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ORIGINAL RESEARCH

Influence of access cavity design on fracture strength of endodontically treated lower molars

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Abstract

To assess whether access cavity design influences the fracture strength of endodontically treated and restored molars. Fifty human lower molars with standard crown dimensions were selected and assigned to the following groups: S – positive control (healthy tooth), ET – negative control (conventional endodontic access (CEA) and no restoration), NI – negative control (minimally invasive endodontic access (MEA) and no restoration), ETR (CEA + restoration with Bulkfill flow) and NIR (MEA + restoration with Bulk-fill flow). The specimens were subjected to a compression test. The teeth were inspected for the site of fracture: either pulp floor or cusp. ANOVA, followed by Tukey's multiple comparison test ($\alpha = 5\%$), was used for statistical analysis. The type of access cavity preparation did not increase the fracture strength of endodontically treated teeth. Even with the restoration, all teeth with endodontic access performed had a higher incidence of fractures at the pulp chamber floor level.

Introduction

Post-endodontic treatment fractures are often attributed to a pronounced loss of dental structure (1). Molars and premolars are extracted within 4 to 5 years after endodontic treatment (2,3), and coronal fractures account for 47% of this loss (4,5).

According to Clark and Khademi (6), coronal access cavity preparation is the first 'invasive' step of endodontic treatment and therefore plays a critical role in the desired outcome and longevity of the treated tooth.

Conventional access cavity preparations consist of the complete removal of the pulp chamber roof and wear on the lateral surfaces of the cavity, which could compromise access and visualisation of the root canals during treatment (7). Ree and Schwartz (8) and Tang *et al*. (9) have stated this excessive removal of tooth structure is closely related to coronal fractures in teeth subjected to functional loads.

With the use of nickel–titanium instruments, clinical microscopy and more detailed image resources, such as cone beam computed tomography, minimally invasive access cavity preparation have become more clinically feasible, preserving dentinal structures and maintaining the quality of endodontic treatment (10). The more conservative access design is mainly supported by the preservation of a greater amount of tooth structure on the occlusal surface, seeking to increase its fracture strength (9,11). This technique consists of a small hole made on the occlusal surface of the tooth to be treated, preventing the complete removal of the pulp chamber roof and allowing access of the endodontic instrument to the root canals (12,13).

Therefore, the present study aims to evaluate whether endodontic access cavity design influences fracture strength and site of the fracture in endodontically treated and restored molars. The null hypothesis was that the use of more conservative preparations would provide greater fracture strength than the conventional coronal opening technique in molars subjected to endodontic treatment.

Materials and methods

Sample selection and preparation

Fifty human lower third molars free of carious lesions, restorations or cracks were used in the study. We calculated sample size on the basis of a pilot study and considered the following parameters: type I error probability of .05, nominal test power of 0.8, difference between groups of 230 newtons (N) and average standard deviation of 90 N. The minimum sample size was set to 10 specimens per group.

The buccopalatal (11 mm $\pm$ 0.5 mm) and mesiodistal (9.5 mm $\pm$ 0.5 mm) dimensions of the selected crowns were measured with a digital caliper (Mitutoyo, Suzano, SP, Brazil) at the most prominent point of the respective surfaces.

After the cleaning procedures, the teeth were disinfected by immersion in a 0.5% chloramine solution (Seachem Laboratories, Madison, GA, USA) for 48 h. The teeth were randomly assigned to five experimental groups (Table 1).

Endodontic access cavity preparation

In teeth of the ET and ETR groups, coronal opening followed the basic preparation principles, with complete removal of the pulp chamber roof (Fig. 1a) using a spherical diamond bur #1012 (KG Sorensen, Barueri, SP, Brazil) and Endo Z bur (Dentsply/Maillefer, Ballaigues, Switzerland).

In the NI and NIR groups, minimally invasive coronal opening was performed with the aid of a clinical microscope (DF Vasconcellos, Valença, RJ, Brazil). The access to the pulp chamber was made in the central fossa of the main groove of the occlusal surface, perpendicular to the long axis of the tooth (Fig. 1B), with a spherical diamond bur #1014 (KG Sorensen, Barueri, SP, Brazil), following the access cavity preparation performed in the study by Plotino *et al.* (13).

Table 1 Experimental group design

Group	*n*	Description
S	10	Healthy tooth (positive control)
ET	10	Conventional endodontic access + endodontic treatment and no restoration (negative control)
NI	10	Minimally invasive endodontic access + endodontic treatment and no restoration (negative control)
ETR	10	Conventional endodontic access + endodontic treatment with restoration
NIR	10	Minimally invasive endodontic access + endodontic treatment with restoration

After access to the pulp chamber, the entrance to the mesiobuccal, mesiolingual and distal canals was located with the aid of a Rhein probe #3 (Golgran Industria e Comercio de Instrumental Odontológico Ltda., São Paulo, SP, Brazil). No intervention was performed in group S.

Endodontic treatment

Initially, the canals were probed with a K file #10 (Dentsply/Maillefer Instruments S.A., Ballaigues, Switzerland) until the tip of the instrument was juxtaposed to the outlet of the foramen. From the length measured on the instrument, 1 mm was reduced and the working length (WL) was determined. The chemomechanical preparation of the root canals was performed using ProDesign Logic® instruments (Easy Dental Equipamentos, Belo Horizonte, MG, Brazil). After exploring the root canal, the rotary instrument #25 taper .01 was coupled to the electric motor (Easy Dental Equipamentos, Belo Horizonte, MG, Brazil) at a speed of 350 rpm and torque of 1 N and used to maintain apical patency. Following the preparation, Prodesign Logic® instruments were used successively along the WL – no.15 taper 03 (speed 350 rpm and torque 2 N) and no. 25 taper .04 (speed 950 rpm and torque 4 N). Each set of instruments was used for the preparation of five molars.

Intracanal irrigation during instrumentation was performed with 2.5% sodium hypochlorite solution using an irrigation syringe and Endo-Eze needle (Ultradent, South Jordan, UT, USA). After the preparation, the canal was filled with 17% tri-sodium EDTA (Iodontec Indústria e Comércio de Produtos Odontológicas Ltda., Porto Alegre, RS, Brazil) and the solution was stirred for 2 min with K file #15. EDTA was then removed with 2 mL of distilled water and the canals were dried using absorbent paper points (Tanari Indústria Ltda., Manaus, AM, Brazil) along the WL.

Endodontic filling was performed using Tagger's hybrid technique associated with the use of Endofill® filling cement (Dentsply/Maillefer, Ballaigues, Switzerland). The filling was performed at the entrance to the canals, the pulp chamber was cleaned, and radiographs were taken in the buccolingual direction to confirm the correct filling of the root canals.

Restorative procedure

The restorative procedure was performed with Bulkfill flow resin (3M ESPE, St. Paul, MN, USA), according to the following protocol:

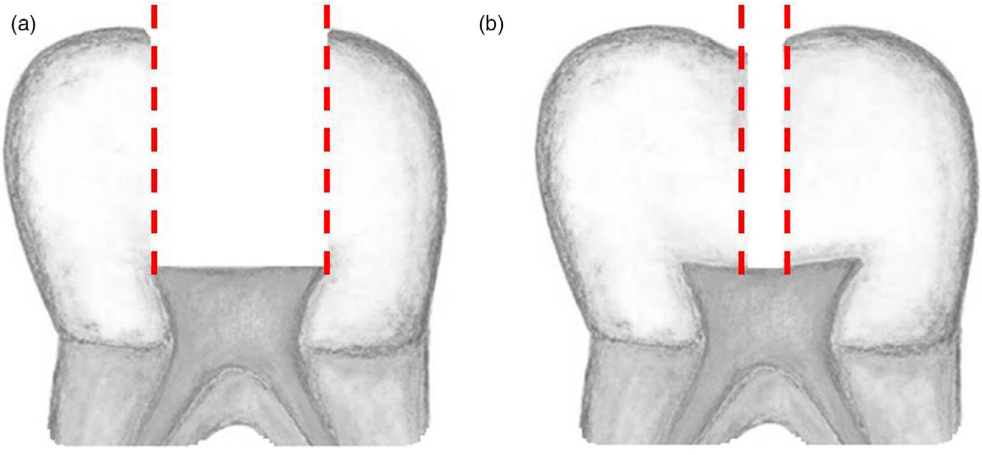

Figure 1 Sagittal section of the dental crown showing the access cavity preparation. (a) Access cavity preparation with complete removal of the pulp chamber roof; (b) Minimally invasive coronal access cavity preparation.

- etching of enamel and dentin with 35% phosphoric acid (Dentisply Ind e Com. Ltda, Petrópolis, RJ, Brazil) for 20 s, washing for 20 s and drying with air jets.
- application of Singlebond Universal adhesive (3M ESPE, St. Paul, MN, USA), drying for 5 s and photoactivation for 20 s (Bluephase, Ivoclar Vivadent, AG, FL-9494 Schaan/Liechtenstein).
- filling of the whole access cavity with Bulkfill flow resin and photoactivation for 40 s.

Preparation of specimens

The teeth were inserted individually in self-curing acrylic resin based on a polymer (powder) and a monomer (liquid), spatulated according to the manufacturer's recommendations. The teeth were centred inside a plastic cylinder with a height of 2 cm and diameter of 3 cm so that the anatomical neck of the tooth was exposed 2 mm above the edge of the acrylic. The specimens were stored in distilled water and kept in an oven at 37°C for 48 h.

Mechanical test

The specimens were initially thermocycled between 5°C and 55°C for 500 cycles according to ISO TR 11405 before being subjected to a fracture strength test.

The fracture strength test was performed on an EMIC DL – 2000 universal testing machine (São José dos Pinhais, PR, Brazil). A 10-kN load cell and a speed of 0.5 mm min^{-1} were selected.

A steel cylinder (7.5 mm in diameter and 16 mm in length) coupled to a load cell was applied to the inclined planes of the occlusal contacts in the intercuspal position in the mesiodistal direction. There was no contact with the restorative material. Compressive stress was applied parallel to the long axis of the tooth until its fracture. The maximum loading force (rupture) for each specimen was recorded in newtons (N).

Analysis of tooth fracture site

After the fracture strength test, the teeth were visually examined using a magnifying glass (4× magnification) to assess the site of the tooth fracture: (i) pulp floor fracture and (ii) cusp fracture only. Floor fracture was considered when the fracture line split the tooth into two parts at the level of the pulp floor, regardless of whether it was buccal/palatal or mesial/distal. Cusp fracture was considered when the fracture line totally or partially involved the cusp, regardless of the presence or absence of its displacement.

Statistical analysis

ANOVA, followed by Tukey's multiple comparison test, was used to assess fracture strength. The level of significance was set at 5% ($P \leq 0.05$). Statistical analysis was performed using GraphPad Prism 7 (GraphPad Software Inc., San Diego, CA, USA).

Results

The S group showed greater mean fracture strength, differing statistically from the ET, NI, ETR and NIR groups (Table 2). None of the groups showed a similar pattern of failure distribution to that of the S group.

Table 2 Fracture strength (newtons (N)) and strength recovery in relation to group S, and pulp and cusp floor fracture in different experimental groups

Groups	Mean ± SD (N)	Strength recovery	Cusp fracture	Pulp floor fracture
S	$3722^{A} \pm 825.9$	—	90% (9)	10% (1)
ET	$1233^{B} \pm 325.1$	33%	20% (2)	80% (8)
NI	$1425^{BC} \pm 222$	38%	40% (4)	60% (6)
ETR	$1994^{CD} \pm 551.9$	54%	40% (4)	60% (6)
NIR	$2526^{D} \pm 704.5$	68%	50% (5)	50% (5)

Means followed by different uppercase letters differ significantly in one-way ANOVA and Tukey's test ($P < 0.05$).

Discussion

Fractures in endodontically treated teeth are frequently observed in clinical dental practice. The fracture of endodontically treated teeth results from their biomechanical compromise. The higher incidence of fracture is related to the loss of tooth structure due to cavity preparation (14). For Ikram *et al.* (15), minimally invasive endodontic access cavity preparation can improve the prognosis of the risk of fracture in endodontically treated teeth.

According to the results obtained, the fracture strength of healthy teeth (positive control) was significantly higher than that of the other groups tested. This finding was also observed in studies by Moore *et al.* (16), Consertino *et al.* (17) and Özyürek *et al.* (18). The greater risk of tooth fracture can be explained by the partial or total loss of the pulp chamber roof, considered one of the fundamental tooth strengthening structures (19). Depending on the degree of impairment of the dental crown, the chamber roof becomes the closest 'link' between the cusps, absorbing and assisting in the distribution of masticatory and functional forces along the entire tooth surface (9).

The initial hypothesis of the study was rejected since the performance of a minimally invasive endodontic access did not considerably improve the fracture strength of the dental crown when compared to conventional access, which was also verified by Özyürek *et al.* (18) and Sabeti *et al.* (20). Some contributing factors could have been the lack of cervical preparation and very conservative instrumentation, without great power to dilate the root canal. In 2018, Silva *et al.* (21) emphasised the importance of maximum preservation of the pericervical dentin area, because tissue loss of this structure associated with the dental contrition normally observed in the dental 'neck' could eventually lead to a greater stress, which would reduce the forces required for tooth fracture.

The instrumentation protocol followed in this study (file #25 taper. 04) could also have contributed to the lack of influence of cavity access preparation on coronal fracture. According to the manufacturer of the instruments, one of the basic principles of the Prodesign Logic® system is to shape the root canal while preserving the dentinal structure as much as possible, which explains the lower taper of the instruments used at the apical third.

On the other hand, Krishan *et al.* (4) and Plotino *et al.* (13) observed a significant difference in fracture strength in relation to the design of the access cavity preparation performed. In teeth subjected to minimally invasive access, a significantly higher fracture strength was observed when compared with teeth subjected to conventional access. These studies corroborate, to some extent, that by Al-Omiri *et al.* (22), in which the authors report better fracture strength with preservation of the dentinal structure when minimally invasive endodontic access cavity preparation is used.

Regarding the influence of the restorative procedure on fracture strength, regardless of the type of endodontic access performed, there was a significant increase in fracture strength in restored teeth when compared to negative control groups (no restoration). Studies by Atalay *et al.* (23) and Cobankara *et al.* (24) showed that, regardless of the restoration techniques carried out in their studies, none was able to fully restore the fracture strength lost with access cavity preparation.

Direct restoration with adhesive materials is a routine procedure in the clinical setting (16). According to Taha *et al.* (25), adhesive restorations strengthen the remaining tooth structure, thus increasing its fracture strength. Traditional composite resins must be worked and placed on the bottom of the cavity preparation incrementally (increments of ± 2 mm in thickness). This precaution should be taken since polymerisation shrinkage stress is relatively high in larger increments, which could cause a mismatch at the adhesive interface between the dentin substrate and the composite (26).

Recently, flowable resin composites have been launched on the market, allowing for the filling of larger cavities (4–5 mm deep in a single increment) with excellent curing power (27). The polymerisation shrinkage stress of these more fluid materials tends to decrease owing to modifications of the matrix resin, which can improve bond strength (28,29). Atalay *et al.* (23) described no difference in the fracture strength of teeth restored with nanohybrid composite resins – Tetric N-Ceram® and Filtek Bulkfill flow®.

Regarding the site of fracture, all endodontically treated teeth either with or without restoration showed a higher rate of pulp floor fractures than cusp fractures when compared to healthy teeth (positive control group). This encourages reflection on the performance of direct restorative procedures without prior reinforcement of the remaining tooth structures. Pulp chamber floor fractures are usually catastrophic and clinically irreparable, requiring tooth extraction. Irreparable fractures almost 100% of the time are bevelled towards the outer tooth edge, with major subgingival and supporting tissue complications. Some studies, such as Favero *et al*. (30), observed that the use of posts transfixed in the dental crown, associated with the direct restorative procedure, considerably increases the fracture strength of the dental crown and at the same time induces the fracture to more recoverable levels for the treatment and survival of endodontically treated teeth. Thus, clinical studies should be conducted to verify whether the outcomes proposed in the present study will be confirmed.

Conclusions

It can be concluded that the type of endodontic access cavity preparation did not influence the fracture strength of the dental crown in endodontically treated and restored teeth. Even with the restoration procedure, the teeth showed a higher incidence of catastrophic fractures in the pulp chamber floor.

Conflict of interest

The authors deny any conflict of interest. The authors do not have any financial interest in the companies whose materials are included in this article.

Author contribution

All authors have contributed significantly. All authors are in agreement with the manuscript.

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