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POSITION STATEMENT

European Society of Endodontology

Position statement on longitudinal cracks and fractures of teeth

Shanon Patel[1,2,3] | **Peng-Hui Teng**[4] | **Wan-Chuen Liao**[5] | **Matthew Craig Davis**[6] | **Ales Fidler**[7,8] | **Franziska Haupt**[9] | **Cristiano Fabiani**[10] | **Ronald Ordinola Zapata**[11] | **Rahul Bose**[2]

[1]Guy's & St Thomas NHS Foundation Trust, London, UK

[2]Centre for Oral, Clinical & Translational Sciences, King's College London, London, UK

[3]Specialist Practice, London, UK

[4]Unit of Endodontology & Endodontics, Faculty of Dentistry, Universiti Kebangsaan Malaysia, Kuala Lumpur, Malaysia

[5]School of Dentistry, College of Medicine, National Taiwan University, Taipei, Taiwan

[6]Private Practice in Endodontics, Winnetka, Illinois, USA

[7]Department of Endodontics and Restorative Dentistry, Faculty of Medicine, University of Ljubljana, Ljubljana, Slovenia

[8]Department of Restorative Dentistry and Endodontics, University Medical Centre Ljubljana, Ljubljana, Slovenia

[9]Department of Preventive Dentistry, Periodontology and Cariology, University Medical Center Göttingen, Göttingen, Germany

[10]Specialist Practice, Rome, Italy

[11]Department of Endodontics, University of Minnesota, Minneapolis, Minnesota, USA

Correspondence
Shanon Patel, Faculty of Dentistry, Oral & Craniofacial Sciences, King's College London, UK.
Email: shanonpatel@gmail.com

Abstract

This position statement is a consensus view of an expert committee convened by the European Society of Endodontology (ESE). The statement is based on current clinical and scientific evidence as well as the collective reflective practice of the committee. The aim is to provide clinicians with evidence-based, authoritative information on the aetiology, clinical presentation, and management of cracks and fractures that typically manifest along the long axis of the crown and/or root.

KEYWORDS

cracked tooth, longitudinal fractures, split tooth, vertical root fracture

INTRODUCTION

The incidence of cracked teeth (CT) and vertical root fractures (VRF) is increasing (American Association of Endodontists, 2022; Pan et al., 2022). The term 'Longitudinal' encompasses cracks and fractures that are vertical in nature and may progress over time (Figure 1 and Table 1) (Rivera & Walton, 2015). If left untreated, CT may progress to irreversible pulpal disease and possibly tooth loss. A VRF commonly progresses subtly, leading to a delayed diagnosis that results in extraction.

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Timely identification and appropriate management are essential to increase the life span of the affected tooth.

CRACKED TEETH

A crack extending into the dentine, of unknown depth or size, which may extend subcrestally into the root. There may be pulpal involvement.

Prevalence

The prevalence of coronal (visible) CT has been reported to be as high as 70% (Hilton et al., 2011). Posterior teeth (maxillary (pre)molars and mandibular molars) are more commonly affected by cracks (Hilton et al., 2017; Krell & Caplan, 2018; Yang et al., 2017). Historically, cracks were associated with restored teeth (Cameron, 1976; Kahler, 2008); however, over the last two decades studies have reported an increasing incidence of cracks in unrestored teeth (Alaugaily & Azim, 2022; Kang et al., 2016; Lee et al., 2021).

CT incidence increases with age and is most prevalent in patients over 40 years of age (Hilton et al., 2017). Age-related changes in the biomechanical properties of dentine result in an increasing mineral-to-collagen and cross-linking ratio that renders the radicular dentine less resilient and more susceptible to crack propagation (Chen et al., 2023; Montoya et al., 2015). A significant increase in the prevalence of CT has been reported since the Coronavirus disease (COVID-19) pandemic (Mirhashemi et al., 2022; Nocini et al., 2023; Nosrat et al., 2022).

Aetiology

CT aetiology is multifactorial, involving occlusal interferences, tooth morphology, previous operative dentistry, increased masticatory loading due to hard food diets, and/or parafunctional habits (Table 2).

The apical propagation of a dentinal crack occurs over a period of prolonged cyclical loading, which may result in the ingress of microbes into the pulp chamber, culminating in pulp necrosis (Ricucci et al., 2015).

Clinical features

The clinical presentation varies depending on the location, size, and extension of the crack(s), as well as the pulpal, periapical, and periodontal involvement (Table 3).

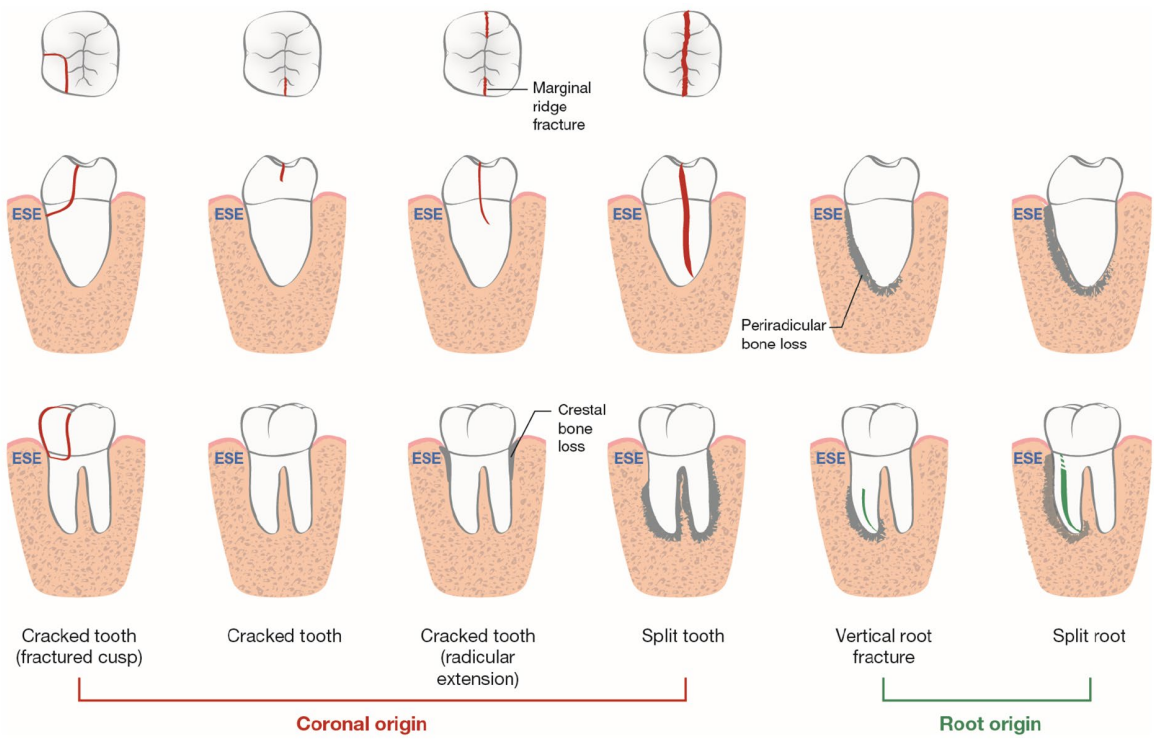


FIGURE 1 Common presentation of cracked tooth, split tooth, vertical root fracture, and split root. Top row: occlusal, middle row: mesio-distal, lower row: bucco-lingual aspects of a mandibular molar.

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TABLE 1 Definitions of longitudinal cracks and fractures of teeth.

Craze Line	Superficial, coronal crack line confined to the enamel with no compromise of the integrity of the tooth.
Cracked Tooth (CT)	A crack extending into the dentine, of unknown depth or size, may extend subcrestally into the root. There may be pulpal involvement.
Fractured (cracked) Cusp	*Molars*-(in) complete fracture extending down a bucco/lingual groove and mesio-distal direction of the affected cusp. *Premolars*-usually involve marginal ridges. +/− pulpal involvement.
Split Tooth (ST)	Complete, visible separation of the entire tooth into 2 parts, usually in a mesio-distal direction
Vertical root fracture (VRF)	An incomplete longitudinal (axial) root fracture, involving the cementum, dentine, and root canal space.
Split Root	A complete VRF with visible separation of the root into distinct segments.

TABLE 2 Potential predisposing and contributory factors for cracked teeth and vertical root fractures (VRF).

	Cracked teeth	VRF in non-root-filled teeth	VRF in root-filled teeth
Clinical features	*Predisposing factors* • Compromised structural integrity • Changes in dentinal biomechanical properties due to ageing • Specific cuspal anatomy (functional cusp, buccal-lingual dimension, cuspal inclination, etc.) • Posterior location of the tooth • Parafunction and/or unfavourable occlusal arrangement. • Dietary habit *Contributory factors* • Stress generated from restorative procedures • Thermal expansion, contraction, and/or corrosion of restorative materials	*Predisposing factors* • Presence of pre-existing (micro) cracks and fractures • Changes in dentinal biomechanical properties due to ageing • Specific root canal anatomy and morphology (narrow mesiodistal width, ovoid shape canal) • Posterior location of the tooth • Parafunction and/or unfavourable occlusal arrangement. • Dietary habit	*Predisposing factors* • Compromised structural integrity • Pre-existing (micro)cracks and fractures • Changes in dentinal biomechanical properties due to ageing and/or endodontic treatment • Specific root canal anatomy and morphology (e.g. narrow mesiodistal width, ovoid shape canal) • Specific cuspal anatomy (functional cusp, buccal-lingual dimension, cuspal inclination etc.) • Posterior location of the tooth • Parafunction and/or unfavourable occlusal arrangement. *Contributory factors* • Excessive removal of sound dentine during RCT • Prolonged exposure to intracanal medicaments and disinfectants. • Inappropriate execution of post-endodontic restoration (including post preparation) • Excessive pressure generated during root canal obturation • Root end preparation with ultrasonic retro-tips

A practice-based study of 2858 teeth from 209 dentists in the USA reported that 45% of CT were symptomatic, the most common symptoms being pain to cold (37%), biting pain (16%), and spontaneous pain (11%) (Hilton et al., 2018). Tenderness to percussion and marginal fracture lines are also commonly reported findings (de Toubes et al., 2022).

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TABLE 3 Clinical and radiographic features.

	Craze line	Fractured cusp	Cracked teeth	VRF in non-root filled teeth	VRF in root filled teeth	Split tooth
Clinical features	• Typically asymptomatic • Craze line blocking transilluminated light	*Early stage* • Thermal sensitivity • Short sharp pain upon mastication or releasing from pressure *Advanced stage* • Symptoms may be relieved when the cusp fractures off • Separated cuspal fragment • May develop pulpitis or apical periodontitis symptoms if fracture involves pulp	*Early stage* • Attrited occlusal surface • +/− symptoms (e.g., thermal sensitivity, pain upon mastication or releasing from pressure) • Positive response to the sensibility test • Direct visualization of craze/crack line(s) blocking transilluminated light *Advanced stage* • May elicit negative response to the sensibility test • +/− symptoms of pulpitis or apical periodontitis (e.g., dull throbbing pain, tenderness to percussion and/or palpation, abscess etc.) • Usually either buccal or lingual cups will be tender to pecussion • +/− isolated, deep, narrow periodontal pocket	*Early stage* • Attrited occlusal surface • +/− symptoms (e.g., thermal sensitivity, pain or discomfort upon mastication, or persistent ache) • Positive response to the sensibility test *Advanced stage* • Negative response to the sensibility test • +/− symptoms of apical periodontitis (e.g., dull throbbing pain, tenderness to percussion and/or palpation, abscess etc.) • Direct visualization of a fracture • Mimicking periodontal disease +/− isolated, deep, narrow periodontal pocket • Mobility	• +/− symptoms of apical periodontitis (e.g., pain upon mastication, tenderness to percussion and/or palpation, abscess etc.) • Mimicking periodontal disease +/− isolated, deep, narrow periodontal pocket • Direct visualization of a fracture • Presence of a sinus/multiple sinuses close to gingival margin • Mobility	• Pain upon mastication • Periodontal attachment loss and/or abscess • Mobility
Radiographic features	Unremarkable	Unremarkable	*Early stage* • Not remarkable • May have subtle radiolucent lines in the coronal tooth structure *Advanced stage* • +/− periapical radiolucency in necrotic teeth	*Early stage* • No obvious changes +/− subtle crestal bone loss • Radiographic density changes or unusual radiolucent lines in the root canal • Abnormal widening of the root canal space • Subtle periodontal ligament widening or periradicular bone loss on the lateral root walls *Advanced stage* • Separated root fragments • Periradicular bone loss adjacent to the VRF (Halo or J-shaped radiolucency)	*Early stage* • No obvious changes +/− subtle crestal bone loss • Radiographic density changes or unusual radiolucent lines in the root filling • Subtle periodontal ligament widening or periradicular bone loss on the lateral root walls *Advanced stage* • Separated root fragments • Periradicular bone loss adjacent to the VRF (Halo or J-shaped radiolucency)	• Separated tooth fragments • Periradicular bone loss

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Diagnosis of early-stage CT can be challenging due to poorly localised symptoms, which may be misdiagnosed as (non-)odontogenic conditions, or in some cases CT may be an asymptomatic, incidental finding (Hilton et al., 2020). At a later stage, a discernible crack line on interproximal marginal ridges or buccal/lingual aspects may be seen. The patient may also develop a fractured cusp as a result of a crack propagation.

Clinical examination of the suspected CT should include appropriate sensibility tests, tooth mobility, and assessment of the surrounding soft tissues. Occlusal assessment may reveal indirect signs of increased (para) functional forces; these include wear facets, loss of canine guidance, and/or occlusal interferences (Table 3). Narrow periodontal probing of less than 6 mm is associated with CT, whereas periodontal probing depths of VRF are deeper (Alaugaily & Azim, 2022).

In vital teeth, detection of a crack is aided by a bite test (eg., tooth sleuth) (Hilton et al., 2020). The aim of the bite test is to reproduce the patient's symptoms, particularly sudden sensitivity and sharp pain when biting hard foods and/or clenching, which ceases upon the release of pressure. In non-vital teeth, there may be symptoms and/or signs of apical periodontitis (AP) as well as evidence of marginal ridge fractures.

Removal of existing restorations will facilitate visualisation of the nature of the crack (Abbott, 2004). Fibre optic transillumination and/or the use of stains such as methylene blue are recommended. The use of a dental operating microscope or loupes is critical in detecting dentinal cracks, as well as distinguishing them from craze lines (Clark et al., 2003; Kim et al., 2020). CT should be differentiated from craze lines, which are confined to the enamel, naturally occurring through mastication and becoming more prominent with age (Rivera & Walton, 2015). Craze lines are readily visible on anterior teeth but also evident on marginal ridges and/or axial surfaces of posterior teeth. Treatment of craze lines is not indicated, except for aesthetic reasons, i.e., stained craze lines.

Radiographic features

The radiographic appearance (Table 3) on periapical radiographs (PRs) can be highly variable. Early-stage CT may include no obvious signs of a crack and/or pathology. Hilton et al. (2017) reported that only 2% of CTs with vital pulps had evidence of a crack on a radiograph.

Radicular extension of a crack may result in (subtle) crestal vertical bone loss associated with pulpal necrosis. With long-standing CT, there may be evidence of periapical lesions, thickening of the periodontal ligament, and/or radiolucency along the lateral aspect of the root.

CBCT may be indicated if clinical and/or PR assessments are inconclusive (American Association of Endodontists/American Academy of Oral & Maxillofacial Radiology, 2015; European Society of Endodontology, 2014). CBCT is not predictable in detecting cracks but may reveal subtle crestal bone loss associated with CT (Alaugaily & Azim, 2022; Gao et al., 2020).

Management options

Clinically normal pulp and normal apical tissue

Shallow cracks and/or low risk of crack propagation may be periodically reviewed (Chen et al., 2023). It remains unclear for how long asymptomatic, untreated CT can remain stable and without further crack propagation, as current studies have only monitored cracks for 1–3 years (Ferracane et al., 2022; Hilton et al., 2020). When indicated, patients should be given advice on managing parafunctional habits. Occlusal interferences should also be managed to create a more harmonious occlusal scheme to limit extension of CT; this may require a multi-disciplinary approach.

Untreated CT in high-risk teeth may progress to a fractured cusp or a split tooth (see below), for example, the distal marginal ridge of last-standing (pre-)molars, an extensively restored tooth, a lone/last-standing tooth, and/or patients with chronic parafunctional habits. In these cases, active treatment is indicated, e.g., cuspal coverage restoration, to reduce the likelihood of the crack propagating, thus increasing the longevity of the tooth (see VRF section below).

Reversible pulpitis

CT associated with reversible pulpitis may be monitored or (in-)completely traced out depending on extent and restored with a composite restoration or a cuspal coverage restoration (American Association of Endodontists, 2022; Hilton et al., 2017). Treatment (type) is dependent on several factors and should be determined on a case-by-case basis. In some instances, it will not be pragmatic to trace out the entire crack, as this may result in inadvertent removal of a significant amount of sound tooth tissue and/or render the tooth unrestorable.

The decision on the type (and extent) of the restoration must be tailored to each patient's unique characteristics, rather than taking a 'one fits all' approach. Factors that may indicate a cuspal coverage restoration include the extent of the crack, history of spontaneous pain, moderate/significant caries, existing direct restorations, pain on

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biting, volume of residual coronal tooth structure, proximal contacts, as well as indirect factors such as occlusal scheme and parafunctional habits should be considered (Ferracane et al., 2022; Kakka et al., 2022).

A single-stage approach, i.e., immediate definitive restoration, or a multiple-stage approach, i.e., interim treatment (temporary crowns, direct composite splint) and review of pulpal status prior to definitive restoration, may be selected (Banerji et al., 2014; Ehrmann & Tyas, 1990; Kakka et al., 2022). While interim treatment allows pulpal healing and confirms initial diagnosis prior to definitive restoration, pulp vitality may be compromised due to microleakage, cement breakdown, and/or further definitive treatment (Kang et al., 2016; Wu et al., 2019).

There is no clear evidence on the most suitable restorative treatment approach to manage CT (de Toubes et al., 2022; Lee et al., 2021). CT managed with direct bonded composite restorations may be more likely to require root canal treatment and/or further repair of fractured restorations compared with CT managed with cuspal coverage restorations (Signore et al., 2008; Wu et al., 2019; Zhang et al., 2024). The reported incidence of endodontic intervention after restorative management has been reported to be between 7.7% and 20% (Krell & Rivera, 2007; Opdam et al., 2008).

Irreversible pulpitis/pulp necrosis

The survival rate of root filled with irreversible pulpitis, pulp necrosis, or pulp exposure following root canal treatment ranges from 84% to 88% over 1–5 years of follow-up, and the success rate ranges from 76% to 82% after 1–2 years (Chen et al., 2021; Leong et al., 2020; Olivieri et al., 2020).

A 5 + mm periodontal probing is associated with reduced survival rates (Kang et al., 2016; Olivieri et al., 2020). Other negative prognostic factors include the presence of multiple cracks, radicular extension of cracks, location in the arch (terminal tooth), preoperative presence of AP, and/or placement of an intracanal post (Chen et al., 2021; Krell & Caplan, 2018; Leong et al., 2020).

Historically, radicular cracks extending beyond the root canal entrance have been regarded as having an unfavourable prognosis (Malentacca et al., 2021; Sim et al., 2016). Placing an intracanal barrier apical to the crack after endodontic treatment has been completed could increase the fracture resistance and provide a good seal from further microbial penetration. Davis and Shariff (2019) reported that this approach in combination with a cuspal coverage restoration and careful management of the occlusion had a 4-year survival rate of 96.6%.

Conclusion and summary

Current evidence suggests encouraging outcomes for vital as well as endodontically treated CT restored with cuspal coverage restorations. Early management, cuspal coverage restorations, and absence of deep periodontal probing depth of non-endodontic origin increase the survival rate of CT management. Careful occlusal assessment and management of parafunctional habits and/or occlusal interferences is essential to reduce the likelihood of the propagation of existing cracks, thus improving the longevity of CT. Due to the broad variability in presentation, the term ‘CT syndrome’ should be avoided.

SPLIT TOOTH

Complete, visible separation of the entire tooth into two parts, usually in a mesio-distal direction.

Prevalence

Split tooth (ST) is the result of the progression and expansion of a coronal crack resulting in mechanical failure of the crown and root, resulting in complete longitudinal separation of the tooth, usually in a mesio-distal direction (American Association of Endodontists, 2022). The literature on the prevalence and presentation of ST is sparse (Schurz et al., 2020).

Aetiology

ST is a progression of CT (Table 2).

Clinical features

The tooth fragments are completely separated or separated with pressure. There may be symptoms of AP, including pain on biting, a narrow, isolated periodontal probing, or tooth mobility. Gentle probing of the ST occlusally will wedge the fragmented tooth apart (Table 3).

Radiographic features

Visible separation into at least 2 fragments, the tooth is usually, but not exclusively, root filled. A periradicular radiolucency will be associated with the separated fragment.

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Management options, conclusion, and summary

ST has an unfavourable prognosis, and timely extraction should be considered to minimise the development of acute symptoms and limit bone loss.

VERTICAL ROOT FRACTURES (VRFs) IN NON-FILLED TEETH

An incomplete longitudinal (axial) root fracture, involving the cementum, dentine, and root canal space of non-root-filled teeth.

Prevalence

The incidence of VRFs in non-root-filled teeth (NRFT) has been reported to be between 6% and 37%, with a predilection for males and patients over 50 years of age (Chan et al., 1998, 1999; Liao et al., 2017). The majority of research on VRFs in NRFT involves the Chinese population (Liao et al., 2021).

VRFs in NRFT mainly affect first molars, particularly the mesio-buccal root of maxillary and the mesial root of mandibular molars (Liao et al., 2021). The fracture line typically originates from the root apex and appears on the buccolingual aspect of the root (Wang et al., 2012). Affected teeth are commonly (minimally) unrestored but have signs of excessive tooth surface loss, indicating repetitive and/or increased occlusal forces and/or an unfavourable cusp/fossae relationship (Chan et al., 1998; Yang et al., 1995).

Aetiology

Multiple predisposing factors have been reported (Table 2). Certain dietary patterns, specifically relating to Asian populations, have been suggested to contribute to the higher incidence of spontaneous VRF in NRFT (Yang et al., 1995; Yeh, 1997).

Clinical features

Teeth may be asymptomatic, have temperature sensitivity, have discomfort upon mastication, and/or have pulpitis or symptoms of AP (Bhaskar et al., 2011; Wang & Su, 2009; Yang et al., 2023).

An isolated, deep, narrow periodontal pocket is not as commonly identified in VRF of NRFT compared with VRF in root-filled teeth (RFT) (Lee et al., 2023). Sensibility testing may reveal a positive or negative response, depending on the extent of the VRF and severity of the pulp necrosis (Chan et al., 1998; Liao et al., 2021; Yang et al., 1995).

Radiographic features

A subtle or obvious fracture line within the root, periodontal ligament thickening, or periradicular bone loss adjacent to the separation of root fragments being evident radiographically (Chan et al., 1998; Yang et al., 1995). The European Society of Endodontology recommend small field of view CBCT may be used to confirm peri-radicular signs of bone loss if clinical and/or PR assessment is inconclusive (Patel et al., 2019) (Table 3).

Management options

Exploratory surgery may be indicated if the above findings are inconclusive and/or the nature and feasibility of management versus extraction need to be determined (Chan et al., 1998, 1999; Walton, 2017).

Early intervention is essential to limit the progression of VRF in NRFT and (further) bone destruction adjacent to the affected root. Extraction of single-rooted teeth is recommended. Root resection (complete or partial) of the affected root may be an option in multirooted teeth depending on the position, level, and extent of the VRF. Endodontic treatment of the intact roots, followed by restoration of the access cavity with a direct plastic restoration, which should extend into the affected canal and apical to the planned root resection or amputation level. Cuspal coverage restoration is recommended (Ferracane et al., 2022; Kanamaru et al., 2017; Zhang et al., 2024). At present there is limited evidence to support intentional replantation and extraoral bonding for VRF.

Conclusion and summary

The current evidence on treatment strategies for VRFs in NRFT is limited; more clinical studies with long-term follow-up are needed.

VERTICAL ROOT FRACTURES (VRFs) IN ROOT FILLED TEETH

An incomplete longitudinal (axial) root fracture, involving the cementum, dentine, and root canal space of root-filled teeth.

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Prevalence

VRF is more commonly associated with RFT than NFRT. The reported prevalence of extraction of RFT with VRF ranges from 4% to 32% (Lee et al., 2023; von Arx et al., 2021).

Maxillary (pre-)molars and mandibular molars are the most commonly affected (Patel et al., 2022; PradeepKumar et al., 2016). The incidence of VRF increases with age, being more prevalent in 40+ year-old patients (PradeepKumar et al., 2016; Yoshino et al., 2015).

Aetiology

The aetiology is multifactorial; several putative predisposing and contributory factors have been reported (Table 2). The most critical factor(s) are unknown and difficult to elucidate. VRF is a common cause of extraction (13–21%) of RFT (Kim et al., 2024; Touré et al., 2011; Yoshino et al., 2015).

The pathogenesis of a VRF in RFT is complex and has not been clearly established. There are three main stages: crack initiation, propagation, and separation.

In the early stages, a crack may develop at either the coronal or apical aspect of the root and progress in either the apico-coronal and/or bucco-lingual aspects of the tooth. Unlike traumatic dental injuries, which are acute, high-impact in nature, and usually present immediately after a recognised impact, VRFs develop as a result of a dynamic cyclical fatigue process over a long period of time (Kishen, 2015; Patel et al., 2022).

In advanced stages, continuous microbial ingress leads to biofilm formation and the loss of periodontal attachment adjacent to the fracture line (Walton et al., 1984). Complete longitudinal separation of the root eventually occurs, resulting in a split root (American Association of Endodontists, 2022).

Clinical features

Presentation depends on the location, extent, and nature of the VRF. Early-stage VRFs are a challenge to detect as the patient may be asymptomatic (Table 3).

There may be symptoms and/or signs of AP. Typical features of advanced VRF include an isolated, narrow, deep periodontal pocket (pathognomonic if detected on both sides of a root) and the presence of multiple sinus tracts (Patel et al., 2022) (Table 3).

Increased probing depths should be cautiously interpreted in the context of the history of the tooth and distinguished from probing attributed to periodontal disease and/or a sinus tract of endodontic origin (Lee et al., 2023).

Removal of existing restorations and root filling materials helps to determine the presence and/or extent of a VRF (Abbott, 2004). Removal of interproximal restorations allows probing of the mesial and distal surfaces, which may otherwise be inaccessible due to the presence of proximal contacts.

It is essential to use magnification (see CT section); if the VRF is still not readily visible, exploratory surgical procedures may be indicated. However, only fracture line(s) on the approximal root surfaces (i.e., buccal and lingual) will be accessible and visible.

Radiographic presentation

The radiographic appearance (Table 3) of early-stage VRFs may vary from no obvious bone loss to subtle periradicular bone loss, with long-standing VRFs typically presenting with periradicular (J-shaped) radiolucency and/or frank separation of the root (split root).

A CBCT may be indicated to confirm periradicular signs of bone loss if clinical and/or PR assessment is inconclusive (see VRF in NRFT section) (Chavda et al., 2014; Patel et al., 2019, 2022). CBCT cannot reliably detect VRFs within the root due to the image resolution being insufficient to detect fractures that are typically 50-100 μm in width (Brady et al., 2014).

Clinical management

The prognosis is poor (Fuss et al., 2001; Walton, 2017; Zadik et al., 2008). Prompt management is recommended as soon as diagnosis is reached to reduce the likelihood of acute AP symptoms and/or further periradicular bone breakdown, as this may complicate and/or delay dental implant treatment. Extraction is recommended in a single-rooted tooth with a VRF (Patel et al., 2022).

In multi-rooted RFT, root resection or root amputation may be considered as an alternative to extraction. A multi-disciplinary approach is recommended in the treatment planning. There is no data on survival rates of root resection or root amputation for VRF in RFT; however, extrapolation from root resection on periodontally affected teeth has been reported to be 90.6% and 96.8% over 10 and 15 years, respectively (Derks et al., 2018; Fugazzotto, 2001).

Preventive management

The prevention of VRFs is critical; identifying susceptible teeth and utilising conservative endodontic procedures together with expedient and appropriate post-endodontic

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restorative procedures, is paramount to reducing the incidence of terminal VRFs (Patel et al., 2022). Minimising excessive removal of dentine during access cavity and canal instrumentation preserves pericervical dentine, which may reduce the impact of (para)functional occlusal forces (Clark & Khademi, 2010). Adhesive post-endodontic restorative techniques are recommended to minimize dentine removal, and posts, if required, should be placed 'passively', and excessive 'post-space' preparation should be avoided. After the root canal system has been obturated, the access cavity should be immediately restored with a resin-based composite restoration. When indicated, prompt cuspal coverage restoration is essential to reduce the likelihood of VRF.

Proximal contacts help to dissipate occlusal forces. The replacement of missing posterior units is desirable to increase the number of occlusal and proximal contacts and distribute (non-)occlusal loading (Gulabivala & Ng, 2023).

In cases of an RFT with a pre-existing crack(s), the placement of bioactive or adhesive intracanal materials beyond the extension of crack(s) may reduce further propagation and/or microbial leakage (Davis & Shariff, 2019; de Toubes et al., 2024).

UNIVERSAL CONSIDERATIONS FOR CT AND VRF

The impact of excessive occlusal forces cannot be overemphasised in the aetiology of CT, ST, and VRF. Consideration should be given to the opposing dentition, including their restoration status and occlusal topography. Fabrication of occlusal stabilisation splints and/or referral to relevant specialists should be considered for the management of parafunctional habits (Kui et al., 2020; Shehri et al., 2022).

Occlusal interferences on all, not just the affected teeth and/or restorations, should be managed appropriately. When indicated, composite resin canine ramps may help re-establish canine guidance, allowing for posterior disocclusion in excursions, reducing lateral forces on these teeth, and lowering masticatory muscular activity (Abduo & Tennant, 2015). An interdisciplinary approach may be required for complex cases. It is essential to educate the patient of the prognosis and recommend reducing excessive occlusal loading on cracked RFT.

CONCLUSION

Clinicians should be mindful of the significance, prevention strategies, and timely management of CT and VRF. Patients should be made aware of the part they play in limiting the CT and VRF. This is especially relevant as life expectancy as well as patients' expectations are increasing. Periodic monitoring of (root filled) CT is essential for detecting early signs of periradicular bone loss, which may indicate an early stage VRF.

AUTHOR CONTRIBUTIONS

Shanon Patel: conceptualisation, methodology, visualisation, resources, writing—original draft, writing—review and editing, project administration. Peng-Hui Teng, Wan-Chuen Liao, Matthew Craig Davis, Ales Fidler, Franziska Haupt, Ronald Ordinola Zapata, Rahul Bose. Cristiano Fabiani, writing—review and editing.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

ETHICS STATEMENT

None.

ORCID

Shanon Patel https://orcid.org/0000-0003-0614-6951
Peng-Hui Teng https://orcid.org/0000-0002-5358-6565
Ales Fidler https://orcid.org/0000-0003-3916-1111
Franziska Haupt https://orcid.org/0000-0002-2316-5137
Ronald Ordinola Zapata https://orcid.org/0000-0001-9738-0828
Rahul Bose https://orcid.org/0000-0002-7506-5007

REFERENCES

Abbott, P.V. (2004) Assessing restored teeth with pulp and periapical diseases for the presence of cracks, caries and marginal breakdown. *Australian Dental Journal*, 49(1), 33–39.

Abduo, J. & Tennant, M. (2015) Impact of lateral occlusion schemes: a systematic review. *Journal of Prosthetic Dentistry*, 114(2), 193–204.

Alaugaily, I. & Azim, A.A. (2022) CBCT patterns of Bone loss and clinical predictors for the diagnosis of cracked teeth and teeth with vertical root fracture. *Journal of Endodontics*, 48(9), 1100–1106.

American Association of Endodontists. (2022) Cracked teeth and vertical root fractures: a new look at a growing problem. In: *Endodontics: Colleagues for Excellence newsletter*. USA: American Association of Endodontists, pp. 1–8.

American Association of Endodontists/American Academy of Oral & Maxillofacial Radiology. (2015) AAE and AAOMR joint position statement: use of cone beam computed tomography in Endodontics 2015 update. *Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology*, 120(4), 508–512.

Banerji, S., Mehta, S.B., Kamran, T., Kalakonda, M. & Millar, B.J. (2014) A multi-centred clinical audit to describe the efficacy of direct supra-coronal splinting – a minimally invasive approach to the management of cracked tooth syndrome. *Journal of Dentistry*, 42(7), 862–871.

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Bhaskar, U., Logani, A. & Shah, N. (2011) True vertical tooth root fracture: case report and review. *Contemporary Clinical Dentistry*, 2(3), 265–268.

Brady, E., Mannocci, F., Brown, J., Wilson, R. & Patel, S. (2014) A comparison of cone beam computed tomography and periapical radiography for the detection of vertical root fractures in nonendodontically treated teeth. *International Endodontic Journal*, 47(8), 735–746.

Cameron, C.E. (1976) The cracked tooth syndrome: additional findings. *The Journal of the American Dental Association*, 93(5), 971–975.

Chan, C.-P., Lin, C.-P., Tseng, S.-C. & Jeng, J.-H. (1999) Vertical root fracture in endodontically versus nonendodontically treated teeth: a survey of 315 cases in Chinese patients. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics*, 87, 504–507.

Chan, C.-P., Tseng, S.-C., Lin, C.-P., Huang, C.-C., Tsai, T.-P. & Chen, C.C. (1998) Vertical root fracture in nonendontically treated teeth—a clinical report of 64 cases in chinese patients. *Journal of Endodontics*, 24(10), 678–681.

Chavda, R., Mannocci, F., Andiappan, M. & Patel, S. (2014) Comparing the diagnostic accuracy of digital periapical radiography with cone-beam computed tomography for the detection of vertical root fracture. *Journal of Endodontics*, 40(10), 1524–1529.

Chen, S., Arola, D., Ricucci, D., Bergeron, B.E., Branton, J.A., Gu, L.-s. et al. (2023) Biomechanical perspectives on dentine cracks and fractures: implications in their clinical management. *Journal of Dentistry*, 130, 104424.

Chen, Y.-T., Hsu, T.-Y., Liu, H. & Chogle, S. (2021) Factors related to the outcomes of cracked teeth after endodontic treatment. *Journal of Endodontics*, 47(2), 215–220.

Clark, D. & Khademi, J. (2010) Modern molar endodontic access and directed dentin conservation. *Dental Clinics of North America*, 54(2), 249–273.

Clark, D.J., Sheets, C.G. & Paquette, J.M. (2003) Definitive diagnosis of early enamel and dentin cracks based on microscopic evaluation. *Journal of Esthetic and Restorative Dentistry*, 15(7), 391–401.

Davis, M.C. & Shariff, S.S. (2019) Success and survival of Endodontically treated cracked teeth with radicular extensions: a 2- to 4-year prospective cohort. *Journal of Endodontics*, 45(7), 848–855.

de Toubes, K.M.S., Corrêa, I.S., Valadares, R.C.L., Tonelli, S.Q., Bruzinga, F.F.B. & Silveira, F.F. (2024) Managing cracked teeth with root extension: a prospective preliminary study using biodentine™ material. *International Journal of Dentistry*, 2024, 2234648.

de Toubes, K.M.S., Soares, C.J., Soares, R.V., Côrtes, M.I.S., Tonelli, S.Q., Bruzinga, F.F.B. et al. (2022) The correlation of crack lines and definitive restorations with the survival and success rates of cracked teeth: a long-term retrospective clinical study. *Journal of Endodontics*, 48(2), 190–199.

Derks, H., Westheide, D., Pfefferle, T., Eickholz, P. & Dannewitz, B. (2018) Retention of molars after root-resective therapy: a retrospective evaluation of up to 30 years. *Clinical Oral Investigations*, 22(3), 1327–1335.

Ehrmann, E.H. & Tyas, M.J. (1990) Cracked tooth syndrome. *Australian Dental Journal*, 35(4), 390–391.

European Society of Endodontology. (2014) European Society of Endodontology position statement: the use of CBCT in Endodontics. *International Endodontic Journal*, 47(6), 502–504.

Ferracane, J.L., Hilton, T.J., Funkhouser, E., Gordan, V.V., Gilbert, G.H., Mungia, R. et al. (2022) Outcomes of treatment and monitoring of posterior teeth with cracks: three-year results from the National Dental Practice-Based Research Network. *Clinical Oral Investigations*, 26(3), 2453–2463.

Fugazzotto, P.A. (2001) A comparison of the success of root resected molars and molar position implants in function in a private practice: results of up to 15-plus years. *Journal of Periodontology*, 72(8), 1113–1123.

Fuss, Z., Lustig, J., Katz, A. & Tamse, A. (2001) An evaluation of Endodontically treated vertical root fractured teeth: impact of operative procedures. *Journal of Endodontics*, 27(1), 46–48.

Gao, A., Cao, D. & Lin, Z. (2020) Diagnosis of cracked teeth using cone-beam computed tomography: literature review and clinical experience. *Dento Maxillo Facial Radiology*, 49(5), 20200407.

Gulabivala, K. & Ng, Y.L. (2023) Factors that affect the outcomes of root canal treatment and retreatment-A reframing of the principles. *International Endodontic Journal*, 56, 82–115.

Hilton, T., Mancl, L., Coley, Y., Baltuck, C., Ferracane, J., Peterson, J. et al. (2011) Initial treatment recommendations for cracked teeth in northwest PRECEDENT. *Journal of Dental Research*, 90, 2387.

Hilton, T.J., Funkhouser, E., Ferracane, J.L., Gilbert, G.H., Baltuck, C., Benjamin, P. et al. (2017) Correlation between symptoms and external characteristics of cracked teeth: findings from the National Dental Practice-Based Research Network. *The Journal of the American Dental Association*, 148(4), 246–256.

Hilton, T.J., Funkhouser, E., Ferracane, J.L., Gilbert, G.H., Gordan, V.V., Bennett, S. et al. (2020) Symptom changes and crack progression in untreated cracked teeth: one-year findings from the National Dental Practice-Based Research Network. *Journal of Dentistry*, 93, 103269.

Hilton, T.J., Funkhouser, E., Ferracane, J.L., Gordan, V.V., Huff, K.D., Barna, J. et al. (2018) Associations of types of pain with crack-level, tooth-level and patient-level characteristics in posterior teeth with visible cracks: findings from the National Dental Practice-Based Research Network. *Journal of Dentistry*, 70, 67–73.

Kahler, W. (2008) The cracked tooth conundrum: terminology, classification, diagnosis, and management. *American Journal of Dentistry*, 21(5), 275–282.

Kakka, A., Gavriil, D. & Whitworth, J. (2022) Treatment of cracked teeth: a comprehensive narrative review. *Clinical and Experimental Dental Research*, 8(5), 1218–1248.

Kanamaru, J., Tsujimoto, M., Yamada, S. & Hayashi, Y. (2017) The clinical findings and managements in 44 cases of cracked vital molars. *Journal of Dental Science*, 12(3), 291–295.

Kang, S.H., Kim, B.S. & Kim, Y. (2016) Cracked teeth: distribution, characteristics, and survival after root canal treatment. *Journal of Endodontics*, 42(4), 557–562.

Kim, D.H., Tawil, P.Z., Albouy, J.-P. & Duqum, I. (2024) Retrospective assessment of Endodontically treated teeth replaced by dental implants. *Journal of Endodontics*, 50(3), 310–315.

Kim, J.-H., Eo, S.-H., Shrestha, R., Ihm, J.-J. & Seo, D.-G. (2020) Association between longitudinal tooth fractures and visual detection methods in diagnosis. *Journal of Dentistry*, 101, 103466.

Kishen, A. (2015) Biomechanics of fractures in endodontically treated teeth. *Endodontic Topics*, 33(1), 3–13.

Krell, K.V. & Caplan, D.J. (2018) 12-month success of cracked teeth treated with Orthograde root canal treatment. *Journal of Endodontics*, 44(4), 543–548.

13652591, 2025, 3, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/iej.14186 by sharon patel - King's College London , Wiley Online Library on [17/04/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Krell, K.V. & Rivera, E.M. (2007) A six year evaluation of cracked teeth diagnosed with reversible pulpitis: treatment and prognosis. *Journal of Endodontics*, 33(12), 1405–1407.

Kui, A., Pop, S., Buduru, S. & Negucioiu, M. (2020) The use of occlusal splints in temporomandibular disorders - an overview. *Acta Stomatologica Marisiensis Journal*, 3(2), 3–8.

Lee, J., Kim, S., Kim, E., Kim, K.-H., Kim, S.T. & Jeong Choi, Y. (2021) Survival and prognostic factors of managing cracked teeth with reversible pulpitis: a 1- to 4-year prospective cohort study. *International Endodontic Journal*, 54(10), 1727–1737.

Lee, K., Ahlowalia, M., Alfayate, R., Patel, S. & Foschi, F. (2023) Prevalence of and factors associated with vertical root fracture in a Japanese population: an observational study on teeth with isolated periodontal probing. *Journal of Endodontics*, 49, 1617–1624.

Leong, D.J.X., de Souza, N.N., Sultana, R. & Yap, A.U. (2020) Outcomes of endodontically treated cracked teeth: a systematic review and meta-analysis. *Clinical Oral Investigations*, 24(1), 465–473.

Liao, W.-C., Chen, C.-H., Pan, Y.-H., Chang, M.-C. & Jeng, J.-H. (2021) Vertical root fracture in non-Endodontically and Endodontically treated teeth: current understanding and future challenge. *Journal of Personalized Medicine*, 11(12), 1375.

Liao, W.-C., Tsai, Y.-L., Wang, C.-Y., Chang, M.-C., Huang, W.-L., Lin, H.-J. et al. (2017) Clinical and radiographic characteristics of vertical root fractures in Endodontically and Nonendodontically treated teeth. *Journal of Endodontics*, 43(5), 687–693.

Malentacca, A., Zaccheo, F., Scialanca, M., Fordellone, F., Rupe, C. & Lajolo, C. (2021) Repair of teeth with cracks in crowns and roots: an observational clinical study. *International Endodontic Journal*, 54(10), 1738–1753.

Mirhashemi, A., Khami, M.R., Kharazifard, K. & Bahrami, R. (2022) The evaluation of the relationship between oral habits prevalence and COVID-19 pandemic in adults and adolescents: a systematic review. *Frontiers in Public Health*, 10, 860185. Available from: https://doi.org/10.3389/fpubh.2022.860185

Montoya, C., Arango-Santander, S., Peláez-Vargas, A., Arola, D. & Ossa, E.A. (2015) Effect of aging on the microstructure, hardness and chemical composition of dentin. *Archives of Oral Biology*, 60(12), 1811–1820.

Nocini, R., Lippi, G. & Mattiuzzi, C. (2023) Increased burden of cracked teeth in US and UK during the COVID-19 pandemic: evidence from an infodemiological analysis. *Journal of Dental Sciences*, 18,1398e1399, 1398–1399.

Nosrat, A., Yu, P., Verma, P., Dianat, O., Wu, D. & Fouad, A.F. (2022) Was the coronavirus disease 2019 pandemic associated with an increased rate of cracked teeth? *Journal of Endodontics*, 48(10), 1241–1247.

Olivieri, J.G., Elmsmari, F., Miró, Q., Ruiz, X.-F., Krell, K.V., García-Font, M. et al. (2020) Outcome and survival of Endodontically treated cracked posterior permanent teeth: a systematic review and meta-analysis. *Journal of Endodontics*, 46(4), 455–463.

Opdam, N.J.M., Roeters, J.J.M., Loomans, B.A.C. & Bronkhorst, E.M. (2008) Seven-year clinical evaluation of painful cracked teeth restored with a direct composite restoration. *Journal of Endodontics*, 34(7), 808–811.

Pan, X., Tang, R., Gao, A., Hao, Y. & Lin, Z. (2022) Cross-sectional study of posterior tooth root fractures in 2015 and 2019 in a Chinese population. *Clinical Oral Investigations*, 26(10), 6151–6157.

Patel, S., Bhuva, B. & Bose, R. (2022) Present status and future directions: vertical root fractures in root filled teeth. *International Endodontic Journal*, 55(S3), 804–826.

Patel, S., Brown, J., Semper, F., Abella, F. & Mannocci, F. (2019) European Society of Endodontology position statement: use of cone beam computed tomography in endodontics: European Society of Endodontology (ESE) developed by. *International Endodontic Journal*, 52(12), 1675–1678. Available from: https://doi.org/10.1111/iej.13187

PradeepKumar, A.R., Shemesh, H., Jothilatha, S., Vijayabharathi, R., Jayalakshmi, S. & Kishen, A. (2016) Diagnosis of vertical root fractures in restored Endodontically treated teeth: a time-dependent retrospective cohort study. *Journal of Endodontics*, 42(8), 1175–1180.

Ricucci, D., Siqueira, J.F., Jr., Loghin, S. & Berman, L.H. (2015) The cracked tooth: histopathologic and Histobacteriologic aspects. *Journal of Endodontics*, 41(3), 343–352.

Rivera, E.M. & Walton, R.E. (2015) Longitudinal tooth cracks and fractures: an update and review. *Endodontic Topics*, 33(1), 14–42.

Schürz, A., Gehrig, H., Schuessler, D.L. & Mente, J. (2020) Preservation of a split tooth: nonsurgical clinical management. *Journal of Endodontics*, 46, 1002–1008.

Shehri, Z.G., Alkhouri, I., Hajeer, M.Y., Haddad, I. & Abu Hawa, M.H. (2022) Evaluation of the efficacy of low-dose botulinum toxin injection into the masseter muscle for the treatment of nocturnal bruxism: a randomized controlled clinical trial. *Cureus*, 14(12), e32180.

Signore, A., Benedicenti, S., Covani, U. & Ravera, G. (2008) A 4- to 6-year retrospective clinical study of cracked teeth restored with bonded indirect resin composite onlays. *The International Journal of Prosthodontics*, 20(6), 609–616.

Sim, I.G.B., Lim, T.-S., Krishnaswamy, G. & Chen, N.-N. (2016) Decision making for retention of Endodontically treated posterior cracked teeth: a 5-year follow-up study. *Journal of Endodontics*, 42(2), 225–229.

Touré, B., Faye, B., Kane, A.W., Lo, C.M., Niang, B. & Boucher, Y. (2011) Analysis of reasons for extraction of Endodontically treated teeth: a prospective study. *Journal of Endodontics*, 37(11), 1512–1515.

von Arx, T., Maldonado, P. & Bornstein, M.M. (2021) Occurrence of vertical root fractures after apical surgery: a retrospective analysis. *Journal of Endodontics*, 47(2), 239–246.

Walton, R.E. (2017) Vertical root fracture: factors related to identification. *The Journal of the American Dental Association*, 148(2), 100–105.

Walton, R.E., Michelich, R.J. & Smith, G.N. (1984) The histopathogenesis of vertical root fractures. *Journal of Endodontics*, 10, 48–56.

Wang, P., He, W., Sun, H., Lu, Q. & Ni, L. (2012) Detection of vertical root fractures in non-endodontically treated molars using cone-beam computed tomography: a report of four representative cases. *Dental Traumatology*, 28(4), 329–333.

Wang, P. & Su, L. (2009) Clinical observation in 2 representative cases of vertical root fracture in nonendodontically treated teeth. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics*, 107(4), e39–e42.

Wu, S., Lew, H.P. & Chen, N.N. (2019) Incidence of pulpal complications after diagnosis of vital cracked teeth. *Journal of Endodontics*, 45(5), 521–525.

Yang, S.-E., Jo, A.R., Lee, H.-J. & Kim, S.-Y. (2017) Analysis of the characteristics of cracked teeth and evaluation of pulp status

13652591, 2025, 3, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/iej.14186 by sharon patel - King's College London , Wiley Online Library on [17/04/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

according to periodontal probing depth. *BMC Oral Health*, 17(1), 135.

Yang, S.-F., Chen, Y.-W., Tsai, C.-L., Cheng, H.-C., Wu, S.-L., Tamse, A. et al. (2023) Incidence and contributing factors of non-root canal treated teeth with chronic fatigue root fracture: a cross-sectional study. *Journal of the Formosan Medical Association*, 122(12), 1338–1344.

Yang, S.-F., Rivera, E.M. & Walton, R.E. (1995) Vertical root fracture in nonendodontically treated teeth. *Journal of Endodontics*, 21(6), 337–339.

Yeh, C.J. (1997) Fatigue root fracture: a spontaneous root fracture in non-endodontically treated teeth. *British Dental Journal*, 182(7), 261–266.

Yoshino, K., Ito, K., Kuroda, M. & Sugihara, N. (2015) Prevalence of vertical root fracture as the reason for tooth extraction in dental clinics. *Clinical Oral Investigations*, 19(6), 1405–1409.

Zadik, Y., Sandler, V., Bechor, R. & Salehrabi, R. (2008) Analysis of factors related to extraction of endodontically treated teeth. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics*, 106(5), e31–e35.

Zhang, S., Xu, Y., Ma, Y., Zhao, W., Jin, X. & Fu, B. (2024) The treatment outcomes of cracked teeth: a systematic review and meta-analysis. *Journal of Dentistry*, 142, 104843.

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