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Fracture Resistance of Endodontically Treated Maxillary Premolars Restored With Different Methods

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Clinical Relevance

Ceramic inlays, as well as composite resin restorations with or without a horizontal fiber post, seem to restore the fracture resistance of endodontically treated maxillary premolars to a level compared to that of intact teeth.

SUMMARY

Purpose: The purpose of this *in vitro* study was to evaluate the resistance and patterns of fracture of endodontically treated maxillary premolars (ETPs) restored with different methods.

Methods and Materials: Mesio-occluso-distal cavities were prepared in 50 extracted caries-free human maxillary premolars after endodontic treatment. The teeth were divided into five groups (n=10), according to the restorative method. G1: intact teeth (control group); G2: conventional composite resin; G3: conventional composite resin with a horizontal glass fiber post inserted between buccal and palatal walls; G4: bulk-fill flowable and bulk-fill restorative composites; and G5: ceramic inlay. For direct restorations, Filtek Z350 XT, Filtek Bulk Fill Flowable Restorative, and Filtek Bulk Fill Posterior Restorative were used. Indirect restorations were fabricated from a pressable lithium disilicate glass-ceramic (IPS e-max Press) and adhesively cemented (RelyX Ultimate). All specimens were subjected to thermocycling (5°C to 55°C/5000 cycles) and additionally submitted to cyclic loading 50,000 times in an Electro-Mechanical Fatigue Machine. Next, the specimens were subjected to a compressive load at a crosshead speed of 1 mm/min until fracture. The fractured specimens were analyzed to determine the fracture pattern using a stereomicroscope, and then representative specimens were carbon coated to allow for the studying of the fracture surface under scanning electron microscopy. One-way analysis of variance (ANOVA) was used to compare fracture resistance of the groups.

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The results of fracture patterns were submitted to the Fisher exact test (α=0.05).

Results: All specimens survived fatigue. Mean (standard deviation) failure loads (N) for groups were as follows: G1: 949.6 (331.5); G2: 999.6 (352.5); G3: 934.5 (233.6); G4: 771.0 (147.4); and G5: 856.7 (237.5). The lowest fracture resistance was recorded for G4, and the highest ones were recorded for G2, followed by that of G1 and G3. One-way ANOVA did not reveal significant differences between groups ($p>0.05$). The highest repairable fracture rates were observed in G1 (100%) and G3 (80%).

Conclusions: ETPs restored with conventional composite resin with or without horizontal fiber post, bulk-fill composite, and ceramic inlay showed fracture resistance similar to that of sound teeth. Conventional composite resin restorations exhibited the highest prevalence of unrepairable fractures, and the insertion of a horizontal fiber post decreased this prevalence. Intact teeth showed 100% of repairable fractures. It is difficult to extrapolate the results directly to a clinical situation due to the limitations of this study.

INTRODUCTION

Endodontically treated teeth present a greater risk of biomechanical failure than teeth with pulp vitality. Cusp fractures are more concentrated in premolars due to the anatomical shape, the ratio of unfavorable crown to root, and exposure to shear and compressive forces.[1] In addition, endodontic access jeopardizes structural integrity, resulting in increased cusp deflection during function and leading to a higher occurrence of fractures.[2] The substantial loss of structure may worsen the situation when endodontic treatment is associated with mesio-occluso-distal (MOD) cavities. The prognosis of endodontically treated premolars (ETPs) is influenced by different parameters, such as amount of hard tissue loss,[3] depth and design of the cavity preparation,[4,5] presence of a minimum ferrule height preparation of 1.5 to 2.0 mm,[6] and post and core material used.[7]

Restorative treatment techniques and materials for ETPs, such as the use of post and core, total or partial crowns, direct composite resin, and amalgam or ceramic restorations, are described in the literature. Glass fiber posts can be used due to their favorable physical properties.[8] The use of horizontal glass fiber posts in MOD cavities restored with composite resin increased fracture resistance of ETPs.[9]

Bulk-fill resin composites have emerged as a new category of low- and high-viscosity composites that can be used in class I and class II restorations in increments of 4 or 5 mm.[10-12] The difference in the chemical monomeric resin formulations and filler characteristics, such as the type, volume fraction, density, and particle size and distribution, can affect the depth of cure and mechanical properties,[13] justifying further investigations for the indication of bulk-fill resin composites in MOD cavities.

Ceramic restoration is another option for restoring ETPs. Ceramics have many advantages, such as translucency, fluorescence, chemical stability, biocompatibility, high compressive strength, and a thermal expansion coefficient similar to tooth structure.[14] Despite their desirable characteristics, ceramics are fragile under tensile and occlusal forces, making them susceptible to fracture.[15]

The purpose of this *in vitro* study was to evaluate fracture resistance and failure modes of ETPs restored with composite resin or ceramic using different methods. The null hypothesis was that there would be no significant difference among the sound and restored maxillary premolars.

METHODS AND MATERIALS

Tooth Selection and Preparation

Fifty recently extracted caries-free maxillary premolars that were removed for orthodontic reasons were selected, cleaned with periodontal curettes, and stored in 0.1% thymol solution (F.Maia Ind. Com., Cotia, Brazil) at room temperature for two weeks and then kept in 0.9 NaCl solution at 4°C. Endodontic access cavities were prepared with round burs #1012, #1013 (KG Sorensen, Cotia, Brazil), and an Endo-Z bur (Dentsply Maillefer, Ballaigues, Switzerland). Endodontic treatment was performed according to the crown-down technique using the ProTaper system (Dentsply Maillefer), which includes rotary instruments made of nickel-titanium (NiTi) alloy (M-Wire) and the X-Smart-Endo-motor (Dentsply Maillefer). The apical foramen was prepared to file F2, size 25. Irrigation was performed by alternating 2.5% NaOCl solution and 17% EDTA solution. The root canals were dried with paper points (Cellpack Protaper, Dentsply Maillefer) and obturated 1 mm short of the apex with Sealer 26 (Dentsply Indústria e Comércio Ltda, Petropolis, Brazil) and tapered gutta-percha cones (Guta Percha Protaper, Dentsply Maillefer) using the single-cone

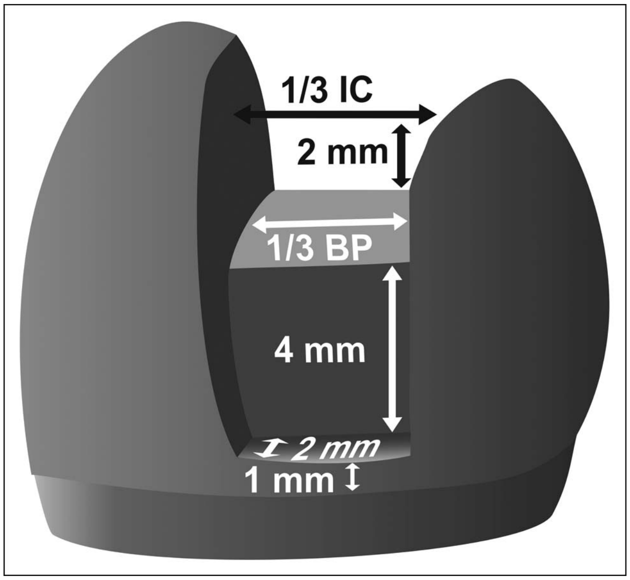

Figure 1. *Dimensions of MOD inlay preparation. IC, intercuspal distance; BP, buccopalatal distance.*

technique. The access cavities were sealed with temporary filling (Coltosol, Coltene, Brazil).

MOD cavity preparation was performed in all teeth except the control group. Diamond burs were replaced every six preparations to ensure high cutting power. For all preparations, conical diamond burs #3131 (KG Sorensen) were used in a high-speed hand piece mounted on a device used to standardize the preparation of all specimens. The dimensions of the MOD inlay cavities are shown in Figure 1. On completion of the preparations, all internal angles were rounded. Only one operator was responsible for performing all the cavity preparations. Root surfaces were then dipped into melted wax (Wilson Polidental, Cotia, Brazil) up to 2.0 mm below the cemento-enamel junction (CEJ), resulting in a 0.2- to 0.3-mm-thick wax layer to act as a spacer. Next, the teeth were centrally embedded in acrylic resin (Vipi Flash, Pirassununga, Brazil) up to 2 mm apical to the CEJ to simulate the bone level using polyvinyl chloride cylinders as molds. The teeth long axes were oriented perpendicular to horizon by using a custom-made parallelometer. After resin polymerization, the teeth were removed from the cylinder, and the wax was removed from the root surface and resin cylinder "alveolus." The polyether impression material (Impregum Soft, 3M ESPE, Seefeld, Germany) was placed in the resin cylinders, the tooth was reinserted into the cylinder, and the excess impression material was removed with a surgical blade. The method used to simulate the periodontal ligament was described by Soares and others.[16]

The teeth were randomly divided into five groups (n=10) as follows: G1: control group, intact teeth without cavity preparation or endodontic treatment; G2: MOD preparation with conventional composite resin restoration; G3: MOD preparation with conventional composite resin restoration and a horizontal glass fiber post inserted between the buccal and palatal walls; G4: MOD preparation with bulk-fill flowable and bulk-fill restorative composites; and G5: MOD inlay preparation with lithium disilicate glass-ceramic restoration (IPS e-max Press, Ivoclar Vivadent, Schaan, Liechtenstein).

Restorative Procedure

All specimens, except the intact teeth (G1), had 2 mm of root canal filling removed from canal orifices with Gates Glidden drills (#2-3, Dentsply Maillefer) for subsequent insertion of bulk-fill flowable composite. A probe was used to control the depth of the intraorifice cavity. The selective enamel etching technique was carried out according to the instructions of the dentin adhesive. Tooth enamel was etched using 37% phosphoric acid (Condac 37, FGM Produtos Odontológicos Ltda, Joinville, Brazil) for 15 seconds, rinsed with water spray for 15 seconds, and air-dried. The dentin bonding agent (Single Bond Universal, 3M ESPE) was then applied to the entire tooth structure of the MOD cavities, rubbed in for 20 seconds, air-dried for five seconds, and light cured for 10 seconds using a LED light curing unit (1200 mW/cm^2, Radii-cal, SDI, Bayswater, Australia). The light output of the Radii-cal was measured by a specific radiometer for LED (Demetron L.E.D Radiometer, SDS/Kerr, Orange, CA, USA). Flowable composite (Filtek Bulk Fill Flowable Restorative, 3M ESPE) was applied in the root canal orifices and polymerized from proximal and occlusal areas. A metal matrix band was placed around the tooth using a Tofflemire retainer, and conventional composite resin (Filtek Z350XT, 3M ESPE) was placed in the teeth of G2 by using an oblique layering technique. Each layer was 2 mm thick. In G4, the MOD preparations were restored with the bulk-fill technique that consisted of one 4-mm increment of Filtek Bulk Fill Flowable Restorative (3M ESPE) including proximal boxes plus one 2-mm capping layer of Filtek Bulk Fill Posterior Restorative (3M ESPE). In both techniques, each composite resin increment was light cured for 20 seconds. The perforations in the teeth of G3 for the horizontal glass fiber post were made at the prominent point on the buccal and palatal surfaces at the midpoint between mesial and distal. The holes were carried

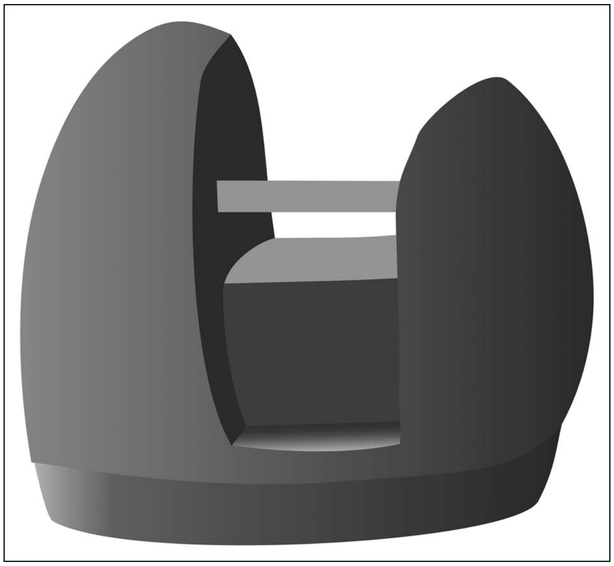

Figure 2. *Horizontal glass fiber post view.*

out with round diamond burs #1013 (KG Sorensen) with air-water spray. The post extremities were cut close to the buccal and palatal surfaces. Glass fiber posts (White Post DC number 0.5, FGM Produtos Odontológicos) of 1.4 mm diameter were cleaned with 70% alcohol, and then Single Bond Universal adhesive was applied on their surfaces and light cured for 10 seconds. The walls of the MOD cavities were etched using the selective enamel etching technique described previously. The posts (Figure 2) were fixed in the holes using dual-curing resin cement (RelyX Ultimate, 3M ESPE). Composite resin (Filtek Z350 XT, 3M ESPE) was applied and polymerized according to the incremental technique. After 24 hours in distilled water at 37°C, the composite resin groups were submitted to finishing procedures with flexible discs (Sof-lex, 3M ESPE).

Fabrication of Ceramic Restorations

Impressions of preparations in G5 were made with polyvinylsiloxane material (Express XT, 3M ESPE). All restorations were fabricated from a pressable lithium disilicate glass ceramic (IPS e.max Press) according to the manufacturer‘s instructions.

Adhesive Luting

The intaglio surface of the restoration was etched with 5% hydrofluoric acid etching gel (Condac porcelana 5%, FGM Produtos Odontológicos) for 20 seconds, rinsed thoroughly with water for 15 seconds, and dried with water-free and oil-free air, according to the manufacturer's instructions. Single Bond Universal Adhesive (3M ESPE) was applied to the entire surface to be luted, allowed to react for 20 seconds, and dried for five seconds with gentle air. Since Single Bond Universal Adhesive contained silane in its composition, there was no need to apply silane, separately, on the restoration. The selective enamel etching technique was performed as described previously. The dual-curing resin cement (RelyX Ultimate, 3M ESPE) was mixed and applied on the intaglio surface of the restoration, which was seated on the prepared tooth. The excess luting cement was removed, and the margins of the restoration were covered with an air-inhibiting gel (Liquid Strip, Ivoclar Vivadent). The restoration was seated with finger pressure, and the occlusal and proximal surfaces of the tooth were light cured for 60 seconds. The teeth of all groups were stored in an incubator at 37°C in 100% humidity for a week. The materials used in the restorative procedure are presented in Table 1.

Thermocycling, Cyclic Loading, and Fracture Load

All specimens were thermocycled between 5°C and 55°C in water with a 30-second dwell time at each temperature, following a regimen of 5000 cycles, which represents six months of clinical function,[17,18] and additionally submitted to cyclic loading 50,000 times, which represents approximately three to 12 months of clinical service,[19] in an Electro-Mechanical Fatigue Machine- MSFM (Elquip, São José dos Pinhais, Brazil). A loading cycle frequency of 2 Hz or 120 revolutions per minute with a load ranging from 0 to 100 N was selected to simulate high physiologic masticatory forces. During the cyclic loading, the specimens were kept in distilled water at 37°C ± 1°C. The specimens were placed in the machine in a way that the indenter, used as an antagonistic surface to simulate the opposite teeth, could apply the load on the occlusal surfaces of the specimens. All specimens survived the cyclic loading.

To determine the fracture resistance, a 6 mm diameter stainless-steel cylinder mounted in a universal testing machine (EMIC DL 10000, Brazil) was used to apply compressive load on the long axis of the restored teeth at a crosshead speed of 1 mm/min until fracture. The cylinder was centered over the tooth until it contacted the occlusal surface of the restoration on the buccal and lingual cusp inclines. The compressive load required to cause fracture was recorded in N. The specimens were examined regarding the kind, location, and direction of the failure with a stereomicroscope (Axio Zoom V16, Zeiss, Oberkochen, Germany). Failures were classi-

Table 1: *Materials Used in the Restorative Procedure*

Material	Manufacturer	Batch Number
Filtek Bulk Fill Posterior Restorative (composite resin)	3M ESPE (St Paul, MN, USA)	N 685666
Filtek Bulk Fill Flowable Restorative (composite resin)	3M ESPE	N 772034
Filtek Z350XT (composite resin)	3M ESPE	559841
RelyX Ultimate (resin cement)	3M ESPE	1617300197
White Post DC (fiber post)	FGM (Joinville, Brazil)	020916
IPS E-Max Press (lithium disilicate–reinforced ceramic)	Ivoclar Vivadent (Barueri, Brazil)	V08364

fied as repairable when the fracture line was above the simulated bone level and unrepairable when the fracture line was below the simulated bone level according to the classification of Zicari and others[20] (Figure 3). Representative specimens were carbon coated (Carbon Coater 108carbon/A, Cressington, Watford, England) to allow for the studying of the fracture surface in a scanning electron microscope (JSM-6460, JEOL, Akishima, Tokyo, Japan).

The Shapiro-Wilk test showed that data were normally distributed. The homogeneity of variance was tested using the Levene test and one-way analysis of variance (ANOVA) was used to compare fracture resistance of the groups. The results of fracture patterns were submitted to the Fisher exact test. The significance level was 5% (SPSS, version 23, SPSS Inc, Chicago, IL, USA).

RESULTS

The mean fracture resistance and standard deviations are displayed in Table 2. They ranged from 771.0 (147.4) N to 999.6 (352.5) N. The lowest fracture resistance was recorded for G4 (Bulk fill) and the highest for G2 (conventional composite resin), followed by those of G1 (control group) and G3 (conventional composite resin and horizontal fiber post). One-way ANOVA did not reveal significant differences between groups ($p>0.05$).

The mode of failure is presented in Table 3 and Figure 4. Regarding the repairable mode of failure, the frequencies for the groups were as follows: G1 (100%), G3 (80%), G4/G5 (50%), and G2 (30%). Significant difference was found in failure modes among the groups ($p<0.007$). G1 showed a significant difference when compared to G2, G4, and G5.

DISCUSSION

The null hypothesis that there would be no significant difference among the sound and restored premolars was accepted. The fracture resistance exhibited by all groups was superior to those efforts developed during normal masticatory function, situated between 22.65 and 45.40 Kgf.[21]

Previous studies[22-26] and the present study were common in that the use of ceramic inlays showed fracture resistance similar to that of healthy teeth. In contrast, other studies[27-30] showed that ceramic inlay restorations used in premolars were not able to restore the total resistance to load of healthy teeth. It needs to be pointed out that different cements and ceramic systems were used in the studies and that cements with higher flexural modulus exhibit higher values of fracture resistance.[22] This may help to explain the different performance of the ceramic inlays in the mentioned studies.

In the present study, the MOD cavities restored with conventional composite resin exhibited fracture resistance comparable to the ceramic inlays, which is

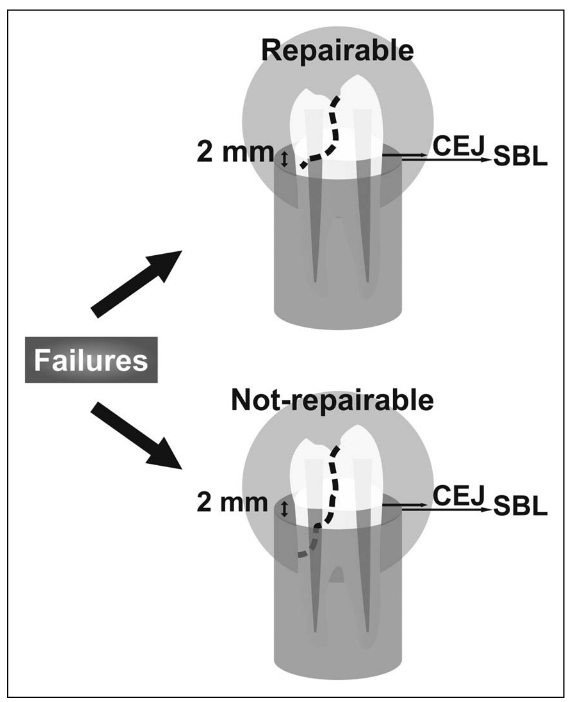

Figure 3. *Fracture mode classification. CEJ, cemento-enamel junction; SBL, simulated bone level.*

Table 2: *Mean Fracture Resistance (N), Standard Deviation Values, and Variation Coefficients of Experimental Groups*

Group	Mean (N)	Standard Deviation (N)	Variation Coefficient (%)
G1	949.6	331.5	34.9
G2	999.6	352.5	35.3
G3	934.5	233.6	25.0
G4	771.0	147.4	19.1
G5	856.7	237.5	27.7
p-value	$p^a = 0.372$		

Abbreviations: G1, control group; G2, conventional composite resin; G3, conventional composite resin with horizontal fiber post; G4, bulk fill; G5, ceramic inlay.
[a] *One-way analysis of variance.*

in agreement with the findings of other studies.[26,29,30] Although ceramic restorations present disadvantages with regard to antagonist wear and friability, ceramic inlays show better clinical performance than composite inlays, according to the results of two systematic reviews.[31,32] Although the difference was not statistically significant (Table 2), the fracture resistance of ETPs restored with composite resin was slightly higher than that of ETPs restored with ceramic inlays. Since IPS e-max Press has higher fracture toughness than Filtek Z 350 XT, an explanation for the higher fracture resistance of the composite resin group would be the lower elastic modulus of the composite that resulted in lower stresses in the composite restorations.[33]

Previous studies[26,34] and the present study were common in that maxillary premolars restored with composite resin exhibited statistically similar fracture resistance compared to sound teeth. This finding may be attributed to the ability of the resinous materials to undergo elastic deformation similarly to tooth structure.[35] In contrast, other studies[9,29,30,36-38] revealed that premolars restored with composite resin showed statistically lower fracture resistance than that of intact teeth. In the present study, the dominant mode of failure for the composite resin group was unrepairable, including axial fractures, while that for the sound teeth was repairable. These findings are in agreement with earlier studies.[9,39] In the investigation by Plotino and others,[40] intact teeth showed more restorable fractures than all the prepared ones.

A systematic review[41] showed that root canal–treated teeth (RCT) covered with crowns have a higher long-term survival rate (81%±12% after 10 years) than RCT without crown coverage (63%±15% after 10 years). RCT without crown coverage included teeth restored with resin composites, amalgam, and cements. The authors concluded that the survival rate for RCT without crown coverage is quite satisfactory for the first three years, while there is a significant decrease in the survival of RCT after this period. Although in the present study the MOD composite showed quite satisfactory fracture resistance result, it should be highlighted that the strengthening effect of the MOD composite will significantly decrease with years.

In this study, ETPs restored with composite resin placed in increments and in bulk did not provide statistically significant different mean fracture resistances that can be compared with previous studies.[37,42-47] Bulk-fill flowable composites present characteristics, such as low viscosity, elastic buffer effect, low modulus of elasticity,[48] high degree of conversion,[49] and less polymerization shrinkage and shrinkage stress[50] causing less cuspal deflection when compared to a conventional composite used in increments. Regarding the mode of failure, the present study and that by Atalay and others[44] were common in that the bulk-fill technique exhibited higher prevalence of repairable fractures than those of the incremental filling technique, and it should be considered a great advantage of the bulk-fill technique. In this study, the bulk-fill group showed 50% of repairable fractures. Other studies[45,46] revealed

Table 3: *Fracture Mode of Each Group*

Group[a]	Repairable		Unrepairable		Group Total		*p*-Value
	n	%	n	%	n	%	
G1 A	10	100.0	—	—	10	100.0	$p < 0.007$
G2 B	3	30.0	7	70.0	10	100.0	
G3 AB	8	80.0	2	20.0	10	100.0	
G4 B	5	50.0	5	50.0	10	100.0	
G5 B	5	50.0	5	50.0	10	100.0	

Abbreviations: G1, control group; G2, conventional composite resin; G3, conventional composite resin with horizontal fiber post; G4, bulk fill; G5, ceramic inlay.
[a] *Statistically different percentages ($p<0.05$) are indicated by different letters (Fisher exact test).*

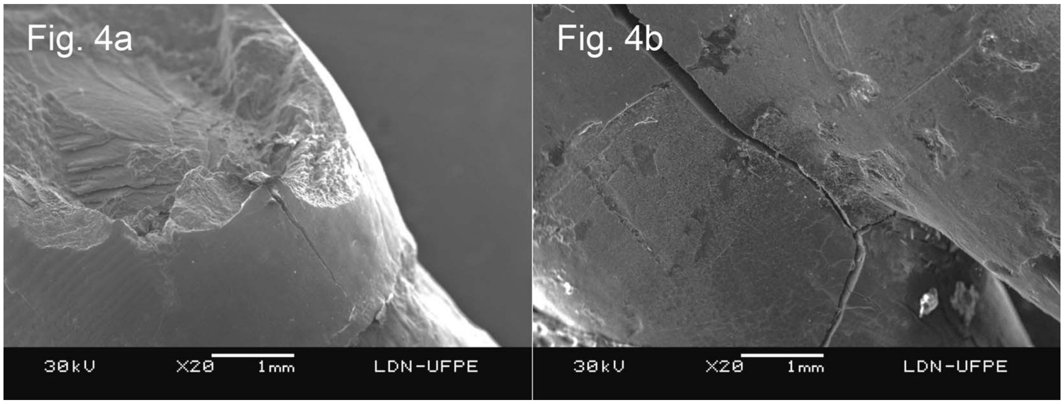

Figure 4. *SEM images of the fracture surface. A, repairable fracture (control group); B, unrepairable fracture (conventional composite resin group).*

that specimens restored with nanohybrid or bulk-fill composites were more prone to unrepairable fractures.

With regard to the use of fiber posts, the current study investigated if posts placed horizontally between the buccal and palatal walls of premolars would increase the fracture resistance. A study revealed that the extension of a horizontal glass fiber post through the buccal and palatal cusps strengthens the composite resin restoration and through adhesion reinforces the cusps and enhances the fracture resistance of ETPs.[9] Considering that, in the present study, the holes made to support the posts were less than 1 mm deep, one must consider that the integrity of the tooth was not adversely affected prior to occlusal load. The choice for glass fiber posts was due to their low elastic modulus, which matches that of dentin.[51] The achieved fracture resistance values of G1 (healthy teeth) 949.6 (331.5) N and G3 (conventional composite resin with horizontal fiber post) 934.5 (233.6) N were comparable with those of Karzoun and others[9] (994.5±147.3 N and 961.3±245.2 N, respectively). In both studies, ETPs restored with composite resin and a horizontal fiber post provided a mean fracture resistance that was similar to the control group (healthy premolars). In that study, ETPs restored with composite resin and horizontal fiber post provided higher fracture strength compared to those restored with composite resin, whereas in the present study, these two groups did not differ statistically. Regarding the fracture pattern, in the current study, G3 (conventional composite resin with horizontal fiber post) showed 80% repairable fractures, whereas G2 (conventional composite resin) showed 30% repairable fractures. This result suggests that the use of a horizontal fiber post in the composite resin restoration seems to be a promising approach for practitioners.

Different fracture resistance results may be justified by the differences in the testing parameters, such as crosshead speed and the different loading tip shapes and sizes, including the direction and location of the applied load. Some studies recommend the use of tin foil[52,53] or 1.0 mm-thick polyethylene film[5] to be placed between the occlusal surface and the load cell to distribute the loading forces more homogeneously. In the present study, as well as in previous studies,[4,9,27,37,42,43,54,55] tin foil or any kind of film was not used, and this may have influenced the results together with the other factors mentioned above. A study[53] suggested the use of a natural tooth to act as the antagonist during dynamic loading, but in this study, a 6-mm-diameter metal jig was used, and this may have affected the crack propagation.

In vitro tests still remain an indispensable method to evaluate the performance of materials, and considering the available protocols, thermal cycling seems to be a valid *in vitro* method to accelerate the aging of restorative materials.[17] Although this aging method is, together with cyclic loading, the most widely used, there is a lack of a standardized protocol.[56] Adhesive failures may be found between the bonding resin and dentin after thermocycling, showing that this method has an influence on bond-strength values.[57] Many investigations that used the ISO standard (ISO TR 11450)[58] protocol (500-cycle regimen) concluded that thermocycling did not affect the bond strength of adhesive systems.[18,59,60] Thermocycling stresses the bond between resin and tooth and, depending on the adhesive system, may affect bond strength;[61] furthermore, it can affect the marginal integrity of the restoration, causing microleakage.[62] A study[63] concluded that a regimen of

30,000 cycles was able to decrease bond strength. This finding suggests that thermocycling has a negative effect on the restorative interface after a large number of cycles, indicating that the most important factor that accelerates the aging process during thermocycling may be the deleterious effect of water.[64]

Clinically, dental restorations are subjected to biochemical challenges in addition to mechanical loads. These additional challenges will accelerate the degradation of the tooth-restoration interfacial bond.[65] In the present study, ETPs were subjected to cyclic loading before the fracture test in order to simulate clinical function. Many studies that investigated fracture resistance of restorations of endodontically treated teeth used only static load.[9,22,29,39,43] Results of a study[66] indicated that the most important influence on dentin fatigue is attributed to the high shrinkage stress of the composite filling. The level of occlusal load in the simulation of 1,000,000 cycles does not produce high fatigue of dentin when the residual stress is close to zero; therefore, the authors of that study emphasized that it is important to minimize the shrinkage stress of the composite materials when restoring vital or devitalized teeth. Studies that used mechanical testing differ with regard to the number of cycles, varying from 1000 to 8000,[67] 50,000,[68] 100,000,[69] 200,000,[70] and up to 1,200,000 cycles,[52,54,71] which is equivalent to five years of clinical performance.[71] Cyclic loading is a great way to describe fatigue behavior, but its expense has caused the development of other methods that have been used for dental composites and other materials; the staircase method is an example that is more economical and easier to perform than the fatigue resistance test.[72] A study concluded that the dental materials community has not yet adopted fatigue testing as one of the most important methods for evaluating the potential clinical success of new restorative materials.[73] The author of that study stated that new approaches have recently been developed for evaluating the durability of the bonded interface that consider fatigue failures promoted by the synergistic degradation of cyclic loading with biofilm attack and cyclic loading after activation of endogenous dentin proteases. However, it should be highlighted that the thermocycling and fatigue testing do not represent the weakening effect on dentin bonding that progressively increases over the years in clinical function.

It is difficult to extrapolate the results of this study directly to a clinical situation. One of the limitations is that this investigation used freshly extracted, intact teeth, and in a common clinical situation, an endodontically treated tooth would have been previously restored before completing endodontic therapy. Tooth walls might have irregular outlines and thicknesses, and the intact dentin would be thinner than that designed in the present study. It must be considered that the decision to include in the study only caries-free maxillary premolars was necessary in order to standardize the preparation procedures, according to the methodology of other studies.[9,22,29]

Although a compressive load test is important when investigating the behavior of the restorations under certain circumstances, other tests, such as finite element analysis, tension tests, and long-term clinical trials, are necessary to evaluate the performance of restorations.

CONCLUSIONS

ETPs restored with conventional composite resin with or without horizontal fiber post, bulk-fill composite, and ceramic inlay showed fracture resistance similar to that of sound teeth. Conventional composite resin restorations exhibited the highest prevalence of unrepairable fractures, and when a horizontal fiber post was inserted in these restorations, there was a dominance of repairable fractures. Intact teeth showed 100% repairable fractures. It is difficult to extrapolate the results directly to a clinical situation due to the limitations of this study.

Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of University of Pernambuco Ethics Committee. The approval code for this study is: 50910015.5.0000.5207.

Conflict of Interest

The authors of this article certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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