The cracked tooth conundrum: Terminology, classification, and management

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ABSTRACT: Purpose: To provide an overview of the clinical features, diagnosis, classification and management of cracked teeth which may be a diagnostic challenge in clinical practice. **Results:** Cracks may initiate from coronal tooth structure or from within the root and affect healthy or root treated teeth. There are many terminologies and classifications in the literature for cracked teeth that can be as confusing as the array of clinical symptoms which are associated with this condition. The term "cracked tooth syndrome" is misleading as there are a range of symptoms that do not form a distinct and reliable pattern. Symptoms will vary with teeth that have healthy pulps, for teeth with inflamed or necrotic pulps, and for teeth that have been root treated. The American Association of Endodontists have classified five specific variations of cracked teeth; craze line, fractured cusp, cracked tooth, split tooth, and vertical root fracture. The importance of differentiating dentin, pulpal and periodontal pain for diagnosis and treatment for these specific entities will be elaborated. A decision flow chart indicating the treatment options available is presented. (*Am J Dent* 2008;21:275-282).

CLINICAL SIGNIFICANCE: A cracked tooth should be considered in the diagnosis of teeth which are sensitive to bite and thermal change. The American Association of Endodontists classification of cracked teeth is useful, though non-vital and root filled cracked teeth and teeth with periapical pathosis should be also considered in forming a diagnosis.

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Introduction

Cracked or incompletely fractured teeth can become symptomatic. Patients often present with a protracted history of pain of varying intensity; the origin of which may be difficult to locate. While intermittent pain on biting is the most consistent complaint associated with these teeth, cracks in teeth may result in a wide range of symptoms ranging from occasional discomfort to severe and prolonged pain. Symptoms are often dependent on the depth and direction of the crack and the tissues involved.

Cracks in teeth may occur in both horizontal and vertical directions involving the crown and/or root. The etiology is generally a result of occlusal forces and iatrogenic procedures.[1] Crown and crown-root fractures are usually incomplete fractures commencing in the crown of posterior teeth from an internal line angle at the floor of a restoration, and often involving a marginal ridge with the fracture extending in a mesiodistal direction. The fracture commences in the crown and may terminate in the vicinity of the cemento-enamel junction or extend apically into the root.[2-6] Vertical root fractures are longitudinally orientated fractures of the root that extend from the root canal to the periodontium.[7] These fractures are usually complete and extend a variable length along the root generally in a bucco-lingual direction and may extend into the crown.[4,8-10]

This paper reviewed the literature for an appropriate classification for cracked teeth and to determine the symptoms and processes that allow for correct diagnosis and treatment.

TERMINOLOGY AND DEFINITION

Many authors have proposed different terminologies and definitions for cracks in teeth (Table 1). Gibbs[11] first described the clinical symptoms of incomplete fracture of posterior teeth involving the cusp, naming it "cuspal fracture odontalgia".

Cameron[2,12] coined the term "cracked tooth syndrome" in describing signs and symptoms associated with cracked teeth. However, there is considerable overlap and confusion in these proposals. For instance, cracked tooth syndrome has been defined as an "incomplete fracture of a vital posterior tooth involving the dentin and possibly the dental pulp"[13] despite the fact that Cameron[12] reported that only 75% of teeth with "cracked tooth syndrome" will have vital pulps. Many authors confuse the terminology by illustrating teeth with "cracked tooth syndrome" which are in fact teeth with vertical root fractures.[14] The term "cracked tooth syndrome" is misleading as there are a range of symptoms that do not form a distinct and reliable pattern. Symptoms will vary with teeth that have healthy pulps, for teeth with inflamed or necrotic pulps, and for teeth that have been root treated.

Ellis[15] defined incomplete tooth fracture as a "fracture plane of unknown depth and direction passing through tooth structure that, if not already involving, may progress to communicate with the pulp and/or periodontal ligament". Cracks in teeth can be found in symptomatic and asymptomatic teeth, and are an etiological factor in pulpal disease. This can be a direct result of fracture extension to involve the pulp chamber as bacteria have been reported to be present in cracks,[16,17] or, indirectly *via* the microleakage of bacterial toxins.[18]

CLASSIFICATION

Several authors have proposed classifications which are generally based on either the type or location of the crack, the direction and extent of the crack, and/or the risk of symptoms and/or pathological processes (Table 2).

The American Association of Endodontists, in a document titled "Cracking the Cracked Tooth Code"[40] identified five types of cracks in teeth which can be viewed at http://www.aae.org/dentalpro/colleaguenews.htm and are briefly described in Table 3.

Table 1. Terminology and definitions for cracks/fractures in teeth.

Year	Author(s)	Terminology	Definition
1954	Gibbs[11]	Cuspal fracture odontalgia	
1954	Thoma[19]	Fissured fracture	A crack in the crown of the tooth
1957	Ritchey et al[20]	Incomplete tooth fracture	
1957	Down[21]	Fissural fracture	Fractures involving enamel and dentin without loss of tissue
1961	Sutton[22]	Crack lines	A break in the continuity of the tooth revealed only by the presence of a visible transverse line
1962	Sutton[23]	Greenstick fractures	A fracture line forms in a part of a tooth underlying a cusp
1964	Cameron[2]	Cracked tooth syndrome	
1972	Wiebusch[24]	Hairline fracture	
1973	Hiatt[3]	Incomplete crown-root fracture	
1974	Talim & Gohi[25]	Incomplete coronal fracture	
1976	Silvestri[26]	Split-root syndrome	
1977	Maxwell & Braly[27]	Incomplete tooth fracture	A fracture of tooth structure which extends into dentin but in which the tooth remains grossly intact
1981	Andreasen[28]	Enamel infraction	An incomplete fracture (crack) of the enamel without loss of tooth substance
1981	Caufield[29]	Hairline tooth fracture	
1981	Johnson[30]	Crown craze/crack	Injury of enamel without loss of enamel
1983	Abou-Ras[31]	Tooth structure cracks	A line that breaks or splits the continuity of tooth dentin surface but does not perceptibly separate the surface
1983	Abou-Rass[31]	Crack/craze lines	Located in coronal enamel
1984	Luebke[32]	Incomplete tooth fracture	A demonstrable fracture but with no visible separation of the segments along the plane of fracture
1984	Kruger[33]	Cracked cusp syndrome	
1986	Brännström[18]	Dentin crack syndrome	
1988	Williams[34]	Incomplete vertical tooth fracture	
1989	Lost et al[35]	Tooth infraction	
1989	Schweitzer[36]	Odontiatrogenic tooth fracture	
1990	Ehrmann & Tyas[13]	Cracked tooth syndrome	Incomplete fracture of a vital posterior tooth involving the dentin and possibly the dental pulp
1998	Zuckerman[37]	Cracked tooth	Fractured segments are still joined to one another by a portion of that tooth through which the fracture has not yet extended
2001	Ellis[15]	Incomplete tooth fracture	A fracture plane of unknown depth and direction passing through tooth structure that, if not already involving, may progress to communicate with the pulp and/or periodontal ligament

Table 3. American Association of Endodontists classification of cracked teeth.

Classification	Originate	Direction	Symptoms	Pulp Status	Prognosis
Craze Line	Crown	Variable	None	Vital	Excellent
Fractured cusp	Crown	M-D and/or F-L	Mild and generally, only to biting and cold	Usually vital	Good
Cracked tooth	Crown±Root	M-D often Central	Acute pain on biting Occasionally sharp pain to cold	Variable	Questionable: Dependent on depth and extent of the crack
Split tooth	Crown+Root	M-D	Marked pain on chewing	Often root filled	Poor unless crack terminates just subgingivally
Vertical root fracture	Roots	F-L	Vague pain Mimics periodontal disease	Mainly root filled	Poor: Root resection in multi-rooted teeth

Craze lines are found in the majority of adult teeth and only involve enamel. In posterior teeth, craze lines are usually evident crossing marginal ridges and/or extending along buccal and lingual surfaces. Long vertical craze lines are often found in anterior teeth (Fig. 1).

Fractured cusps usually result from insufficient cusp support when the marginal ridge is weakened by an intra-coronal restoration (Fig. 2). The crack often extends in mesio-distal and bucco-lingual directions commonly involving one or both marginal ridges as well as a buccal or lingual groove and terminates in the cervical region either parallel to the gingival margin or slightly subgingival.

A cracked tooth is indicative of a crack extending from the occlusal surface of the tooth apically without separation of the two segments. The crack is generally located centrally in a mesio-distal direction and may involve one or both marginal ridges (Fig. 3).

A split tooth is indicative of a crack extending through both marginal ridges usually in a mesio-distal direction splitting the tooth completely into two separate segments (Figs. 4a-c). The crack is generally located centrally in the tooth and this entity is the result of crack propagation of a cracked tooth.

Vertical root fractures commence in the root generally in a bucco-lingual direction (Figs. 5a-b). The crack is generally complete though may be incomplete and involve only one surface. The crack may involve either the entire root or only a portion of the root.

The American Association of Endodontists classification identifies four types of cracks that that are located in the crown-root as well as vertical root fractures that originate from the

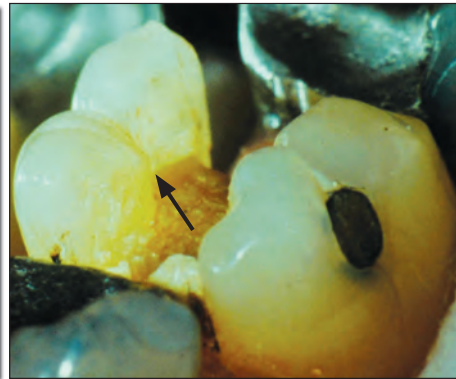Fig. 1. Craze lines in enamel are evident.

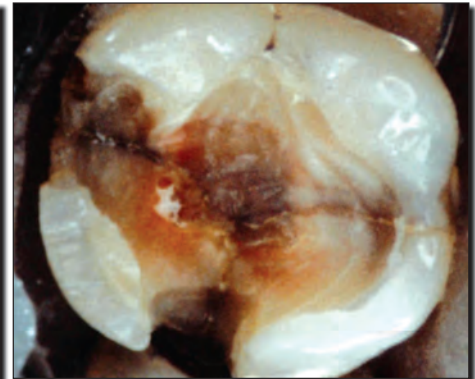Fig. 2. A fractured cusp is located at the base of the cavity (arrow).

Fig. 3. A cracked tooth is shown where there is a mesio-distal crack without separation of the segments.

Table 2. Proposed classifications for cracked teeth.

Pruden[38]

A. Crack line
   1. No separation of parts, no pain symptoms
   2. No apparent separation, but tooth sensitive to percussion-or patient
      has persistent, vague pain not definitely related to the tooth
B. Fractured cusp
   1. No pain or pulp involvement
   2. Possible pulp involvement
C. Fractured crown
   1. No pulpal involvement
   2. Pulp involved
D. Fractured root tip

Talim & Gohil[25]

Class 1 - Fracture involving enamel
   a. Horizontal or oblique
   b. Vertical
      1. Complete
      2. Incomplete
Class 2 - Fracture involving enamel and dentin without involving pulp
   a. Horizontal or oblique
   b. Vertical
      1. Complete
      2. Incomplete
Class 3 - Fracture of enamel and dentin involving the pulp
   1. Horizontal
   2. Vertical
      1. Complete
      2. Incomplete
Class 4 - Fracture of the roots
   a. Vertical or oblique
      1. Involving the pulp
      2. Not involving the pulp
   b. Horizontal
      1. Cervical third
      2. Middle third
      3. Apical third

Luebke[32]

Class 1 -   Incomplete, supra-osseous with no periodontal defect
Class 2 -   Incomplete, intra-osseous with a minor periodontal defect
Class 3 -   Complete or incomplete, intra-osseous with a major
            periodontal defect

Williams[34]

Category 1 – Incomplete vertical fracture through enamel into dentin
            but not into pulp
Category 2 – Incomplete crown fracture involving the pulp
Category 3 - Incomplete vertical fracture crossing the attachment
Category 4 – Fracture divides the tooth completely

Clark *et al*[39]

Type 1 Cracks – Little or no risk of underlying pathology
Type 2 Cracks – Moderate risk of underlying pathology
Type 3 Cracks – High risk of underlying pathology

root. For the purpose of this review, the four coronal fractures will be considered together to assess aspects of tooth fracture such as diagnosis, causes, mechanisms and treatment of fractured teeth.

INCIDENCE

The presence of a cracked tooth occurs primarily in adulthood. Cameron[2] reported that 80% of 102 cracked teeth occurred with patients over 40 years of age. Other reports[3,12,31,42-45] about the incidence and prevalence of cracked teeth were commonly associated with intracoronal restorations and most prevalent in mandibular molars. The wedging effect of the prominent mesio-palatal cusp of the maxillary first molar may account for this observation.[3,43] The transverse ridge of the maxillary molars may provide structural reinforcement and account for the lower incidence of fracture in these teeth.[3] The maxillary molars and premolars have a similar incidence of fracture, with the mandibular premolars being the least susceptible.[30,42-44]

The disto-lingual cusp of mandibular molars is the most susceptible cusp for fracture. The findings for the prevalence of cusp fracture in other teeth were not consistent.[42,44-45] Non-functional cusps may be more susceptible to fracture than functional cusps.[42,45] This observation may be a result of cuspal dimension as functional cusps are significantly larger in a bucco-lingual dimension and are covered with a thicker layer of enamel.[46] While functional cusps are supported on the inner and outer inclines by the opposing tooth, non functional cusps may be more susceptible to fracture from lateral excursive occlusal forces due to the lack of support from the outer incline.[45] Molar non functional cusps were found to have a steeper cuspal incline. As the cuspal inclines are the guiding planes for lateral excursive movements for group function occlusal relationships, these cusps may be subjected to greater occlusal forces. If other teeth in the arch have been restored with flatter cuspal inclines, then the steeper cusps are further exposed.[46] Over-carving of a restoration during placement, with loss of appropriate occlusal contact can result in the extrusion of a tooth, altering the cusp-fossae relationship and resulting in fracture of the non-functional cusp. However, the fracture of cusps, whether functional or non-functional, is primarily associated with large intra-coronal restorations and carious lesions.[27,42,47]

CLINICAL SYMPTOMS

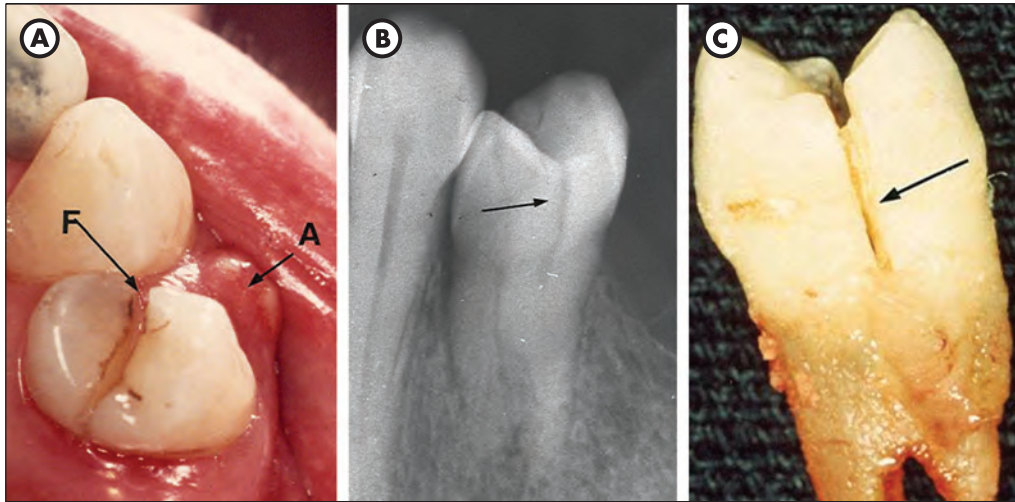The clinical signs and symptoms may vary according to the

Fig. 4**A.** A split tooth where the mesio-distal fracture has resulted in separation of the segments. **B.** A radiograph of the tooth in Fig. 4A where the fracture is clearly seen. **C.** Separation of the fragments resulting in the split tooth is shown (arrow).
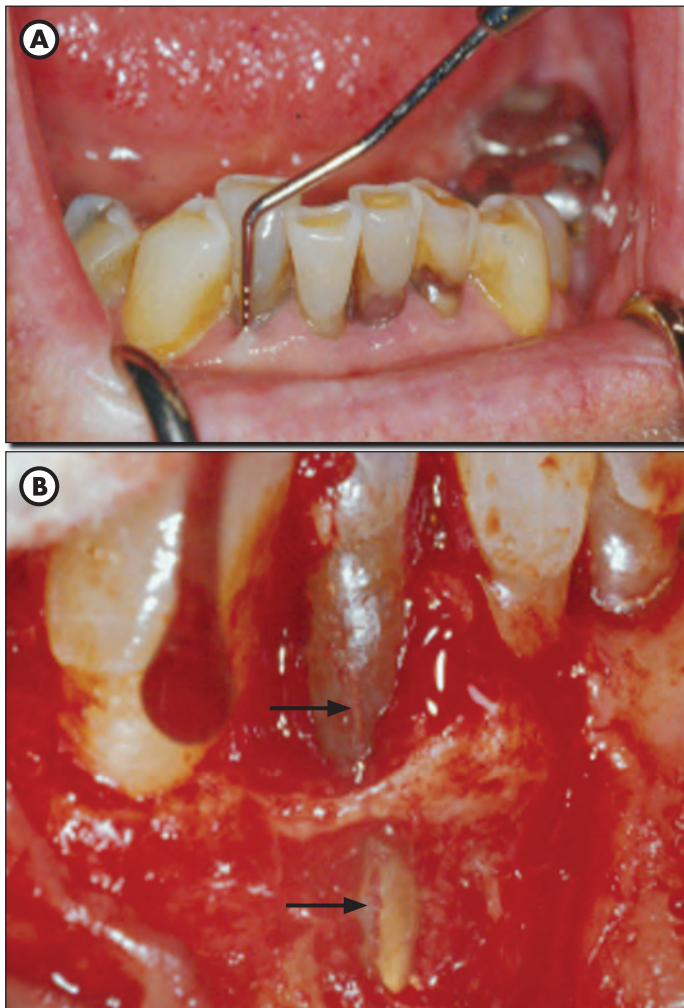

Fig. 5**A.** A deep and narrow periodontal defect is located with a probe on the buccal aspect of the right mandibular incisor. **B.** Surgical exposure confirms the presence and extent of the vertical root fracture (arrows).

position and extent of the incomplete fracture.[13,43,48] Classically, the symptoms related to these teeth are pain on biting and sensitivity to thermal changes, particularly cold.[2,3,11,13,18,31,49,50] Pain associated with the release of pressure, 'rebound pain' is also a consistent finding.[12,13,18] Occasionally, there is sensitivity

to sweets.[3,51] A chronic pulpitis with no clinical symptoms can exist as a result of microleakage of bacterial by-products and toxins. Pulpal and periodontal symptoms may occur when the fracture extends to involve the pulp.[16,53]

DIAGNOSIS

A provisional diagnosis can generally be attained by a thorough history of the complaint. Early diagnosis is important, as restorative intervention can limit propagation of the fracture, subsequent microleakage and involvement of the pulpal or periodontal tissues, or catastrophic failure of the cusp.[54] The ease of diagnosis will vary according to the position and extent of the fracture.[13,43] Dentin fractures are not generally evident radiographically, although radiographs are necessary to assess for caries, periapical status and the presence of periodontal lesions.[13,31] Rubber dam isolation of the suspected tooth, and the application of cold or hot water are recommended. Once the tooth is identified, the offending cusp can be located by controlled wedging so as to load test individual cusps.[2,13,31,43] A "Tooth Slooth[a]" is an appropriate instrument. When the tooth and cusp have been identified, the tooth can be anesthetized and all restorations removed to allow a thorough visual inspection so as to identify the position and extent of the fracture. The use of dyes, microscopes and transillumination are useful guides. Pulp sensibility testing of the tooth may be indicative of pulpal pathology. A tooth with an incomplete fracture may not be tender to percussion in a tooth with a healthy pulp.[13,31]

MECHANISM OF PAIN

The character, duration and the stimuli of pain has important implications for both diagnosis and treatment.[55] An understanding of the mechanism of pain will often aid in assessment of the extent and direction of the crack. Luebke[32] suggested the following terms to diagnose pain from a cracked tooth:

1. Dentin pain - A brief, sharp twinge.
2. Pulpal pain - The deep, demanding, radiating pain precipitated by thermal shock to an inflamed pulp. The pain at times may be spontaneous.
3. Periodontal pain - The aggravating throbbing of a sore tooth.

The pain associated with an incomplete fracture of a cusp is

generally accepted to be due to the rapid movement of dentin fluid in the dentin tubules according to the "Hydrodynamic theory of dentin sensitivity" as proposed and investigated by Brännström.[16,18] Thermal changes, air, evaporation, osmotic stimuli such as sucrose, and increases in hydrostatic pressure caused by cuspal flexure as a result of occlusal forces can all act as stimuli for the rapid movement of dentin fluid. This movement stimulates A-delta nerve fibers in the vicinity of the odontoblastic processes and the pulp-dentin border, resulting in a sharp pain of short duration indicative of a vital tooth. Rebound pain, indicative of a vital tooth, is similarly explained when the pressure is released from the cusp as the tooth is free of the occlusion.[16,18] When bacterial toxins have infiltrated the pulp, "hyperalgesia" can result. With this condition A-delta fibers are stimulated producing a sharp pain of short duration at what appears as a lower threshold than normal. The pain is due to the rapid movement of dentin fluid and probably a result of slight pulpal inflammation. During inflammation, the stimulation threshold of the A-delta fibers is lowered.[56]

A second type of pulpal pain is produced by the stimulation of C-fibers as a response to inflammation, heat and mechanical deformation. A dull, poorly localized ache is often the result.[57] Alternatively, the pain can be a dull, aching pain with a continuous throbbing nature, or arise spontaneously and last for minutes or hours.[55] The C-fibers are activated by inflammatory mediators as a result of pulpal inflammation or prolonged application of heat.[58]

A tooth with a painful pulpitis can present with a severe, sharp pain, indicative of A-delta fiber activation followed by a prolonged, dull ache that radiates throughout the jaw, indicative of C-fiber activation as well.[55] The C-fibers are resistant to tissue anoxia and can remain responsive long after the A-delta fibers.[59] A tooth with an incomplete fracture exhibiting C-fiber activation is strongly suggestive of pulpal damage and may require root canal treatment.

VERTICAL ROOT FRACTURE

The clinical presentation of a vertical root fracture is variable. Teeth with vertical root fractures often present with a history of discomfort and localized chonic inflammation. Patients may complain of a bad taste and pain on biting. If swelling is present it is generally broad-based and any sinus tract is located in or close to the attached gingiva rather than in the apical area. Double or multiple sinus tracts are common.[7] A common feature of vertically root fractured teeth is the presence of a narrow periodontal pocket adjacent the fracture. Deep probing in two positions on opposite sides is almost pathognomonic for the presence of a fracture. The probing pattern for a tooth with a vertical root fracture is different from that seen with teeth with periodontal disease, where the pocketing is fairly consistent in depth around a large portion of the tooth.[7,60]

The radiographic appearance of teeth with vertical root fractures is variable dependent on the angulation of X-ray beam in relation to the plane of the fracture and the degree of separation of the fragments. When separation of the root fragments has occurred, the root fracture is clearly visible. Alternatively, the radiographic image may show fracture lines along the root or root fillings, a space beside a root filling or

post, double images, radiolucent halos, unexplained bifurcation bone loss, J-shaped radiographic appearance, step-like bone defects, a widening of the periodontal ligament space, isolated horizontal bone loss in posterior teeth, V-shaped diffuse bone loss on roots of posterior teeth or dislodgement of a retrograde filling material.[7,60]

While clinical and radiographic signs give a reasonably clear indication of the presence of a fracture, direct observation of the fracture is often required to confirm the presence of a fracture in many instances. This may involve a surgical approach and the use of transillumination is a useful diagnostic aid.

MANAGEMENT OF CRACKED TEETH

Coronal fracture

Management of cracked teeth should involve recognition of predisposing factors, recognition of signs and symptoms and the provision of adequate restorations that protect the tooth from fracture.[47] Early diagnosis is most important in the management of incomplete fracture so as to limit the propagation of the crack, subsequent microleakage and involvement of the pulpal and periodontal tissues.[2,3,13,54] The treatment requirement of a cracked tooth is dependent on the position and extent of the fracture.[13,43,61] An assessment of the stimuli, character and duration of the pain is also an influential guide for treatment.[55] As discussed, Luebke[32] suggested pain from a cracked tooth be considered as dentin, pulpal or periodontal in character.

Cracks that enter the pulp indicate the need for root canal treatment though Bader et al[62] reported that the majority of tooth fractures do not result in either pulp or tooth loss and can be managed successfully in a single visit using direct restorative materials. A multi-disciplinary approach involving endodontic, periodontic, orthodontic, prosthodontic and surgical intervention may be required.[7] Fractures that involve the periodontal attachment may require extraction, though hemisection or root amputation may be appropriate for some multi-rooted teeth.[7,63] However, teeth with cracks that are intraosseous with periodontal type pain often involving the mesial and distal aspects of the tooth and the cavity floor have a hopeless prognosis.[64,65] A decision flow cart for the different classifications of cracked teeth can be seen in Fig 6.

Gutmann & Rakusin[65] suggested that treatments consist of an initial investigative and sedative stage followed by definitive treatment and restoration. Initial treatment involves the removal of all existing restorations to fully assess the extent of the fracture. Transillumination is a useful guide.[31] In the initial diagnostic phase, the use of copper or stainless steel bands,[13,43,49] stainless steel crowns,[48] and acrylic resin crowns[67] have been advocated. Placement of a sedative temporary restoration is not advised as this approach does not stabilize the fracture leaving the tooth susceptible for further extension of the crack.[68]

In the absence of irreversible pulpitis, many techniques have been described to bind or remove the fracture so as to prevent flexure of the cusp, crack propagation and bacterial microleakage. Definitive treatment has included pin retained amalgams,[61,64] bonded amalgams,[52,69] bonded composites,[70-73] cusp overlay restorations,[74-76] and full coverage crowns.[12,13,43,67]
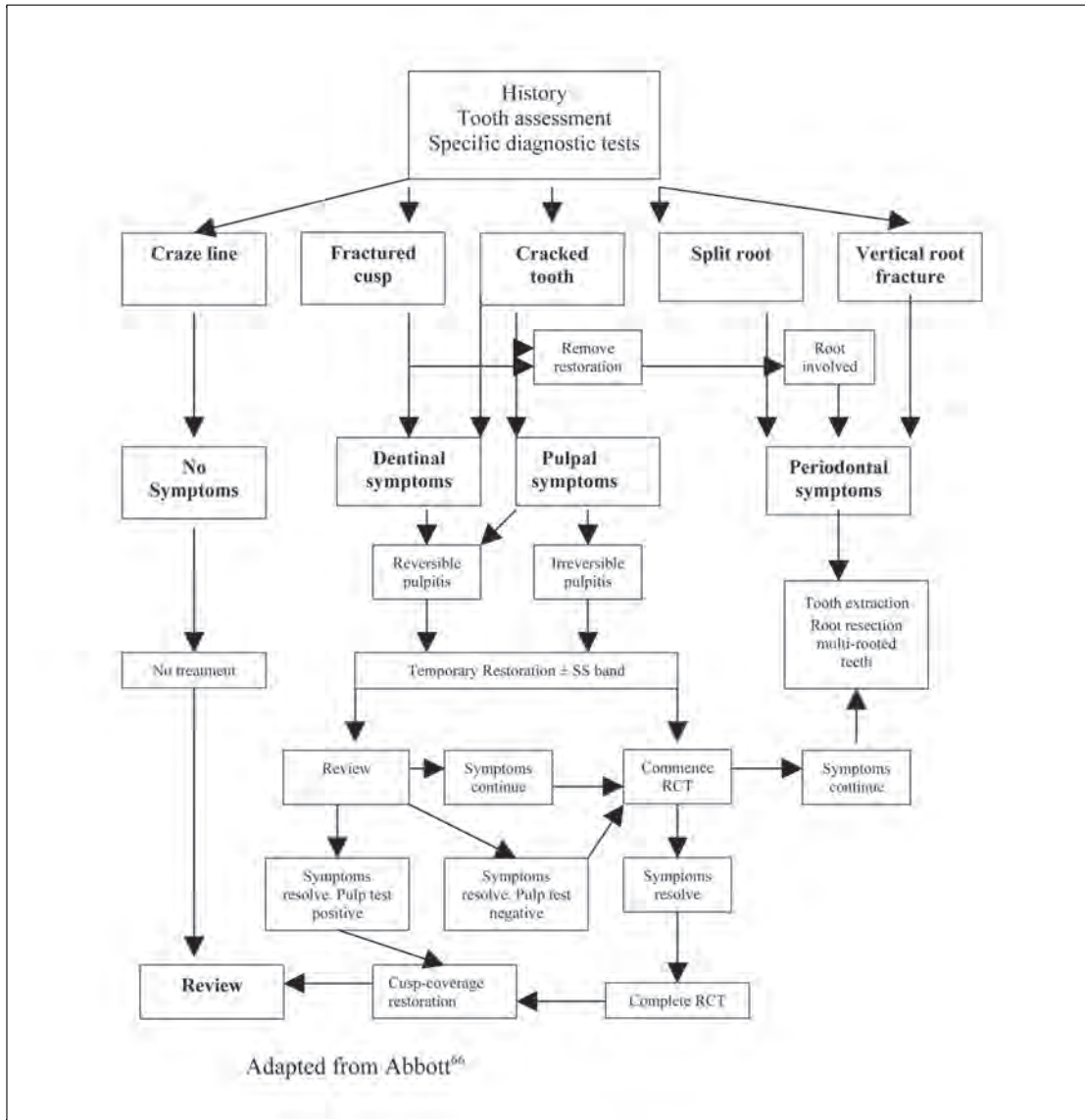
Fig. 6. Treatment flow chart for AAE classification of cracked teeth. Adapted from Abbott.[66]

Teeth restored with cuspal amalgam overlays had fracture energies, measured as the force required to fracture, equal to that of an intact tooth whereas gold crowns increased the fracture energy by more than three-fold.[77]

Clark & Caughman[64] have categorized the prognosis of cracked teeth as excellent, good, poor and hopeless.

1. Excellent: (a) Cuspal fracture confined within the dentin that angles from the facio-pulpal or linguo-pulpal line angle of a cusp to the cemento-enamel junction or slightly below. (b) Horizontal fracture of a cusp not involving the pulp.

2. Good: A coronal vertical fracture that runs mesio-distally into the dentin but not into the pulp.

3. Poor: A coronal vertical fracture that runs mesio-distally into the dentin and pulp but is confined to the crown.

4. Hopeless: A coronal vertical fracture that runs mesio-distally through the pulp and extends into the root.

The provision of an acrylic splint is recommended for prevention of further fractures in patients with parafunctional occlusal activity or a history of incomplete fracture in other teeth.[50]

Vertical root fracture

Single-rooted teeth that are fractured should be extracted as soon as is practical to prevent further bone loss. Multi-rooted teeth can often be successfully treated by resecting the fractured root, either by root amputation or hemisection.[78] Studies of root resected teeth have reported 5-year retention rates of 94%[79] and 10-year retention rates of 68%.[80] However, the desire to retain part of a root fractured tooth should be carefully considered against extraction and replacement with a denture, bridge or implant.

SUMMARY

The clinical features, diagnosis and management of cracked teeth have been reviewed. Fractures may initiate from coronal tooth structure or from within the root. There are many terminologies and classifications in the literature for cracked teeth which can be as confusing as the array of clinical symptoms that are associated with this condition. The term "cracked tooth syndrome" is misleading as there are a range of symptoms that do not form a distinct and reliable pattern. Symptoms will vary with teeth that have healthy pulps, for

teeth with inflamed or necrotic pulps, and for teeth that have been root filled.

The American Association of Endodontists has classified five specific variations of cracked teeth; craze line, fractured cusp, cracked tooth, split tooth, and vertical root fracture. Furthermore, the character, duration and the stimuli of pain have important implications for both diagnosis and treatment. Diagnostically, it is important to differentiate the differences between dentin, pulpal and periodontal pain before treatment is commenced. Early diagnosis is most important in the treatment of cracked teeth to limit the propagation of the crack. A decision flow chart indicating the treatment options available has been presented to clarify the cracked tooth conundrum.

a.   Professional Results, Inc., Laguna Niguel, CA, USA.

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