Original Article

The effect of preserving the mid-occlusal enamel-dentin bridge during access cavity preparation on fracture resistance of endodontically treated mandibular molars

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Abstract

Objective: The access cavity preparation technique might influence the fracture resistance of endodontically treated teeth. This study evaluated the impact of preserving the enamel-dentin bridge on fracture resistance of endodontically treated mandibular molars.

Methods: A total of 42 mandibular molars were randomly divided into three groups according to the access cavity design: Traditional endodontic access cavity (TEC), truss endodontic access cavity (TREC), and control (CON) (n=14). The teeth in each group were divided into two equal subgroups (with and without thermocycling). The control group was stored in saline over the experiment, whereas class II mesio-occlusal access cavities were prepared in the two experimental groups. In the TEC design, a conventional access cavity was prepared. In the TREC design, the occlusal enamel and dentin between the mesial and distal root canal orifices were not removed. Endodontic treatment, and composite resin restoration were performed similarly in the experimental groups. The teeth were subjected to fracture resistance testing in an Instron machine and the load at fracture was compared among the groups.

Results: The CON group had significantly superior fracture resistance than the two experimental groups ($P<0.05$), which showed comparable fracture load values at both conditions ($P>0.05$). Thermal cycling reduced fracture resistance in both TEC and TREC groups ($P<0.05$), but had no significant effect in the control group ($P=0.624$).

Conclusions: Considering the similar fracture resistance of the TEC and TREC groups, the study suggested that preserving the enamel-dentin bridge does not enhance fracture resistance in endodontically treated teeth with mesio-occlusal cavities.

Keywords: Conservative treatment, Dental pulp cavity, Dentin, Fracture resistance, Root canal obturation, Root canal therapy

Introduction

Endodontic treatments aim to preserve long-term tooth functionality but may make the tooth susceptible to fractures. Evidence shows that tooth fracture mainly occurs due to the loss of tooth structure as a result of extensive caries and subsequent access cavity, and root canal preparation (1).

Access cavity preparation is an important step in endodontic treatments. In the traditional endodontic access cavity (TEC) design, the tooth structure is removed in a controlled manner to access the root canal orifices, enhance cleaning and shaping, facilitate the obturation of the root canal system, and prevent procedural errors (2).

Different conservative endodontic access cavity (CEC) designs have been proposed such as the conventional conservative design (a small conservative cavity in the occlusal surface that allows the clinician to access all canal orifices), the truss design (direct access from the occlusal surface to the mesial and distal canal orifices while preserving the dentinal bridge between the two parts), and the 'ninja' access cavity. The 'ninja' design is a form of ultraconservative access cavity preparation and consists of preparing a "point access" in the central fossa, aiming to improve the fracture resistance of endodontically treated teeth and reduce the need for subsequent extensive, and costly restorative procedures (3).

In contrast to the TEC design, the truss endodontic access cavity (TREC) design is less invasive, better preserves the dentinal structure at the paracervical area, and increases the fracture resistance of endodontically treated teeth (4). Silva et al. (5) reported that the TREC design increases the fracture resistance of endodontically treated

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teeth while the ultraconservative 'ninja' access cavity design did not increase the fracture resistance of endodontically treated two-rooted maxillary premolars. However, it should be noted that such modified access cavity designs often complicate efficient cleaning and shaping, and obturation of the root canal system (2). Also, insufficient extension of the access cavity can lead to the occurrence of iatrogenic errors (6, 7).

Thermocycling is commonly used in in vitro studies to simulate the aging process due to thermal alterations in the oral environment (8). The fracture resistance of teeth may be different after exposure to thermal changes (9). A previous study demonstrated that under thermal stresses, the TREC design in teeth with intact marginal ridges yielded a fracture resistance comparable to that of intact teeth; whereas, teeth with the TEC design showed minimal fracture resistance (9).

Mesial carious lesions are among the factors that may necessitate endodontic treatment (10). There are controversial reports on the effect of the access cavity design on fracture resistance of endodontically treated teeth. This study was designed to assess the effect of preserving the enamel-dentin bridge during access cavity preparation on fracture resistance of mandibular molars without a mesial marginal ridge.

Materials and Methods

Ethical approval for this in vitro study was obtained from the research committee of Zahedan University of Medical Sciences (IR.ZAUMS.REC.1395.243). Forty-two mandibular first and second molar teeth were included in the experiment. The teeth had mature apices and were obtained from patients between 20 and 45 years, after taking informed consent.

The collected teeth were intact and did not contain any carious lesions, restorations, cracks, or fractures. The teeth were cleaned with a rubber cup and pumice paste, then stored in 0.9% saline at 4°C. This storage method was maintained throughout various phases of the experiment to prevent dehydration. All teeth underwent digital radiography in buccolingual and mesiodistal directions using a posterior film holder (Dentsply DeTrey GmbH, Konstanz, Germany) customized by putty impression material (Speedex, Asia Chemi Teb Co. Tehran, Iran). Teeth with narrow canals or calcified pulp chambers were excluded to maintain standardization. Anatomic crown height was measured by a digital calliper (Digimatic 500; Mitutoyo, Kanagawa, Japan) on all four surfaces from the occlusal level to the cementoenamel junction. The buccolingual and mesiodistal dimensions of the teeth were measured from the occlusal surface. Care was taken to ensure that all teeth had similar dimensions (within 0.5 mm difference from the mean value) to minimize the effect of variable sizes and shapes of the teeth on the results (11).

The teeth were then randomly allocated into two experimental and one control (n=14) groups with two subgroups in each group as follows:

Group 1: a) Intact control group without thermocycling (CON)

b) Intact control group with thermocycling (CON-TC)

Group 2: a) TEC design without mesial marginal ridge and thermocycling

b) TEC design without mesial marginal ridge and with thermocycling (TEC-TC)

Group 3: a) TREC design without mesial marginal ridge and thermocycling

b) TREC design without mesial marginal ridge and with thermocycling (TREC-TC)

Control group teeth were stored in saline throughout the experiment, whereas class II mesio-occlusal (MO) access cavities were prepared in the two experimental groups. These cavities were prepared using a diamond bur (No. 856; Intensiv SA, Switzerland) and high-speed hand-piece under air and water coolant. A class II MO box was prepared with specific dimensions (6 mm width × 3 mm depth × 4 mm height) in all samples.

Preparation of TEC and TREC designs

In the TEC design, occlusal enamel and dentin between the mesial and distal root canal orifices were removed (Figure 1).

In the TREC design, the occlusal enamel and dentin between the mesial and distal root canal orifices were not removed (Figure 1). This means that part of the pulp chamber roof was preserved in the TREC design, and the mesial and distal access cavities were separated by the enamel-dentin bridge (12).

The distal marginal ridge thickness in both cavity designs was at least 1.5 mm.

Efforts were made to standardize the dimensions and depth of the access cavity in the experimental groups. Samples that did not meet these criteria were excluded and replaced.

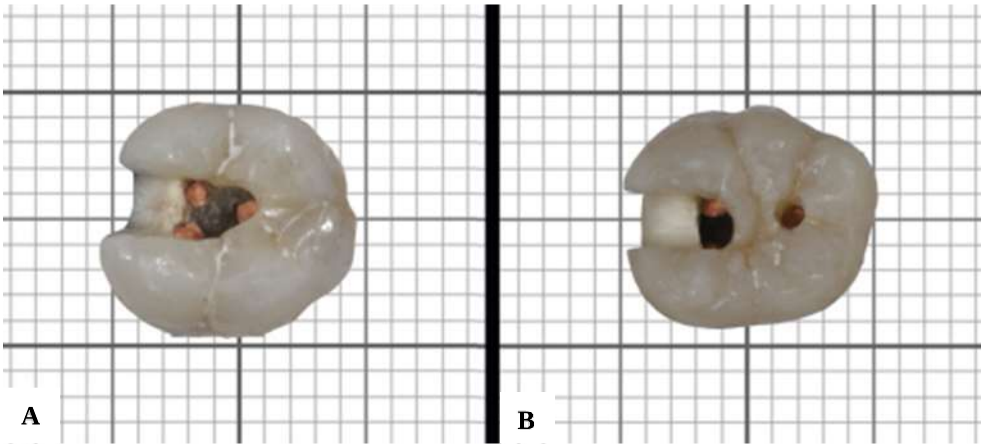

Figure 1. Type of access cavity designs. (A) Traditional endodontic access cavity (TEC). (B) Truss endodontic access cavity (TREC).

Endodontic treatment and restoration of teeth

In the experimental groups, standard endodontic treatment was performed. Subsequently, the enamel and dentinal walls were etched with 37% phosphoric acid gel (Morva Etch, Tehran, Iran); 30 seconds for enamel and 15 seconds for dentin. The samples were then washed and dried. Each tooth was covered by two layers of a bonding agent (Ultimate Bond; Master-Dent, USA). Gentle air blast was applied for 5 seconds to the adhesive solvent followed by 10 seconds of light curing by an LED curing unit. Then, the cavities were restored with composite resin (Gradia Direct, Japan) using a Tofflemire retainer and an ultrathin matrix band. Composite was applied by the oblique incremental technique intercalated with 40 seconds of light curing to the level of the occlusal surface.

Simulation of periodontal ligament

The roots were coated with wax from the root apex to the cementoenamel junction. Next, they were mounted in a metal mold containing auto-polymerizing acrylic resin (Acropars, Tehran, Iran) to the level of their cementoenamel junction. To eliminate the heat generated by the polymerization reaction of resin, the crowns were constantly water sprayed. After acrylic polymerization, the teeth were removed from the acrylic mold and the wax was rinsed off with hot water. Hot water was used for its ability to melt and easily remove wax without damaging the tooth structure or affecting the other materials used in the study. To simulate the periodontal ligament, the created space was filled with silicone light body (wash) impression material (Speedex; Asia Chemi Teb Co.), and the teeth were embedded to the level of their cementoenamel junction. The teeth were then stored in a 0.9% saline solution at 4°C until their fracture resistance was measured. The storage duration ranged between 24 and 36 hours.

Thermocycling

All teeth in the control, TEC, and TREC groups were stored in distilled water with no additional treatment. However, the teeth in CON-TC, TEC-TC, and TREC-TC subgroups underwent 1000 thermal cycles between 5°C and 55°C with a dwell time of 30 seconds and a transfer time of 5 seconds in a thermocycler (Nemo, Iran).

Fracture resistance testing

The load was applied to the central fossa of the teeth along their lingual surface at a 15° angle relative to their longitudinal axis, using an Instron universal testing machine (Santam, Iran). Load application was done using a round-end piston with a 6 mm diameter at a crosshead speed of 1 mm/min until tooth fracture. The load at fracture was recorded in Newtons (N) for each tooth.

Statistical analysis

Data were analyzed using SPSS version 23.0 (IBM Corp., Armonk, NY, USA). Considering the normal distribution of the data a two-way analysis of variance (ANOVA) was applied. The level of significance was set at $P<0.05$.

Results

There was a significant interaction between the two variables ($P=0.04$). Therefore, a t-test was applied to compare each group with and without thermocycling, whereas ANOVA followed by Tukey's test was employed to assess between-group differences in fracture resistance.

Table 1 compares the fracture resistance of the study groups with and without thermocycling. There was no significant difference in the fracture resistance of the control group with and without thermocycling ($P=0.624$). However, the fracture resistance of the TEC and TREC groups was significantly higher than the corresponding groups with thermocycling ($P<0.05$; Table 1).

ANOVA revealed a significant difference in fracture resistance among the study groups with and without exposure to thermal cycles ($P<0.05$; Table 1). Tukey test revealed that the fracture resistance of the control group was significantly higher than the other groups ($P<0.05$), whereas the experimental groups showed comparable fracture load values at both conditions ($P>0.05$; Table 1).

Discussion

The current study presented an in-depth analysis of the impact of access cavity preparation design on the fracture resistance of endodontically treated teeth. A previous study indicated that age-related differences, such as sclerotic dentin and secondary dentin deposition, can affect dentin structure (13). Accordingly, the teeth used for this study were extracted from patients between 20 and 45 years old to minimize this effect on the results. The fracture resistance was measured by an Instron universal testing machine, and the load was applied along the lingual surface at a 15° angle relative to the longitudinal axis of the tooth, using a ball with a 6-mm diameter. This methodology was similar to that of a previous study (14).

Mandibular molars were used in the experiment because they are the most common posterior teeth that require endodontic treatment and are susceptible to fracture due to the presence of a wide occlusal table that increases the occlusal stresses. To simulate the clinical cases that undergo endodontic treatment, a mesial box was prepared in the experimental groups (10).

It is believed that in mandibular molars, dentin and enamel at the center of the occlusal surface tolerate maximum masticatory forces (15). Thus, the preservation of the pulp chamber roof and enamel-dentin bridge in the TREC design can lead to a better distribution of loads before reaching the pulp chamber floor (16). However, the present findings do not corroborate this assumption.

The current results indicated that the fracture resistance of both thermocycled and non-thermocycled control groups was significantly higher, compared to that of other groups. Consistent with our results, many other studies reported that the fracture resistance of intact teeth was significantly higher than that of teeth with conventional and CEC designs without a mesial marginal ridge (6, 10). Silva et al. (17) indicated that access cavity preparation can decrease fracture resistance due to the elimination of dentin structure from the center of the teeth. Others believe that the maximum reduction in fracture resistance occurs following the loss of the marginal ridge integrity; one study reported up to a 46% reduction (18).

The present findings contradict the results of Shahrbaf et al. (19), who found no significant difference in fracture resistance of sound and endodontically treated premolars with disto-occlusal (DO) cavities and a marginal ridge thickness between 1-2 mm. They concluded that in the presence of a marginal ridge with adequate thickness in a tooth with a DO cavity, the fracture resistance of the respective tooth would not be significantly different from that of a sound tooth (19).

The present results indicated that access cavity design had no significant effect on fracture resistance of endodontically treated mandibular molars, and the fracture resistance of the TEC and TREC groups was comparable. Thermocycling had no significant effect on the fracture resistance of control teeth, but it did significantly decrease the fracture resistance of endodontically treated teeth with TREC and TEC designs. In agreement with the present findings, Özyürek et al. (10) indicated that CECs with class II mesial cavities did not increase the fracture resistance of endodontically treated teeth. Platino et al. (3), Corcentino et al. (11), Moore et al. (6), and Rover et al. (20) found no significant difference in fracture resistance of teeth with CEC and TEC designs. Sabeti et al. (21) showed that the CEC design had no significant effect on fracture resistance of the teeth but increasing the canal taper decreased the fracture resistance of endodontically-treated teeth.

On the contrary, Saberi et al. (9) indicated that the TREC design enhanced the fracture resistance of endodontically treated teeth after exposure to thermal stresses. Additionally, Krishan et al. (22) stated that the CEC design enhanced the fracture resistance of endodontically

Table 1. Comparison of the fracture resistance of the study groups with/without thermocycling

Group	With thermocycling*	Without thermocycling*	P value
Control	$1595.7^{a} \pm 72.7$	$1676.3^{a} \pm 106.5$	0.624
TEC design	$1203.2^{b} \pm 127.56$	$1469.9^{b} \pm 121.9$	0.03
TREC design	$1264.9^{b} \pm 209.3$	$1551.2^{b} \pm 143.0$	0.015
P value	0.001	0.003	

TEC= Traditional endodontic access cavity, TREC= Truss endodontic access cavity
* Similar superscripted letters indicate no statistically significant difference between groups at $P<0.05$.

treated teeth compared to the TEC design but also compromised the efficacy of instrumentation in the distal canal of mandibular molars. It should be noted that the application of restorative materials in teeth with a mesial box and a TREC design is more difficult compared with the TEC design. The restorative materials may not be optimally packed in the TREC design, and consequently, some stress points may be formed in the area below the enamel-dentin bridge, which decreases the fracture resistance of the tooth (10). The controversies observed in the results of previous studies may be attributed to methodological differences in the study designs including the type of teeth (mandibular first molars (10, 23) or maxillary first molars (24) in previous studies versus the mandibular first and second molars in the present study), type of restorative material, and the applied methodology for fracture resistance testing (25).

Due to the in vitro design of this study. It was not possible to simulate conditions such as the presence of adjacent teeth, tooth position in the dental arch, number of occlusal contacts, status of periapical tissue (26), as well as the dynamic interactions of forces applied at different directions (27). This should be taken into account when interpreting the results. In this study, load was applied at a 15-degree angle relative to the longitudinal axis of the teeth to simulate load application in the clinical setting. Nonetheless, lateral forces cannot be simulated in vitro (28). Another limitation of this study was the absence of MO cavities in the control group. Further studies are suggested to assess the effects of various access cavity designs on fracture resistance of teeth in clinical settings.

Conclusion

Within the limitations of this study, it appears that the preservation of the enamel-dentin bridge in the access cavity of mandibular molars without a mesial marginal ridge has no significant effect on their fracture resistance when compared with the traditional access cavity design.

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