Fracture Strength of Endodontically Treated Teeth with Flared Root Canals and Restored with Different Post Systems

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ABSTRACT

Background: Many post systems are available to clinicians, yet no consensus exists about which one is better in restoring endodontically treated teeth.

Purpose: This study evaluated the fracture strength of teeth with flared canals and restored with two fiber-reinforced resin systems (glass fiber: FRC Postec [Ivoclar Vivadent, Schaan, Liechtenstein]; quartz fiber: D.T. Light-Post [Bisco Dental Products, Schaumburg, IL, USA]), and one custom cast base metal (Ni-Cr) post and core system.

Methods: Thirty anterior teeth had their crowns removed below the cemento-enamel junction and were endodontically treated. The canals were prepared for post fixation, and the canal walls were flared using a taper diamond bur. The prepared roots were randomly divided into three groups according to the post system. All posts were cemented with an adhesive resin cement. For the fiber-reinforced resin posts, cores were built up using microhybrid composite. Metallic crowns were luted using zinc phosphate cement. Specimens were loaded at 45 degrees in a universal testing machine at a crosshead speed of 0.5 mm/min until failure. The mode of failure was classified as repairable or nonrepairable.

Results: Teeth restored with cast posts had fracture strength twice that of teeth restored with resin posts. Fiber-reinforced resin posts failed at a compressive force comparable to clinical conditions, but all failures were repairable.

Conclusion: Fracture strength and mode of failure in anterior teeth with flared canals varied according to the type of post used to support a crown.

CLINICAL SIGNIFICANCE

Under the conditions of this study, cast posts are preferable to restore endodontically treated teeth with flared canals and no ferrule.

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INTRODUCTION

Many options are available for the reconstruction of endodontically treated teeth, but clinical decision is complicated when teeth are weakened and the root canals are compromised. This situation occurs with open apices, overprepared teeth for previous post-retained restorations, inadequate post removal, caries, fractures, or internal resorption. These flared root canals with thin dentine walls may require reinforcement and restoration using dentine bonding agents and composite, posts, and cores.[1–3]

The selection of the most adequate post system for each case is influenced by the treatment plan to restore aesthetics and function, remaining tooth structure, post design, and mechanical properties.[4] Endodontically treated teeth have been restored using cast metal posts for decades; however, these conventional posts have biological and mechanical disadvantages, such as high modulus of elasticity, excessive tooth reduction, lack of retention, and root fracture.[1,5,6] Direct post and core restorations with prefabricated fiber-reinforced resin posts became popular because of their lower modulus of elasticity compared with metal posts, decreasing the risk for root fracture.[7] But even when using posts with modulus of elasticity similar to that of dentine, root fracture strength seems to be related to the amount of remaining dentine around the post.[8,9]

Prefabricated posts associated with resin reinforcement of the root dentine walls have been used to increase fracture strength of flared canals.[2,3] Nevertheless, up to date, there is no consensus in the literature about which material and technique are better to restore endodontically treated teeth with enlarged root canals. In vitro and in vivo studies with different post systems have showed variability of fracture strength and mode of failure.[10]

Thus, the purpose of this study was to compare the fracture strength of endodontically treated teeth with flared canals and restored with two prefabricated fiber-reinforced resin systems (one glass fiber-reinforced resin system and one quartz fiber-reinforced resin system) and one custom cast base metal (Ni-Cr) system. The null hypothesis was that the fracture strength of endodontically treated flared single-root teeth does not vary as a function of the post system. After the fracture strength test, the mode of failure was classified as repairable or nonrepairable.

MATERIALS AND METHODS

Human maxillary central incisors and canines that were extracted for therapeutic reasons were donated and used in this experiment according to the study protocol approved by the institutional review board. The teeth were scaled to remove organic debris and stored in physiologic solution at 4°C. Crowns were removed below the cemento-enamel junction to obtain a root length of 17 mm. Inclusion criteria were straight roots with mesial-distal width of 5.0 to 5.5 mm and buccal-lingual width of 7.0 to 8.0 mm. Teeth with large root canals or roots with apex dilacerations, fissures, or surface defects were excluded.

Thirty roots were selected and endodontically treated. After endodontic instrumentation up to file size #40 using files Hedstrom (Moyco Union Broach-Thompson, Montgomeryville, PA, USA) and K-Flexofile (Dentsply, York, PA, USA) and rinsing with 1% sodium hypochlorite, all canals were obturated with gutta-percha (Dentsply, Petropolis, RJ, Brazil) and Sealer 26 cement (Dentsply, Petropolis, RJ, Brazil). Canal entrances were sealed with glass ionomer cement and teeth were stored in a physiologic solution at 4°C. After 48 hours, the gutta-percha was removed using a #2 Peeso reamer (Moyco Union Broach-Thompson) until a depth of 11 mm, leaving 6 mm of canal filling at the apex. For standardization, all root canals were prepared for post placement with a drill from the D.T. Light-Post Kit (#1, 1.5 mm in diameter) (Bisco Dental

Products, Schaumburg, IL, USA). The root canal entrances were enlarged with a taper diamond bur (#3131, KG Sorensen, São Paulo, SP, Brazil), with a length of 4 mm and diameter of 2.5 mm, 2 mm, and 1.8 mm in its cervix, middle, and apex portions, respectively. A schematic representation of the shape of the canal preparation is shown in Figure 1.

The prepared roots were randomly divided into three groups ($N = 10$ per group) according to the experimental treatment (post and core system):

- group A—Quartz fiber-reinforced resin post D.T. Light-Post #1, 1.5 mm in diameter and passive taper shape
- group B—Glass fiber-reinforced resin post FRC Postec (Ivoclar Vivadent, Schaan, Liechtenstein), with the same dimensions and shape of group A
- group C—Cast metal post obtained by direct modeling with a prefabricated acrylic post–core pattern (Pin-Jet, Angelus, Londrina, PR, Brazil), which was adjusted to the prepared root canal with Duralay acrylic resin (Reliance Dental Manufacturing Company, Chicago, IL, USA). The final resin pattern had a intraradicular portion with passive taper, and coronal portion with a standardized height of 6 mm and shape of a canine preparation for a full crown. These resin patterns were cast with the Ni-Cr alloy Wiron 99 (Bego, Bremen, Germany) (Figure 2A).

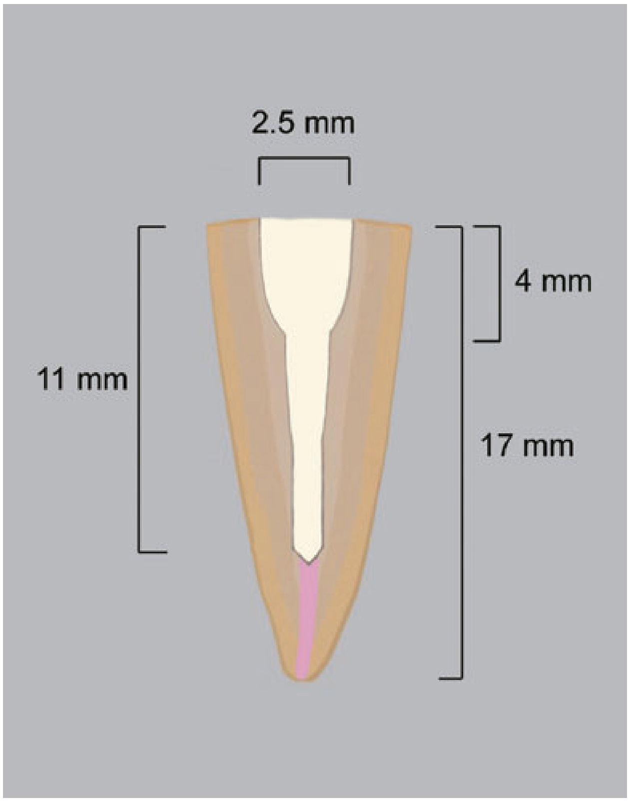

Figure 1. Graphic representation of the shape of tooth preparation.

All posts were cemented with a resin cement (Rely X, 3M/ESPE Dental Products, St. Paul, MN, USA) using one bottle of adhesive (Single Bond, 3M/ESPE Dental Products) and following the manufacturer's directions. In groups A and B, the intraradicular space not occupied by the post was filled with resin cement during post cementation. The fiber-reinforced resin posts were cut, leaving 6 mm above the root canal entrance to retain a composite core. Using one cast post and core from group C, 20 matrices of polyester were fabricated to reproduce its coronal shape using the Adaptus system (Bego). These matrices were filled with microhybrid composite resin (Tetric-Ceram, Ivoclar Vivadent) and used in groups A and B to build up the cores (Figure 2B–D). Polymerization of the resin was performed using the manufacturer's instructions.

To fabricate the full crowns, a pattern with a canine shape was

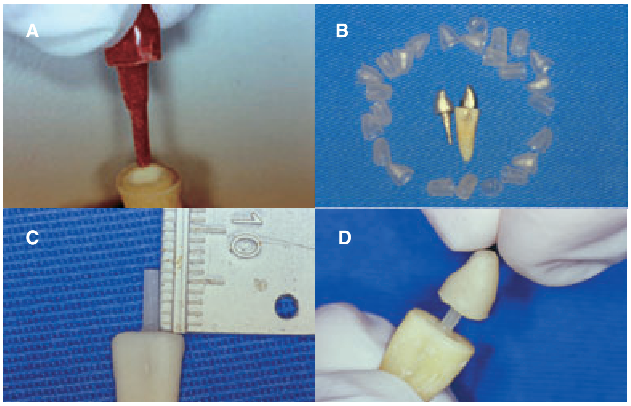

Figure 2. A, Post and core pattern in acrylic resin used to obtain the metallic cast post (group C). B, Metallic cast post and core used for fabrication of polyester matrices. C, Cemented fiber-reinforced resin post. D, Fabrication of the composite core using the polyester matrix (groups A and B).

fabricated with wax over one specimen of group C and cast with a Ni-Cr metallic alloy (Wiron 99, Bego). After finishing, this crown (7 mm in height and 1.5-mm thick) was used as a master crown for the fabrication of matrices of polyester using the Bego Adaptus system. The matrices were filled with fluid Duralay acrylic resin and positioned over the cores in groups A, B, and C, which were previously coated with a disclosure medium. After polymerization, the resin patterns were removed and cast with the same procedures used for the master crown. All metallic crowns were cemented with zinc phosphate cement (SS White, Rio de Janeiro, RJ, Brazil).

To simulate the periodontal ligament, the roots were covered with a uniform layer of wax #7, 2 mm below the cervical margin, and were embedded in metallic cylinders (60 mm in diameter and 20 mm in height) with self-polymerized acrylic resin. The set was immersed in water at 75°C for 1 minute to remove the wax layer, leaving a space between the root and the acrylic resin. A polyether-based impression material (Impregum, ESPE, Seefeld, Germany) was manipulated and coated on the surface of the roots, which were repositioned into the resin cylinders. After polymerization, the excess impression material was removed with a surgical blade at the predetermined limit of 2 mm below the cervical margins (at the surface of the acrylic resin cylinder).

Specimens were submitted to the fracture strength test using a universal testing machine (EMIC DL-2000, EMIC, São José dos Pinhais, PR, Brazil). A compressive load was applied on the lingual surface (2 mm below the incisal edge) at a 45-degree angle and crosshead speed of 0.5 mm/min until a fracture occurred. Fracture strength values were recorded in Newtons (N). Data were analyzed by univariate analysis of variance and Tukey tests for post-hoc pairwise multiple comparisons. A two-tailed 0.05 level of significance was used for rejecting the null hypothesis.

Subsequently, the mode of failure of each specimen was classified as repairable (displacement of crown, cervical fracture or other failure, or fracture that allows tooth/root restoration) or nonrepairable failure (fracture below the cervical third of the root, oblique or vertical root fracture, or horizontal fracture in the middle or apical root third, which condemns tooth to extraction).

RESULTS

Statistics of the fracture strength values (N) of the experimental groups are displayed in Table 1. Mean fracture strength was found to be significantly larger for group C (cast posts) than groups A and B (fiber-reinforced resin systems) ($p < 0.001$). There was no difference in fracture strength values between groups A and B ($p = 0.687$).

Table 2 shows the distribution of mode of failure (repairable or

TABLE 1. FRACTURE STRENGTH (N) OF THE TESTED QUARTZ AND GLASS FIBER-REINFORCED RESIN SYSTEM AND CAST METAL POST GROUPS (*N* = 10/GROUP).

Statistics	Fracture Strength (N)		
	Quartz Fiber-Reinforced Resin Post	Glass Fiber-Reinforced Resin Post	Cast Metal Post
Mean*	108.63A	93.28A	207.65B
Standard deviation	33.94	30.69	54.94
Minimum	60.71	49.06	119.60
Maximum	162.20	136.30	265.30
Coefficient of variation	32.9%	31.2%	26.5%

*Means followed by different letters are statistically different at the 0.05 significance level.

TABLE 2. FREQUENCY OF MODE OF FAILURE AFTER FRACTURE STRENGTH TESTING (*N* = 10/GROUP).

Mode of Failure	Quartz Fiber-Reinforced Resin Post	Glass Fiber-Reinforced Resin Post	Cast Metal Post
Repairable	10	10	3
Nonrepairable	0	0	7
TOTAL	10	10	10

nonrepairable) of the three experimental groups after the mechanical testing. All failures in teeth restored with the fiber-reinforced resin posts were classified as repairable. Seven out of 10 specimens with cast posts had nonrepairable failures.

DISCUSSION

This study showed that the fracture strength and the mode of failure were different in anterior teeth with flared root canals and restored with fiber-reinforced resin systems and cast posts, thus rejecting the null hypothesis. The fracture strength of teeth restored with cast posts was larger than those with glass or quartz fiber-reinforced resin posts, which presented similar behavior. In relation to the mode of failure, most teeth with cast posts had nonrepairable failures, such as oblique or horizontal fractures in the middle third of the root. This type of failure after mechanical testing suggests that cast posts transfer the applied stress to the root, resulting in irreversible fracture.[11,12] A recent retrospective study reported that 13.2% of endodontically treated teeth restored with metal posts had complications, such as root or crown fractures.[13]

Glass and quartz fiber-reinforced resin post groups showed approximately half the fracture strength of teeth restored with cast posts and cores. Ferrario and colleagues[14] reported single-tooth bite forces in healthy young men and women ranging from 75 to 190 N in anterior teeth. The fracture strength values found for the fiber-reinforced resin groups were similar to the maximum bite force in the anterior teeth of women but lower than that of men. This lower fracture strength compared with the values for cast metal posts may be attributed to the displacement or fracture of the resin cement layer, composite core, or resin post during the mechanical testing. All failures in teeth restored with fiber-reinforced resin posts were classified as repairable, without any root fracture even in the cervical third. Other studies also related low levels of stress in teeth with resin posts to retrievable failures, such as rupture of composite cores or teeth.[15,16] One possible explanation is that fiber-reinforced resin posts have a modulus of elasticity similar to that of dentine, which facilitates stress dissipation.[11] For the fiber-reinforced resin post groups, the empty space between the dentine canal walls and the post was wider and filled solely with the resin cement in opposition to the cast posts that were molded to adjust the post shape to the canal walls. Therefore, besides the fact that fiber-reinforced resin posts are less rigid than metallic posts, the thicker resin cement layer for the former should have acted as a stress breaker for the system under compressive loading. This effect was reported for root reinforcement with composite resin, which resulted in the transference of low levels of stress to the cervical region of artificially simulated roots.[3] Conversely, a systematic review found no difference of fracture loads between cast and direct posts and cores,[17] but the root canals were not flared in the selected articles.

This study tested teeth simulating the loss of root canal dentine at the cervical third, which may have contributed to reduced fracture strength of the experimental groups, in comparison with other studies that used cast and prefabricated posts in uniradicular teeth. However, Marchi and colleagues[8] tested several methods of reinforcement for flared roots and also obtained higher values of fracture strength than the values recorded in the present study. In that study the authors used bovine incisors restored with a prefabricated metallic post and no crown. As different methods and materials have been used to test the fracture strength of endodontically treated teeth, direct comparison of results is not always possible. For example, some studies did not simulate the use of full crown or the presence of periodontal ligament, which affect both fracture strength and failure mode. The simulation of periodontal ligament with polyether material has been used in previous studies to allow better distribution of stress from crown to root.[11,16]

This in vitro study has limitations as the tests were carried out in uniradicular teeth, with specific dimensions and post preparation, under a compressive static loading and fixed angulation. Thus, dynamic or fatigue behavior cannot be inferred. Extrapolation of results should be conservative as the tooth preparation simulated a clinical condition where the enlargement of canal walls was limited to the cervical third but no ferrule preparation was possible. Other studies[17,18] showed that a circumferential ferrule preparation increases the fracture strength of teeth with post-retained restorations, but they did not test flared canals. Moreover, the type of luting agent (adhesive resin cement versus zinc phosphate cement) did not affect fracture strength of teeth with cast gold post independently of ferrule,[18] although this factor may be relevant when the cement thickness varies. Further studies are warranted to address these issues as well as the potential use of tapered versus parallel fiber-reinforced resin posts for restoration of enlarged canals. Recent literature reviews sought to create guidelines for the reconstruction of endodontically treated teeth using posts and cores, but they concluded that more evidence from laboratory and clinical studies is needed.[1,4,19]

In conclusion, fracture strength and mode of failure in single-rooted teeth with flared roots varied according to the type of post used to support a full crown. Teeth restored with cast posts had fracture strength twice that of teeth restored with glass or quartz fiber-reinforced resin posts, but most fractures would not allow preservation of the teeth. Roots restored with fiber-reinforced resin post failed at a compressive force comparable to clinical conditions,[14] although root fractures would be repairable. The ultimate clinical decision making should also consider the patient's related variables, such as occlusion, masticatory force, level of alveolar bone attachment, and parafunctional habits, to maximize the long-term prognosis of endodontically treated teeth with flared canals.

DISCLOSURE

The authors do not have any financial interest in the companies whose materials are included in this article.

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