 55° to the occlusal plane [3] depending on the region to be X-rayed. 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, not only will the observer 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

In the mandibular arch, this view is properly executed by tipping the patient’s head backwards and pointing the X-ray tube at right-angles to a film, held between the teeth, in the occlusal plane (Figure 2.1). The head will need to be tipped back further and the tube pointed at the symphysis menti, at an angle of 110° to the horizontal, in line with the long axes of the incisor teeth. To achieve the same for the molar teeth, the 90° angle to the horizontal 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 film should...
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Fig. 2.2 A diagram showing incisor inclination, film position and central X-ray beam, differentiating the periapical view, the anterior (oblique) occlusal view and the true vertex occlusal view. Reproduced from previous edition with the kind permission of Informa Healthcare – Books.

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 2.2). The view will ‘shorten’ the apparent length of the roots, but it will be a far cry from the cross-sectional view that is so easy to achieve in the mandibular arch. Since the central ray passes through cancellous rather than the compact bone that is found in the mandible, detail is usually good, although not as clear as with the periapical view.

True (vertex) occlusal

A true occlusal view of the anterior maxilla is a view in which the central ray of the X-ray beam runs parallel to the long axis of the central incisors (Figure 2.3). This is only possible when the cone is placed over the vertex of the skull, to produce the vertex occlusal film. Since the beam has to travel a great distance through the cranium and its contents, the base of the skull and the maxilla, there is a considerable loss in clarity. An excellent alternative method of producing this view, with the film positioned extra-orally, has been described [4]. Notwithstanding, a very long exposure is required, and a fast film should be used in a cassette with intensifying screens. For all these reasons, 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. This imaging modality, which can give the same and much more information with little or no increase in radiation dosage, has developed considerable sophistication within a very short space of time and is discussed at the end of this chapter.

Nevertheless, in this view (Figure 2.3), all the anterior teeth will be seen in their cross-sectional aspect as small circles with a tiny concentric circle in the centre, denoting the pulp chamber and root canal. No information is available regarding the relative height of the object in the alveolus and it certainly cannot be used for fine detail. A single tooth which is palatal to the line of the arch will appear within this arc of small circles. If the tooth is at an angle, not parallel with its neighbours, it will show up in its elliptical, oblique cross-section, representing a tilted long axis. In the event that the tooth is horizontal across the palate, its full length will be obvious on this view, together with the exact mesio-distal and bucco-lingual orientation of both the root and the crown, in the horizontal plane.

The difference may not seem to be very great between the two types of occlusal film, but it should be appreciated that from the vantage point of an anterior occlusal film, the anterior teeth will be foreshortened, but they will still have appreciable length. In this situation, a high and mesially placed labial canine could give virtually the same picture as
a low and mesially placed palatal canine. This could not happen in a vertex occlusal projection.

**Extra-oral radiographs**

The panoramic view, while not showing detail to the same degree as a periapical film, 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 film 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 2.4a–e) and the variously angulated oblique occlusal films all provide information that may be used to complement the periapical film, particularly when tooth displacement is severe. However, the use of any oblique film for the accurate localization of a buried tooth may frequently be misleading, be

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**Fig. 2.4** (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 from this view. (b) The anterior maxilla seen on a lateral cephalometric radiograph shows the high impacted central incisor, facing the labial sulcus. (c) and (d) The same views as (a) and (b) after removal of the supernumerary tooth and bracket bonding on the exposed incisor. (e) A parallel intra-oral photographic view. The film has been laterally inverted to simplify comparison (Courtesy of Dr D. Harary.)
it a single periapical, an occlusal or a lateral jaw film. 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. Thus, the choice of treatment will be inappropriate.

**Three-dimensional diagnosis of tooth position**

As dentists, we are used to seeing periapical films of individual teeth and, provided that the teeth concerned are erupted and in the line of the arch, these films 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. Thus, while it gives a good two-dimensional representation of the tooth, this view has limited value when visualization of an unerupted tooth is required in the three planes of space.

**Parallax method [5]**

By following the principles involved in binocular vision, two periapical views of the same object and taken from slightly different angles can provide depth to the flat, two-dimensional picture depicted by each of the films individually (Figure 2.5). This is of considerable help with 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 2.6):

1. A periapical-sized film is placed in the mouth, with the patient’s finger holding 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 a 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 film 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, but 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 films is the ortho-radial view and which was taken from the distally deviated aspect by studying the relative distortion of the erupted teeth on the two films. However, by radiographically ‘labelling’ the deviated film with the placement of a paper clip in one corner or by using a different film size for the deviated view, such as an occlusal-sized film, this distinction will be simplified.

Let us assume that a right unerupted canine is palatally placed (Figure 2.6), and then this tooth will be close to the
middle of the picture obtained in both films. However, 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.

Jacobs [7, 8] enjoins the observer to use the right eye in place of the X-ray tube and suggests the useful exercise of 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, his/her 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 method has its limitation, 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 with the roots of the erupted teeth, or where the superimposition is only in the apical area, then the overall picture may be very misleading and a different method of localization should be used. 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 critical for the successful resolution of an impacted tooth, as we shall see in the following chapters.

Vertical parallax may sometimes be a useful variant of the same technique, in which two films are taken of the area, with the central ray of one periapical film 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) film will result in a palatal tooth being more superiorly related vis-à-vis the target tooth than in the regular film.

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 films that showed vertical parallax and once with films 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 on 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 whether the parallax principles may be applied to other types of film 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 2.7). 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 film 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 (6°–65°) or periapical view (5°–55°) is angled much more steeply to the film. These will both show superimposition of an ectopic tooth over the tooth in the line of the arch, but a degree of vertical discrepancy between these films and the panoramic view will reveal the position of the displaced tooth.

The same panoramic view will project the anterior midline area in its postero-anterior aspect, with the X-ray beam hitting this area when the cone is at the back of the patient’s head. 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 film as the consequence of the further rotation of the X-ray beam.

If all the teeth are in the same approximate semicircular line of the arch, then their mesio-distal relationships will be fairly accurately represented on the film. 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
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Fig. 2.7 The vertical tube shift method using a panoramic film and periapical views. (a) The panoramic film 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.

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 film (an oblique lateral view) and a lateral cephalogram (a true lateral view) may be used together 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, in which unavoidable superimposition in the anterior region may sometimes invalidate the method (Figure 2.8).

One further clue to the position of an ectopic canine is governed by the physical principle that objects projected optically on a screen become markedly larger as the distance between the object and the screen increases, or the distance between the object and the source decreases, with the degree of enlargement being directly proportional to the square of the object–screen distance.

The panoramic X-ray machine is normally adjusted so that its circling of the jaws maintains a fixed distance of the cone to the dental arch, whose perimeter falls within the focal trough of the machine. Teeth which are palatal to the line of the dental arch become enlarged, because they are further from the film and closer to the cone.

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 film may be slightly larger than that of the central incisor, due to the form of the arch in that area.
Radiographic Methods Related to the Diagnosis of Impacted Teeth

Fig. 2.9 A panoramic film showing two unerupted maxillary canines. Note the contrast in image size of the two canines. By direct measurement of the crown of the right canine, the mesio-distal width of its crown is considerably more than 15% larger than that of the right central incisor and the left is approximately the same width as the left central incisor. Since each shows superimposition on the middle portion of the root of its immediate neighbour, the right canine is palatal and the left buccal.

Thus, in these cases, it is common to see similar mesio-distal widths of these two teeth on the panoramic film. A buccally displaced canine, on the other hand, will generally reflect the true width difference between the two teeth, because its distance from the film is similar to that of the central incisor (Figure 2.9).

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 film) was 1.15 times larger (i.e. 15% greater) than that of the adjacent central incisor (the canine-to-incisor index), then the canine was palatally displaced [10, 11]. This was found to be reliable in 100% of cases in which the canine was seen on the film to be superimposed on the coronal or middle portions of the root of the adjacent incisor.

Earlier studies that attempted to diagnose canine position on the panoramic film 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 2.10). This means that the root apices are considerably more distant from the film drum of the panoramic machine 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 film than the crowns of the incisors. Thus, the image of the canine crown will be enlarged to a greater extent than those of the incisor crowns and will appear disproportionately large on the film.

Fig. 2.10 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 at the level of their apices. A canine impacted labially in this depression will be more distant from the panoramic film than the incisor crowns and will therefore cast a much enlarged image on the film. 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.

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

Standardization

Standardization of views within the confines of a strict adherence to the planes of space is required. Performed in
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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. 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 films, we may conclude that the apices are ideally placed and that the long axes of the teeth have a downward, mesial and palatal inclination. 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.

In this manner, each two-dimensional view obtained becomes simple for the observer to appreciate and, when information from the other views at right-angles is merged with it, the composite three-dimensional picture is easy to mentally reconstruct. A true lateral view (Figure 2.11a) 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 not give any clue to the bucco-lingual (transverse plane) picture. A true occlusal view will provide positional information in both the antero-posterior and transverse planes, but not in the vertical plane. The third possibility is the true antero-posterior view (Figure 2.11b, c), which defines the height (vertical plane) and the bucco-lingual relationship only. By combining the information provided by any two of these three films, three-dimensional localization may be accurately determined.

Translating these principles into radiographic practice presents some difficulties. However, these are not insurmountable and, insofar as they provide the clinician with accurate positional visualization of the unerupted tooth, they may be entirely worthwhile.

For most orthodontic cases, a lateral cephalometric radiograph (a cephalogram) is a prerequisite whose primary purpose is the routine measurement of angles and planes. However, this film potentially contains much useful positional information regarding the location and angulation of unerupted teeth. The film represents a true lateral view of the skull and, for present purposes, of the jaws and the anterior maxilla in particular (Figure 2.11a). 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 defined, together with the mesio-distal position of both crown and apex.

In the mandibular posterior area, we have pointed out that the routine periapical radiograph is also 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 to complete the three-dimensional picture. Accordingly, these two views will provide accurate localization of the position of unerupted teeth in this area (Figure 2.12).

If a cephalometric radiograph is not available, the same view of the anterior maxilla may be obtained on a small, occlusal-sized film. This film 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 film. 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.