Diagnosis, therapy, and prevention of the cracked tooth syndrome

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Many morphologic, physical, and iatrogenic factors, such as deep grooves, pronounced intracranial temperature fluctuation, poor cavity preparation design, and wrong selection of restorative materials, may predispose posterior teeth to an incomplete fracture. The resulting cracked tooth syndrome is frequently associated with bizarre symptoms that may complicate diagnosis and can persist for many years. Epidemiologic data reveal that splits or fractures are the third most common cause of tooth loss in industrialized countries, primarily affecting maxillary molars and premolars and mandibular molars. This finding indicates that the cracked tooth syndrome is of high clinical importance. Thus, at-risk teeth should be reinforced early, for instance by castings with cusp coverage or by internal splinting with adhesive ceramic restorations.

Key words: cracked tooth, diagnosis, etiology, prevention, therapy

Many innovative restorative techniques and materials have been introduced into operative dentistry during the past two decades, such as ultraconservative cavity preparation, modern dentin adhesives, hybrid-type resin composites, ceramic inserts, and inlays. In addition, adhesive techniques, like the acid-etch technique and dentin bonding have been considerably improved. Altogether, it may be concluded that the spectrum of modern restorative therapy has been significantly extended.

On the other hand, however, these modern techniques require much more time to be done compared to amalgam restorations, etc. Another problem that also arises is the increasing number of very large cavities in posterior teeth that are adhesively restored using hybrid-type resin composites or compomers. But it must be considered that these restorations often cannot resist physiologic loads. Thus, those overloaded teeth frequently split.

Initially, the resulting cracks are incomplete and invisible in most cases, which may make diagnosis very difficult. Sooner or later, however, the vast majority of these unidentified "greenstick fractures" progress toward a complete crack, which could severely complicate a new restoration or even require the extraction of the tooth.

CLINICAL MANIFESTATION

The cracked tooth syndrome is defined as the incomplete fracture of the natural crown of a premolar or molar tooth. Gibbs in 1954 was the first author to describe an incomplete fracture in the dental literature, using the term cuspal fracture odontalgia. In 1957, Ritchey et al reported various cases of incomplete fracture with subsequent pulpitis. Finally, Cameron created the common term cracked tooth syndrome in 1964. Occasionally, greenstick fracture or split tooth syndrome are synonymously used by several authors.

Incomplete tooth cracks generally run in a mesiodistal direction (Figs 1, 2c, and 3a). Rarely horizontal, horizontal-vertical, or orovestibular cracks have been observed (Figs 4 and 5). Incomplete cracks

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are either limited to the crown or may also include the root. Combined fractures are called split root syndrome (Figs 2 and 6 to 8). Initial cracks are usually limited to the coronal area of the crown without inclusion of the pulp (Figs 1 and 3a).}

**EPIDEMIOLOGY**

Most incompletely fractured teeth are restored. However, the share of caries-free and nonrestored teeth is amazingly high (see Fig 1). Their percentage varies between 13% and 35%. In particular, mandibular molars are affected (Table 1; Figs 2, 5, and 9). It is hypothesized that the maxillary molars are more resistant to partial cracks than mandibular molars due to their stabilizing occlusal oblique ridge. In addition, loading of mandibular molars during mastication is higher than in maxillary molars. Further, a potential "wedging effect" of the prominent mesiopalatal cusp of maxillary molars may predispose the mandibular molars for incomplete cracks. This was confirmed by a recent clinical study in which the maxillary molars and premolars and mandibular molars were much more frequently affected by a cracked tooth syndrome than mandibular premolars (Table 1).
Various authors investigated a potential connection between a patient's age and the prevalence of incompletely fractured teeth. Contradictory data were reported: Cameron determined that predominantly persons older than 50 years suffer from a cracked tooth syndrome, whereas Hiatt and Talim and Gohil reported the maximum number of split teeth to be in patients between the ages of 40 and 49. On the contrary, Fitzpatrick observed that incomplete fractures primarily occurred in people between the ages of 30 and 39. These findings indicate that more and more younger patients are affected by a cracked tooth syndrome.

Additionally, Cameron and Fitzpatrick reported that female patients more frequently had incomplete fractures. On the contrary, Dewberry found little difference in sex distribution, with slightly more cracks occurring in male patients (52.3%). Recently, it was reported that 20% of the participants in the Florida Dental Care Study who were examined during a 2-year period sustained a tooth fracture (Fig 2).
Fig 6  Extracted maxillary molar revealing a split root syndrome.

Fig 7a  (top left) Clinical view of a maxillary first premolar with a pronounced buccal abscess.

Fig 7b  (top right) Radiologically, the premolar reveals signs of an initial circumferential periodontal breakdown which is indicative of a split root syndrome.

Fig 7c  (bottom left) First premolar after extraction revealing a split root, very likely due to an overzealous lateral condensation of the gutta-percha root canal fillings.

Fig 7d  (bottom right) Cross section in the middle of the root. The crack penetrates the root completely.
Fig 8a Mandibular first premolar with gingival abscess (arrow) at the facial aspect.

Fig 8b Radiographic view shows a severe periodontal breakdown due to a split root syndrome.

Fig 8c After extraction, a vertical split is visible extending to the apical area of the root.

Table 1 Percentage of cracked teeth related to the various types of posterior teeth

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<th>Author</th>
<th>Maxillary (%)</th>
<th>Mandibular (%)</th>
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<td>Veltmaat et al17</td>
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ETIOLOGY

The most common cause for an incomplete fracture is masticatory or accidental trauma.9,19 For instance, unintentional biting with physiologic masticatory force on a small and very hard object, such as a seed, may suddenly generate an excessive load due to the very small contact area. As a consequence, the loaded tooth may split or fracture (see Fig 1).20

A number of cofactors that decrease the stability of a tooth may predispose it to a cracked tooth syndrome, like a wide cavity preparation (Figs 2 to 4 and 10),13,21 wrong cavity design (see Fig 9),22 and non-restored deep carious lesions.9,23 Further, endodontically treated teeth show an increased risk of fractures, predominately due to the unavoidable loss of hard tooth substance during preparation of the access cavity.24 In addition, it must be considered that the high pressure applied during lateral condensation of gutta percha or the cementation of a tightly fitting post may cause incomplete vertical root cracks (Figs 7 and 8).23,26 Thus, it is not surprising that between 26% and 72% of endodontically treated posterior teeth restored with mesio-occlusal, occlusodistal, or mesio-occlusodistal amalgam restorations cracked over a 20-year-period.27
Various morphologic cofactors are also associated with the emergence of a cracked tooth syndrome, like deep occlusal grooves, pronounced vertical radicular grooves, or a bifurcation. Thus, maxillary premolars are significantly more susceptible to fracture than mandibular premolars (see Fig 1). Additionally, an extensive pulp space, a "steep cusp/deep groove" intraradicular relationship between the maxillary and mandibular premolars, and the resulting wedging effect of the prominent facial cusps of mandibular premolars, contribute to the increased susceptibility to fracture of maxillary premolars (see Figs 1 and 5).15,28

The lingual inclination predisposes the oral cusps of mandibular molars to cracks or fractures (see Fig 9). This hypothesis was confirmed by an epidemiologic study that found especially lingual cusps fractured in mandibular molars, with the first molar most likely to suffer complete fracture of both lingual cusps.29

Recently, various authors have speculated that posterior teeth with wide and deep cavity preparations can be internally splinted using adhesive resin composite restorations. Experiments by the current authors, as well as studies from other scientists, resulted in very contradictory findings (Table 2).1,2 Obviously, each cavity significantly reduces the fracture resistance. A subsequent filling increases stability again, very likely due to a better distribution of the loading forces being effective on the restored tooth. But it must be considered that no restorative material, neither amalgam nor conventional or polyacid-modified resin composites (compomers), can restore the original fracture resistance of an unrestored, caries-free tooth.19 Recently, it was observed that one out of two tested modern, hybrid-type resin composites applied in combination with the appropriate dentin adhesive increased fracture resistance of human molars to values that were not significantly different from unrestored controls. It may be speculated that these effects were due to improved mechanical properties of this particular product and an increased interfacial stiffness between the various components.1,4

This hypothesis, however, needs to be verified by further studies, including a number of other new resin composites, before adhesive restorations with modern resin composites can be generally recommended for internal splinting of at-risk posterior teeth.

Finally, it should be pointed out that an acidogenic extensive loss of enamel and dentin, for instance caused by bulimia or anorexia nervosa, may also increase the risk of a fracture (see Fig 5).

There is evidence in the dental literature that numerous iatrogenic parameters may contribute to fractures, such as rotating instruments during cavity preparation,41 the wedging effect of poorly fitting metal inlays, the over-zealous (mechanical) condensation of amalgam,9,15 excessive lateral condensation of gutta percha during root canal filling (see Figs 7 and 8), and the injudicious application or placement of friction-lock or self-threading pins.26,42,43

Additionally, cyclic thermal stress with a clinically relevant temperature fluctuation of 50°C44 or overloading due to an occlusal trauma, parafunction, or malposition also increase susceptibility to fracture.9,24,28 Altogether, it may be concluded that most fractures are very likely caused by a combination of several factors.

**Symptoms**

The symptoms of an incomplete fracture mainly depend on the depth and location of the crack. Patients frequently feel a brief and sharp pain when eating hard or tough food. Many authors consider this phenomenon a primary symptom (see Figs 1 and 4).5,29 It has been speculated that this short and sharp pain is generated by an alternating stretching and compressing of the odontoblastic processes located in the crack.13 But it is also hypothesized that this typical pain is created by the stretching of the fractured tooth segments with subsequent irritation of the pulp or the periodontal ligament.4 Nearly every patient also complains about an increased sensitivity to thermal or osmotic stimuli.45,46

Since many fractures are not diagnosed in time, these bizarre symptoms may continue for many years. Finally, many undiagnosed fractures enter the pulp chamber, causing pulpal inflammation and necrosis (see Figs 2 and 10).47
Fractures extending to the root generally cause periodontal inflammation. Thus, a localized periodontal breakdown adjacent to a restored and particularly unrestored tooth frequently indicates a fracture (see Figs 2, 7, and 8).

**Diagnosis**

It may be difficult to diagnose a split tooth since the symptoms associated with this syndrome are often bizarre and varying. Diagnosis is only simple when the crack is visible, for instance due to exogenic staining from food or beverages. In most cases, however, fractured teeth are restored with occlusal and proximal restorations. Thus, the most common mesiodistal cracks are invisible (see Fig 2a). Furthermore, it must be considered that the majority of the initial clefts are so tiny that they cannot be seen with the naked eye.\(^2\)

Radiographic examination rarely improves the diagnosis of a crack since it usually runs parallel to the plane of the film. But the radiologic findings of a localized periodontal breakdown in an otherwise periodontally healthy dentition may indicate a split tooth (see Figs 2, 7, and 8).\(^2\)

Sharp pain on chewing of hard or tough food is very important diagnostic evidence for a cracked tooth.\(^49\) This type of pain predominantly is triggered as the pressure is released. In order to provoke this characteristic sharp and brief “relief” pain and thus to verify a case of cracked tooth syndrome, the patient should be asked to bite on a hard object, like an orange wood stick, and then release the pressure quickly. Extensive restorations should be removed in order to determine the direction and extension of the crack. Various authors recommend staining the crack using methylene blue. Staining, however, takes several days, and thus requires a temporary restoration of the cavity. Alternatively, translumination is applied to visualize the crack.

The application of magnifying glasses (two-/four-fold) or an operating microscope is clinically more important than the two aforementioned time-consuming methods. Affected cusps can be determined by selective loading from various aspects with an orange wood stick.\(^12,11\)

**Therapy**

**Immediate therapy.** The primary goal must be to splint and stabilize a cracked tooth immediately. This reinforcement prevents a further extension or complete
fracture of the tooth. Orthodontic steel bands are ideal for this purpose, whereas copper bands must be carefully put into the necessary anatomic shape in order to avoid gingival or periodontal irritation. Diagnosis can be verified directly after splinting since the diagnostic bite test will no longer provoke the typical relief pain.

Some authors have suggested reducing or eliminating the occlusal contacts and thus avoiding an overload of a split tooth. It must be considered, however, that the tooth may still be critically stressed by the food bolus to such an extent that the risk of fracture persists. This also applies for an internal temporary splinting with adhesive Class I or II resin composite filling as previously mentioned (see Table 2).

Final therapy. Cast metal inlays with cusp coverage or partial crowns with circumferential external splinting are applied when esthetics are of little significance (Fig 3). If esthetic appearance is of importance, adhesive ceramic restorations are the therapy of choice (see Table 2; Fig 11).12

PREVENTION

Epidemiologic data clearly reveal that fewer teeth will be extracted in the future due to caries or periodontal diseases. However, epidemiologic findings also demonstrate that simultaneously more and more patients will suffer from a split or fractured tooth. There is evidence in the dental literature that fractures are the third most common cause of tooth loss in industrialized countries. Thus, it is of outstanding importance to avoid or eliminate risk factors, such as injudicious wide and deep cavity preparations. Experimental studies indicate that the orovestibular dimension of amalgam or resin composite restorations should not exceed one fourth to one third of the intercusal distance. Cavity preparations wider than half of this distance significantly increase the risk of splits or cracks if the tooth is not sufficiently splinted by a reinforcing casting or an adhesive ceramic restoration. In addition, occlusal adjustment, orthodontic treatment of malposed teeth, conservative cavity preparation, and early restorative reinforcement of at-risk teeth are important measures for eliminating or minimizing the occurrence of the cracked tooth syndrome.

REFERENCES


