

Fracture resistance to fixed partial denture abutments with direct and indirect posts

Resistência à fratura de pilares de próteses fixas restaurados com núcleos diretos e indiretos

Resistencia a la fractura de pilares de prótesis fija restaurados con muñones directos e indirectos

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Abstract

The objective of this study was to evaluate the resistance to fracture of three-element fixed partial dentof glasstment teeth restored with glass fiber posts (GFP) and cast post-and-core (CPC) retainers. Herein, 60 bovine mandibular incisors were divided into two groups (n = 30) according to the retainer type in: 1) resin composite core reinforced with GFP; and II) CPC (Cu-Al). Each pair of roots consisted of one sample, simulating a three-element fixed partial denture. The structures of the fixed three-element partial dentures were made in Ni-Cr alloy. A conventional dual resin cement (RelyX ARC - 3M Espe, USA) was used for all cementation procedures. Samples were subjected to a compressive load onto an orifice at occlusal contact region of the pontic until collapse or fracture. Normal data distribution was verified by D'Agostino & Pearson normality test. Unpaired t test was used for data analysis ($\alpha = 5\%$). The results showed that the the three-element fixed partial denture abutment teeth restored with composite resin cores retained by GFP presented higher fracture resistance compared to the ones restored with CPC ($p=0.0009$). In conclusion, the resistance to fracture of three-element fixed partial denture restored with resin composite core reinforced with glass fiber posts was higher to the one restored with post-and-core retainers.

Keywords: Dental prosthesis; Post and core technique; Dentistry; Prosthesis design; Prosthesis failure.

Resumo

O objetivo deste estudo foi avaliar a resistência à fratura de próteses parciais fixas de três elementos restaurados com pinos de fibra de vidro (GFP) e núcleos metálicos fundidos (CPC). Neste trabalho, 60 incisivos inferiores bovinos foram divididos em dois grupos (n = 30) de acordo com o tipo de retentor: 1) núcleo de resina composta reforçada com GFP; e II) CPC (Cu-Al). Cada par de raízes consistiu em uma amostra, simulando uma prótese parcial fixa de três elementos. As estruturas das próteses parciais fixas de três elementos foram confeccionadas em liga de Ni-Cr. Um cimento resinoso dual convencional (RelyX ARC - 3M Espe, EUA) foi usado para todos os procedimentos de cimentação. As amostras foram submetidas a uma carga compressiva em um orifício na região de contato occlusal do pântico até seu colapso ou fratura. A distribuição normal dos dados foi verificada pelo teste de normalidade de D'Agostino & Pearson. O teste t não pareado foi usado para análise dos dados ($\alpha = 5\%$). Os resultados mostraram que os dentes pilares de prótese parcial fixa de três elementos restaurados com núcleos de resina composta retidos por GFP apresentaram maior resistência à fratura quando comparados aos restaurados com CPC ($p=0,0009$). Em

conclusão, a resistência à fratura de prótese parcial fixa de três elementos restaurada com núcleo de resina composta reforçada com pinos de fibra de vidro foi superior à restaurada com retentores pino e núcleo.

Palavras-chave: Prótese dentária; Técnica para retentor intrarradicular; Odontologia; Desenho de prótese; Falha de prótese.

Resumen

El objetivo de este estudio fue evaluar la resistencia a la fractura de prótesis parciales fijas de tres elementos restauradas con postes de fibra de vidrio (GFP) y muñones de metal colado (CPC). En este trabajo se dividieron 60 incisivos inferiores bovinos en dos grupos ($n = 30$) según el tipo de retenedor: I) núcleo de resina compuesta reforzado con GFP; y II) CPC (Cu-Al). Cada par de raíces consistió en una muestra, simulando una prótesis parcial fija de tres elementos. Las estructuras de las prótesis parciales fijas de tres elementos fueron fabricadas con aleación de Ni-Cr. Se utilizó un cemento de resina dual convencional (RelyX ARC - 3M Espe, USA) para todos los procedimientos de cementación. Las muestras se sometieron a una carga de compresión en un orificio en la región de contacto oclusal del pónico hasta su colapso o fractura. La distribución normal de los datos se verificó mediante la prueba de normalidad de D'Agostino & Pearson. Se utilizó la prueba t no pareada para el análisis de datos ($\alpha = 5\%$). Los resultados mostraron que los dientes pilares de prótesis parcial fija de tres elementos restaurados con núcleos de resina compuesta retenidos con GFP mostraron una mayor resistencia a la fractura en comparación con los restaurados con CPC ($p = 0,0009$). En conclusión, la resistencia a la fractura de una prótesis parcial fija de tres elementos restaurada con un núcleo de resina compuesta reforzada con postes de fibra de vidrio fue superior a la restaurada con postes y retenedores de muñones.

Palabras clave: Prótesis dental; Técnica de perno muñón; Odontología; Diseño de prótesis; Falta de prótesis.

1. Introduction

The rehabilitation of endodontically treated teeth (ETT) affected by extensive crown destruction aims at protecting the reminiscent tooth structure (Iqbal & Kim, 2007; E. Silva et al., 2018). However, the longevity of partial fixed dentures depends on the space's size to be rehabilitated, the connectors' stiffness to be used, and the type of core and post chosen (Goga & Purton, 2007). Endodontic treatment and the use of intra-radicular retainers may negatively affect the mechanical behavior of fixed dentures (Nagase et al., 2011).

Cast posts and cores (CPC) promote adequate retention due to their adaptation to root canal, leading to a uniform cementation line. However, CPC might undergo corrosion, require laboratory step of preparation, are stiffer than dentin, and do not favor aesthetics or adhesion to the tooth structures (Amanajás Neto et al., 2011). Thus, other materials have been searched to rehabilitate ETT.

In this context, glass fiber posts (GFP) arose as alternative to CPC once they require a more accessible application technique, conservative tooth preparation, and immediate cementation, excluding the need for a laboratory steps (Novis et al., 2013). Moreover, they present elastic modulus similar to the one of the dentin (Marchesi et al., 2013).

The restorative core, over which the prosthetic crown will be placed, might be metallic, composed of stainless steel alloy, titanium, or noble metallic alloys (Kaur et al., 2012; Partiyani et al., 2017). The type of core chosen influences the mechanical behavior of anterior abutment teeth when they are evaluated alone (Zarow, Devoto, & Saracinelli, 2009). However, the literature lacks evidence regarding the behavior of partially fixed denture abutment tooth associated with the rehabilitation of vast edentulous space. Thus, this study evaluates the resistance to fracture of fixed partial denture abutment tooth restored with direct or indirect post and core.

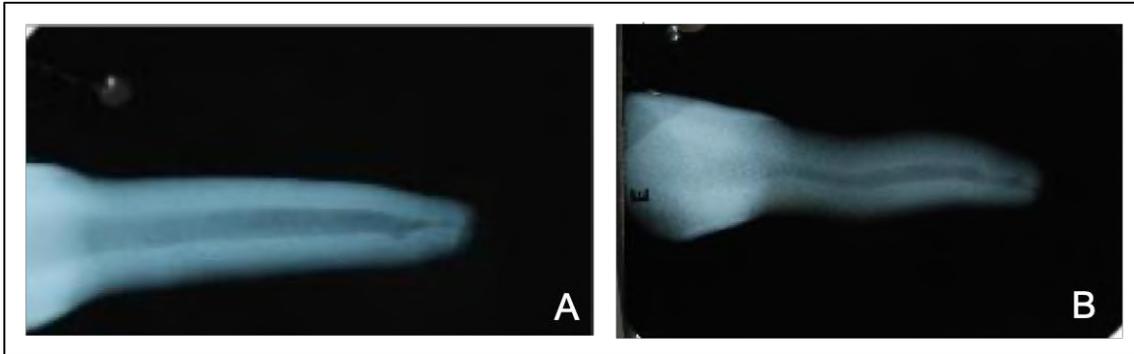
2. Methodology

2.1 Tooth Selection and Specimen Preparation

Bovine incisors were used in this in vitro study ($N=60$). Such teeth were cleaned and stored in thymol 0.1%. The root width was measured at 15 mm from the root apex with a digital pachymeter with 0.01 precision (Marberg, Pequim, China). In this phase, teeth measuring between 5.8 to 6.2 mm of external diameter were selected. The selected teeth were radiographed

with periapical radiographic films (Agfa, Heraeus Kulzer, São Paulo, Brasil) using the parallelism technique (Figure 1). In this phase, all teeth that presented incomplete rhizogenesis, root dilaceration, or any root canal malformation were excluded from the study.

Figure 1. Periapical radiography for root analysis. A) Selected root with straight root. B) Root with deviation.



Source: Authors.

All the selected specimens were transversally sectioned with a diamond drill under refrigeration at 15 mm from the root apex using the #4138F diamond drill (KG Sorensen, Cotia, Brasil) (Figure 2). After being sectioned, the root canal lumen was measured from the mesial to the root's distal side. The roots that presented a lumen measuring 1.8 to 2.2 mm were excluded.

Figure 2. A) Cross-sectioning of specimens. B) Different roots and lumen.



Source: Authors.

2.2 Root Canal Preparation

The specimens were mechanically prepared using #2 and #3 Gates Glidden drills ([AR Maillefer - Dentsply Sirona](#), York, Pennsylvania, USA). During the mechanical instrumentation, the root canal was irrigated with a 2.5% sodium hypochlorite solution (ASFER – São Caetano do Sul, São Paulo, Brazil). Then, the root canal was dried with absorbent paper, and the obturation was performed with a gutta-percha cone of a diameter compatible with the size of the last Gates Glidden drill used. The obturation was performed using the single cone technique with endodontic cement (Sealer 26, Dentsply, Buenos Aires, Argentina).

Each root had 11 mm of obturation removed from the root canal, and four millimeters of gut-percha was left at the apical root third. The obturation was removed using the drill recommended by the post manufacturers (White Post – FGM) (FGM Produtos Odontológicos, Joinville, SC, Brasil), which allowed standardization. The sequence suggested by the manufacturer was followed, promoting a conservative preparation of the root canal walls and a passive adaptation of the intraradicular retainers. The process was performed under refrigeration, and the root canals were washed and dried after obturation removal.

2.3 Periodontal Ligament Simulation

The periodontal ligament simulation was performed as follows: the roots were immersed in liquid hot wax (New Wax – TechNEw, Rio de Janeiro, Brazil). Thus, a pellicle of 0.2 to 0.3 mm of wax was formed on the root length after the wax cooled down. In the sequence, PVC cylinders were filled with acrylic resin (Jet – Clássico Ltda, São Paulo, Brazil), and the roots covered with wax were positioned parallel to the long axis of the cylinder and then they were immersed into the resin.

After the resin polymerization, the teeth were removed from the resin, and the wax was removed from the roots using a two second-bath in hot water (55 °C) and a scalpel. A polyether was then placed where the roots were before, and the teeth were immersed again into the cylinders in the same position using a polyether (Impregum F, 3M-Espe, Seefeld, Germany). This periodontal ligament simulation was done as described elsewhere (Bortoluzzi, Souza, Reis, Esberard, & Tanomaru-Filho, 2007) using a polyether molding material (Impregum Soft- 3M). After these procedures, the specimens were stored in distilled water.

Figure 3. Periodontal ligament simulation using polyether.



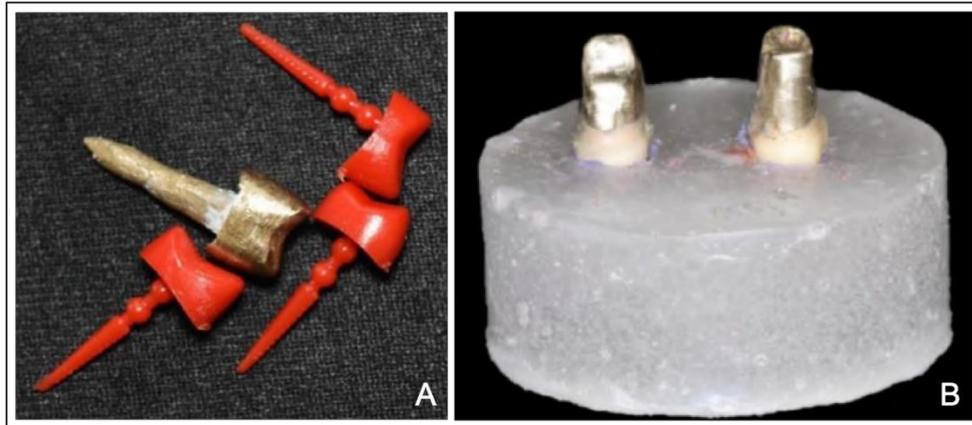
Source: Authors.

2.4 Sample Preparation

The specimens were allocated in two groups according to the type of post and core used: group I (n=15) - partial fixed denture with metallic post and core; and group II (n=15) with glass fiber post and composite resin core.

The metallic posts (group I) were prepared using pre-manufactured polycarbonate standards (Nucleojet, Angelus Science and Technology). The standards were aligned using chemically cured acrylic resin (Duralay; Reliance Dental Mfg Co, Worth, Ill), placed onto the root canal and the tooth's coronary portion. In the sequence, the individual specimens had their coronary height adjusted to 5 mm. The metallic post and cores were fused with CuAl alloy (Duracast ®: (Odonto Comercial – São Paulo – SP) and cemented onto the tooth with resinous cement (RelyX ARC - 3M Espe) into the root canal (Figure 4).

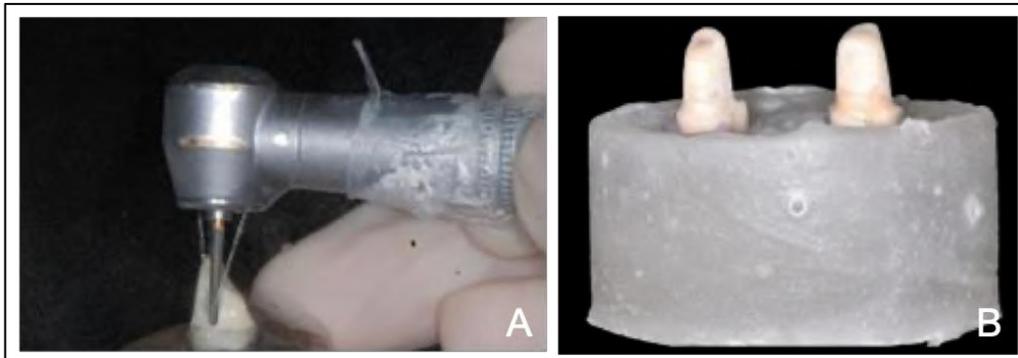
Figure 4. Group I: A) Metallic posts and pre-manufactured polycarbonate standards. B) Metallic post and cores cemented onto the tooth.



Source: Authors.

The glass fiber posts (group II) were prepared using the post system's #2 drill (Whitepost DC). Acid etching was performed on the root canal walls and on the post surface, following the manufacturer's instructions. The glass fiber posts were cemented using resinous cement (Relyx ARC – 3M Espe). The core's coronary portion was made using an acetate membrane (Whiteness – FGM) and composite resin (BisCore – Bispo – Figure 5).

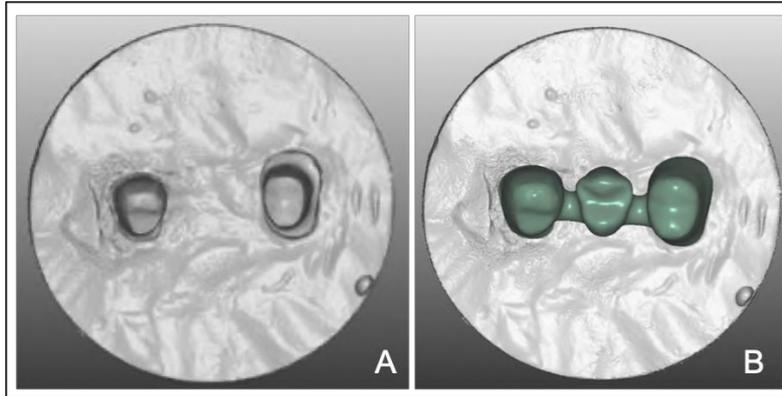
Figure 5. Group II: Coronary portion of the core (using glass fiber posts) being prepared (A) and ready to be analyzed (B).



Source: Authors.

After being polished, the samples of groups I and II were scanned on a CAD/CAM system Scanner s600 arti (Zirkonzahn – Italy) to obtain a digital model (Figure 6). The metallic infrastructure of the tree element prosthesis was obtained in wax (ARTWAX Odontomega – Ribeirão Preto SP), then it was fused in CoCr metallic alloy (Fit Cast Cobalto – Talmax) and cemented on the abutment tooth with resinous cement (Relyx ARC – 3M Espe).

Figure 6. Samples scanned on a CAD/CAM system Scanner to obtain a digital model.

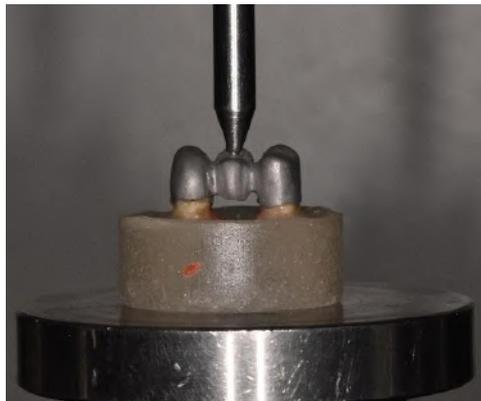


Source: Authors.

2.5 Resistance to Fracture Assay

A hole was made onto the contact region of the vestibular cusp of the first pre-molar of the fixed partial denture to allow the positioning of the universal machine Instron (Model 4511, series H4188 – England). The samples were subjected to a vertical load (1mm/min) until their collapse, registering the maximum fracture force (Figure 7).

Figure 7. Sample subjected to a vertical load to register the maximum fracture force.



Source: Authors.

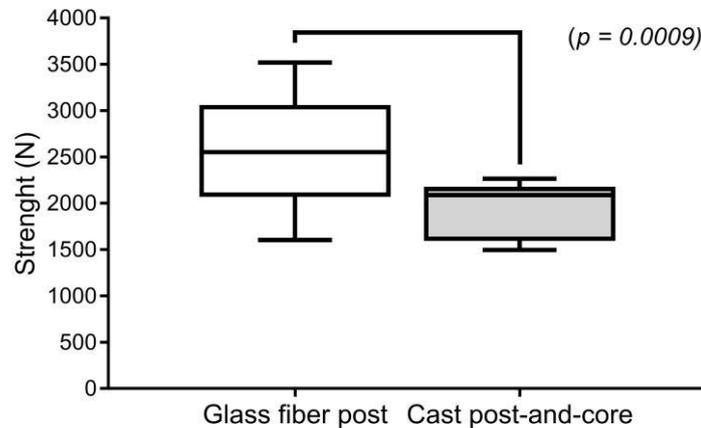
2.6 Data Analysis

The data were analyzed using the GraphPad Prism 7.00 (GraphPad Software, Inc., CA, US). Normal data distribution was verified by D'Agostino & Pearson normality test. Unpaired t test was used for data analysis ($\alpha = 5\%$).

3. Results

The results presented in Figure 8 shows that the average force needed to cause fracture on the GFP group was higher ($p=0.0009$) than the needed to cause fracture on the CPC.

Figure 8. Resistance to fracture (N) of partially fixed denture abutment teeth according to the type of post and core used.



Source: Authors.

4. Discussion

There is no consensus in the literature regarding metallic posts' superiority over glass fiber posts regarding the resistance to fracture (Bolay et al., 2012; Castro et al., 2012; Da Silva et al., 2010; Figueiredo et al., 2015; Heydecke & Peters, 2002; Santos et al., 2010; Zhou & Wang, 2013). Our study evaluated the resistance to fracture of direct and indirect restorative procedures to rehabilitate abutment teeth. The results showed that glass fiber posts associated with composite resin cores presented higher resistance to fracture than metallic posts and cores. Therefore, our null hypothesis was rejected.

Literature (Da Silva et al., 2010; Silva, 2008) shows that GFP performed better in rehabilitation with a three-element partial fixed denture than the metallic ones. Such a result is explained since, in three-element partial fixed dentures in which the abutment teeth are rehabilitated with glass fiber posts, less traction tension remains concentrated on the radicular dentin interface than metallic posts.

Moreover, our results also showed that samples restored with metallic post and core presented a linear behavior, which indicated that the force applied to the abutment teeth caused fatigue on the root, which leads to complete fracture. Such behavior is observed when the abutment tooth presents a rigid restoration with high elastic modulus (Giovani et al., 2009). When such tooth is subjected to a compressive load, the energy is transmitted to the dentin, which presents a lower elastic modulus (Zhou & Wang, 2013), increasing the chances of radicular fracture (Clavijo et al., 2009; Kondoh et al., 2013).

Metallic posts present a satisfactory survival rate. However, fracture in such posts is frequently irreversible, contrary to what is observed for glass fiber posts (Clavijo et al., 2009). The behavior of the graph of the samples restored with glass fiber posts and composite resin cores presents fluctuation, which is explained by the occurrence of slight movements of the post within the root canal. As the post readapts to the root canal, the restoration is maintained, but minor fractures might occur on the interface between the post and the cement (Akman et al., 2012). The glass fiber posts present elastic modulus similar to the dentin, making them capable of absorbing forces concentrated on the root, reducing the chances of fracture (Akman et al., 2012; Naumann et al., 2008). Moreover, even when fiberglass posts fracture, the restoration can still be recovered (Bolay et al., 2012).

The slight movements that fiberglass post suffer within the root canal have the adverse effects of pigmentation of the restoration margin, secondary caries, and cementation failure (Goodacre & Spolnik, 1995). However, such problems can be solved with new cementation, which increases the post and core survival for a longer period (Ferrari et al., 2007).

Partial fixed dentures present a complex biomechanical behavior once such devices are subjected to several masticatory tension forces such as compression, traction, and shear or all of them together (Oh et al., 2002). In our study, a Ni-Cr infrastructure was used to support the three-element partial denture. Such structure presents a high elastic modulus, which increases the risk of stress transference to the restorative treatment, mainly affecting the roots (Arunpraditkul et al., 2009). The inclusion of a ferrule of 1.5 to 2 mm is an essential factor when using intraarticular retainers once such procedures might increase the resistance to fracture (Juloski et al., 2012; Sendhilnathan & Nayar, 2008).

In our study, roots of bovine incisors were used. They were all subjected to endodontic treatment and restorative treatment with posts and cores, reproducing a clinical situation. The use of bovine teeth does not affect the mechanical analyses we performed once it has already been shown that bovine and human teeth present similar histological characteristics (Duarte Santos Lopes et al., 2021). Bovine dentin is frequently used for in vitro tests once it presents a similar configuration and histological composition to the human dentin (Da Silva et al., 2010). Moreover, the bovine teeth are more easily obtained, do not present carious lesions and other defects, and their mineral composition is more homogeneous than human teeth (Duarte Santos Lopes et al., 2021).

Fiberglass post and composite resin core are a reasonable option to rehabilitate partially fixed denture abutment teeth since such material presents elastic modulus similar to dentin (Li et al., 2006). On the other hand, when metallic materials are used, the interface between the post and the cement is the fragility point, once metallic material presents a different elastic modulus than the one of the dentin (Santos et al., 2010). The absence of adhesive union between the metallic post and the root canal increases the interface's tensions, which lead to irreversible fractures (Goracci et al., 2007; Santos et al., 2010).

Finally, we point that our study presents the limitation of all in vitro protocols. Thus, other investigations such as the ones with finite element simulation to evaluate where the tensions are concentrated must be encouraged.

5. Conclusion

We might conclude that the glass fiber post and composite resin core were more resistant to fracture than the metallic post and core. Thus, fiberglass post and composite resin core are reasonable alternatives to restore partially fixed denture abutment teeth.

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