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Cracked Tooth Syndrome in an Unrestored Maxillary Premolar: A Case Report

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Clinical Relevance

Cracked tooth syndrome is an uncommon finding in unrestored teeth. However, these phenomena appear to be found with increasing frequency, creating a challenge for a correct diagnosis. Direct-bonded restorations may be a safe and conservative option for teeth affected by incomplete cracks.

SUMMARY

Cracked tooth syndrome is known to occur most frequently in heavily restored teeth. Nevertheless, when the symptoms occur in intact teeth, there is difficulty in obtaining a correct diagnosis because it is difficult for the dentist to find where the crack is located. This clinical report describes the diagnostic procedures and the direct bonded composite restoration used to restore an incompletely fractured unrestored maxillary premolar in a 22-year-old female patient. To achieve a correct diagnosis, the following were performed: periapical and bitewing radiographs, percussion and thermal vitality tests, a bite test, and the placement of a stainless steel band. Once the symptoms ceased with band placement, cone beam computed tomography, transillumination, macro photographs, and isolation with a rubber dam helped to visualize the crack line along the occlusal surface involving distal and mesial marginal ridges. The crack was traced using a high-speed tungsten carbide bur until the fracture line was not visible. The tooth was restored with a direct composite resin, associated with a total-etch adhesive system, and the symptoms were immediately eliminated.

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INTRODUCTION

Fractures are one of three major conditions in human teeth that cause pain.[1] However, when a tooth fracture is incomplete, the presentation is more subtle and frequently remains undiagnosed because signs and symptoms are often confusing and are not sufficiently recognized by clinicians. Cracked tooth

syndrome (CTS) is described as an incomplete fracture of a vital posterior tooth involving enamel and dentin and possibly the dental pulp. It may cause a complete fracture, reaching the dental pulp and/or periodontal ligament.

The term *cracked-tooth syndrome* was first used by Dr Cameron in 1964 and was defined based on three clinical observations.[2] First, a patient complained of pain upon application of cold or pressure to a tooth that had been recently restored with a mesio-occlusal inlay, and there was relief of the pain a year later when the distal cusp broke off, even though sensitive dentin was then exposed. In the second observation, some posterior teeth had abscessed with small shallow restorations and no periodontal disease; however, there was evidence of rarefactions at the apex. Upon extraction and examination with magnification, many of these teeth were found to have cracks extending from the mesial, distal, or both marginal ridges, and the patients had a previous history of pain or occlusal adjustment. The third observation came from three other cases where, after extraction of fractured teeth, patients shortly thereafter complained of pain in another tooth. These latter suspect teeth were covered with crowns and complete fractures were prevented. Other authors had previously described the incomplete fracture as "cuspal fracture odontalgia,"[3] "fissured fractures,"[4] and "greenstick fracture of the tooth crown."[5]

The predominant symptom of a cracked tooth is discomfort from chewing pressure, especially with hard foods of a certain consistency.[1,2,6-9] This pain may have been present for several months previously,[10-12] so the patient might have adapted to the pain by learning to avoid the painful side when biting tough foods.[6] The pain is sharp and brief, usually lasting as long as the pressure persists and ceasing when the force ends. This can be explained by dentinal tubular fluid flow, which is a result of the movement of the tooth fragments away from and toward each other.[13] These movements also can stretch and possibly disrupt dentinoblastic processes along the fracture plane.[6] In vital teeth, depending on the depth of the crack and its duration, an additional symptom may include sensitivity to thermal changes, particularly to colder temperatures.[2,7]

The predisposing factors and etiology of CTS are still not properly understood and have a complex and multifactorial aspect. Usually, the cracks occur in restored teeth, with a direct relationship to the size of the restoration.[11,14] Teeth with restorations have a 29 times greater risk for cracks when compared with intact teeth,[15] and there is a higher incidence of CTS in teeth with restored marginal ridges.[8] However, intact or minimally restored teeth can also be compromised by incomplete fractures, with some studies[16,17] finding an increased incidence of the syndrome, ranging from 13% to 74% in healthy teeth.[9,18-22] An *in vitro* study confirmed that unrestored molars could withstand higher stresses under mechanical and thermal loads than restored molars with amalgam and composite restorations.[23]

It is interesting that CTS can affect multiple teeth in the same patient.[2,24-27] Cameron treated 50 patients with CTS, and seven patients had lost another tooth due to fracture.[2] In another study, nine patients (28%) exhibited incomplete fractures in more than one tooth, ranging from two to six.[11] A couple of case reports described bilateral cracked teeth in intact maxillary molars and premolars.[24,25] In those cases, the authors mentioned there was evidence of tooth wear, habits of chewing very hard nuts,[24] wear facets, hypertrophy of the masseter muscles, and extremely steep cusp-fossa relationships, which could have acted as a splitting force on maxillary teeth.[25]

The following clinical case describes the occurrence of CTS in an unrestored maxillary premolar. After the use of simple and sophisticated tools for diagnosis, the crack was traced with a carbide bur and a direct-bonded composite resin restoration was performed.

CLINICAL CASE REPORT

A 22-year-old female patient presented to the Department of Operative Dentistry at the Federal University of Santa Catarina complaining of discomfort with the maxillary left premolar during mastication of soft food (Figure 1). Her medical history revealed no systemic problems. The patient reported that she had suffered a road traffic accident 2 years prior but with no major trauma to the head region. Tooth 24 was intact with no periodontal or endodontic disease, based on clinical and radiograph exams (Figure 2). No symptoms related to cold sensitivity were present, but some pain presented when chewing sweet food. The patient was asked to bite a wooden wedge and complained of pain when the biting pressure was released (Figure 3). Transillumination (Microlux, Addent, Danbury, CT, USA) showed a fracture line on the occlusal surface in a mesiodistal direction, affecting both marginal ridges (Figure 4). Because it was not clear whether this

Figure 1. *Initial view of the nonrestored tooth 24.*

Figure 3. *Bite test using a wooden wedge revealed pain in tooth 24.*

crack was causing all of the symptoms, and to exclude others sources of pain, a stainless steel orthodontic band was cemented on the tooth and the patient tested the tooth for 21 days (Figure 5).

The placement of the orthodontic band immediately eliminated all symptoms. The band was removed after 21 days and, in an attempt to assess the depth and length of the crack, cone beam computed tomography was conducted. The images localized the crack at the same position as was observed in macro photographs and transillumination (Figures 4 and 6). The tooth was isolated with a rubber dam, where the crack became more evident due to dehydration (Figure 7). A high-speed tungsten carbide bur was used to create a conservative cavity preparation and the crack was removed until no fracture line was visible. The crack involved enamel and the external dentin. A fiber optic light was used to confirm crack removal during the cavity preparation (Figure 8). A provisional restoration (Bioplic, Biodinâmica, Londrina, Brazil) was placed and the patient tested the tooth for two weeks (Figure 9). Given that no more symptoms were present, the mesial-occlusal-distal (MOD) defect was restored (Figure 10) with a direct composite resin (Filtek Z350 XT shade A2E, 3M ESPE, St Paul, MN, USA), using a total-etch adhesive system (Adper Single Bond 2, 3M ESPE).

DISCUSSION

By eliminating the symptoms before and after the restorative treatment, and by making the crack visible, it may be concluded that the intact maxillary premolar in the current study suffered from CTS.

Figure 2. *Periapical radiograph of left maxillary premolars. No significant findings were present*.

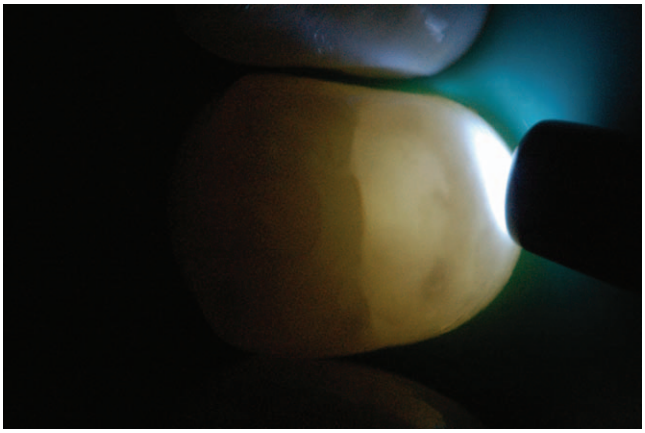

Figure 4. *A crack was observed under transillumination on the occlusal surface of tooth 24, from a mesial to distal orientation.*

Figure 5. *A stainless steel orthodontic band was cemented to confirm the diagnosis. The patient could bite without pain after this procedure.*

In a more recent clinical investigation of 154 cracked teeth, most of the affected teeth (89.6%) were intact or minimally restored.[17] Similarly, another study found that 40% of incomplete fractures were in healthy teeth or in teeth with a single occlusal restoration.[28] This is not a recent event. Hiatt,[18] in an earlier clinical study, found a high percentage (74%) of incompletely fractured teeth with no restoration or without a significantly weakened tooth due to a Class I restoration. Therefore, the possibility of an unrestored cracked tooth should be considered, regardless of the location of the tooth or the presence and size of a restoration.

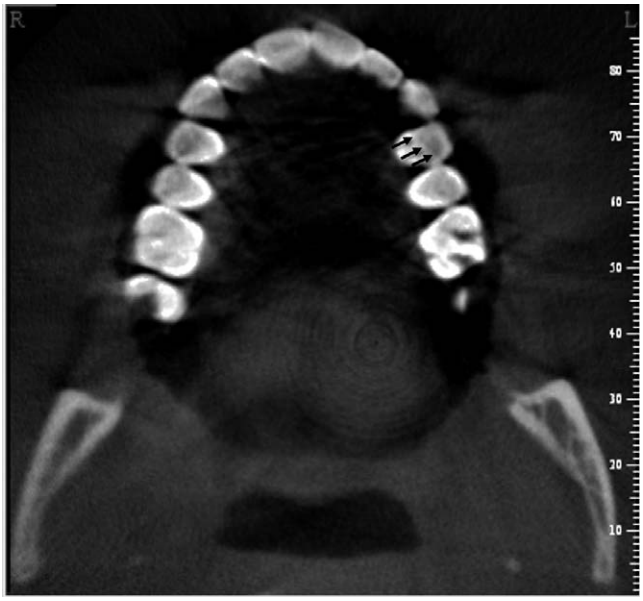

Figure 6. *A cone beam computed tomography showing the crack in a mesial-distal direction, involving the mesial, occlusal, and distal faces.*

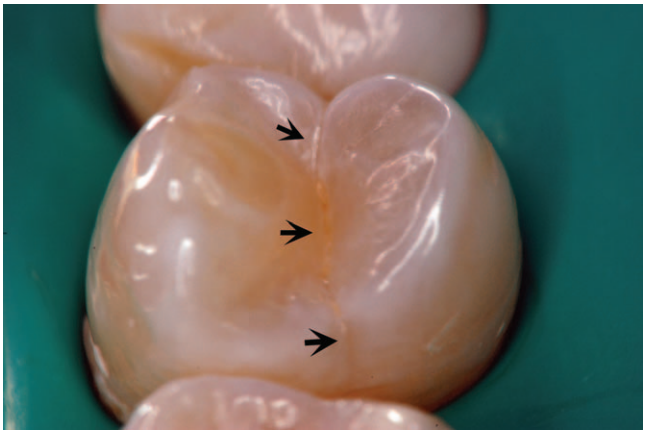

Figure 7. *Using a rubber dam, the crack was better visualized by giving a contrasting color to background and keeping the tooth dehydrated.*

An unintentional bite on a very hard and small object, like a seed, is the most common cause for CTS.[1,6,20] This event can immediately cause an

Figure 8. *(a): Transillumination was useful to confirm the defect removal during the cavity preparation, until no more cracks were visualized. (b): Completed MOD cavity preparation.*

Figure 9. *The tooth received a provisional restoration, and the patient tested the tooth for 21 days.*

Figure 10. *After the symptoms were eliminated, a direct bonded MOD composite restoration was performed.*

excessive masticatory load, due to the small contact area. As a result, the tooth may crack or fracture.[20,21] The same can happen during heavy impact in an accident involving the mandible and maxilla, as is believed to have happened in this present clinical report. Patients with healthy physiologic occlusion are inherently more confident to chew and might unexpectedly exert an excessive masticatory force on a hard object when compared with patients with periodontal disease. Patients with periodontal disease are naturally more cautious with biting due to the presence of mobile teeth, and consequently, these patients are less prone to splitting teeth due to mastication.[6]

Another etiological factor for the presence of CTS in unrestored teeth is excessive occlusal forces.[2,14,19] Cameron proposed that the force exerted to cause the crack seems to be a prolonged hammering.[2] Almost 60% of the cases provided histories of discomfort from one month to 10 years, and few patients could remember a sudden force. However, these patients had usually suffered complete fractures.[2] In addition, most patients exhibit worn occlusal surfaces and canines, which are evidence of interferences, interceptive contacts, or bruxism.[2,8,10,24,25,29,30] Occlusal trauma also can be present when there are severe occlusal premature interferences from working and nonworking sides, teeth adjacent to an unrestored edentulous region, or malposed teeth.[6,10,19] The general dental exam of occlusion should observe disclusion movements. Patients with anterior disclusion rarely have a fractured tooth, unless it occurs during a "masticatory accident." The incidence of fracture is greater in extreme Angle Class II occlusal relationships because anterior disclusion is poor or nonexistent, relegating shearing forces to the posterior teeth.[10]

In this current clinical report, it is possible that the anatomical features contributed to the crack occurrence. Cameron[2] affirmed that premolars and molars are frequently fractured and split in a mesiodistal direction into buccal and lingual fragments. Bifurcated roots and the occlusal relationship with antagonist teeth are crucial for the incidence of the CTS.[7,20,21,31] Teeth with deep cusps and steep fossae are more vulnerable to fracture due to the wedge effect from antagonist cusps, resulting in compressive forces in the cusps and tension forces in the pits.[1,6,18,20,25] This wedge effect has been suggested as a major cause of broken intact teeth,[14,18,31] especially in maxillary premolars with deep grooves,[11,20,21,32] as presented in this current clinical case. Another causative factor, suggested by Hiatt,[18] is an internal structural weakness that might exist between cusps at calcification sites that have failed to coalesce. These developmental weaknesses are noted in the formation of pits, fissures, grooves, and lamellae, creating a point of structural fatigue that tends to spread or separate cusps.[18]

This clinical condition, when present in intact teeth, carries a puzzling challenge to the professional, when compared with restored teeth, because it has been recommended to remove all of the restorative material in order to visualize fractures in teeth with CTS.[2,8,16,19-21,27] The crack in an unrestored tooth is frequently hard to see during a common clinical examination. Moreover, it is even harder to trace the crack with a bur. Fortunately, simple tools may help find where the crack is located, such as transillumination, application of dyes, isolation with rubber dam, macro photographs, and surgical loupes or microscopes,[8,11,19,20,24,28,30,33,34] although these tools cannot reveal the extent or depth of a

fracture.[35] The use of a rubber dam enhances the visibility of these cracks because it isolates the tooth with a contrasting color and keeps the area free of saliva, removing peripheral distractions.[8] However, these tools should be used in association with bite tests: This type of test is the most reliable for reproducing the symptoms of CTS because biting pain is present in more than 80% of the cases.[9,22,27] Transillumination, for instance, dramatizes all cracks to the point that craze lines (shallow cracks confined to enamel that are nonsymptomatic and do not require treatment) appear as serious structural cracks, confounding the visualization of symptomatic cracks.[1,19,36,37] In this current clinical case, another confounding factor was centrally located cracks, because they seem to follow the lines of the dentinal tubules, more closely approximating the dental pulp and causing more severe symptoms.[2,17]

Although the crack in the current case was visible by transillumination, the placement of an orthodontic stainless band was indicated to confirm the diagnosis. This procedure has been advocated for unrestored cracked teeth and for those teeth where the existence of a crack can only be presumed by the symptoms.[1,7,16,20,35,38] As shown in this present clinical report, the stainless steel band aided in a correct diagnosis and appeared to be the most conservative approach. The band serves as a splint; if the pain on chewing stops, the diagnosis is confirmed. After cementation of the band, the biting test is repeated and the patient should not feel any pain. The patient is then instructed to use the tooth normally, and is reexamined after two to four weeks. The band should be cemented with a glass ionomer or carboxylate cement and fit tightly, sometimes requiring adjustment so as not to interfere with occlusion.[1,16,20] If the patient is able to chew normally with the band in place, the crack should be removed and a restoration can be placed. If pain or sensitivity to temperature has not ceased, then endodontic therapy has to be considered, because the crack may extend close to the pulp or may even involve it.[1,16,35] If endodontics is indicated, the orthodontic band should be used to reinforce the tooth during endodontic treatment.[1] It is not cost-effective to subject the patient to a restoration without knowing whether the pulpal condition is reversible; however, it is much more logical to apply a provisional restoration and/or a stainless steel band, because it eliminates this source of error if the pulp is involved.[16]

In an attempt to confirm whether the visible crack was in dentin and possibly responsible for symptoms, cone beam computed tomography was performed. Although a cone beam exam may not detect a small defect, such as an incomplete fracture, an *in vitro* study concluded that this approach was more successful than digital radiography in detecting cracks smaller than 0.2 mm in thickness.[39] This technique involves a single 360° beam scan in which the x-ray source and a reciprocating detector synchronously move around the patient's head. This produces submillimetric resolution, ranging from 0.4 mm to as low as 0.125 mm,[40] and is a noninvasive tool for assessing the length of the fracture.[41] Some limitations of this computed tomography are related to artifacts that may appear as dark zones or streaks around metallic materials, implants, and, to a lesser extent, endodontic filling materials, which present similarly to root fractures and thus lead to false positive readings.[42,43] Clinicians should use cone beam computed tomography only when the need for imaging cannot be answered adequately by other, simpler tools, because this modality has a higher radiation dose than conventional dental radiography, especially in the case of children or young adults.[44] Although the use of cone bean imaging is a relatively new technique for detecting cracks causing symptoms of CTS, a recent clinical case[41] reported a very similar condition in an unrestored upper premolar, which appeared as a faint craze line on the distal marginal ridge and extending mesiodistally, involving the lingual pulp horn of tooth 24.

Several therapies have been proposed to treat painful cracked teeth; however, the specific therapy depends on the severity of symptoms and location of the crack.[7,45,46] Many authors have suggested an occlusal reduction to provide relief from occlusal stresses in centric and lateral relationships.[18,19,47] However, the reduction or elimination of occlusal contacts is temporary and is not sufficient because 1) the tooth could be loaded by a food bolus while chewing and occlusal reduction does not eliminate the risk of fracture,[2,18,20] and 2) this procedure also involves the removal of healthy, sound tooth tissue.[12] If the affected cusps fracture off spontaneously during removal of the filling, treatment is straightforward and consists of replacing the lost tooth substance and overlaying the remaining cusps.[16]

Before restorative procedures, careful tracing of the crack to decide the next line of approach has been advocated.[35] It is possible that the crack disappears into the dentin; however, if the crack continues in a pulpal direction, it is likely that the root is involved.[19] A clinical study has recommended an interim restoration using traditional glass ionomer

cements after the removal of restorations and/or cracks from the affected tooth to sedate the pulp and help with the healing response.[27] After this procedure, the patient should be asked to record whether the pain disappeared and to be alert for possible postoperative sensitivity. In case of continuous pain or persisting thermal sensitivity, an endodontist should evaluate the tooth for endodontic treatment.[11,16] According to Abbott, three months is the time indicated to assess the pulpal status of reversible pulpitis caused by CTS.[27]

In early clinical studies, the treatment of CTS was the placement of a complete crown restoration.[1,2,16,17,19,20,35,48] Conversely, it seems that full crowns are less effective in preserving the pulpal vitality. In a one-year clinical investigation, 84.4% of cracked teeth were treated with crowns; half of those teeth needed root canal treatment, considering that around 60% of the cases were initially intact teeth.[17] In another short-term clinical evaluation of cracked teeth, approximately 20% needed endodontic treatment after crown placement within six months of service.[49] Even when the root canal treatment is performed in advance of crown placement, this association has a survival rate of only 85.5% based on a two-year clinical evaluation of root-filled, cracked teeth.[50] Opdam and others[46] noted that painful cracked teeth often presented a long period of persisting pain, but gradually reduced postoperative sensitivity, and that maintaining the vitality of the dental pulp might improve the long-term prognosis of the tooth.

A more invasive treatment includes a higher loss of tooth structure and may result in extraction.[46,51] Some reasons for extraction may be pulpitis, restorative failures, and endodontic needs in CTS. First, this is related to the crack itself, because it can be deep enough to invade the pulp chamber, and later this can be confirmed during endodontic opening, because the fracture line is detectable from inside the pulp chamber.[29,30,46] Second, a scanning electron microscopy investigation[52] determined that all symptomatic cracks appear to be extensively contaminated by bacteria and may be the cause of pulpitis after the treatment of cracked teeth. Third, an additional factor that may contribute to pulpitis is the direct diffusion into the pulp of dentin adhesive components used to restore cracked teeth.[30] Finally, the indication of a more invasive restorative treatment, such as a full crown, might be accompanied by a higher loss of teeth in the long term as a result of extraction.[46]

As in this current clinical case, a direct-bonded composite resin restoration can be a successful treatment for a painful cracked tooth.[29,46,51] It is possible that this procedure has the potential to bond the affected cusps,[29] creating less sensitivity during mastication due to cusp reinforcement.[23] Behle,[51] relying on modern bonding restorative materials, stimulated thought on minimally invasive dentistry because clinical experience indicates that even symptomatic cracked teeth can be restored without full coverage by injecting a flowable composite into the crack area, which is especially true for low-force areas, such as with premolars. Simonsen[53] noted that crowns can be considered overtreatment in some situations when a restorative decision is based on expedience or economic advantage. Moreover, indirect restorations can result in more loss of sound tooth tissue and may increase the risk for pulpal complications due to the need for temporary restorations.[29] Cuspal coverage with direct composite resin had no failures after a seven-year clinical investigation[46] of painful cracked teeth, whereas the mean annual failure rate for no-cuspal coverage direct composite restorations was only 6%. It is possible that the direct composite resin has some level of "shock-absorbing effect"[29] by increasing cuspal stiffness and by redistributing occlusal loads away from the crack and toward the axial walls and down the long axis of the tooth.[12]

Nevertheless, for slightly larger defects, the aim of minimizing flexure of the compromised cusp also can be achieved with success using conservative, bonded partial-coverage ceramics[54] or composite onlays.[30] These are great choices for true esthetic demands.

CONCLUSIONS

The prevention and early recognition of cracked tooth syndrome is essential for avoiding more injuries and preventing the progression of cracks into the pulp or root. Simple tools, such as transillumination, bite tests, macro photographs, and isolation with a rubber dam, are useful for locating incomplete fractures. Bonding options, such as with direct composite restorations, should be considered for restoring cracked teeth because they are quick, low-cost, conservative, and readily available restorative techniques, and they have proven to bond to compromised cusps.

Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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