

# Influence of post-thickness and material on the fracture strength of teeth with reduced coronal structure

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## Abstract

**Purpose:** To evaluate the fracture strength of endodontically treated teeth with reduced coronal structure reinforced with glass-fiber posts and cast posts and core (nickel–chromium alloy) with different thickness.

**Materials and Methods:** Forty maxillary central incisors were sectioned at 1 mm of the cemento-enamel junction and endodontically treated. The teeth were divided into four groups ( $n = 10$ ) and restored with cast post and core and glass-fiber posts with diameters of 1.5 mm and 1.1 mm. The fracture strength was evaluated using a Universal Testing Machine (Instron 1144) at 45° of angulation. The results were submitted to analysis of variance two-way and Tukey's test ( $P < 0.05$ ). The failure mode was also evaluated.

**Results:** Cast post and core were statistically superior to the glass-fiber posts with the self-post diameter ( $P = 0.001$ ). When the self-post material was considered, no significant difference was observed between the two post-diameters ( $P = 0.749$ ). The glass-fiber post-groups presented more fractures in the cervical third than the cast post and core groups.

**Conclusion:** Teeth restored with cast post and cores present higher fracture strength than those reinforced with glass-fiber posts. An increased post-thickness does not increase the fracture strength. Glass-fiber posts lead to less severe fractures.

**Keywords:** Fracture strength; intracanal posts; root canal

## INTRODUCTION

Intraradicular posts are commonly used to restore endodontically treated teeth when their remaining coronal structure cannot provide adequate support and retention for the restorative material.<sup>[1]</sup> Cast post and core systems were the standard techniques for many years. However, demands for simpler procedures and esthetic restorations led to the development of prefabricated posts, initially made from metal, and, more recently, non-metallic, as the glass-fiber posts.<sup>[2]</sup>

A key element in post-selection is the amount of remaining coronal structure and the incorporation of a ferrule.<sup>[3]</sup> Endodontically treated teeth with moderate to severe coronal tooth loss have demonstrated a success rate of 90.6% after 5 years of service when restored with cast post and cores.<sup>[4]</sup> Previous *in vitro*<sup>[5,6]</sup> and *in vivo* studies<sup>[4]</sup> showed that

non-metallic posts must be used when broad coronal dentin is remaining and the crown is well supported by the remaining tooth structure; otherwise, cast post and core may be used when there is moderate to severe loss of tooth structure.<sup>[7]</sup>

It is difficult to determine how much remaining dentin is acceptable. A systematic review showed that the presence of a ferrule with 1.5-2 mm has a positive effect to ensure a proper resistance form for a tooth,<sup>[2]</sup> prevent fracture of the root and fracture and dislodgement of the post. However, in a study of de Oliveira *et al.*,<sup>[3]</sup> the fracture resistance of teeth with 0 mm, 1 mm, 2 mm or 3 mm of remaining coronal structure reinforced with prefabricated non-metallic posts did not differ among them and to the group with no remaining coronal structure restored with cast post and cores. Contrary to these findings, a study by Pereira *et al.*<sup>[8]</sup> showed that teeth with ferrules of 1-3 mm of length did not differ among them in the fracture resistance

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of endodontically treated teeth restored with fiber post, but they were less resistant than the fiber post-group without remaining coronal structure and the cast post and core group without coronal structure. There is no consensus of how the performance of the non-metallic posts is in relation to traditionally cast post and cores when a reduced remaining coronal structure, such as 1 mm, is present.

Controversies in recommendations of post-diameter are also observed in the literature. Tilk *et al.*<sup>[9]</sup> studied the root widths to determine the best size of dowel. They reported that a 1.10 mm size of dowel is the more appropriated for upper central incisors, being responsible by a proportion of 1/3 of the root. However, in other studies, the best results were observed with less-conservative post-diameters. A study of Kivanç *et al.*<sup>[10]</sup> found that tooth restored with cast posts with an increased diameter (roots with 1.0 mm and 1.5 mm of remaining coronal structure) presented significant higher fracture resistance than posts with less diameter (root walls with 2.0 mm of remaining structure). Also, a finite element analysis demonstrated that when the diameter of the post was 50% of the root, the stress distributions of the post and dentin were most favorable.<sup>[11]</sup>

Based on such considerations, some conditions are still unclear. The aim of this study was to verify the influence of post-material on the fracture resistance when a minimal coronal structure is remaining and to evaluate whether a minimal post-thick, which requires less root preparation, leads to an equivalent fracture resistance compared with a thicker post.

## MATERIALS AND METHODS

Forty sound maxillary central incisors extracted by periodontal reasons were selected for this study. Each tooth was examined under a microscope to ensure the absence of carious lesions, cracks or microfractures. Buccolingual and mesiodistal dimensions were measured with a digital caliper and teeth with mesio-distal width of 5-5.5 mm and bucco-lingual width of 7-8 mm were selected. Tooth crowns were reduced perpendicular to the root axis with double-faced diamonds discs (KG Sorensen, Barueri, SP, Brazil), maintaining 1 mm of coronal remaining structure and leaving a standardized root length of 13 mm ± 1 mm. Each root canal was prepared at 1 mm of the radiographic apex and instrumented up to a file size #35 (Dentsply-Maillefer, Ballaiguess, Switzerland) with a conventional step-back technique. The canals were filled with an ISO 35 primary gutta-percha master cone (Tamari; Tamariman Industrial Ltda.), accessories gutta-percha cones (Tanari; Tanariman Industrial, Ltda.) and eugenol-free sealer (Sealer 26, Dentsply Ind. e Com. Ltda., Petrópolis, RJ, Brazil).

Each root was fixed in cylinders with 20 mm diameter and 20 mm height with acrylic-resin (Clássico Artigos

Odontológicos S.A., Campo Limpo Paulista, SP, Brazil) keeping 2 mm of the cervical root exposed. Previous to acrylic immersion, the root was evolved with a 0.6-mm-thick foil (Adapta foil; BEGO Bremer Goldschlägerei Wilh. Herbst GmbH and Co., Bremen, Germany). The tooth was positioned into the cylinder and the acrylic resin was applied. After the first signals of acrylic polymerization, the tooth was removed along its long axis. The foil was removed and elastomeric material (Flexitime Correct flow, Heraeus Kulzer, Hanau, Germany) was injected into the resin acrylic blocs and the tooth was repositioned, creating a standardized layer that simulates the periodontal ligament (approximately 60 µm).<sup>[12]</sup> The cylinders were numerated and kept in distilled water (37°C).

The teeth were randomly assigned into four experimental groups ( $n = 10$ ) as follows:

- G1: Cast post and core with 1.5 mm of diameter
- G2: Cast post and core with 1.1 mm of diameter
- G3: Glass-fiber post with 1.5 mm of diameter
- G4: Glass-fiber post with 1.1 mm of diameter.

The root canal of each tooth was gradually prepared at 9 mm of the cemento-enamel junction, being that the last bur was the #3 (1.10-mm diameter) for the Groups 2 and 4 and the #5 (1.50 mm diameter) for Groups 1 and 3. Each matrix for the cast post and core groups were standardized using a poly (methylmethacrylate) core-forming matrix and made from prefabricated acrylic pins (Pin Jet-Angelus, Londrina, PR, Brazil) and low-shrinkage acrylic resin (Duralay-Reliance Dental Mfg. Co. Worth-Illinois, USA). They were cast with nickel-chromium (Ni-Cr) alloy (Durabond, Sao Paulo, SP, Brazil), adjusted to its respective tooth and cemented with dual cure resin cement (RelyX ARC; 3M/ESPE, St. Paul, MN, USA) following the manufacturer's instructions. Cement excess was removed and the remainder was light polymerized for 40 s.

The glass-fiber group were reinforced with prefabricated master post (Reforpost; Angelus, Londrina, PR, Brazil), accessories posts (Reforpoin; Angelus, Londrina, PR, Brazil) and composite resin (Z250; 3M/ESPE, St. Paul, MN, USA) core. The master posts were cut previous to the cementation, maintaining 6 mm of height in the core portion and cemented with an adhesive system (Single Bond Dental Adhesive System; 3M/ESPE, St. Paul, MN, USA) and dual-polymerizing resin cement (RelyX ARC; 3M/ESPE) following the manufacturer's instructions. The size and shape used to the composite resin cores were standardized using a poly (methylmethacrylate) core-forming matrix. Cores were fabricated with composite resin (Z250; 3M/ESPE) by incremental technique.

The remaining coronal structures of all specimens were prepared to receive complete crowns (1.5-mm facial reduction with a chamfer finish line and 0.5-mm chamfered

lingual reduction). Thin acrylic-crowns previous obtained from a mold of one coronal structure were relined on the cores, numerated and cast with Ni–Cr alloy. After casting, the metallic crowns were adjusted on the cores and cemented with zinc–phosphate cement (SS-White Artigos dentários Ltda, Rio de Janeiro, RJ, Brazil).

After 24 h, the fracture resistance was evaluated in a Universal Testing Machine (Instron 1144, Instron Corporation, Canton, MA, USA) with load at a 135° angle to the root long axis (45° to the horizontal plane) with a crosshead speed of 0.5 mm/min. In each tooth, the type of failure (tooth or post-failure) and local of fracture (third of the root) was registered as represented in Figure 1. The mode of failure was recorded after the test using an X4 binocular loupe (Bio-Art Equipamentos Odontologicos Ltda, São Carlos, SP, Brazil).

Two-way analysis of variance was used to compare fracture strength means among the four groups. Multiple comparisons by Tukey's test determined which groups were statistically different from the others. The confidence level adopted was 95%.

## RESULTS

Mean values and standard deviations for each group are represented in Table 1. The groups reinforced with cast post and cores showed a statistically significant difference in relation to the glass-fiber reinforced with the self-post-diameter ( $P = 0.001$ ). No significant difference was observed between the two post-diameters with the self-post-material ( $P = 0.749$ ). The interaction between the two factors was demonstrated to be not significant ( $P = 0.177$ ).

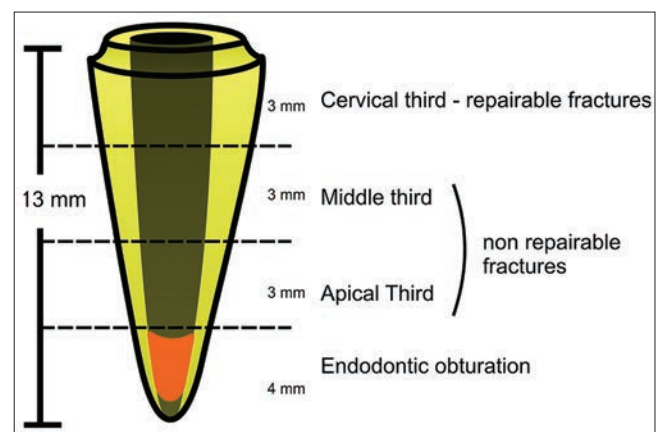
The highest incidence of failures in the cast post and core groups was observed in the middle third of the root. In the fiber post-groups, an equal distribution of the failures was observed in the cervical and middle thirds, being that for G4, 40% of them were in the cervical third. Only cast post and core group presented failures in the apical third. The mode of failure for all groups is described in Table 2.

## DISCUSSION

This study evaluated the resistance to fracture of anterior endodontically treated teeth with few remaining coronal structures (1.0 mm ferule) when reinforced with different posts (cast post and cores or glass-fiber posts) with different diameters (1.0 mm and 1.5 mm). The present results showed that teeth reinforced with cast post and cores present a significantly higher resistance to fracture than teeth restored with glass-fiber posts. It was also previously mentioned that posts with higher elastic modulus as the Ni–Cr alloys have the capacity to allow a high amount of stress concentration previous to bending, and previous to

transmitting stress to the tooth, promoting higher failure resistance.<sup>[1,13-15]</sup> In addition, the juxtaposition of the cast post to the root canals minimizes the cement layer and may contribute to increased fracture strength.<sup>[1,16]</sup> The lower fracture strength of the glass-fiber groups may also be attributed to the displacement of fracture of the resin cement layer, composite core or the post during the mechanical testing.<sup>[17]</sup> The fracture strength of teeth reinforced with glass-fiber posts showed a large standard deviation, which was previously hypothesized to be caused by its lower fracture resistance.<sup>[13]</sup>

A previous report<sup>[18]</sup> evaluated the influence of tooth position along the arch and the gender of healthy subjects (aged 19-29 years) on its maximum bite force. The mean values ( $N$ ) for the central incisors were 146.17 for men and 93.88 for women. The fracture strength values found



**Figure 1:** Schematic illustration of the fracture pattern and reparability of the roots

**Table 1: Mean values ( $N$ ) and standard deviations of resistance to failure**

Post-material	Post-diameter (mm)	
	1.5	1.0
Ni–Cr alloy	803.60±210.20 aA	688.20±162.20 aA
Glass-fiber	469.70±271.70 bA	541.20±208.10 bA

Same uppercase letters on the same row and same lowercase letters in the same column indicate statistical similarity ( $\alpha < 0.05$ ). Analysis of variance of the data revealed a significant influence of the post-material ( $P = 0.001$ ). However, it was not observed significant influence of the post-diameter ( $P = 0.749$ ) and the interaction between the two factors ( $P = 0.177$ )

**Table 2: Mode of failure**

Group	Fracture pattern			
	Cervical third	Middle third	Apical third	Post-fracture*
G1	01	07	02	0
G2	02	06	01	01
G3	05	05	0	0
G4	01	05	0	04

\*All post fractures occurred in the cervical third, G1: Cast post and core with 1.5-mm of diameter, G2: Cast post and core with 1.1-mm of diameter, G3: Glass-fiber post with 1.5-mm of diameter, G4: Glass-fiber post with 1.1-mm of diameter

for the glass-fiber-reinforced groups in our study were higher than those observed, which can suggest that the fiber post-groups can be indicated to clinical use, which was also observed by other authors,<sup>[3]</sup> who affirmed that the results of fracture resistance on endodontically treated teeth restored by cast posts or prefabricated posts found in the literature were clinically acceptable. However, clinical evaluations are still needed to further elucidate this question.

Achieving a post-diameter that is strong to support the occlusal loads and does not interfere with the resistance of the remaining root structure is one of the aims in these rehabilitations. The comparison of different post-thicknesses (1.0 mm and 1.5 mm) showed no statistically significant differences in both materials. This result suggests that when restoring an anterior endodontically treated tooth, the thin post can be indicated. Thus, with a minimum preparation of the root canals, the capacity of reinforcement and the resistance to fracture is maintained. These findings are in agreement with previous studies<sup>[19-21]</sup> that suggested that a smaller post-diameter might be used to avoid excessive wear of the inner root dentin during the post-site preparation once the amount of the remaining dentin wall around the post is directly related to the fracture resistance of the tooth.<sup>[19,21,22]</sup> However, some studies indicated that posts with increased diameters were more resistant to fracture and provided more resistance to the restored teeth,<sup>[10]</sup> and led to less stress distribution to the remaining dentin.<sup>[11]</sup> In spite of these considerations, our study indicates a more conservative root canal preparation, being a 1.10-mm size (1/3 of the root) able to perform proper resistance.<sup>[9]</sup>

The ferrule effect has been considered one of the most important factors for the resistance of endodontically treated teeth. Although it is important, no consensus was established of which ferrule height ensures resistance to the teeth. Despite some studies having shown that a ferrule of 1.5-2 mm<sup>[2]</sup> and 2-3 mm<sup>[23]</sup> has a positive effect, others studies did not find a difference in the resistance of roots reinforced with ferrules of 0-3 mm<sup>[3]</sup> and 1-3 mm,<sup>[8]</sup> which justifies the need for evaluating the influence of the post-thickness and material on the resistance of tooth restored with a few remaining coronal structures.

Teeth restored with cast post and cores showed the majority of fractures in the middle third, and also presented fractures in the apical third. The high elastic modulus of Ni-Cr alloy compared with dentin, and its capability to concentrate stresses in critical areas of root, may be responsible for these catastrophic fractures.<sup>[10,13-15,24,25]</sup> Conversely, glass-fiber posts have a lower elastic modulus, similar to that of dentin, distributing stresses more uniformly along the dentin/post-interface.<sup>[21,24,25]</sup> The bonding between the fiber post and dentin root creates a “monobloc,” which

is another factor that might contribute to a better stress distribution on the tooth.<sup>[11]</sup> These reasons can explain the higher amount of favorable fracture patterns (cervical third) when compared with cast groups. The fracture pattern of the root in this study seemed to have a relation with the post-material but not with its thickness.

Although we observed in this study that a thin post-diameter should be utilized, further observations are necessary such as the ferrule height that provides equal resistance to tooth reinforced to fiber posts and cast post and cores. Still, evaluations of the resistance of these reinforced teeth in relation to intact tooth, evaluations under thermomechanical loads and clinical evaluations can contribute to elucidating these conditions.

## CONCLUSION

Within the limitations of this *in vitro* study, considering the conditions evaluated, it can be concluded that:

- Teeth reinforced with cast post and cores present higher fracture strength than those reinforced with glass-fiber posts
- The mean values of fracture strength of the groups restored with glass-fiber posts were higher than the mean values of bite force in the central incisors observed in the literature
- Increased post-thickness did not lead to an increase in the fracture strength
- The glass-fiber posts led to more favorable failures.

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