Survival and prognostic factors of managing vital cracked teeth with occlusal veneer restoration: A 1-to 2 years prospective clinical study

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Research Article

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Abstract

Background

To evaluate the treatment outcomes of the cracked tooth restored using occlusal veneer.

Methods

Thirty-seven cracked tooth with normal pulp or reversible pulpitis were analyzed, and their demographic and clinical data and medical history were collected. Patients were followed-up to examine the thermal/biting sensitivity and clinical features.

Results

The maxillary first molar was the most prevalent (N = 17, 46%), and most patients could accurately locate the offending teeth (N = 32, 83.5%). The crack lines (CL) were divided into 5 types depending on tooth preparation. Within 16 months of followed-up, 2 out of 32 teeth developed pulp necrosis, resulting in a rate of 93.75%. A cracked tooth with probing depth > 6mm, number of CL on the finish line > 4, number of CL through preparation on finish line > 2 and widened periodontal ligament (PL) of the apical area were inclined to pulp necrosis after restoring the occlusal veneer. After restoration, 45.71% of the patients felt relief from thermal pain after 1 week, 71.42% after 1 month, 88.57% after 3 months, 94.28% after 6 months, and 100% after 12 months, while biting pain was 54.28%, 77.14%, 94.28%, 97.14%, and 100% cases after 1 week, 1, 3, 6 and 12 months, respectively. Probing depth > 3mm was related to thermal sensitivity, while teeth located in the mandible were correlated with biting sensitivity post-treatment. Widened PL of the apical area was related to thermal and biting sensitivity with 9–19 months followed-up period.

Conclusions

Occlusal veneer is a feasible and effective therapy for the protection of cracked tooth.

Trial registration:

The Research Ethics Committee approved this study (PKUSSIRB-202272008). While it was also registered on the webpage of Chinese Clinical Trial Registry and approved by their Institutional Review Board (ChiCTR2200057462, 13/03/2022).

Background
Cracked tooth is an incomplete fracture that originates from the crown and extends subgingivally, usually being directed mesiodistally [1]. Factors contributing to a cracked tooth include steep cusps, weakened developmental grooves, repetitive heavy mastication, and so on [2, 3]. Initially, patients may suffer from biting and/or thermal sensitivity, spontaneous pain may occurs later, ultimately leading to split [4]. In addition, diagnosing a cracked tooth is challenging, and observation of the crack lines (CL) does not necessarily indicate the actual fracture plane size and shape [2, 5].

Cracked tooth is often undiagnosed or mis-diagnosed that may be challenging to treat [2]. Therefore, multiple treatment options are usually applied, including direct restoration, the full crown, and the full crown with preventive root canal therapy (RCT)[6]. Yet, direct resin restoration cannot prevent further crack propagation, while a full coverage crown may lead to irreversible pulpitis or pulp necrosis because of a mechanical and thermal stimulus to the pulp [7, 8].

Occlusal veneer is an ultrathin restoration, which relies on bonding to the retention that could completely cover cusps. It is used to treat chemical or mechanical abrasion, occlusal developmental defects, and reconstruction of the occlusal surface morphology [9–11]. Monolithic lithium disilicate occlusal veneers in patients with severe tooth wear has reliable therapeutic effect for full-mouth rehabilitation up to 11 years [12]. Yet, thus far, no studies have reported on cracked teeth treated by occlusal veneer.

In our study, we investigated the clinical characteristics of cracked tooth with normal pulp or reversible pulpitis, the risk factors for subjective symptoms, and the pulp survival of the teeth restored by occlusal veneer.

**Materials And Methods**

**Study Design**

37 cracked teeth with normal pulp or reversible pulpitis in 34 patients were included. The inclusion and exclusion criteria are detailed in the supplementary files. All the patients presented with pain during mastication and/or release of bite, and part of them had localized sensitivity to cold or hot. The Research Ethics Committee approved this study (PKUSSIRB-202272008).

**Data Collection**

The detail demographic data and medical history were listed in the supplementary files. Clinical examinations included sensibility testing, percussion, periodontal probing depths, and mobility tests. The tooth status, biting test, and periapical radiographic findings were also analyzed. The visual inspection of the cracks before and after tooth preparation was documented, including the number of cracks (single or multiple), the extent of cracks (coronal or radicular), and the location and direction of cracks (mesial, distal, buccal or palatal/lingual).
Clinical followed-up was reexamined at 1 week, 1, 2, 3, 6, and 12 months after treatment, and then annually after that. The subjective symptoms, pulpal responses to cold test, palpation and percussion tests, and periodontal probing depths were reassessed. These teeth and the adjacent teeth were clinically tested for painful reaction after loading the individual cusp by using the Tooth Slooth. In addition, a periapical radiograph was used to detect any periapical pathosis. The success of the occlusal veneer was defined as the absence of signs or symptoms without progressive radiographic pathosis.

Statistical Analysis

Statistical software SPSS Version 27 (International Business Machine, IBM) was used for statistical analysis. Univariate and multivariate analyses were performed using a Cox regression model. A Kaplan-Meier survival analysis was applied to the results by log-rank test and Breslow. The level of significance was set at $\alpha = 0.05$. A $P$ value $< 0.05$ represented statistical significance.

Results

Demographic features

The patients’ demographic data are shown in Table S1. There were 17 men (50%) and 17 women (50%) with age ranging from 24 to 69 years old. Most of the cracked teeth occurred in patients between 30 to 40 years old (61.8%), followed by those aged 20 to 30 years old (20.6%) and those aged 40 to 49 years old (11.8%). Most of the cracked teeth occurred in the maxilla (75.7%); the maxillary first molars were the most common (N=17, 46%), followed by 7 maxillary second molars (18.9%), and 7 mandibular first molars (18.9%).

All patients suffered various degrees of biting pain, and none had spontaneous pain. Most patients could accurately locate the offending teeth (N=32, 83.5%), and the chewing pain was more pronounced when biting on hard food. The pain was present before clinical reception ranging from less than 1 month to approximately 2 years. In addition, some had the concomitant symptom, i.e., occasional slight sensitivity when contacting cold or hot food (N=15, 40.5%). Patients consulted the hospital when their symptoms persisted for 1 to 6 months (N=15, 40.5%), 1 to 2 years (19%), and 6 to 12 months (16.2%). Seventeen patients (22 teeth) had the habit of eating hard food (59.5%). Six patients also suffered from bruxism (13.5%), and five tended to clench their teeth (13.5%).

Clinical characteristics

Biting sensitivity was the most frequently observed symptom when examined with a small cotton ball (N=30, 81%) or with Tooth Slooth (N=33, 89.2%) (Table S2). When biting with Tooth Slooth, at least one cusp was symptomatic, and a few cracked teeth had two or more symptomatic cusps. In addition, some patients exhibited biting pain during centric occlusal contact (N=3, 8.1%) or lateral occlusal movement (N=8, 21.6%). Moreover, part of the cracked teeth had pain to percussion either from vertical direction (N=2, 5.4%) or from lateral direction (N=15, 40.5%). None of them exhibited mobility or only had physical
mobility. Most teeth had a probing depth between 4 and 6 mm (N=21, 56.8%), and part of the teeth (29.7%) had initial interproximal probing < 3 mm in the site associated with crack.

Before treatment, most of the teeth exhibited normal sensitivity to cold (N=10, 27%), while some had moderate sensitivity (N=22, 59.5%). Five teeth (13.5%) showed cold sensitivity lasting 3–5 seconds, which was diagnosed as reversible pulpitis. Periapical radiography further showed that the majority exhibited normal width of the periodontal ligament (PL) in apical area (N=30, 81.1%). Nevertheless, 7 teeth appeared the broadening PL in the apical area (18.9%, Figure 1), which was defined as being wider than the normal PL but less than twice as wide. Considering the affected teeth, 18 were intact except for the CL (48.6%), while others had intracoronal restoration, or had caries and wear. Most of the contralateral teeth (N=30, 81.1%) were asymptomatic, and the cracks were undetected until visiting the doctor. However, a few of them were symptomatic and were treated with different therapeutic measures, such as filling, crown, RCT, RCT+crown, or even extraction.

Features of crack lines (CL)

The CL features are shown in Table 1 and Figure 2. A number of teeth had 3 (N=8, 21.6%) or 4 (N=12, 32.4%) CL on the finish line, while 7 patients (18.9%) were found with 5 CL. Moreover, 2 CL through preparation were the most prevalent (N=18, 48.7%), followed by zero CL (N=10, 27%) and 3 CL (N=8, 21.6%). A majority of the teeth had CL with mesial-distal direction through the marginal ridge (N=17, 46%), followed by the cracks limited on one side without radicular extension (N=10, 27%), and the cracks surrounded and limited on one cusp (N=7, 18.9%). Only 3 teeth had CL with mesial-distal direction and buccal/lingual or buccal-lingual through the marginal ridge.

The symptoms after occlusal veneer treatment

The followed-up time was ranged from 9 months to 19 months. During the followed-up period, 2 teeth developed irreversible pulpitis or pulp necrosis at 1 month and 9 months after occlusal veneer treatment, respectively; these teeth were excluded from the final analysis. The symptom changes after occlusal veneer were recorded (Table 2).

After 1 week, 45.71% of the patients experienced relief from thermal pain, and 54.28% experienced relief from biting pain. After 3 months, most patients experienced relief from thermal pain (88.57%) and biting pain (94.28%). At 12 months, all the teeth were asymptomatic.

The procedure treatment of cracked tooth by occlusal veneer was showed in Figure 3.

The clinical examination after occlusal veneer treatment

Five teeth in 5 patients were later excluded because of incomplete data collection (Table S3). The final results showed healthy pulp vitality after 3 to 16 months of followed-up in 26 teeth (81.25%). Five teeth were diagnosed with irreversible pulpitis (12.5%), and 2 teeth developed pulp necrosis (6.25%) at 1-month and 9-months, respectively. Moreover, 21 teeth (65.62%) kept normal probing depth (≤3mm) after
1.5 years of followed-up. Eight (25%) teeth had pockets between 4 and 6 mm, and no teeth were extracted because of deep probing depths. After the occlusal veneer was applied, most teeth were asymptomatic [percussion test (N=30, 93.76%) and biting test with a small cotton ball (N=31, 96.88%)].

The risk factors of pulp survival

The univariate cox model showed that no risk factor was significantly associated with the requirement of RCT after occlusal veneer (Table 3). Among all the parameters, probing depth> 6mm (P=0.089) and location of the CL> 3 (P=0.067) showed marginal statistical differences. Kaplan-Meier analysis further showed that risk factors of pulp survival after treatment were associated with probing depth> 6mm (P< 0.05), number of CL on finish line > 4 (P< .05), widening of PL of apical area (P< 0.01), number of CL through preparation on finish line >2 (P< 0.01) (Table 4).

The risk factors of thermal/biting sensitivity

The univariate cox model showed that the widened PL of the apical area (P=0.007) had a significant relationship while probing depth > 3mm (P=0.056) had a marginal difference with thermal sensitivity after treatment (Table 3). The two parameters were subsequently evaluated by a multivariate cox model. Results showed that widened PL of the apical area (P=0.021) could be a significant predictor for thermal sensitivity after treatment (Table 3). Kaplan-Meier analysis revealed that probing depth > 3mm (P=0.013 for Log Rank; P=0.01 for Breslow) and widened PL of apical area (P=0.001 for Log Rank; P=0.007 for Breslow) were statistically significant predictors for thermal sensitivity after treatment (Table 4).

Cox model analysis showed that location in the mandible (P=0.018 for univariate; P=0.026 for multivariate) and widened PL of apical area (P=0.013 for univariate; P=0.021 for multivariate) were biting sensitivity indicators after treatment (Table 3). Kaplan-Meier analysis also revealed that location in the mandible (P=0.009 for Log Rank; P=0.084 for Breslow) and widened PL of apical area (P=0.004 for Log Rank; P=0.005 for Breslow) were significant predictors for biting sensitivity (Table 4).

Discussion

Biting pain is the most common symptom of cracked tooth [13]. In our study, most patients could precisely locate the offending teeth, while 3 patients couldn’t identify whether these teeth were located, and 2 patients misjudged. Pain symptoms caused by external stimuli originate from sensory nerve fibers in the dentin-pulp complex. Pain conducted by Aδ and C fibers is difficultly localized because of a high degree of convergence from pulp tissue and the lack of proprioceptive information [14].

Opam found no difference when direct resin restorations were used with or without cuspal coverage [15]. Other results showed that direct resin restorations couldn’t effectively prevent further crack development [7]. 71% of cracked teeth with reversible pulpitis after crown tend to remain healthy for 3 years or more [16]. Another study revealed that 27 out of 127 cracked teeth with reversible pulpitis converted to irreversible pulpitis or necrotic pulp during a 6-year evaluation [17]. Yet, identifying pulp status, especially
for molars, is challenging; this increases the uncertainty of pulp status for cracked teeth after crown restoration. Full crown with synchronous RCT is an optional way to solve patients’ pain, but RCT is more appropriate for irreversible pulpitis [6].

Full-coverage crown could protect the cracked tooth [4, 18, 19]. 21–29% of the reversible cracked tooth were restored by crown-required RCT in a period of 3 to 6 years [16, 17]. Vital teeth restored by crown had a certain risk of RCT. Previous studies showed that the pulp survival rates were 84.4% after 10 years and 81.2% after 15 years when vital teeth were restored with metal-ceramic crowns [20]. Compared with full crown, the main advantages of occlusal veneer are simple preparation and no need for restricting clinical crown height because of bonding to retention, reducing the pulp risk.

Our results showed that crack direction, crack extension, pre-treatment periodontal probing depth, and terminal abutment are associated with long-term teeth survival rates, which is consistent with previous study [21]. Hilton et al. [22, 23] reported that cracks located on distal surface were significantly correlated with biting or thermal symptoms. Teeth with multiple and radicular cracks had a higher risk of extraction than teeth with single crack and cracks confined within crown [21]. In addition, we found that the cracks orientation was unpredictable before tooth preparation (Fig. 4). Therefore, we further classified the number and location of CL after tooth preparation. Krell found that cracked tooth requiring RCT had cracks located on the distal marginal ridge in 15 of the 27 cases (56%) [17].

Our study aimed to prevent the propagation of cracks and keep the vital pulp of cracked tooth. The cracks were identified as difficult even when using a dental operating microscope. Therefore, we maintained partial cracks and ensured restorative space and caries-free. Some researchers prefer to eliminate cracks before tooth preparation because cracks extending to dentin result in bacteria invading dentinal tubules [3, 24] and inflammation [3]. In contrast, others would leave partial cracks and guarantee enough space for restorations to prevent further crack progression [17].

In our study, periodontal probing depth > 6 mm was associated with pulp disease post-treatment, while > 3 mm was related to thermal/biting sensitivity post-treatment. In the previous review [25], teeth with an associated periodontal pocket had a lower survival rate and thus were more prone to extraction (11%). Krell and Caplan [26] reported a probing depth of ≥ 5 mm, and Kang et al. [27] found that a probing depth > 6 mm was associated with poorer prognoses. The deep periodontal pocket might signify that the cracks extended to the outer external tooth surface, impeding the epithelium from adhering to the root surface [28].

Furthermore, a widened PL in the apical area was found to be associated with dental pulp vitality and thermal/biting sensitivity post-treatment. Out of the 37 patients, 7 showed widened PL in the apical area, but their cold test exhibited normal (2 patients) or moderate sensitivity (4 patients), or severe sensitivity (1 patient). Although the cold test is a classical way to predict the pulp status, it is inaccurate in multirooted molars. Cold stimulus by frost (-50°C) was adopted to obtain more accurate results. If the status of the pulp was necrobiosis, the apical PL was widened by radiographic evidence [29]. The widened PL was also
related to high occlusal force [30]. Our results showed that widened apical PL was an important standard for predicting treatment outcomes.

**Conclusion**

CL could be identified more clearly after tooth preparation. Probing depth, number of CL on the finish line, number of CL through preparation on the finish line, PL of the apical area, and tooth location resulted as essential factors affecting pulp survival and thermal/biting sensitivity of vital cracked tooth restored by occlusal veneer. An occlusal veneer is a reliable way to protect a cracked tooth.

**Abbreviations**

- crack lines (CL)
- periodontal ligament (PL)
- root canal therapy (RCT)

International Business Machine (IBM)

**Declarations**

**Ethics approval and consent to participate**

The Research Ethics Committee approved this study (PKUSSIRB-202272008). We carefully examined and confirmed that all methods were performed in accordance with the relevant guidelines and regulations.

**Informed consent statement**

Informed verbal and written consent were obtained from each patient on enrollment.

**Consent for publication**

Not applicable

**Availability of data and materials**

All data generated or analyzed during this study are included in this published article [and its supplementary information files].

**Competing interests**

The authors declare that they have no competing interests

**Funding**
None.

**Authors’ contributions**

**Mengke Wang**: Contributed to conception, design, data acquisition and interpretation, performed all statistical analyses, drafted and critically revised the manuscript

**Yingying Hong**: Contributed to conception, design, data acquisition and interpretation, performed all statistical analyses, drafted and critically revised the manuscript

**Xiaomei Hou**: Contributed to conception, design, and critically revised the manuscript

**Yinfei Pu**: Contributed to conception, design, data acquisition and interpretation, performed all statistical analyses, drafted and critically revised the manuscript

All authors gave their final approval and agreed to be accountable for all aspects of the work.

**Acknowledgements**

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**References**


Tables

Table 1. The crack lines (CL) features of the involved cracked tooth after preparation
<table>
<thead>
<tr>
<th>Category/Variable</th>
<th>Subgroup</th>
<th>N</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>The number of CL on the finish line</td>
<td>1</td>
<td>1</td>
<td>2.7%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4</td>
<td>10.8%</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>8</td>
<td>21.6%</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>12</td>
<td>32.4%</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>7</td>
<td>18.9%</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>4</td>
<td>10.9%</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>1</td>
<td>2.7%</td>
</tr>
<tr>
<td>The number of CL through preparation on the finish line</td>
<td>0</td>
<td>10</td>
<td>27%</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>18</td>
<td>48.7%</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>8</td>
<td>21.6%</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1</td>
<td>2.7%</td>
</tr>
<tr>
<td>The location of CL</td>
<td>One side of the CL is limited in the occlusal surface</td>
<td>10</td>
<td>27%</td>
</tr>
<tr>
<td></td>
<td>Surrounding one cusp</td>
<td>7</td>
<td>18.9%</td>
</tr>
<tr>
<td></td>
<td>Mesial-Distal direction through the Marginal ridge</td>
<td>17</td>
<td>46%</td>
</tr>
<tr>
<td></td>
<td>Mesial-Distal and Buccal/Lingual direction through the Marginal ridge</td>
<td>2</td>
<td>5.4%</td>
</tr>
<tr>
<td></td>
<td>Mesial-Distal and Buccal-Lingual direction through the Marginal ridge</td>
<td>1</td>
<td>2.7%</td>
</tr>
</tbody>
</table>

CL: crack lines

**Table 2.** The thermal and biting pain changes of the cracked tooth after occlusal veneer during the recall periods
The relief time of subjective symptom

<table>
<thead>
<tr>
<th>The relief time of pain</th>
<th>1 week</th>
<th>1 month</th>
<th>2 months</th>
<th>3 months</th>
<th>6 months</th>
<th>12 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal pain N</td>
<td>16</td>
<td>25</td>
<td>28</td>
<td>31</td>
<td>33</td>
<td>35</td>
</tr>
<tr>
<td>P</td>
<td>45.71%</td>
<td>71.42%</td>
<td>80%</td>
<td>88.57%</td>
<td>94.28%</td>
<td>100%</td>
</tr>
<tr>
<td>Biting pain N</td>
<td>19</td>
<td>27</td>
<td>29</td>
<td>33</td>
<td>34</td>
<td>35</td>
</tr>
<tr>
<td>P</td>
<td>54.28%</td>
<td>77.14%</td>
<td>82.85%</td>
<td>94.28%</td>
<td>97.14%</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Table 3.** Cox model for pulp vitality (vital; necrosis) and thermal & biting sensitivity (≤ 1 week ≥ 1 month) of cracked tooth restored by occlusal veneer

<table>
<thead>
<tr>
<th>Items</th>
<th>Parameter</th>
<th>95% CI</th>
<th>HR</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>UCM for dental pulp vitality</td>
<td>Probing Depth (≤ 6mm 6mm)</td>
<td>0.692~190.814</td>
<td>11.489</td>
<td>0.089</td>
</tr>
<tr>
<td></td>
<td>Location of the cracked lines (≤ 3 3)</td>
<td>0.834~217.518</td>
<td>13.466</td>
<td>0.067</td>
</tr>
<tr>
<td>UCM for thermal sensitivity</td>
<td>Probing Depth (≤ 3mm 3mm)</td>
<td>0.976~7.868</td>
<td>2.771</td>
<td>0.056</td>
</tr>
<tr>
<td></td>
<td>PL of apical area (Normal Widened)</td>
<td>1.636~20.941</td>
<td>5.854</td>
<td>0.007</td>
</tr>
<tr>
<td>MCM for thermal sensitivity</td>
<td>Probing Depth (≤ 3mm 3mm)</td>
<td>0.806~6.996</td>
<td>2.374</td>
<td>0.117</td>
</tr>
<tr>
<td></td>
<td>PL of apical area (Normal Widened)</td>
<td>1.259~16.605</td>
<td>4.572</td>
<td>0.021</td>
</tr>
<tr>
<td>UCM for biting sensitivity</td>
<td>Location in the arch (Maxillary; Mandible)</td>
<td>1.261~12.412</td>
<td>3.956</td>
<td>0.018</td>
</tr>
<tr>
<td></td>
<td>PL of apical area (Normal Widened)</td>
<td>1.488~30.996</td>
<td>6.791</td>
<td>0.013</td>
</tr>
<tr>
<td>MCM for biting sensitivity</td>
<td>Location in the arch (Maxillary; Mandible)</td>
<td>1.171~11.792</td>
<td>3.716</td>
<td>0.026</td>
</tr>
<tr>
<td></td>
<td>PL of apical area (Normal Widened)</td>
<td>1.317~28.29</td>
<td>6.103</td>
<td>0.021</td>
</tr>
</tbody>
</table>

UCM: Univariate cox model; MCM: Multivariate cox model; PL: Periodontal ligament

**Table 4.** Kaplan-Meier analysis for pulp vitality (vital; necrosis) and thermal/biting sensitivity (≤ 1 week; ≥ 1 month) of cracked tooth restored by occlusal veneer
<table>
<thead>
<tr>
<th>Items</th>
<th>Parameter</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Log Rank</td>
</tr>
<tr>
<td>Dental pulp vitality</td>
<td>Probing Depth (≤6mm 6mm)</td>
<td>0.032</td>
</tr>
<tr>
<td></td>
<td>No. of cracked lines on finish line (≤4 4)</td>
<td>0.034</td>
</tr>
<tr>
<td></td>
<td>PL of apical area (Normal Widened)</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>No. of CL through preparation on finish line (≤2 2)</td>
<td>0.004</td>
</tr>
<tr>
<td>Thermal sensitivity</td>
<td>Probing Depth (≤3mm 3mm)</td>
<td>0.013</td>
</tr>
<tr>
<td></td>
<td>PL of apical area (Normal Widened)</td>
<td>0.001</td>
</tr>
<tr>
<td>Biting sensitivity</td>
<td>Location in the arch (Maxillary; Mandible)</td>
<td>0.009</td>
</tr>
<tr>
<td></td>
<td>PL of apical area (Normal Widened)</td>
<td>0.004</td>
</tr>
</tbody>
</table>

PL: Periodontal ligament; CL: crack lines

**Figures**

![A](image1.png) ![B](image2.png)

**Figure 1**

**Radiographic evidence of widening of apical PL.** (A) Apical PL widened in the mesial-buccal root of the maxillary first molar. (B) Normal apical PL of the mesial-buccal root of the maxillary first molar.
Figure 2

Patterns of CL. (A) One side of the CL limited in the occlusal surface. (B) Surrounding one cusp. (C) Mesial-distal direction through the marginal ridge. (D) Mesial-distal and buccal or lingual direction through the Marginal ridge. (E) Mesial-distal and buccal-lingual direction through the marginal ridge.

Figure 3

Treatment procedure of cracked tooth restored by occlusal veneer. (A) Occlusal view of pre-treatment of the mandibular first molar. (B) Buccal view of pre-treatment of the mandibular first molar. (C) The CLs were seen clearly after tooth preparation. The black arrow shows the CL. (D) Occlusal view of mandibular first molar restored by occlusal veneer. (E) Buccal view of mandibular first molar restored by occlusal veneer. (F) Bite mark of mandibular first molar restored by occlusal veneer.
Figure 4

CLs were identified more accurately after tooth preparation. (A) Cracked tooth before preparation. (B) Cracked tooth after tooth preparation. CLs were labeled by black arrows.

Supplementary Files

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