



Research Article

DOI: 10.31021/JDDM20236177

Diagnosis and restorative options for the management of longitudinal tooth fractures

Al Telmesani A

Assistant Consultant (Endodontist), Dentistry department, King Fahad Specialist Hospital, Dammam, Saudi Arabia

Abstract

The aim of this review is to discuss the longitudinal tooth fractures in terms of definition and classification, aetiologies, incidence, diagnosis and management as well as to assess literatures including critical appraisal. Electronic library search was undertaken between January 2017 to March 2017 through different well known journals such as International Endodontic Journal (IEJ), Journal of Endodontics (JOE), Journal of Endodontics, Oral Surgery Oral Medicine Oral Pathology Oral Radiology Endodontology (OOOOE) and Australian Dental Journal (ADJ).

Longitudinal tooth fracture is defined as a fracture that occurs over time with a vertical direction. Mainly, cracks and fractures can be divided into either incomplete and/or complete. In 2008, a classification of longitudinal tooth fracture was established to be from the least severe to the most. Longitudinal tooth fracture categorized into (a) craze line; (b) fractured cusp; (c) cracked tooth; (d) split tooth; and (e) vertical root fracture. The incidence of longitudinal tooth fracture is increasing due to many factors including that diagnosis of longitudinal tooth fracture is improved; therefore, it is not difficult to be identified and reported. Moreover, doing restorative procedures on teeth with no enough dentin support and placing restorations that eventually create wedging/displacing forces and cause longitudinal tooth fracture.

Longitudinal tooth fractures are findings; they are not considered to be pulpal or periapical diagnosis. Clinical signs and symptoms, results of objective tests such as a selective biting test aid detection of longitudinal tooth fracture. In addition, radiographic findings assist also to diagnose some types of longitudinal tooth fracture. There were numerous studies that used different imaging modalities and compared them to each other in order to evaluate their diagnostic accuracy. In fact, three-dimensional imaging modalities produce an image with high accuracy than the two-dimensional ones. However, some recent studies that have some limitations concluded that there was no statistical difference between the sensitivity or specificity of both 2D and 3D imaging modalities to detect vertical root fractures certainly.

Management of longitudinal tooth fracture is complex and challenging in some cases; however, some cases are severely fractured and the tooth is considered to be non-restorable; therefore, tooth or root extraction is the required treatment approach. Management of longitudinal tooth fracture varies based on the fracture extent as well as on tooth vitality and the associated symptoms. An essential initial step to be followed which is the removal of any existent restoration in order to assess tooth restorability and check for cracks and fractures. For instance, if the affected tooth is non-vital, severely symptomatic or a fracture is extended to the pulp, a root canal treatment is required. In addition, an orthodontic band to be placed in order to hold the segments together and to prevent the increase of the existing fracture during the root canal procedure. On the contrast, if the tooth is vital and asymptomatic. A bonded composite resin restoration to be placed in the assessment cavity and a cusp coverage restoration such as an onlay or a crown to be on the top eventually. Regarding vertical root fracture (VRF), the predictable treatment approach is either to extract the tooth or to remove the fractured root by either hemisection or root amputation in multirooted teeth. Prevention of the different types of longitudinal tooth fracture can be achieved by following some preventive measures that can increase the fracture resistance ultimately.

Received Date: 03 May 2023, **Accepted Date:** 14 May 2023, **Published Date:** 17 May 2023

***Corresponding author:** Dr. Abdullah Al Telmesani, BDS, MCD, Assistant Consultant (Endodontist), Dentistry department, King Fahad Specialist Hospital, Dammam, Saudi Arabia, Phone: +966138043333, EXT: 1245, Email: Abdullah.Telmesani@kfsh.med.sa

Citation: Al Telmesani A. Diagnosis and restorative options for the management of longitudinal tooth fractures. J Dents Dent Med. 2023 May;6(1):177

Copyright: © 2023 Al Telmesani A. This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Keywords:

Longitudinal tooth fractures; Vertical Root Fracture; Split tooth; Cracked tooth; Fractured cusp; Craze lines

Introduction

In 1996, a longitudinal tooth fracture term was firstly introduced by Rivera. The reason behind using the term longitudinal fractures is that they represent vertical extensions of cracks or fractures over distance and time (1). Therefore, the definition of a longitudinal tooth fracture is a combination of two meanings or components. The first implies distance (length), particularly in the vertical (occlusal-cervical) plane. The second indicates that these fractures occur over a period of time (2).

According to the American Association of Endodontists (AAE) in 2008, a longitudinal tooth fracture is classified into five classifications from the least severe to the most: (a) craze line; (b) fractured cusp; (c) cracked tooth; (d) split tooth; and (e) vertical root fracture (3). There are many terms that have been used for tooth fractures and this show the confusion about this complex condition (4). Therefore, in order to lower this confusion throughout researchers and clinicians, these five classifications aid to provide global definitions (5). The term crack differs from the term fracture. Crack means an incomplete break in a substance, while fracture is a complete or incomplete break in a substance (1).

There are many reasons behind the increase in the incidence of longitudinal tooth fractures. First of all, patients when they age, treatment modalities for their teeth that include restorative procedures (e.g. loss of marginal ridges) are their first treatment of choice rather than teeth extraction. A fracture happens once a force exceeds the dentine or enamel elastic limit (6, 7). Secondly, due to the improvement in diagnosing longitudinal tooth fractures, they can be more identified and their incidence is increased (1).

Generally, longitudinal tooth fractures occur as a result of occlusal displacing forces and/or dental procedures. These forces exceed the dentin strength (weaken dentin) and eventually lead to a longitudinal tooth fracture. These types of fractures are more common in posterior teeth although they can occur in all teeth (8). Bader et al identified the incidence rate for complete tooth fracture and that was based on 143 complete fractures identified during 14 days from a candidate population of 74,503 adults. Complete fracture rates of 5.0 and 4.4 per 100 adults per year for all teeth and for posterior teeth, respectively (9). In a recent study, it was found that 175 teeth out of 1977 teeth were diagnosed over a five-year period as cracked teeth (8.9%) (10). Vertical Root Fracture (VRF) is another common type of fracture. According to many studies that were conducted on certain participants who had extraction of root canal treated teeth because of VRF, the prevalence of VRF was reported and found to be as the main reason of teeth extraction.

Longitudinal tooth fractures are considered findings; they are not pulpal or periapical diagnosis. The diagnosis of these fractures is developed and there are many clinical tests that help in identifying these fractures such as trans-illumination, biting devices, staining and magnification improve the longitudinal tooth fracture diagnosis in addition to radiographic findings (1).

Treatment options for these fractures vary according to the fracture type. For instance, no treatment is needed for craze lines but other fractures require a treatment. Moreover, the prognosis of the fracture also depends on the fracture type and extent that ranges from hopeless to very good prognosis (1). For instance, teeth with extensive fracture have a poor prognosis and extraction is the possible treatment option (11).

Classification of Longitudinal Tooth Fractures

Craze lines

Craze lines are a longitudinal defect in anterior teeth and also

a defect that extends over marginal ridges in posterior teeth. These craze lines occur naturally and confined to enamel structure. When they occur on marginal ridges of posterior teeth, they can be confused with cracked teeth (12).

Fractured cusp

Fractured cusp is defined as either complete or incomplete fracture that starts from the crown and extends subgingival with both mesio-distal and facio-lingual direction. On molar teeth, both buccal and lingual cusps may be involved (**Figure 1**) (13). Fortunately, fractured cusp is considered as the least devastating fracture type as well as the easiest to diagnose and manage (1).

Incidence: Fractured cusp is more common than the other types of longitudinal tooth fracture. Teeth without cusp protection with extensive caries or large restorations are the more common teeth to have this type of fracture (14).

Mandibular cusps fracture is more common than maxillary cusps fracture, also nonfunctional cusps fracture is more often to occur than the functional cusps fracture. In 1985, hundred and eighteen cusp fractures were observed in an *in vivo* study (clinical survey). Mandibular molars presented 59 cusp fractures, eleven (19%) occurred on the functional buccal cusps, while 48 (81%) were on the nonfunctional lingual cusps. On the other hand, Maxillary molars presented 32 cusp fractures, 14 (44%) were on the functional lingual cusps while eighteen (56%) occurred on the nonfunctional buccal cusps (15).

Etiology: Longitudinal tooth fractures occur by occlusal wedging forces and/or dental procedures. In fractured cusp, there is usually a history of extensive deep interproximal caries or a subsequent large **Class II** restoration (1). Extensive caries or large restorations cause inadequate dentine support of the cusp (16); hence, a cusp fracture occurs.

Cracked tooth

Cracked tooth is an incomplete fracture started from the crown with subgingival extension, usually directed mesio-distally.

Incidence: Kang et al analyzed the distribution and characteristic features of cracked teeth and evaluated the outcome of root canal treatments (RCTs) for cracked teeth; the incidence of cracked teeth was stated. Out of 1977 teeth were examined over a five-year period, 175 teeth were diagnosed as cracked teeth (8.9%). According to AAE classification, of 175 cracked teeth, 25 were fractured cusps (14.3%), 111 were cracked teeth (63.4%), 21 were diagnosed with VRF (12.0%), and 18 were diagnosed with split tooth (10.3%). Cracks were more prevalent among men (61.1%) than women. The lower second molar was most frequently cracked (25.1%).

The majority of patients with cracked teeth were in the age ranges of 50–59 years (32.0%) and > 60 years (32.6%) (10). This study has some limitations. Although the title of this study is “Cracked teeth”, the results included all types of tooth fractures. In addition, this study

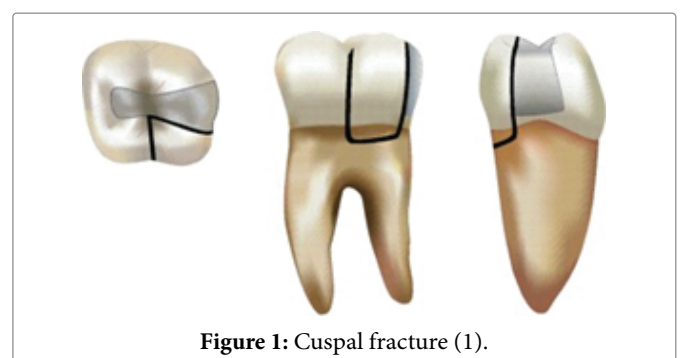


Figure 1: Cuspal fracture (1).

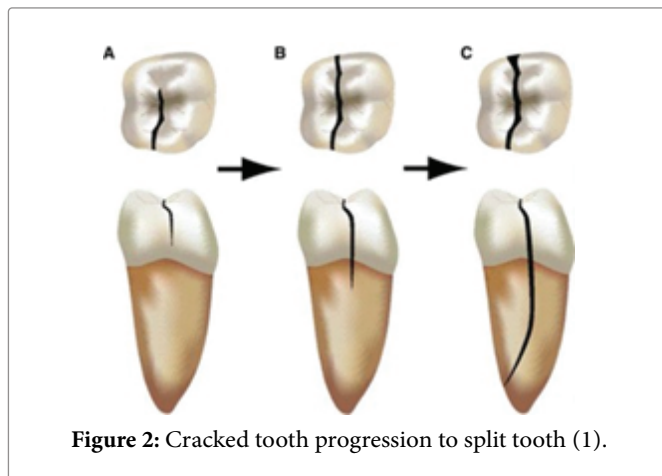


Figure 2: Cracked tooth progression to split tooth (1).

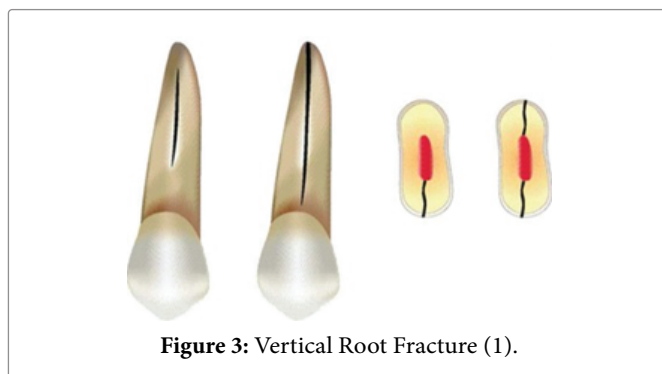


Figure 3: Vertical Root Fracture (1).

was conducted on a specific population, those patients who visited the Department of Conservative Dentistry at Ewha Womans University Dental Hospital, Seoul, Korea. Therefore, the results of this study do not reflect the prevalence of cracked tooth on the whole population.

Etiology: Cracked teeth depend on both time and patient habits such as patients who chew hard on hard substances. Therefore, these forces exceed dentin strength and cracked teeth may occur. According to inconclusive evidence, another suggested cause is that differences in expansion and contraction of restorations versus tooth structure may weaken and crack dentin (17).

Split tooth

The end-result of a long-term progression of a cracked tooth is a split tooth (18) (Figure 2). The term split tooth means a complete fracture initiated from the crown with subgingival extension, usually directed mesio-distally. Both marginal ridges and proximal surfaces are involved (1).

Incidence: The incidence of split tooth is increasing as the incidence of cracked tooth (19).

Etiology: Both cracked and split teeth have the same causes. Split tooth may be more common in root canal treated teeth and this is because caries, restorations, or overextended access preparations compromise the strength of these teeth. In summary, the causes of split tooth include wedging forces on existing restorations and new traumatic forces that exceed the elastic limits of the remaining intact dentin.

Vertical Root Fracture (VRF)

Vertical Root Fracture (VRF) is either complete or incomplete fracture initiated on the root at any level with facio-lingual direction usually. This fracture may include one or both proximal surface (facial or/and lingual) (Figure 3) (20).

Incidence: Vertical Root Fracture (VRF) is a common fracture

type to occur (21). Vire *et al.* evaluated extracted teeth which had been endodontically treated over a 1-year period. The reason for extraction was VRF in 4.3 % of the 116 extracted teeth (22). Fuss *et al.* researched a total of 564 permanent teeth which were extracted over 6 months. VRF was 10.9 % among 147 endodontically treated teeth (23). Moreover, Yoshino *et al.* investigated the prevalence, by gender, of vertical root fracture (VRF) as the main reason for the extraction of permanent teeth in dental clinics in Tokyo, Japan. The results of this study showed that 736 teeth were extracted from 626 patients during the 6-month period. A total of 233 teeth were extracted by VRF (31.7 %), and 93.6 % of these were endodontically treated teeth. In females, the percentage of extractions due to VRF (34.7 %) was higher than males (29.4 %) (24).

Etiology: Vertical Root Fracture (VRF) occurs due to wedging forces within the canal such as condensation (lateral and vertical) of the root canal filling (25) as well as post placement and cementation (26). Different condensation techniques for gutta-percha have revealed many fracture potentials (27, 28); however, larger canal preparations can cause higher stresses when these condensation forces are applied (28).

Diagnosis of Longitudinal Tooth Fractures

Subjective findings and objective tests as well as radiographic findings aid diagnosis of longitudinal tooth fractures. According to Abbott in 2004, it was concluded that the presence of marginal breakdown, caries, cracks and fractures which are the most common causes of pulp and periapical disease cannot be fully diagnosed without removing the existing restoration (29). Therefore, restoration removal is a must, so the crack is to be visible or disclosed by staining and/or transillumination (1).

According to a recent *ex-vivo* study in 2016, the ability of a quantitative light-induced fluorescence (QLF) technology was evaluated in the detection of enamel cracks. It was concluded that QLF is a non-destructive method and a useful tool for the diagnosis of enamel cracks (30). However, this is a laboratory based study on extracted teeth and there is no clinical report of using the QLF technology to detect tooth crack.

Craze lines

Craze lines occur naturally on enamel structure. Direct visualization and transillumination are both ways in identifying craze lines. Light transillumination gives more details as to how the light penetrates through the craze line. Actually, the light is not blocked or reflected when its transilluminated from the facial or lingual surface (Figure 4).

Fractured cusp

As a subjective finding of a tooth with fractured cusp, a sharp and brief pain upon the release (teeth separation) after biting or closure on an object. Henceforth, biting test is considered as the most indicative objective test for cuspal fracture. A Tooth Slooth is a specially designed instrument to be used for the biting test and placed on individual cusps (Figure 5). A cotton applicator or a rubber polishing wheel can also be used (1).

In terms of radiographic findings, a fractured cusp is not visible on radiograph usually. However, there may be a "ghost" appearance on the radiograph in case of a complete missing cusp.

Cracked tooth

Cracked tooth diagnosis is often challenging and this is due to the fact that the associated symptoms tend to be very variable (31). Signs and symptoms, test results and radiographic findings of cracked teeth vary upon the extent of the fracture. If the fracture is not close to the pulp, then there is no pulpal inflammation. However, if the



Figure 4: Transillumination provides further details as to how the light penetrates through the craze line (1).



Figure 5: The use of Tooth Slooth (13).

fracture in a close approximation to the pulp, pulpal inflammation should be expected. A range of symptoms may present with cracked teeth varying from slight to very severe spontaneous pain consistent with irreversible pulpitis, pulp necrosis, or apical periodontitis (32). Riccucci et al stated that cracked teeth are colonized by bacteria that are arranged in biofilms that may reach the pulp and periodontal ligament. This is the most significant problem related to cracked teeth (20). In summary, a severe pulp and/or periapical pathosis will likely be present once the fracture has extended to and exposed the pulp (1).

Objective tests include pulp and periapical tests have variable results. Pulp test results indicate that the pulp is vital (responsive) most of the time; however, the pulp may be necrotic (non-responsive) (33). In addition, direct visualization in combination with staining and light transillumination is usually effective to detect cracks (34) after the removal of tooth restoration (29). Moreover, when pain is reported on mastication specifically, a selective biting test on objects such as the Tooth Slooth is helpful (1).

Split tooth

Identification of split tooth is considered to be easy in general and the reason behind this is that there is a visual separation of the segments usually. Moreover, split tooth differs from cracked tooth that it doesn't have the variable signs and symptoms as well as variable tests results. Pain on mastication is commonly reported by the patient including the significant damage to the periodontium (35, 36). The findings of objective tests including pulpal and periapical tests are not helpful to diagnose split tooth in particular. Additionally, wedging technique is used to know whether segments are separable or not. Radiographic findings reveal the damage to the periodontium more likely. Radiographs show a horizontal loss of interproximal bone or interradicular bone with a U-shaped furcation lesion appearance (1).

Vertical Root Fracture

Vertical Root Fracture (VRF) has a variety of signs, symptoms,

and radiographic findings. However, a tooth that has had root canal treatment, with or without a post placement with a sinus tract and a narrow, isolated periodontal probing is considered to be an indicator for the presence of a vertical root fracture (21, 23). Actually, it is not easy to reach a definitive diagnosis on the basis of signs and symptoms alone because they are nonspecific to fractures and are very similar to endodontic or periodontal disease.

Commonly, there is a mild pain on pressure or mastication. A periodontal-like abscess occurs often and this because vertical root fractures look like periodontal lesions (37, 38). The best method to identify vertical root fractures is flap reflection by exposing both soft tissues and bone surgically (39).

Radiographic findings include marked bone resorptive patterns that extend from the root apex along the lateral root surface and described as a "J-shaped" or "Halo" pattern (40). Periapical radiography is not accurate for a definitive diagnosis of vertical root fractures as it was concluded by numerous studies. Therefore, using computed tomography (three-dimensional imaging technology) may be more helpful to detect vertical root fractures rather than using conventional radiography (two-dimensional imaging technique) (41, 42). Because of the advantages of cone-beam computed tomography (CBCT) imaging technology in comparison to the medical computed tomography (CT) including lower radiation doses as well as greater cost-effectiveness (43).

Several studies that were conducted to detect the accuracy of CBCT to diagnose vertical root fractures and to evaluate different radiographic modalities to be used to detect vertical root fractures. According to an *ex vivo* study in 2014, the aim was to compare the diagnostic accuracy of digital radiography (DR) and cone-beam computed tomography (CBCT) imaging in the detection of vertical root fracture (VRF). Both digital radiographs (CCD sensor) and small-volume CBCT scans (3D Accuitomo F170; J Morita, Kyoto, Japan) were taken for 21 teeth from 20 patients, then atraumatic extraction of these teeth was done in order to lower possible creation of intraoperative fracture. Furthermore, the teeth were visually inspected using a microscope to confirm the presence/absence of fracture. The width of the fracture was measured and the teeth were divided into two groups according to the fracture width (60-300 μ m and 300-770 μ m). Thirteen examiners (3 endodontists and 10 endodontic postgraduates) assessed the radiographs and CBCT scans. Results showed that there was no statistical difference between the sensitivity or specificity of either DR and CBCT imaging. Both imaging modalities have poor sensitivity and high specificity (44). This study has some limitations include a small sample size first of all. Secondly, a certain CBCT scan was used and compared with the digital radiography. Moreover, radiographs were assessed by a high number of postgraduate students in comparison to the more experienced clinicians (3 endodontists).

Another study that was published in 2015 with the purpose to compare the diagnostic accuracy of cone-beam computed tomography (CBCT) for the detection of artificially induced Vertical Root Fractures (VRF) of different widths both *ex vivo* and *in vivo*. The sample was 45 extracted single rooted human teeth (non-endodontically treated) including maxillary canines, maxillary first premolars and mandibular incisors. The control group was 20 teeth without VRF and 25 teeth in the fractured group (test group). Five teeth were excluded from the fracture group because the created fracture did not reach the root canal wall (narrower than 50 μ m). Both *ex vivo* and *in vivo* CBCT (3D Accuitomo) scanning were performed. Five examiners evaluated and assessed the CBCT images for sensitivity, specificity and accuracy. Results indicated that the accuracy of CBCT to detect VRF of 50-300 μ m width *ex vivo* was significantly higher when compared to the *in vivo* (45). There are some drawbacks and limitations of this study such as the sample was small in size and only single rooted teeth were used. In addition, vertical root fractures were created by using a hammer

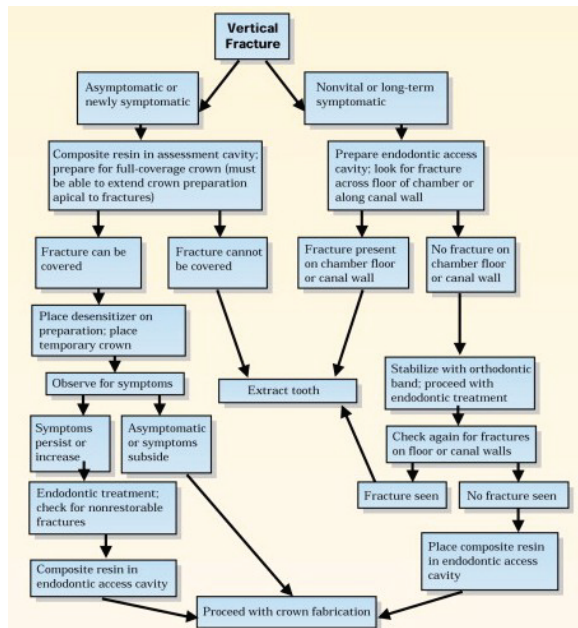


Figure 6: Management of incomplete vertical fractures (48).

with a gentle tapping. It was not stated the amount of force needed to induce the fracture and was that force controlled to be the same to all teeth or not? Moreover, the study results were only related to the incomplete vertical root fracture.

Recently, a retrospective cohort study that was published with the aim to examine different patient and treatment-related factors in association with the time of presentation of vertical root fractures (VRFs) in root canal treated teeth with crown restorations. The sample was 197 root filled teeth with crown restorations and without post. Clinical signs and symptoms were recorded and radiographs were taken. It was suspicious that those teeth have VRFs but after surgical flap elevation, a diagnosis of VRFs was confirmed. Results showed that within 5 years of the postoperative period, the most common observed clinical findings were pain on percussion (60%), pain on palpation (62%), presence of a deep narrow pocket (81%), and sinus tract/swelling (67%). Moreover, the most common radiographic feature is the “Halo” type radiolucency (48.7%). It was concluded that pain on palpation and percussion, deep narrow pocket, sinus tract, and “Halo”-type radiolucency are characteristic features of VRFs (46). The drawbacks and limitations of this study include that it's a retrospective study. Moreover, a small sample size was included in the study.

Management of Longitudinal Tooth Fractures

Management of longitudinal tooth fractures is challenging usually. It is easy to manage some cases, while others are considered to be destructive and require tooth or root extraction.

Fractured cusp

The management of fractured cusp includes either to retain the cusp or remove it based on its mobility. If the fractured cusp is mobile (complete cuspal fracture), removal of that cusp is indicated and the tooth is restored with an appropriate cusally reinforced restoration. On the contrary, if the fractured cusp is not mobile (Incomplete cuspal fracture), the cusp can be retained by placing a cusally reinforced restoration to hold the segments. Root canal treatment is only indicated if the pulp is exposed (1).

Cracked tooth

The course of treatment and prognosis are determined based

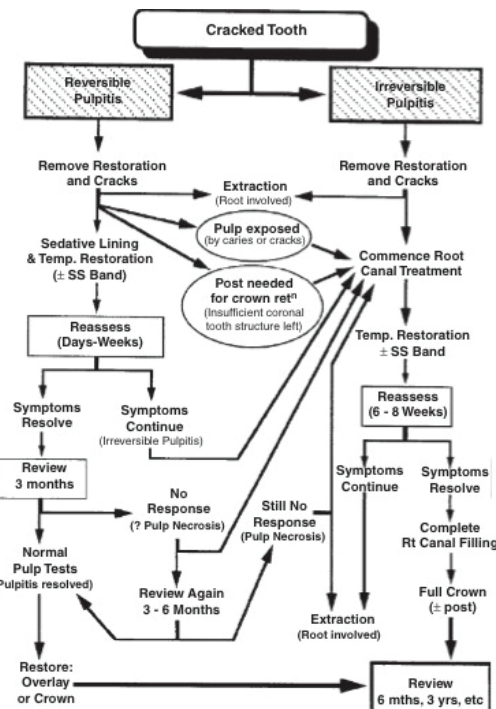


Figure 7: Protocol for managing teeth with cracks and pulpitis (49)

on vitality and symptoms. For instance, an immediate endodontic intervention is indicated in case of the tooth is non-vital or long-term symptomatic. During access cavity preparation, a careful examination for any fracture extending through the floor of the pulp chamber or any fracture along the canal wall with apical extension must be checked. The tooth is considered to be non-restorable in case of one of these fractures is present. Therefore, the tooth is for extraction (47).

However, if there is no fracture on the pulp chamber floor or the canal wall, the tooth is to be stabilized with an orthodontic band immediately in order to prevent the increase of the existing fracture while doing root canal treatment (31).

On the contrast, an immediate endodontic intervention is contraindicated if the tooth is vital and asymptomatic or newly symptomatic. The assessment cavity should be restored with a bonded composite resin restoration immediately as well as performing a crown preparation. The tooth is considered restorable if the crown margin can be placed apical to any fracture (**Figure 6**) (48).

According to a prospective study in 2009, the aims were to assess signs and symptoms caused by cracks in teeth and to assess a conservative management protocol. The sample was 100 teeth that were diagnosed with reversible pulpitis because of the cracks. After diagnosis confirmation, the conservative management approach was explained to the patients in details (**Figure 7**).

In this study, none of the teeth required extraction, 85 teeth did not require endodontic treatment and 15 teeth required endodontic treatment and this due to carious or mechanical pulp exposure and not because of irreversible pulpitis. In teeth that did not need endodontic intervention, a sedative lining (Ledermix cement) with a temporary restoration was placed after the removal of restorations, caries and cracks. A stainless steel band was used in combination with the temporary restoration when more retention is needed. A 3-month review was arranged in order to assess the healing process and the pulp status. Once the symptoms had resolved, those teeth were referred to be restored with an onlay or a crown restoration. The overall summary stated that 80% of the teeth did not require root canal treatment as shown in **Table 1**

Treatment outcome			Number of teeth
No endodontic treatment - pulpitis resolved			80
Uncertain pulp status - Patient did not return for further follow-up as scheduled			1
Endodontics required			19
1. At investigation appointment due to:		15	
• exposed by caries	4		
• crack into pulp chamber	2		
• post required	9		
2. At later times due to:		4	
• pulpitis continued with lemp.rest ⁿ	1		
• pulpitis after core	2		
• pulp necrosis at 3 months	1		
total			100

Table 1: Treatment outcome of 100 cracked teeth with reversible pulpitis (Abbott & Leow 2009)

The conclusion revealed that cracked teeth with reversible pulpitis can be treated conservatively without endodontic treatment (49).

Split tooth

The management of split tooth depends on the location and severity of the fracture. The tooth must be extracted if the fracture is deep apically and severe. However, if the fracture is not deep apically (middle to cervical third of the root), then the mobile small segment can be removed and the remaining of the tooth can be saved. Particularly, if the tooth had a previous root canal treatment and already restored (with no exposed root canal filling material), the appropriate treatment of choice is the removal of the fractured segment and no further treatment to be performed (the defect frequently granulates in, and reattachment occurs to the fractured dentin surface). Another approach to manage a split tooth is to remove the fractured segment first of all, then a root canal treatment to be performed (if not already treated), followed by an orthodontic extrusion or a crown lengthening procedure and finally a placement of an appropriate restoration. However, this approach is considered as a not practical approach because the fracture is too deep on the root surface usually (1).

Vertical Root Fracture

Treatment of teeth with vertical root fracture is not easy and depends on the tooth type and on the location, duration and extent of the fracture (50). The only predictable treatment is either tooth extraction or fractured root removal (Rivera & Walton 2015). In multirooted teeth, the removal of the fractured root can be done by either hemisection or root amputation is considered as a successful treatment option (51, 39).

Moreover, other treatment approaches that have been proposed to reduce the fracture or retain the root. For example, placement of calcium hydroxide, ligation of the fractured segments, or cementation of the fractured segments, trying to bind them by adhesive resins, epoxies, or glass ionomer (52, 53). In addition, an impractical treatment method is to extract the tooth, repair the fracture with a laser, cement or bonding agent, and then replant the tooth. Many of these suggested methods have not been shown to be effective long-term (1).

According to a case report that was published regarding the treatment and prognosis of a maxillary second molar exhibiting a complete vertical crown-root fracture. There was a wide separation of the buccal and palatal segments by as much as 2 mm, but they were not mobile. It was necessary to bring the segments into close apposition to restore the tooth. This was accomplished by application of orthodontic elastics to the tooth crown in combination with a wire splint. After approximately 1 month of continuous use of the orthodontic elastics,

the dislodged segments were suitably repositioned close to their original positions. The tooth was then root canal treated and restored with a cast complete crown. The restored tooth has been functioning well, with periodic periodontal maintenance for more than 3.5 years. Therefore, this indicating a promising prognosis (54). There are some limitations in regard to this case report. First of all, it is a case report and has a low quality of evidence.

Moreover, it's only reported a selected and single case (maxillary second molar). There was no definite outcome with a long-term follow-up.

Prevention of Longitudinal Tooth Fractures

In general, there are some preventive measures that can be applied to reduce the risk of longitudinal tooth fractures to occur. Fractured cusp can be prevented by minimizing the width and depth of cavity preparation to avoid removal of dentin support (55).

Moreover, avoid placing wedging restorations such as inlays especially when there is not enough dentin support. In case of undermined cusps, it should be reduced and covered by gold or amalgam onlay to provide a significant fracture resistance (56). Both cracked tooth and split tooth have the same preventive measures. In addition to the measures related to fractured cusp, patients need to eliminate the oral destructive habits. Teeth with large access preparations require an appropriate cusp protection such as using an onlay or a crown restoration (57).

Prevention of vertical root fracture is considered to be not difficult and this is because the causes of it are well known. Vertical root fracture can be prevented by avoiding the excessive removal of the intraradicular dentin and minimizing the internal wedging forces (1). For instance, selecting the appropriate treatment procedure that require a minimally invasive dentin preparation (58, 59). Regarding the root canal filling condensation, it should be carefully controlled. For example, the use of a more flexible and less tapered finger pluggers or spreaders rather than the use of stiff, conventional hand-type spreaders and this is because they are more safe (60, 61).

According to an *in vitro* study that was conducted to assess the influence of MetaSEAL and AH Plus on the resistance to vertical root fracture of root canal treated teeth when using either the matched-taper single-cone or lateral condensation technique. The sample was 90 extracted single-canal mandibular premolar teeth were sectioned and a standard root length of 13 mm were left. In addition, both buccolingual and mesiodistal diameters were measured. Teeth were randomly divided into 6 groups with 15 teeth in each group. No instrumentation or obturation was performed in the first group (control group). The roots in the remaining groups 2–6 were instrumented by using ProTaper rotary instruments including

irrigation with 2 mL of 5% NaOCl, 5 mL of 17% EDTA was applied for 3 minutes, followed by 5 mL of distilled water. No obturation was performed in group 2. The roots in group 3 and 4 were obturated with AH Plus used with the matched-taper single-cone and lateral condensation techniques, respectively; whereas, MetaSEAL was used instead of AH Plus sealer in group 5 and 6. Afterwards, the roots were subjected to a vertical loading force (1 mm/min). Results showed that there was significant difference between the group treated with AH Plus and the lateral condensation technique and the group treated with AH Plus and the matched-taper single-cone technique in terms of resistance values. It was concluded that the use of the matched-taper single-cone technique, MetaSEAL and AH Plus have the potential to reinforce endodontically treated teeth (60). This study has some limitations that include it is an *in vitro* study. A small sample size with selected single-canal mandibular premolar teeth were included in the study. Moreover, different types of root canal sealers with different properties were used.

A recent study that was published in 2016 to evaluate the resistance to vertical root fracture of root filled teeth using different root canal preparation concepts (apical stop and continuously tapering preparation, with different foraminal enlargement). The sample size was smaller than the previous study (90 single-rooted premolars) and a control group with no instrumentation or obturation was performed. Only AH Plus sealer was used with the Gutta-percha in the root filled teeth. It was concluded that different canal preparation techniques reduced resistance to fracture when compared with the control group; however, after root filling, there was a significant increase in resistance (63).

Conclusion

Diagnosis of longitudinal tooth fracture and its management varies in complexity based on the type of the fracture as well as the extent and location of each type. Some types are easy to diagnose; whereas, other types require several tests including clinical and radiographic findings in order to reach a definitive diagnosis. For instance, a split tooth is easy to be diagnosed and this is because the separated segments can be detected visually most of the time. Additionally, its management depends on the location of the fracture. If the fracture is not deep apically, then the tooth can be saved; however, tooth extraction is the required management approach if the fracture is located deep apically.

Diagnosis of a cracked tooth is challenging usually and this is due to the variety of the associated symptoms, tests result and radiographic findings. Furthermore, the management of a cracked tooth ranges from saving the tooth with the use of different restorative materials with or without endodontic intervention to tooth extraction. Similarly, vertical root fracture (VRF) has this variety and complexity in both diagnosis and management. Although there are some findings that indicate the presence of vertical root fracture such as sinus tract and a narrow, isolated periodontal probing, flap reflection by surgical exposure of both soft tissues and bone is considered as a reliable approach to identify vertical root fracture.

Interestingly, longitudinal tooth fracture can be prevented to occur by taking in consideration different preventive measures by both patient and clinician. The patient has to lower or even eliminate the destructive oral habits, while the clinician should not remove dentin support by being conservative in the cavity preparation; however, if the tooth is already with a large cavity or access preparation and there is not enough dentin support, an adequate cusp coverage restoration (onlay or crown) is required to be placed to provide the tooth a significant fracture resistance. In addition, the clinician needs to avoid excessive intraradicular dentin removal during root canal treatment to lower the risk of vertical root fracture hopefully.

References

- Rivera EM, Walton RE. Longitudinal tooth cracks and fractures: an update and review. *Endodontic topics*. 2015;33(1):14-42.
- Rivera EM, Williamson A. Diagnosis and treatment planning: cracked tooth. *Tex Dent J*. 2003 Mar;120(3):278-83.
- Rivera E, Walton R. Cracking the cracked tooth code: detection and treatment of various longitudinal tooth fractures. *Eur J Dent*. 2015 Apr-Jun; 9(2): 293-303.
- Hiatt WH. Incomplete Crown-Root Fracture in Pulpal-Periodontal Disease. *J Periodontol*. 1973 Jun;44(6):369-79.
- Rivera EM, Walton RE. Longitudinal tooth fractures: findings that contribute to complex endodontic diagnoses. *Endodontic Topics*. 2007 Mar;16(1): 82-111.
- Carter J, Sorensen S, Johnson R, Teitelbaum R, Levine M. Punch shear testing of extracted vital and endodontically treated teeth. *J Biomech*. 1983;16(10):841-8.
- Renson C, Braden M. The experimental deformation of human dentine by indenters. *Arch Oral Biol*. 1971 Jun;16(6):563-72.
- Tamse A, Fuss Z, Lustig J, Kaplavi J. An evaluation of endodontically treated vertically fractured teeth. *J Endod*. 1999 Jul;25(7):506-8.
- Preliminary estimates of the incidence and consequences of tooth fracture. *J Am Dent Assoc*. 1995 Dec;126(12):1650-4.
- Kang S, Kim BS, Kim Y. Cracked Teeth: Distribution, Characteristics, and Survival after Root Canal Treatment. *J Endod*. 2016 Apr;42(4):557-62.
- Mora MA, Mol A, Tyndall DA, Rivera EM. In vitro assessment of local computed tomography for the detection of longitudinal tooth fractures. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2007 Jun;103(6):825-9.
- Abou-Rass M. Crack lines: the precursors of tooth fractures-their diagnosis and treatment. *Quintessence Int Dent Dig*. 1983 Apr;14(4):437-47.
- Homewood C. Cracked tooth syndrome-incidence, clinical findings and treatment. *Aust Dent J*. 1998 Aug;43(4):217-22.
- Fennis WM, Kuijs RH, Kreulen CM, Roeters FJM, Creugers NH, Burgersdijk RC. A survey of cusp fractures in a population of general dental practices. *Int J Prosthodont*. 2002 Nov-Dec;15(6):559-63.
- Cavel WT, Kelsey WP, Blankenau RJ. An in vivo study of cuspal fracture. *J Prosthet Dent*. 1985 Jan;53(1):38-42.
- Silvestri AR, Singh I. Treatment rationale of fractured posterior teeth. *J Am Dent Assoc*. 1978 Nov;97(5):806-10.
- Brown W, Jacobs H, Thompson R. Thermal fatigue in teeth. *J Dent Res*. 1972 Mar-Apr;51(2):461-7.
- Ehrmann E, Tyas M. Cracked tooth syndrome: Diagnosis, treatment and correlation between symptoms and post-extraction findings. *Aust Dent J*. 1990 Apr;35(2):105-12.
- Geurtsen W, Schwarze T, Günay H. Diagnosis, therapy, and prevention of the cracked tooth syndrome. *Quintessence Int*. 2003 Jun;34(6):409-17.
- Ricucci D, Siqueira JF, Loghin S, Berman LH. The Cracked Tooth: Histopathologic and Histobacteriologic Aspects. *J Endod*. 2015 Mar;41(3):343-52.
- Tamse A. Vertical root fractures in endodontically treated teeth: diagnostic signs and clinical management. *Refuat Hapeh Vehashinayim* (1993). 2006 Jan;23(1):13-7, 68.
- Vire DE. Failure of endodontically treated teeth: classification and evaluation. *J Endod*. 1991 Jul;17(7):338-42.
- Fuss Z, Lustig J, Tamse A. Prevalence of vertical root fractures in extracted endodontically treated teeth. *Int Endod J*. 1999 Aug;32(4):283-6.
- Yoshino K, Ito K, Kuroda M, Sugihara N. Prevalence of vertical

- root fracture as thereason for tooth extraction in dental clinics. Clin Oral Investig. 2015 Jul;19(6):1405-9.
25. Pitts DL, Matheny HE, Nicholls JI. An in vitro study of spreader loads required to cause vertical root fracture during lateral condensation. J Endod. 1983 Dec;9(12):544-50.
 26. Ross RS, Nicholls JI, Harrington GW. A comparison of strains generated during placement of five endodontic posts. J Endod. 1991 Sep;17(9):450-6.
 27. Onnink PA, Davis RD, Wayman BE. An in vitro comparison of incomplete root fractures associated with three obturation techniques. J Endod. 1994 Jan;20(1):32-7.
 28. Ricks-Williamson LJ, Fotos PG, Goel VK, Spivey JD, Rivera EM, Khera SC. A three- dimensional finite-element stress analysis of an endodontically prepared maxillary central incisor. J Endod. 1995 Jul;21(7):362-7.
 29. Abbott P. Assessing restored teeth with pulp and periapical diseases for the presence of cracks, caries and marginal breakdown. Aust Dent J. 2004 Mar;49(1):33-9; quiz 45.
 30. Jun M-K, Ku H-M, Kim E, Kim H-E, Kwon H-K, et al. Detection and Analysis of Enamel Cracks by Quantitative Light-induced Fluorescence Technology. J Endod. 2016 Mar;42(3):500-4.
 31. Liu H, Sidhu S. Cracked teeth--treatment rationale and case management: case reports. Quintessence Int. 1995 Jul;26(7):485-92.
 32. Brynjulfson A, Fristad I, Grevstad T, Kvinnsland I. Incompletely fractured teeth associated with diffuse longstanding orofacial pain: diagnosis and treatment outcome. Int Endod J. 2002 May;35(5):461-6.
 33. Cameron CE. The cracked tooth syndrome: additional findings. J Am Dent Assoc. 1976 Nov;93(5):971-5.
 34. Wright HM, Loushine RJ, Weller RN, Kimbrough WF, Waller J, et al. Identification of Resected Root-End Dentinal Cracks: A Comparative Study of Transillumination and Dyes. J Endod. 2004 Oct;30(10):712-5.
 35. Burke F. Hemisection: a treatment option for the vertically split tooth. Dent Update. 1992 Jan-Feb;19(1):8-12.
 36. Helft M, Marshak B. Split root: a common cause of undiagnosed or misdiagnosed pain Quintessence international, dental digest. 1981; 12:1031-6.
 37. Meister F, Lommel TJ, Gerstein H. Diagnosis and possible causes of vertical root fractures. Oral Surg Oral Med Oral Pathol. 1980 Mar;49(3):243-53.
 38. Walton RE, Michelich RJ, Smith GN. The histopathogenesis of vertical root fractures. J Endod. 1984 Feb;10(2):48-56.
 39. Pitts DL, Natkin E. Diagnosis and treatment of vertical root fractures. J Endod. 1983 Aug;9(8):338-46.
 40. Tamse A, Kaffe I, Lustig J, Ganor Y, Fuss Z (2006) Radiographic features of vertically fractured endodontically treated mesial roots of mandibular molars. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2006 Jun;101(6):797-802.
 41. Huang C-C, Chang Y-C, Chuang M-C et al. Analysis of the width of vertical root fracture in endodontically treated teeth by 2 micro-computed tomography systems. J Endod. 2014 May;40(5):698-702.
 42. Youssefzadeh S, Gahleitner A, Dorffner R, Bernhart T, Kainberger FM. Dental vertical root fractures: value of CT in detection. Radiology. 1999 Feb;210(2):545-9.
 43. Hassan B, Metska ME, Ozok AR, van Der Stelt P, Wesselink PR (2009) Detection of Vertical Root Fractures in Endodontically Treated Teeth by a Cone Beam Computed Tomography Scan. J Endod. 2009 May;35(5):719-22.
 44. Chavda R, Mannocci F, Andiappan M, Patel S. Comparing the In Vivo Diagnostic Accuracy of Digital Periapical Radiography with Cone-beam Computed Tomography for the Detection of Vertical Root Fracture. J Endod. 2014 Oct;40(10):1524-9.
 45. Makeeva I, Byakova S, Novozhilova N et al. (2015) Detection of artificially induced vertical root fractures of different widths by cone beam computed tomography *in vitro* and *in vivo*. Int Endod J. 2016 Oct;49(10):980-9.
 46. Pradeepkumar AR, Shemesh H, Jothilatha S, Vijayabharathi R, Jayalakshmi S, et al. Diagnosis of Vertical Root Fractures in Restored Endodontically Treated Teeth: A Time- dependent Retrospective Cohort Study. J Endod. 2016 Aug;42(8):1175-80.
 47. Gutmann J, Rakusin H. Endodontic and restorative management of incompletely fractured molar teeth. Int Endod J. 1994 Nov;27(6):343-8.
 48. Ailor JE. Managing incomplete tooth fractures. J Am Dent Assoc. 2000 Aug;131(8):1168-74.
 49. Abbott P, Leow N. Predictable management of cracked teeth with reversible pulpitis. Aust Dent J. 2009 Dec;54(4):306-15.
 50. Moule AJ, Kahler B. Diagnosis and management of teeth with vertical root fractures. Aust Dent J. 1999 Jun;44(2):75-87.
 51. Korte P, Carr Jr J, Cohen J. Vertical root fracture and its relationship to the periodontium. J Conserv Dent. 2014 Mar;17(2):103-10.
 52. Andreasen JO, Munksgaard EC, Bakland LK. Comparison of fracture resistance in root canals of immature sheep teeth after filling with calcium hydroxide or MTA. Dent Traumatol. 2006 Jun;22(3):154-6.
 53. Doyon GE, Dumsha T, von Fraunhofer JA. Fracture resistance of human root dentin exposed to intracanal calcium hydroxide. J Endod. 2005 Dec;31(12):895-7.
 54. Takatsu T, Sano H, Burrow M. Treatment and prognosis of a vertically fractured maxillary molar with widely separated segments: a case report. Quintessence Int. 1995 Jul;26(7):479-84.
 55. Re GJ, Norling BK, Draheim RN. Fracture resistance of lower molars with varying faciocclusolingual amalgam restorations. J Prosthet Dent. 1982 May;47(5):518-21.
 56. Salis SG, Hood JA, Kirk EE, Stokes AN. Impact-fracture energy of human premolar teeth. J Prosthet Dent. 1987 Jul;58(1):43-8.
 57. Reeh ES, Messer HH, Douglas WH. Reduction in tooth stiffness as a result of endodontic and restorative procedures. J Endod. 1989 Nov;15(11):512-6.
 58. Clark D, Khademi J. Modern molar endodontic access and directed dentin conservation. Dent Clin North Am. 2010 Apr;54(2):249-73.
 59. Gutmann JL. Minimally invasive dentistry (Endodontics). J Conserv Dent. 2013 Jul-Aug; 16(4): 282-283.
 60. Dang DA, Walton RE. Vertical root fracture and root distortion: effect of spreader design. J Endod. 1989 Jul;15(7):294-301.
 61. Murgel CAF, Walton RE. Vertical root fracture and dentin deformation in curved roots: the influence of spreader design. Endod Dent Traumatol. 1990 Dec;6(6):273-8.
 62. Ersev H, Yilmaz B, Pehlivanoglu E, Özcan-Çalışkan E, Erişen FR. Resistance to Vertical Root Fracture of Endodontically Treated Teeth with MetaSEAL. J Endod. 2012 May;38(5):653-6.
 63. Prado M, Lima NRB, Lima CO, Gusman H, Simão RA. Resistance to vertical root fracture of root filled teeth using different conceptual approaches to canal preparation. Int Endod J. 2016 Sep;49(9):898-904.