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Analysis of 154 cases of teeth with cracks

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Abstract – It is well known that cracked teeth occur most frequently in the mandibular molars with large or poor restorations, in those over 50 years of age. However, with increasing knowledge and experience with cracks of teeth, cracks appear to be found frequently in intact teeth without restorations. The aim of this study is to analyze the cases of tooth cracks in a dental hospital in a year, and to find out the characteristic features of cracks of teeth. For 1 year, each tooth that were identified as a cracked tooth was recorded and analyzed in terms of the classification of cavity and restorative material, the nature of opposing tooth, the location in the arch, the age and gender, and the clinical signs and symptoms, and treatment result. Cracked teeth were observed most frequently in the teeth with no restorations (60.4%) and with class I restorations (29.2%). The most prevalent age was in those over 40 years of age (31.2% in their 40s, 26.6% in their 50s) and the prevalence was similar in men (53.9%) and women (46.1%). Cracked teeth were found most frequently in the maxillary molars (33.8% in first molar, 23.4% in second molar) than in the mandibular molars (20.1% in first molar, 16.2% in second molar). 96.1% of the cracked teeth responded to the bite test, and 81.1% of the cracked teeth were observed in the mesiodistal direction. The prevalence of cracked tooth was highest in the intact teeth with no restoration, in maxillary molars, and in those over 40 years of age. When examining a intact maxillary posterior tooth that is sensitive to a bite and thermal change, crack in the mesiodistal direction need to be considered one of the causes.

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In 1964, Cameron (1) used the term 'cracked tooth syndrome' in his report to describe the uncommon clinical situations characterized by discomfort to chewing pressure and abnormal sensitivity to thermal changes in otherwise normal teeth. As a reason for these unusual symptoms, incomplete tooth fracture was suggested and it was termed as 'cracked tooth syndrome'. According to him (2), cracks were prevalent in females (66.7%), over 50 years of age (58%), in the mandibular second molar (37.2%) followed by the mandibular first molar (29.4%), and five teeth had no restoration, and 28 teeth had occlusal class I restoration from 50 cracked teeth. He reported that there was a direct relationship between the size of the restoration and the occurrence of a crack of tooth. Teeth with a class II restoration were cracked approximately three times more than the teeth with a class I restoration. The loss of a marginal ridge in a class II restoration was considered to be one of the major causes of tooth weakening, and a properly small class I restoration was considered to have little effect on the crack of the tooth.

Other reports about the incidence and prevalence of incomplete tooth fractures have since been published, and most authors agreed that cracked teeth were significantly associated with intracoronal restorations and were prevalent in mandibular molars (2–12). The most commonly identified etiologic factor was the design of cavity preparations. Large restorations, improper and overzealous preparations, the inappropriate use of pins, and marginal ridge restorations were mentioned as factors responsible for cracks of teeth, although other factors, such as sudden biting of hard substances, the excessive contact of a posterior

tooth during eccentric jaw movement, wear, bruxism, malocclusion, steep cusp inclines and/or deep grooves in the occlusal morphology, and thermal cycling were mentioned as the causes of the cracks of teeth (1, 5, 8, 10, 13–16).

Cracks in intact teeth are still considered to an unusual and embarrassing situation. Only a few cases of cracks in intact teeth with no restoration have been reported, which occurred bilaterally in intact maxillary first molars (17, 18). They suggested that these were caused by occlusal traumas such as a steep cusp inclination and too heavy bite forces.

Although cracks in intact teeth are still considered to be unusual, cracks in teeth with no restoration appear more frequently in dental offices these days, and the location of cracked teeth in the mouth seems to vary. This may partly be because of advances in the diagnosis of crack of tooth by increasing knowledge and experiences about the nature of crack, and partly because of the changes in the chewing patterns.

The aim of this study is to analyze the cracks of teeth encountered in one dental hospital in a year, and to find out the characteristic features of cracks of teeth.

Materials and methods

All the teeth, which were suspected as cracked teeth in department of conservative dentistry in Yonsei dental hospital during 1 year, were examined thoroughly. The identification of a crack was carried out using transillumination, the application of dye, or a bite test with a tooth slooth or a roll of a rubber dam. The teeth that were diagnosed as cracked teeth were double-checked during the treatment sessions.

Once a crack had been identified, the subjects' age, gender, tooth number, restorative material and cavity classification, pulp vitality, mobility of the tooth, rate of wear, direction of crack, result of percussion and bite tests, depth of periodontal probing, the nature of occluding tooth, chewing habit and favorite food type, and the treatment result were recorded.

In 1 year, 154 teeth from 141 patients were diagnosed as cracked tooth. The data of these teeth were collected and analyzed according to the restorative material and the classification of the restoration, clinical signs and symptoms, age and gender, the location of the tooth in the jaw, the direction of the crack line, and the treatment result.

Results

From the data of 154 teeth, the following results were found (Tables 1–6).

Ninety-three cracked teeth were intact teeth with no restorations (60.4%), and 61 with restorations (39.6%). From the 61 restored teeth, 45 teeth (29.2%) had a class I restoration and 14 teeth (9.1%) had class II restorations. Regarding the type of restorative materials, there were almost equal numbers of amalgam restorations and gold inlay restorations regardless of the classification of restorations and the gender of the subjects. 120 cracked teeth were occluded with intact teeth with no restorations (77.9%).

Cracked tooth was found most frequently in the upper first molar (33.8%). The upper second molar was the next (23.4%), and lower first molar (20.1%) and lower second molar (16.2%) followed. The prevalence of crack in the premolar was 4.5% in the maxilla, and 2% in the mandible. In males 53.9% of cracked teeth were found, and cracks were most frequently found at the age of 40s and 50s. At the age 20s, 12.3% of cracks were found, while no cracks were found under the age of 20.

The most common direction of the crack was the mesiodistal direction in both jaws (108 teeth, 70.1%). The buccolingual direction was found in 29 teeth (18.8%) and 17 teeth (11%) cracked in both directions.

Table 1. The relationships between the crack and the type of restorative material and opposing tooth

Variables	Cracked tooth [*n* (%)]					Opposing tooth [*n* (%)]						
Sex	Male		Female		Total	N	G	P	A	C	I	Total
No restoration (N)	54 (35.1)		39 (25.3)		93 (60.4)	84	7	1			1	93
Gold crown (G)	1 (0.6)		1 (0.6)		2 (1.3)		2					2
Classification	Cl I	Cl II	Cl I	Cl II								
Amalgam (A)	9	2	10	3	24 (15.6)	14	4		6			24
Composite (C)	1	0	1	0	2 (1.3)	2						2
Gold inlay (I)	9	2	8	3	22 (14.3)	10	4	1			7	22
Temporary filling	3	2	4	2	11 (7.1)	10				1		11
Sum of restorations	22	6	23	8	59 (38.3)							
Total	83 (53.9)		71 (46.1)		154 (100)	120 (77.9)	17 (11)	2 (3.9)	6 (3.9)	1 (0.7)	8 (5.2)	154 (100)

N, no restoration; G, gold crown; P, porcelain; A, amalgam; C, composite resin; I, gold inlay.

Table 2. Distribution of cracks according to the location of the teeth

Type of teeth	Male	Female	Total [*n* (%)]	Type of teeth	Male	Female	Total [*n* (%)]
Max. 1st PM	3	1	4 (2.6)	Mn. 1st PM	1	0	1 (0.7)
Max. 2nd PM	2	1	3 (1.9)	Mn. 2nd PM	1	1	2 (1.3)
Max. 1st M	25	27	52 (33.8)	Mn. 1st M	15	16	31 (20.1)
Max. 2nd M	18	18	36 (23.4)	Mn. 2nd M	18	7	25 (16.2)
Total	48	47	95 (61.7)	Total	35	24	59 (38.3)

Table 3. The relationship between age, gender, and cracked tooth

Age (year)	Male	Female	Total	%
20–29	12	7	19	12.3
30–39	19	11	30	19.5
40–49	21	27	48	31.2
50–59	20	21	41	26.6
60–69	8	2	10	6.5
>70	3	3	6	3.9
Total [*n* (%)]	83 (53.9)	71 (46.1)	154	100

Table 5. Clinical sign and symptom of a cracked tooth

	Negative	Mild	Moderate	Severe
Pocket depth	(0–3 mm)	(3–6 mm)	(6–9 mm)	(9–12 mm)
(periodontal)	64	45	32	13
Wear facet (occlusal)	148	0	0	6
Bite test	6	138	7	3
Percussion test	66	71	17	0
Pulp vitality test (cold)	4	81	53	16

Table 6. Treatment of cracked tooth

Treatment	Number of the teeth (%)
Crown	65 (42.2)
Crown + root canal treatment	61 (39.6)
Temporary crown + root canal treatment + crown	2 (1.3)
Band + root canal treatment + crown	2 (1.3)
Resin filling	3 (2.0)
Extraction	21 (13.6)

Almost of the cracked teeth showed responses to the bite test (96.1%). Eighty-eight teeth were percussion-positive (57.1%) and 69 teeth showed moderate to severe sensitivity to the ice test (44.8%). Forty-five teeth (29.2%) had a deep pocket (over 6 mm), and another 45 teeth had pocket of the middle depth (3–6 mm) while 64 teeth (41.6%) showed normal periodontal tissues. Severe occlusal wear facets were observed in six teeth.

Sixty-five teeth were covered with a full veneer crown without a root canal treatment (42.2%), and the other 65 teeth were restored with a full veneer crown after the root canal treatment. Twenty-one teeth had to be extracted (13.6%).

Discussion

In a tooth with a large restoration, the crack tends to be more superficial because the occlusal stress concentrates in the tooth-restoration interface. Consequently it may produce mild or no symptoms. In one report, in which the cracks of teeth were found more frequently in restored teeth, two teeth were endodontically treated and one tooth was extracted out of 62 cracked teeth (9). Snyder (19) and Lagouvrdos et al. (10) examined the fractured posterior teeth including cracks and complete cuspal fractures, and reported that the majority of fractures did not involve the pulp but ended above the epithelial attachment. Because the crack did not involve the pulp, there was little pain initially and the history of mild pain would often had been lasted 12–18 months before the patient visited dental clinic. If the crack developed to a complete cuspal fracture, the pain would disappear.

On the contrary, the cracks in the teeth with no restorations would occur more centrally and closer to the dental pulp, which might produce more severe symptoms. One of the highest prevalence reports about cracks in intact natural teeth were reported by Hiatt (8). In his reports, 35% of cracks occurred in teeth with no restorations, 39% in class I restorations, and 26% in class II restorations. As

Table 4. Direction of the crack line

	M-D [*n* (%)]			B-L [*n* (%)]			M-D & B-L [*n* (%)]		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Maxilla	32	39	71(74.7%)	9	7	16(16.8%)	7	1	8(8.5%)
Mandible	23	14	37(62.7%)	9	4	13(22.0%)	3	6	9(15.3%)
Total	55	53	108(70.1%)	18	11	29(18.8%)	10	7	17(11%)

M-D, Mesiodistal direction; B-L, Buccolingual direction.

the causes of cracked teeth, he suggested the occlusal habits and the wedging effect of the cusp-fossa relationship. According to him, an internal structural weakness might exist at the calcification sites that had failed to coalesce between the cusps. These weak areas were noted in pits, fissures, grooves and lamella. When cusp-fossa relationships were exerted in these weak areas, internal stresses were induced in these areas. Gradually the stresses were concentrated at the interproximal surfaces and these could lead mesiodistal crack. Ehrmann and Tyas (20) reported the crack usually originated more centrally than a complete cusp fracture and extended into the dentin without a loss of the tooth structure. Centrally located cracks appear to follow the lines of the dentinal tubules and lead toward the pulp, which might result in a split tooth.

In this study, 60.4% of cracks occurred in intact teeth with no restoration and 29.2% in class I restorations. This means that 89.6% of cracks of teeth occurred without serious weakening of the tooth structure, and 42.2% of these cracked teeth were treated endodontically and 13.6% had to be extracted.

Therefore, the cracks in intact teeth with no restoration and largely restored teeth should be to be regarded as different ones, even though they were similar in the early stage. Many papers on 'cracked tooth syndrome' with large intracoronal restorations or cavity preparations (1–12) might be the results of incomplete cusp fractures instead of cracked teeth.

There have been a few categorization schemes suggested for tooth fractures. Talim and Gohil (21) categorized the tooth fracture mainly according to the depth of the tooth fracture. Their second category was whether the fracture was horizontal or vertical, and the third category was whether it was complete or incomplete.

Another proposal for classification of tooth fractures was to categorize the tooth fracture simply into a complete tooth fracture and an incomplete fracture (14, 22, 23). The criterion was whether there was loss of the tooth structure, or whether the fractured segment was independently movable or not. Because it was quite simple and was able to include the broad variations of tooth fractures, this classification was used widely. However, it was too simple to express the clinical and pathological characteristics of tooth fracture properly.

Recently, Simon (24) categorized a tooth fracture into five major classes; craze line, cuspal fracture, cracked tooth, split tooth and vertical root fracture. The craze line is a fracture line confined to the coronal enamel without signs and symptoms. Split tooth means a complete tooth fracture, which was already movable equally, and it usually involves the infrabony structures. A vertical root fracture is defined as a longitudinal fracture confined to the root. It usually begins on the internal wall of root canal and extends outward to the root surface. A crack is defined as an incomplete fracture of a vital tooth involving the dentin and possibly the dental pulp, while a cusp fracture is a tooth fracture caused by the lack of cusp support as a result of a weakened marginal ridge. The main characteristics of a cusp fracture are that it generally involved one cusp and usually terminated parallel to the gingival margin or slightly subgingivally.

Regardless of these classifications, several reports have used the term 'tooth fracture' without discriminating between a complete and an incomplete tooth fracture. Some authors included the complete and incomplete fracture in their studies under the broad term 'tooth fracture' (7, 15, 19, 21, 25, 26), while others excluded incomplete fracture or complete fracture in order to prevent contamination of their results (3, 5, 6, 10, 27).

Similarly, a 'cusp fracture' could be used to describe both the incomplete and complete cusp fracture. And it seems to be impossible to distinguish the crack from incomplete cusp fracture in early stage. The differences between them were the weakened marginal ridge and the symptoms that could not be trusted. New categorization scheme may be necessary to clarify these problems.

Ellis et al. (25) examined 271 tooth fractures, and reported that 97% were complete and 3% were incomplete fractures. They examined the relationship between the patients' age and tooth fracture. The median age of the patients with 263 complete fractures was 21, whereas that of those with incomplete fractures was 34 years. They concluded that the age distribution of those with complete and incomplete fractures was significantly different, and incomplete fracture was caused by an age-related tooth fatigue and minor traumas of cumulative effects.

In this study, 57.2% of cracks were found in maxillary first molars. However, many authors reported that the mandibular molars were the most common area of cracks and complete cusp fractures (1–12). Ehrmann and Tyas (20) suggested that the lingual cusp of upper molars could act as a plunger that was inducing structural fatigue in their mandibular antagonists, and the lower molars had central fossa deeper than the upper molars, while the oblique ridge in the upper molar provided the strength needed to resist cracks.

It was known that Korean had more lingually tilted lower molars (28), and smaller and shorter teeth than Caucasian (29). The lingually tilted lower molars might be able to reverse the situations. The

buccal cusps of the lingually tilted lower molars could act as plunger cusps to the maxillary molars. Smaller amounts of dentin and the surface area of the roots absorbed less occlusal stress and transferred less occlusal forces to the alveolar bone. Also, the prevalence of the C-shaped root canal in the mandibular second molar is higher in Asian than in Caucasian (30, 31). C-shaped canal joined the mesial and distal root, which may provide the additional resistance to the lower second molar.

In this study, 89.6% of cracks were found in teeth with no restorations or class I restorations. The one of possible explanations for this high percentage of cracks in natural intact teeth was that general practitioner usually referred their patients to a dental hospital, whose teeth were symptomatic but the causes of the symptoms were not easily identified. In dental hospitals, endodontists usually examined the teeth. Therefore, there might be a high frequency of cracked teeth in natural teeth and maxillary molars. Another possible explanation for high prevalence of crack in intact teeth was the favor of hot food in Korean. Brown et al. (32) showed that severe cracking or the propagation of existing cracks were developed by the thermal cycling in extracted teeth. This might play some role in crack formation in intact teeth.

Besides the racial and cultural differences, it should be mentioned that this study was designed to include the symptomatic and incomplete tooth fractures only. Therefore, asymptomatic cracked teeth were not examined in this study regardless of the coverage by a full veneer restoration.

From this study, it was found that cracks of teeth could occur frequently in intact natural maxillary teeth that were considered to be relatively crack-safe teeth. In examining the teeth that appeared to be intact and had no restorations, but showed typical symptoms of cracked tooth, the possibility of a cracked tooth should be considered regardless of its location in the mouth and the restorations.

Conclusions

The following characteristics were obtained from the analysis of 154 cracked teeth:

1 In natural teeth with no restorations 60.4% of cracks of teeth were found, and 29.2% in teeth with class I restoration.
2 Cracks of teeth were found more frequently in maxillary molars (57.2%) than in mandibular molars (36.3%).
3 The incidence of cracked teeth in men (53.9%) and women (46.1%) was similar, and was more frequently in those in their 40s (31.2%) and 50s (26.6%).
4 The most common direction of a crack was in the mesiodistal directions (81.1%).
5 Cracked teeth were occluded with natural teeth with no restorations (77.9%) and 3.9% of occluding teeth to the cracked teeth showed severe occlusal wear facets.
6 The most reliable clinical test result was the bite test (96.1%).
7 Cracked teeth were treated with crowns (84.4%) and in half of these cases root canal treatment were performed (42.2%).

In the limit of this study, it was found that cracks could occur frequently in intact natural teeth that are occluded with natural teeth. So when examining the intact teeth that are sensitive to bite test and thermal changes, the possibility of cracks must be checked carefully.

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