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ORIGINAL ARTICLE

The clinical findings and managements in 44 cases of cracked vital molars

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KEYWORDS
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Abstract *Background/purpose:* The aim of this study was to evaluate the associations between the clinical findings and managements in cracked vital molars that were caused by various factors including restoration and occlusion.
Materials and methods: The subjects' gender, age, chief complaint, type of tooth, percussion test results, pulp vitality, restoration material and cavity classification, clinical depth of the crack, evaluation of occlusion, depth of periodontal probing, and final management were recorded.
Results: A total of 44 vital cracked teeth (molars) were diagnosed in 40 patients. Regarding the type of tooth, a greater number of mandibular molars were affected than maxillary molars. Nonworking-side interference (NWI) was recognized in 38 cases (86.4%). Eight teeth (18.2%) had not been restored. Thirty-six teeth (81.8%) had been restored; 26 teeth (72.2%) with a metal inlay, 6 (16.7%) with an amalgam, and 4 (11.1%) with a composite resin. Regarding the final treatment in the endodontically-treated group, all 17 teeth were covered with a metal full crown. Regarding the final treatment in the pulp-reserved group, 19 teeth (70.4%) were covered with a metal full crown, and the other managements were as follows: occlusal adjustment (n = 4, 14.8%), composite resin (n = 2, 7.4%), and only follow-up without treatment (n = 2, 7.4%). All of the cases showed a good clinical prognosis.
Conclusion: The NWI group restored with 58% of metal inlay accounted for more than 86% of the cracked teeth. Thus, in order to achieve a good outcome, cracked teeth, particularly those originating due to occlusal interference should be protected with coverage-type restorations.

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Introduction

The location, direction and extent of a crack have a profound effect on the choice of treatment. Thus, the determination of these factors is important for the management of cracked teeth. The American Association of Endodontists (AAE) has clarified five types of longitudinal tooth fractures: craze lines, fractured cusp, cracked tooth, split tooth, and vertical root fracture.[1] In the present study, cracked teeth were defined according to the AAE classification. Many reports have indicated an association between cracked teeth and intracoronal restorations.[2–5] The major problem in a cracked tooth is the potential for bacteria to penetrate to the pulp, which may lead to pulpits, and ultimately to apical periodontitis.[6] The critical issues involved in saving cracked teeth are: the proper confirmation of cracks; the improvement of symptoms and signs; and the proper choice of final restorations. As a result, a combination strategy of simple macrography, transillumination, staining with dyes, diagnostic surgery, microscopy, and cone-beam computed tomography[7] is necessary when examining cracked teeth.

In the management of cracked teeth, it is important to investigate various associated factors. Although occlusal factors, such as the biting of hard substances, the excessive contact of a posterior tooth during jaw movement, malocclusion, and steep cusp inclines and deep grooves in the occlusal plane are suspected as causes of cracks,[8–14] a direct relationship between the occurrence of tooth cracks and the premature contact of occlusion, particularly nonworking-side interference (NWI)[15–17] and protrusion interference (PI),[18] has not yet been described in detail. Thus, the aim of the present study was to evaluate the associations between the clinical findings and managements of cracked vital molars that were caused by various factors, including restoration and occlusion.

Materials and methods

This clinical study was approved by the ethics committee of Nagasaki University Graduate School of Biomedical Sciences (authorized number: 1508). All of the patients were informed about the study described in this article and provided their informed consent. The cracked vital first or second molars of patients who visited the Kanamaru Dental Clinic in the three years prior to the study were examined. Forty-four cracked teeth were identified (based on the criteria of the AAE) by the naked eye, an oral miniature camera (STV-pro, Trophy Radiology Japan, Tokyo, Japan) or an operating microscope (UNIVERSA300, MOLLER-WEDEL GmbH & Co. KG, Wedel, Germany).

The following data were recorded: the subjects' gender, age, type of tooth, chief complaint, percussion test results, pulp vitality as tested using an electric pulp tester (Analytic Technology Pulp Tester, Redmond, WA, USA) and a cold aerosol, the restoration material, the classification and size of the restoration, the position and direction of the crack, the depth of periodontal probing, and the subjects' bite check results. In the present study, the teeth treated with pulpectomy showed a vital pulp but severe spontaneous pain. The infected root canal was treated if the pulp became non-vital during the observation period. An evaluation of subjects' occlusion was made to confirm NWI as a premature contact on molars, which was disclosed to guide the patients' mandibular position from the centric relation to the centric occlusion. NWI has generally been observed at the mesiolingual site of the occlusal plane in the maxillary molars and at the distobuccal site of the occlusal plane in the mandibular molars.[15,16] To facilitate the statistical analyses, the mesial, mesiolingual, and lingual sites were counted together in the maxillary molars. Similarly, the distal, distobuccal, and buccal sites were similarly counted together in the mandibular molars. These six sites were considered to be inside the fixed location; other sites were considered to be outside the fixed location. In the NWI group, the relationship between cracked teeth with or without restoration and the crack lines inside or outside the fixed locations was analyzed. Furthermore, the relationship between the crack teeth with a metal inlay (the most frequently used restoration) or without restoration and the crack lines inside/outside the fixed locations was also analyzed. Regarding the PI in the group without NWI, the relationship between restoration and crack teeth (frequently located distally in the mandible and mesially in the maxilla[18]) was also analyzed.

The extent of the cracks was clinically divided into three types: 1) to the middle part of dentin; 2) to the deep part of dentin, and 3) to the pulp, in both the pulp-reserved group and the endodontic treatment group. Five direct pulp capping cases were included in the pulp-reserved group. The relationship between the time to endodontic treatment and the extent of crack was also analyzed. Five direct pulp capping cases were included in the pulp-reserved group. The prognosis from the first visit and the final management were also recorded in both groups. Furthermore, the final treatment results were evaluated during the follow-up period (range, 1–3 years).

Statistical analysis

The data were expressed as the mean ± SD. The differences between the two groups were assessed using Student's *t*-test and the chi-squared test. *P* values of <0.05 were considered to indicate statistical significance.

Results

A total of 44 vital cracked teeth (Table 1) were diagnosed in 40 patients. The average ages of the patients were 47.4 ± 15.4 (20–74) years in males, and 46.8 ± 14.5 (17–68) years in females. There were no significant gender-based differences in the patients' ages or tooth types. The chief complaints (spontaneous pain, occlusal pain, sensitivity to heat or cold, discomfort, and the lack of symptoms) of both the pulp-reserved and endodontically-treated groups are summarized in Table 2. Five direct pulp capping cases were classified into the pulp-reserved group (n = 27), because the pulp of both the coronal and root remained vital. All direct capping procedures were performed for the cases in which the pulp was exposed during caries removal at the cracked area. No pulp treatment was performed for the remaining 22 cases, which were treated by occlusal adjustment and temporary restoration. During the

Table 1 The distribution of age and the type of tooth.

Age (years)	Male		Female		Total, n (%)	
	p	t	p	t	p	t
10–19	0	0	1	1	1 (2.5)	1 (2.3)
20–29	3	3	1	1	4 (10)	4 (9.1)
30–39	1	1	7	7	8 (20)	8 (18.2)
40–49	3	4	5	8	8 (20)	12 (27.3)
50–59	5	5	3	3	8 (20)	8 (18.2)
60–69	3	3	7	7	10 (25)	10 (22.7)
70–79	1	1	0	0	1 (2.5)	1 (2.3)
Total, n (%)	16 (40)	17 (38.6)	24 (60)	27 (61.4)	40 (100)	44 (100)
Type of tooth						
Maxillary 1st molar	0		4		4 (9.1)	
2nd molar	3		7		10 (22.7)	
Mandibular 1st molar	9		8		17 (38.6)	
2nd molar	5		8		13 (29.5)	
Total, n (%)	17 (38.6)		27 (61.4)		44 (100)	

p, patient; t, tooth.

Table 2 The relationships between the clinical symptoms and treatments.

Clinical symptoms	Vital pulp		Root canal treatment (RCT)	
	No treatment	Direct pulp capping	Pulpectomy	Infected RCT
Spontaneous pain	3	2	5	3
Occlusal pain	5	2	4	1
Sensitivity to cold or heat	11	0	1	3
Discomfort	3	0	0	0
No symptoms	0	1	0	0
Total	22	5	10	7
Pocket depth				
<3 mm	21	4	8	4
4–5 mm	1	1	2	3
Total	22	5	10	7

observation period, electric and cold aerosol pulp tests were performed to check the vitality of the pulp. All of the examined teeth were vital at the first visit. The endodontically-treated group includes 10 cases in which pulpectomy was performed and 7 cases in which infected root canal treatment was performed. Pulpectomy was performed for 10 cases in which severe spontaneous pain continued. The infected root canal treatment was started, after teeth that showed vital pulp at the first visit were found to be non-vital after checking almost every week using electric and cold aerosol pulp tests. There was no significant difference in the clinical symptoms of these groups. With regard to the endodontically-treated group, 10 patients whose clinical symptoms (spontaneous pain, and sensitivity to heat or cold) increased over time were diagnosed with pulpitis, and 7 patients whose vital signs using an electric pulp tester disappeared were diagnosed with apical periodontitis. There was no significant difference in the clinical symptoms of the pulpectomy and the infected root canal treatment groups. Furthermore, there was no significant difference in the pocket depth of the two above-mentioned groups (Table 2).

Eight teeth (18.2%) were not restored, while 36 teeth (81.8%) were treated with restorations (Table 3). Regarding the 36 restored teeth, 26 were restored with a metal inlay (72.2%), 6 with an amalgam (16.7%), and 4 with a composite resin (11.1%). Furthermore, although the pulp of 27 teeth was preserved, 17 teeth were endodontically-treated. There was no significant difference between the existence of restorations and pulp preservation. In the 17 endodontically-treated teeth, there was no significant

Table 3 The relationships among restoration size, classification, material, and crack.

Restoration size in occlusal plane	Cavity classification			Material			Extending crack patterns in MIN		
	I	II	MOD	MIN	CR	AM	1)	2)	3)
<1/3	15	0	0	8	2	5	2	4	3
1/3–2/3[a]	14	4	0	15	2	1	5	5	4
>2/3[b]	1	1	1	3	0	0	1	0	2
Total	30	5	1	26	4	6	8	9	9

MOD, Mesio-occluso-distal; MIN, Metal inlay; CR, composite resin; AM, amalgam. Note the significant difference ($P < 0.01$) between a and b in the extending crack pattern in the MIN group. 1), to the middle part of dentin; 2), to the deep part of dentin; 3), to the pulp.

difference in the number of cases in which pulpectomy (8 cases with restoration and 2 cases without restoration) and infected root canal treatment (all 7 cases with restoration) were performed. In the teeth with the three types of extending crack pattern, there were no significant differences in the material, classification, or the size of restorations (Table 3). In the teeth that were treated with a metal inlay, there were significant differences in the size of restoration and the extending of crack pattern ($P < 0.01$) (Table 3). Regarding the three extending crack patterns (from type 1 to 3), 12, 14, and 1 cases were observed in the pulp-reserved group, and 1, 2, and 14 cases were observed in the endodontically-treated group, respectively. There was a significant difference between the pulp-reserved and endodontically-treated groups ($P < 0.01$).

Thirty-eight (24 pulp-reserved, and 14 endodontically-treated cases) out of 44 cases (86.4%) were in the NWI group. Regarding the NWI group, cracked lines were located inside the fixed locations in 32 out of the 38 cases (84.2%). Six cases (pulp-reserved, n = 3; endodontically-treated, n = 3) belonged to the non-NWI group (PI, n = 5; working-side interference,[19] n = 1). There was no significant difference between these two groups.

The five types of initial managements, eugenol sedation, occlusal adjustment (OA), resin coating for dentin hypersensitivity (DH), restoration (R), and follow-up (FU) only were applied for cracked teeth. In the pulp-reserved group, the initial managements were performed (in the above order) in 6, 14, 2, 0, and 5 cases, respectively. In the endodontically-treated group, the initial managements were performed in 3, 11, 1, 2, and 0 cases, respectively. Although there was no significant differences in the managements of the two groups, there were significant differences between OA and DH, OA and R, OA and FU ($P < 0.05$). Although the time to the endodontic treatment varied greatly, regarding the extent of crack, there was no significant difference between the cracks that occurred within the dentin (30.7 ± 41.0 days) and those that extended to pulp (21.5 ± 33.3 days). When the time to treatment was limited to within 7 days, the duration of treatment of the teeth in which the crack extended to the pulp was significantly shorter (6.4 ± 2.5 days) in comparison to the teeth in which the crack occurred within the dentin (7 days) ($P < 0.01$).

The most popular final treatment was a metal full crown in both pulp-reserved group (n = 19, 70.4%) and the endodontically-treated group (n = 17, 100%). Regarding the interval between the initial visit and the setting of a metal full crown, there was a significant difference between the pulp-reserved group (73.7 ± 51.8 days) and the endodontically-treated group (116.4 ± 64.8 days) ($P < 0.05$). However, in the interval between the initial visit and the start of endodontic treatment, there was no significant difference between the cases in which pulpectomy (24.8 ± 27.3 days) and infected root canal treatment (24 ± 43.0 days) were performed. In the endodontically-treated group, pulpectomy was performed in 10 cases and infected root canal treatment were performed in 7 cases. Regarding the interval between the endodontic treatment and the setting of a metal full crown, there was no significant difference between the cases in which pulpectomy (100.2 ± 49.4 days) and infected root canal treatment (56.7 ± 49.3 days) were performed.

Regarding the final treatment in the endodontically-treated group, all 17 teeth (100%) were covered with a metal full crown. Regarding the final treatment whose criterion was generally due to the extending crack patterns in the pulp-reserved group, 19 teeth (70.4%) were covered by a metal full crown, while the other treatments included FU (n = 5, 18.5%), a composite resin (n = 2, 7.4%), and an inlay (n = 1, 3.7%). The final treatment for the direct pulp capping cases were metal full crowns (n = 3, 60%), and composite resins (n = 2, 40%). In cases involving a type 1 extending crack pattern, the treatments consisted of metal full crowns (n = 8, 66.7%), OA (n = 2, 16.7%), and FU (n = 1, 8.3%). In the type 2 pattern, the treatments consisted of metal full crowns (n = 11, 78.6%), OA (n = 2, 14.3%), and FU (n = 1, 7.1%). In the type 3 pattern, only one composite resin was performed. All cases showed a good clinical prognosis.

Discussion

In the present study, the age of the subjects with cracked teeth (range, 30–69 years of age) was similar to those reported in previous studies (range, 30–59 years of age).[20–23] More than 80% of the cracked teeth were treated with restorations, and belonged to the NWI group, which indicates the importance of the further analyses that were performed in the present study to elucidate the characteristics of restoration, occlusion, and cracks. Furthermore, it is noteworthy that OA was selected as the initial management in approximately 90% of the cases in the NWI group. To the best of our knowledge, this is the first report to directly analyze the relationship between cracked teeth, occlusion, and management. Furthermore, the relationship between the restoration and occlusion is also gaining attention. The present data concerning the NWI clearly indicated that the occlusal factor significantly contributes to the occurrence of cracked teeth. This study strongly suggests that an occlusal check when performing clinical inspection and management is indispensable for cracked teeth.

The middle size (1/3–2/3 in Table 3) of occlusal inlay-type restorations was related to a higher prevalence of crack extending compared to the large size (>2/3 in Table 3) of inlay restorations. This means that the occlusal interference affects the important role for crack formation and extending. The significant large number of cracks extending to the pulp was confirmed in the endodontically-treated group. This finding suggests that the cracks extending to the pulp cause pulp and periapical pathoses, and inevitably the interval to the final setting of a metal full crown in the endodontically-treated group might become longer than that in the pulp-reserved group. Five direct pulp capping treatments with an MMA/TBB resin[24,25] after the removal of caries were used for the pulp preservation. Although the crack was observed to extend to the pulp in one out of these five direct pulp capping cases, a good prognosis was confirmed in all five cases, which indicates that it is not always necessary to perform pulp removal. The present study clearly demonstrates that the significant longer interval between the initial visit and the setting of the metal full crown is needed for the endodontically-

treated group. Furthermore, in the endodontically-treated group, the interval between endodontic treatment and the setting of the metal full crown tended to be longer in 10 pulpectomy cases compared to 7 infected root canal treatment cases.

There is very little consensus among practitioners as to which cracked teeth require protective restorations, what the restoration should be, or the appropriate timing of restoration.[26] Despite the fact that many practitioners prescribe restorative treatment for asymptomatic teeth with visible crack lines in order to prevent cracked tooth syndrome or a complete tooth fracture, there is no evidence in the literature to support this practice.[26] However, a crown prevents the flexure of the weakened supragingival tooth structures, by transferring the stress of occlusal forces to the crown section of the tooth structure circumscribed by the crown margin; this cross-section subsequently resists occlusal forces. A full crown thus increases the biomechanical stability of a cracked tooth.[27] In this study, the final treatment in the endodontically-treated group was a metal full crown, and large and extending types of crack teeth in the pulp-reserved group were treated in principle with a full crown. Then, 81.8% of cracked teeth were covered by a crown, and this treatment was associated with a good prognosis. These clinical findings indicate that cracked teeth, particularly those originating from occlusal interference, should be protected with full coverage restorations because NWI and PI continue to cause stress at the specific site on the occlusal plane in daily life.

Conflicts of interest

The authors have no conflicts of interest relevant to this article.

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