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Assessment of fracture resistance capacity in endodontically treated teeth with fiberglass post comparing different therapeutic techniques

Avaliação da capacidade de resistência à fratura em dentes tratados endodonticamente com pino de fibra de vidro comparando diferentes técnicas terapêuticas

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ABSTRACT

Endodontically treated teeth show lower resistance when compared to teeth with pulp vitality, a fact associated to the reduction of mineralized structure. The aim of this study was to evaluate the fracture strength of endodontically treated teeth with 2.5 mm of coronal remnant, which received different intraradicular fiberglass retainers. For sample acquisition, 30 endodontically treated canines were selected, which had their coronal portions removed at 3 mm above the cemento-enamel junction, performing a 2.5 mm splint effect. Three groups were formulated in this study: Fiberglass post without reline (hereafter, FGP); fiberglass post relined with composite resin (anatomical post - hereafter, RFGP), and fiberglass post Splendor-Sap (hereafter, SS). All pins were cemented with dual resin cement, and restored with a core filling and a composite resin dental crown. The samples were subjected to mechanical cycling and fracture strength testing by universal testing machine. The one-way anova test and Tukey's test were used for statistical evaluation (p-value < 0.05). There were significant differences in fracture strength between the comparative groups (p-value < 0.05), in which the relined (anatomic) fiberglass pin showed higher mean levels of fracture strength (p-value < 0.05), followed by the non-reinforced fiberglass pin and Splendor-Sap fiberglass pin groups.

Keywords: Endodontically treated teeth. Ferrule effect. Fiberglass pin. Fracture resistance.

RESUMO

Dentes tratados endodonticamente apresentam menor resistência quando comparados com dentes que possuem vitalidade pulpar, fato associado à redução da estrutura mineralizada. O objetivo deste estudo foi avaliar a resistência à fratura de dentes tratados endodonticamente com 2,5 mm de remanescente coronário que receberam diferentes retentores intrarradiculares com fibra de vidro. Para a aquisição das amostras, selecionaram-se 30 caninos endodonticamente tratados, cujas porções coronárias foram removidas em 3 mm acima da junção cemento-esmalte, realizando efeito férula de 2,5 mm. Três grupos foram formulados para este trabalho: Pino de fibra de vidro sem reembasamento (doravante, PFV); pino de fibra de vidro reembasado com resina composta (pino anatômico – doravante, PFVR) e pino de fibra de vidro Splendor-Sap (doravante, SS). Todos os pinos foram cimentados com cimento resinoso dual e restaurados com núcleo de preenchimento e coroa dentária em resina composta. As amostras foram submetidas à ciclagem mecânica e ao teste de resistência à fratura pela máquina universal de ensaio. O teste anova *one-way* e o teste de Tukey foram utilizados para a avaliação estatística (valor-p < 0,05). Verificaram-se diferenças significativas da força de resistência à fratura entre os grupos comparativos (valor-p < 0,05), em que o pino de fibra de vidro reembasado (anatômico) apresentou níveis médios da força de resistência à fratura superiores (valor-p < 0,05), seguido pelo grupo pino de fibra de vidro não reembasado e pino de fibra de vidro Splendor-Sap.

Palavras-chave: Dentes tratados endodonticamente. Efeito férula. Pino de fibra de vidro. Resistência à fratura.

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INTRODUCTION

The development of materials applied in the dental office has brought new, more practical ways to restore endodontically treated teeth with greater esthetic results. For many years, cast metal cores were applied as an option for restoring endodontically treated teeth that had lost their coronal structure. However, in addition to being unesthetic, this type of material has a high modulus of elasticity, which can lead to irreversible fracture of the root remnant (Cailleteau, Rieger & Akin, 1992). In order to overcome the problems related to the high modulus of elasticity and esthetics of cast metal cores, fiberglass posts were developed. They have a modulus of elasticity similar to dentin, are esthetic, can be cemented to both dentin and dental composites (Asmussen, Peutzfeldt & Heitmann, 1999), and allow coronal reconstruction in a single session.

The survival of teeth that have undergone endodontic therapy is directly related to the quality and quantity of the remaining tooth structure (Assif & Gorfil, 1994). During endodontic treatment, there is considerable loss of dentin and pulp chamber roof, and, usually, a tooth affected by extensive caries also loses marginal ridges and cusp tips. Intraradicular posts are commonly used to restore endodontically treated teeth when the tissue can no longer provide adequate support and retention for the restoration (Silva, Arias, Soares, Martin & Martins, 2007), being an option for providing retention to the filling core and, consequently, to the prosthetic crown (Mishra et al., 2020).

Fiberglass posts, introduced in dentistry in the 1990s, essentially consist of unidirectional glass fibers embedded in a resin matrix (Mannocci, Ferrari & Wastson, 1999). Matrix polymers are typically high conversion epoxy polymers with a highly interconnected chain structure (Goldberg & Burstone, 1992). The modulus of elasticity of fiberglass posts can vary from 16 to 40 GPa and is characterized by the stress distribution on the surface (Freedman, 1996). These are the advantages of using these posts, in addition to the ease in clinical procedures, as this technique prevents the laboratory stage and saves clinical time (Rijk, 2000). Being more esthetic, they are not corrosive, and their installation technique is relatively easy (Lima et al., 2020).

The presence of coronal remnant structure is considered fundamental for the success of the treatment (Ferrari et al., 2012), as it allows for the ferrule effect. A circumferential dentin collar of 1.5 to 2.5 mm in height is considered to be the most responsible for fracture resistance and, consequently, longer survival (Samran, Bahra & Kern, 2013). The ferrule improves the biomechanical stability, resistance to occlusal load, dynamics and integrity of the tooth. If there is more than 3.0 mm of ferrule, it is expected that there is not as much risk of tooth fracture (Samran et al., 2013).

Resin cements have been used in the cementation of fiber posts, as they can adhere to the post and to the base of the tooth. Fiberglass posts cemented with resin cement have been proving to be efficient, since both have a modulus of elasticity similar to that of dentin, thus more homogeneously dissipating stress to the remaining tooth structure (Chaves et al., 2021). The effect of these cements on post-cementation is related to factors such as: post type, dentin walls, and cement thickness (Mendoza & Eakle, 1994; Grandini, Goracci, Monticelli, Borracchini & Ferrari, 2005).

A clinically significant problem that dentists face when restoring endodontically treated teeth is the mismatch between the fiberglass post diameter and the available root canal space, resulting in an excessively thick layer of resin cement (Grandini et al., 2005).

Reline with composite resin has been the main technique used for large canals, as it increases the conformation of the post to the canal walls and reduces the cement line, making retention less dependent on mechanical properties (Ferrari et al., 2012).

This technique has been applied and has shown to be effective and promising in creating a customized retainer with better adaptation, reduction of cement lines, and mechanical locking (Velmurugan & Parameswaran, 2004). Recently, a Brazilian company proposed a fiberglass post system with adjustable diameter, called Splendor-Sap (Single Adjustable Post); it is a universal system composed of only one drill, along with a fiberglass post and sleeve, with the latter conforming to the canal walls as it is slid over the post.

In light of the foregoing, this study aims to conduct an *in vitro* assessment of the resistance to fracture of teeth with 2.5 mm of coronal remnant, endodontically treated with intraradicular retainers reinforced with fiberglass and cemented traditionally, relined, and Splendor-SAP posts, as well as to assess the fracture pattern.

MATERIALS AND METHODS

Ethics and Research Committee

The research was submitted to and approved by the State University of Maringa's Ethics Committee on Research Involving Human Beings (CAAE: 30304120.00000.0104).

Specimen preparation

For this research, thirty freshly extracted upper canines were collected and stored in 0.1% thymol solution. All roots had an average of 23 mm, single, straight canal, intact apex, no caries or extensive restorations, no prior endodontic treatment, and no cracks that would compromise fracture resistance.

Periapical radiographs of all teeth were taken using a Saevo digital x-ray sensor (Alliage S/A Indústrias Médico

Odontológica, Ribeirão Preto, SP, Brazil) connected to a computer. The crowns of the teeth were cut 3 mm above the cementoenamel junction with the aid of a double-sided diamond disk (American Burrs), at low speed under water cooling. The teeth were prepared following the silhouette technique, with 2.5 mm of ferrule, using diamond burs 1014, 2200, 3216, 3118 and 4138 (KG Sorensen, Cotia, SP, Brazil).

The endodontic treatment was carried out with TDKa rotary files (Shenzhen Superline Technology, Shenzhen, Guangdong Province, China). Root diameter was determined and biomechanically prepared by instrumenting 1 mm short of the apex, through the Crown Down technique. The canal was dried with a Tanari paper cone (Tanari Industrial Ltda, Manacapuru, AM, Brazil), obturated with Endofill filling cement (Dentsply Maillefer, Petrópolis, RJ, Brazil), and, lastly, the Tanari gutta-percha lateral condensation technique was applied (Tanariman Industrial Ltda, Manacapuru, AM, Brazil).

Then, the root canal was unfilled. Drills no. 1, 2 and 3, 28 mm (MK Life, Porto Alegre, RS, Brazil) were used sequentially, corresponding to 2/3 of the total length of the remaining tooth available (Pegoraro et al., 1998). Next, drill no. 3 (Exacto®-Angelus-Londrina, PR, Brazil) was used specifically for the Exacto post. For the SS pin (Angelus, Londrina, PR, Brazil), the Splendor drill (Splendor®-Angelus-Londrina-Brazil) was used.

The thirty specimens were divided into three groups of ten elements, namely: FGP Group, Exacto no. 2 (Angelus, Londrina, PR, Brazil), RFGP Group, Exacto no. 2 (Angelus, Londrina, PR, Brazil) + Composite Resin (color OA3, Filtek Z250, 3M-Espe), and SS Group (Angelus Splendor-Sap (Angelus, Londrina, PR, Brazil). All groups were cemented with Allcem dual resin cement (FGM, Joinville, SC, Brazil).

Post and canal preparation

Before preparation and cementation, the diameter and length of the post in relation to the canal were confirmed by new radiographs. Prior to the cementation procedures, for all groups, the canal was irrigated with 17% ethylenediaminetetraacetic acid (EDTA; Maquira), followed by 2.5% sodium hypochlorite, then washed with saline solution. All fiberglass posts were cleaned with 70% alcohol, then air-jet dried. Following the manufacturer's recommendations, there was salinization with silane (Angelus, Londrina, PR, Brazil), and a one-minute wait. Subsequently, the adhesive (FGM, Joinville, SC, Brazil) was applied and photoactivated for 40 seconds.

The root canals were conditioned with 37% phosphoric acid for 15 seconds (Condac 37 Phosphoric Acid – FGM, Joinville, SC, Brazil), irrigated abundantly with water, and air-jet dried; soon after, the adhesive (FGM, Joinville, SC, Brazil) was applied against the walls, with a subsequent application of light air jets, then photoactivated for 40 seconds.

Cementation

The Allcem dual resin cement (FGM, Joinville, SC, Brazil) was manipulated and inserted with the aid of a self-mixing tip attached to a double-body syringe. Cement was applied inside the canal, and the post was placed in the intracanal space and pressed with digital force. Light curing was performed for 40 seconds on each face. Cement excesses were removed with a double spatula (Millennium). After the fiberglass posts were fixed, the filling core was made in composite resin (color OA3, Filtek Z250, 3M-Espe), followed by finishing and polishing, using the composite resin kit (KG Sorensen, Cotia, SP, Brazil), and the fine and ultrafine bur kit (KG Sorensen, Cotia, SP, Brazil).

Crown making

To standardize the crown models, a 0.25 mm thick acetate matrix was made from an upper canine of a dental manikin (Mod.300-Mom) in a vacuum laminator (Plastivac P7, Bio-art). The selected matrix was filled with composite resin (color OA3, Filtek Z250, 3M-Espe), positioned over the filling core, and photoactivated for 40 seconds on the incisal, buccal, palatal and proximal surfaces, providing specimen standardization.

Mechanical cycling

All specimens were inserted into self-curing acrylic resin at a level of 1 mm below the cementoenamel junction at an angle of 45º. The desired angle was obtained and standardized using a 180º acrylic protractor. A total of 300,000 cycles (3x106) were applied with a load of 60N to the cingulum region in the ERIOS 11000 Plus mechanical cycler (ERIOS Equipamentos Eireli, São Paulo, SP, Brazil) for aging in all samples before the fracture resistance test.

Fracture resistance analysis

For the fracture resistance test, a universal mechanical testing machine (EMIC Instron, São Paulo, SP, Brazil) was used. The specimens were positioned in a way that the tip of the load applicator coincided with the cingulum region and then subjected to crown/apical compressive load at a rate of 1 mm/min until failure.

Force values at the moment of fracture were obtained in Newton using a computer connected to the machine. The fracture pattern was assessed and classified as repairable, if located in the cervical third of the root, with a limit of 2 mm apical to the cervical end of the crown, or catastrophic if located below.

Statistical analysis

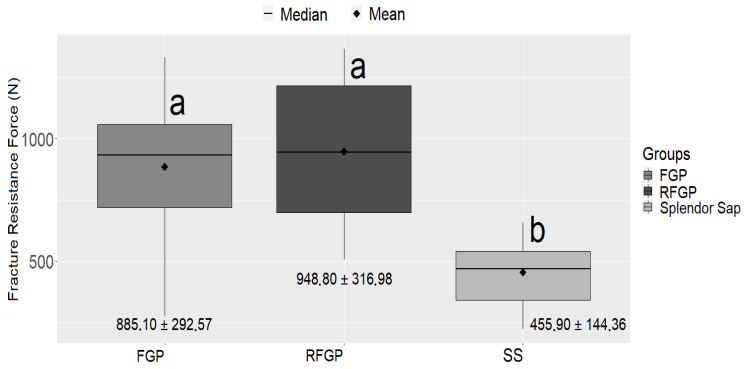
Data were analyzed using the R software, version 4.0.2 (R Core Team, 2020). Descriptive analysis of the data was performed through boxplots. The normality of the "fracture resistance force (N)" variable was assessed by means of the Shapiro-Wilk test. In order to investigate

the existence of possible significant differences between the groups, the one-way ANOVA test was used to compare the means; if significant differences were found, Tukey's significant difference test was run. For all statistical tests, a significance level of 5% was adopted (p-value < 0.05).

RESULTS AND DISCUSSION

Figure 1 shows data variability and mean values in boxplot charts. The SS group presented fracture resistance of 455.90 ± 144.36 N, followed by the FGP group (885.10 ± 292.57 N), and the RFGP group (948.80 ± 316.98 N), with these values representing the mean ± the standard deviation. The one-way ANOVA test indicated significant differences in fracture resistance force (N) (p-value < 0.05) between groups. To investigate in which groups such differences were observed, Tukey's test was applied; its results are also displayed in Figure 1, allowing for the conclusion that the SS group showed significant differences compared to the other ones (p-value < 0.05). In turn, the FGP and RFGP groups did not show significant differences between them (p-value > 0.05).

Figure 1
Fracture resistance force (N) boxplot considering the comparative groups.



Source: The authors.

Endodontically treated teeth are at high risk of biomechanical damage (Amarnath et al., 2015). For this reason, it is important for the intraradicular retainer to be able to distribute the bite force along the axial axis of the tooth and improve retention (Velmurugan & Parameswaran, 2004). The best performance of the RFGP group is expected, since the anatomical customization of the post increases its adaptation to the root walls and reduces the thickness of the resin cement (Grandini et al., 2005).

The closer contact between the cement and the dentin is also important to improve the frictional retention of the post (Goracci, Sadek, Fabianelli, Tay & Ferrari, 2005), being directly proportional to the contact area and the retention, since the larger the contact surfaces, the better the retention (Macedo, Silva & Martins, 2010). The dentin/cement/post set results in better contact and reduces the formation of bubbles in the cement (Chieffi et al., 2007), thus explaining the higher fracture resistance values in the RFGP group (Figure 1).

The result observed for the SS group, however, was surprising, given that greater resistance was expected from this retainer, as the "reline" of the post was done with a sleeve made of glass fibers. Further studies, with different methodologies, or assessing the properties of this particular system, can elucidate this issue.

A study carried out by Kaizer (2006) assessed a fiberglass post system involved only by resin cement inside the root canal. The author, however, found values lower than the mean observed in this research. The resistance to fracture in the group composed only of fiberglass post showed a result of 745.69 N, whereas, in this research, the anatomical post resulted in 948.80 N. The numerical differences are probably due to the method used, which presents a post diameter that is more compatible with the canal and has a less thick layer of resin cement, which reduces the possibility of creating bubbles and adhesive failures.

All the failures found were repairable, that is, non-catastrophic, which corroborates the idea of prescribing intraradicular retainers with a modulus of elasticity similar to that of dentin in order to distribute the forces applied to the tooth uniformly along the root, thus preventing catastrophic failures (Habibzadeh, Rajati, Hajmiragha, Esmailzadeh & Kharazifard, 2017).

Madfa, Al-Hamzi, Al-Sanabani, Al-Qudaimi and Yue (2015) concluded in their study that the fiberglass post proved to be excellent in evenly distributing the stress from the coronal region to the apical region of the post and dentin interface. The ferrule effect is another aspect to be taken into account, since its presence provides a more favorable failure, means, possible to repair (Pereira, Valle, Shiratori, Ghizoni & Melo, 2009; Naumann, Schmitter, Frankenberger & Krastl, 2018).

The importance of cementation steps to allow stress distribution should also be discussed. In this study, the surface treatment of the fiberglass posts was performed by salinization, which is an important step for successful cementation. Moraes et al. (2015) reported the importance of this method when using dual resin cement. Due to their properties, resin cements provide resistance in the cement line, thus allowing for a certain flexibility and damping effect, being able to absorb micromovements, leading to a lower stress load on the dental element and, consequently, increasing resistance to fracture, which explains the good performance of the FGP group in this study, although this technique is more susceptible to decementation (Aggarwal et al., 2013).

Kaizer (2006) assessed fracture resistance in canines reconstructed with posts and metal crown. The anatomical-post group presented 80% of favorable fracture and 20% of unfavorable fracture in sample group (n=10). This differs from the results of this research, which

presented 100% (n=10) of favorable fracture, probably due to the failure of the sample occurring in the composite resin crown, which is a limitation of this study, leading to a lack of direct analysis on the post, since the increase in force along the axis of the tooth caused the composite resin to detach at its elastic limit, followed by crown fracture without significant loads actually being transferred to the post and root.

CONCLUSION

Considering this *in vitro* study, it can be concluded that the fiberglass post relined (anatomical) and cemented in the traditional way showed greater resistance to fracture when compared to the post and sleeve (SS) group. Repairable failure being the most frequent failure mode.

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