

# Diagnosis and management of teeth with vertical root fractures

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## Abstract

Vertical fractures in teeth can present difficulties in diagnosis. There are, however, many specific clinical and radiographical signs which, when present, can alert clinicians to the existence of a fracture. In this review, the diagnosis of vertical root fractures is discussed in detail, and examples are presented of clinical and radiographic signs associated with these fractured teeth. Treatment alternatives are discussed for both posterior and anterior teeth.

**Key words:** Endodontics, diagnosis, vertical fractures.

(Received for publication March 1999. Accepted March 1999.)

## Introduction

Vertical root fractures have been described as longitudinally oriented fractures of the root, extending from the root canal to the periodontium.<sup>1</sup> They usually occur in endodontically treated teeth, although occurrence in non-restored teeth has been described.<sup>2-4</sup> The vertical fracture may involve the whole length of the root or only a section of it. It may involve only one or both sides of the root.<sup>5-7</sup> In molar teeth, the fracture is most commonly bucco-lingual in orientation in individual roots. Mesio-distal fractures are less common. In anterior teeth, the fractures are most commonly in a bucco-lingual direction.<sup>5</sup> Vertical root fractures can be initiated from coronal tooth structure (Fig. 1) or at the apex (Fig. 2). Incomplete and complete root fractures have been described.<sup>8,9</sup> Most vertical root fractures are complete.<sup>6</sup> The radiographic and clinical signs of vertical root fractures were extensively reviewed by Pitts and Natkin in 1983.<sup>1</sup> A number of other diagnostic reviews have been published.<sup>7,10-13</sup> Numerous case reports also appear in the literature describing single or multiple cases of vertical root fractures.<sup>14-28</sup>

If unrecognized, vertical root fractures can lead to frustration and inappropriate endodontic treatment. Diagnosis is sometimes difficult as there is often no

single clinical feature which indicates that root fracture is present<sup>11</sup> and signs and symptoms are often delayed. Indeed, average time between root filling and the appearance of a vertical root fracture has been estimated to be between 39 months<sup>23</sup> and 52.5 months<sup>29</sup> with a range of three days to 14 years. In general, however, all vertically fractured teeth exhibit specific clinical and radiographic signs which should alert the practitioner to the possibility of a root fracture being present. This paper reviews these diagnostic features, presenting examples of each. Treatment alternatives are discussed but causes of vertical root fractures are not addressed. They will be the subject of a further review.

## Clinical presentation

The clinical presentation of a vertical root fracture is extremely variable. The clinical signs and symptoms vary according to the position of the fracture, tooth type, time after fracture, the periodontal condition of the tooth and the architecture of the bone adjacent to the fracture. Teeth with vertical root fractures often present with a long history of variable discomfort or soreness, usually associated with local chronic infection. The pain is usually mild to moderate in intensity.<sup>23</sup> Rarely is severe pain associated with these teeth. Vertically fractured teeth can also present with a history of pain on biting.

Vertical root fractures should be considered if an apparently well root filled tooth does not settle after the root filling is completed.<sup>16</sup> Where a root filled tooth is associated with 'pain on biting' and is also accompanied by a 'bad taste', a vertical root fracture is most likely present. Occasionally, the patient can be aware of a sharp cracking sound at the time of condensation of gutta percha,<sup>1,2,23</sup> or the cementation of a post.<sup>21</sup> Bleeding during condensation of a root filling material and an apparent lack of resistance within the canal during condensation, leading to an almost unlimited ability to condense gutta percha into the canal,<sup>11</sup> are also signs that a vertical root fracture is present.

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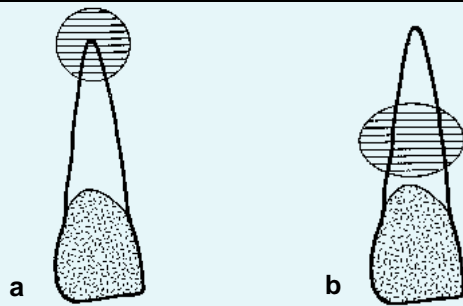
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**Fig. 1.** - Upper central incisor showing complete crown-down vertical root fracture.



**Fig. 2.** - Maxillary second premolar shows an incomplete bucco-lingual vertical root fracture which has been initiated in the apex. Note the V-shaped resorptive defect which has occurred apically.



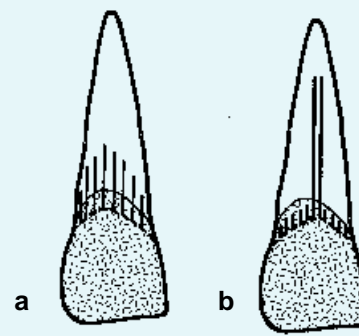
**Fig. 3.** - Diagrammatic representation of the position of soft tissue swelling (a) in a tooth with a periapical abscess, and (b) in a tooth with a vertical root fracture.



**Fig. 4.** - A broad-based swelling over the mesio-buccal root of this mandibular first molar is typical of that associated with a vertical root fracture.



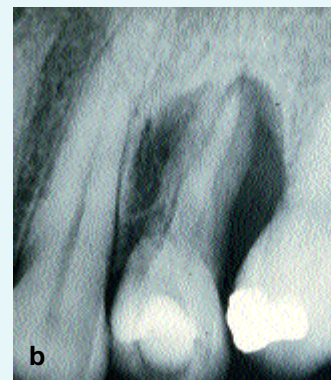
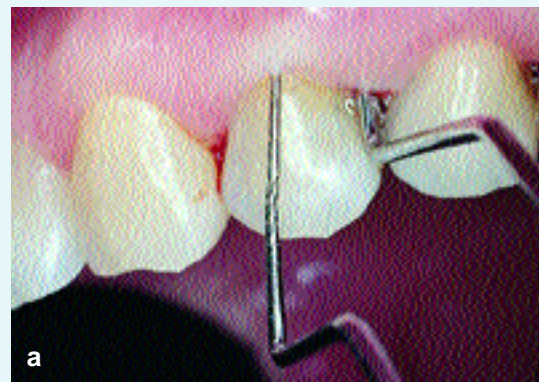
**Fig. 5.** - Double or multiple sinus tracts are a feature of vertically fractured teeth.



**Fig. 6.** - Diagrammatic representation of a probing pattern seen in (a) periodontal disease and (b) vertical root fracture. A deep narrow pocket in one position around the circumference of the tooth and the presence of otherwise normal attachment is a feature of vertically fractured teeth. When similar pocketing occurs in two points around the circumference of the tooth, a vertical root fracture is inevitably present.



**Fig. 7.** - Maxillary central incisor tooth exhibiting a deep narrow pocket on the labial surface of the tooth with normal attachment in the interproximal area. The presence of a bucco-lingual vertical root fracture was confirmed by surgery.



**Fig. 8.** - (a) Maxillary right first premolar with a mesio-distal fracture. Deep probing is evident mesially and distally but attachment is normal on the buccal and lingual aspect. (b) Radiograph of same tooth. Note the extensive bone loss mesially and distally but little evidence of bone loss apically.

Some swelling of soft tissues is usually present. The swelling is usually broad-based, and mid-root in position. Palpation will often show swelling and tenderness over the root itself, but little swelling in the periapical region (Fig. 3, 4). When a sinus tract is present, it may be situated in or close to attached gingiva rather than in the apical region. Double or multiple sinus tracts are common.<sup>1</sup> Where multiple sinus tracts are present one or more of these tracts may be located some distance from the involved tooth. The insertion of a gutta percha point into each sinus tract can assist with diagnosis. An example of a vertically root fractured tooth exhibiting multiple sinus tracts is shown in Fig. 5.

A common feature of vertically root fractured teeth is the development of deep, narrow, isolated periodontal pockets. Pocketing is usually situated adjacent to the fracture site. When the fracture extends right through the root, probing patterns may be bilateral. The probing pattern for a tooth with a vertical root fracture is different from that seen in teeth with periodontal disease, where the pocketing is fairly consistent in depth around a large part of the tooth (Fig. 6). Deep probing in one position around the circumference of the tooth in the presence of otherwise normal attachment usually indicates that the tooth is fractured (Fig. 7, 8). Deep probing in two positions on opposite sides of the infection is almost pathognomonic for the presence of a fracture. It may be necessary to remove the restoration before deep pocketing can be probed in the interproximal region of molar teeth with mesio-distal fractures.<sup>1</sup>

A common presenting feature is the dislodgement of a post or post crown. A root fracture should be suspected if an apparently well-fitting post or post core becomes dislodged. A typical case is illustrated in Fig. 9. The presence of a vertical root fracture should be strongly suspected in teeth where there has been a history of repeated dislodgement of a post or post crown. Because of problems with diagnosis, it is not uncommon for teeth with vertical root fractures to have been treated repeatedly by surgery before the presence of a fracture is suspected. When surgery fails for no obvious reasons, a vertical fracture should be considered a possibility before the periapical area is re-entered surgically.

### **Radiographic signs**

While the clinical presentation of a vertical root fracture can be variable, radiographic signs are, at times, quite specific. These signs can vary considerably from case to case, depending on the angle of the X-ray beam in relation to the plane of fracture, the time after fracture and the degree of separation of the fragments. Radiographic changes seen in vertical root fractures are summarized below.

### ***Separation of root fragments (Fig. 10-13)***

When separation of root fragments occurs, the root fracture is clearly visible. Once separation of fragments has occurred, proliferation of granulation tissue<sup>22</sup> often results in the rapid movement of the fragment away from the remaining root, in many cases until the fragment comes into contact with an adjacent tooth. Wide separation of fragments can occur very rapidly, sometimes occurring in a matter of weeks.

### ***Fracture lines along the root or root fillings (Fig. 14-19)***

On occasions, direct evidence of a fracture can be seen as a vertical radiolucent line running across the root or the root filling. Direct evidence of a vertical root fracture line is often difficult to visualize. For the fracture to be seen the X-ray beam must pass almost directly down the fracture line. Small changes in horizontal angulation may render the fracture undetectable. A four degree variation in the horizontal angulation of the film can prevent visualization of the fracture.<sup>30</sup> Pitts and Natkin<sup>1</sup> suggest that a fracture line that deviates from the long axis of the canal may be radiographically more obvious, whereas a fracture line running parallel and adjacent to a root filling may be less easy to see. While it is sometimes possible to see fracture images clearly on a radiograph, care should be taken when attempting to identify vertical lines as fracture lines, as anatomical features, palatal grooves, artefacts and scratches can mimic the appearance of a fracture.

### ***Space beside a root filling (Fig. 20)***

Minor separation of fragments can result in the radiographic appearance of a vertical space adjacent to the root filling material in an otherwise well-obtimated canal. Vertical root fractures should be suspected if the root filling appears well condensed but is in close contact with only one wall of the root canal.

### ***Space beside a post (Fig. 21)***

In general, posts are constructed so that they fit the canal. When a post is present in a vertically root fractured tooth, slight separation of the fractured fragments can result in the appearance of a space between the edge of a root canal, which may be coated with cement, and the post itself.

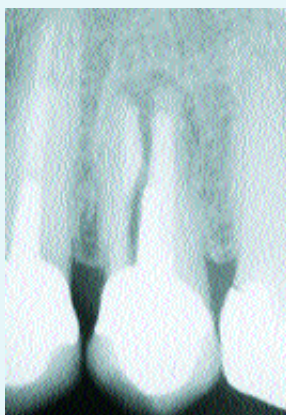
### ***Double images (Fig. 22)***

When separation of fragments occurs in a direction other than parallel to the X-ray beam, overlapping of fragments may result in double images of the external root surface. While this effect is sometimes seen in normal teeth, for example, in the mesial concavity of maxillary premolar teeth, step-like double images on the external outline of a

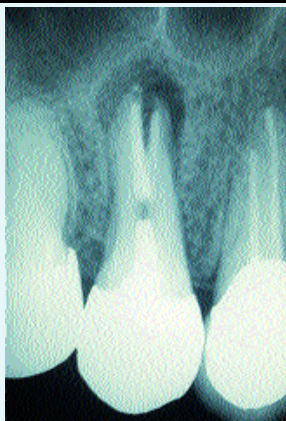




**Fig. 9.** – (a) Clinical presentation of a patient with discomfort associated with the maxillary right central incisor which was crowned. The patient has experienced a low grade discomfort, and an itchy feeling associated with this tooth for some months. (b) Periapical radiograph shows the tooth to be restored with a post retained crown. No evidence of root filling is present although the lamina dura at the apex appears intact. There is slight widening of the periodontal ligament space in the mid-root region. (c) Clinical photograph six months after Fig. 9a. The post crown is dislodged and a root fracture is evident on the labial surface. (d) Dislodged crown from Fig. 9a. Dislodgement of an apparently well-fitting post or post crown is a sign that the root may be fractured.



**Fig. 10.** – Separation of the fragments is clearly visible in this vertically fractured maxillary left first premolar.

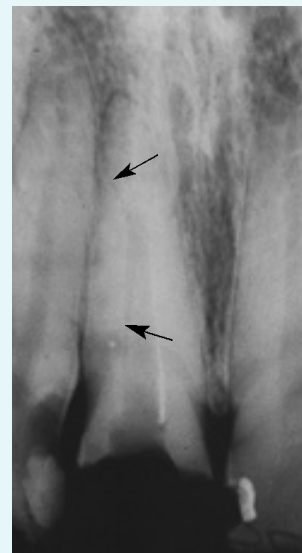


**Fig. 11.** – Vertically fractured mandibular lateral incisor showing wide separation of the fragments. The distal fragment is completely separate from the tooth and has moved distally to be in contact with the canine. Granulation tissue separates the gutta percha fill from both fragments.

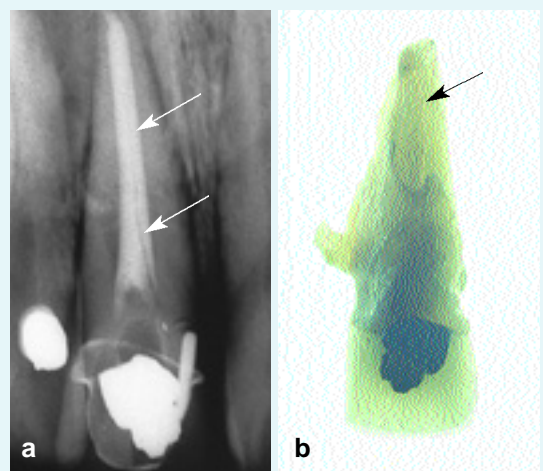
**Fig. 12.** – Maxillary canine showing a vertical root fracture in the apical portion and wide separation of the fragments.



**Fig. 13.** – Separation of the fragments in the mesial root of this mandibular right molar can be clearly seen. The mesial fragment has remained attached to the large restoration.

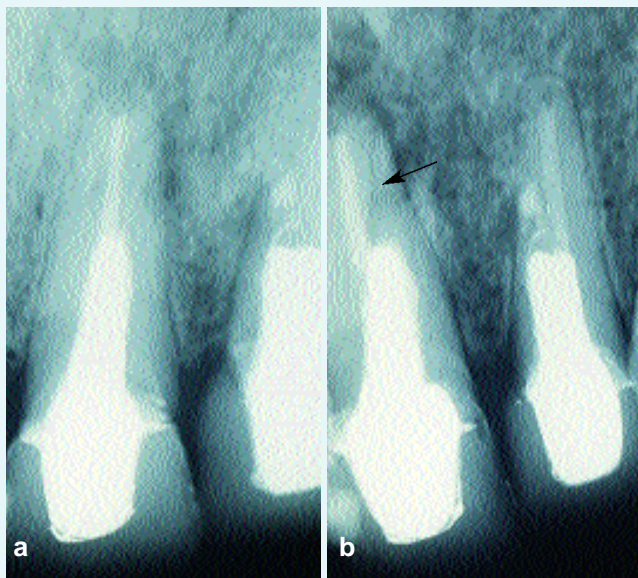


**Fig. 14.** – A fracture line (arrows) can be seen running parallel to the root canal and then exiting distally in the apical third in this maxillary left central incisor tooth.

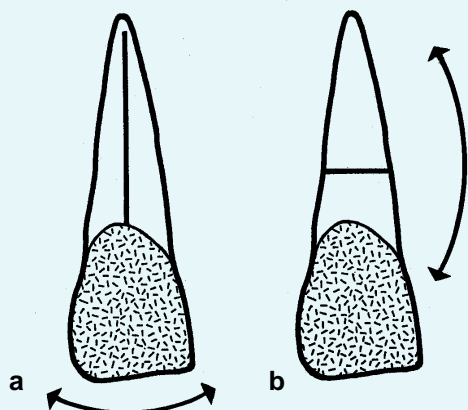


**Fig. 15.** – (a) A vertical fracture (arrows) radiographically superimposed over the root filling is present in this maxillary left central incisor tooth. (b) Clinical photograph of a tooth from Fig. 15a showing the fracture (arrow). Note the amount of fibrous tissue which is attached to this tooth once it has been extracted. This is a feature of teeth that are vertically root fractured.

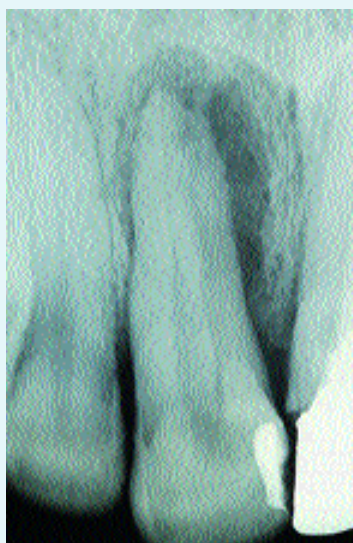




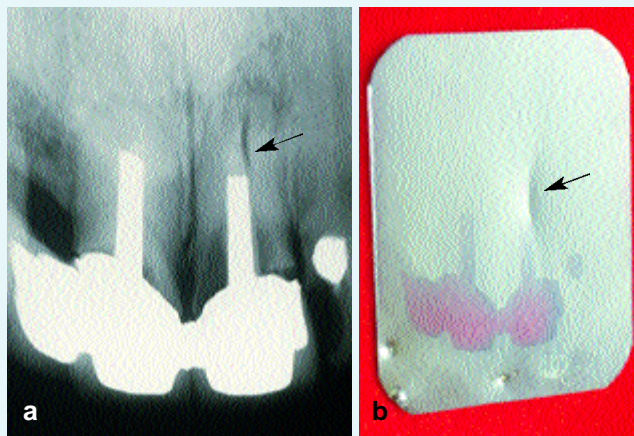
**Fig. 16.** – Two periapical radiographs taken at the same consultation showing the effects of angulation changes on the visibility of the root fracture on the right maxillary central incisor tooth. (a) The fracture is difficult to see. (b) The fracture is easy to see (arrow) where the X ray beam passes down in the plane of the fracture.



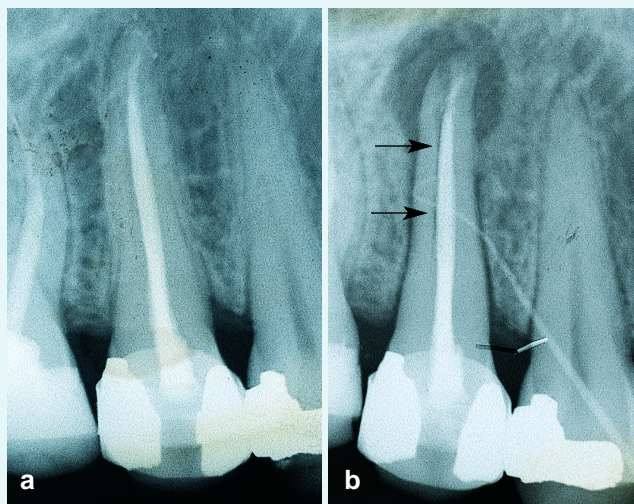
**Fig. 17.** – Diagrammatic representation of the changes in horizontal angulation of the X-ray beam that are necessary to detect a vertical root fracture (a). For better visualization of a transverse root fracture, the angulation is changed vertically rather than horizontally (b).



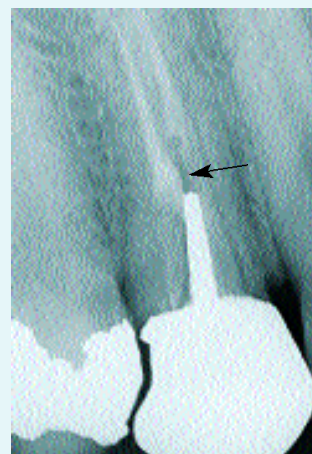
**Fig. 18.** – Periapical radiograph of maxillary right central incisor with a deep palatal groove, the radiographic picture of which mimics a vertical root fracture.



**Fig. 19.** – (a) Periapical radiograph of a failed anterior bridge. A dark line extending from the bottom of the post in the maxillary right central incisor to the apex (arrow) gives the appearance of a vertical root fracture being present. (b) Clinical photograph of the radiograph showing a mark (arrow) responsible for the radiographic image. In interpreting radiographic lines on radiographs consideration must be given for the presence of artefacts and scratches.



**Fig. 20.** – Periapical radiographs of a root filled premolar tooth. (a) At one year recall, there is no evidence of any radiographic changes which are suggestive of a problem. (b) Two years later there is widening of the periodontal ligament space and the appearance of a large periapical lesion. The fracture is seen as a space (arrows) which has developed on the distal side of the root filling due to slight separation of the fragments.



**Fig. 21.** – Maxillary right first premolar restored with a post/crown restoration. A space is present between the post and the root which is covered with a layer of cement. The space can be traced past the post beyond where the fracture line is clearly shown (arrow).

tooth are often an indication that a fracture is present.

### ***Radiopaque signs (Fig. 23-25)***

Where a vertical root fracture is present prior to root filling, or occurs during the root filling procedure, extrusion of cement or root filling material can occur into the fracture site or apically. When the plane of the fracture is predominantly in a bucco-lingual direction, the excess cement material can be seen as a more intensely radiopaque line superimposed over the root filling.<sup>1</sup> In some instances, this can give the appearance of a second canal or an irregularly obturated root canal. Where the plane of the fracture is mesio-distal, the cement excess can sometimes be seen as a thin film extending proximally from the root canal filling to the root surface. Where separation of the fracture occurs during root filling, extension of root filling material through the apex can result in a tangle of accessory points at the apex ('apical spaghetti').

### **Patterns of bone loss**

Vertical fractures allow the ingress of bacteria and associated irritants which cause localized periodontal destruction and bone loss adjacent to the fracture site.<sup>6</sup> The amount of bone loss is dependent on the nature of the fracture and the time the fracture has been present. Radiographically, there are certain specific patterns of bone loss which are found to be associated with vertically fractured teeth. The radiographic appearance of the bone loss is dependent on the extent of destruction, the plane of fracture and the architecture of the bone adjacent to the fracture. Thus, the appearance of bone destruction seen when the fracture plane is bucco-lingual will be different from that seen when the plane of the fracture is mesio-distal. Bone destruction associated with anterior teeth will be easier to see than that associated with lower molars, where changes are masked by a thick buccal plate of bone.

### ***Widening of periodontal ligament space (Fig. 26)***

Wide enlargement of the periodontal ligament around the whole length of the root is an indication that the tooth is vertically fractured. The radiographic appearance of bone loss is quite different from that seen in a periapical lesion where apical bone loss can occur but without destruction of the lamina dura along the root surface. When the fracture is in a bucco-lingual direction and involves the apical portion, there is loss of bone on the buccal and lingual surfaces of the tooth. Radiographically, the tooth root can be seen more clearly (or appears more 'in focus') than adjacent teeth. Widening of the periodontal ligament space around the whole length of the root is a classic sign that a vertical root fracture is present.

### ***Radiolucent halos (Fig. 27)***

When the plane of fracture is at right angles to the X-ray beam, the pattern of bone loss appears wider and more diffuse than that seen in bucco-lingual fractures. Pitts and Natkin<sup>1</sup> have described this appearance as a 'halo-like' radiolucency running around the whole of the tooth. While the width of the diffuse bone loss may vary, a radiolucent halo which runs around the whole of the root surface is a classic sign of a vertical root fracture.

### ***Step-like bone defects (Fig. 28)***

When the fracture runs obliquely across the root, or where the fracture does not extend into the apical portion, a characteristic step-like bone defect develops.<sup>1,31</sup> The width of the bone loss can vary. However, the depth of the step is governed by the apical extent of the fracture. The appearance of a step-like bone defect on a particular tooth is subject to the angulation of the X-ray beam. Additional radiographic examination with the X-ray beam angled 15 degrees to the mesial or distal may provide a better view of the defect. It must be remembered that step-like bone defects can mimic simple endodontic lesions resulting from other causes, for example, post perforations and vertical grooves. Similar defects can also be associated with non-vital teeth that have not been root filled but such defects will include the apex. Step-like bone defects are only a sign that a fracture may be present. The presence of the fracture needs to be confirmed by other means. Pitts and Natkin<sup>1</sup> have suggested that the possibility of a fracture is increased if the pocket extends to the mid-root level rather than to the apex, as this eliminates apical pathology from consideration.

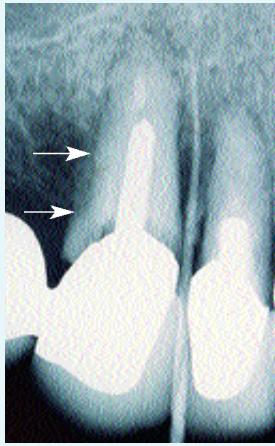
### ***Isolated horizontal bone loss in posterior teeth (Fig. 29)***

It is unusual for one tooth in a dentition to be severely involved with periodontal disease without involvement of other teeth. When only an isolated tooth shows bilateral horizontal bone loss the presence of a mesio-distal root fracture should be expected, particularly in the presence of apparently successful endodontic therapy, and where the overall periodontal situation is stable. Occasionally, the same radiographic appearance can be seen where there is a foreign body wedged in the periodontium.

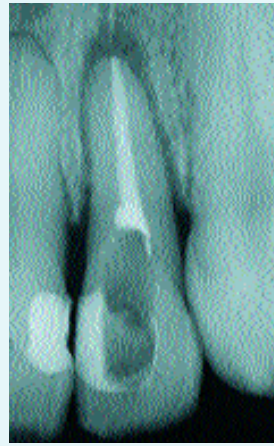
### ***Unexplained bifurcation bone loss (Fig. 30, 31)***

Bone loss in the bifurcation region of molars can occur in patients without overt periodontal disease in situations where there is ingress of bacteria through defects in the bifurcation, for example, perforations and other defects in the pulpal floor. Bifurcation bone loss is also seen in lower molars with non-vital pulps but this is usually in association with periapical bone loss. Where bifurcation bone

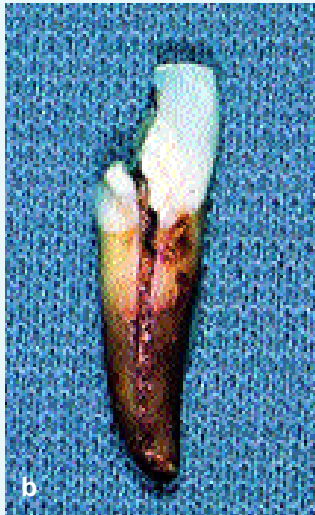




**Fig. 22.** – Wide separation of the fragments has occurred in this vertically fractured maxillary right canine which is fractured mesio-distally. Double images of the distal root surface (arrows) are caused by overlapping of the fragments.



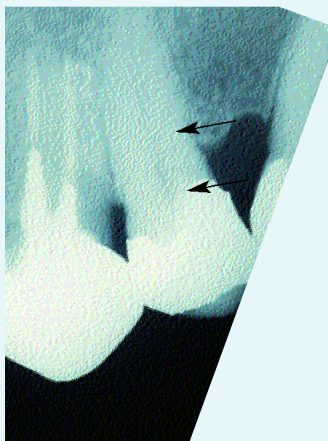
**Fig. 26.** – Periapical radiograph of maxillary left lateral incisor showing widening of the periodontal ligament space around the whole of the root. This is a classic sign that a root fracture is present.



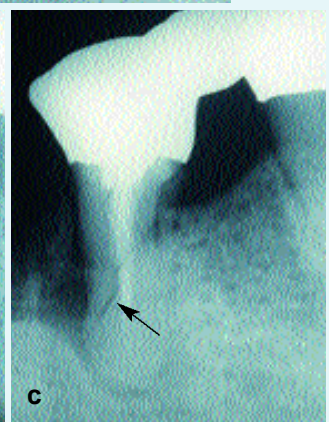
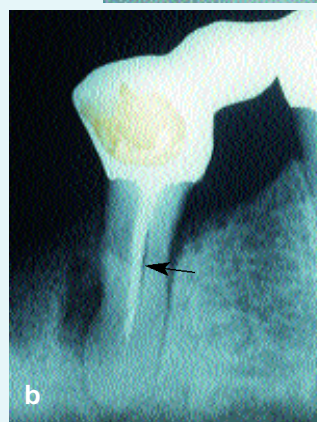
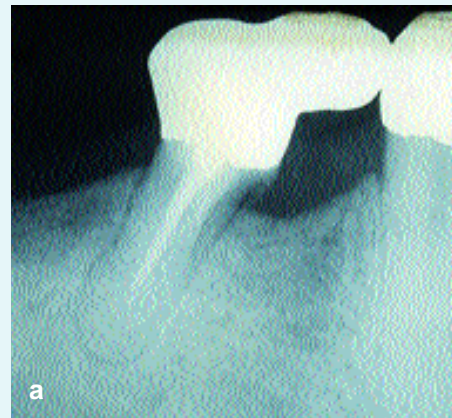
**Fig. 23.** – (a) Periapical radiograph of a recently root filled maxillary right canine showing a well condensed root filling with an irregular outline. (b) Extracted tooth showing vertically fractured root.



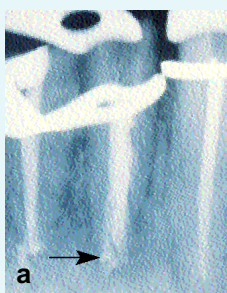
**Fig. 27.** – Periapical radiograph of mandibular left first molar showing a wide diffuse radiolucent 'halo' around both roots. The tooth was fractured mesio-distally. Radiolucent halos of this type are a classic sign that a vertical root fracture is present.



**Fig. 24.** – Periapical radiograph of a root filled maxillary right first molar which suffered a vertical root fracture. A thin film of cement (arrows) is evident in the buccal root extending from the root filling to the root surface.

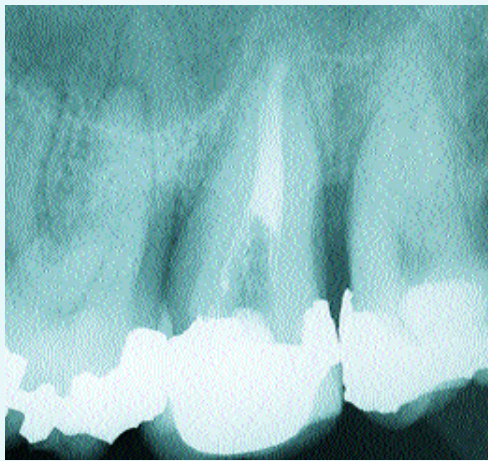


**Fig. 28.** – (a) Periapical radiograph of hemisected lower molar showing good bone adaptation to the distal surface. (b) A step-like bone defect has developed on the distal in association with a vertical fracture in the root. (c) A periapical radiograph taken at a slightly different angle reveals that the step-like bone defect finishes at the level of the fracture.

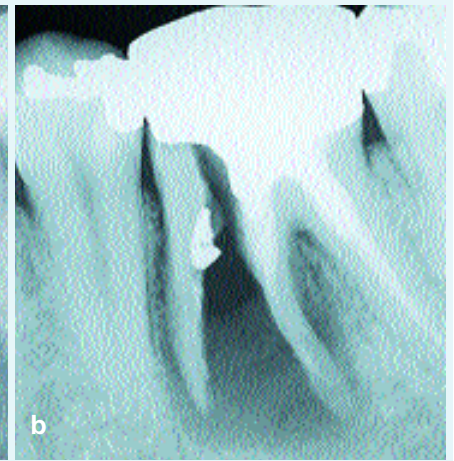
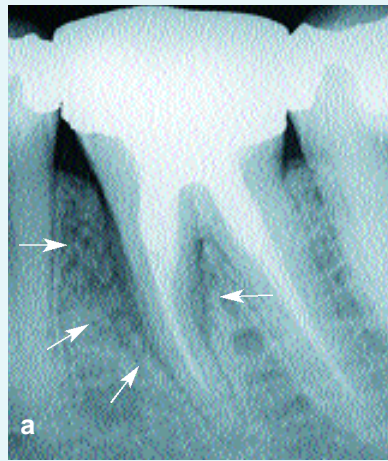


**Fig. 25.** – (a) Periapical radiograph of root filled mandibular left lateral incisor showing a tangle of accessory points in the apical portion (arrow). (b) Extracted tooth showing the fractured root and the tangled array of accessory points through the apex.

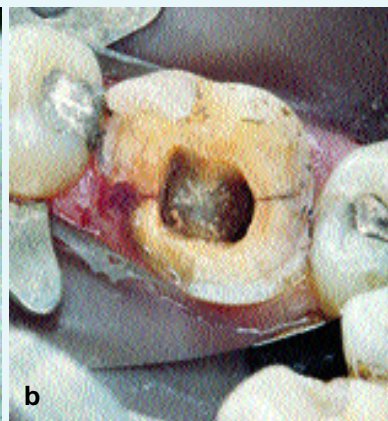
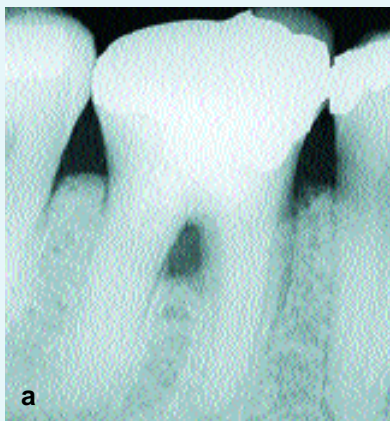




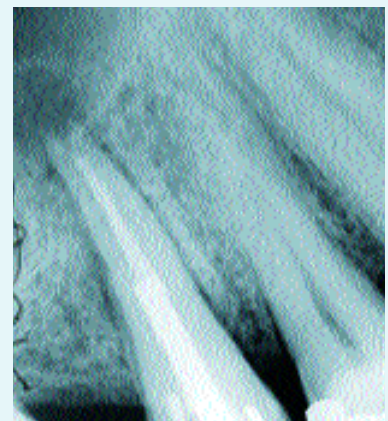
**Fig. 29.** – Isolated horizontal bone loss occurring in association with a single isolated tooth, in an otherwise periodontally stable mouth, is an indication that a vertical root fracture is present.



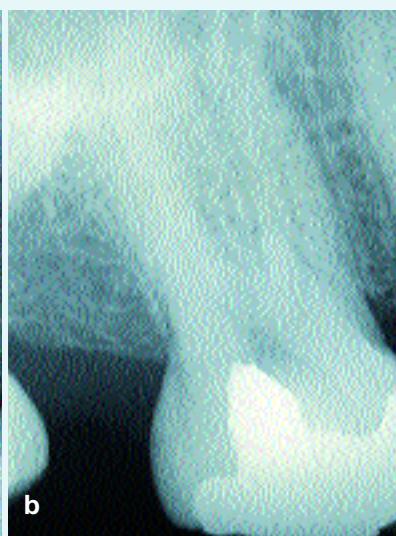
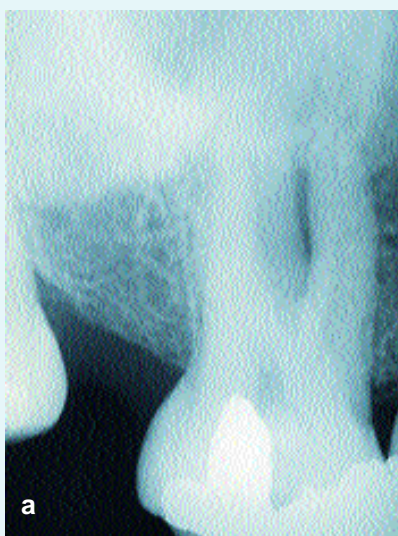
**Fig. 32.** – (a) Mandibular right first molar which has been root filled and restored with a large amalgam restoration. Note the diffuse V-shaped bone loss (arrows) around the mesial root which is a classic sign that a root fracture is present. (b) Periapical radiograph taken four months later clearly shows a major fracture with wide separation of fragments.



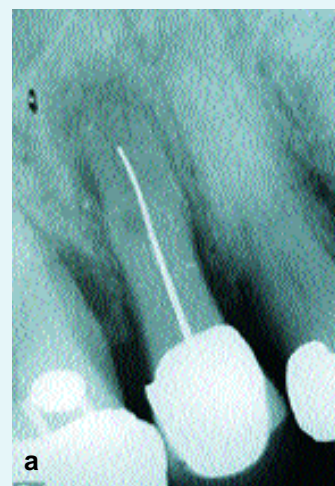
**Fig. 30.** – (a) Periapical radiograph of mandibular right first molar tooth showing unexplained bone loss in the bifurcation region. The lamina dura is intact apically and there is normal attachment buccally and lingually. (b) Clinical photograph of the tooth showing the mesio-distal fracture running across the pulp chamber. A vertical fracture should be suspected if there is unexplained bone loss in the bifurcation region of the molar teeth.



**Fig. 33.** – Vertically fractured second premolar tooth showing a V-shaped resorptive defect at the apex. The periodontal ligament space is widened around the whole root.

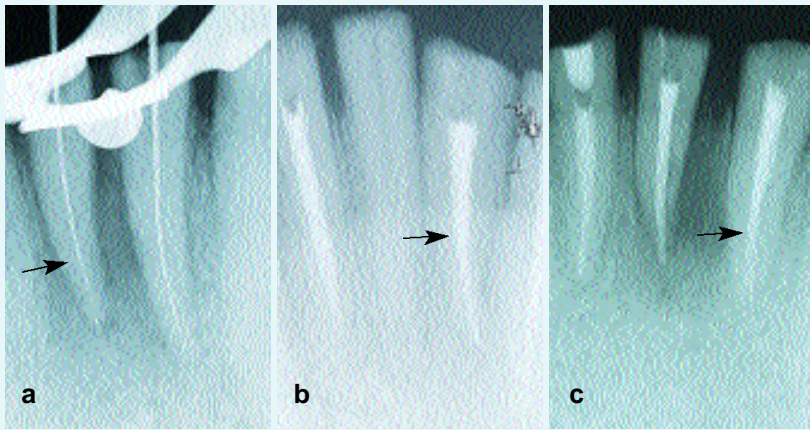


**Fig. 31.** – (a) Periapical radiograph of vertically fractured maxillary left first molar shows bone loss in the bifurcation region of this molar. (b) In a straight on view of the same tooth, the lesion in the bifurcation is masked by the palatal root. There is widening of the periodontal ligament space around the mesio-buccal root. The lamina dura appears to be intact around the tooth. This tooth was fractured mesio-distally.



**Fig. 34.** – Dislodgement of a retrofilling material is a sign that a root fracture may be present. This premolar was treated surgically and a retrofilling material was placed at the apex. (a) A periapical radiograph taken prior to extraction shows the retrofilling material is no longer in place. (b) This patient returned with the amalgam restoration which had been dislodged through the soft tissues. The existence of a vertical root fracture is clearly evident.





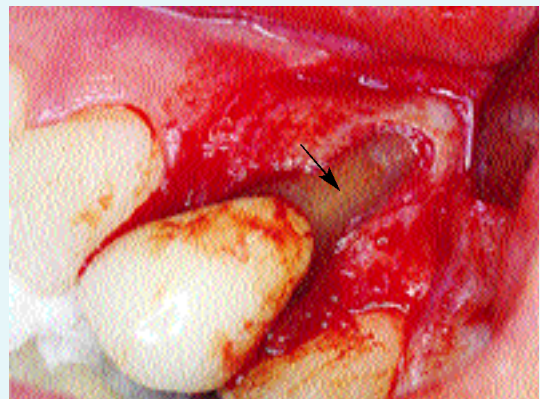
**Fig. 35.** – A vertical fracture should be suspected if there is breakdown of bony architecture which occurs subsequent to the complete resolution of an endodontic lesion. (a) At the time of initial endodontic treatment the mandibular left central incisor (arrows) is associated with a periapical lesion. (b) On review there has been complete healing. (c) Six years later a lesion has developed. This tooth is obviously vertically fractured. Note the resorption along the fracture line.



**Fig. 39.** – Where it is important to determine the type and extent of the fracture, a full thickness periodontal flap is recommended. Often a single vertical incision one tooth distal or mesial to the suspect tooth is all that is required to expose sufficient root surface to visualize the fracture (arrow).



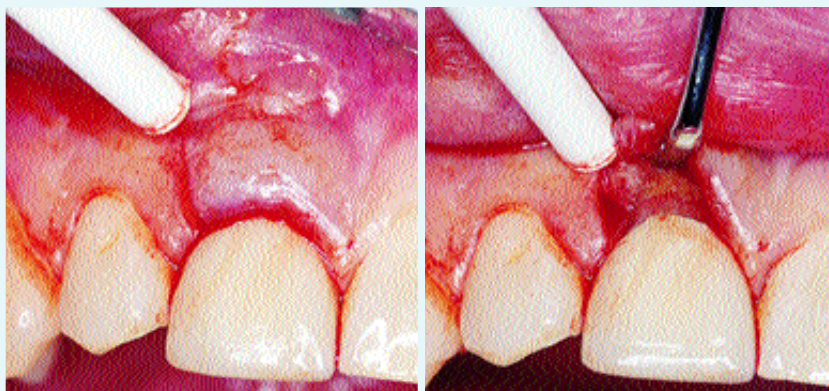
**Fig. 36.** – The presence of a vertical root fracture is clearly visible on the root face. The post crown has been dislodged.



**Fig. 40.** – Loss of bone and deposition of soft tissue adjacent to the tooth root is usually found in the presence of a root fracture. On this occasion, the fracture can be seen as a linear yellowish line in the mid-root region, running vertically from crown to apex (arrow).



**Fig. 37.** – Gentle reflection of soft tissues under local anaesthesia is often all that is required to confirm the presence of a vertical root fracture.



**Fig. 38.** – A triangular 'miniflap' involving a single vertical incision (a) in the attached gingiva on the side of the tooth away from the probing defect or suspected fracture is a relatively atraumatic way of exposing the coronal root surface and (b) of confirming the presence of a suspected vertical root fracture.



**Fig. 41.** – Reflection of a full thickness flap reveals the full extent and complexity of the root fracture in this central incisor tooth. Flap reflection is recommended to confirm the presence of a vertical root fracture.

loss occurs for no apparent reason, and without any obvious sign of apical pathosis, the presence of a vertical fracture through the bifurcation needs to be considered. In mandibular teeth, bifurcation bone loss is usually fairly easy to see. In maxillary molar teeth, however, it is usually masked by the position of the palatal root. An oblique angle on the radiograph is necessary to bring the bone loss into view.

### ***V-shaped diffuse bone loss on roots of posterior teeth (Fig. 32)***

Where the buccal roots of maxillary molars or the roots of lower molars are vertically fractured, the characteristic radiographic image of bone loss is a diffuse V-shaped radiolucency, widest at the crestal bone, narrowing towards the apex.<sup>1</sup> The shape and diffuse radiographic evidence of the bone loss is due to the fact that much of the bone lost is lingual to the buccal plate of bone, which to some extent masks its presence. Diffuse bone loss of this type, when confined to a single root or a single tooth in the mouth, is almost pathognomonic of a vertical root fracture.

### **Resorption along the fracture line (Fig. 33)**

One of the presenting signs of a vertical root fracture is resorption along the fracture line.<sup>1,15</sup> This resorption may occur apically where it causes a V-shaped notch in the apical region, or longitudinally along the whole length of the fracture, giving the appearance of an irregular long resorptive defect running along the gutta percha root filling. Disintegration of root canal sealer, silver points and gutta percha in association with extensive resorption of the root has been reported as being a feature of vertically root fractured teeth.<sup>15</sup>

### **Dislodgement of retrograde filling material (Fig. 34)**

Dislodgement of retrograde filling material in association with vertical root fractures has been described previously.<sup>1,32,33</sup> Dislodgement of retrograde root fillings can occur due to inadequate retention.<sup>33</sup> However, for the retrograde root filling to be displaced, some force usually has to be applied to move it away from the root apex. Should a retrograde root filling become dislodged, a likely cause is a vertical root fracture. In some cases the dislodged retrograde root filling material can be expelled through soft tissues.<sup>32</sup>

### **Endodontic failure after healing has occurred (Fig. 35)**

Endodontic failure can occur many years after the tooth is root filled for a large number of reasons.<sup>34</sup> Coronal leakage<sup>35</sup> is considered to be one major cause of long-term failure of endodontic procedures. However, when the endodontic status of a tooth

deteriorates rapidly after a long time without symptoms, or where radiolucencies reappear after healing has previously taken place, a vertical root fracture should be considered as a cause and further investigations of the tooth should be undertaken with this possibility in mind.

### **Direct visualization of the fracture**

While clinical and radiographic signs give a reasonably accurate indication that a root fracture is present, direct observation of the fracture is the only sure way to confirm the presence of the fracture in many cases. Where sufficient coronal structure has been lost, or where a crown restoration has become dislodged, it may be possible to view the fracture directly by examining remaining tooth structure (Fig. 36). Where separation of fragments has occurred, the fracture space is clearly evident. Where separation has not occurred, a sharp probe can be used to identify the fracture. Should this not be possible, then gentle retraction of the soft tissues in the region of the suspected fracture line with a flat plastic or other instrument (under anaesthetic if required) may be sufficient to view the fracture on the root surface (Fig. 37). Once the soft tissues are displaced, the fracture often can be clearly seen. Location of the fracture can be assisted by passing a sharp probe lightly over the tooth surface. A 'clicking' sound can be heard as the probe is passed over the fracture line.<sup>1</sup> Where this is not possible, reflection of a small flap is recommended in order to view the root and confirm the presence of a fracture. The simplest way to do this is with a triangular 'miniflap'. A single vertical incision can be made in the attached gingiva on the side of the tooth away from the probing defect or suspected position of the root fracture and around the offending tooth only. This conservative flap usually allows sufficient reflection of soft tissues to confirm the presence of most vertical root fractures (Fig. 38). Where the extent of the root fracture is important to determine, or where it is considered that a miniflap will not expose sufficient tooth structure, a full thickness periodontal flap can be used. In general, a vertical root fracture is easy to see once the flap is retracted, particularly if there is some separation of the fragments (Fig. 39). Its presence is always accompanied by loss of bone and the deposition of soft tissue adjacent to the fracture. At the time of surgery, the appearance of the fracture can vary. Where the fracture is stained, visualization is easy. On many occasions, however, subtle linear colour change (Fig. 40) is all that is apparent. Change in the angle of lighting or the position of viewing is sometimes necessary to confirm the presence of the fracture. It is sometimes necessary to remove the soft tissue over the portion of the root being examined so the fracture can be visualized. A fibre-optic light is a useful diagnostic tool, particularly where the fracture



is not stained, or where separation of fragments has not occurred. It is proposed by these authors that, where possible, a small flap should be raised routinely to confirm the presence of a fracture, rather than just to suspect that one is present (Fig. 41).

### Treatment alternatives

Once the presence of a vertical root fracture is confirmed, the decision needs to be made regarding the future treatment of the tooth. The discomfort associated with these fractures is often not acute, and often patients have put up with discomfort for many years. Some are reluctant to have the tooth removed, and this is understandable from a symptomatic point of view. However, it should be remembered that while the fracture is present, bone loss continues and should the fractured tooth be left in place indefinitely, the amount of bone loss that occurs may severely compromise the success of future restorative procedures and may result in the need for complex periodontal surgery or ridge augmentation. It is, therefore, recommended that root fractured teeth be removed as soon as practical. A number of complications have been reported where vertical root fractures have been left in place for some length of time.<sup>36,37</sup>

Treatment of vertically fractured teeth is difficult and is dependent on the tooth type as well as on the extent, duration and location of the fracture. The majority of vertical fractures involve the gingival sulcus and result in destruction of the periodontium to the apical extent of the fracture, due to ingress of bacteria and other irritants,<sup>6</sup> resulting in alveolar bone loss in almost all teeth.<sup>30</sup> Repair of the periodontium and the bone cannot occur in the presence of the bacterial infection.<sup>1</sup> The aim of treatment is therefore to eliminate the fracture or the leakage of bacteria along the fracture plane.<sup>1</sup> From a treatment planning point of view, a distinction must be made between a tooth that is cracked and a tooth that is fractured. Where there is separation of fragments and/or radiographic changes and/or bone loss associated with the root defect, a vertical fracture can be assumed to be present and elimination of the crack is a treatment priority. Where the tooth is cracked or crazed without bone loss or attachment loss the root is cracked. Conservative management of these cracked root filled teeth is sometimes possible.

Multirrooted teeth can often be successfully treated by resecting the fractured root, either by root amputation or hemisection.<sup>1,38</sup> Prognosis for posterior teeth is good, provided the fracture can be removed in its entirety. Studies of root resected teeth have reported five year retention rates of 94 per cent<sup>39</sup> and ten year retention rates of 68 per cent.<sup>40</sup> A series of treatment options for posterior teeth involving hemisection and root amputation has been described in the literature.<sup>1,7</sup>

In general, prognosis for single rooted teeth is poor and extraction is often the treatment of choice. However, many case reports are described in the literature where innovative attempts to treat and retain anterior teeth have been attempted with varying success. Clinicians have either removed the fractured segment or attempted to bond the root using a biocompatible material.

Cyanoacrylate has been used in an attempt to bond the fragments of anterior teeth.<sup>41</sup> While the treated teeth were comfortable at a 16 month follow-up, long-term prognosis was considered poor due to deep pocketing and resorption. An *in vitro* study<sup>42</sup> assessing the resistance to fracture of root segments bonded with glass ionomer cement, composite resin, and cyanoacrylate concluded that the bond strengths of composite resin and cyanoacrylate were superior to glass ionomer cement. A number of case reports appear in the literature suggesting the use of glass ionomer cement in vertically root fractured teeth. It has been proposed that glass ionomer cement may bond around the fracture line, preventing propagation of the fracture.<sup>43</sup> Glass ionomer and amalgam condensed into the coronal half to two-thirds of the root canal in teeth with incomplete vertical root fractures has been reported successful at eight month follow-ups<sup>44</sup> but long-term follow-ups have not been recorded in the literature.

Calcium hydroxide has been used to promote tissue repair and resolve osseous defects before the roots were restored. Teeth treated with calcium hydroxide, then 'reinforced' with glass ionomer cement, have shown healing at six month follow-up appointments.<sup>14</sup> Studies using an expanded polytetrafluoroethylene Gore-Tex membrane to establish a new periodontal attachment after the fragments have been bonded with glass ionomer cement have reported differing results; six teeth failed in a twelve month period.<sup>45</sup> Only one study has reported success with this method of treatment. Trope and Rosenberg<sup>46</sup> extracted both segments of a maxillary second molar and protected the periodontal ligament by soaking it with Hanks balanced salt solution, while bonding the segment with glass ionomer and subsequently replanting the tooth using Gore-Tex membrane to establish a new periodontal attachment. After six months, they reported a reduction in pocket depth from 10 mm to 2-3 mm. A crown was placed after one year as the tooth was functioning normally.

It can be concluded from these results that the use of glass ionomer cement in teeth with incomplete vertical root fractures may be an effective way of treating the teeth on a short-term basis. Long-term follow-ups have yet to be reported on these teeth and this treatment can only be regarded as experimental. Also, on balance, the use of Gore-Tex membrane in association with glass ionomer bonding of the fragments can only be regarded as experimental. It

may be appreciated that there is no point in attempting such treatment in anterior teeth if there is not sufficient coronal tooth structure to allow for an adequate ferrule to hold the coronal tooth structure together.<sup>47</sup>

Regeneration of bone has been shown to occur after surgical removal of the fractured segment from an anterior tooth, but long-term follow-up was shown to be unfavourable due to deep pocketing and mobility.<sup>48</sup> Successful three year follow-up has been reported where the fractured fragment was removed in a tooth without periodontal disease and the remaining root filling covered by an amalgam restoration.<sup>49</sup>

Though the majority of vertical root fractures are complete, fracture of only one side may occur.<sup>6</sup> In these instances, complete removal of the fracture has been proposed.<sup>1</sup> It has been suggested that in instances where the gingival sulcus is intact, the root can be sectioned, maintaining a long bevel and eliminating the entire fractured segment. A fibre-optic light source or the use of a dye are valuable aids in assessing the fracture lines.<sup>31</sup> Despite considerable loss of root length, provided plaque control is adequate and the entire fracture is eliminated, these teeth with a reduced periodontium can still have a good long-term prognosis.<sup>1,50</sup> Claims have also been made for the successful conservative treatment of vertical root fractures which originate apically but which do not involve the gingival sulcus. Root extrusion<sup>51</sup> or intentional replantation in an extruded and/or rotated position are possible. It has also been suggested that if the fracture only involves the facial wall, and does not involve the gingival sulcus, the fracture may be eliminated with the preparation of a long amalgam restoration.<sup>1,18,52</sup> Vertucci<sup>49</sup> treated a single tooth with an incomplete bucco-lingual vertical fracture by removal of the buccal segment, covering of the root canal filling with an amalgam restoration and treating the remaining root surfaces with 20 per cent citric acid solution for five minutes. The tooth was considered functional with no probable periodontal defects or radiographic evidence of disease at a three year review. The advantage in these procedures is that the original root length is maintained. It may be reasonable to expect that the fracture could still propagate to the lingual wall. The placement of a long buccal restoration may be indicated if resection of the tooth root in a coronal dimension would not leave the tooth with adequate root support. Obviously, any detection of a lingual fracture would require beveling of the root as described earlier. None of the above procedures would be effective in the long term in the presence of a contaminated root filling. Thus, if such treatment is considered, re-root filling is indicated wherever possible.

A number of other case reports discussing treatment alternatives have been published. Takatsu *et al.*<sup>53</sup> used orthodontic elastics to join the buccal and palatal segments of a vertically fractured maxillary second molar which were then sealed with a photocured resin liner to allow the tooth to be endodontically treated and restored with a cast crown. The tooth remained in function for more than three and a half years with a reduction in pocket depth. Sinai and Kratz<sup>48</sup> demonstrated regeneration of bone and healing when the detached root segment, root canal filling and soft tissues were surgically removed. However, long-term follow-up was unfavourable due to deep pocketing and mobility.

An *in vitro* study<sup>54</sup> proved CO<sub>2</sub> and Nd:YAG laser to be an ineffective way to fuse fractured tooth roots. Scanning electron microscopy revealed heat-induced fissures and cracks, areas of cementum breakdown and separation of cementum from underlying dentine. Energy densities required to induce melting were considered excessive and damaging to pulp tissue. At the present time, there does not seem to be any justification for the use of a laser to fuse fractured portions of tooth together.

## Conclusion

Many of the treatment options reported in this review have involved extensive procedures on small numbers of teeth, often with poor outcomes. Where successful outcomes have been claimed, the long-term prognosis has yet to be proven. All case reports published so far which describe a treatment rationale, do not include enough teeth to ascertain the efficacy of any procedure. There is room for further clinical research on the treatment of teeth that are vertically root fractured. While there is no doubt that, with some posterior teeth, treatment procedures which successfully remove the fractured fragments completely (either by hemisection or root amputation) can result in a long-term successful result, treatment of anterior teeth can at best be regarded as experimental. While it must be acknowledged that attempts to treat strategic teeth in an effort to defer complicated or extensive restructure treatment<sup>1</sup> may be warranted, before any complex experimental treatment procedures are considered, the desirability for retention of the tooth root should be carefully weighed up against extraction and replacement with a denture, bridge or implant.

## Acknowledgements

Particular thanks must be given to Dr John Mayne for use of illustrative materials in this paper. Contribution of cases by Drs Gil Shearer, Ross Parry and Grahame Brown is also gratefully acknowledged.



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