Intraradicular fiberglass posts: comparison among different techniques for restoring flared roots

Pinos intrarradiculares de fibra de vidro: comparação entre diferentes técnicas para restauração de raízes alargadas

Postes intrarradiculares de fibra de vidrio: comparación entre diferentes técnicas para restaurar raíces acampanadas

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Abstract
This *in vitro* study aimed to analyze the fracture strength and failure pattern of flared bovine roots restored with different intraradicular fiber posts and core materials, without a ferrule. To conduct this study fifty bovine incisor roots were treated endodontically, and divided into five groups (n=10), according to the following fiber post techniques and core materials: prefabricated fiberglass post and full-body bulk-fill resin composite (PF-BF); prefabricated fiberglass post and dual function resin cement (PF-RC); direct anatomic post and full-body bulk-fill resin composite (AP-BF); CAD-CAM integrated fiberglass post-and-core (CAD-PC); and adjustable fiberglass post and full-body bulk-fill resin composite (AD-BF). Intraradicular fiber posts were cemented with dual functional resin cement (Allcem Core, FGM), restored with CAD-CAM composite crowns (Brava, FGM), and subjected to loading. The data were analyzed by generalized linear models ($p < 0.05$). It was revealed that AP-BF presented lower fracture strength values compared with PF-RC ($p=0.006$) and AD-BF ($p=0.013$). Fractures involving the apical third only in CAD-PC. PF-RC presented only failure patterns involving the core restoration or were limited to the cervical third. PF-RC and AD-BF presented higher failure patterns limited to the core restoration, compared with other groups (60% and 50% respectively). Fractures involving the middle third were observed in the PF-BF, AP-BF, CAD-PC, and AD-BF groups. In conclusion, most of the intraradicular fiber post techniques used, and different core materials presented similar fracture strength values. CAD-CAM integrated fiberglass post-and-core presented more fractures involving the middle and apical thirds than the other groups.
Keywords: CAD-CAM; Post and core technique; Compressive strength; Permanent dental restoration; Dental prosthesis; Health teaching.

Resumo

Este estudo *in vitro* teve como objetivo analisar a resistência à fratura e o padrão de falha de raízes bovinas restauradas com diferentes pinos de fibra intrarradicular e materiais de núcleo, sem férula. Para realizar este estudo, cinquenta raízes de incisivos bovinos foram tratadas endodonticamente, e divididas em cinco grupos (n=10), de acordo com as seguintes técnicas de pino de fibra e materiais de núcleo: pino de fibra de vidro pré-fabricado e resina composta bulk-fill (PF-BF); pino pré-fabricado de fibra de vidro e cimento resinoso de dupla função (PF-RC); pino anatômico direto e resina composta bulk-fill (AP-BF); Poste e núcleo de fibra de vidro integrado CAD-CAM (CAD-PC); e pino de fibra de vidro ajustável e resina composta bulk-fill (AD-BF). Os pinos de fibra intrarradicular foram cimentados com cimento resinoso de dupla função(Allcem Core, FGM), restaurados com coroas de resina composta CAD-CAM (Brava, FGM) e submetidos a carga. Os dados foram analisados por modelos lineares generalizados ($p<0,05$). Foi revelado que AP-BF apresentou menores valores de resistência à fratura em comparação com PF-RC ($p=0,006$) e AD-BF ($p=0,013$). Fraturas envolvendo o terço apical apenas em CAD-PC. O PF-RC apresentou apenas padrões de falha envolvendo a restauração do núcleo ou foram limitados ao terço cervical. PF-RC e AD-BF apresentaram padrões de falha limitados a restaurações de núcleo mais altas, em comparação com outros grupos (60% e 50% respectivamente). Fraturas envolvendo o terço médio foram observadas nos grupos PF-BF, AP-BF, CAD-PC e AD-BF. Em conclusão, a maioria das técnicas de pinos de fibra intrarradicular utilizadas e diferentes materiais de núcleo apresentaram valores de resistência à fratura semelhantes. Os pinos e núcleos de fibra de vidro integrados CAD-CAM apresentaram mais fraturas envolvendo os terços médio e apical do que os outros grupos.

Palavras-chave: CAD-CAM; Técnica para retentor intrarradicular; Força compressiva; Restauração dentária Permanente; Prótese dentária; Ensino em saúde.

Resumen

Este estudio *in vitro* tuvo como objetivo analizar la resistencia a la fractura y el patrón de falla de raíces bovinas restauradas con diferentes postes de fibra intrarradicular y materiales de muñón, sin férula. Para llevar a cabo este estudio, se trataron endodónticamente cincuenta raíces de incisivos bovinos, y se dividieron en cinco grupos (n=10), de acuerdo con las siguientes técnicas de materiales de poste y muñón de fibra: poste de fibra de vidrio prefabricado y resina compuesta bulk-fill (PF-BF) ; poste prefabricado de fibra de vidrio y cemento de resina de doble función (PF-RC); poste anatómico directo y resina compuesta bulk-fill (AP-BF); Poste y núcleo de fibra de vidrio CAD-CAM integrado (CAD-PC); y poste ajustable de fibra de vidrio y resina compuesta bulk-fill (AD-BF). Los postes de fibra intrarradicular se cementaron con cemento de resina de doble propósito (Allcem Core, FGM), se restauraron con coronas de resina compuesta CAD-CAM (Brava, FGM) y sometidos a carga. Los datos se analizaron mediante modelos lineales generalizados ($p<0,05$). Se reveló que AP-BF tenía valores de resistencia a la fractura más bajos en comparación con PF-RC ($p = 0,006$) y AD-BF ($p = 0,013$). Fracturas que afectan al tercio apical solo en CAD-PC. El PF-RC solo mostró patrones de falla que involucraban la restauración del núcleo o se limitaron al tercio cervical. PF-RC y AD-BF mostraron patrones de falla limitados a restauraciones de núcleo más altas en comparación con otros grupos (60% y 50% respectivamente). Se observaron fracturas del tercio medio en los grupos PF-BF, AP-BF, CAD-PC y AD-BF. En conclusión, la mayoría de las técnicas de poste de fibra intrarradicular utilizadas y los diferentes materiales de núcleo mostraron valores de resistencia a la fractura similares. Los postes y muñones de fibra de vidrio integrados CAD-CAM mostraron más fracturas que involucraban los tercios medio y apical que los otros grupos.

Palabras clave: CAD-CAM; Técnica de perno muñón; Fuerza compresiva; Restauración dental permanente; Prótesis dental; Enseñanza en la salud.

1. Introduction

The ability of the tooth to resist occlusal forces after endodontic treatment is directly related to the quality and amount of remaining dental tissue (Kar et al., 2017; Santos et al., 2018). Not only is it important to have a well-executed endodontic treatment, but the quality and the resistance of the restorative procedure are also crucial to long-term clinical longevity (Julosky et al., 2012). When the remaining coronal tissue can no longer provide adequate retention and support for the restorative material, intraradicular posts and core buildup are frequently used to maintain the mechanical stability of the restoration (Smith et al., 1998; Theodosopoulou et al., 2009).

Prefabricated fiberglass posts cemented with adhesive luting systems may present greater retention, lower microleakage, and higher resistance to root fractures, compared with cast post-and-cores (Kotch et al., 2014; Newman et al., 2003). In addition, these prefabricated systems ensure optimal biomechanical behavior, and have the effect a ferrule for endodontically treated dental incisors (Julosky et al., 2012). However, the remaining dental structure of flared roots does not always allow using a ferrule, and prefabricated fiber posts designed for flared roots are still scarce. A misfit of the fiberglass post to flared roots can increase the resin cement thickness, and lead to higher polymerization shrinkage of the material, hence lower fracture resistance or debonding (Silva et al., 2011).

Some techniques and alternative prefabricated fiber posts have been developed to resolve the fiber post misfit (Gama et al., 2021). Remodeling the prefabricated fiber post with resin composite (direct anatomic post) is a widespread technique developed to decrease the resin cement thickness, and increase the post adaptation to the root walls (Silva et al., 2011; Delgaldio 2021). A multi-directional glass fiber-reinforced composite material designed for manufacturing post-and-core using CAD-CAM (computer-aided design and computer-aided manufacture) technology is also an alternative for restoring flared roots, and is preferred because it can be customized by scanning the root canal shape (Pang et al., 2019). Special size double tapered fiber posts with enlarged coronal diameter, and self-adjustable fiber posts are other intraradicular materials developed to enable better adaptation to flared roots (Wandscher et al., 2015; Nobrega et al., 2015).

Core buildup is yet another technique that can influence the mechanical resistance to masticatory forces and survival rates of indirect restorations. (Magne et al., 2016) Bulk-fill resin composites can be used for core buildup, and further reduce chairside time (Warangkulkasemkit & Pumpaluk, 2019). Moreover, dual functional resin cement was developed to cement the post and build the core, using the same dual-polymerized composite material (Agrawal & Mala, 2014). This technique may also decrease chairside time, and the number of materials used in this procedure, thus reducing technique sensitivity. (Walcher et al., 2019)

However, little is known about how different intraradicular fiberglass posts combined with different core materials behave under compressive forces in flared roots without a ferrule (Silva et al., 2021). Therefore, the present study aimed to compare the fracture strength and failure pattern of flared bovine roots restored with different intraradicular fiber posts and core materials. The null hypotheses were that no significant difference would be found (1) in the fracture strength, and (2) in the failure pattern among the combined restorative techniques.

2. Materials and methods

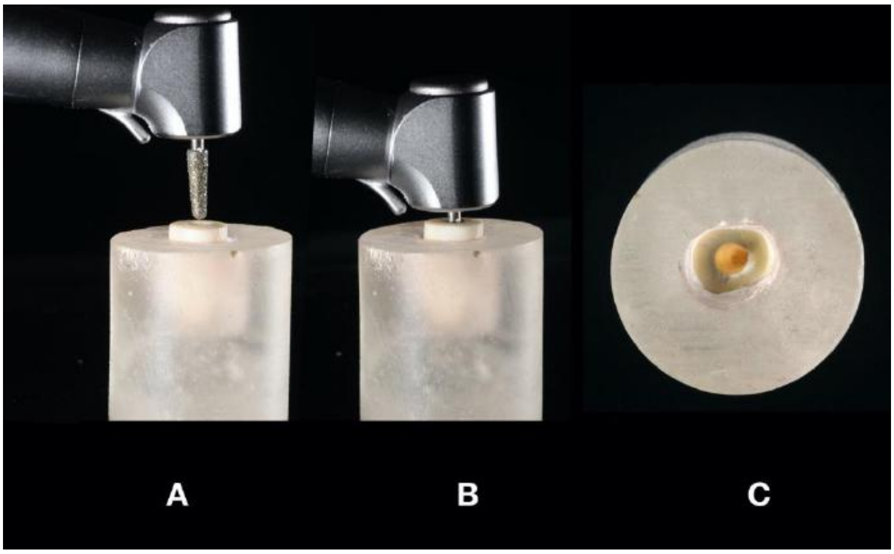
2.1 Specimen preparation

To conduct this *in vitro* quantitative study, caries-free extracted bovine incisors of similar dimension were cleaned and stored in a 0.1% thymol solution at 4ºC for 30 days at most. Fifty bovine incisors without cracks or fractures were selected, and the crowns were removed using a diamond disk (KG Discoflex 7013, KG Sorensen) coupled to a water-cooled handpiece, to obtain 13 mm long roots.

The roots were treated endodontically by the same operator who used the Reciproc system (VDW Reciproc 25.08, Munich, Germany), with 2.5% sodium hypochlorite (Soda Clorada, Asfer) irrigation. After instrumentation of the roots, the inorganic particles were removed with 17% EDTA (EDTA-T, Lysanda) for three minutes, followed by 2.5% NaOCl irrigation. The water was removed with paper cones (Protaper, Dentsply Sirona), and the root canal was filled with gutta-percha cones (Protaper, Dentsply Sirona) and endodontic epoxy resin-based sealer (AH Plus™, Dentsply Sirona).

The coronal gutta-percha was removed leaving an 8-mm-long space to fit an intraradicular fiber post, while maintaining 5 mm of the apical sealer. This step was performed initially with a heated instrument, followed by a rotary instrument (Largo drill #3, Dentsply Sirona). The root canals were enlarged with high-speed diamond burs (4137; KG Sorensen) to obtain a simulated flared canal. The diamond burs penetrated up to the 8-mm space that was unobstructed. Then, the roots were washed thoroughly with distilled water for one minute, and dried with absorbent paper cones (Figures 1a, 1b and 1c).

Figures 1a and 1b: Side view of the diamond #4137 enlarging the root canal. **Fig 1c**: Incisal view of the flared root canal.



Source: Own authorship.

2.2 Division of groups and post-and-core procedures

The roots were randomly divided into five groups (n=10), according to the combination of intraradicular fiber post and core material factors:

- PF-BF: Prefabricated fiberglass post and full-body bulk-fill resin composite
- PF-RC: Prefabricated fiberglass post and dual functional resin cement
- AP-BF: Direct anatomic post and full-body bulk-fill resin composite
- CAD-PC: CAD-CAM integrated fiberglass post-and-core
- AD-BF: Adjustable fiberglass post and full-body bulk-fill resin composite

The compositions of the materials appear in Table 1. The Whitepost DCE #2 drill system (FGM) was used on the prefabricated fiber posts (PF-BF, PF-RC, and AP-BF) to remove any remaining gutta-percha at the 8-mm coronal length. The fiber posts were cut 11 mm long (8 mm intracanal and 3 mm above the root edge). Direct anatomic posts (AP-BF) were obtained using a full-body bulk-fill resin composite (Opus Bulk Fill APS shade A2, FGM) as a remodeling agent. The prefabricated post was cleaned with 70% ethanol and dried, after which a layer of silane (Prosil, FGM) was applied. The resin composite was placed covering the prefabricated fiberglass post, inserted into the water-based lubricated root canal (K-Y gel, Jhonson & Jhonson,), and light-cured for 10 s (Valo Cordless, Ultradent Products). The direct anatomic post was removed from the root canal, light-cured for another 60 s, and water-rinsed to remove the lubricant gel (Figures 2a, 2b, 2c and 2d).

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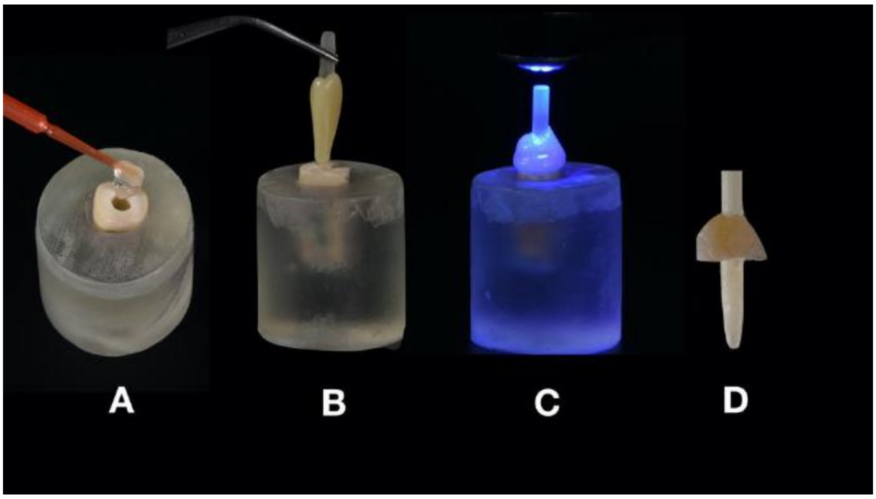
Table 1. Classification, manufacturer, batch number, composition, and application technique of the materials used.

Classification	Material (Manufacturer)	Composition	Application technique
Prefabricated fiberglass post	White post special size DCE #2/double tapered (FGM)	Glass fiber and epoxy resin Dimensions: 18mm long, 2.2mm top diameter, and 1.05 bottom diameter.	Prepare the root canal with suitable drills according to the fiber post number.
CAD-CAM fiberglass post	Fiber CAD – Post & Core (Angelus)	Glass fiber and epoxy resin	Scan the preparation of the root in the mouth or the dental wax/ resin pattern. Machine using tungsten carbide drills. Make the final adjustments with diamond drills.
Self-adjustable fiberglass post	Splendor-SAP (Angelus)	Glass fiber and epoxy resin	After partially removing the root canal filling, position the pin in the duct, up to the end of the preparation. Insert the sleeve on the pin and position it as close to the apex as possible with slight pressure.
Full-body bulk fill resin composite	Opus Bulk Fill APS – Shade A2 (FGM)	Urethane dimethacrylate, triethylene glycol dimethacrylate, ethoxylated *bisphenol* A glycol dimethacrylate, ethyl 4-dimethyl aminobenzoate, camphorquinone, ytterbium trifluoride, tinuvin P, butylated hydroxytoluene, lumilux blue, red iron oxide, t*itanium dioxide white, b*arium-borosilicate glass, and silanized silica (79 wt%).	After completing the adhesive procedures, apply in increments up to 5mm deep. Light-cure for 40s.
Silane	Silano (Angelus)	Silane and ethanol	Apply the product, wait for 1 min and gently dry with air.
Adhesive	Ambar Universal APS (FGM)	10-methacryloyloxydecyl dihydrogen phosphate, methacrylate monomers, photoinitiators, coinitiators, stabilizer, silica nanoparticles, and ethanol.	Fiber post: apply one layer of the product after silanization. Evaporate the solvent for 10s. Fiber post cementation: apply two layers of the product into the root canal rubbing vigorously for 10s. Evaporate the solvent with gentle blasts of oil-free air for 10s, and then light-cure for 20s.
Dual function resin cement	Allcem Core – Shade A2 (FGM)	Bisphenol A-glycidyl methacrylate, triethylene glycol dimethacrylate, ethoxylated *bisphenol* A glycol dimethacrylate, and barium aluminum silicate glass silicon dioxide (62 wt%).	Cementation: after applying the adhesive, apply the resin cement using the auto-mix tip with nozzle. Core: Fill the mold (acetate matrices) with the cement and adapt it on the crown part of the pin; then light-cure for 40s each face.
Resin-based ceramic	Brava – Shade A2 (FGM)	Methacrylic monomers, initiators, co-initiators, stabilizers, silane, glass-ceramic load particles, silica, and pigments.	After milling and finishing the crown, apply one layer of silane to the internal part. Apply a thin layer of adhesive for 30s and evaporate the solvent.

Source: Own authorship.

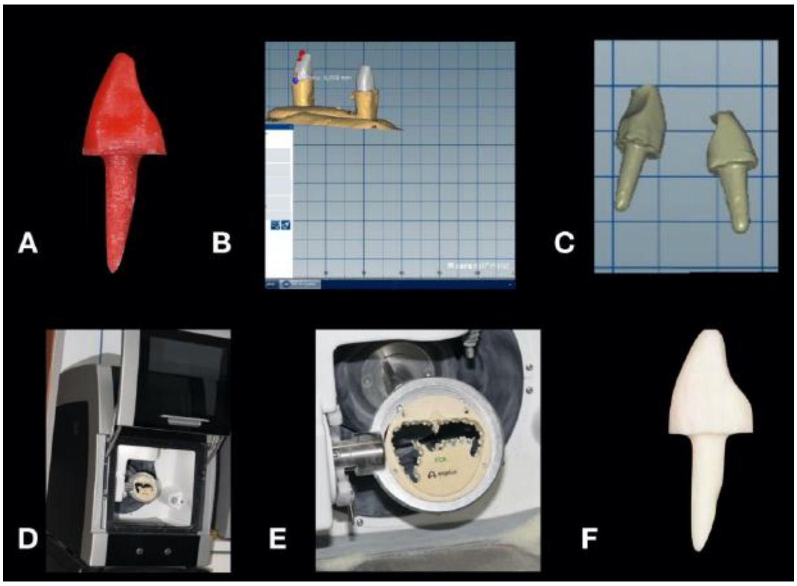
Figure 2a: occlusal view of the water-based lubricant being inserted via brush inside the flared root canal **Figures 2b and 2c**: Side view of the set (post and composite resin) being inserted and light-cured. **Figure 2d**: side view of the Direct anatomic post fabricated.



Source: Own authorship.

The roots of the group that received a CAD-CAM integrated fiberglass post-and-core (CAD-PC) were molded with acrylic resin (Duralay®; Reliance Dental Manufacturing Company), and the core was built with the same acrylic resin, using a polypropylene matrix (8 mm high x 4- to 5-mm base diameter) obtained from a polypropylene sheet and a prefabricated core (NucleoJet, Angelus), using a laminate vacuum machine. The molds were then scanned (Ceramill Map200, Amann Girrbach, Koblach, Vorarlberg, Austria), the data were imported into the Ceramill Mind software program (Amann Girrbach), and the integrated glass fiber post-and-core was designed by the program. Afterwards, the data were converted to STL format, and the fiberglass post-and-core was manufactured in a milling machine (Ceramill® motion-Amann Girrbach) using a matrix glass fiber resin block (Fiber CAD-Angelus Science and Technology) (Figures 3a to 3f).

Figure 3a: side view of the acrylic post-and-core mold. **Figure 3b and 3c**: digital models made by scanning the post-and-core depicted in 3a. **Figure 3d and 3e**: glass fiber block being milled. **Figure 3f**: integrated fiberglass post-and-core fabricated.



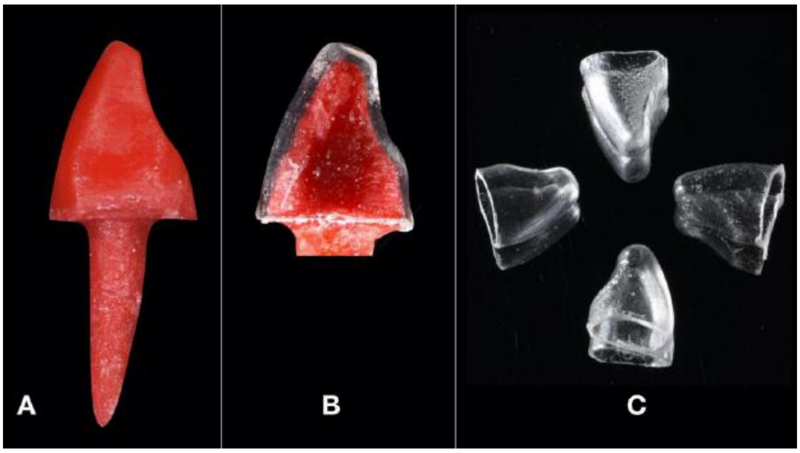
Source: Own authorship.

In the group that received an adjustable fiber post (Splendor SAP, Angelus Science and Technology) (AD-BF), the pin was inserted into the root canal with slight pressure, and the sleeve was placed as close to the apical portion as possible.

After each fiber post preparation, the post was cleaned with 70% ethanol and dried. A layer of silane (Silano, Angelus) was applied and left in contact with the post for 60 s prior to volatilization. The universal adhesive (Ambar Universal APS, FGM) was applied into the root canal, to the remaining dental tissue of the coronal portion, and to the silanized post, as described in Table 1. The dual-function resin cement (Allcem Core, FGM) was inserted into the root canal with a self-mixing tip designed for root canal filling. Then, the post was inserted, the excess resin cement was removed with a disposable brush (Micro Tim, VOCO, Cuxhaven, Germany), and the cement was light-cured for 40 s on each face (Valo Cordless).

Regarding building up of the core, a polypropylene matrix was used to standardize the dimensions of the coronal portion, as described above (Figures 4a, 4b and 4c).

Figures 4a, 4b and 4c: process of fabrication of the polypropylene matrix.



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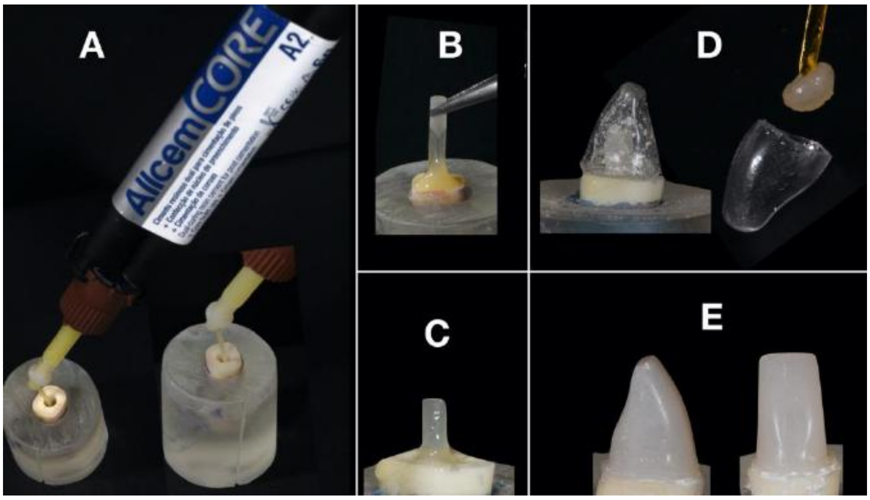
The matrix was filled with full-body bulk-fill resin composite (PF-BF, AP-BF, and AD-BF), or with dual-functional resin cement (PF-RC) (Figures 5a to 5f). Afterwards, the matrix was positioned on the top of the cemented post and light-cured for 40 s on each face.

Figures 5a, 5b and 5c: Oclusal and side view of the post cementation. **Figure 5d**: lateral view of the adaptation and composite resin insertion inside the polypropylene matrix. **Figure 5e**: side and front view of the composite core constructed.



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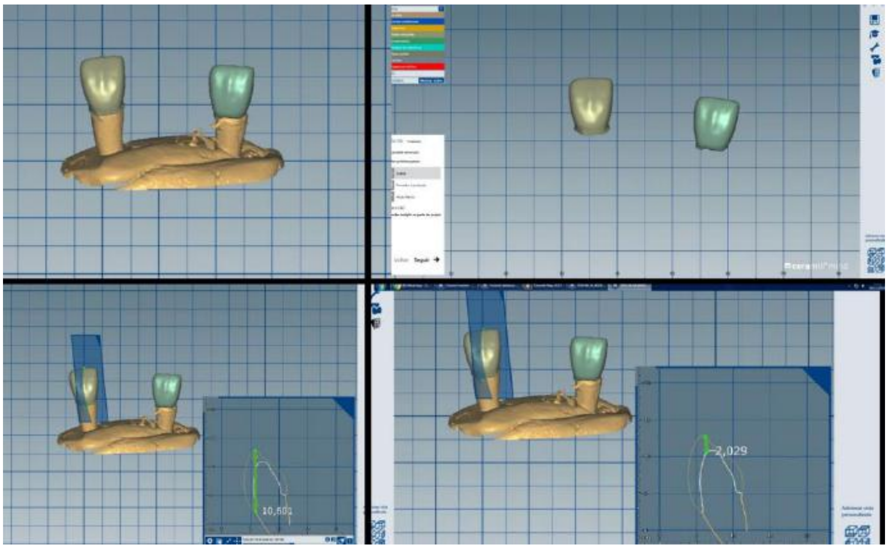
2.3 Resin-based ceramic CAD-CAM crowns

All the groups received CAD-CAM crowns (Brava Block - FGM) with standardized dimensions (10 mm high and 2 mm thick). Each core was finished with *Sof-Lex*™ disks (Extra Thin Contouring and Polishing Disks – 3M, St Paul, MN, USA). Then, each set (tooth/core) was scanned (Ceramill Map200, Amann Girrbach). After the digital model of the core was obtained, the crown was designed using the Ceramill Mind software program (Amann Girrbach) and milled with the Ceramill® motion system (Amann Girrbach) (Figure 6).

Figure 6: Digital design of the prosthetic crown.



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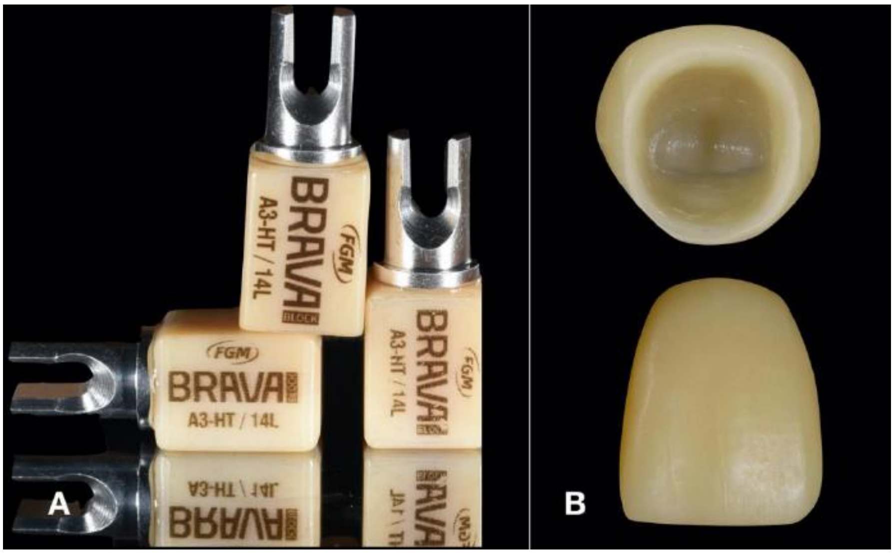
Afterwards, a layer of silane was applied to the internal part of the crown. An adhesive layer was also applied, and the crown was cemented with the same dual-function resin cement (Figures 7a and 7b, and Figures 8a to 8d).

Figure 7a: Composite resin block. **Figure 7b**: Composite crown milled.



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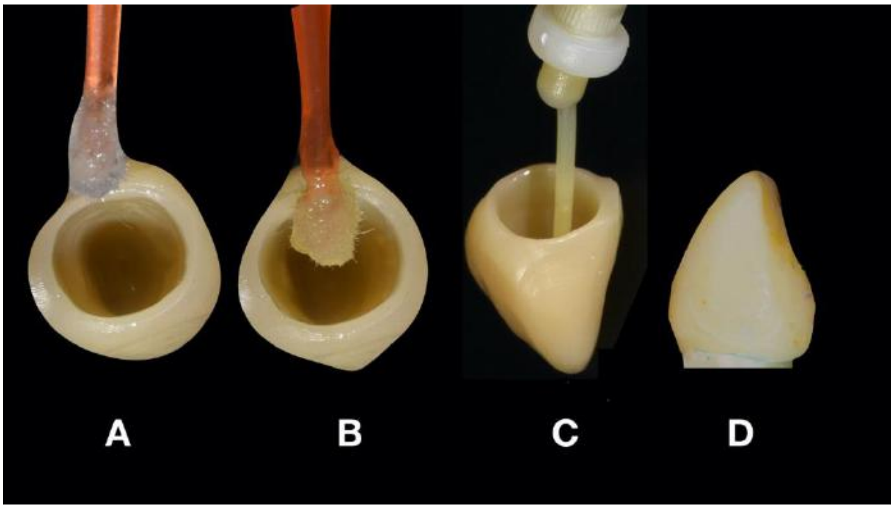
Figures 8a to 8d: Process of crown cementation.



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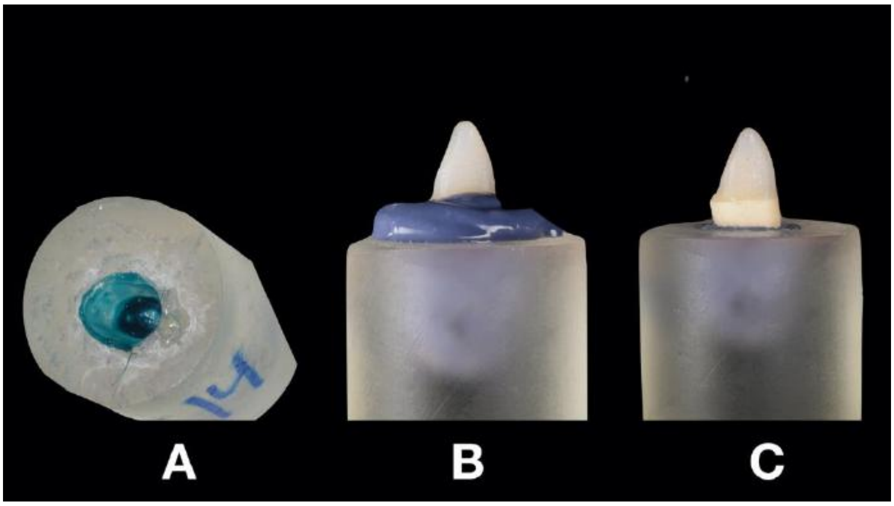
2.4 Simulation of the periodontal ligament

A simulated periodontal ligament using a polyether impression material (Impregum Soft, 3M) was obtained to reproduce a clinical situation, and provide a more accurate assessment of the bovine root fracture strength (Pang et al., 2019). The roots were covered with a 0.2 to 0.3-mm-thick layer of melted wax (Horus; Herpo Produtos Dentários, Petrópolis, RJ, Brazil), up to 2 mm below the cervical limit (simulating the height of the alveolar bone). Each root was embedded in self-cure acrylic resin cylinders (25 mm diameter x 22 mm high). Afterwards, the acrylic resin was polymerized, and the wax was removed from the acrylic resin surface and the roots. Then, the polyether impression material was placed between the roots and the acrylic resin to simulate the periodontal ligament (Figures 9a, 9b and 9c). All the samples prepared were kept in a humid environment until the test (Estrela et al., 2018).

Figures 9a, 9b and 9c: Process of fabrication of the synthetic periodontal ligament.



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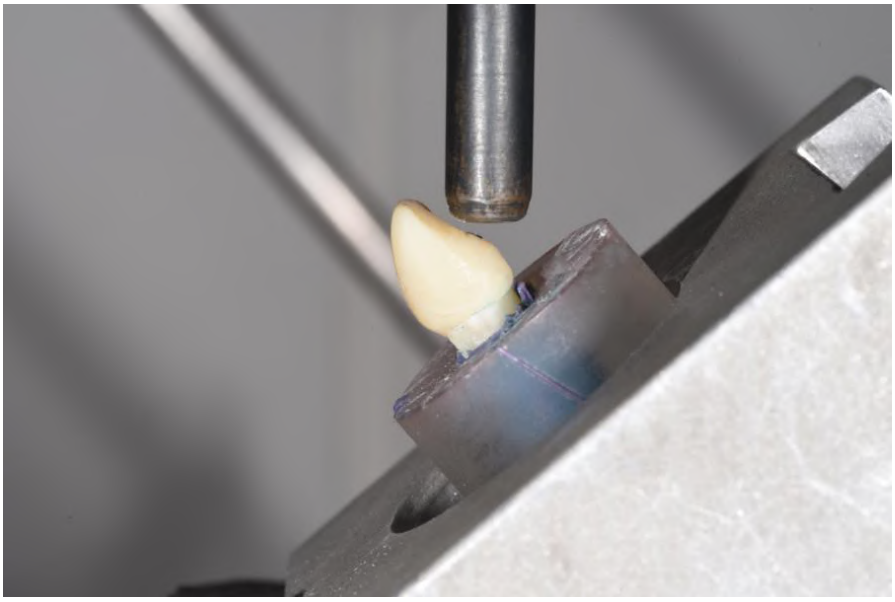
2.5 Fracture strength test and failure pattern analysis

The load was applied at the palatal surface with a 135° inclination to the long axis of the tooth, simulating the Class I occlusion relationship of the antagonist tooth (Melo et al., 2005), as described elsewhere (Clavijo et al., 2009). After adjusting to the correct positioning, the specimens received a compressive load, at a constant speed of 0.5 mm/min until failure (Universal testing machine – Instron 23-5D, Instron, Norwood, MA, USA) (Figure 10). The maximum load was recorded in Newtons (N). The data did not follow the assumptions for a parametric test (normality and homoscedasticity), and were analyzed by generalized linear models. (Estrela et al., 2018)

Figure 10: Side view of the compressive load being applied.



Source: Own authorship.

These procedures were used to simulate a traumatic blow on middle third of the dental crowns from a buccal direction.

The failure patterns were classified into four criteria, according to the level of fracture or crack observed under a microscopy: (Coronary) coronary fractures involving the core restoration; (Cervical third) coronary/root fractures or cracks extending to the cervical third; (Middle third) root fractures or cracks extending to the middle thirds; (Apical third) root fractures or cracks extending to the apical third.

3. Results

The fracture strength test results are shown in Figure 11, and the failure pattern, in Figure 12. AP-BF presented lower fracture strength values compared with PF-RC (p=0.006) and AD-BF (p=0.013), whereas no statistical difference was observed among the other groups. Fractures involving the apical third were observed only for CAD-PC. PF-RC presented only failure patterns involving the core restoration, or were limited to the cervical third. PF-RC and AD-BF presented higher failure patterns limited to the core restoration, compared with other groups (60% and 50% respectively). Fractures involving the middle third were observed in the PF-BF, AP-BF, CAD-PC, and AD-BF groups. None of the combined techniques were able to restrict all the fractures to enable core restoration.

Figure 11. Boxplot graph of fracture strength for each group tested. (+) Mean. Different lowercase letters indicate a significant difference (p<0.05).

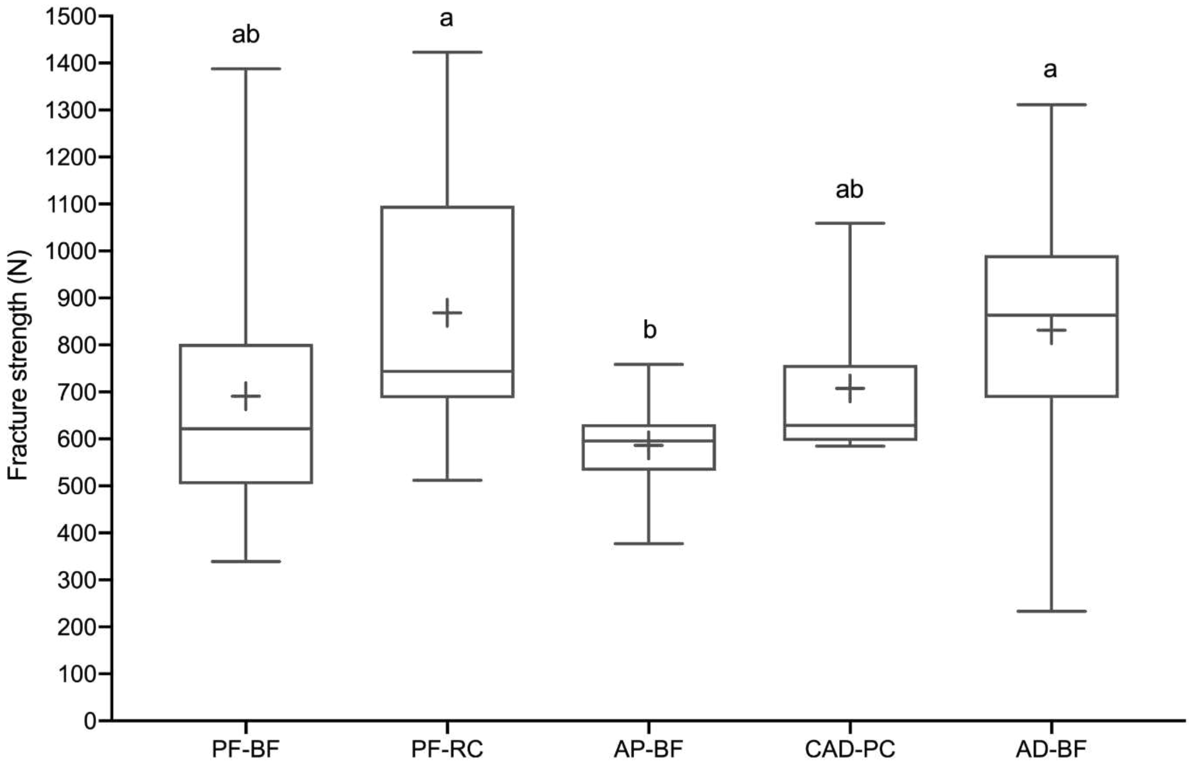


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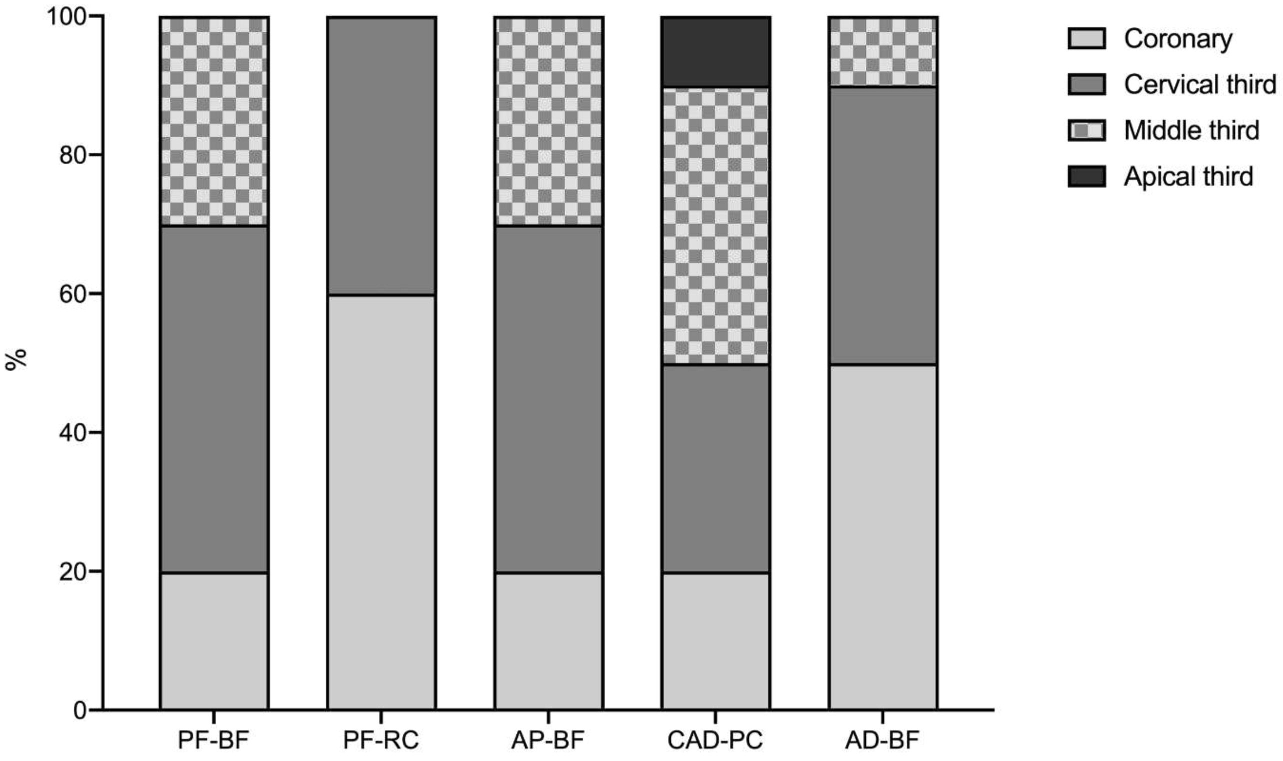
Figure 12. Failure pattern percentage for each group tested.



Source: Own authorship.

4. Discussion

The longevity of endodontically treated teeth may be improved by restoring them with materials that have an elastic modulus similar to that of dentin, that are capable of distributing the stress homogenously, and that avoid catastrophic root fractures (Naumann et al., 2005; Santos et al., 2010; da Silva et al., 2010). Flared roots have a higher risk of biomechanical failure, because of a large amount of root structure loss (Clavijo et al., 2009) In this study, the fracture strength of different intraradicular fiberglass posts, combined with different core materials, was evaluated in restoring flared roots without a ferrule. Based on the statistical analysis, the first null hypothesis was rejected, because AP-BF presented lower fracture strength than PF-RC and AD-BF. However, the AP-BF group presented no statistical difference from PF-BF (same materials without any direct anatomic post technique). The direct anatomic post technique involves adding an adhesive interface between the fiber post and the resin composite, and another interface to the cementation interface, an inclusion that can increase technique sensitivity and chairside time. No increase in fracture strength, or any better failure pattern, was achieved when restoring a flared root with a direct anatomic post (PF-BF), in comparison with a special size prefabricated fiberglass post. This result seems to discourage use of the direct anatomic post technique, despite its recommended application in the literature (Clavijo et al., 2009; Gomes et al., 2016; Mongruel et al., 2014). Furthermore, none of the techniques or materials used as a core or post-and-core were able to increase the fracture strength, as achieved by PF-BF.

On the other hand, PF-RC and AD-BF presented a better failure pattern, but one limited to the core restoration (60% and 50% respectively) or the cervical third (40%), hence rejecting the second null hypothesis. Fractures involving only the core restoration have a better prognosis regarding restoration replacement. Both groups presented numerically higher fracture strength values, with no statistical difference between PF-BF and CAD-PC. The dual-functional resin cement (Allcem Core) presented physical properties (flexural strength and degree of conversion) similar to those of a resin composite (GrandioSo, VOCO, Cuxhaven, Germany) (Walcher et al., 2019). In this study, the fracture strength values of PF-RC were not statistically different from those of the bulk-fill used as a core material (PF-BF and AD-BF groups), despite the reduced number of filler particles in this material (62 wt%). On the other hand, this reduced number seems to have increased the percentage of failure patterns limited to the core restoration, an outcome that may be related to the elastic modulus of this material. Composites with a lower percentage of filler particles exhibit a reduced elastic modulus (Lohbauer et al., 2013).

The self-adjustable prefabricated fiber post system has an additional sleeve combined with a pin that can be adjusted to the coronal part of the flared root. The difference between this sleeve system and that of the special size prefabricated post is the possibility of manually inserting the sleeve, unlike the tapered coronal fixed dimension of the special size prefabricated post. This seems to suggest that the untied sleeve may have promoted a higher incidence of fractures limited to the core restoration or the cervical third. To the best of our knowledge, this is the first study investigating self-adjustable fiberglass posts. Further studies are needed to gain a better understanding of the mechanical behavior and stress distribution of this material in flared roots.

Custom CAD-CAM integrated fiberglass posts (CAD-PC) presented fracture strength values similar to those of other techniques combined with different core materials. However, only this group presented a failure pattern involving the apical third, and a reduced failure pattern limited to the core restoration or cervical third (50%). Conversely, when the CAD-CAM integrated fiberglass posts were cemented with a self-adhesive resin cement, a reduction was achieved in irreparable root fractures (Ruschel et al., 2018). For this reason, we believe that the mechanical performance and the stress distribution of CAD-CAM integrated fiberglass posts may be dependent on the type of resin cement used, and the positioning of the fiber within the matrix when milled. This technique also reduces the cement layer thickness and avoids the combination of different materials between the post and the core buildup (Liu et al., 2010). Moreover, this material has lower flexural strength and elastic modulus than prefabricated glass fiber posts (Ruschel et al., 2018). Despite the reduced cement thickness and lower flexural strength, no increase in fracture strength was obtained in this study for the CAD-PC group compared with the PF-BF group.

Despite the noteworthy results for PF-RC and AD-BF, further research should be developed to focus on the fracture strength of these materials when subjected to different load cycles, and when cemented to human flared teeth roots, considering the compositional differences and the root canal size, in evaluating the stress distribution characteristics.

5. Final Considerations

This study aimed in comprehending how different intraradicular fiberglass posts combined with different core materials behave under compressive forces in flared roots without a ferrule. Within the limitations of this *in vitro* study, it succeed in concluding that: (1) Most of the intraradicular fiber post techniques combined with different core materials presented similar fracture strength values for flared roots without a ferrule; (2) PF-BF and AD-BF presented a higher percentage of failure pattern limited to the core restoration; (3) CAD-CAM integrated fiber post-and-core presented more fractures involving the middle and apical thirds, compared with the other groups.

Being an in *vitro study*, the results may not express complexly how such techniques and materials behave in real mastication, for the applications addressed in this research. Therefore, further studies are needed to further the knowledge regarding fiberglass posts and their properties when used to restore teeth with flared roots.

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