

## REVIEW ARTICLE

### Vertical Root Fracture: An Endodontic Enigma

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#### ABSTRACT:

Vertical root fractures associated with endodontically treated teeth is one of the most difficult condition to diagnose and equally difficult to treat. The condition further complicates if any use of dowel is indicated. Prognosis is often hopeless and differential diagnosis from other pathosis may be difficult. Traditionally, this condition was managed by extraction of offending tooth but with advent of adhesive dentistry, there is a paradigm shift towards preservation of these teeth. This article focuses on the etiopathogenesis, diagnosis and management of vertical root fracture.

**Key words:** Vertical root fracture, root fracture, endodontically treated tooth, cracked tooth

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#### INTRODUCTION

Vertical root fractures (VRF) are root originated fracture of endodontically treated tooth (ETT) that accounts for third most common cause of extraction of tooth after dental caries and periodontal disease.<sup>1,2</sup> VRF are initiated due to stress i.e. developed during the endodontic procedure or due to masticatory load. Depending on the stress, VRF might originate at the apical third of the root and propagate coronally or at the cervical portion of the root and propagate apically.<sup>3,4</sup> In horizontal cross-section, VRF is seen to expand from canal wall outwardly towards the surface.

VRF often presents as a diagnostic problem that challenges the expertise of even skilled and most experienced clinicians. This is due to the fact that clinically and radiographically, VRF mimics signs and symptoms of failed endodontic treatment or periodontal disease.<sup>5-8</sup> Thus, it is the most frustrating complication of the endodontic treatment as it is diagnosed years after the completion of the endodontic and prosthetic procedures.<sup>9</sup>



Fig. 1. VRF originating from apical third and propagating coronally.

#### DEFINITION<sup>3</sup>

According to the American Association of Endodontics (AAE), VRF is defined as “a longitudinally oriented fracture of the roots that originates from the apex and propagates to the coronal portion.”

## CLASSIFICATION OF VERTICAL ROOT FRACTURES

VRF are classified into three types.

A) Based on the position of the fracture related to the alveolar crest.<sup>10</sup>

CLASS 1: Incomplete supraosseous fracture as one terminating coronal to alveolar crest not initiating a periodontal defect.

CLASS 2: Incomplete supraosseous fracture as one terminating at or slightly apical to the alveolar crest creating a shallow osseous defect.

CLASS 3: Complete or incomplete intraosseous fracture resulting in loss of periodontal attachment

B) Based on separation of fragments. (LEUBKE'S CLASSIFICATION)<sup>10</sup>

1. COMPLETE FRACTURE: Total separation is visible or the fragments can be moved independently

2. INCOMPLETE FRACTURE: Absence of visible separation.

VRF are dynamic in nature and an incomplete fracture may propagate into a complete fracture after it is exposed to mastication for a longer time.

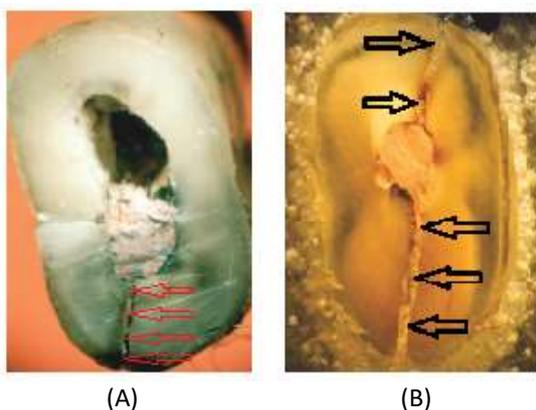


Fig. 2. Vertical root fracture by Raymond L. Leubke. (A) Incomplete vertical root fracture, (B) Complete vertical root fracture.

C) Based on presence or absence of infection.<sup>1</sup>

**HISTOLOGICAL VRF:** VRF without infection. It is not evident till the space between the fragment is infected.

**CLINICAL VRF:** VRF with infection

## ETIOLOGY OF VERTICAL ROOT FRACTURE

The etiology of vertical root fracture in an endodontically treated tooth is complex and multifactorial. Although the fractures that originates in roots, occurs mostly in the endodontically treated teeth but in rare occasion they can occur in Non-endodontically treated molars. The combination of a variety of predisposing and contributing factors for these fractures makes their prevention quite difficult.

## PREDISPOSING ETIOLOGICAL FACTORS

Although the predisposing factors for VRF are beyond the control of the clinicians, they should be considered carefully as a part of endodontic and restorative planning. The most important predisposing factor is the *reduction in rigidity due to healthy tooth substance loss*. This is due to caries and trauma, which increases the risk for cracks in the body of dentin that can later propagate to fracture.

The *anatomy of roots of the tooth* plays an important role. The shape of the roots of the teeth i.e. the narrow mesio-distal dimension compared to bucco-lingual, makes these roots and tooth susceptible to fracture especially at later stage when additional tooth structure is removed during root canal and dowel preparation. These includes the maxillary and mandibular premolars, mesial roots of mandibular molars, mandibular incisors and the mesio-buccal roots of maxillary molar. In contrast to this, round, oval or bulky roots are resistant to fracture (Example maxillary central incisors, palatal roots of maxillary molars and maxillary canines).<sup>11</sup>

In addition to the shape of the roots of teeth, presence of root depression in the proximal surface of the tooth in case of posterior as well as mandibular anterior teeth can predispose the likelihood for fractures and root perforations when excessive removal of dentin occurs. Thus, these areas are considered as "Danger Zones" as they pose an increased risk of strip perforation during biomechanical preparation.<sup>12</sup>

Other recognized predisposing factors are *moisture loss in pulpless teeth*<sup>13</sup>, *previous cracks in dentin*<sup>14</sup> and *loss of alveolar bone support*<sup>15</sup>.

## CONTRIBUTING ETIOLOGICAL FACTORS

*Root canal treatment procedures* and *the use of intraradicular dowels* are two main contributing etiological factors (iatrogenic factors) associated with vertical root fracture.

Root canal procedures induce micro-cracks in the dentin which later propagates to produce vertical root fractures. The *use of rotary nickel titanium instruments* to prepare the canal space by cutting dentin reduces the tooth substance, hence, weakening the root structure.<sup>16</sup> This flaw of nickel titanium instrument is gaining more focus leading to development of endodontic rotary files system such as Self Adjusting File (ReDent-Nova, Israel) which induces no micro-cracks during canal preparation.<sup>17</sup> The *wedging forces induced during vertical and lateral condensation of gutta percha* causes vertical root fracture.<sup>7,18</sup> *Root end preparation with ultrasonic retro-tip* causes dentinal cracks which can be an etiological factor. *Erosion of dentinal walls with irrigation fluids* reduces the strength of the dentin and predisposes them to development of micro-cracks.<sup>19</sup>



Fig.3. VRF associated with endodontically treated tooth restored using post and core.

VRF can also be caused by restorative procedures carried out after root canal therapy, such as *over-preparation of the canal for the dowel, selection of improper dowel and traumatic seating of intracanal restoration*. Factors such as post length, post diameter, post design, material and fittings, the core material, the ferrule effect, the luting cement, coronal coverage, remaining coronal structure, loading conditions and alveolar bone support all play a major role in affecting the fracture resistance of post-restored teeth. Based on the studies of various types and techniques of post and core, it is recommended to use either *prefabricated, parallel-sided posts with round edges with passive insertion* or *fibre-reinforced resin based composite posts*, that have same modulus of elasticity as dentin.<sup>19</sup>

### **PATHOGENESIS OF VERTICAL ROOT FRACTURE**

VRF can be complete or partial, but it extends from the pulp canal to the periodontal ligament. Soft tissue grows into this fracture space and further increases the separation between the fractured root segments. This space between the fractured segments is contaminated with food, debris and bacteria when the fracture extends causing the communication with oral environment via the gingival sulcus. This induces an inflammatory process in the adjacent periodontal space resulting in loss of periodontal ligament and alveolar bone as well as formation of granulation tissue.<sup>20,21</sup> This defect propagates apically and interproximally in a very rapid manner especially if the buccal plate is thin.<sup>5,22</sup> In case, VRF is limited to the apical third without any communication with the oral environment, the inflammatory process depends upon the release of existing irritants in root canal such as bacteria and root canal sealers.<sup>20</sup>

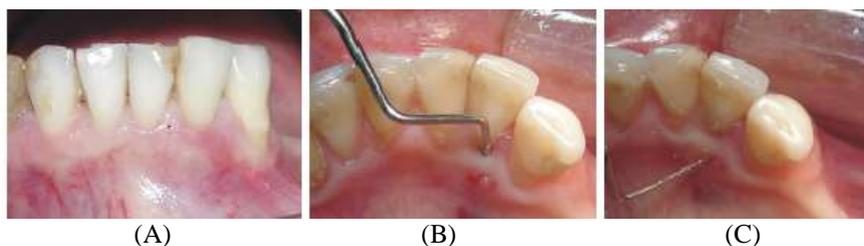


Fig. 5. Clinical features of Vertical root fracture. (A) Mandibular left lateral incisors in supra-occlusion. (B) Periodontal pocket probing. (C) Horizontal sinus probing.

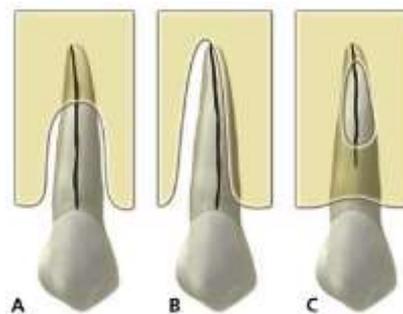


Fig.4. Pattern of bone loss. (A) and (B) shows dehiscence of the alveolar bone whereas, (C) shows fenestration of the alveolar bone.

Lustig et al described “dehiscence” as the typical pattern of bone loss in VRF and especially in the buccal plate in 90% of cases. The bone cleft follows apico-coronal direction i.e. it propagates with the fracture to form an oval or oblong type of bones resorption. This defect becomes wider with time as the it grows. This is visible after flap reflection and removal of granulation tissue.<sup>23</sup> A “fenestration” type of bone defect may occur if the fracture exists somewhere along the root without involving the coronal or apical part.<sup>3</sup>

### **DIAGNOSIS OF VERTICAL ROOT FRACTURE**

A diagnostic process is based on the combination of patients subjective complaints and clinicians objective clinical and radiographic evaluation. Most means of examination at the clinicians disposal must be employed when trying to achieve an accurate and timely diagnosis of VRF. This may include the following steps i.e.

- 1) Subjective Evaluation
- 2) Objective Tests
- 3) Radiographic findings
- 4) History of the tooth and
- 5) Flap reflection, if indicated.

### **SUBJECTIVE EVALUATION<sup>11</sup>**

Subjective evaluation tends to be minimal in VRF as they are seldom painful and it is often asymptomatic or shows mild, insignificant signs & symptoms. Often some mobility is detectable, but many teeth are quite stable. Periapical symptoms such pain on pressure or mastication are common but mild. Many of VRF resemble periodontal lesions, a periodontal-type abscess. Patient may also report a “gum boil” i.e. draining sinus tract.

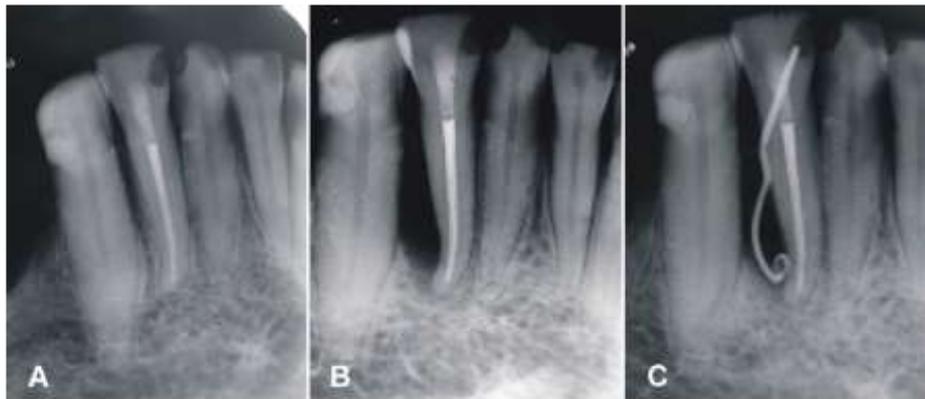


Fig. 6. Radiographical features of Vertical root fracture. (A) Quality of root canal filling immediately after endodontic therapy. (B) Distal radiolucent image of tooth. (C) Mapping of sinus.

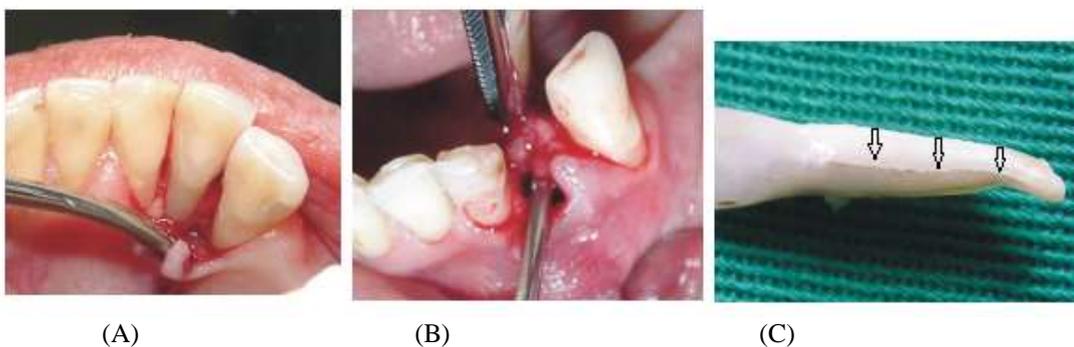


Fig. 7. Exploratory surgery of vertical root fracture. (A) Surgical access. (B) Extraction of left lateral incisors and socket curettage. (C) Extraction of tooth and visualization of VRF.

### OBJECTIVE TESTS<sup>11,22</sup>

Different clinical diagnostic tests are used for diagnosis of vertical root fractures. *Bite test* is done by asking the patient to bite on rubber wheel, moist cotton rolls, tip applicator and commercial biting applicator. Pain on biting indicates a fractured tooth. *Periodontal probing* of the offending tooth will demonstrate presence of a periodontal pocket in association with the fracture. *Staining with disclosing dyes* such as methylene blue to visualize the suspected crack. *Direct visualization of the fracture* by removal of all restoration under good illumination via fiber optics and magnification.

### CLINICAL PRESENTATION

Vertical root fracture represents 2-5% of tooth crown fracture with highest incidences in Endodontically treated teeth and in patients older than 40 years of age. Maxillary and mandibular premolars (52%), mesial roots of the mandibular molars (24%), maxillary & mandibular incisors (14%) and mesio-buccal & palatal root of maxillary molars (10%) are most susceptible to fracture.<sup>5</sup>

VRFs shows various signs and symptoms which are as follows.<sup>11,22</sup>

1. Swelling of soft tissue and tenderness over the root.
2. Sinus tract closed to attached gingiva (not apical region).
3. Development of deep narrow pocket.

4. Repeated dislodgement of crown or dowel.
5. Sharp cracking sound at the time of condensation of gutta percha or cementation of the dowel/crown.
6. Bleeding at time of obturation and/or loss of apical tugback.

### RADIOGRAPHICAL PICTURE<sup>6,24</sup>

Diagnostic radiograph is an essential tool in daily dental practices, is of limited significance in diagnosis of VRF. This is still incapable of demonstrating incipient fractures. Radiographic features may vary from case to case i.e.

- A. Separation of root fragments.
- B. Radiolucent fracture line across root and root fillings.
- C. Space beside a root canal filling or a post.
- D. Double images due to overlapping of the fragment.
- E. Radiopaque signs due to filling of fracture space with sealer or medicament.
- F. Widening of the PDL space around the full expanse of root.
- G. J shaped focal bone loss.
- H. Dislodgement of retrograde root canal filling.
- I. Endodontic failure in form of persistent radiolucency after healing has occurred without symptom.

Cone beam computer tomography (CBCT) scan is clinically effective and possess superior efficacy over conventional intraoral periapical radiograph (IOPAR).

But presence of intracanal radiopaque materials adversely effects the diagnostic efficacy of CBCT. Thus, CBCT is not beneficial for the diagnosis of VRF when metal Dowels are present.<sup>25</sup>

### FLAP REFLECTION<sup>11</sup>

Signs, symptoms and radiographs all give variable findings but having a sinus tract and a narrow, isolated periodontal probing defect in association with a tooth with a history of root canal treatment, with or without a post placement is considered to be *pathognomonic indicator* for the presence of vertical root fracture. Flap Reflection is the only reliable diagnostic approach as it enable direct visualization of the fracture by surgical reflection of both soft and hard tissue

Vertical root fracture has a consistent pattern i.e. it usually presents as punched-out bony defect that tends to be oblong and overlies the root surface. This defect may take form of a dehiscence or fenestration at various root levels. This defect is filled with granulomatous tissue which should be removed for visualization of fracture under naked eye and sometimes microscope. Transillumination or staining with dyes may also be helpful.<sup>11</sup>

### MANAGEMENT OF VERTICAL ROOT FRACTURE

Modern endodontic modalities offer a wide variety of treatment alternatives that enables the preservation of severely compromised teeth. Vertical root fracture is still considered as a common cause of tooth loss. When a VRF is diagnosed, the case selection process requires a combination of endodontic as well as prosthetic, periodontal and esthetic considerations. The tooth type, presence of a predisposing periodontal disease, the type of coronal restoration, the alternatives in case of treatment failure, post-treatment quality of life and patient values should all be considered in decision making.

Early diagnosis of VRF is an important factor. VRF usually is diagnosed after the entire endodontic and prosthetic therapy has been finished due to lack of specific signs and symptoms. Thus, the timing of diagnosis of VRF becomes a crucial factor in deciding whether to preserve the vertically fractured tooth or not.<sup>9</sup> In addition to this, many prosthetic and periodontal parameters affect the long term prognosis of the endodontically treated teeth such as amount of remaining tooth substance, tooth mobility, ferrule effect, crown-root ratio and an appropriate post-endodontic restoration.<sup>11</sup>

For multi-rooted tooth having a diagnosis of VRF in one of the roots, there are alternatives for the preservation of tooth such as root amputation of the affected root. But, for a single rooted tooth with VRF, the survival of the entire tooth relies on the ability to maintain the fractured root. The periodontal status of the affected tooth and presence of predisposing periodontal diseases are important for the ability to successfully treat and preserve the tooth.<sup>6</sup>

***Replantation of root filled teeth with vertical root fracture reconstructed with resin based materials has emerged as a new promising method in recent years.***<sup>26</sup> In 2004, Hayashi et al conducted a study of 26 vertically fractured roots using replantation and reconstruction with dentin bonding resin. He found that 18 cases were functional and retained with 6 being fully successful after 4-76 months. It was also observed that teeth with longitudinal fracture extending from crown to 2/3<sup>rd</sup> of the root and of posterior teeth showed significantly less success.<sup>27</sup> In 2014, Hadrossek and Dammaschke conducted repair with Biodentine instead of dentin bonding resin in VRF in maxillary central incisors of a 78 year old patient. A 24 month clinical and radiological follow up showed asymptomatic tooth with reduction of periodontal depths from 7mm to 3mm and gingival reattachment in the area of fracture with no ankylosis. This established the treatment of VRF with biodentine as a possible and promising treatment.<sup>28</sup>



Fig. 8. Replantation of root filled teeth with vertical root fracture reconstructed with biodentine (A) and (B). (C) shows the re-implanted tooth with titanium trauma splint.<sup>28</sup>

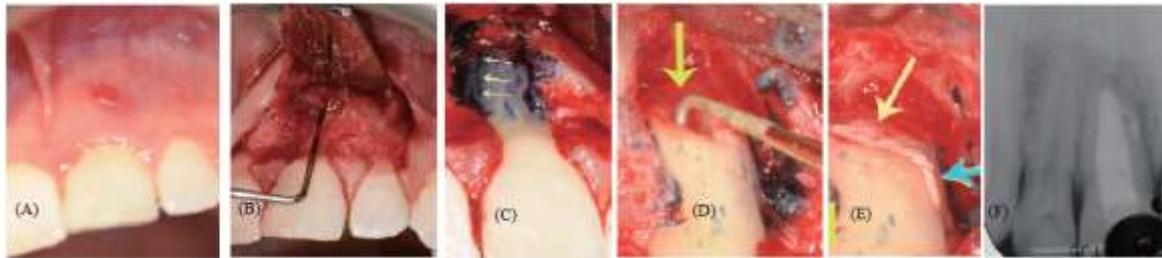


Fig. 9. Surgical flap elevation and reconstruction by resin bonding is another treatment modality if its not possible to extract the tooth with vertical root fracture. (A) shows clinical presentation of VRF with sinus track close to attached gingiva. (B) surgical exposure of the lesion. (C) Exposure of VRF with help of dye. (D) Surgical resection followed by root end preparation and preparation of the VRF fracture line with Ultrasonics. (E) demonstrates repair done with MTA. (F) 24 month post treatment radiograph.<sup>32</sup>

The prognosis of the replantation therapy depends upon various factors such as Atraumatic extraction of the fragments; Extra-oral time < 15minutes; Disinfection using short term calcium hydroxide dressing and systemic tetracycline administration (for reduction of collagenase action and motility of osteoclast in addition to disinfection).<sup>6</sup>

Limitation of this modality are the cases in which the teeth cannot be extracted and repositioned due to complicated root anatomy, teeth with severe periodontitis, teeth without adjacent teeth, a non-compliant patient and patients with critical general medical condition.<sup>28</sup>

**Surgical flap elevation and reconstruction by resin bonding is another treatment modality if it's not possible to extract the tooth with vertical root fracture.** In 1996, Selden described the treatment of teeth with incomplete VRF using silver-glass ionomer cement and a bone graft. However, eventually, all six cases failed.<sup>29</sup> Modern endodontic materials such as mineral trioxide aggregate (MTA) were proposed as sealing materials to repair VRFs.<sup>29</sup> In 2012, Floratos and Kratchman presented the surgical approach to treatment of vertical root fracture. They treated mandibular and maxillary molars with incomplete fracture by flap elevation to expose the fracture line. The fracture line was eliminated by resecting the root inn bevelled manner and the defect was restored with MTA. The osteotomy was covered with absorbable collagen membrane. The cases demonstrated clinical success after 8-24 months.<sup>31</sup> Taschieri et al conducted the same procedure for anterior teeth. At 24 months follow up, all cases were successful. The flap procedure has better prognostic value but also has several disadvantages such as formation of a scar in aesthetic area of the gingiva, an additional osteotomy may be needed which generates extra loss of healthy bone structure and a gingival recession may be seen.<sup>32</sup> Careful case selection and informed consent are essential prior to commencing treatment of VRFs. Patients should be made aware of the risks and complications. Root resorption might be expected to occur if replanted teeth are held in dry conditions during reconstruction and if the extraoral time is excessive. Another important complication is Replacement resorption/ankylosis. Patients should

also be advised of the guarded long-term prognosis of teeth with a VRF and be provided with alternative treatment options should extraction eventuate.<sup>33</sup>

## CONCLUSION

Vertical root fractures are mostly associated with endodontic treated teeth and the chances are increased many fold if the final restoration includes placement of a post in the root canals. The condition is difficult to diagnose and equally difficult to treat. Traditionally the condition was treated with extraction of single rooted teeth. But with the introduction of adhesive dentistry, there is a paradigm shift towards preservation of these teeth.

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