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Original Article

Evaluation of the fracture resistance of root filled thin walled teeth restored with different post systems

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ABSTRACT

Background: Restoration of the teeth with extensive root canals with different post systems is a challenge for clinicians. Evaluation of these systems is important for clinical success. The aim of this study was to compare the fracture resistance and fracture mode of endodontically treated thin-walled teeth which restored with different post systems.

Methods: Eighty extracted and endodontically treated maxillary canines were divided into 4 groups (n = 20) and the thickness of the radicular dentin walls was reduced by using diamond burs. Each root was embedded in an autopolymerizing resin with a 0.25 mm layer of vinyl polysiloxane material to simulate the periodontal ligament. The subgroups were restored with one of the following post systems: only composite resin (Group 1), cast post (Group 2), glass-fiber post (Group 3), and I-TFC post (Group 4). The samples were subjected to a gradually increasing force (0.5 mm/min). The force required to fracture was recorded, and the data were analyzed with ANOVA, Tukey test's and Chi-Square test (p < 0.05).

Results: The highest fracture resistance was recorded for Group 2, followed by the Group 3, Group 4, and Group 1. Differences in the fracture resistance of teeth were significant among the groups (p < 0.05). The fracture resistance of Group 4 was significantly different than the other tested post systems (p < 0.05).

Conclusions: The lowest fracture resistance was recorded for Group 1, but among all post systems, Group 4 had the lowest fracture resistance. The fracture mode of the fiber posts (Radix and I-TFC posts) would permit repair of the tooth.

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At a glance of commentary

Scientific background on the subject

Although treatment options for endodontically treated teeth have been reported in previous studies, the ideal treatment modality for root-filled teeth with extensive root canals is uncertain.

What this study adds to the field

Different post-core systems that used as a treatment modality for teeth with extensive structure loss have advantages and disadvantages in terms of fracture strength and failure modes. Therefore, this study was designed to determine the optimum post-core system for treatment of thin-walled teeth.

Post-and-core systems are frequently used for restoring endodontically treated teeth with extensive structure loss. Endodontically treated teeth exhibit a higher fracture risk than vital teeth and the thickness of the remaining dentin is critical [1] and a thin residual root wall can seriously compromise long-term success [2]. An extreme structural detriment of the root occurs as a result of immature development, dental caries, over-instrumentation, previous restoration with an excessively large dowel and core and internal resorption [3].

Clinically, dental restorations are subjected to repeated tension, compression, and torque forces [4]. The mechanical behavior of endodontically treated teeth is influenced by many factors such as interface characteristics between the post and dentin and the rigidity, and stiffness of the post material. Use of improper posts and post materials may increase the fracture risk of a tooth structure [5,6]. Traditionally, posts are classified as prefabricated (commercially available in different geometries, dimensions, and materials) and custom fabricated (cast post) [6]. Custom fabricated and prefabricated posts were found to be clinically acceptable in order to reinforce weakened endodontically treated teeth [7–9]. Many materials and techniques exist for restoring endodontically treated teeth with extensive root canals, but no consensus exists respecting the best method for endodontically treated teeth which have enlarged root canals [10]. Fiber posts are easily bonded to the dental structure with the use of adhesive systems and resin cement [11], and they have an elastic modulus similar to that of dentin and a more pleasing aesthetic quality than that of metallic posts [12,13]. So, compared to metallic posts, fiberglass and carbon-fiber posts present a more homogeneous stress distribution on teeth and may decrease the incidence of catastrophic root fractures [14]. A number of articles investigated the fracture resistance of different post systems [15–17].

Nowadays, newly developed post systems are available which made from a resin composite-impregnated woven glass fiber. It consists of a fiber post, a second hollow fiber structure, which is called a sleeve, self-resin cement of the system, and a

core material. These posts were cemented with resin composite by direct and direct-indirect techniques. The post length is not standard in this system, but adjustable. There is little information in the literature regarding the newly developed post systems. This study was conducted to compare the fracture resistance and fracture mode of endodontically treated thin-walled teeth which restored with different post systems. The null hypothesis of the study was that different post systems have no effect on the fracture resistance and fracture mode of endodontically treated thin-walled teeth.

Materials and methods

Eighty extracted non-carious, human maxillary canines of similar root lengths and free of cracks and restorations were selected for this study. The study protocol adhered to the general principles of the local ethics committee for in vitro studies, so no separate study number was given to this study. Teeth were kept in 0.1% thymol solution at 4 °C and pH 7 after extraction. Similarly sized and shaped teeth were selected by measuring the buccolingual and mesiodistal widths in millimetres, allowing a maximum deviation of 10% from the determined mean (buccolingual dimension, 8.07 mm; mesiodistal dimension, 5.64 mm). The crowns were separated transversally at the cemento-enamel junction using a diamond double-faced disc (SS WhiteBurs, Lakewood, NJ) with a slow-speed hand-piece and cooled with an air/water spray. Roots were standardized with an approximate 15-mm length. The step-back procedure and size 55 file (FlexR File; Union Broach, York, PA). The working length was determined visually by subtracting 1 mm from the length of a size 15 K-file (Dentsply Maillefer, Ballaigues, Switzerland) at the apical foramen. The root canals were irrigated with 2 mL of 2.5% sodium hypochlorite (NaOCl) between each file size. Canals were dried with absorbent paper points (Dentsply GmbH, Konstanz, Germany) and then obturated with AH Plus sealer (Dentsply GmbH, Konstanz, Germany) and gutta-percha cones (Dentsply GmbH, Konstanz, Germany). Root canals were obturated using a lateral condensation technique and accessory gutta-percha points. Extracoronary excess of gutta-percha was removed using a heated condenser (GuttaCut; VDW, München, Germany). After vertical compaction and placement of



Fig. 1 Teeth with extensive root canal in acrylic block.

Table 1 Overview of the experimental groups.

Groups	Post System	Type of Material	Manufacturer	Composition ^a
Group 1	No Post	Composite Resin (Clearfil Majesty Posterior)	Kuraray Co., Ltd	Silanated glass ceramics Surface treated alumina micro fillers Bisphenol A diglycidylmethacrylate (bis-GMA) Triethyleneglycol dimethacrylate (TEGDMA) Hydrophobic aromatic dimethacrylate DL-Canphorquinone Accelerators Pigments and others
Group 2	Cast Post (Custom-fabricated)	Base Metal Alloy (Biosil-F)	Degudent GmbH	Cobalt (Co), Chromium (Cr), Molybdenum (Mn), Silicon (Si), Manganese (Mn), Carbon (C)
Group 3	Fiber Post (Prefabricated)	Glass-fiber-reinforced epoxy post system (Radix Fiber Post)	Dentsply GmbH	Zirconium-Enriched glass fibers Epoxy resin matrix
Group 4	Fiber Post (Prefabricated)	Glass-fiber-reinforced epoxy post system (I-TFC ipost)	Sun Medical	Optical Fiber Post: Glass fiber Urethane dimethacrylate (UDMA) based matrix resin Optical fiber Sleeve: Glass fiber Urethane dimethacrylate (UDMA) based matrix resin

^a Information as provided by the manufacturers.

provisional restorations (Citodur; Septodont, Switzerland), the roots were stored under conditions of 100% relative humidity and at 37 °C for 24 h. After 24 h, the gutta-percha was removed by using the number 4, 3, and 2 Gates–Glidden drills (Dentsply GmbH, Konstanz, Germany), and the root canal was heated with digital compactors (Dentsply GmbH, Konstanz, Germany), maintaining 4 mm of filling material in the apical third. Post spaces were prepared to a drilling depth of 10 mm from the sectioned surfaces. For all experimental groups, the thickness of the radicular dentin walls were reduced by using diamond burs (#4137; KG Sorensen, São Paulo, SP, Brazil) leaving approximately 2 mm circumferential dentine and cooled under an air/water spray to provide a circumferential space between the post and circumjacent dentin walls (Fig. 1). To simulate the periodontal ligament, the root surface was covered with a silicone impression material, approximately 0.25 mm thick (Speedex; Coltane/Whaledent, Alstatten, Switzerland). Each tooth was then embedded in an auto polymerizing acrylic resin (Shanghai Medical; Shanghai, China) with surveyor (APF450; Amann–Girrbach, Koblach, Austria).

All teeth were divided into 4 experimental groups (Table 1) (n = 20) as follow:

Group 1: Teeth without any post-core; teeth only restored with a composite resin.

Group 2: Teeth restored with a casting post-core.

Group 3: Teeth restored with a glass fiber post and a composite resin core.

Group 4: Teeth restored with the I-TFC (Sun Medical, Shiga, Japan) post system and a composite resin core.

Group 1: Before composite resin restoration, the canals of the flared roots were irrigated with distilled water and dried with absorbent paper points. The root canal and access cavities were sealed with Clearfil SE Bond (Kuraray Co., Ltd, Osaka,

Japan) and filled with composite resin (Clearfil Majesty Posterior, Kuraray Co., Ltd, Osaka, Japan). Then, the specimens were mounted in a surveyor, and a ferrule was prepared. The height of the ferrule was standardized to 2 mm. The height of the composite resin cores was prepared to be 4 mm.

Group 2: Cast posts were fabricated from a base metal alloy (Biosil-F; Degudent GmbH, Hanau, Germany). The core dimensions were kept the same as in Group 1. The posts were cemented with the dual-polymerize adhesive resin cement (Panavia F 2.0; Kuraray Co., Ltd., Osaka, Japan) according to the manufacturer's instructions.

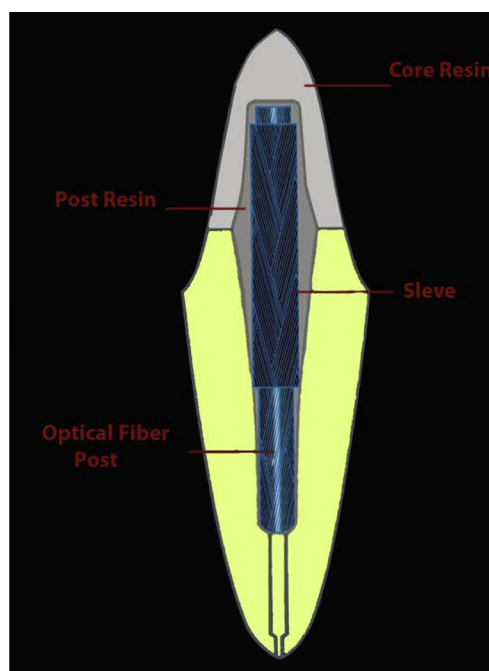


Fig. 2 I-TFC post-system.

Group 3: For an intracanal restoration, the canal space was filled with composite resin (Clearfil Majesty Posterior, Kuraray Co., Ltd, Osaka, Japan). The composite resin was incrementally inserted into the root canal until the canal space was completely filled. In each canal, a fiber post (Radix Fiber Post, Dentsply GmbH, Konstanz, Germany) (diameter, 1.3 mm) coated with a thin layer of petroleum jelly (Vimak Produtos, São Paulo, Brazil) was centrally inserted into the resin mass along the whole post-space extension. After composite resin polymerization, the posts were cemented with the dual-polymerize adhesive resin cement (Panavia F, Kuraray Co., Ltd, Osaka, Japan).

Group 4: The diameter of the posts was 1.3 mm. The canal space was filled with the I-TFC resin cement. According to the manufacturer's instructions, the post attached to the sleeve by cement. Polymerization was carried out after filling the inside of the channel with resin cement. The core structure was completed with the composite resin included with the system.

The specimen, along with an acrylic resin block, was mounted on a special fixture on a computer-controlled Universal Test Machine (Lloyd Instruments, Fareham Hants, England) (Fig. 3). The specimens were loaded with tension at a crosshead speed of 0.5 mm/min until the root fractured. The load was measured in Newtons (N). The force at the time the fracture occurred was measured, and the fracture modes were recorded as restorable or nonrestorable (Fig. 4).

All data were evaluated by Shapiro–Wilk test for normality and the homogeneity of the variances was evaluated with Levene's test. The results of the Shapiro–Wilk test ($p > 0.05$) and the Levene's test for all groups ($p > 0.05$) demonstrated normality and homogeneity of variances. Therefore, the fracture strength of the groups were statistically compared by one-way analysis of variance (ANOVA), complemented by Tukey's test and failure modes of the groups were analyzed by Chi–Square test using a software program (SPSS version 20, IBM Corp.). The level of significance was determined as 5% ($p < 0.05$).

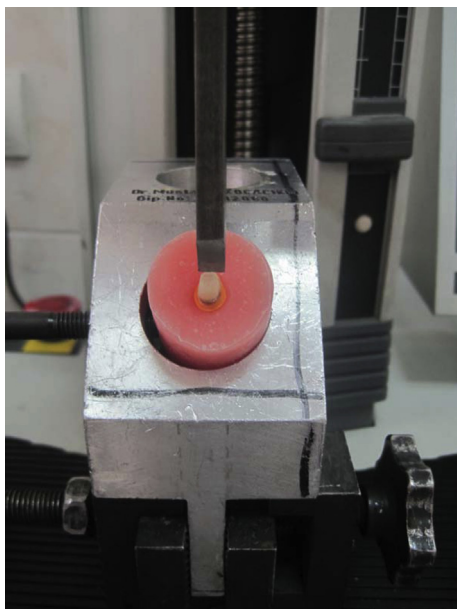


Fig. 3 Specimen on the universal testing machine.

Results

The mean and standard deviation values for fracture resistance (N) are shown in Table 2. Fracture modes are shown in Table 3. A comparative analysis of the fracture resistance values between groups shows statistical significance ($p < 0.05$). The highest fracture resistance was recorded for the Group 2, Group 3, Group 4 and Control Group respectively. Differences in the fracture resistance of teeth were significant among the groups ($p < 0.05$). The statistical analysis for comparing all groups according to the failure mode was performed using the Chi–Square test and was found to be statistically significant ($p < 0.05$).

Among the post systems, the specimens in Group 4 exhibited the lowest mean resistance to fracture. The specimens in Group 2 demonstrated the highest mean resistance to fracture with the highest catastrophic fractures. The fracture mode of the fiber posts (Group 3,4) would permit repair of the tooth.

Discussion

The purpose of this study was to evaluate the fracture resistance of endodontically treated teeth with thin dentine walls, which were restored using 3 different post restorations and a new post system.

The functional restoration of a devitalized tooth is a challenge for a dentist because the forces on the teeth and the adjacent tissue are typically induced by internal stress [5]. In the biomechanical analysis of tooth structures and restorative materials, using disruptive mechanical tests for determining fracture resistance is an important means of analyzing tooth behavior in situations of concentrated and high-intensity load application [8–10].

Using in vitro tests to evaluate the performance of post materials is one way to assess the effectiveness. However, fracture tests have limitations with regard to obtaining information on the internal behavior of the tooth-restoration complex before failure. The test standards and conditions are not identical to the clinical situation; they allow for comparison of different materials within a given standard [4]. So all preparations and restorations were performed by a single clinician for standardization. All roots were filled, and care was taken to create standard cores. The manufacturer's instructions were followed carefully during the fabrication period of the dowels to ensure that the laboratory procedures were the same as those used clinically. Complete crown coverage was not performed and resin cement was used for luting the posts into the canals with the advantage of increasing the load capability [11]. So that in this study dual-polymerize adhesive resin cement was used as a luting agent for the fiber-reinforced posts in all samples.

The cast posts and core are stiffer than that of glass-fiber posts; they can resist higher loads without fracturing and post diameter have a significant effect on the post stiffness, but the effect of post thickness on fracture resistance is not well known [17]. In the present study, it was found that the cast metal post group had significantly higher fracture

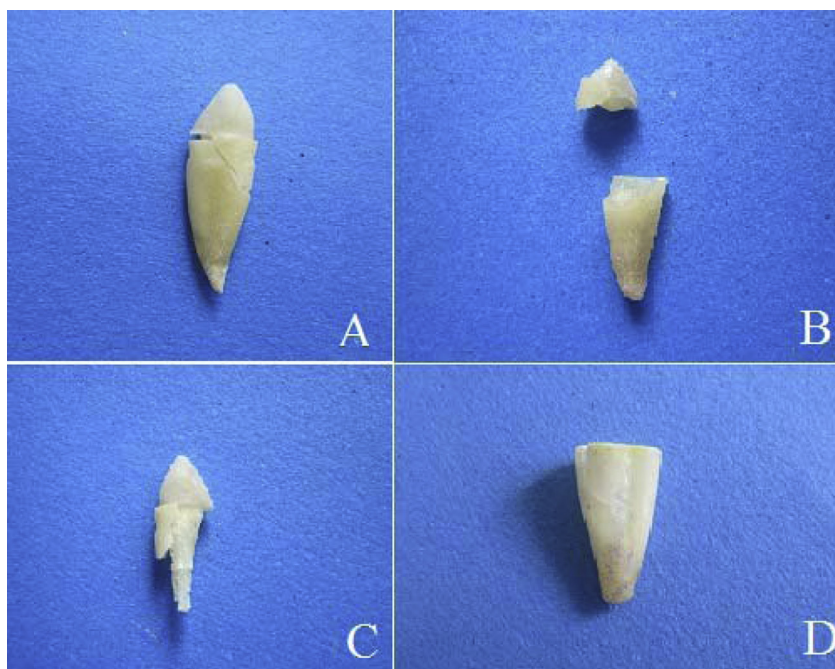


Fig. 4 Fracture modes: A; B; C: Nonrestorable fractures; D: Restorable Fracture.

strength than that of the fiber-post systems. These findings are in agreement with other studies [9,10,13] and may be occurred as a result of the better adaptation of the custom cast cores to the dentin wall. Besides, different from our study, Kivanc et al. [9] reported no significant differences among the different types of fiber-reinforced composite posts, and for different dentine thicknesses. However, roots that thin-walled and restored with conventional cast metal post-cores at the risk of fracture [8]. In a study, Liang et al. reported that placing a thick, intermediate layer of resin-based composite, between the root dentine and a metal post or dowel, may improve the fracture resistance [8]. Contrary to the metal structure of custom cast cores, the composite resin, which was used around the prefabricated posts, might reinforce the weakened and semi-weakened roots [3] and increase their fracture resistance. Additionally, in this study teeth without any post-core system showed the least fracture resistance and this demonstrates the requirement for reinforcing the tooth structure. Otherwise, Marchi et al. [10] also concluded that the thickness of the remaining dentine around the intraradicular wall is the major factor for resistance to root fracture and in the cases of severely weakened roots, with a very thin dentine wall, the use of adhesive restoring materials does not rebuild

the roots with the same levels of fracture resistance that healthy roots have.

In the present study, the cast post-core demonstrated nonrestorable fractures and fiber posts frequently demonstrated restorable fracture modes and differences between the groups were statistically significant. Parallel to our study, Makade et al. [19] and Coelho et al. [14] concluded that cast-post-core restorations caused nonrestorable tooth fracture; however, glass-fiber post restorations enable teeth to be amenable to retreatment in all core fractures. Additionally, similar to our study, Kivanc et al. [9] concluded that thick metal posts with large canals could resist a higher fracture load, but the increased rigidity of the thick metal may cause to catastrophic fractures with overloads.

The material comprising of the post has been shown to affect the stress distribution [5,14]. In the present study, the access cavities were sealed with composite resin in groups 1 and 3. However, in Group 4, the canal spaces were filled with I-TFC resin cement and Group 4 had the least fracture resistance among all the other post systems ($p < 0,05$). Group 4 includes two fiber structures for attaching/connecting and has cement usage which may cause nonhomogenous post

Table 2 Mean and standard deviation values of fracture resistance (N) of the groups.

	n	Mean ± S (N)
Group 1	20	236.077 ± 34.84 ^a
Group 2	20	494.381 ± 49.64 ^d
Group 3	20	466.704 ± 55.03 ^c
Group 4	20	323.500 ± 49.82 ^b

Groups with different superscript letter are significantly different from each other ($p < 0.05$).

Table 3 Fracture mode distributions among the groups.

	Restorable Fracture		Nonrestorable Fracture	
	n	%	n	%
Group 1	4	20,0%	16	80,0% ^a
Group 2	0	0,0%	20	100,0% ^b
Group 3	16	80,0%	4	20,0% ^c
Group 4	12	60,0%	8	40,0% ^d

Groups with different superscript letter are significantly different from each other ($p < 0.05$).

thickness. These situations may cause reducing fracture resistance and stress distribution.

Fiber-reinforced composite posts have elasticity modulus similar to that of dentine and provide homogenous stress distribution so they could be a good alternative treatment modality [16]. Despite higher fracture resistance, cast-post systems may predispose root fractures [18]. For cast systems, insufficient post length causes uneven stress distribution on the tooth structures. Prefabricated posts have different advantages, including better aesthetics, higher biocompatibility, higher corrosion resistance, and easier removal from the root canal [15]. Despite the advancements in the prefabricated systems and the adhesive restorative materials, there is no consensus regarding the best approach for restoring weakened teeth. Furthermore, few laboratory studies evaluating the fracture resistance of root-filled teeth were performed under clinical conditions [10,15]. In addition, filling materials and restoration technique can also influence the fracture mode and resistance of weakened roots. Additional in vitro and in vivo studies are required to demonstrate long-term results regarding different post systems. The clinical significance of these findings remains to be determined.

Conclusion

Teeth without any post-core system showed the least fracture strength ($p < 0,05$) and require to reinforce the roots. Cast metal posts had the highest fracture strength, but all specimens had nonrestorable fractures ($p < 0,05$). Group 4 had the least fracture resistance among all the other post systems, but Group 4 had more advantageous fracture modes than other post systems ($p < 0,05$).

Conflicts of interest

Authors declare that there are no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.bj.2018.12.003>.

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