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REVIEW ARTICLE

Cracked Teeth: A Review of the Literature

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Abstract

Teeth in their physiological state serve as mechanical devices for mastication and are able to handle high pressures along with flexing or bending during the chewing process. Many iatrogenic and non-iatrogenic factors have been cited responsible for the compromised resistance to fracture in both endodontically and non-endodontically treated teeth. It is quintessential to determine the prognostic factors for vertical root fractures to prevent and better manage cracked teeth. This article aims to review the factors leading to the occurrence of cracks in teeth and vertical root fractures.

Keywords: Cracked Tooth Syndrome; Root canal therapy; Nonvital tooth; Tooth crown; Tooth fracture.

Introduction

Oral restorative procedures require expertise and deep understanding of the mechanics of stresses and strains that develop on teeth during various phases of treatment. The teeth in their natural healthy state can handle high pressure and tensile stresses. However, different forms of pathology that deviate or destroy their structure can lead to development of uneven load on the tooth, which in turn can cause trauma and fracture. The most common outcome of improper restorative procedure is cracked tooth. [1-3]

The article aims to review literature on the etiological factors associated with the propagation of cracks and vertical root fractures.

Aetiology

Root fractures are unpredictable and can occur anywhere in the root. There are many factors which interact in influencing fracture susceptibility. Quite a few factors have been suggested to have a role in the development of coronal cracks or VRFs. These include masticatory, parafunctional, occlusal, and restorative factors.

Masticatory Trauma

The most common cause of cracks in the coronal part of teeth is biting on very hard objects. In such cases sudden force is applied on the teeth, such as cracking hard nuts.[4,5] Numerous studies have suggested that masticatory forces could be associated with cracked teeth. A recent study quantitatively assessed risk factors such as poor oral masticatory habits for cracked teeth. They reported that thermal cycling and eating habits were strongly associated with cracked teeth. Eating coarse food, chewing on hard objects, and unilateral mastication were also found to be independent risk factors.[6]

Parafunction

Cameron reported that attrition was a common finding and suggested that excessive masticatory forces, parafunction, or occlusal prematurity may be the cause of fractures.[4] Hiatt reported similar findings.[7] This is consistent with a study which identified that fractured teeth occur more frequently among bruxists.[8] This again shows, that a thinning of enamel layer reduces the tooth's capacity to bear high levels of stress. Continued pressure and force on these teeth, as is the case in bruxism leads to eventual failing of the tooth and crack formation. Another study has mentioned that patients who reported grinding or clenching their teeth had a higher chance of having a symptomatic cracked tooth.[9]

Occlusal factors

The involvement of mandibular molar teeth (in particular the mandibular second molars) may be because occlusal forces are greater in the posterior rather than the anterior region.[8] Steep cusp-fossa relationships of posterior teeth may be a contributing factor in the development of fractures.[10] Cameron suggested that prominent mesiopalatal cusps of maxillary molars might exert a wedging effect on mandibular molars.[4] On the contrary, the oblique ridge of the maxillary molar may provide structural reinforcement and account for the lower incidence of fracture in these teeth.[11]

Restorative factors

Restorative procedures such as cementation of inlays or placement of dentine pins may induce cracks.[1] Cavity preparation significantly reduces the cuspal rigidity, especially if one or more of the marginal ridges are involved. It has been suggested that large, deep restorations may predispose teeth to fracture.[1,12] It has also been suggested that expansion of amalgam during setting (particularly if contaminated with moisture) might induce fractures.[2,3] A recent study explained that there are two major factors that dictate fracture initiation during restorative procedures. One being that restoration design is inadequate in cases where there is over preparation of a cavity. In other cases, the cuspal protection in the inlay or onlay designs are not thought through, leading to weak cusps, which eventually cause fractures.

The second factor is concentration of stresses due to its inadequate distribution in the cavity designing. The causes of this include placement of pin restorations, hydraulic pressure when seating cast restorations which are a tight fit, the physical force applied by the operator when placing conventional tooth filling materials such as amalgam and gold.

Root canal treatment

Endodontic procedures and especially lateral condensation attribute to vertical root fracture in endodontically treated teeth.[13-18] This is possible as endodontic procedures involve a series of steps which requires different types of force application. The poor quality and structure of the tooth may reduce the ability of the tooth to bear forces during debridement and condensation processes. In addition, the use of chemical debridement can also reduce the ability of the tooth to respond well to occlusal forces. All these factors can contribute to fracture of the tooth.

On the contrary, several studies have examined biomechanical properties of endodontically treated and vital teeth and suggest that teeth do not become brittle following root canal treatment. A study examined three pairs of patient-matched vital and pulpless incisors and reported no significant difference in the modulus of elasticity, proportional limit, and strength of dentine.[19] Taylor concluded from cantilever bending studies that the strength and modulus of elasticity of dentine from vital and endodontically treated teeth was similar.[20] Another study has shown that endodontic treatment does not alter the biomechanical properties of endodontically treated teeth as compared to vital teeth. They examined the punch shear strength, toughness, and load to fracture 23 endodontically treated teeth and their contra lateral pairs and found no statistically significant differences. Their results suggest that endodontically treated teeth do not become more brittle following root canal treatment. They opine that other factors may be more critical to failure of endodontically treated teeth.[21] Literature reports compressive and tensile strength of dentine from pulpless teeth were statistically similar to vital teeth.[22] A study on the rigidity of roots after different endodontic procedures showed no statistical difference in root deformability after manual root canal preparation but showed significant destabilization after access preparation and post space preparation.[23]

Root canal preparation

It has also been suggested that root canal preparation has the potential in inducing dentinal cracks.

Excessive enlargement of the root canal may weaken the tooth and increase the susceptibility for vertical root fracture(VRF).[24] A study aimed to evaluate the incidence of defects in root dentine before and after root canal preparation and filling. Their results showed that canal preparation alone created significantly more defects than unprepared canals. They concluded that root canal preparation and filling created dentine defects such as fractures, craze lines and incomplete cracks.[18]

A study reported that the use of some nickel titanium (NiTi) instruments could result in an increased chance for dentinal defects which can be precursors to tooth fractures. This study compared the incidence of dentinal defects such as fractures and craze lines after canal preparation with different nickel-titanium rotary files. Two hundred sixty teeth were prepared with either with manual Flexofiles or with ProTaper, ProFile, SystemGT, or S-ApeX. Roots were then sectioned 3, 6, and 9 mm from the apex and observed under a microscope. The presence of dentinal defects was noted. Their results showed that Protaper files resulted in the highest incidence of dentinal defects. Whereas, no defects were found in the unprepared roots and those prepared with hand files and S-ApeX. ProTaper, ProFile, and GT preparations resulted in dentinal defects in 16%, 8%, and 4% of teeth, respectively.[25] These findings were in agreement with other studies that concluded Protaper files tend to create more dentinal defects.[26]

Another study reported that root canal preparation with NiTi instruments resulted in more dentinal defects when they were measured in association with cyclic loads. The aim of this study was to evaluate the effects of root canal preparation, filling techniques, and mechanical cycling on the incidence of dentin defects and vertical root fractures. This study used 1,000,000 cycles of a mechanical fatigue test to simulate approximately 5 years of clinical function. Their results showed that cyclic load alone does not increase the incidence of dentinal defects. However, VRFs occurred only when the mechanical cycling was associated with lateral compaction or Tagger's hybrid technique. Incidence of dentinal defects increased when mechanical cycling was associated with NiTi rotary instruments for root canal cleaning and shaping, although no VRFs were observed. Moreover, VRFs occurred in 13.3% of teeth obturated with lateral compaction and 33.3% of teeth obturated with Tagger's hybrid technique of the teeth that were subjected to apical pressure associated with cyclic load.[27] Another study reported that all rotary files created micro cracks in the root dentin, whereas the Self-Adjusting File (SAF) and hand instrumentation presented with satisfactory results with no dentinal micro cracks.[28] These results were similar to another study which reported that Protaper files tend to create more dentinal defects. They observed the incidence of cracks in root dentin after root canal preparation with hand files, self-adjusting file (SAF), ProTaper, and Mtwo files. They reported that defects were found in all groups. However complete cracks were only found in the ProTaper and Mtwo groups. They also reported that SAF had a tendency to cause less dentinal cracks as compared with ProTaper or Mtwo.[29] These findings were similar to a study where they compared incidence of root cracks observed at the apical root surface or in the root canal wall after canal instrumentation with different file systems. They stated that Nickel-titanium instruments can cause cracks on the apical root surface or in the canal wall. In their study cracks were found in 50% of the teeth prepared with Pro- Taper files, 35% with OneShape, 5% with Reciproc files while no cracks were found in teeth prepared with the Self-Adjusting File.[30]

The abovementioned studies have shown that root canal preparation can damage the dentine and create defects in root canal walls. It is very likely that undergoing these procedures twice for an endodontic retreatment will increase the number of defects. A study that explored the influence of retreatment procedures on the appearance of defects on the root canal walls showed that retreatment significantly caused more defects than the initial treatment group.[31]

Working length

Studies have also shown that the length of the root canal preparation also had a significant role in the development of cracks in the root canal.[27,32,33]

A study compared the effects of root canal preparation techniques and instrumentation length on the development of apical root cracks. Their results indicated that cracks were more likely to appear when the teeth were prepared when working length was at the level of the root apex as compared to when it was 1mm short of it.[32] These findings are similar with other studies that showed length of root canal preparation had a significant effect in the development of root cracks. In a study where a comparison was made on the effects of three brands of nickel-titanium (NiTi) rotary files with different designs on the initiation of apical root cracks when working short, at, and beyond the apical foramen. Their results suggested that instrumentation with NiTi rotary files could potentially cause cracks on the apical root surface. They further mentioned that working 1 mm short of the apical foramen caused less cracks on the apical surface. No significant difference was found between the file types (Profile, K3, EndoWave) used.[33] Repetitive use of rotary instruments causes more dentinal defects than flexible hand instruments. Furthermore, instrumentation short of apical foramen reduces the risk of dentinal defects. This is substantiated by a study conducted by Liu et al who found that apical crack had developed in only 1.3% of teeth prepared with hand files whereas cracks developed in 19.4% of teeth prepared with rotary files. Apical dentinal detachment developed in 2.5% with hand files and 21.9% with rotary files. They also stated that less cracks and detachments occurred when instrumentation was terminated short of the apical foramen as compared to at or beyond it.[34]

Obturation technique

Wedging forces used in lateral condensation when the tooth is obturated is considered a common cause for vertical root fracture.[13,14] According to several studies, lateral condensation has been shown to induce stresses and strains in the root of the tooth.[35,36,37] A study that looked at 32 cases of vertical root fracture suggested that excessive force during lateral condensation of the gutta-percha caused 84.38 % of the fractures.[14] Tamse suggested that the most common cause of vertical root fracture in endodontically treated teeth is the excessive force used during lateral condensation of gutta-percha.[13] Studies have suggested that lateral condensation creates stresses in the root during obturation, which could lead to subsequent fracture. They also suggested that the canals that have a greater flare in their preparation will be subjected to more condensation force in the apical third of the root.[15,16] Lertchirakarn et al., suggested that vertical root fracture is initiated in the apical third of the root because of spreader induced strains. The fracture then propagates both apically and coronally.[38] Hand spreaders, such as the D11T have been shown to produce significantly more strain in the root that finger pluggers.[36,38] Dang and Walton observed that vertical root fractures are observed months or years after obturation of the tooth and suggested that obturation resulted in a root surface strain that was incorporated in the root, creating micro-fractures.[38] Vertical root fracture resulted from the additional stresses that were applied from occlusal forces applied to the restored tooth. Another study examined a total of 53 endodontically treated teeth that were extracted for vertical root fracture. They stated that vertical root fractures in endodontically treated teeth were caused by poorly designed dowels, inappropriate selection of the tooth as a bridge abutment or as a consequence of excessive endodontic forces during lateral condensation of gutta-percha.[17] These findings were similar to a study that reported that the total number of defects after lateral compaction was significantly larger than after non-compaction canal filling.[18]

On the contrary it has also been shown that the forces applied during lateral condensation are much lesser as compared to the force required to create a fracture. A study that compared the load and strain generated during lateral condensation with loads and strains at fracture suggested that lateral condensation should not be considered a direct cause of vertical root fracture unless condensation forces are excessive or the root is much weaker than normal.[38] The load and strain recorded at obturation are significantly lower than those recorded at fracture.[37,38] The load applied during lateral condensation was found to range from 1-3 kg.[15,37,38] Pitts et al., (1983) reported that a spreader load of 7.2 kg resulted in a vertical root fracture of a maxillary incisor, with 16% of the teeth tested fracturing at loads less than 10 kg.[39] However, the mean load required to induce fracture ranges from 10-20 kg.[37,38,39] A study compared the effects of lateral compaction with the continuous wave technique. Their results showed that root canal preparation and obturation had significantly more defects as compared to unprepared teeth. But no difference in the incidence of cracks was exhibited between lateral compaction technique and the continuous wave compaction technique.[31] These results suggest that lateral condensation should not be considered as the primary cause of vertical root fracture.

A recent study that investigated the impact of apical extent of root filling, concluded vertical root fractures had a greater association with root canals filled to or beyond the radiographic apex as compared to root canals filled short of it ,when the age, gender, tooth type, MAF size and taper, canal filling technique and time period after root filling were controlled.[39]

Intrinsic factors

Other than the above mentioned external factors such as root canal preparation and obturation techniques, it has also been suggested that the factors that influence root fractures are intrinsic to the root and canal morphology like dentin thickness, curvature of the external proximal root surface, canal size and shape.[40] This was also confirmed by another study that showed that canal width had an association with root fractures. They looked at the relationship of root canal enlargement to finger spreader induced vertical root fracture. 34 teeth were prepared with step back technique and were obturated using lateral condensation technique with a finger spreader. It was shown that no VRF occurred when the canal width was 30% of the total root width whereas 5 and 7 teeth fractured when the canal width was 40% and 50% of the total root width respectively.[41]

Conclusion

To summarize the above discussion, the weight of evidence collected in the studies cited here provides us with the following take-away points. Keeping these in mind may help in diagnosing and preventing cracked teeth in clinical practise. Excessive masticatory forces, parafunction or occlusal prematurity can lead to tooth fracture. Restorative procedures such as the cementation of inlays or the placement of dentine pins along with large, deep restorations may induce cracks in teeth. Root fractures are also influenced by root morphology such as dentin thickness, curvature of the external proximal root surface, canal size and shape.

Vertical root fractures are more commonly associated with endodontically treated teeth. Although root canal treatment does not alter the biomechanical properties of endodontically treated teeth, excessive enlargement of the root canal may weaken the tooth and increase the susceptibility for root fracture. While instrumentation short of apical foramen reduces the risk of dentinal cracks, root canals filled to or beyond the radiographic apex have a greater association with root fractures.

Conflict of interest

None declared by the authors.

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