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Vertical root fractures in endodontically treated teeth: diagnostic signs and clinical management

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A most frustrating complication to root canal therapy is vertical root fracture (VRF) in an endodontically treated tooth. Prognosis most often is hopeless and differential diagnosis from other pathoses may be difficult at times. Nevertheless, proper diagnosis is critical to distinguish a fracture complication from clinical manifestations of periodontal and endodontic diseases. This review emphasizes the importance of the correct diagnosis of VRF, describes the more typical clinical and radiographic features of this disorder, and summarizes its prevalence and multifactorial etiology.

Introduction

Vertical root fracture (VRF) is an untoward complication to root canal therapy that often calls for tooth extraction. It may be initiated during the filling procedure or subsequently because of stress factors maintained by forces of mastication (1, 2). Depending on the nature of the stress factors, VRF usually originate from the apical end of the root and propagate coronally or can originate from the cervical portion of the root with extension in an apical direction (1, 2). In a horizontal aspect, VRF expands laterally from the root canal wall to the root surface where it may result in an incomplete fracture involving only one side of the root (Fig. 1A, B). A complete fracture expands in opposite directions of the root canal and involves two root surface aspects (3) (Fig. 2A, B).

VRF in an endodontically treated tooth is a frustrating phenomenon for both the dental practitioner and the patient for several reasons:

The above alterations in the mechanical characteristics of dentine, together with the variation in the biomechanical response, predisposes endodontically treated tooth to fracture.

(1) The fracture is usually diagnosed years after all endodontic and prosthetic procedures have been completed (4).
(2) The final diagnosis of VRF is, at times, difficult because of either lack of specific signs and symptoms and/or of typical radiographic features. Therefore, the differential diagnosis from other pathologic entities can be a challenging task (5–8).
(3) Several etiologic factors may be involved (4, 7, 9).

The affected root or tooth has an unfavorable prognosis and extraction is usually the only treatment option (3, 10).

This review focuses on the clinical and radiographic features of VRF in endodontically treated teeth and summarizes the prevalence, diagnosis, etiology, and clinical management of this disorder.

Pathogenesis

When a VRF occurs, whether incomplete or complete, it extends to the periodontal ligament, whereupon soft tissue grows into the fracture space and increases the separation of the root segments. On communication with the oral cavity through the gingival sulcus, foreign

Fig. 1. Incomplete fracture at the buccal aspect of a mesial root of a mandibular molar (A) and of a single-rooted maxillary premolar (B). The fractures extend from the root canal system to the buccal wall of the roots.

material, food debris, and bacteria obtain access to the fracture area. Upon entry of these elements to the fracture space, an inflammatory process is induced in the adjacent periodontal tissue (3), resulting in periodontal ligament breakdown, alveolar bone loss, and granulation tissue formation (11). The osseous defect usually propagates apically and interproximally in a very quick manner. The breakdown is especially rapid in teeth and roots in which the buccal plate is thin, i.e., in the maxillary premolars and the mesial roots of the mandibular molars, the most susceptible teeth, and roots to fracture (5, 12). In VRF confined to the apical root portion without communication with the oral cavity, the inflammatory process in the surrounding supporting tissues will depend on the release of any existing irritants in the root canal, including bacteria and sealer material (3, 13).

Bone resorption patterns

The most fractured teeth and roots are the maxillary and mandibular premolars and the mesial roots of mandibular molars. The typical pattern of bone resorption facing these teeth was described by Lustig et al. (14) as ‘dehiscence’ and was found in the buccal plate in 90% of the cases examined. Initially, when a thin buccal plate is resorbed, a narrow bone cleft develops and resorbs in an apico-coronal direction; i.e., it propagates with the fracture to form an oval or oblong type of bone resorption (15) (Fig. 3). At a later stage, the bone defect becomes wider as it extends laterally to the interproximal areas. This is a rather typical feature seen after flap reflection and removal of the granulation tissue (Figs 4A–C).

At the lingual aspects, the spongeous bone and the thicker cortex create a ‘shield phenomenon’ by which the bone resorptive process following backward and lateral propagation forms a shallow rounded U-shaped bone defect with the height of the plate preserved. Usually, in a periapical radiograph no radiolucent area is seen when a dehiscence type of bone resorption has occurred (16). It may only be diagnosed in radiographs when the osseous defect has extended laterally to the interproximal areas (Fig. 4D, E).

A ‘fenestration’ type of bone resorption may occur when the fracture exists somewhere along the root, usually at the buccal aspect without involving coronal or apical parts (Fig. 5). Although fenestration is not a typical sign of VRF as described by the AAE definitions (1), it was found in 10 of 110 examined fracture cases (14). As the bone loss was opposite to the fracture site, the bone coronally and apically to the fracture line remained intact. No osseous defect was found at the gingival aspect after flap reflection because the fracture had no marginal communication. An abscess, similar to a dento-alveolar abscess of endodontic origin, was the only clinical sign in these 10 cases of fenestration.

Prevalence

VRF seems to be a more common reason for extraction of endodontically treated teeth currently than in the past. This may be an effect of increased awareness among dental practitioners that endodontically treated

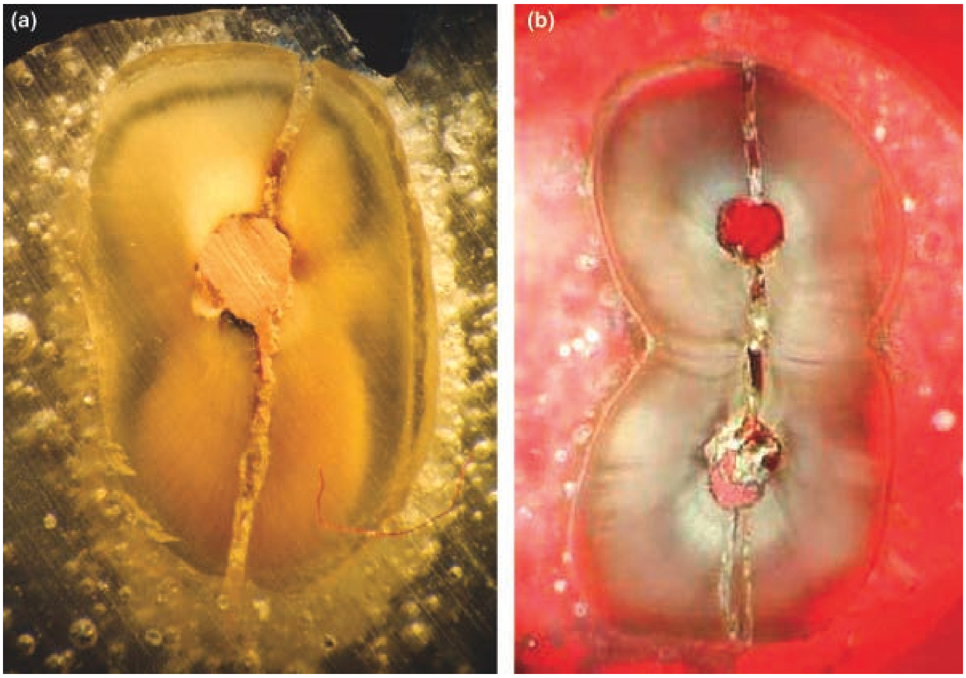

Fig. 2. Cross-section of a vertically fractured maxillary premolar showing a complete fracture from the buccal to the lingual aspect (A). (B) Complete fracture from the buccal to the lingual aspects of a maxillary premolar with two root canals is shown.

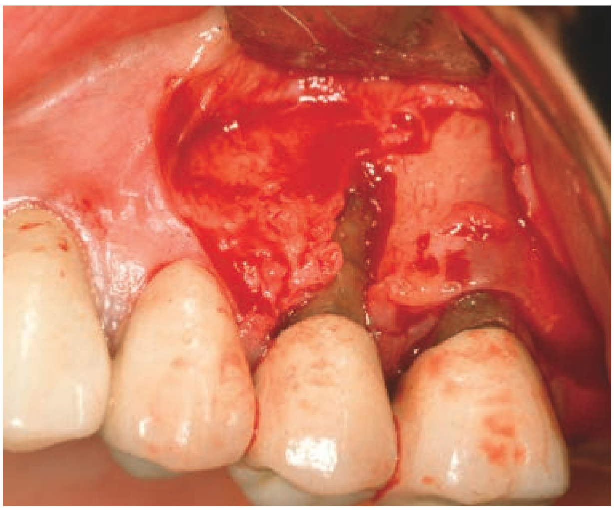

Fig. 3. Narrow bone cleft – full dehiscence of the buccal plate at a maxillary premolar. The bone in the interproximal area is still intact.

teeth are vulnerable to fracture, combined with reports and texts highlighting the difficulty of making a correct diagnosis of this condition (11). However, the prevalence of VRF leading to tooth extraction is not well established. Reports from case series (8, 17) and follow-ups of patients treated with prosthetic reconstructions (18, 19), and retrospective radiological studies (10) suggest a prevalence of 2% and 5%. However, postulating percentages of VRF from studies on presumed causes for extraction of endodontically treated teeth (20, 21) may be inaccurate. Some VRF cases included in these studies were probably diagnosed incorrectly, as either root canal treatment failure or as progressive periodontal disease. Recently, a higher prevalence of VRF among extracted teeth has been reported (22–24). In two studies (23, 24) on root-filled teeth referred for extraction, 11% and 20% of vertically fractured teeth were found, respectively.

Clinical signs and symptoms

A definitive diagnosis of VRF in endodontically treated teeth is at times a challenge. Clinical signs and symptoms as well as radiographic presentations are often similar to those associated with non-healing root canal treatments and with certain manifestations of periodontal disease. Nevertheless, a rapid decision is required to avoid unnecessary bone loss, which can result in difficulty in reconstructing the area, should implant replacement of the tooth be the treatment of choice. Yet, the diagnostic information may be insufficient or the patient may be reluctant to undergo a diagnostic surgical procedure, thus forcing postponement of a conclusive decision on the diagnosis.

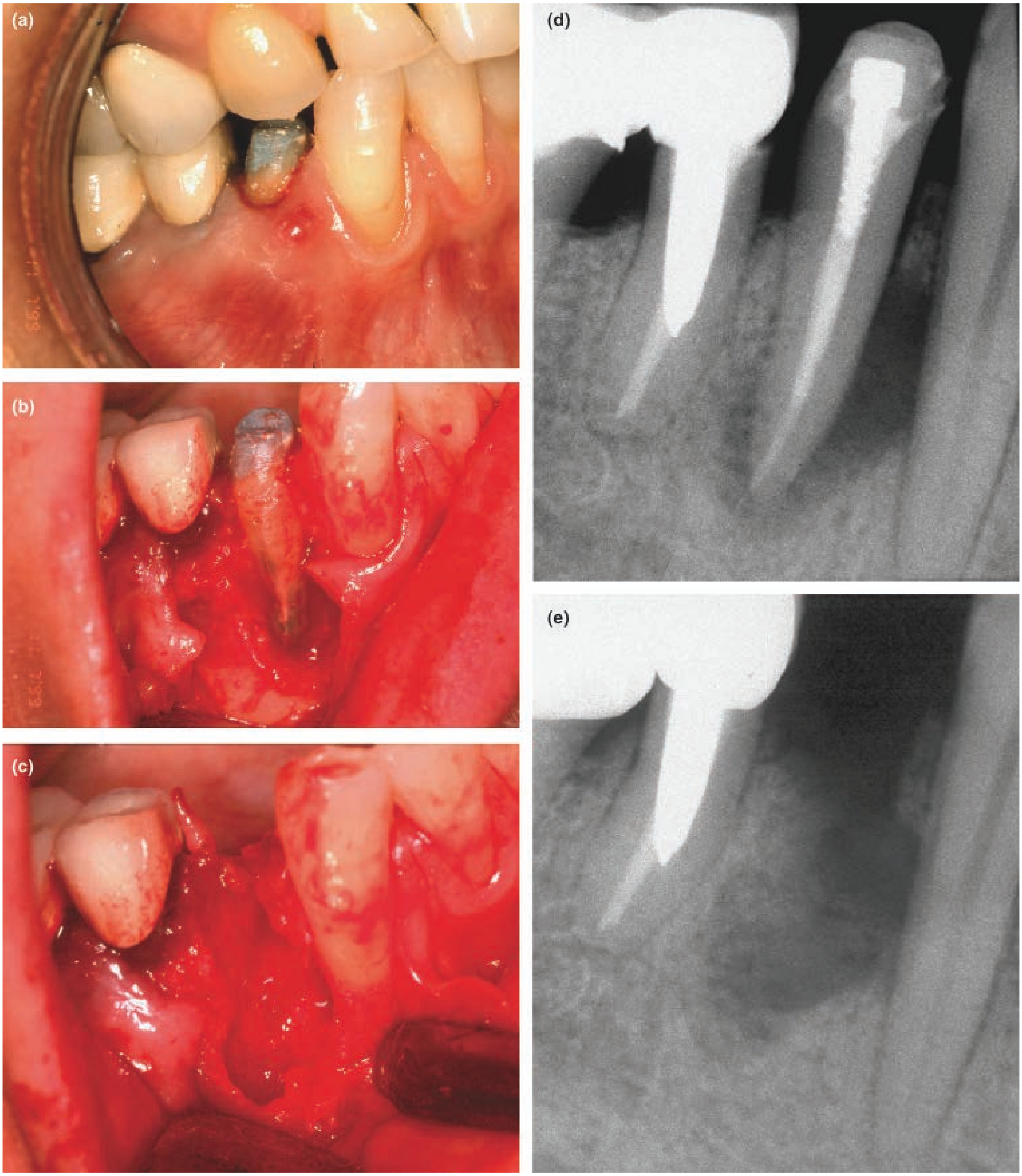

Fig. 4. Case of a vertical root fracture in a mandibular first premolar, seen after the removal of a temporary crown (A). A full dehiscence of the buccal plate with bone resorption extending into the interproximal area is seen after raising a full exploratory flap (B). The tooth was extracted and granulation tissue is seen filling the defect (C). The radiograph in (D) shows a large 'halo'-shaped radiolucency primarily at the mesial aspect but also involves the periapical area and the apical third of the distal aspect of the root. The amount of bone loss is demonstrated in the post-extraction radiograph (E).

Common signs and symptoms associated with VRF have been analyzed in some recent retrospective studies (Table 1). Frequently occurring were osseous defect, mild pain, sinus tract, and exacerbation of a chronic lesion. More than half of the patients reported some form of mild pain and complained of pressure on mastication. An average of 35% of the patients presented with an abscess, which was typically an exacerbation of a chronic inflammatory lesion in the area (14) (Table 1). Although the finding of an osseous defect is typical of periodontal disease and sinus tract of non-healing root canal treatments, it carries distinct diagnostic value that can lead the practitioner to the correct diagnosis of VRF.

As can be seen in Table 1, a sinus tract was found in 13–42% of the VRF cases (4, 5). A typical feature was its location close to the gingival margin (Fig. 6A) as opposed to failed root canal treatment where sinus tracts often are located more apically. The presence of two sinus tracts at both buccal and lingual aspects (Fig. 7A, B) is almost pathognomonic for a VRF.

Tamse et al. (5) observed that in 35% of their cases with a sinus tract, 24% also had a deep osseous defect, mostly at the buccal tooth aspect (Fig. 6B, C). The probing area was then limited to the site that faced the fracture line in the root, which initially is narrow and difficult to locate and probe. At a later stage, when the bone defect has extended apically and laterally, probing is easier. From a differential diagnostic point of view, it is sensible to recognize that pocket probing depths in VRF are in isolated areas, whereas in a patient with periodontal disease more sites can be probed and more than one tooth are usually involved. Thus, it is important that the clinician distinguishes bone resorption in VRF cases from bone losses in periodontal disease (13). Although bone loss in both instances originates from the gingival margin and advances apically, bone loss in periodontal disease is usually a slow process. An exception is a periodontal abscess.

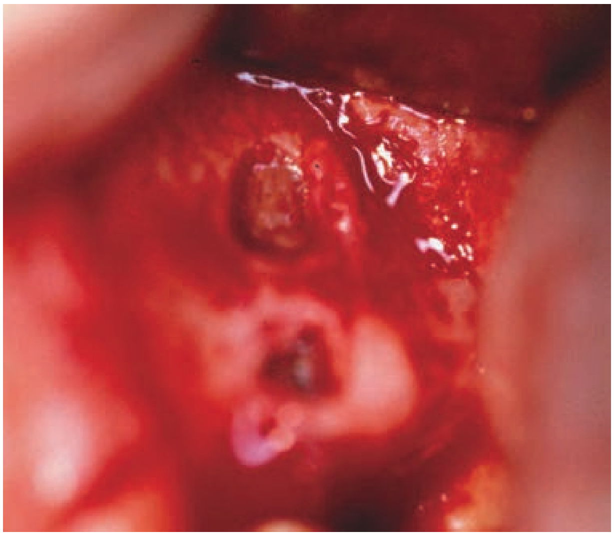

Fig. 5. Fenestration-type bone resorption at the buccal aspect of a fractured maxillary premolar.

A definitive diagnosis of VRF is best attained by an exploratory flap (8, 25, 26) (Figs 3 and 5). If during the surgical procedure, dehiscence, fenestration, and/or a clear sign of fracture are not found, an apicoectomy may be attempted. Yet, prognosis for the tooth may still be questionable as an undiagnosed incomplete fracture may exist at the lingual aspect.

Radiographic features

A definitive diagnosis of VRF based on radiographs can be made in only two instances. One is the appearance of a hair-like fracture line radiolucency in the dentin body. Such lines, however, are difficult to detect and are usually not seen in routine orthoradial periapical radiographs. Nevertheless, Rud & Omnell (16) saw hair-like fracture lines in 35.7% of 375 VRF cases. The other obvious sign of fracture is the radiographic appearance of root segment separation (6, 16), usually accompanied by large bone losses surrounding the tooth or root (Fig. 8A, B).

Table 1. Signs and symptoms of VRF observed in retrospective studies in percent of teeth examined

Author	Number of teeth	Osseous defect	Mild-to-moderate pain	Sinus tract	Perio-type abscess
Meister et al. (8)*	32	93	66	13	28
Tamse (7)†	25	64	41	14	24
Testori et al. (17)†	36	78	58	42	53
Tamse et al. (5)*	92	67	55	35	34

*Retrospective survey of original cases.
†Retrospective survey of original and published cases.
VRF, vertical root fracture.

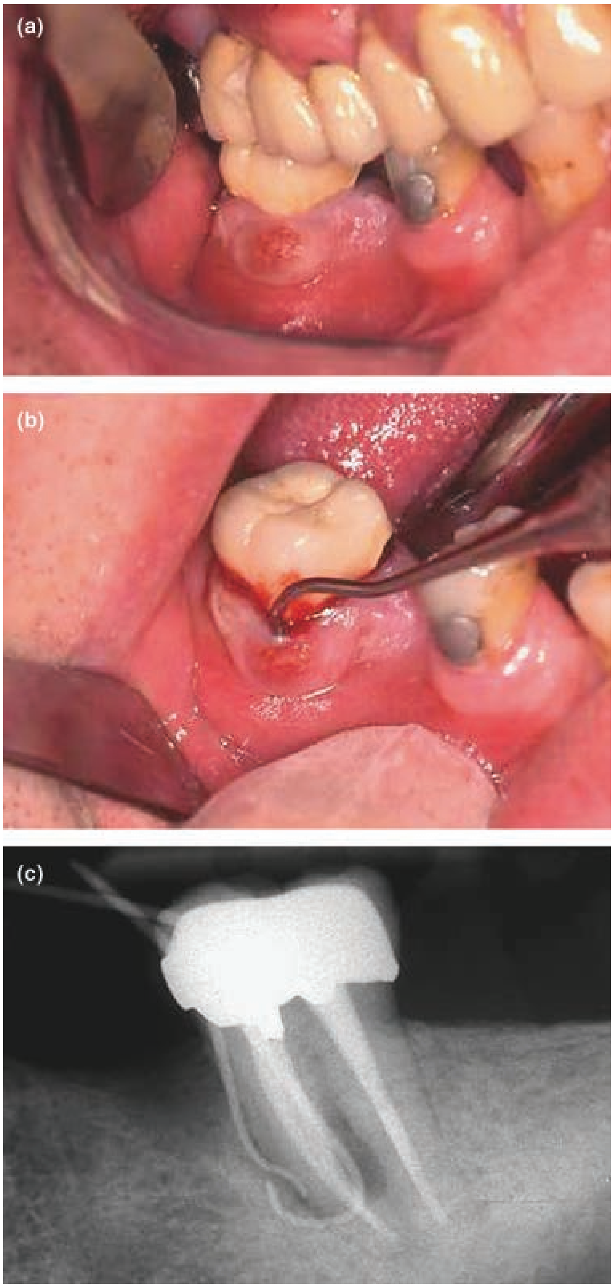

Fig. 6. Highly located sinus tract in a fractured mesial root of a mandibular second molar (A). Periodontal probe demonstrating loss of the buccal plate (B). Periapical radiograph showing bone loss around the distal and mesial aspects of the mesial root and gutta-percha points placed in the sinus tract and in the osseous defect (C). Amalgam dowel can also be seen in mesial root.

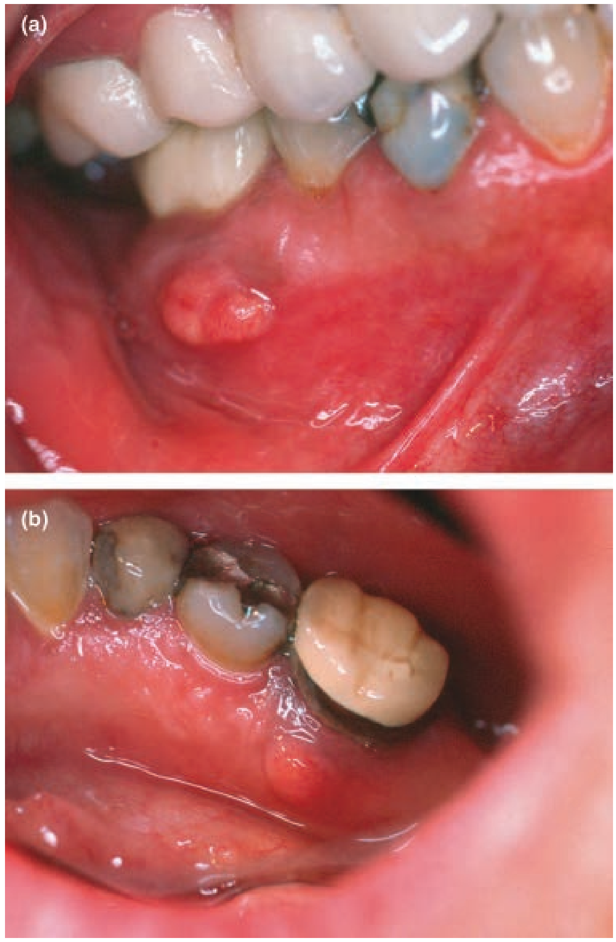

Fig. 7. Highly located sinus tracts on both the buccal (A) and lingual (B) aspects of fractured mesial root of a mandibular second molar.

In most other cases requiring support of radiography, the practitioner has to make interpretations on the basis of the various patterns of periodontal destruction that unfortunately are also shared by periodontal and endodontic-like lesions (12, 27, 28). Yet, in some cases, there are no visible bone lesions (5, 16), which means that a VRF may go undetected and thus delay the final diagnosis and treatment. Rud & Omnell (16) correlated the direction of the fracture, the amount of bone destruction, and the radiographic appearance and emphasized that the extent of bone destruction around a fractured root depends on the location of the root fracture and the time lapse from the inception of the fracture. Meister et al. (8) confirmed the significance of time. They demonstrated that the difficulty of immediate radiographic detection is due to the time sequence needed for soft tissue proliferation to occur in between the segments and that subsequently separates them.

As root fractures mostly propagate in a bucco-lingual direction, and as only the bone facing the fracture resorbs at the early stage, it may be difficult to detect associated radiolucencies because of root superimposi-

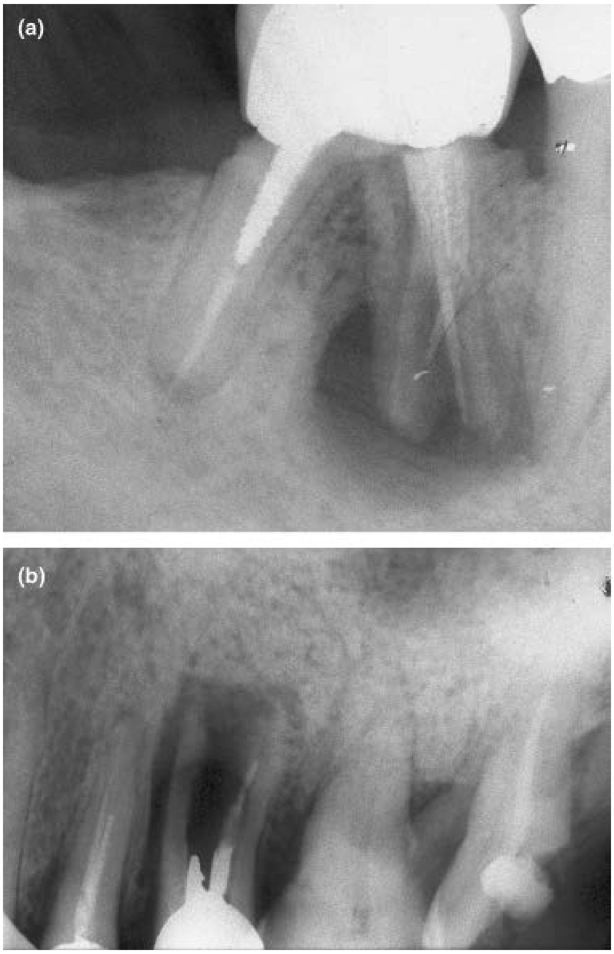

Fig. 8. Large bone defects of a vertically fractured mesial root of a mandibular molar (A) and of a second upper premolar (B).

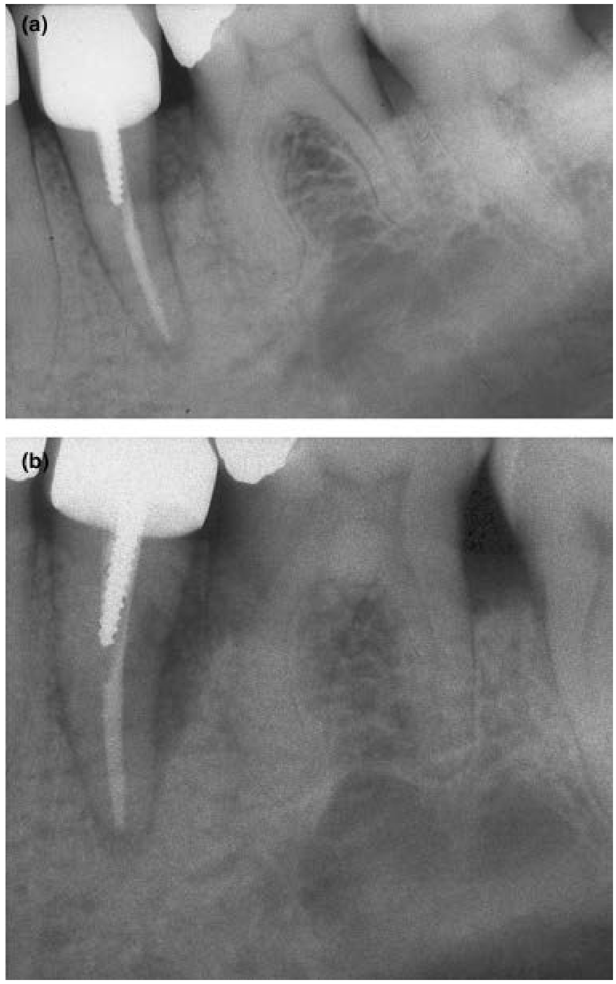

Fig. 9. Angular bone loss on the distal aspect of the coronal third of a mandibular premolar in a patient with periodontal disease (A). As the pockets in the mesial and buccal aspects were deeper compared with the other teeth, a different horizontal angulation was taken (B) demonstrating a periodontal-type bone loss at the coronal two thirds of the root. Vertical root fracture was revealed after tooth extraction.

tion. However, as the bone resorption extends laterally, it may be possible to detect. When a VRF is suspected in a specific tooth, two periapical radiographs taken from different horizontal angulations are mandatory (Fig. 9A, B). In their study on the pattern of bone resorption in 110 VRF cases, Lustig et al. (14) found that in 72% of the patients with either chronic signs and symptoms (sinus tract, osseous defect, mobility) or acute exacerbations, greater interproximal bone loss was recorded than in patients in whom the diagnosis of VRF was made at an early stage.

Despite the difficulties often encountered in ascertaining a diagnosis of VRF in endodontically treated teeth, there are several radiographic signs that should be recognized as strong indications (8, 27). The 'halo' appearance, a combination of periapical and perilateral radiolucency, was associated with a high probability of VRF in a double-blind radiographic study involving 102 endodontically treated maxillary premolars (Figs 4D, 10A, B) (28). An angular resorption of the crestal bone along the root on one or both sides without involving the periapical area mimicking a 'periodontal radiolucency' (Fig. 11A) was found in 14% of the cases. Tamse et al. (29) also found the 'halo' (Fig. 10A) and 'periodontal' types (Fig. 11B) in vertically fractured mesial roots of mandibular molars (37% and 29%, respectively). In that study, the use of these two variables, combined with bifurcation involvement (63%, Fig. 11B) and amalgam dowel (67%, Fig. 6C), predicted fracture in 78% of cases. Others have reported similar findings (11, 17, 25).

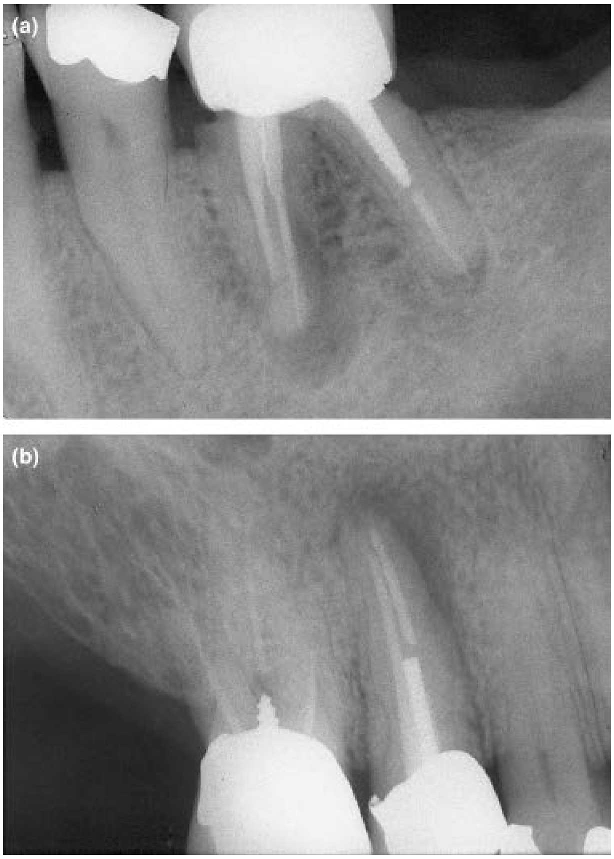

Fig. 10. 'Halo'-shaped radiolucency around the vertically fractured mesial root of a mandibular molar extending coronally toward the bifurcation area (A). 'Halo' radiolucency of the mesial aspect is seen in a maxillary second premolar (B).

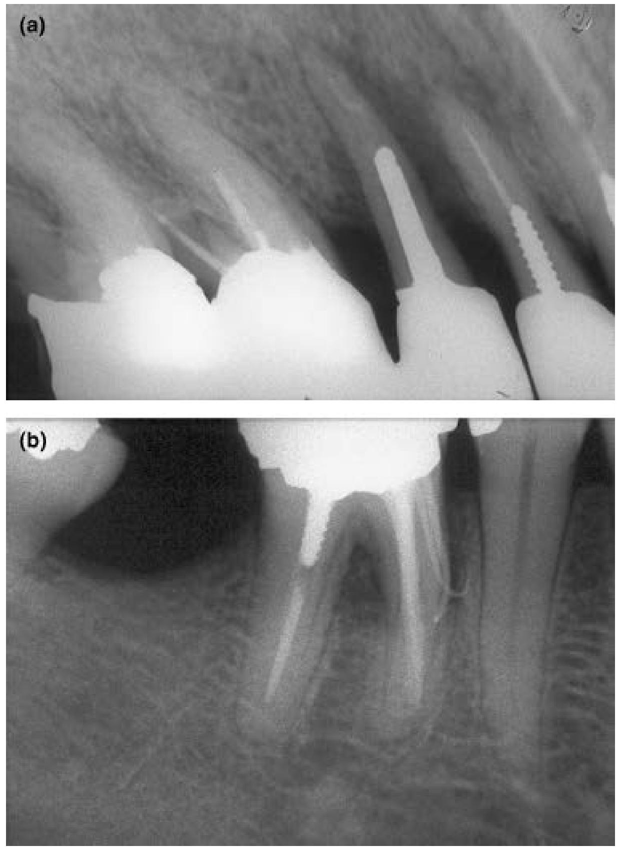

Fig. 11. 'Periodontal'-type radiolucency involving the entire mesial aspect of a second maxillary premolar and the coronal portion of the distal surface (A). The same type of defect in a fractured mesial root of a mandibular molar (B). A gutta-percha cone is placed in the osseous defect on the mesial aspect of the root. A radiolucency in the bifurcation can also be seen.

Table 2 summarizes the findings of six studies on bone resorption patterns in vertically fractured teeth. Despite the different sample size, study designs, and objectives, the most common radiographic feature was lateral radiolucency along the root and the 'halo' appearance.

The new radiological techniques to aid in endodontic diagnosis have recently been reviewed (30). Conventional axial computed tomography (CT) helps visualize VRF (31), but cannot depict small, hairline cracks. When available for clinical use, the micro CT system (32), the flat panel volume detector CT (33), and tuned aperture CT (34) may provide clues to an early detection of VRF.

Diagnosis

The clinical signs and radiographic features suggestive of VRF in susceptible teeth and roots include the deep osseous defect on the buccal aspect, the highly located sinus tract, the typical bone resorption at the exploratory flap procedure, and the 'halo' and 'periodontal type' of bone radiolucency. To ascertain a diagnosis of VRF, the clinician should undertake the following steps:

- identify susceptible teeth and roots for fractures,
- take a complete history of the susceptible tooth,
- clinically examine for pain on mastication and prolonged discomfort,
- use a periodontal probe to detect an osseous defect, especially at the buccal aspect of the suspected root,
- take at least two angulations with periapical radiographs to detect either a fracture line or typical periradicular radiolucency, and
- elevate an exploratory flap that usually helps to visualize the pattern of bone loss and fracture.

Table 2. Patterns of bone resorptions in radiographic in percent of examined cases

Author	Number of cases	Halo	Lateral periodontal	Periapical	Separation of segments	Angular	None
Meister et al. (8)*	32	75†		22	3	–	
Tamse (7)‡	42	26	29	0	7	24	14
Testori et al. (17)§	36	72†		Numbers	Not included	–	Numbers not given
Nicopoulou-Karayianni et al. (27)¶	22	45	27	5	Not included	0	5
Tamse et al. (5)	51	57	14	4	Not included	14	2
Tamse et al. (28) ‖	92	39	24	24	Not included	–	13
Tamse et al. (29)**	49	37	29	10	Not included	6	8

*Defined as 'widening of the periodontal ligament.'
†Described as a combined entity.
‡Survey of 31 published and 11 original cases.
§Survey of 32 published and 36 original cases.
¶Additional 18% 'widening of the PDL.'
‖Additional 9.8% 'isolated perilateral'; maxillary premolars only.
**Additional 4.1% 'isolated perilateral.'

Etiology

VRFs in endodontically treated teeth have a multifactorial etiology that can be divided into *predisposing* and *iatrogenic factors*.

Predisposing factors include loss of healthy tooth substance, as a result of caries and trauma, which increases the risk for cracks in the body of dentin that can later propagate to fracture (35, 36). The unique anatomy of the susceptible roots (37), i.e., the narrow mesiodistal dimension compared with the buccolingual, makes these roots and teeth susceptible to fracture, especially at a later stage when additional tooth structure is removed during root canal and dowel preparations (38, 39). Moisture loss in pulpless teeth (9), previous cracks in the dentin (40), and loss of alveolar bone support (41) are other recognized predisposing factors to VRF (see further the article by Kishen in this volume of *Endod Topics*).

Root canal treatment procedures and the use of intraradicular dowels are the two main iatrogenic factors associated with VRF. Enlargement of the coronal third of the root canal space is considered important to support root canal length measurement, debris removal, and canal obturation. However, extensive use of rotary instruments during preparation of the canal space by cutting dentin to straight lines at curvatures weakens the root structure (42). In the infected root canals especially, a balance between the need to remove infected dentin and maintaining sufficient root thickness to withstand the forces of mastication should therefore be sought. Special attention to securing sufficient remaining dentin should be given to the teeth and roots most susceptible to fracture, i.e., the maxillary and mandibular premolars (38, 39) and the mesial roots of the mandibular molars (43).

Lateral condensation of gutta-percha is considered one of the main etiologic factors of VRF (7). However, with the use of mathematical models, Gimlin et al. (44) have shown that the pressure on the tip of the root is much smaller when using lateral condensation compared with vertical condensation. Studies using the Instron machine have shown that a pressure of 15–16 kg is actually needed to cause a root fracture, which contrasts the with clinical situations, in which 3 kg is usually sufficient to attain space for additional gutta-percha cones (45). Regardless of force, root deformations have been shown in numerous teeth when pressure was applied in laboratory tests (46).

VRFs can also be caused by restorative procedures carried out after root canal therapy, such as overpreparation of the canal for a dowel, selection of an improper dowel and traumatic seating of intra-canal restorations. Today, it is recommended to use either prefabricated, parallel-sided posts with round edges and passive insertion, or the fiber-reinforced resin-based composite posts that have the same modulous of elasticity as dentin (47, 48, 49).

Clinical management

Destruction of the supporting tissues, opposite to the fracture as a result of the constant release of irritants including bacterial elements to the area, precludes any treatment other than extraction (6). A few case reports have been published on attempts to save fractured roots from extraction (50). The use of CO_2 and Nd–YAG laser to fuse fractured roots was tested in an *in vitro* study, but proved ineffective (51). Recently, bonding of the extracted fragments with adhesive resin cement was reported as being successful after intentional replantation of three vertically fractured maxillary premolars with follow-ups between 18 months and 3 years (52, 53). In posterior teeth with multiple roots, hemisection or root amputation of the fractured root may be the treatment of choice, followed by a new restoration of the tooth.

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