

Radiographic diagnosis of root resorption in relation to orthodontics

H. A. Leach,¹ A. J. Ireland,² and E. J. Whaites,³

The literature regarding external root resorption in relation to orthodontics and its radiographic diagnosis is reviewed, including a summary of the more common radiographic techniques available. Sample cases are presented which demonstrate the need for good radiographic technique and an awareness of the limitations of certain radiographs. A provisional diagnosis of external root resorption may need to be confirmed by further radiographic views where appropriate.

Resorption of the roots of the permanent teeth is a pathological process originating either internally or externally. It develops when the natural protection of the predentine and odontoblasts in the root canal, or the precementum and cementoblasts on the root surface are damaged or removed. Orthodontic forces are just one of several aetiological factors that have been implicated in external root resorption. Other aetiological factors include reimplantation, trauma, pressure from adjacent unerupted teeth and related pathological conditions such as odontogenic and non-odontogenic tumours.

Andreason¹ has subclassified external root resorption into 3 subgroups:

- Surface resorption
- Inflammatory resorption
- Replacement (ankylosis) resorption

External resorption associated with orthodontic forces is typically surface resorption and is most commonly found in the apical region of the roots causing them to become shorter. Repair with new cemen-

tum and periodontal fibres, with recontouring of the root, usually occurs rapidly after the causative factors have been removed.

External surface root resorption has long been recognised as an unwanted sequel of orthodontic tooth movement,² with some of this type of root resorption almost inevitably occurring during orthodontic treatment involving the use of fixed appliances.^{3,4} Such resorption tends to follow the application of a force to a tooth, sufficient to cause hyalinisation, or aseptic necrosis, of its periodontal ligament.^{5,6} Whereas in some patients only small areas of surface resorption occur, in others it can be much more extensive, with the amount lost being unpredictable and irreversible. Microscopic signs of external resorption are very common, even in non-orthodontically treated teeth,⁷ but following orthodontic treatment, macroscopic evidence of resorption has been reported in up to 40% of adults and 16.5% of children.⁸ Schwartz⁹ reported that when the pressure

In brief

- Discusses the causes of root resorption.
- Summarises radiographic techniques commonly used in orthodontics with particular reference to root resorption.
- Illustrates the limitations of the three commonly used radiographic views: the upper standard occlusal, DPT and true cephalometric lateral skull radiograph when used for such purposes.
- Suggests that the paralleling techniques should be used when serial assessments of resorption are to be made over time.

decreases below the threshold for optimal tooth movement, external surface root resorption ceases. Other workers have also found such macroscopic resorption stops on completion of orthodontic treatment.^{10,11} Factors suggestive of a tooth being more susceptible to external root resorption include short roots, roots which are abnormally shaped (blunt or pipette-shaped) and roots already showing resorption.^{12,13} Traumatized teeth are only more prone to resorption if they show signs of pre-treatment resorption.¹⁴ Previously root treated teeth on the other hand are thought to be less prone.⁸ Functionally root resorption is of importance, as recent work¹⁵ has suggested that roots less than 9

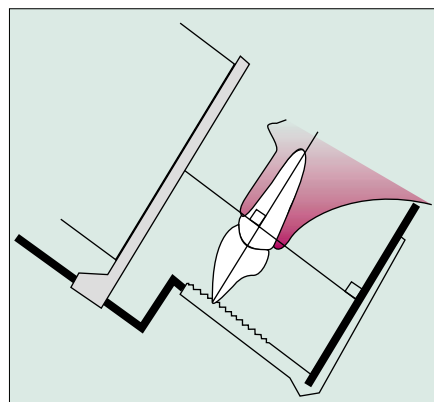


Fig. 1 Diagram illustrating the ideal geometrical relationship between film, tooth and X-ray beam. Such close proximity of the tooth to the film is not possible clinically.

¹Specialist Registrar, Department of Child Dental Health, Bristol Dental Hospital, Lower Maudlin St., Bristol BS1 2LY ²Consultant Orthodontist, Orthodontic Department, Royal United Hospital, Combe Park, Bath BA1 3NG ³Senior Lecturer and Honorary Consultant, Dental Radiology Department, Guy's, King's and St Thomas' (GKT) Dental Institute, London SE1 9RT

*Correspondence to: H. A. Leach, Whitetree Orthodontic Centre, 1 North View, Westbury Park, Bristol BS6 7PU

REFEREED PAPER

Received 27.03.00; Accepted 07.08.00

© British Dental Journal 2001; 190: 16–22

mm in length will lead to increased tooth mobility, although the effects in the longer term are not known.

Radiographs are required before the start of orthodontic treatment for the assessment of general dental health, including root form and the presence or absence of any underlying disease, and to show the position and number of developing teeth.¹⁶ The dental panoramic tomograph (DPT) is widely regarded as a valuable tool for these purposes, as it provides an overall view of the entire dentition and yet the patient is subjected to a lower radiation dose than from a full-mouth series of intra-oral radiographs.¹⁷ The British Orthodontic Society *Radiography Guidelines*¹⁸ states that an upper standard occlusal radiograph may be necessary to supplement the panoramic tomograph. This is because the focal trough of the tomograph is narrow in the incisor region, sometimes causing the apices and palatal structures to be out of focus or even invisible. Periapical views or an upper standard occlusal are therefore recommended to be taken in addition to the dental panoramic

tomograph when there is a clinical indication, such as suspected underlying midline pathology or developmental anomaly.¹⁹

Radiographic techniques

Intraoral radiographs

Intraoral radiographs of the teeth should be geometrically accurate. The idealised positioning requirements are shown in Figure 1 and include:

- The tooth/teeth under investigation and the film packet should be in contact or, if

- not feasible, as close together as possible
- The tooth/teeth and the film packet should be parallel to one another
- The X-ray tubehead should be positioned so that the beam meets the tooth and the film at right angles in both the vertical and horizontal planes
- The positioning should be reproducible – particularly if the films are to be used for comparative purposes.

For periapical radiography two techniques exist — the paralleling technique and the bisected angle technique. As the

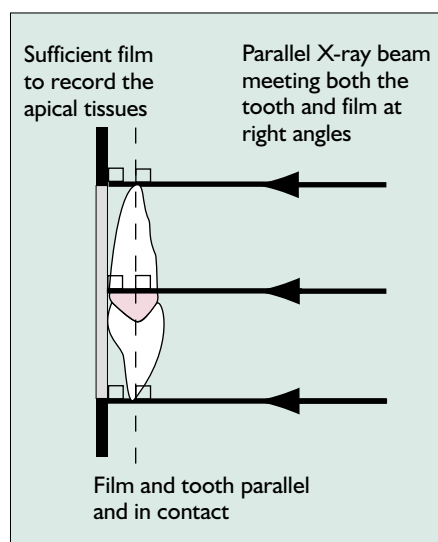


Fig. 2 Diagram showing the relative positions of the film, maxillary central incisor and X-ray beam using a film holder for the paralleling technique.

Fig. 3 Radiographs taken using the paralleling technique. Film a. shows marked resorption of the upper incisor teeth. Film b. shows resorption of the distal root of the lower first permanent molar.



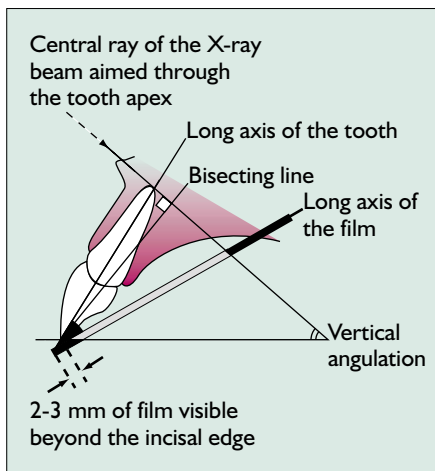


Fig. 4 Theoretical basis of the bisected angle technique. The angle between the long axes of the tooth and film is bisected and X-ray beam aimed at right angles to this line, through the apex of the tooth.

name implies, with the paralleling technique the film packet is placed in a holder and positioned parallel to the tooth/teeth under investigation. The X-ray tubehead is then aimed at right angles (vertically and horizontally) to both the teeth and film packet as shown in Figure 2. The resultant films are geometrically accurate and are the views of choice for assessing external root resorption. By using a film holder, with fixed film packet and X-ray tubehead positions, the technique is reproducible and thus sequential films can be used for comparative purposes to assess the progression of resorption. Two examples of films taken with the paralleling technique are shown in Figures 3a and 3b.

In the bisected angle technique the film packet is placed as close as possible to the

tooth/teeth under investigation without bending the film packet. The angle between the long axes of the tooth and film is bisected and the X-ray beam is aimed at right angles to this line, through the apex of the tooth as shown in Figure 4.

With this geometrical arrangement the length of the tooth in the mouth is equal to the length of the tooth on the film, but incorrect vertical tubehead positioning can cause either foreshortening or elongation of the image as shown in Figure 5. The many variables involved with this technique means that it is not usually possible to obtain reproducible views. Thus, bisected angle technique periapicals are not ideal for the radiographic assessment of the amount of external root resorption, particularly over time.

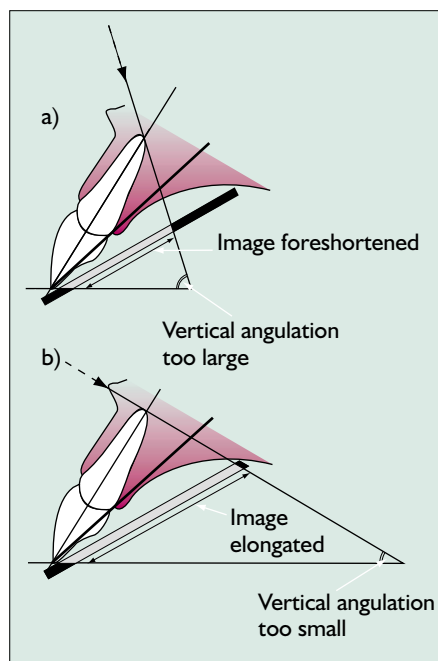


Fig. 5 Diagrams showing the effects of incorrect vertical tubehead positioning. A. Foreshortening of the image. B. Elongation of the image.

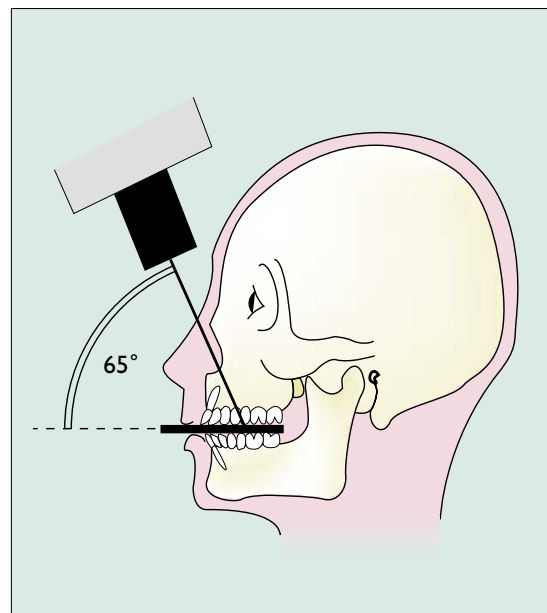


Fig. 6 Diagram showing the relative positions of the film, teeth and X-ray beam for the upper standard occlusal radiograph.

The upper standard occlusal radiograph shows the anterior part of the maxilla and the upper anterior teeth on one film. It can therefore demonstrate on one film the presence or absence of supernumeraries, supplementals or odontomes, as well as allowing examination of root form and any underlying disease such as external root resorption of the upper incisor teeth. However, the upper standard occlusal radiograph is in effect a large bisected angle technique periapical as shown in Figure 6. It is therefore subject to the same disadvantages and distortion. As a result, considerable caution needs to be exercised if this view is used to assess external root resorption.

Digital radiography

Digital radiography is a relatively recent development in dentistry enabling the film packet to be replaced with a digital image receptor. Two types of receptors have been developed — CCD (charge coupled device) sensors and photo-stimulable phosphor imaging plates. Both systems have intraoral receptors suitable for periapical radiography but only photo-stimulable phosphor plates have been produced for occlusal radiography. Digital radiography has been shown to demonstrate a similar degree of sensitivity to film-based radiography in the detection of resorption, but with a lower radiation dose.²⁰ However, the geometric relationship of the digital receptor, tooth and X-ray beam is just as important as in conventional radiography if geometric distortion is to be avoided. Digital images have the additional advantages that they can be manipulated including enlargement, contrast enhancement, inversion and pseudo-colouration which may prove to be an advantage when assessing external root resorption.

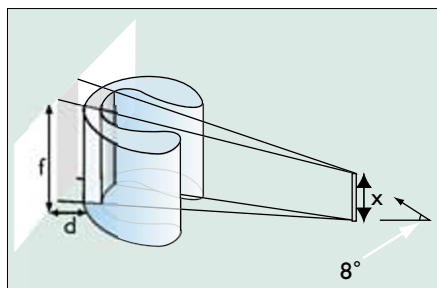


Fig. 7 Diagram showing the approximately horseshoe-shaped focal trough with the X-ray beam aimed upwards at 8°. The height (x) of the narrow X-ray beam is collimated to just cover the height (f) of the film. The film passes in front of the patient close to the focal trough and separated from it by a small distance (d).

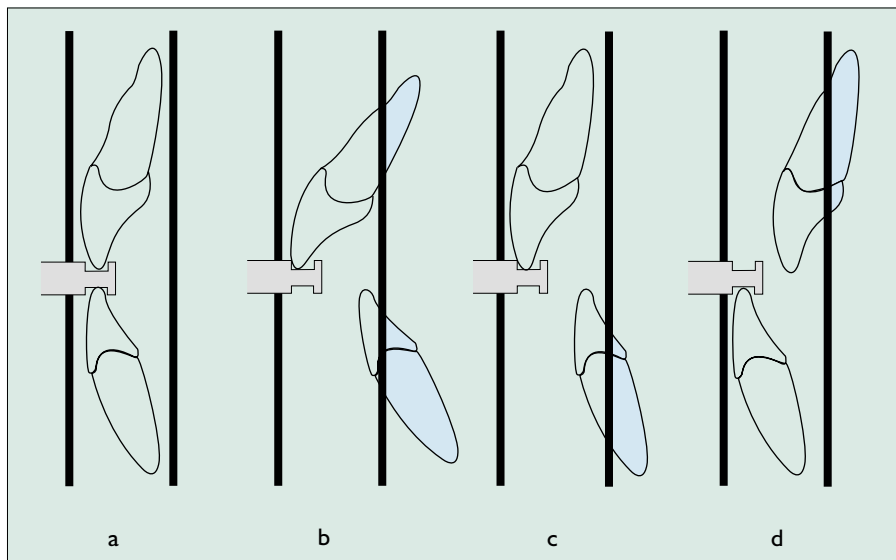


Fig. 8 Diagrams showing the vertical walls of the focal trough in the incisor region and the relative positions of the teeth with different underlying dental or skeletal abnormalities. *a*, Class I skeletal pattern. *b*, Class II division I malocclusion with large overjet due to the proclined upper incisors. *c*, Class II skeletal base. Here the large overjet is as a result of the skeletal pattern and not proclination of the upper incisor teeth. *d*, Class III skeletal base. The blue parts of the teeth outside the focal trough will be blurred and out of focus on the final film.

Dental panoramic tomograph (DPT)

The dental panoramic tomograph is a sectional radiograph and only structures that are within the section will be evident and in focus on the film. This in focus section, or focal trough, is approximately the same shape as the dental arch and resembles a three

dimensional horse-shoe shape. During an exposure the X-ray tubehead orbits around the back of the patient's head while the film moves past the face. A narrow slit X-ray beam is used which is aimed upwards at approximately 8° to the normal, as shown in Figure 7.

The shape of the curved focal trough is

pre-determined and patients have to be positioned carefully within the machine to ensure that their teeth and the supporting structures appear in focus on the resultant image. Incorrect positioning results in a distorted image with teeth appearing foreshortened, magnified and/or out of focus depending on the positioning error. In addition, normal anatomical structures can appear as radiolucent or radiopaque shadows superimposed over the teeth as either real or actual shadows or as ghost or artefactual shadows all of which can degrade the quality of the final image.²¹

In orthodontic patients, another common problem is one of skeletal base discrepancy. In markedly class II or class III cases, it may not be possible to position both the upper and lower labial segment teeth within the focal trough of the machine simultaneously as shown in Figure 8. Roots that are outside the focal trough and are positioned lingually/palatally to it may appear magnified. In addition to skeletal problems, teeth may be outside the focal trough if excessively proclined or retroclined. This can occur in either the upper or lower arches, or both as illustrated in Figure 8b. In this case the main effect may be to foreshorten the final image. In such instances supplemental intraoral views are indicated to cover the region that is out of focus.

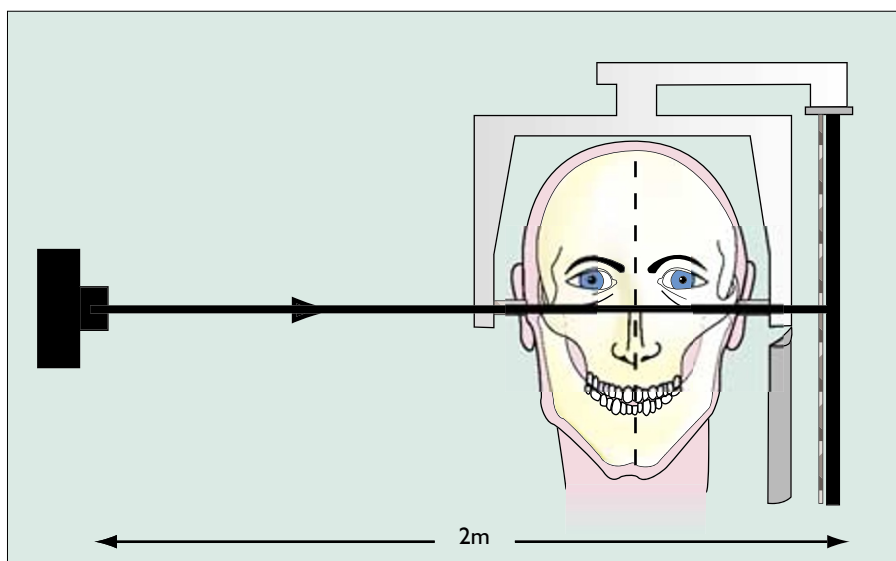


Fig. 9 Diagram of the positioning for the true cephalometric lateral skull projection - the sagittal plane of the head is parallel to the film, and the X-ray beam is horizontal and perpendicular to the sagittal plane and the film. The X-ray tubehead and cephalostat are in fixed positions approximately 2m apart. The magnification factor may be between 5 and 12%.

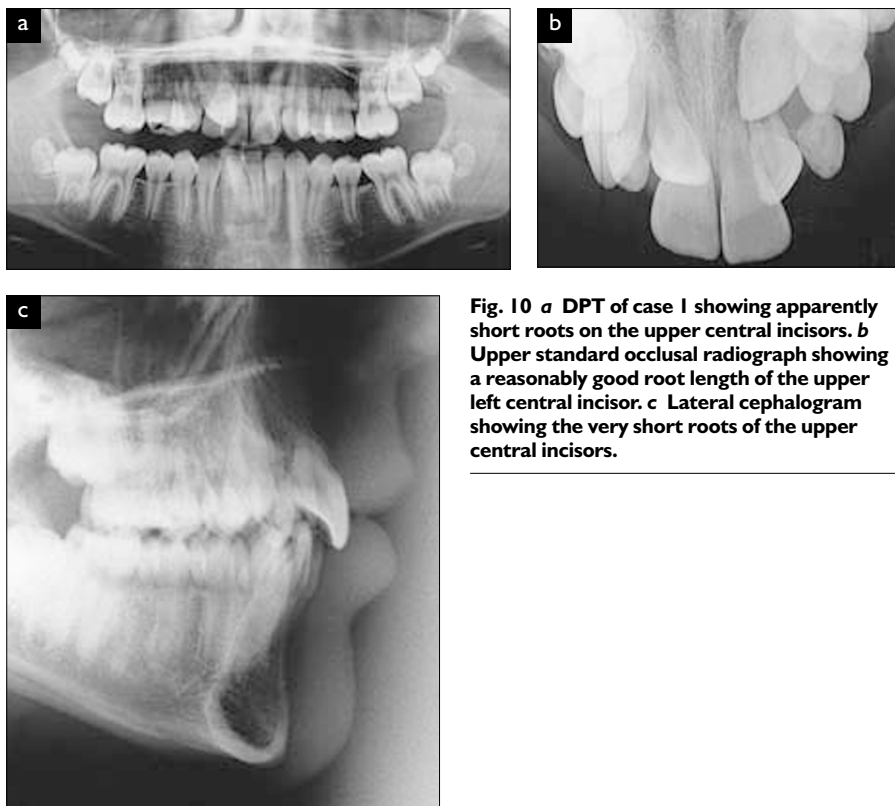


Fig. 10 *a* DPT of case 1 showing apparently short roots on the upper central incisors. *b* Upper standard occlusal radiograph showing a reasonably good root length of the upper left central incisor. *c* Lateral cephalogram showing the very short roots of the upper central incisors.

result of the radiographic set up, i.e. X-ray tubehead to patient and patient to film distance as shown in Figure 9. In addition, superimposition of one side on the other may make the image unclear, particularly for the detailed assessment of external root resorption.

Illustrative Cases

These cases are presented to illustrate the limitations of a single radiographic view when assessing external surface root resorption in relation to orthodontics

Case 1

At first glance the DPT for this patient suggested that there may have been localised external root resorption present on the upper central incisor teeth (Fig. 10a), but this was contradicted by the upper standard occlusal radiograph (Fig. 10b) where geometrical distortion has resulted in the teeth appearing elongated. The true cephalometric lateral skull (Fig. 10c) confirmed that the roots of the upper central incisors were indeed short and this was considered to be the definitive view, as it is more reliable and not subject to the distortions inherent with the other techniques. This proved to be an orthodontic diagnostic dilemma since the patient had severe upper arch crowding. As part of the extraction pattern the upper central incisors were extracted, the upper laterals moved towards the midline and the upper canines aligned. Another problem of the DPT in this instance is the band of radiolucency over the apices of the upper teeth due to the air between the tongue and the palate. Patients should ideally be asked to press their tongue against the palate during the taking of the DPT.

Case 2

The DPT for this patient (Fig. 11a) again suggested apparent external root resorption. The upper standard occlusal radiograph (Fig. 11b) was not consistent with this finding. Upon closer examination, it can be seen that the patient has been slightly incorrectly positioned in the machine during the taking of the DPT. The patient's chin has been raised too high as evidenced by the flatness of the occlusal plane and of the mandible on the resulting film. This posi-

In view of the effect that incorrect patient positioning can have on the accuracy and definition of the final DPT image, considerable caution needs to be exercised when interpreting these films and relying on them to assess external root resorption.

True cephalometric lateral skull

The true cephalometric lateral skull radiograph provides an accurate and reproducible view of the length of the upper incisors. However, this is likely to be subjected to a 5–12 % enlargement factor as a

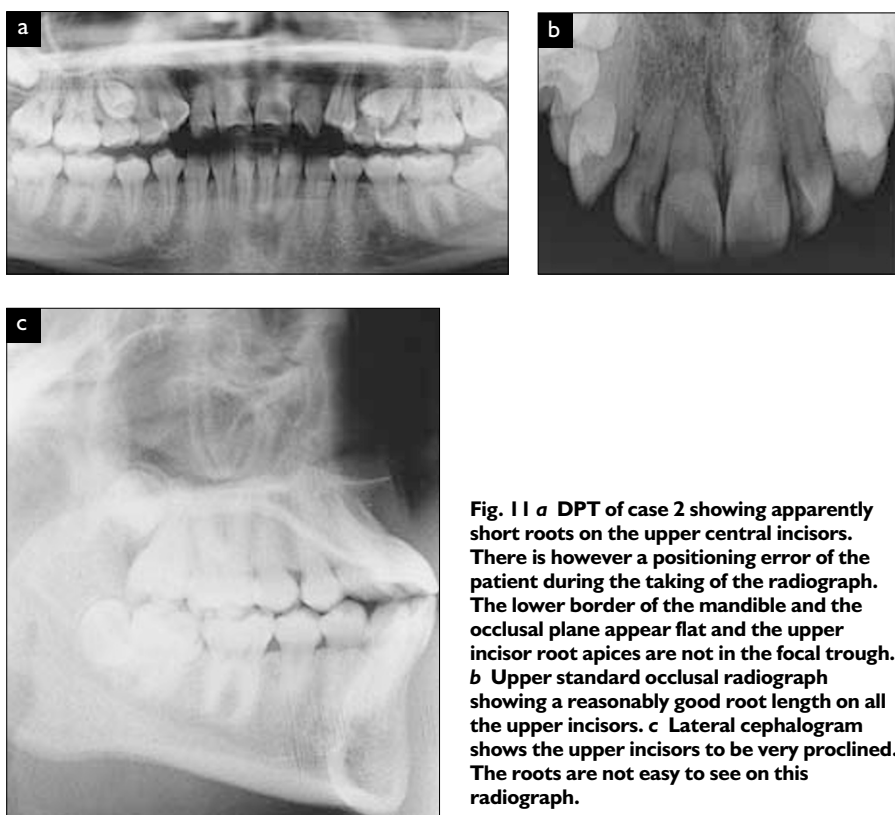


Fig. 11 *a* DPT of case 2 showing apparently short roots on the upper central incisors. There is however a positioning error of the patient during the taking of the radiograph. The lower border of the mandible and the occlusal plane appear flat and the upper incisor root apices are not in the focal trough. *b* Upper standard occlusal radiograph showing a reasonably good root length on all the upper incisors. *c* Lateral cephalogram shows the upper incisors to be very proclined. The roots are not easy to see on this radiograph.

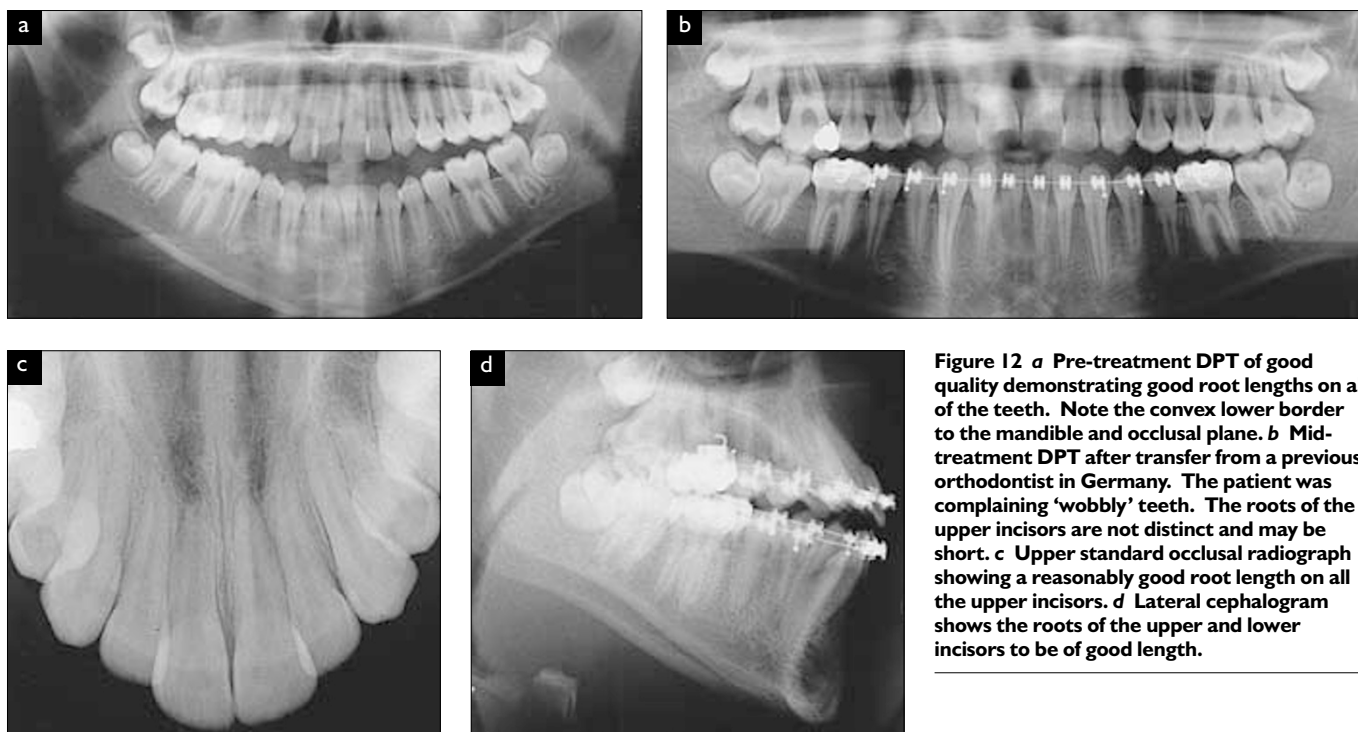


Figure 12 *a* Pre-treatment DPT of good quality demonstrating good root lengths on all of the teeth. Note the convex lower border to the mandible and occlusal plane. *b* Mid-treatment DPT after transfer from a previous orthodontist in Germany. The patient was complaining 'wobbly' teeth. The roots of the upper incisors are not distinct and may be short. *c* Upper standard occlusal radiograph showing a reasonably good root length on all the upper incisors. *d* Lateral cephalogram shows the roots of the upper and lower incisors to be of good length.

tioning error can lead to the apices of the maxillary anterior teeth being outside the focal trough, and the angulation of the teeth to the X-ray beam leads to foreshortening of the image giving the appearance of short roots. However, although the true cephalometric lateral skull (Fig. 11c) did not provide a good view of the apices of the upper incisors, it does illustrate the degree of proclination of the upper incisors. This would have been the main factor responsible for the radiographic appearance of short roots. The upper standard occlusal view was felt to be the most informative in this case.

Case 3

This case was transferred from an orthodontist in Germany and presented in mid-treatment. There was a lower fixed appliance present and the patient had intermittently worn an upper removable expansion appliance, but had ceased wearing this due to discomfort and 'wobbly' teeth. The referring practitioner had supplied a pre-orthodontic DPT of reasonable quality (Fig. 12a), which showed no evidence of external root resorption.

A mid-treatment DPT was obtained prior to continuing treatment, in view of the complaint of "wobbly" teeth, which revealed, what initially appeared to be, severe external root resorption of the upper central incisors (Fig. 12b). None of the other teeth showed signs of shortened roots on this second DPT. As in case 2, closer examination reveals the patient to have been incorrectly positioned during the taking of

the second radiograph. The chin has again been raised slightly too high, the patient is also positioned too far away from the film (as evidenced by the mesio-distal magnification of the upper and lower incisor crowns). These positioning faults result in the apices being outside the focal trough and thus seemingly resorbed. An upper standard occlusal radiograph taken at the same time showed the roots of the upper incisors to be unaffected (Fig. 12c) and it was felt the patient would be able to continue treatment with an upper fixed appliance. This was confirmed on a later true cephalometric lateral skull (Fig. 12d), which also showed the incisor proclination that would contribute to the upper incisors being outside the focal trough.

The sample cases illustrate the ease with which it is possible to make an erroneous diagnosis of root resorption, its presence or absence, based on radiographs which do not adequately demonstrate the area of interest. This can be either because of poor radiographic technique or because of the inherent limitations of the chosen view(s). Knowledge of the techniques and their limitations is therefore essential when assessing external root resorption.

In the cases described the limitations of the DPT were principally caused by the proclination of the upper incisor teeth and the patients being incorrectly positioned within the machine. Malposition of the teeth may make it impossible to position the teeth accurately within the narrow focal trough. Previous work looking at the role of the

upper standard occlusal radiograph and DPT has shown the latter to be affected by the degree of both upper and lower incisor proclination.²² Indeed, in the same work, of the 3 cases of root resorption seen in the 100 cases studied, the DPT had falsely indicated resorption in 2 of the cases, which was not subsequently seen on the upper standard occlusal radiograph.

The cases presented here clearly show the resultant image distortion and how diagnostic interpretation of external root resorption was also compromised.

The true cephalometric lateral skull radiograph is one of the most accurate ways of determining the root length of the upper incisors, but detailed diagnosis of external root resorption is often not possible as a result of superimposition of adjacent tooth roots, in particular the maxillary lateral and canine teeth, as shown in case 2.

The upper standard occlusal is a good view for showing the anterior part of the maxilla but upper incisor root length will be greatly affected by the geometrical set-up when the film is taken. Ideally, paralleling technique periapicals, as shown in Figures 3a and 3b, should be used to minimise the effects of geometrical distortion, which would otherwise lead to apparent lengthening or shortening of the roots, particularly if resorption is to be monitored over time with repeat radiographs.

Conclusions

The cases presented highlight the potential problems and limitations of using a dental

panoramic tomograph for pre-orthodontic assessment and the need for vigilance in the correct patient positioning during radiographic exposure. The narrow focal trough in the anterior portion of the maxilla presents a particular problem for many orthodontic patients with abnormally positioned or proclined incisors. The apices of the upper incisors may not be shown and the appearance can mimic root resorption, while supernumerary and/or unerupted teeth may not be detected. Supplementary views may therefore be necessary whenever there is any doubt that the dental panoramic tomograph demonstrates the necessary detail in this region. Paralleling technique periapicals are the intraoral views of choice but if unavailable an upper standard occlusal can demonstrate the anterior maxilla but the image may be geometrically inaccurate. The true cephalometric lateral skull can be used to assess incisor root length, but not for detailed diagnosis of external root resorption. In order to correctly assess the degree of external root resorption care should be taken to employ the radiographic technique(s) that ensure geometrically accurate images. In some instances it may be necessary to take more than one radiograph.

The authors would like to thank Helen Knight for her assistance in the management of one of the cases described, and to thank Churchill Livingstone for

their permission to reproduce Figures 1,2, 4 – 9 from Whaites' 'Essentials of Dental Radiography and Radiology' 2nd Ed.

- 1 Andreason J O. External root resorption: its implications in dental traumatology, paedodontics, periodontics, orthodontics and endodontics. *Int J Endodontics* 1985; **18**: 109-118
- 2 Bates S. Absorption. *Br J Dent Science* 1856; **1**: 256.
- 3 Brezniak N, Wasserstein A. Root resorption after orthodontic treatment: Part 1. Literature review. *Am J Orthod Dentofacial Orthop* 1993; **103**: 62-66.
- 4 Brezniak N, Wasserstein A. Root resorption after orthodontic treatment: Part 2. Literature review. *Am J Orthod Dentofacial Orthop* 1993; **103**: 138-146.
- 5 Rygh P. Orthodontic root resorption studied by electron microscopy. *Angle Orthod* 1977; **47**: 1-16.
- 6 Reitan K. Initial tissue behaviour during apical root resorption. *Angle Orthod* 1974; **44**: 68-82.
- 7 Henry J L, Weinmann J P. The pattern of root resorption and repair of human cementum. *J Am Orthod Assoc* 1951; **42**: 270-290.
- 8 Mirabella A D, Årtun J. Prevalence and severity of apical root resorption of maxillary anterior teeth in adult orthodontic patients. *Eur J Orthod* 1995; **17**: 93-99.
- 9 Schwartz A M. Tissue changes incidental to tooth movement. *Int J Orthod* 1980; **18**: 331-352.
- 10 Copeland S, Green L J. Root resorption in maxillary incisors following active orthodontic treatment. *Am J Orthod* 1986; **89**: 51-55.
- 11 Remington D, Joondeph D R, Årtun J, Riedel R A, Chapko M K. Long term evaluation of root resorption occurring during orthodontic treatment. *Am J Orthod* 1986; **96**: 43-46.
- 12 Linge B O, Linge L. Evaluation of the risk of root resorption during orthodontic treatment: a study of upper incisors. *Eur J Orthod* 1983; **5**: 173-183.
- 13 Levander E, Malmgren O. Apical root resorption in upper anterior teeth. *Eur J Orthod* 1988; **10**: 30-38.
- 14 Malmgren O, Goldson L, Hill C, Orwin A, Petrini L, Ludberg M. Root resorption after orthodontic treatment of traumatised teeth. *Am J Orthod* 1982; **82**: 487-491.
- 15 Levander E, Malmgren O. Long-term follow-up of maxillary incisors with severe apical root resorption. *Eur J Orthod* 2000; **22**: 85 – 92.
- 16 Smith N J D. Orthodontic radiology: a review. *Int Dent J* 1987; **37**: 16-24.
- 17 McNicol A, Stirrups D R. Radiation dose during the dental radiographic techniques most frequently used during orthodontic treatment. *Eur J Orthod* 1985; **7**: 163-171.
- 18 Isaacson K G, Jones M L. *Orthodontic Radiography Guidelines*. British Orthodontic Society, 1st ed, 1994.
- 19 Ferguson J W, Evans R I, Cheng L H. Diagnostic accuracy and observer performance in the diagnosis of abnormalities in the anterior maxilla: a comparison of panoramic with intraoral radiography. *Br Dent J* 1992; **173**: 265-271.
- 20 Borg E, Kallqvist A, Grondahl K, Grondahl H G. Film and digital radiography for detection of simulated root resorption cavities. *Oral Surg, Oral Med, Oral Path, Oral Radiol, Endod* 1998; **86**: 110-114.
- 21 Whaites E. *Essentials of Dental Radiography and Radiology*. 2nd ed. Churchill Livingstone, 1996.
- 22 Giles S A, Taylor N G. Are anterior occlusal radiographs still indicated for orthodontic assessment? *Br Dent J* 1997; **183**: 325-328.

Submitting illustrations to the BDJ

Authors submitting manuscripts for publication in the BDJ are reminded that two copies of all illustrations must be supplied. This will assist in speeding up the refereeing process — manuscripts and illustrations are always sent to referees and a set of illustrations is required at the editorial office for reference. If you choose to submit 35-mm transparencies then one set of these and one set of prints (colour or black & white) will be acceptable.

We strongly advise authors to keep copies of all illustrations submitted in case letters are lost or damaged in transit. Please do not send glass-mounted transparencies — even when securely wrapped the glass will often arrive cracked or shattered, resulting in damage to the surface of the slide which usually renders it unsuitable for reproduction.