Original Article

In vitro fracture resistance of zirconia, glass-fiber, and cast metal posts with different lengths

Ashutosh B. Palepwad, Rahul Shyamrao Kulkarni

Department of Prosthodontics, Nair Hospital Dental College, Mumbai, Maharashtra, India

Abstract

Aim: Post-and-core restorations require sufficient length of the post for retention of the prosthesis and root strength. The effect of different lengths of prefabricated zirconia posts (ZPs) on the fracture strength of endodontically treated teeth needs evaluation. Hence, the aim of this study was to evaluate the in vitro fracture resistance of endodontically treated incisors restored with ZP, glass-fiber (GFP), and cast posts (CP) of different lengths.

Settings and Design: Comparative *in-vitro* study.

Materials and Methods: Sixty extracted incisors were endodontically treated, tooth preparations were carried out, and the impression of the coronal portion of each prepared tooth was made using polyvinyl siloxane impression material loaded in copper tubes. The coronal portion of each tooth was removed, maintaining a 2 mm ferrule. The teeth were restored with one of the three posts: CPs, GFP, or ZPs, with intraradicular lengths of either 6 or 8 mm ($n = 10$). The CP and core patterns were fabricated using post space impressions and core buildup and cast using Nickel–Chromium alloy. After composite resin core buildup of GFP and ZPs treated teeth using the previously made copper tube impressions, the teeth were loaded to fracture in an oblique direction in the universal testing machine.

Statistical Analysis Used: Data were analyzed using two-way ANOVA and Tukey–Kramer tests ($\alpha = 0.05$).

Results: The highest and lowest values of fracture resistance were reported with ZP8 and GFP6 groups, respectively. There was no significant difference in fracture resistance between the posts of length 6 mm and 8 mm in CP, GFP, and ZP groups. There was no significant difference ($P = 0.953$) in fracture resistance between CP (284.8 N) and ZP (258.31 N) groups, while the GFP group (160.61 N) had a significantly lower value of fracture resistance than the CP and ZP groups. Two-way ANOVA test for fracture resistance of the post systems and post lengths showed that there was no significant correlation between the post systems and post length on the fracture resistance. There was a greater percentage of favorable fractures in GFP and ZP groups (65% each), than the CP group (20%).

Conclusion: For the post systems tested, extending the post length does not significantly increase the fracture resistance of the restored teeth. The ZP represents a viable alternative to the cast metal post during the esthetic restoration of endodontically treated anterior teeth.

Keywords: Endodontically treated teeth, fracture resistance, post length, root fracture

Address for correspondence: Dr. Rahul Shyamrao Kulkarni, 703 – B, Satsang II Apartments, Poonam Sagar Complex, Mira Road (E), Thane - 401 107, Maharashtra, India. E-mail: drrahulprostho@yahoo.com

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INTRODUCTION

Endodontically treated teeth (ETT) present a high risk of biomechanical failure due to the loss of tooth substance resultant on access opening, caries, and alterations of mechanical, chemical, and physical properties.[1-5] The choice of full coverage restoration for an endodontically treated anterior tooth is guided by strength and esthetics and may necessitate placement of intraradicular posts and core to aid in the retention of artificial crowns.[6-10] Conventionally, metal posts have been used to restore ETT; however, their propensity to affect the final shade of a translucent ceramic crowns may result in inferior esthetics.[11-14] High modulus of elasticity of metallic posts in comparison to dentin and microleakage associated with metallic posts also present a concern, and treatment using cast metallic posts requires more number of visits in comparison to the prefabricated posts. Recently developed prefabricated esthetic posts such as zirconia posts (ZPs) and glass-fiber posts (GFP) present various advantages over the metal posts, such as better esthetics, convenience of use, and biocompatibility.[15,16] The development of zirconia and GFP and effective application of adhesive composite cements may be considered as a step forward in restoring the ETT since clinical and laboratory investigations related to prefabricated zirconia and GFP have yielded promising results.[17-20]

The optimum length of post for restoration of the ETT using a particular type of post remains a controversial topic due to factors such as availability of a wide range of post-core systems, differences in physical properties of posts, and differences in study designs comparing various lengths of posts.[2-9] Analysis of prosthodontic literature reveals various guidelines regarding the optimum length of posts for the restoration of the ETT. While Rosen,[12] Kafalias,[21] and Goldrich[22] proposed that the length of the post should be equal to the length of the clinical crown, Baraban[23] suggested that the dowel should extend up to half of the root length. Weinberg[24] advocated that the post length of two-third of the radicular length is the most favorable for the longevity of post-core treated teeth. A literature review by Goodacre and Spolnik[25] indicates that the post length equal to three-fourth of the root canal length or at least equal to the length of the crown leaving 4 mm of gutta-percha is a commonly followed clinical guideline for post-core restorations. Following Braga *et al.*,[26] if neither goal can be reached, the post must extend at least half of the root length. It should be noted, however, that these recommendations were applicable to metal posts and may not be suitable for adhesively retained esthetic posts such as ZP and GFP.

Despite the availability of a number of studies evaluating the effect of different lengths of posts on fracture resistance of the ETT, authors could not identify a study assessing the effect of different lengths of prefabricated ZPs on the fracture resistance. Hence, this *in vitro* study was conducted to compare the fracture resistance of teeth restored with prefabricated zirconia (ZP; ER CeraPost), glass-fiber (GFP; Hi-Rem Post), and cast posts (CPs) of two different lengths. The null hypothesis was that there would be no difference in the fracture resistance and fracture patterns of the ETT restored with three post systems of two different lengths.

MATERIALS AND METHODS

Sixty freshly extracted central incisors free of caries, cracks, fractures, and restorations were selected for the study. External debris was removed with an ultrasonic scaler, and the teeth were stored in deionized water until testing. The selected teeth had average root lengths of 16.10 mm measured from cementoenamel junction (CEJ) on the facial surface to the apex and mesiodistal widths of 6.8 mm when measured between the proximal surfaces at the CEJ. Access cavities were prepared to obtain a straight-line access and carry out endodontic therapy following conventional step-back technique. After negotiating the canal, the working length was recorded using no. 10 file by inserting it in the canal until it appeared at the apex and subtracting by 1 mm. Each tooth was instrumented at the recorded working length up to no. 50 K-file, along with 5% sodium hypochlorite irrigation. After instrumentation, the root canals were dried using paper points and obturation procedures were accomplished following the lateral condensation technique using gutta-percha points and eugenol free sealer cement (AH plus). Each tooth was prepared to receive a complete veneer crown with a 1.5 mm wide shoulder margin using high-speed rotary instrumentation under copious irrigation. The finish line of each preparation was located at the CEJ. Tooth preparations were made freehand with a subjective convergence angle of 6°–10°. The impression of the coronal portion of each prepared tooth was made using polyvinyl siloxane impression material loaded in copper tubes. These impressions were later used as custom molds for fabrication of the cores. The coronal portion of each tooth was removed, but a 2 mm ferrule was maintained. At this stage, the specimens were randomly divided into three groups (n = 20) according to their composition, namely cast metal (CP), GFP, or ZP. Each group was divided into two subgroups, according to the post length (n = 10), i.e., 6 mm or 8 mm.

For fabrication of the CP group specimens [Figure 1], the root canals were prepared by 1.6 mm diameter post drill for the 6 mm and 8 mm groups. Preformed plastic post pattern and pattern resin were used to obtain post space impression. The core buildup was done using pattern resin and custom made molds. The completed resin patterns were sprued and invested in phosphate-bonded investment material and cast using nickel–chromium alloy. The CPs and cores were refined, finished, air-abraded with 50 μm aluminum oxide, and cemented into the prepared canals. CPs were cemented with a dual-polymerizing resin cement (LuxaCore Z). The root canal and root face were etched with 37% phosphoric acid for 30 s and irrigated with water. Canals were dried with an air syringe and paper points but left moist and were bonded with a dentin bonding system with a microbrush according to the manufacturer's instructions. The excess bonding agent was absorbed with paper points. The resin cement was mixed according to the manufacturer's instructions and applied into the canal with a lentulo-spiral drill and a low-speed contra-angle handpiece. The cement was applied to the post, and the post was slowly seated by finger pressure. During cementation, hydraulic back pressure was allowed to release and the post was gently seated. Finger pressure was maintained till the cement set, excess cement was removed, and each specimen was cleaned with moist cotton roll. In Group 2 (GFP; Hi-Rem post), the root canals were prepared with no. 2 prefabricated post drills provided by the manufacturer. The conditioning of root canals and post cementation was carried out as previously described. Three millimeter length of the post was left above the canal orifice for core construction, in both 6 mm and 8 mm subgroups. Excess filled composite cement was removed with a disposable brush and the resin was light cured. The cores were restored with Luxacore-Z core material using custom-made molds by adjusting them on the post end at the center and injecting the core material from the opening at the top of the mold. Composite was cured for 20 s from the occlusal surface and allowed to set for 5 min to auto polymerize. The molds were removed from the tooth and additional curing of 20 s was carried out from the buccal and lingual sides of the core. The cores were finished using medium and fine grit diamond burs to the height to 3 mm from the CEJ. To obtain specimens in Group 3 (ZP; ER CeraPost), a similar protocol to that of fabricating Group 2 specimens was followed, with the exception that the ZPs were used in place of GFP. The root surfaces were dipped in molten wax and removed to create a thin layer of wax 2 mm below the CEJ similar to the periodontal ligament. Clear autopolymerizing PMMA resin was poured in polyvinyl chloride (PVC) tubes with a 20 mm internal diameter and 25 mm height. Teeth were mounted in the tubes containing the resin and removed when the first signs of polymerization were observed. Clear acrylic resin cylinders were retrieved from PVC tubes after polymerization of the resin. Wax was removed from the root surfaces and alveoli of the acrylic resin cylinders. Light-body polyvinyl siloxane impression material was injected into the acrylic resin alveoli, and the teeth were reinserted into the respective resin cylinders. Excess silicone material was removed with a scalpel blade to provide a flat surface 2 mm below the facial CEJ of each tooth. The specimens were tested using a universal testing machine (Instron), at a crosshead speed of 0.5 mm/min, at an angle 130° to the long axes of the roots [Figure 2]. The teeth were loaded in an oblique direction to simulate forces of mastication.[5,9] Failure threshold was defined as the point at which a specimen could no longer withstand increasing load and fracture of the post-core complex or root occurred.

RESULTS

The mean fracture loads after static loading are presented in Table 1. The highest and lowest values of fracture resistance were reported with ZP8 and GFP6 groups, respectively [Figure 3]. One-way ANOVA test within CP, ZP, and GFP groups showed that there was no significant difference in fracture resistance between the posts of length 6 mm and 8 mm in each group. Two-way

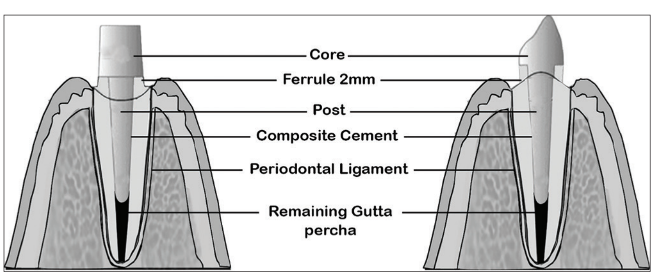

Figure 1: Representative diagram of the specimen tested in the study

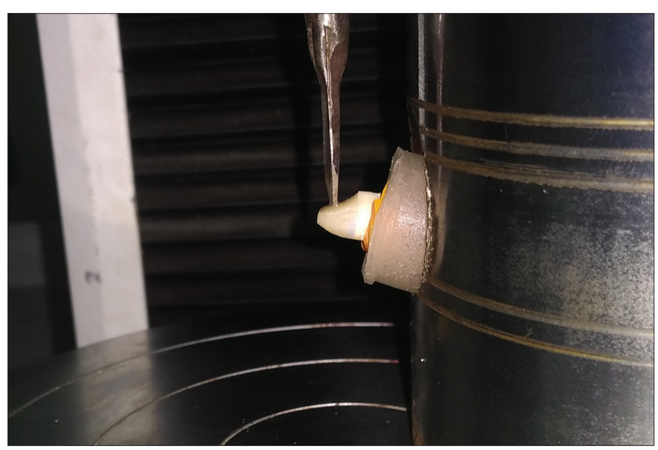

Figure 2: Specimen in the Instron machine

ANOVA and Tukey–Kramer test between CP, ZP, and GFP groups indicated that there was no significant difference (P = 0.953) in fracture resistance between CP (284.8 N) and ZP (258.31 N) groups, while GFP group (160.61 N) had a significantly lower value of fracture resistance than the CP and ZP groups. Two-way ANOVA test for fracture resistance of the post systems and post lengths showed that there was no significant correlation between the post systems and post length on the fracture resistance [Table 2]. The fracture patterns of the specimens are presented in Table 3. It can be observed that there was a greater percentage of favorable (cervical) fractures in GFP and ZP groups (65% each) than the CP group (20%).

DISCUSSION

Research indicates that the fracture susceptibility of teeth restored with posts is related to factors such as the amount of remaining healthy tooth structure, amount and location of dentin walls, presence of the ferrule, and characteristics of the post such as the modulus of elasticity and diameter and length of the post.[27-34] The amount of tooth structure that remains after post space preparation correlates with the length and diameter of the posts. A deeper post-space preparation and use of long posts may jeopardize the root by removal of healthy dentin and decrease the resistance to root fracture.[8] Further, with the deeper insertion of posts, it becomes more difficult to obtain a reliable bond with the luting agent due to a reduction in a number of dentinal tubules in the apical part of the root and limited cleansing of canal walls.[7,8] The anatomical complexity of the apical part of the root and presence of accessory and lateral canals may increase the risk of apical pathosis resulting from long length posts.[5,9] Based on these considerations, the present study was conducted to compare the fracture resistance of teeth restored with prefabricated ZP, GFP, and CP of 6 and 8 mm lengths. The results of the current study support rejection of the null hypothesis that there would be no difference in the fracture resistance and fracture patterns of the ETT restored with three post systems of two different lengths.

The GFP6 group exhibited the lowest value of fracture resistance among all the groups tested (143.03 ± 49.17N), a finding similar with the study of Giovani *et al.*,[5] who observed the lowest value of fracture resistance with 6 mm GFP in comparison to CP and GFP of 6, 8, and 10 mm lengths. Similar results were found in the previous studies.[1,5,6,26] This implies that short GFPs may not be able to provide adequate retention and strength, given that the maximum bite force in the anterior region ranges from 108 N (females) to 176 N (males).[32] Hence, authors recommend that a minimum post length of 8 mm, or at least half of the root length, should be maintained when the GFP is used.

There was no significant difference in fracture resistance between the posts of length 6 mm and 8 mm in each group. This indicates that increasing the length of the post does not provide additional resistance to fracture. Similar findings were observed in independent studies conducted by Schiavetti *et al.*,[10] Mobilio *et al.*,[7] do Valle *et al.*,[33] and Santos-Filho *et al.*[9] The 6 mm and 8 mm posts used in this study correspond, respectively, to 37.5% and 50.0% of the

Table 1: Mean failure loads

Postsystem	Mean failure loads (±SD)		Mean
	6 mm	8 mm	
CP	269.02±88.22 (N)[a]	299.15±92.13 (N)[a]	284.8 (N)
GFP	143.03±49.17 (N)[b]	178.18±56 (N)[bc]	160.61 (N)
ZP	216.91±66.43 (N)[ac]	299.70±113.95 (N)[a]	258.31 (N)

[a,b,c]Statistically similar values. CP: Cast posts, GFP: Glass-fiber posts, ZP: Zirconia post

Table 2: Two-way ANOVA of fracture strength values

Source of variation	df	Sum of square	Mean square	F	P
Postmaterial	2	169,704.775	84,852.387	12.977	<0.001
Postlengths	1	36,543.182	36,543.182	5.589	0.022
Material × length	2	8446.794	4223.397	0.646	0.528
Error	54	353,100.735	6538.902		
Total	59	567,795.486			

Table 3: Root fracture patterns

Place of fracture	Posttype (n=20)					
	CP		GFP		ZP	
	Postlength (n=10)					
	6 mm	8 mm	6 mm	8 mm	6 mm	8 mm
Cervical	2	2	6	7	6	7
Middle	1	0	4	2	3	2
Apical	7	8	0	1	1	1

CPs: Cast posts, GFP: Glass-fiber posts, ZP: Zirconia post

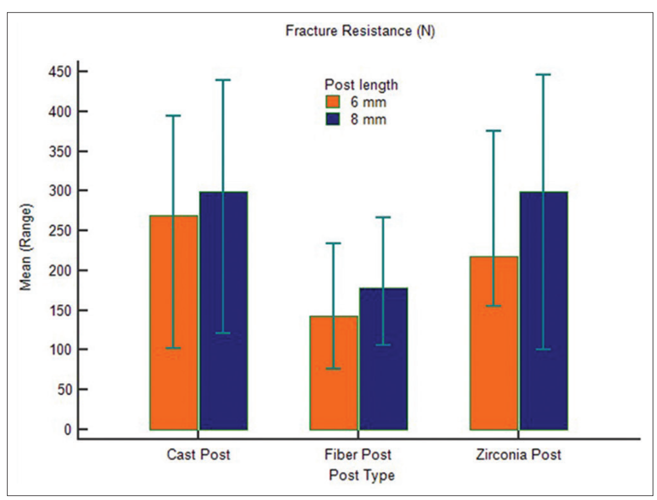

Figure 3: Mean fracture loads and standard deviations (N) after static loading of specimens

radicular length of 16.10 mm. These lengths, approximately between one-third to one half of the root length, may be recommended for CPs, ZPs, and 8 mm GFP. There was no significant difference ($P = 0.953$) in fracture resistance between CP (284.8 N) and ZP (258.31 N) groups, which indicates that ZP may be considered as viable alternatives for esthetic restoration of ETT with high esthetic demands, without compromise in fracture strength. The fracture patterns of the specimens are exhibited in Table 2. It was observed that the apical and middle third fractures predominated in comparison to cervical fractures in the CP group, while there was a greater incidence of cervical fractures in ZP and GFP groups.

Various studies have included numerical models independently or along with laboratory testing of post-and-core restorations using different types and lengths of posts. Similarly, future investigations evaluating the effect of different lengths of ZP may be accompanied by finite element analysis. Besides, the effect of different lengths of copy milled ZPs[17] on fracture resistance of ETT needs to be evaluated. Some limitations must be considered related to this study, such as an in vitro study may not exactly replicate the clinical situation, use of natural teeth may cause slight variations in specimen dimensions, cement pressure was not standardized as only finger pressure was used, and cyclic loading[35] was not applied. Controlled clinical trials may be conducted to evaluate the fracture resistance and longevity of ZPs in the oral environment.

CONCLUSIONS

Within the limitations of this study, the following conclusions were drawn:

1. There was no significant difference in fracture resistance of teeth restored with CPs and ZPs, while the teeth restored with prefabricated GFP had significantly lower fracture resistance as compared to cast and ZPs
2. While using CPs and ZPs, a minimum post length of one-third to half of the root length can be recommended for the restoration of the ETT. When the use of GFP is planned, a minimum post length of half of the root length is recommended
3. Zirconia and GFP groups had a greater percentage of favorable fractures than the CP group
4. ZPs can be recommended as a substitute for the CPs during the esthetic restoration of endodontically treated anterior teeth.

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Conflicts of interest

There are no conflicts of interest.

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