Fracture resistance of endodontically treated teeth reinforced with customized glass and carbon fiber posts

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ABSTRACT

Objective: The aim of this study was to compare the fracture resistance of four types of prefabricated intraradicular posts - glass fiber, glass fiber customized by composite resin, carbon fiber, and customized carbon fiber - on bovine teeth. **Methods:** Sixty bovine teeth were submitted to endodontic treatment and divided into the following groups: GF - glass fiber post; CGF - customized glass fiber post; CF - carbon fiber post; CCF - customized carbon fiber post; control - composite resin restoration. The teeth were embedded in acrylic resin blocks at 2 mm from the cement-enamel junction, simulating the teeth-bone interface. The specimens were submitted to a fracture resistance test in a universal test machine under a 0.5 mm/min load until the fracture of the specimen. The values obtained were submitted to ANOVA and Tukey tests. The analysis of the fracture patterns was performed by the Kruskal-Wallis test. **Results:** The CCF group presented the highest values of fracture resistance, followed by GF, CGF, and CF posts. The control group offered less resistance than the other groups that received intraradicular posts. The CGF presented the highest number of favorable fractures, in contrast to the control group, which presented the highest number of unfavorable fractures. **Conclusion:** The use of customized posts reduced the incidence of catastrophic fractures. The lack of intracanal posts led to a higher incidence of irreparable fractures.

Keywords: Endodontics. Post and Core Technique. Compressive Strength. Tooth Fractures. Dental Restoration, Permanent.

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Introduction

The structural rehabilitations of endodontically treated teeth are indispensable to ensure the long-term success of the coronal restoration. Several researches and published studies have evaluated different materials for restoration of such teeth. The most frequent complications observed during the treatment of root-filled teeth are related mainly to extensive coronal destruction by cavities, fractures, previous restorations, and the endodontic treatment itself. The use of intracanal retainers, such as metallic cores and prefabricated posts, is particularly indicated for teeth with 50% or more structural loss.[1]

These teeth have traditionally been rehabilitated with custom casts or metallic posts and cores. The conventional metal custom post consumes more time, represents an aesthetic challenge, and is highly associated with fracture and failure for its much higher elasticity modulus than that of the dentine.[2,3] Various prefabricated posts have been developed to improve aesthetic results and mechanical performance, such as carbon and glass fiber, quartz, and zirconia posts.[4]

Carbon fiber posts were the first prefabricated non-metallic posts commercially available. These posts present advantages, such as dental biocompatibility and high resistance to corrosion and fracture. Glass fiber posts are highly estimated for their more aesthetic results, as well as their great stress distribution, fracture and corrosion resistance, and biocompatibility.[2,4]

To obtain adequate biomechanical performance of the coronal restoration, the most important factor is the prefabricated posts' retention in the canal.[5] Therefore, post customization has been proposed, which consists in the direct modeling of the canal with composite resin to construct the core over the fiber post, allowing better adaptation to the root canal walls and reducing the cementation line.[6,7,8]

The objective of this study was to compare the in vitro fracture resistance of endodontically treated bovine teeth reconstructed with the aid of different intracanal posts and evaluate the fracture patterns that occurred.

Materials and methods

Sixty recently extracted bovine teeth with similar root anatomy and complete apex formation were selected. Periapical radiographs were taken to confirm the canal anatomy. Teeth that presented any visual or radiographic signs of root resorptions, extensive caries, cracks or deformations were excluded. The teeth crowns were sectioned at 8 mm from the cement-enamel junction (CEJ) and the roots at 12 mm from the same reference, with a rotating diamond disc, standardizing the specimens' total length at 20 mm.

The root canals were prepared by a single trained operator. The pulp tissues were removed, and the canals were irrigated with 1% NaOCl. After the root canals' instrumentation, the apexes were amplified with a carbide bur within 1 mm. The obturation was performed by the lateral condensation technique with gutta-percha cones and endodontic cement (AH Plus, Dentsply Maillefer, Ballaigues, Switzerland).

Five groups divided the specimens, according to the reconstruction protocol proposed, as follows: G1 (GF) - glass fiber post; G2 (CGF) - customized glass fiber post; G3 (CF) - carbon fiber post; G4 (CCF) - customized carbon fiber post; G5 (control) - no intracanal post.

At G5, no posts and flaring were made, only a restoration with composite resin Filtek® Z-350 (3M ESPE, St. Paul, MN, USA). Specimens from G1, G2, G3, and G4 were prepared, removing the gutta-percha with largo n°5 burs until 4 mm from the apex. The posts of G2 and G4 were customized by lubricating and filling the canal with composite resin, then the inserting the fiber post, and light curing for 10 seconds. After the post removal, and light curing for another 40 seconds to complete its polymerization, the full adaptation on the canal walls was checked. No customizations were made in G1 and G3.

All of the canals were etched with 37% phosphoric acid for 15 seconds and then rinsed with distilled water and dried with paper points. An adhesive primer and bonding agent (Adper Scotchbond® Multi-Purpose Plus, 3M ESPE, St. Paul, MN, USA) were applied to the canal and the fiber post and light cured for 20 seconds. The adhesive resin cement, Rely-X ARC (3M ESPE, St. Paul, MN, USA), was dispensed into the canal, and then the post was inserted and light cured for 50 seconds. All specimens were coronally sealed with a temporary filling.

The specimens were stored in distilled water at 37°C for 72 hours and then embedded in acrylic resin blocks 2 mm from the CEJ to simulate the tooth-bone interface. Compression tests at 45° were performed at a speed of 0.5 mm/min, as proposed by Bortoluzzi et al.[9], in a universal test machine (KRATOS, Cotia, SP, Brasil) to obtain the maximum fracture resistance for each specimen. The differences between the groups were verified by the ANOVA and Tukey tests. The fracture pattern was visually evaluated according to the methodology proposed by Heydecke et al.[10] The fractures were analyzed and the following scores were attributed: 1 for fractures above the enamel-cement junction (ECJ); 2 for fractures below the ECJ; and 3 for complete coronal fracture. A score of 1 was classified as reparable, and scores of 2 and 3 irreparable or catastrophic. The Mann-Whitney test was applied to verify differences between the groups. A 5% level of statistical significance was applied to the analyses. The data were submitted to statistical analysis using the BioEstat 5.0 software.

Results

The data were submitted to ANOVA and Tukey tests ($p<0.05$). The mean, standard deviations values of maximum fracture resistance for each group are presented in Table 1. The results showed that the fracture resistance for G4 (CCF) was significantly higher than G5 (control) ($p<0.01$) and G3 (CF) ($p<0.05$). G5 (control) presented a significantly lower fracture resistance when compared to G1 (GF) ($p<0.05$). There was no statistical difference among the other groups.

In the fracture pattern analysis, G1 (GF) and G5 (control) exhibited a significantly higher incidence of catastrophic fracture pattern when compared to G2 (CGF). The incidence of the fracture patterns in each group is displayed in Figure 1.

Table 1. Mean and standard deviation values of fracture resistance (N) analysis.

Groups	G1 (FV)	G2 (FVP)	G3 (FC)	G4 (FCP)	G5 (Control)
Mean±SD	1848,11 ± 380,95^{BC}	1815,12 ± 295,74^{AB}	1778,79 ± 364,76^{AC}	1996,55 ± 476,71^{B}	1606,73 ± 250,17^{A}

ANOVA + Tukey p-value < 0.05. Different capital letters indicate statistically significant differences between the groups.

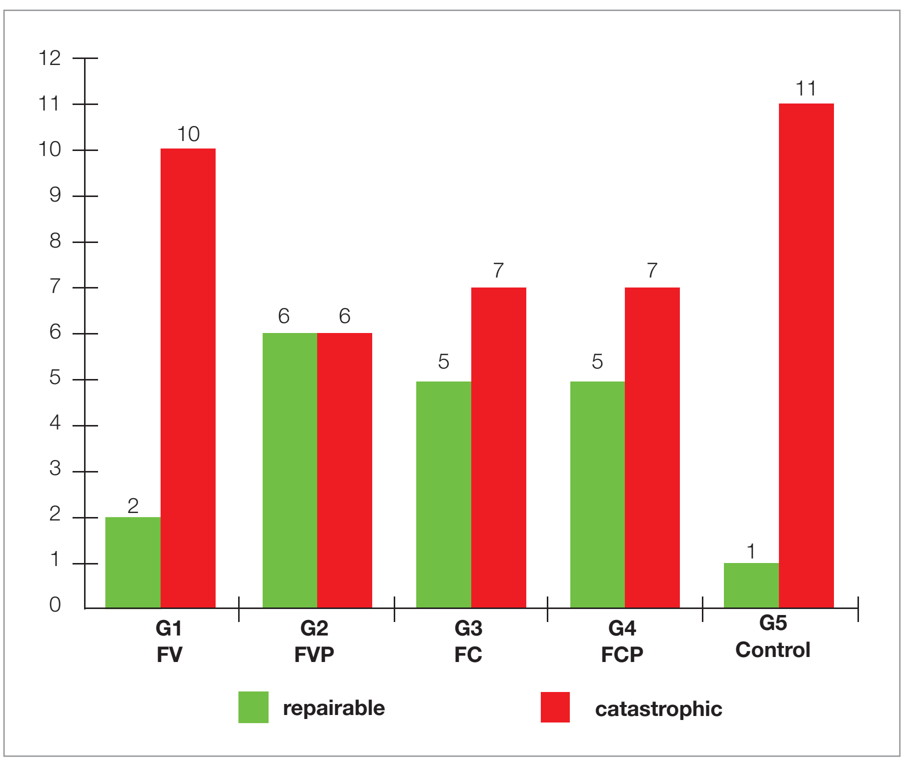

Figure 1. Fracture pattern incidence for each group.

Discussion

It is known that root canal treatment leads to coronary structure loss, which may require an intracanal retainer to support teeth restoration. The longevity of prosthetic rehabilitations of endodontically treated teeth depends on the length, diameter, and design of the post; cementation line; ferrule effect; and amount of remaining tooth structure. Prefabricated posts were developed in the pursuit of more aesthetic and long-term resistant rehabilitations.[11]

This study used bovine teeth, which proved an adequate substitute for human teeth, for different in vitro physical and mechanical analyses.[12] The space of 2 mm between the resin block and the tooth CEJ, used by this study as a method to simulate the clinical interface between teeth and alveolar bone, had no influence on the fracture resistance. This is supported by Komada et al,[13] Ni et al,[14] and Mobilio et al,[15] who demonstrated no difference in fracture resistance values between teeth with different bone levels, varying from 2 to 5 mm.

In this study, the highest fracture resistance was found in G4 (CCF), which was statistically different from G3 (CF). Even though there were no significant differences between G1 (GF) and G2 (CGF), other studies have reported a higher fracture resistance for customized glass fiber posts. According to these studies, the post customization improves the adaptation in the root canal walls, which allows a thinner cementation line, favoring the restoration resistance.[6,7,8,16] Macedo et al.[8] alleged that the post customization increases retention for improving the cement-adhesive contact, not for reducing defects on the cement layer, as suggested before.

G1 (GF) presented higher fracture resistance values than G3 (CF), corroborating with the study of Sharma et al,[3] which obtained superior results for teeth treated with glass and quartz fiber posts compared to carbon fiber posts and the absence of an intracanal post. This can be explained by the biomechanical properties of the posts and dentin. The glass fiber post has a more similar elasticity modulus to dentin than the carbon fiber post, which leads to better stress distribution and preservation of the dentin/post interface, thereby improving fracture resistance. According to Coelho et al,[17] the elasticity modulus is very similar among dentin, glass fiber post, and composite resin, allowing this complex to follow the natural teeth flexural movement, thus reducing the fracture risk.

Higher overall values of fracture resistance were found in this study for all groups compared to the control group, in accordance with Sharma et al,[3] who verified a significantly higher fracture resistance in teeth with intracanal posts, such as carbon, glass, and quartz fiber posts, compared to the absence of posts. Nam et al[18] demonstrated that teeth rehabilitations without posts were submitted to an accentuated stress concentration on the coronal and lingual areas of the CEJ, in contrast with teeth that received intracanal posts.

In the fracture pattern analysis, this study observed a higher incidence of catastrophic pattern for G5 (control) when compared with G2 (CGF), G3 (CF), and G4 (CCF), although a statistical difference was found only for G2 (CGF). The specimens from the control group had a higher stress concentration on the coronal and lingual regions, leading to catastrophic fractures. This is in accordance with Hou et al.[19] in a study with quartz fiber posts, which presented a much more favorable fracture pattern when compared to the group without intracanal posts.

G2 (CGF) presented the best results, with the highest incidence of reparable fracture pattern. The post customization with composite resin and the adhesive cementation technique allows the formation of a single-body complex, which has better stress distribution and reduced risk of catastrophic fracture.[20] Moreover, the reduction of the cementation layer obtained by the post customization reduces the risk of cement defects and adhesion failures, therefore reducing the post displacement inside the canal.[17]

Conclusion

Based on the mechanical test and methodology applied in this study, we concluded that the use of customized posts presented the best results in the incidence reduction of catastrophic fracture patterns. The lack of intracanal posts led to a higher rate of irreparable fractures. The use of customized posts demonstrated superior resistance values, associated with more favorable fracture patterns.

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