

Effect of Glass Fiber Post Diameter on Fracture Resistance of Endodontically Treated Teeth

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Abstract

Objective: To determine the fracture resistance of endodontically treated teeth restored with three different diameters of glass fiber posts and metal-ceramic crowns. **Material and Methods:** Thirty human maxillary canines were selected and subjected to root canal therapy. The teeth were randomly divided into three groups of glass fiber posts with 1.4 mm diameter (Group I), 1.6 mm diameter (Group II), and 2.0 mm diameter (Group III). The teeth were restored with metal-ceramic crowns and subjected to the compressive load applied at 45° angle to the longitudinal axis until fracture. The mode of failure was determined. Data were analyzed using ANOVA, followed by Tukey's post hoc multiple comparisons test ($p < 0.05$). **Results:** The mean fracture resistance of groups I, II and III was 574 ± 91.2 N, 617 ± 85.21 N and 467 ± 99.43 N, respectively. No significant difference was noted between groups I and II, while the fracture resistance was significantly different between groups I and III ($p < 0.05$) and groups II and III ($p < 0.05$). No case of post fracture alone occurred in any group. **Conclusion:** The diameter of glass fiber posts can affect the fracture resistance of teeth. Based on the results, increasing the diameter of the post up to 1.6 mm may increase the fracture resistance of root, although excessive diameters are not recommended.

Keywords: Post and Core Technique; Tooth, Nonvital; Flexural Strength.

Introduction

The concept of post and core restoration has changed in recent years. Different intracanal posts are available, each having advantages and disadvantages [1,2]. Pre-fabricated posts are especially popular as they can be placed within one session and they are easy to use and affordable [3]. Use of bonding agents and resin cements along with non-metallic posts such as carbon fiber, quartz fiber and glass fiber posts results in suitable stress distribution and consequently increases the fracture resistance of teeth [4-6].

Fiber-reinforced composite posts have advantages such as a modulus of elasticity similar to that of dentin [7]. Likewise, post diameter is an important factor affecting the biomechanical behavior of the treated teeth [4,8]. However, some contradictory results have been reported regarding the effect of post diameter on fracture resistance of roots [9]. Posts with larger diameters increase the risk of root fracture [4]. On the other hand, most materials used for post-fabrication need to have a certain diameter to exert optimal physical properties and resist fracture under functional and parafunctional loads [4,9].

The three theories for the use of metallic posts include placing the smallest post diameter possible, post diameter being equal or smaller than one-third of the root diameter and ensuring the presence of 1 mm dentin around the post [10]. However, it is not clear whether these theories apply to glass fiber posts or not. Looking for interest in dental research [11-15], the objective of the present study was to assess the effect of the diameter of glass fiber posts on fracture resistance of endodontically treated teeth restored with crowns. The null hypothesis was that the diameter of glass fiber posts does not influence the fracture resistance of endodontically treated teeth with crowns.

Material and Methods

Study Design and Sample

In this *in vitro*, experimental study, 30 freshly extracted single-rooted human canine teeth were selected and inspected to ensure the absence of cracks, caries, root attrition, erosion and previous endodontic treatment [16,17]. The shape and diameter of the teeth were almost similar.

Root Canal Preparation

The teeth were stored in chloramine T solution (Merck Schanhardt, Hohenbraun, Germany) for 2 days for disinfection [18]. Soft tissue residues and debris were removed with hand and ultrasonic scalers and the teeth were stored in saline at 4°C for a maximum of three months [19]. The buccolingual and mesiodistal dimensions of the teeth were measured at three points of 5 mm, 10 mm and 15 mm from the root apex using a digital caliper (Vernier Caliper, Tricle Brand, Shanghais, China) with 0.01 mm accuracy. The teeth were randomly assigned into three groups. At 5 mm distance from the root apex, the mean root diameter was 4.45 mm at the buccolingual and 3.79 mm at the mesiodistal dimension while these values were 6.53 mm and 4.61 mm at 10 mm and 7.73 mm and 6.01 mm at 15 mm from the root apex, respectively.

The teeth were endodontically treated with hand instruments. After access cavity preparation, the canal path was opened using a #15 stainless steel K-file (Mani Inc., Kiyohara Tochigi, Japan). The cleaning and shaping of the canal were performed using the step-back technique to 1 mm from the root apex. A #40 master apical file was used and all canals were instrumented up to #70 K-file [20-22]. The canals were irrigated with 5.25% sodium hypochlorite, and the length was radiographically controlled. The canals were dried with paper points, filled with eugenol-free sealer (AH26; Dentsply, DeTrey, Konstanz, Germany), and filled with gutta-percha points (Gapadent Co. LTD, Tian Jin City, China) using the lateral compaction technique [22].

The coronal portions of the teeth were cut at 17 mm distance from the root apex using a disc and low-speed hand-piece, leaving 2 mm for the ferrule effect, 10 mm for the post length and a final 5 mm for gutta-percha (Figure 1A). All canal orifices were examined to be smaller than their respective posts.

In the first group, the post space was prepared with a special post bur with 1.44 mm diameter (Glass Fiber Conical, Angelus, Brazil) and up to 12 mm length. ED Primer II (Kuraray Medical Inc., Okayama, Japan) was applied into the post space and the coronal dentin was dried with paper point and gentle air-flow for 60 seconds according to the manufacturer's instructions. Panavia F 2.0 dual-core resin cement (Kuraray Medical Inc., Okayama, Japan) was mixed for 20 seconds and directly applied on the post surface. The Exacto N°1 posts were inserted into the canals with finger pressure and light-cured for 40 seconds from the buccal and lingual directions. The polymerization process was completed by applying Oxyguard II on resin cement surfaces.

The cores with 8 mm height were fabricated using Clearfil Photo Core (Kuraray Medical Inc., Okayama, Japan) composite resin using non-anatomical celluloid molds to maintain similar core dimensions (TENA, Aulnay-Sous-Bois, France) (Figure 1B). When the composite was applied into the molds, the complex was light-cured for 40 seconds at both buccal and lingual directions. Subsequently, the teeth were prepared by an expert clinician using a flat-end taper bur and high-speed handpiece under water spray (Figure 1C). In the second group, the same procedures were repeated using a post (Exacto N°2) with 1.6 mm diameter, and a special bur for post space preparation. In the third group, Exacto N°3 post with 2 mm diameter was used.

The roots of each tooth were embedded in auto-polymerizing acrylic resin (Meliodent, #64713278 Heraeus Kulzer, Hanau, Germany), which was extended from the bottom to 3 mm below the preparation margin. The acrylic resin was added around the teeth in multiple stages to overcome polymerization shrinkage and prevent overheating. Impressions were made by polyvinyl siloxane impression material (Zhermack GmbH Deutschland, Marl, Germany) and were poured with gypsum. The metal-ceramic crowns were then fabricated. The crown length was determined to be 10 mm and they were cemented on the respective teeth using Panavia F2.0 resin cement. For testing of fracture resistance in a universal testing machine (Zwick Roell Group, Ulm, Germany), the teeth were placed in a holder (Figure 1D). The load was applied at 45° angle relative to the horizontal axis at a crosshead speed of 1 mm/minute [23]. The load at failure was recorded.

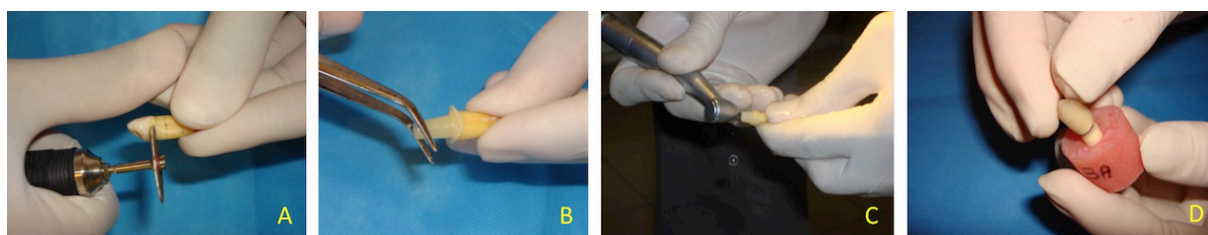


Figure 1. A) Coronal removal at the 17 mm distance from the root end. B) Core fabrication. C) Core preparation. D) Crown cementation.

Data Analysis

The fracture resistance data of the three groups were analyzed using ANOVA ($p < 0.05$) followed by Tukey's post hoc multiple comparisons test. To ensure the accuracy, the mode of failure of the specimens was evaluated under a stereomicroscope (Nikon Inc., Tokyo, Japan) after the fracture (at the core, root or post surfaces).

Ethical Aspects

This research project was approved by the Faculty of Dentistry, Tehran University of Medical Sciences Research center, project number 4752.

Results

The mean fracture resistance was 467 ± 99.42 N for Exacto N°3 posts with 2 mm diameter, 617 ± 85.21 N for Exacto N°2 posts with 1.6 mm diameter and 574 ± 91.2 N for Exacto N°1 posts with 1.4 mm diameter (Figure 2). ANOVA revealed a significant difference in the mean fracture resistance of the groups ($p < 0.05$). According to Tukey's post hoc test, the fracture resistance of Exacto N°1 posts was not significantly different from the mean value obtained for Exacto N°2 posts ($p > 0.05$) while significant differences were found between Exacto N°3 and Exacto N°1 posts ($p < 0.05$) as well as Exacto N°2 and Exacto N°3 posts.

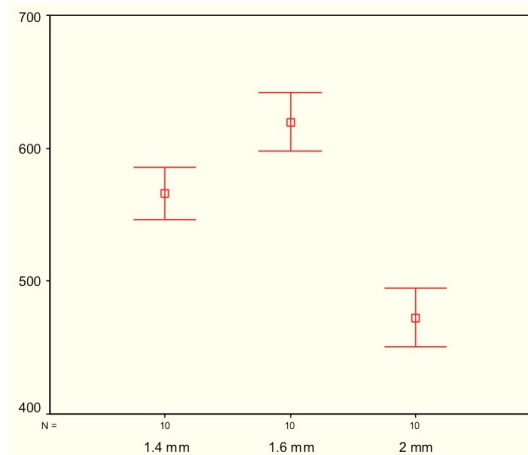


Figure 2. 95% confidence interval of the mean fracture resistance values for the three groups.

Regarding the mode of failure, in Exacto N°1 and Exacto N°2 groups, nine teeth (90%) showed core fracture and one (10%) tooth demonstrated fracture in the root. However, in Exacto N°3 group, four teeth (40%) showed root fracture and six teeth (60%) showed core fracture. In all teeth, the post fractures were observed in the core or the root (Table 1 and Figure 3).

Table 1. Fracture pattern in the root canals with posts of different diameters.

Groups	Post N (%)	Core N (%)	Root N (%)
Exacto N°1	1 (10.0)	9 (90.0)	10 (100.0)
Exacto N°2	1 (10.0)	9 (90.0)	10 (100.0)
Exacto N°3	4 (40.0)	6 (60.0)	10 (100.0)

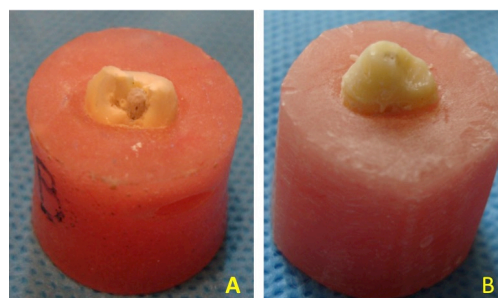


Figure 3. A) Core and post fracture. B) Root and post fracture.

Discussion

This study compared the fracture resistance of endodontically treated teeth restored with posts with three different diameters. The results showed significant differences between group III with groups I and II. Also, a slight insignificant increase was noted with an increase in post diameter from 1.4 mm to 1.6 mm. Therefore, the increase in glass fiber post diameter up to 1.6 was associated with an increase in fracture resistance.

It seems that glass fiber posts distribute the loads more uniformly on the root surface due to having an elasticity coefficient similar to that of dentin well as forming a homogenous structure with the composite core and resin cement [1,4]. However, the remaining dental substrate is a major factor affecting the fracture resistance of endodontically treated teeth [24]. But, some authors have stated that nonmetallic posts create a pressure zone similar to that of natural teeth, and the maximum concentration of pressure has no significant association with post diameter. Moreover, as increased diameter does not weaken the root due to the use of bonding systems, nonmetallic posts with larger diameters are recommended [19,25-27].

Furthermore, some authors recommended using large glass fiber posts to achieve a more stabilized core when restoring teeth with extensive coronal defects and showed that despite the reduced thickness of dentin when inserting larger-diameter posts, fracture resistance had no correlation with the diameter of the fiber post [28]. It was also found that different diameters of glass fiber posts did not affect the distribution of stress around the restored teeth [29].

A previous study analyzed different diameters (1.2, 1.4 and 1.6 mm) of glass fiber posts with a composite core in maxillary central incisors and showed that stress concentration in roots and composite resin cores decreased by use of fiber posts with larger diameters. The authors suggested using composite cores with larger diameters of glass fiber posts in teeth with extensive coronal defects to decrease stress distribution in the remaining root structure [30]. The present study showed higher fracture resistance with a slight increase in post diameter from 1.4 to 1.6 mm, similar to the aforementioned studies.

Some researchers compared the effect of different diameters (#0.5, #2, #3) of quartz fiber posts on fracture resistance of roots and suggested that by increasing the diameter of the post, reduction in wall thickness of root canal would be compensated by the increase in the bonding surface area, and formation of an integrated complex of post and root in crownless teeth [31]. However, in the present study, after increasing the diameter of the post by 2 mm, significant reductions were noted in fracture resistance of restorations. This contrast may arise from the use of different post materials and methodologies. In contrast to our study, previous authors evaluated crownless teeth [31]. Furthermore, the differences observed in fracture resistance of the posts with different diameters or systems can be justified by different elastic moduli of the posts. Using a post with an elastic modulus closer to that of dentin and the core may prevent stress concentration at the post-core-cement interfaces [26,32].

It has been shown that luting-bonding agents can significantly improve the retention of posts inserted into resin core materials [33,34]. Voids at the interface of post and core may result from inadequate condensation of the core material around the post and may negatively affect the integration of post and core and decrease the fracture resistance of the post and core against compressive loads. Thus, resin-luting agents can be applied on the posts before core shaping to improve bonding of the post tip and core [34]. In the present study, all specimens were prepared in this manner.

Masticatory loads are also important in fracture resistance of restored endodontically treated teeth; these loads decrease from the molar area to the incisors region with the mean value of 215 N in a maxillary

canine, which can be increased to 254.8 N in the presence of parafunctional habits [6,35]. It is clear that the mean fracture resistance of all specimens in the present study was significantly higher than the maximum physiologic loads tolerated by teeth in the oral environment. However, fatigue pressure due to constant application of lower forces can cause tooth or restoration fracture.




In the present study, no case of post fracture alone occurred, as shown by previous authors [36]. This finding may be attributed to the use of resin cement, which causes the complex of tooth-core-post to function as an integrated unit. Thus, the fracture resistance of the post increases and the applied forces are well tolerated [36]. On the other hand, only one root fracture was observed in groups I and II, while 4 root fractures occurred in group III, which is probably attributed to root weakening because of using a large post diameter.

The results of in vitro experimental studies must be interpreted with caution as different factors such as the tooth properties prior to extraction, age, pulp status during tooth extraction, root anatomy and dimensions, the load angle and tooth position have significant effects on fracture resistance [24]. Furthermore, in vitro methodologies cannot precisely simulate the oral environment [6].

Conclusion

Within the limitations of this study, increasing the post diameter affects the fracture strength. However, the three groups were within the clinically acceptable range in terms of fracture strength.

Authors' Contributions

SN	 0000-0003-2278-4697	Conceptualization, Methodology, Software, Validation, Formal Analysis, Project Administration and Funding Acquisition.
MSM	 0000-0003-3755-3250	Investigation and Resources.
SN	 0000-0003-3434-1076	Data Curation, Writing – Original Draft Preparation, Writing – Review and Editing, Visualization and Supervision.

All authors declare that they contributed to critical review of intellectual content and approval of the final version to be published.

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Conflict of Interest

The authors declare no conflicts of interest.

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