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ORIGINAL ARTICLE

Effect of glass fiber on the restorative procedure in relation to fracture strength of endodontically treated molars

ABSTRACT

Aim: *To evaluate whether the restorative procedure using glass fibers influence the fracture strength of endodontically treated molars with class II mesio-occlusal (MO) preparation.*
Methodology: *Fifty human maxillary third molars were selected and randomly assigned to five groups (n=10). MO cavity preparation and endodontic treatment were standardized, except for the positive control group (S, sound teeth). The other groups were classified as: ET, no restoration (negative control); SF, restoration with SonicFill 2® system; SFB, restoration with braided glass fiber and SonicFill 2® system; and SFP, restoration with transfixed glass fiber post and SonicFill 2® system. The specimens were subjected to fracture strength testing on a universal testing machine. Fracture site – either pulp chamber floor or cusp – was inspected. Statistical analysis was performed using ANOVA, followed by Tukey's multiple comparison test (α=5%).*
Results: *Means followed by the same letter did not show statistical difference in Tukey's test (P>0.05). S: 3563^{A} ± 780.7; ET: 1001^{D} ± 237.6; SF: 1689^{C} ± 280.7; SFB: 2256^{B} ± 289.2; and SFP: 2493^{B} ± 364.*
Conclusions: *The glass fiber, regardless of composition, increases the fracture strength of endodontically treated teeth. The use of a glass fiber post attached to the dental crown seems to provide more favorable rehabilitation when the fracture position is determined.*

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Introduction

Fractures continue to be a major cause of loss of endodontically treated teeth (1, 2). The restorative procedure aims not only to promote coronal sealing, preventing contamination of the endodontic filling material, but also to strengthen the teeth by restoring lost structures. According to Faria et al (3), there is a direct relationship between the number of missing walls and fracture strength. Plotino et al (4) also observed that the absence of one or two marginal ridges results in considerable loss of tooth stiffness, around 46% and 63%, respectively.

Composite resin restorations are commonly the first clinical rehabilitation alternative. The incremental technique has been the most common placement method for the use of composite resin (5). However, when large cavities are filled, this clinical protocol may result in a higher risk of air bubble formation between increments, greater polymerization stress, and an increase in consultation time (6-8). In an attempt to address these drawbacks, the industry has developed a new type of resin-based restorative material that is applied in single increments of approximately 4 mm in thickness and with reduced shrinkage (9, 10).

SonicFill 2® is a system that uses a specific sonic handpiece to carry resin into the cavity. This sonication feature transmits energy to the composite, reducing its viscosity (11) in order to better adapt the material to the cavity (12). According to Agarwal et al (13), the mechanical properties of this new composite are similar to those of a hybrid composite resin.

Studies have described the application of glass fiber to reinforce composite resin restorations. For Freilich et al (14), the use of fibers associated with the restorative procedure has reduced the risks of permanent deformation and tooth fracture. Belli et al (15) also placed a polyethylene fiber together with a flowable composite resin into mesio-occluso-distal (MOD) cavity preparations and found that there was greater fracture strength than in teeth filled with composite resin alone.

An alternative researched in the literature, in order to increase the fracture strength of endodontically treated teeth, is the use of flexible fiberglass posts horizontally transfixed in the buccal and palatal/lingual surfaces. These prefabricated aesthetic posts have an elasticity module very close to that of dentin (16). According to studies by Favero et al (17), Karzoun et al (18), and Mergulhão et al (19), the groups that received post transfixation and restoration with composite resin showed a significant increase in fracture strength when compared to the groups restored only with resin. In addition, a lower degree of impairment of the dental structure in the face of the fracture can be observed.

The presented study aimed to evaluate whether the use of glass fiber associated with the sonic-resin placement system as restorative material influences the fracture strength and type of fractures in endodontically treated molars with class II mesio-occlusal (MO) preparation. The initial null hypothesis was that there is no statistically significant difference between endodontically treated molars restored with glass fiber (post or braided).

Materials and Methods

This study was approved by the Research Committee of the UFRGS School of Dentistry and its Research Ethics Committee (Process CAAE 06753019.6.0000.5347).

Sample selection and preparation

Fifty human maxillary third molars, free from carious lesions, restorations, or cracks were used in this study. The buccopalatal (11 mm ± 0.5 mm) and mesiodistal (9.5 mm ± 0.5 mm) widths of the selected crowns were measured with a digital caliper (Mitutoyo, Suzano, SP, Brazil) at the most prominent point of the respective surfaces. 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 be-

tween groups of 230 newtons, and average standard deviation of 90 N. The minimum sample size was of 10 specimens per group.
After the cleaning procedures, the teeth were disinfected in 0.5% chloramine solution (Seachem Laboratories, Madison, GA, USA) for 48 hours. The teeth were randomly assigned to five experimental groups (Table 1).

Preparation of specimens
The teeth were inserted individually in self-curing acrylic resin, centered inside a PVC cylinder (height: 2 cm, diameter: 3 cm) so that the anatomical neck of the tooth was exposed 2 mm above the edge of the acrylic.

MO cavity preparation
A piece of equipment was used for MO cavity preparation to standardize the inclination and movements performed by diamond bur #2143 (KG Sorensen, São Paulo, SP, Brazil) during the procedure.
Cavity preparations followed the methodology described by Cötert et al (20) and Beltrão et al (21), in which a line was delimited from the central groove to allow the buccal and palatal walls to be equidistant from the measurement of two thirds of the intercuspal distance. This line, over the central groove, was extended to the mesial surface, passing over the marginal ridge, going towards the dental neck until it reached a height of 4 mm. This was the depth established for the preparation. The predetermined buccopalatal width on the occlusal surface was extended to the mesial surface and likewise established for the proximal box. Diamond bur #2143 was initially positioned on the mesial surface over the centerline to the extent of the predetermined length. Next, a mesial box was made towards the center of the dental crown, preserving a 2 mm wide distal crest structure. From this preparation, the buccal and the palatal walls were set to the predetermined limits so that the gingival floor was joined to the pulp floor of the occlusal box. The bur was changed every five preparations. The cavosurface enamel margin received manual finishing with margin trimmer #28 and #29 (SS-White Art. Dental Ltda., Rio de Janeiro, RJ, Brazil). No cavity preparation was performed in Group 1.

Endodontic treatment
Carbide burs #02 and #04 (KG Sorensen Ind. And Com Ltda., Barueri, SP, Brazil) were used at high speed and under water cooling for access to the pulp chamber. The convenience form was obtained using the Endo Z bur (Dentsply Ind. E Com Ltda., Petrópolis, RJ, Brazil).
Initially, the cervical preparation was performed with the La Axxess® bur (SybronEndo, Glendora, USA) #35 taper 0.6 at a depth of 5 mm from the entrance to the canal, under irrigation with 2.5% sodium hypochlorite. The working length for canal preparation was 1 mm below the outlet of the foramen. Chemomechanical preparation followed the serial technique using K files #15, #20, #25, #30 and #35 (Dentsply/Maillefer, Ballaigues, Switzer-

Table 1

Experimental group design

Groups	n	Description
S	10	Sound teeth (positive control)
ET	10	MO preparation + endodontic treatment and no restoration (negative control)
SF	10	MO preparation + endodontic treatment + SonicFill 2® restoration system
SFB	10	MO preparation + endodontic treatment + braided glass fiber + SonicFill 2® restoration system
SFP	10	Tooth with MO preparation + endodontic treatment + transfixed fiberglass post + SonicFill 2® restoration system

land). Irrigation with a hypochlorite solution was delivered using a 10 mL plastic syringe (Plastipak Indústria Cirurgica Ltda., Curitiba, PR, Brazil) and 0.30 mm Navitip® needle (Ultradent Products, Inc South Jordan, Utah, USA).
After completion of the chemomechanical preparation, the canals received a final rinse with 17% EDTA solution for three minutes under agitation of instrument #35, prior to filling. The canals were filled using epoxy resin cement - AH Plus® (Dentsply/Maillefer Instruments SA, Ballaigues, Switzerland) and by Tagger's hybrid technique using McSpadden® #60 compactor (Dentsply/Maillefer Instruments SA, Ballaigues, Switzerland). After the gutta-percha plastification and removal of the activated McSpadden® from the canal, the vertical condensation of the gutta-percha was carried out using the Paiva instrument No. 2 (SS White, Rio de Janeiro, RJ, Brazil), leaving the material at the entrance level of the root canal.

Demarcation and perforation for post transfixation
Reforpost® (Angelus, Londrina, PR, Brazil) glass fiber posts with 1.1 mm in diameter were placed in the SFP group. Perforations for horizontal transfixation of the posts were made on the buccal and palatal walls with a diamond bur #3145 (KG Sorensen, Sao Paulo, SP, Brazil), at high speed under water cooling. Bur #3145 has a diameter of 1.2 mm. The perforation of both buccal and palatal surfaces was done simultaneously on the same axis of insertion of the tip. The perforations were performed at the coronal middle third of the two dental surfaces at a distance of 2 mm from the mesial border. The bur was changed every five preparations.

Bonding of glass fiber post in transfixed position
The following procedures were performed according to the manufacturer's instructions:
- cleaning of the posts with 70% alcohol and drying with air jets.
- Application of a silane layer (FGM Dental Products, Joinville, SC, Brazil). Drying at room temperature followed by spraying air at a distance of 15 cm for 1 minute.

Figure 1
Schematic drawing with occlusal view of the transfixed post in the dental crown.

Figure 2
Schematic drawing with occlusal view of the position of the braided glass fiber inside the MO cavity preparation.

- Application of a thin layer of Singlebond Universal adhesive (3M ESPE, St. Paul, MN, USA) and photoactivation with LED light unit (Bluephase, Ivoclar) for 20 seconds.
- Eetching of transfixation holes and cavosurface enamel margin of the cavity preparation with 35% phosphoric acid (Dentisply Ind and Com. Ltda, Petrópolis, RJ, Brazil) for 20 seconds, washing for 20 seconds, and drying with air jets.
- Application of Singlebond Universal adhesive to the transfixation holes, pulp chamber, and in the whole cavity preparation, drying for 5 seconds, and photoactivation for 20 seconds.
- Insertion of Bulkfill flow resin (3M ESPE, St. Paul, MN, USA) into transfixation holes, post placement into transfixation holes, and photoactivation for 40 seconds (Figure 1).

Braided glass fiber placement

In the SFB group, a braided glass fiber, Interlig® (Angelus, Londrina, PR, Brazil), was cut according to the internal anatomical design of the MO cavity preparation. The fiber should extend throughout the inner walls: buccal, distal, lingual, and mesial (absent wall), thus having a circular shape (Figure 2).

The following procedures were performed according to the manufacturer's instructions:
- etching of the internal dentin walls of the buccal, lingual, and distal surfaces with 35% phosphoric acid for 20 seconds, air-water spray cleaning for 20 seconds, and air drying for 5 seconds.
- Application of a thin layer of Universal Singlebond adhesive and light curing for 20 seconds.
- Insertion of a thin layer of Bulkfill flow resin on the inner surface of these walls for braided glass fiber placement, and light curing for 40 seconds.

Restorative procedure

All teeth, except those in the S and ET groups, were restored with Single-Fill TM Bulk fill resin (Kerr Corporation, Orange, CA, USA). The restorative procedures were performed as follows: single-Fill TM Bulk fill resin was inserted into the cavity with the SonicFill 2® handpiece (Kerr Corporation, Orange, CA, USA), standardizing resin insertion speed at the "3" level. The cavity was completely filled, starting from the mesial proximal box.

The resin was spread with the aid of a spatula. After spatulation, each surface (buccal, lingual, mesial, and occlusal) was photoactivated for 20 seconds.

After the restorative procedure, the specimens were placed in distilled water and kept at 37 °C in an oven (Fanem, Model 002-CB, São Paulo, SP, Brazil) for 48 hours.

Mechanical fracture testing

The specimens were initially thermocycled at 5 °C to 55 °C for 500 cycles before being subjected to mechanical fracture testing.

The fracture strength testing was performed on an EMIC DL 2000 universal testing machine (São José dos Pinhais, PR, Brazil). A 10 kN load cell and 0.5 mm/min speed were selected. A 6.5 mm steel ball was placed for contact of the inclined planes of the occlusal surface in the intercuspal position with the cusps (buccal and lingual) and not with the restorative material. Compressive stress was applied parallel to the long axis of the tooth until its fracture. The maximum force to fracture (rupture) was recorded in Newtons (N).

Analysis of tooth fracture site

After fracture strength testing, the teeth were visually examined with a magnifying glass (4X magnification) to assess the site of the tooth fracture: 1) pulp chamber floor fracture associated or not with cusp fracture; or 2) cusp fracture only. Floor fracture was considered when the fracture line split the tooth into two parts at the pulp floor level of the cavity, 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

The Shapiro-Wilk test was used to assess

Table 2

Fracture strength (Newtons (N)), coefficient of variation (CV), strength recovery in relation to group S, and pulp and cusp floor fracture in different experimental groups

Groups	Mean ± SD (N)	CV	Strength recovery	Pulp floor fracture	Cusp fracture
S	3563^A ± 780.7	22%	——	——	100% (10)
ET	1001^D ± 237.6	24%	-72%	40% (4)	60% (6)
SF	1689^C ± 280.7	17%	-52.6%	20% (2)	80% (8)
SFB	2256^B ± 289.2	13%	-36.7%	20% (2)	80% (8)
SFP	2493^B ± 364	15%	-30.1%	——	100% (10)

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

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

Results

In Table 2 the healthy teeth group showed greater mean fracture strength, differing statistically from ET, SF, SFB, and SFP. The group restored with transfixed fiberglass post (SFP group) had a similar pattern of failure distribution to healthy teeth group.

Discussion

The initial null hypothesis was rejected since there was statistical difference between teeth restored and not restored with glass fibers. When compared to sound teeth, endodontically treated teeth are more susceptible to fracture because there is substantial tissue loss (4), and reduced dentinal elasticity (22). The irrigating and chelating substances used in endodontics (Ethylenediaminetetraacetic acid and citric acid) can act on the inorganic structure of dentin, compromising the microhardness of the structure (23). The study simulated an unfavorable clinical scenario with class II MO cavities, in which the cusps lost support from the pulp chamber and the mesial marginal crest. The teeth were under deflection when an occlusal load was applied. The method of occlusal loading during the fracture test is another important factor. In this in vitro study, axial forces were applied to the center of the occlusal surface. Clinically, axial forces, in addition to lateral forces and fatigue loading, should be considered. The use of a approximately 6 mm steel sphere for resistance to fracture testing by Dietschi et al (24), and Soares et al (25) was shown to be ideal for molars, because it contacts the functional and nonfunctional cusps in positions close to those found clinically. Although fracture strength was statistically lower in the restored experimental groups than in the positive control group (sound teeth), the results were very impressive. Other studies such as Belli et al (15) and Taha et al (26) also observed that restored teeth, regardless of the technique or direct material used, did not present fracture strength similar to that of sound teeth, although the correct filling (three-dimensional obturation) of root canals combined with a good coronal marginal seal, allows obtaining a long-term high clinical success rate in teeth with a periapical lesion (27).

Regardless of glass fiber composition, the results reveal that, the association of this material with the restorative system presented satisfactory fracture strength. Placement of braided glass fiber (Interlig®)

on all the internal surrounding surfaces of MO cavity preparation is framed under the concept that the presence of this braided mesh could change the stress dynamics generated during the compressive test, promoting a better stress distribution at the tooth/restoration interface as a whole (28). One possible explanation would be the reduction in cusp deflection caused by anchorage and fixation of all surrounding walls with glass fiber (28). This was somewhat confirmed in the results, as fracture strength was higher when glass fiber was used than when it was not. Belli et al (15) used a polyethylene strip, but in the buccal to lingual direction, in a MOD preparation of molars, and observed a significant increase in fracture strength. On the other hand, there was no difference in the site of fracture in teeth restored with or without association of braided glass fiber strips.

A sonic composite resin system (SonicFill 2®) was used because it has a good flow and, consequently, better tooth/restoration bonding (29). SonicFill® organic matrix consists of bis-GMA, TEGDMA (5%), EBPDMA, and inorganic fillers that react to sonic energy that, in turn, decreases its viscosity. This process reduces shrinkage stress to 2.05%. Alrahlah et al (30) evaluated the polymerization depth of numerous single increment resins using the Vickers hardness test and found that SonicFill® presented the best result among the tested materials. Of the Bulk Fill resins tested (Venus Bulk Fill®, SDR®, Tetric N-Ceram Bulk Fill®, and SonicFill®) in the study by Kim et al (31), SonicFill® presented the highest microhardness values. This finding was justified by the high amount of inorganic fillers present in the material.

The teeth restored with glass fiber post transfixation showed considerable increase in fracture strength. This result was also found in the studies by Beltrão et al (21), and Scotti et al (32). The use of a transfixed post in the buccal to lingual dental crown promoted reinforcement of the cusps, thus minimizing their deflections. In addition, the transfixed post served somewhat as a threshold for the level at which fractures occurred. All fractures occurred at the level at which the post was transfixed, restricted to the dental cusp and without involvement of the pulp floor (Figure 3), favoring, to some extent, a better prognosis and survival in relation to a new rehabilitation of the fractured tooth. Bromberg et al (33) also observed high results of fracture strength in molars with transfixed fiberglass posts when compared to direct restoration with composite resin only or the inlay indirect technique. In fact, there was no statistical difference when compared to onlay indirect restoration with cusp coverings, reinforcing the area of the cusps and preventing their deflections. Performing the post transfixation does not present any clinical or technical difficulties. According to Kim et al (34), this is a relatively fast and simple

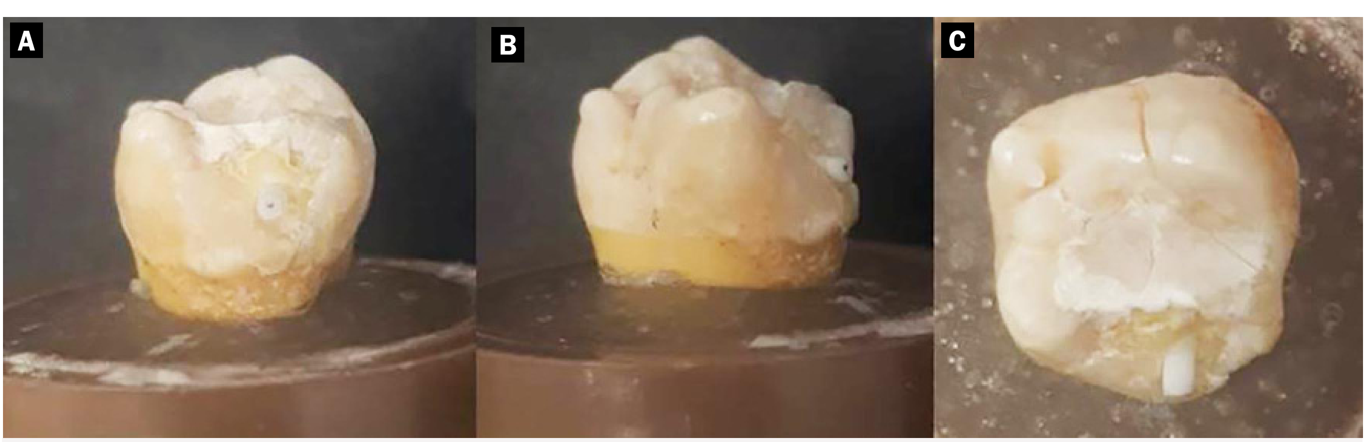

Figure 3
Tooth fracture above transfixed post level after compression test (A=lingual view; B=distal view; C=occlusal view).

procedure (30 minutes) and can be performed by the endodontist or general dentist at a low cost.

It is possible to speculate that fixation of the post closest to the occlusal surface could result in less catastrophic tooth fracture. Thus, it is of great importance to have a careful restorative planning in which it is possible to predict or induce the site of a future tooth fracture.

Considering the results of the presente study, other parameters need to be investigated, such as force vectors in different directions, checking the type of fault that occurred and the power of hermetic sealing on the fiberglass/resin interface, to evaluate the advantages and disadvantages of these restorative protocols. Given the limitations of in vitro tests and the experimental conditions of this study, the combination of sonic-resin placement system and glass fiber tends to increase the dental fracture strength.

Conclusions

It can be concluded that the glass fiber, regardless of the composition of the latter, increased the fracture strength of endodontically treated teeth. However, the use of transfixed glass fiber posts in the dental crown seems to influence the occurrence of fractures with more favorable rehabilitation than that provided by the other protocols tested.

Clinical Relevance

Fractures continue to be a major cause of loss of endodontically treated teeth. The glass fiber, regardless of composition, tends to promote an increase in fracture resistance of teeth.

Conflict of Interest

The authors declares that there is no conflict of interest.

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