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Glass Fiber Post lengths and adhesive strategies to restore extensively damaged canines

Comprimento dos pinos de fibra de vidro e estratégias adesivas para restaurar caninos fraturados

Longitud de postes de fibra de vidrio y estrategias adhesivas para restaurar caninos fracturados

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Abstract
The aim of this study was to evaluate different post lengths and adhesive strategies for restoring extensively damaged canines. Sixty human canines were randomly distributed into two groups (n=30), according to the resin cement used: self-adhesive or conventional. Each group was further distributed into 3 groups (n=10) based on the intracanal post lengths: 5, 7.5 and 10 mm. The radicular portion was endodontically filled, the cervical third was enlarged to simulate extensive damage and the coronal portion was reconstructed with composite resin. The samples were prepared with a simulated periodontal ligament and submitted to fatigue loading (160N – 1,200,000 cycles), followed by fracture resistance testing. The results were submitted to two-way ANOVA and Tukey tests (α=5%). The assessed glass fiber post lengths have not influenced on the fracture resistance (p>0.05). However, the performance of the conventional cements was better than the self-adhesive cements when the same post length was compared (p<0.05). Repairable fractures were prevalent (70-90%) in all groups tested. Conventional resin cement yielded higher fracture resistance than self-adhesive cement, regardless the post length adopted.
Keywords: Post and core technique; Flexural strength; Dental bonding, dual-cure; Fatigue fracture.

Resumo
O objetivo deste trabalho foi avaliar diferentes comprimentos de pinos de fibra de vidro e estratégias adesivas para restaurar caninos com fraturas extensas. Sessenta caninos humanos foram aleatóriamente divididos em dois grupos (n=30), de acordo com o cimento resinoso utilizado: autoadesivo ou convencional. Cada grupo foi então dividido em 3 grupos (n=10) de acordo com os comprimentos dos pinos: 5, 7.5 e 10mm. A porção radicular foi tratada endodônticamente, o terço cervical foi alargado simulando fratura extensa e a porção coronária foi reconstruida com resina composta. As amostras foram preparadas com um ligamento periodontal experimental e submetidas a teste de

fadiga (160N – 1.200.000 ciclos), seguido de teste de resistência a fratura. Os resultados foram submetidos aos testes de ANOVA e Tukey (α=5%). Os comprimentos dos pinos de fibra de vidro testados não influenciaram a resistência a fratura (p<0.05). Entretanto a performance dos cimentos convencionais foi melhor do que a dos cimentos autoadesivos quando comparados pinos de mesmo comprimento (p<0.05) Fraturas reparáveis foram prevalentes (70-90%) em todos os grupos testados. Cimentos resinosos convencionais forneceram maior resistência a fratura do que os autoadesivos, independente do comprimento do pino utilizado.
Palavras-chave: Técnica para retentor intrarradicular; Resistência à flexão; Cura dupla de cimentos resinários; Fratura por fadiga.

Resumen
El objetivo de este trabajo fue evaluar diferentes longitudes de postes de fibra de vidrio y estrategias adhesivas para restaurar caninos extensamente fracturados. Sesenta caninos humanos fueron divididos al azar en dos grupos (n=30), según el cemento de resina utilizado: convencional o autoadhesivo. Cada grupo se dividió en 3 grupos (n=10) según la longitud de los postes: 5, 7.5 e 10mm. La porción radicular fue tratada endodônticamente, se amplió el tercio cervical simulando una fractura extensa y se reconstruyó la porción coronal con resina compuesta. Las muestras se prepararon con un ligamento periodontal experimental y se sometieron a una prueba de fatiga (160N – 1.200.000 ciclos), seguido de una prueba de resistencia a la fractura. Los resultados fueron sometidos a las pruebas ANOVA y Tukey (α=5%). Las longitudes de los postes de fibra de vidrio ensayados no influyeron en la resistencia a la fractura (p<0,05). Sin embargo, el desempeño de los cementos convencionales fue mejor que el de los cementos autoadhesivos al comparar postes de la misma longitud (p<0,05), siendo prevalentes las fracturas reparables (70-90%) en todos los grupos evaluados. Los cementos de resina convencionales proporcionaron mayor resistencia a la fractura que los autoadhesivos, independientemente de la longitud del poste utilizado.
Palabras clave: Técnica de perno muñón; Resistencia flexional; Curación dual de cementos de resinas; Fractura por fatiga.

1. Introduction

Glass fiber posts (GFP) can be used to increase the retention of restorative materials to endodontically treated teeth with extensive damage. GFPs are a great alternative to metallic posts since they allow the use of adhesive strategies, using resin-based materials to adhere the GFPs to dentin.(Cagidiaco, et al., 2008, Hu, et al., 2003, Tay, et al., 2007) The use of adhesive approaches lead to a more conservative procedure (since it requires less tooth preparation when compared to metallic posts) and there is no need for laboratorial steps (like casting), leading to immediate sealing of the root canal.(Cagidiaco, et al., 2008, Schwartz, et al., 2004) Due to similar modulus of elasticity when compared to dentin, GFPs promote a better stress distribution through the tooth structure when compared to metallic post-and-core as well.(Schwartz, et al., 2004)

One of many concerns when performing intracanal retentions is the length of the post, which, for metallic posts, the indication is of two thirds (⅔) of the intracanal length. However, due to the possibility of using adhesive/minimally invasive procedures, some studies have suggested the use of shorter posts (Zicari, 2012) or not even using posts at all. (Lazari, et al., 2018, Magne, et al., 2017) The indication of shorter posts is advantageous since it minimizes tooth preparation, consequently, reducing the risk of root perforation. Also, it provides good visualization of the prepared post space and it may optimize light-curing procedures of resin-based materials (such as resin cements and adhesive systems) inside the root canal. (Zicari, et al., 2012, Fuss, et al., 2001)

For endodontically treated teeth, it is common to find extensive destruction and reduced amount of sound substrate for adhesion. Hence, the adaptation of the fiber post to the canal is affected, leading to a thick cement line, increased polymerization shrinkage and, consequently, de-bonding of the GFP. (D'Arcangelo, et al., 2007) Therefore, relining the fiber post with resin composite is a possible solution for this problem. (Dal Piva, et al., 2018, Faria-e-Silva, et al., 2009) This technique customizes the GFP to fit the root canal geometry and can reduce the thickness of the resin cement, decrease the formation of voids, and increase the retention of the GFP due to friction with the canal walls. (Dal Piva, et al., 2018, Faria-e-Silva, et al., 2009, Borzangy, et al., 2019)

Adhesive protocols that reduce the technique sensitivity, using self-adhesive or self-etch resin cements, can optimize the adhesion between GFP and dentin. These materials commonly contain self-etching monomers (i.e., 10-

methacryloyloxydecyl [MDP]) (Oskoee, et al., 2016), which can preserve minerals in the dentin and lead to chemical bond to the dental substrates, with a reduced number of clinical steps. (Van Meerbeek, et al., 2011)

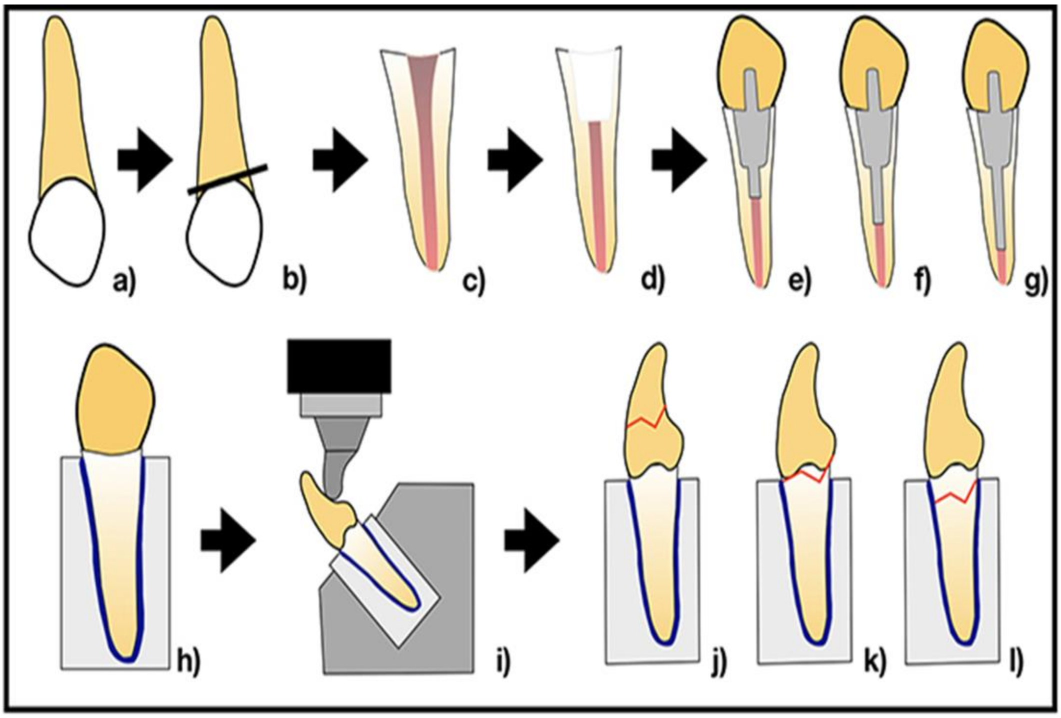
Although several in vitro studies (Lazari, et al., 2018, Magne, et al., 2017, Magne, et al., 2016) do not recommend the use of GFPs, they are not in agreement with available clinical / in vivo studies that show increased longevity for restorative procedures that included these posts, low incidence of fractures and easily repairable, if necessary. (Naumann, et al., 2005, Naumann, et al., 2012, Naumann, et al., 2007) Additionally, systematic reviews do not show a negative effect of the post when appropriately indicated. (Batista, et al., 2020, Naumann, et al., 2018) Thus, modifications in the GFP technique to increase its reliability are important to be considered and studied, since it is still a frequently performed and discussed technique.

The purpose of this study was to test different options for bonding GFPs in extensively damaged and endodontically treated permanent canines. The factors under study were: [1] length of the post; [2] and adhesive strategy (conventional and self-adhesive resin cement). The hypotheses tested were: [1] the post length affects the fracture toughness; and [2] the different types of resin cements affect the fracture resistance.

2. Methodology

For this study, sixty sound extracted human permanent canines (n=10) were stored in 0.5% chloramine solution for a maximum period of 6 months. The inclusion criteria for the teeth were: [1] absence of caries or root cracks; [2] absence of previous endodontic treatments, posts, or crowns; and [3] root length of at least 15 mm (which was the standardized length for the experiment). Additionally, the selected teeth had similar mesio-distal and bucco-lingual dimensions. Roots were separated from crowns to simulate the absence of ferule, and the cervical third of the root canal was enlarged to simulate extensive damage. Teeth were distributed into 6 experimental groups: using a self-adhesive resin cement [SA5] with a 5.0mm GFP, [SA7.5] 7.5mm, or [SA10] 10.0mm; or using a conventional resin cement with a total etch adhesive system [TE5] with a 5.0mm GFP, [TE7.5] 7.5mm, or [TE10] 10.0mm. The specimens were submitted to chewing simulation (fatigue) followed by fracture resistance. The study design is presented in Figure 1.

Figure 1 - Study design.



Source: Authors (2022).

Figure 1 is a representive scheme related to the design of the study. It presents all the sequence of procedures from the preparation of the specimens until the final mechanical test. The sequence of events is described: a) Canines selected for the study; b) Root-crown separation to obtain the roots; c) roots with endodontic treatment; d) simulation of extensive damage in the cervical third; e)/f)/g) cementation of the GFP in the respective length and coronary reconstruction with composite resin; h) inclusion of the samples and simulation of periodontal ligament; i) fatigue and fracture resistance tests; j)/k)/l) analysis of fracture resistance.

2.1 Specimen preparation

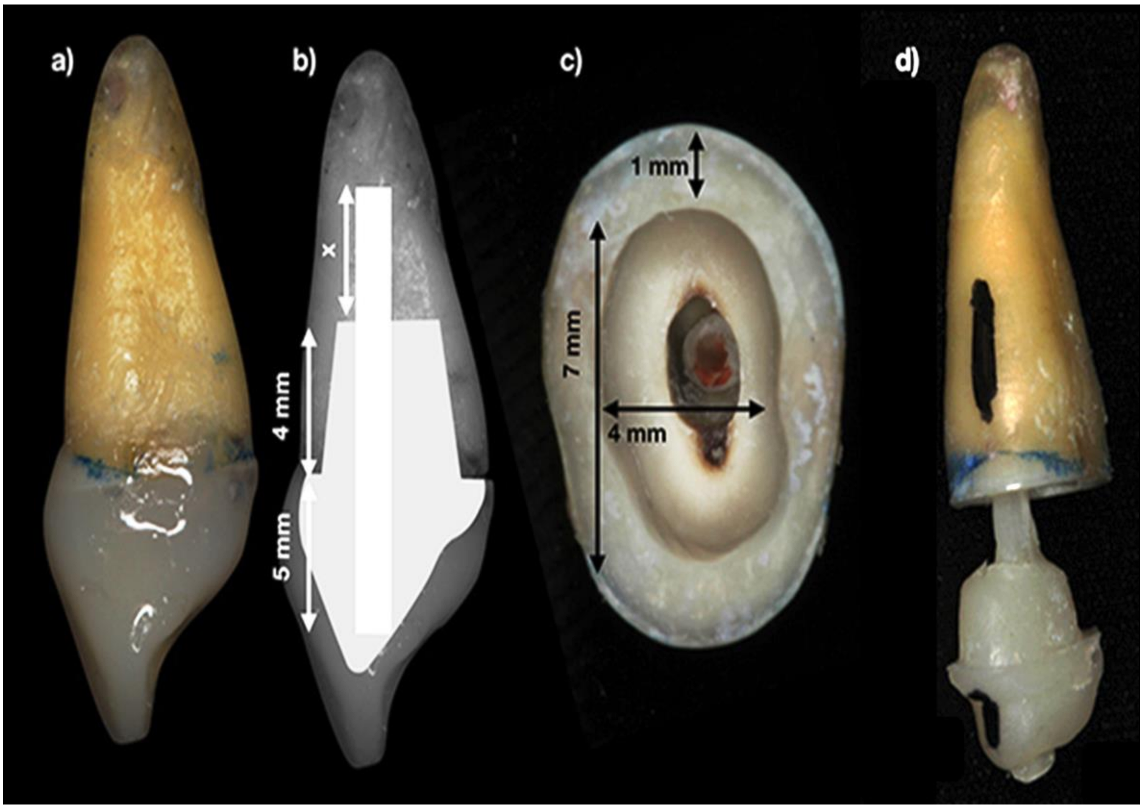
2.1.1 Endodontic treatment

Roots were cut at the most apical point of the cementoenamel junction (CEJ) using a low-speed diamond saw in a precision cutter (Isomet 1000, Buehler, Lake Buff, IL, USA) under water refrigeration. Endodontic treatment was performed using the crown-down technique with Pro-Taper system (Dentsply Maillefer, Ballaigues, Switzerland). The apical third was prepared up to a file #30 and irrigation was performed after each new file alternating between 2.5% NaOCl and 17% EDTA solutions. After drying with paper points (Tanari, Tanariman Industrial, Manacapuru, AM, Brazil), roots were sealed using an endodontic sealer cement (Endofill, Dentsply Maillefer) and gutta-percha (Tanari; Tanariman Industrial) following the cold lateral condensation technique. The root access was temporarily sealed with conventional glass ionomer cement (Maxxion R, FGM Products, Joinvile, SC, Brazil).

2.1.2 Post space preparation

The gutta-percha was removed using Gates-Glidden burs (#2, #3 and #4; Dentsply Malleifer) coupled to slow-speed handpiece. A specific bur for post-space preparation was used (0.5 DCE, FGM Products) following manufacturer's instructions, according to the experimental groups varying the post-core ratio (between the length of the post inside the root canal and its coronal portion) (n=20): [1] 5 mm (1:1 ratio), [2] 7.5 mm (3:2 ratio), and [3] 10 mm (2:1 ratio). The cervical third of the root canal (first 4 mm from cervical to apical) was enlarged using a tapered bur (Tungsten Bur Maxicut, Ref #1512, American Burrs, Palhoça, SC, Brazil), simulating extensive damage in this region. The surrounding walls of all samples were standardized with a thickness of 1 mm, resulting in a buccal-lingual distance of 7 mm and a distal-mesial distance of 4mm (Figure 2). All dimensions were assessed using a digital caliper (Mitutoyo; Kawasaki, Kanagawa, Japan).

Figure 2 - Standardized surrounding walls.



Source: Authors (2022).

Figure 2 shows the specimen preparation with the intention to demonstrate the configuration of the canine after preparation for the post, the aspect of the relined post and the restored tooth. The sequence of pictures is: a) Permanent canine after post cementation and coronary reconstruction; b) Scheme of the dimensions of the enlarged cervical third, the coronary portion of the post and, x, the middle/apical portion of the post (being 1, 2.5 or 5 mm); c) View of the root configuration; d) Post prepared previously the cementation.

2.1.3 Bonding and restorative procedures

Prior to bonding procedures, all fiber posts (White Post DCE, FGM Products) were relined using resin composite (Vitra A2, FGM Products) to improve adaptation to the prepared root canal. (Dal Piva, et al., 2018, Faria-e-Silva, et al., 2009) The post surface was cleaned with ethanol in a sterile gauze, followed by the application of a silane coupling agent (Prosil, FGM Products) using a disposable microbrush, allowed to react for 60 seconds and air-dried using the air syringe. Then, a total-etch 2-steps adhesive system (Ambar, FGM Products) was applied over the treated post surface, solvent was evaporated with air from syringe, and light-cured using a polywave LED light curing unit for 20 seconds (VALO, Standard mode, 1000 mW/cm^2, Ultradent Products Inc., South Jordan, UT, USA). A microhybrid resin composite (Vitra, shade A2, FGM Products) increment was placed around the treated fiber post and inserted into the lubricated post-space that was previously isolated with water-soluble gel (KY, Johnson & Johnson, New Brunswick, NJ, USA). Resin composite was light-cured for 5 seconds in position; the (now) relined fiber post was removed, followed by an extra light-curing period of 40 seconds outside of the post space. For each post length, the specimens were distributed according to the adhesive strategy (n=10). Two resin cements were used for bonding the relined fiber posts to the prepared root canals: a [SA] self-adhesive cement (Rely X U200, 3M ESPE, St. Paul, MN, USA), and [TE] a total etch conventional resin cement (Allcem Core, FGM Products). Materials were used according to manufacturers' instructions (Table 1). The relined posts were again cleaned with air water spray and air-dried. For TE groups, dentin was etched with phosphoric acid at 37% (Condac 37%, FGM Products) for 15 seconds, water rinsed and dentin was kept moist using absorbing paper points. A total-etch 2-steps adhesive system (Ambar, FGM Products) was applied to the dentin surface, solvent was evaporated using the air syringe for 15 seconds, and the resin cement was inserted into the post space using a specific application tip. Then, relined posts were inserted, digital pressure was applied, and light-curing was performed for 5 seconds for preliminary removal of cement excess. Light-curing was then performed for 40 seconds on each surface (buccal, lingual, mesial, and distal) using the polywave LED light-curing unit. For SA groups, a similar procedure was performed, except for the phosphoric acid etching and adhesive system steps. In this group, the radicular portion was irrigated with 1% sodium hypochlorite prior to cementation. After bonding the relined GFPs, the coronal portions of each specimen were restored using total-etch 2-steps adhesive system and resin composite inserted in standardized canine acetate crown-matrixes. Resin composite (Vitra, shade A2, FGM Products) was applied in incremental layers of a maximum thickness of 2 mm each. Each increment was light-cured for 40 seconds. Finishing and polishing procedures were performed immediately after light-curing of the resin composite core using aluminum oxide discs (Sof-Lex, 3M ESPE) and abrasive rubber discs (Jiffy, Ultradent Inc.)

Table 1 – Materials Used.

Type of Material /Commercial Name	**Composition (according to manufacturer)**
Glass Fiber Post **White Post** DCE (FGM Products, Joinvile, SC, Brazil)	Fiber glass, epoxy resin, radiopaque compound, inorganic filler, polymerization promoters
Dual-cure self-adhesive resin cement **RelyX U200** (3M ESPE, St. Paul, MN, USA)	**Base paste:** Methacrylate monomers containing phosphoric acid groups, methacrylate monomers, silanated fillers, initiator components, stabilizers, rheological additives.
Dual-cure self-adhesive resin cement **RelyX U200** (3M ESPE, St. Paul, MN, USA)	**Catalyst paste:** Methacrylate monomers, alkaline (basic) fillers, silanated fillers, initiator components, stabilizers, pigments, rheological additives.
Dual-cure conventional resin cement **AllCem Core** (FGM Products, Joinvile, SC, Brazil)	**Base paste:** methacrylate monomers (such as: TEGDMA, BisEMA, BisGMA), camphorquinone, co-initiators, barium-aluminum-silicate glass, micro and nano-particles of silicon dioxide, inorganic pigments and inhibitors.
Dual-cure conventional resin cement **AllCem Core** (FGM Products, Joinvile, SC, Brazil)	**Catalyst paste:** methacrylate monomers, dibenzoyl peroxide, stabilizers, and barium-aluminum-silicate glass micro-particles.
Total-etch 2-steps adhesive system **Ambar** (FGM Products, Joinvile, SC, Brazil)	**Active Ingredients**: MDP (10-methacryloyloxydecyl dihydrogen phosphate), methacrylic monomers, photoinitiators, co-initiators, stabilizers.
	Inactive Ingredients: Inert fillers (silica nanoparticles) and solvent (ethanol).
Resin composite **Vitra** (FGM Products, Joinvile, SC, Brazil)	**Active ingredients:** monomeric matrix containing monomers (UDMA – Urethane Dimethacrylate and TEGDMA – Triethylene Glycol Dimethacrylate), photo-initiators composition (APS), co-initiators, stabilizers and silane.
	Inactive ingredients: Zirconia and silica fillers, and pigments.
Silane **Prosil** (FGM Products, Joinvile, SC, Brazil)	3-Metacriloxipropiltrimetoxisilan (< 5%); Ethanol (> 85%); Water (< 10%)
Phosphoric acid 37% **Condac 37** (FGM Products, Joinvile, SC, Brazil)	Phosphoric acid at 37%, thickeners, pigments and deionized water

Source: Authors (2022).

2.1.4 Periodontal ligament simulation

To simulate the periodontal ligament, (Soares, et al., 2005) root surfaces were "dipped" in molten wax (Epoxiglass; Diadema, SP, Brazil) up to 2 mm below the CEJ, resulting in a 0.2 to 0.3mm wax layer thickness around the roots. Specimens were then positioned at the center of PVC tubes (Tigre, Rio Claro, SP, Brazil) with a 5 mm internal diameter and 20 mm in height, containing freshly mixed acrylic resin (Jet Clássico; Campo Limpo Paulista, SP, Brazil) and positioned with a 45º inclination. Roots were embedded in resin, up to 2 mm below the CEJ. After acrylic resin polymerization, teeth were removed from the cylinder and the wax was removed from the root surfaces using hot water. Then, an elastomeric material (polyether, Impregum F, 3M ESPE) was manipulated according to manufacturer's instructions and inserted in the acrylic resin "mold". Teeth were reinserted into the acrylic resin, and the elastomeric material occupied the previously wax-occupied space. Excess of polyether was removed using a scalpel blade.

2.2 *Chewing simulation (fatigue)*

The specimens were submitted to chewing simulation using 1,200,000 cycles in a chewing simulator (Zicari, et al., 2012) (ERIOS 11000 Plus, São Paulo, SP, Brazil) at 100% humidity and 37ºC to simulate 5-years of clinical use. (Krejci, et al., 1990) The load was applied at 45º in relation to the cingulum of the canine using a metallic applicator tip of a compatible diameter (2.5 mm). Although the maximum forces on anterior teeth may vary, it is usually below 200 N. Therefore, a load of 160 N was applied at a frequency of 2 Hz.

2.3 *Fracture resistance*

After chewing simulation, all specimens were immediately subjected to fracture resistance analysis using a universal testing machine (EMIC DL 500, São José dos Pinhais, PR, Brazil). For this test, each specimen was positioned 135º in relation to a 2.5 mm diameter stainless-steel ball-shaped stylus, as determined in a pilot study to better simulate the clinical condition at this moment. This angle reflects the position, contacts, and loading characteristics of upper anterior teeth in Class I occlusion.(Hu, et al., 2003) Each test was performed at a cross-head speed of 0.5mm/min using a load cell of 5000N, and the same holder used for chewing simulation. The maximum load at failure was recorded in Newtons (N). Failures were recorded as: [1] repairable, when the fracture line was located in the crown or above the simulated bone level; or [2] catastrophic (non-repairable) when the fracture line was below the simulated bone level.

2.4 *Statistical analysis*

Statistical analysis was performed using the software IBM SPSS 22.0. The obtained data was tested for normal distribution (Kolmogorov-Smirnov test). Data were then submitted to two-way analysis of variance (two-way ANOVA) and Tukey post-hoc test. The level of significance was set at 5%.

3. Results

None of the tested specimens fractured during chewing simulation. The GFP length did not influence the fracture resistance (Table 2), since the three variables showed statistically similar results ($p>0.05$), regardless the resin cement used. Conventional resin cement demonstrated higher fracture resistance than self-adhesive resin cement for all evaluated GFP lengths ($p<0.05$).

The failures are represented in figure 3. In general, most of the failures were repairable. However, for GFP lengths of 7.5 mm demonstrated higher incidence of catastrophic failures. GFPs with 5 mm in length lead to repairable failures only.

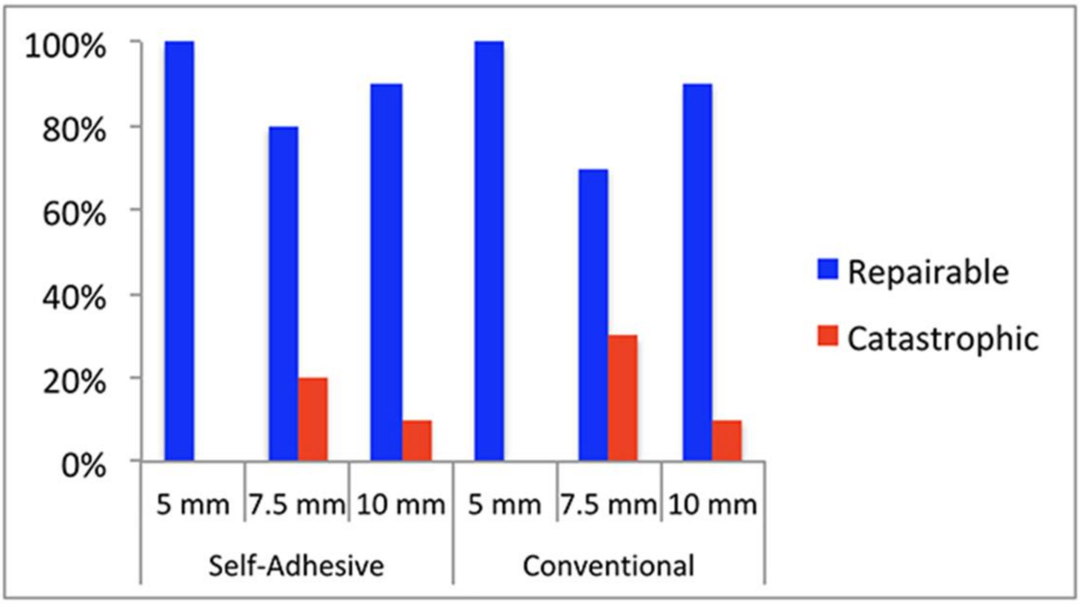
Table 2 - Fracture resistance.

GFP length	Adhesive approach	
	Self-adhesive resin cement	**Conventional resin cement**
10.0mm	738.75 (204.33) Ba	1131.54 (324.28) Aa
7.5mm	662.68 (207.56) Ba	981.46 (326.16) Aa
5.0mm	748.13 (119.20) Ba	1195.69 (387.71) Aa

Source: Authors (2022).

Table 2 shows the results for the fracture resistance of the different groups, considering the post length. It is important to observe the numerical values in conjunction with the letters. Upper case indicates significant differences between cements (rows). Lower case indicates significant differences between post lengths (columns).

Figure 3 – Failures.



Source: Authors (2022).

The blue bars in the Figure 3 show the incidence of repairable fractures. In this case, when a the fracture happens, it is possible to fix the tooth damaged with new treatment. However, in case of catastrophic fractures (red bars) this is not possible.

4. Discussion

Different lengths of GFPs and bonding strategies were tested when restoring extensively damaged teeth. To simulate extensive damage, permanent canines had their crowns removed and their cervical third of the roots enlarged (Figure 2). The primary goal was to evaluate different approaches for the rehabilitation of teeth without ferrule. The first tested hypothesis was rejected, since the post length did not affect fracture resistance. However, the second tested hypothesis was accepted, since conventional and self-adhesive resin cements affected the fracture resistance at different post lengths.

There is a lot of discussion in the dental field regarding the indication of GFPs and their importance. Some *in-vitro* studies (Lazari, et al., 2018, Magne, et al., 2017, Magne, et al., 2016, Bacchi, et al., 2019) have indicated that GFPs are not necessary in cases of extensive destruction when a 2 mm-ferrule is present, and that the use of GFPs in these cases may lead to a higher incidence of catastrophic and non-repairable failures. On the other hand, an *in-vivo* study and a systematic review and meta-analysis (Batista, et al., 2020, Jurema, 2021) has controversially disagreed. The literature is emphatic in showing that the behavior of GFPs is dependent on several factors, including: the amount of remaining coronal structure, the type and position of the tooth, the relation with its antagonist, the type of restoration, and other factors that influence post survival. (Naumann, et al., 2012, Batista, et al., 2020, Naumann, et al., 2018, Ferrari, et al., 2012, Santos, et al.) A recent systematic review and meta-analysis (Batista, et al., 2020) confirmed that there is no difference between the failure of fiber-reinforced composite post-and-core restorations with or without ferrule, indicating that the GFP is an option for use in cases of extensively destroyed teeth.

Previous findings have shown a higher fracture resistance when using greater post lengths,(Adanir, et al., 2008, Giovani, et al., 2009, Macedo, et al., 2010, Nissan, et al., 2001, Turker, et al., 2016, Verissimo, et al., 2014) with recommended posts lengths of at least the clinical crown length. (Adanir, et al., 2008) The results of the present study did not show statistical differences between the post lengths tested. Conversely, Zicari and colleagues (Zicari, et al., 2012) reported that 5mm posts (similar to this study) resulted in increased fracture resistance when compared to 10 mm posts, irrespective of the resin cement used. This may be attributed to a more conservative technique, minimizing the removal of sound dentin where the root dentin itself is narrower. Additionally, increased post lengths may increase the stress concentration at the apical region, increasing the risk of tooth fractures. (Adanir, et al., 2008, Verissimo, et al., 2014) To the best of the authors' knowledge, there are no studies in the literature simulating the lack of ferrule and flared canals on human canines. Only one study was found testing central incisors, however, without evaluating different post lengths. (Borzangy, et al., 2019)

Regarding adhesive strategies, the conventional (total-etch approach) resin cement showed a higher fracture resistance when compared to the self-adhesive cement, which are likely related to their compositions. Self-adhesive resin cements are easier to handle since they do not require the etching step on dentin surfaces and the use of adhesive systems as well. They typically contain acidic monomers, which can demineralize and infiltrate dentin, leading to a micromechanical retention (and, sometimes, a chemical bond is stablished with calcium from hydroxyapatite). (De Munck, et al., 2004, Radovic, et al., 2008) On the other hand, conventional resin cements are more technique-sensitive, with an increased number of steps, which can make it more prone to failure. When the protocol is properly followed, the technique is very reliable. In this study, the adopted adhesive system contains MDP monomer, which chemically bonds with the hydroxyapatite crystals (phosphate groups). (Van Meerbeek, et al., 2011) This interaction with MDP monomer is stable over time and seems to be more stable in water. (Van Meerbeek, et al., 2011, Rodrigues, et al., 2017) This detail might have influenced the present results, since the fatigue testing was performed under 100% humidity.

The filler content is also different when comparing both evaluated resin cements (self-adhesive: ~42%wt; conventional: ~68%wt). Filler morphology, composition, and concentrations may directly affect the flexural properties and shrinkage behavior of these materials. (Pulido, et al., 2016) Another important fact is the reduced degree of conversion observed for self-adhesive resin cements when compared to conventional ones. (Pulido, et al., 2016) This may be related to the amount of TEGDMA in their composition, which is a diluent monomer. The self-adhesive resin cement used in this study (Rely X U200) shows higher viscosity, which may impair the mobility of its functional monomers and radicals during the polymerization reaction. (Di Francescantonio, et al., 2013) Even though RelyX U200 material's safety data sheet (MSDS) does not specify the amount of TEGDMA, it probably presents reduced amount of this monomer, which affects its degree of conversion. (Pulido, et al., 2016, De Souza, et al., 2015)

The present study focused on the biomechanical behavior of different post lengths and adhesive strategies in critical restorations by applying fatigue loading before fracture test. This is important since fractures or clinical failures with restorations rarely occur under static or compressive loads only. (Naumann, et al., 2005) The number of cycles (1,200,000), the conditions in terms of humidity (100%) and temperature (37ºC), the testing angle (135°) and load (160N) were chosen to better fit with clinical conditions based on previous reports. (Hu, et al., 2003, Krejci, et al., 1990, Tan, et al., 2005) Additionally, the periodontal ligament was simulated by using an elastomer, (Soares, et al., 2005, De Souza, et al., 2015) since it is believed that the use of a rigid material (such as using epoxy resin only) to embed the teeth may lead to alterations in values and mode of failure of the specimens. (Soares, et al., 2005) In some recent studies which did not use this technique, higher values of fracture resistance and also higher incidence of catastrophic failures have been found, even in cases with more conservative preparation/restoration. (Lazari, et al., 2018, Magne, et al., 2017)

In this study, the incidence of catastrophic failures was low, which was similar to previous findings. (Giovani, et al., 2009) Interestingly, all the reparable fractures occurred in the composite resin crowns. As previously stated, (Naumann, et al., 2007) resin composites are not indicated for restorations of endodontically treated teeth without a ferrule; however the primary intention was to test the GFPs. The resin composite used in the study is characterized as a nanohybrid resin composite, containing spheres of zirconia with an average size of 200 nm, in a total inorganic content of 72-82% in weight (52-60% in volume). The results of this study might indicate that this material is suitable for restorations of extensively damaged teeth. Future studies should be performed intending to overcome the limitations of the *in vitro* studies and to evaluate the longevity of the results obtained with conventional cements using an MDP-based adhesive system.

5. Conclusion

Within the limitations of this study, it is possible to draw the following conclusions:

1. Conservative approaches should be considered, since no differences were found among the three different post lengths tested.
2. The bonding procedure using an MDP-containing adhesive system associated to a conventional resin cement resulted in higher fracture resistance when compared to a self-adhesive resin cement.

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