The Effects of Endodontic Access Cavity Preparation Design on the Fracture Strength of Endodontically Treated Teeth: Traditional Versus Conservative Preparation

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Abstract

Introduction: The aim of this study was to compare the fracture strengths of mandibular molar teeth prepared using traditional endodontic cavity (TEC) and conservative endodontic cavity (CEC) methods and restored using SDR (Dentsply Caulk, Milford, DE) and EverX Posterior (GC Dental, Tokyo, Japan) base composite materials.

Methods: A hundred mandibular first molar teeth were randomly divided into 5 groups. In group 1 (the control group), samples were kept intact. In group 2, TECs were prepared, and the samples were restored with EverX Posterior and composite resin. In group 3, CECs were prepared, and the samples were restored with EverX Posterior and composite resin. In group 4, TECs were prepared, and the samples were restored with SDR and composite resin. In group 5, CECs were prepared, and the samples were restored with SDR and composite resin. This load was applied on the samples at 1-mm/min speed using a 6-mm round-head tip until fracture. The forces resulting in fracture were recorded in newton units. The data were analyzed using Kruskal-Wallis and Pearson correlation tests at a 5% significance level.

Results: The fracture strengths of the samples in the control group were significantly higher than the experimental groups (P < .05). There was no statistically significant difference in the endodontic access cavity preparation decreased the fracture strength of teeth and increased cuspal deflection during function (2–4). In traditional endodontic cavity (TEC) preparation, the controlled removal of the tooth structure is supported to prevent complications that can occur during endodontic treatment (5, 6). The loss of dentin and anatomic structures, such as cusps, ridges, and the pulp chamber roof, can result in fracture of the tooth after the final restoration (7). In contrast to TEC preparation, conservative endodontic cavity (CEC) preparation is a minimally invasive procedure that can preserve tooth structures, such as pericervical dentin (7–14). There are no exact rules to prepare the CEC; the aim is to preserve as much of the tooth structure as possible and to locate the canal orifices. In the present study, CECs were prepared considering a tooth with a mesial cavity.

Advancements in adhesive technology have enabled conservative and esthetic post-endodontic restoration (15). Conventional composites and flowable bulk-fill base composites, which can be bulk filled in layers up to 4 mm in thickness, are a good alternative for the restoration of endodontically treated posterior teeth (16). A well-known example of bulk-fill base composites is SDR (Dentsply Caulk, Milford, DE). SDR has an increased depth of cure because of increased translucency (17). SDR includes a flexible polymer that does not translate the shrinkage stress to the tooth. Thus, it is hypothesized that this will reduce the strengthening effect of the composite on the tooth. New composite resin–based materials, including polyethylene and glass fibers, are also available for use in endodontic restoration (18). The use of newly developed fiber-based composites means that wide cavities exposed to a high level of stress, especially those in posterior teeth, can be more successfully restored (19). EverX Posterior (GC Dental, Tokyo, Japan) has been introduced for dentin replacement in large, deep, and

Key Words

Conservative access cavity, EverX Posterior, fracture strength, SDR, traditional access cavity

Significance

Conservative endodontic cavity preparation was proposed to reduce fracture risk of endodontically treated teeth. Conservative and traditional endodontic cavity preparation showed similar fracture strength, which was lower than the intact teeth.

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EverX Posterior can be used in 4-mm increments in extensive posterior cavities to mimic the stress absorbing properties of dentin. Because these composites enable 4–5 mm thick increments to be cured in one step, they are time-saving and easy-handling composites (20).

The aim of the present study was to compare the fracture strengths of mandibular molar teeth prepared using traditional and conservative methods and restored using SDR and EverX Posterior base composite materials. The null hypotheses of the present study were as follows:

1. The access cavity preparation method would have no effect on the fracture strength of endodontically treated mandibular molar teeth.
2. The different base composite materials used in the restoration would have no effect on fracture strengths of endodontically treated mandibular molar teeth.

**Materials and Methods**

**Sample Size Estimation**

Based on data from a previous study (14), a power analysis was conducted using G*Power 3.1 (Heinrich Heine University, Dusseldorf, Germany) software by selecting the analysis of variance test of the F tests family. An alpha-type error of 0.05, a beta power of 0.95, and a ratio N2/N1 of 1 were also stipulated. The power calculation indicated that the sample size for each group should be a minimum of 20 teeth.

**Sample Selection**

After ethics committee approval (no. 2016/272), 100 mandibular first molar teeth were included in the study. The teeth were collected from patients aged between 40 and 60 years old. All the teeth had completed root development without any cracks or defects on the surface and no restoration history. Soft and hard tissue residuals on the tooth surfaces were removed using an ultrasonic scaler. The buccolingual (BL) and mesiodistal (MD) diameters of the teeth were measured using a caliper. Care was taken to ensure that all the teeth had similar dimensions for standardization. During the study, the teeth were kept in distilled water at room temperature (24°C ± 2°C) when not used. The maximum storage time for the teeth was 6 months. The teeth were randomly divided into 5 groups (n = 20/each group), and the following procedures were implemented:

1. **Group 1:** The teeth in this group underwent no treatment, and the teeth served as a control group.
2. **Group 2:** In this group, after TEC preparation (Fig. 1A), root canal treatment was performed. EverX Posterior was applied as the base material (Fig. 1B), but the proximal cavity was not completely filled.

**Figure 1.** (A) TEC preparation, (B) EverX Posterior application to TEC, and (C) final restoration of TEC.

**Figure 2.** (A) CEC preparation, (B) a proximal view of CEC, (C) SDR application to CEC, and (D) the final restoration of CEC.
The final restoration was completed using Filtek Z250 (3M ESPE, St Paul, MN) composite resin (Fig. 1C).

3. Group 3: After CEC preparation, root canal treatment was performed. EverX Posterior was applied as the base material, but the proximal cavity was not completely filled. The final restoration was completed using Filtek Z250 composite resin.

4. Group 4: After TEC preparation, root canal treatment was performed. SDR was applied as the base material, and the proximal cavity was completely filled. The final restoration was completed using Filtek Z250 composite resin.

5. Group 5: After CEC preparation, root canal treatment was performed (Fig. 2A). SDR was then applied as the base material, and the proximal cavity was completely filled (Fig. 2C). The final restoration was completed using Filtek Z250 composite resin (Fig. 2D).

**TEC and CEC Preparation**

In TEC preparation, a class II mesio-occlusal endodontic cavity was prepared. Occlusal enamel and dentin tissue between the mesial and distal root canal orifices were removed.

Similarly, in CEC preparation, a class II mesio-occlusal cavity was prepared. In contrast to the TEC preparation, occlusal enamel and dentin tissue between the root canal orifices in the mesial and distal segments were not removed (Fig. 2B). The distal cavity in the CEC preparation was determined and standardized according to the distal marginal ridge thickness. The distal marginal ridge thickness of both cavities was 1.5 mm. On the mesial side, the distance between the gingival margin and the enamel–cement line junction was prepared to be 1 mm. Care was taken to ensure a thickness of 2 mm between the buccal and lingual walls and the interproximal cavity walls. Pulpal tissue in the pulpal chamber was completely removed using an ultrasonic scaler. All the aforementioned procedures were performed by 2 specialist dentists experienced in endodontics and restorative dentistry.

**Root Canal Preparation and Obturation**

After preparing the endodontic access cavity, a #15 K-type canal file (Dentsply Sirona, Ballaigues, Switzerland) was placed into the root canals of the teeth under 2.5 × magnification until the apical foramen was reached. The working length was set at 1 mm shorter than this length. X1 and X2 files of the ProTaper Next (Dentsply Sirona) rotary instrument system were used for shaping the mesial root canals, and X1, X2, X3, and X4 files were used for shaping the distal root canals. The files were operated at 300-rpm speed and 300-g/cm torque using the "DR’S CHOICE" program of the VDW Reciproc Gold (VDW, Munich, Germany) endodontic motor in accordance with the recommendations of the manufacturer. Each of the files was used to shape a maximum of 4 root canals. While changing the files, the root canals were irrigated with 2 mL 5.25% sodium hypochlorite (CanalPro; Coliène/Whaledent, All-stetten, Switzerland) solution. To remove the smear layer, 2 mL 17% EDTA (CanalPro) was applied for 2 minutes, and 2 mL 5.25% sodium hypochlorite was applied in the final irrigation. After drying with paper points, the canals were filled with AH Plus (Dentsply DeTrey, Konstanz, Germany) and gutta-percha (Dentsply Sirona) using the single-cone technique. Redundant gutta-percha was removed from the canal orifices using a hot excavator. The access cavities were then cleaned using ethylene alcohol.

**Simulating the Periodontal Ligament**

The samples were coated with molten wax to 2 mm apical from the enamel–cement line. Then, using a metal mold, all the samples were embedded in a self-curing resin to 2 mm apical of the enamel–cement line. During this procedure, a parallelometer was used for aligning the long axes of the teeth perpendicularly to the ground plane. After visually confirming the beginning of polymerization, the teeth were removed from the acrylic resin, and the molten wax was removed using hot water. To simulate the periodontal ligament, the gap in the acrylic resin was filled with silicon impression material (Panasil Light Body; Kettenbach GmbH & Co KG, Eschenburg, Germany), and the teeth were replaced in the gap.

**Restoration of the Samples**

Except for the control group, all the samples were etched for 15 seconds using 37% orthophosphoric acid (Etch-37 w/BAC; Bisco, Schaumburg, IL) for selective enamel etch, rinsed for 15 seconds, and then gently air dried. After this step, a 2-stage self-etching adhesive (Clearfil SE Bond; Kuraray Noritake Dental Inc, Tokyo, Japan) was applied for 20 seconds, thinned with air, and then polymerized for 10 seconds using an LED device (Elipar S10, 3M ESPE).

For the samples in groups 2 and 3, 4-mm-thick EverX Posterior (GC Dental) was applied as the base material to imitate the lost dentin tissue and then polymerized with an LED light device for 40 seconds. Subsequently, 2 mm composite resin restorative material (Gradia Direct Composite) was applied as the base material to imitate the lost dentin tissue and then polymerized for 2 minutes using an LED light device (Elipar S10, 3M ESPE).
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**Table 1. Cross-sectional Diameters, Buccolingual (BL) × Mesiodistal (MD) Diameters, and Fracture Loads of the Roots**

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>BL</th>
<th>MD</th>
<th>of BL × MB</th>
<th>Fracture (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>20</td>
<td>7.07±0.45</td>
<td>4.97±0.43</td>
<td>34.94±3.18</td>
<td>2472.63±308.21*</td>
</tr>
<tr>
<td>TEC + EverX Posterior</td>
<td>20</td>
<td>7.05±0.66</td>
<td>4.97±0.66</td>
<td>35.04±5.84</td>
<td>971.03±114.28b</td>
</tr>
<tr>
<td>CEC + EverX Posterior</td>
<td>20</td>
<td>7.06±0.84</td>
<td>4.96±0.33</td>
<td>34.96±4.40</td>
<td>1008.25±216.83b</td>
</tr>
<tr>
<td>TEC + SDR</td>
<td>20</td>
<td>6.83±0.75</td>
<td>5.03±0.38</td>
<td>34.36±4.71</td>
<td>1451.92±205.39c</td>
</tr>
<tr>
<td>CEC + SDR</td>
<td>20</td>
<td>7.27±0.92</td>
<td>4.95±0.34</td>
<td>35.84±4.24</td>
<td>1674.07±238.36c</td>
</tr>
<tr>
<td>P value</td>
<td>20</td>
<td>&gt;.05</td>
<td>&gt;.05</td>
<td>&gt;.05</td>
<td>&lt;.05</td>
</tr>
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CEC, conservative endodontic cavity; TEC, traditional endodontic cavity. Different superscript letters indicate a significant difference (P < .05).

**Fracture Strength Test**

The teeth in all the groups were kept in distilled water at room temperature (~25°C) for 24 hours before the fracture strength test. For fracture testing, all the samples were placed on an Instron Universal Testing Machine (Instron, Buckinghamshire, UK), which applies a compressive load on the central fossa in the lingual direction at a 15° angle to the longitudinal axes of the teeth. This load was applied on the samples at 1-mm/min speed using a 6-mm round-head tip until fracture. The forces resulting in fracture were recorded in newton units, and the fracture types were classified by 2 independent observers using a stereomicroscope. The failures including vertical root fractures below the level of bone simulation were defined as nonrestorable fractures (Fig. 3A). The failures including adhesive failures above the level of bone simulation were defined as restorable fractures (Fig. 3B).

**Statistical Analysis**

The BL and MD dimensions and BL × MD diameter were subjected to the Shapiro-Wilk statistical test to examine the normality of continuous variables. The Kruskal-Wallis test was used to evaluate differences between the BL and MD dimensions and BL × MD diameter of the specimens. The fracture load data were analyzed using the Kruskal-Wallis test. Correlations of the fracture data with the BL and MD dimensions and BL × MD diameter were assessed using the Pearson correlation test. All tests were performed at 95% confidence (P < .05).

**Results**

The fracture loads of the roots and other variables in the 5 groups are shown in Table 1. The statistical analysis confirmed the standardization of roots among the groups in terms of the BL, MD, and BL × MD diameter (P > .05).

The fracture strengths of the samples in the control group were significantly higher than those in the experimental groups (P < .05). There was no statistically significant difference in the endodontic access cavities prepared using the TEC and CEC methods and restored using the same composite base material (P > .05). Regardless of the type of method used to prepare the endodontic access cavity, among the experimental groups, the highest fracture strength was observed in group 4 (TEC + SDR) and group 5 (CEC + SDR) restored using the SDR composite base material.

The correlations of the fracture resistance of the teeth with the BL, MD, and BL × MD diameter are presented in Table 2. The fracture resistance of the teeth increased as the BL, MD, and BL × MD dimension increased.

The percentage, frequency, and mode of failure are shown in Table 3. There was more restorable fracture in the control group and group 3 (EC + EverX Posterior) than the other groups (P < .05). In contrast, there were more nonrestorable fractures in group 2 (TEC + EverX Posterior) and group 4 (TEC + SDR) (P < .05). There was no significant difference between restorable and nonrestorable fractures in group 5 (EC + SDR) (P > .05).

**Discussion**

Conservative and minimally invasive approaches are increasingly used in dentistry today. In the present study, TEC and CEC preparation methods were compared. The aim of the study was to compare these 2 types of cavity preparation (TEC and CEC) and examine the effects of different base materials on the fracture strengths of samples in the TEC and CEC groups. In contrast to previous studies using occlusal cavities (21, 22), the present study aimed to imitate clinical cases of endodontic treatment because of interproximal caries that did not affect the entire occlusal segment of the tooth (class II). Such cases have been frequently reported in the literature (23, 24).

In the present study, mandibular molar teeth were selected because vertical fractures are most frequently observed in mandibular molar teeth among endodontically treated posterior teeth (25, 26). In endodontic treatment of posterior teeth, the main problem with cavities prepared using the TEC method is that the pulpal chamber floor also constitutes the cavity floor (27). Among mandibular molar teeth, occlusal enamel and dentin located at the center of a tooth are subject to high chewing pressure (28). By preserving the pulpal chamber roof using CEC preparation, the aim is to distribute the occlusal forces before they reach the pulpal chamber floor (29). An additional aim is to preserve cervical dentin, which is very important for the lifetime and optimal function of teeth (30, 31). The results of the present study showed that the teeth having a CEC design had more restorable fractures than the teeth having a TEC design. The more restorable fracture pattern in the CEC design could be attributed to the different base materials used in dentistry today.
preservation of the pulpal chamber roof. In the present study, as a direct result of using the CEC design, all the canals could be accessed via a straight line, in contrast to previous studies that used ninja endodontic access (21, 22). The main drawbacks of CEC preparation are the limitation in the examination of the pulp chamber and the difficulties in the debridement of the area under the pulp roof that does not get exposed.

According to the findings of the present study, there was no statistically significant difference in the fracture strengths of the samples prepared with the traditional (TEC) and conservative (CEC) methods when restored with the same base material \((P > .05)\). Thus, the first null hypothesis of the present study was accepted. In common with the findings of the present study, Moore et al (12) and Rover et al (22) found no significant difference between the TEC and CEC preparation methods in terms of fracture strength. On the other hand, a study of the fracture strengths of mandibular molar and premolar teeth after preparation with the TEC and CEC methods reported that the CEC method was associated with significantly higher fracture resistance than the TEC method (7). Similarly, Plotino et al (21) found that the fracture strength of teeth prepared with the TEC method was significantly lower than that of teeth prepared with the CEC method and the ultra-CEC method. The same study reported a significant difference between the fracture strengths of teeth prepared with the CEC and ultra-CEC methods (21). The discordant results may be caused by differences in the methodologies used in these studies.

The maximum decrease in the fracture strength of teeth occurs because of the loss of marginal ridge integrity. A previous study reported a 46% decrease in the strength of teeth because of the loss of marginal ridge integrity (2). In the present study, we attribute the absence of a significant difference in the fracture strengths of the TEC and CEC groups restored with the same base material (ie, class II) prepared. In addition, the manipulation of base materials during restorative procedures in cavities prepared using the CEC method is more difficult than in those prepared using the TEC method. Thus, the base materials might have not been adequately placed into the cavity during CEC preparation. Furthermore, we aimed to preserve as much dentin as possible, and spaces under the occlusal enamel and dentin might have created areas of stress and decreased the fracture strength of the teeth.

According to the results of the present study, regardless of the type of prepared endodontic cavity, the fracture strength of the samples restored with SDR was higher than that of the samples restored using EverX Posterior \((P < .05)\). Thus, the second null hypothesis of the present study was rejected. A previous study showed that the choice of restoration material had significant effects on the fracture strength of teeth after root canal treatment (52). In the present study, in contrast to previous studies, the fracture strength of teeth restored with EverX Posterior was lower than that of teeth restored using SDR (33, 34).

In a study of the fracture strengths of EverX Posterior and traditional composites, Fräter et al (35) reported that the best strength was obtained when the former was applied in oblique layers. In the present study, the fracture strength of EverX Posterior may have been decreased because of the application method (ie, bulk filled). Moreover, during the restoration of teeth with CEC preparation, the higher viscosity of EverX Posterior compared with that of SDR might have resulted in less adaptation to the cavity walls.

In the present study, the teeth in the control group and the CEC group had significantly more restorable fractures than teeth in the TEC group \((P < .05)\). In addition to examining the fracture strengths of endodontically treated teeth, it is important to examine the fracture type (36). A nonrestorable fracture in the tooth structure results in extraction of the tooth (37). According to the results of the present study, although there was no significant difference in the fracture strengths of teeth prepared using the TEC and CEC methods, the types of fractures were less serious with CEC preparation. The limitations of the present study are that a static rather than a dynamic force was applied to the samples, and intraoral factors, such as temperature and pH changes, were not simulated (37).

**Conclusion**

Within the limitations of this study, it can be concluded that CEC preparation did not increase the fracture strength of teeth with class II cavities compared with TEC preparation. The fracture strength of teeth restored with the SDR bulk-fill composite was higher than that of teeth restored with EverX Posterior regardless of access type.

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The authors deny any conflicts of interest related to this study.

**References**

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