ORIGINAL RESEARCH

A Comparative Analysis of Fracture Resistance and Mode of Failure of Endodontically Treated Teeth Restored Using Different Fiber Posts: An *In Vitro* Study

Prerak Doshi[1], Aruna Kanaparthy[2], Rosaiah Kanaparthy[3], Disha S Parikh[4]

Abstract

Aim: To evaluate the fracture resistance under static loading of endodontically treated teeth (maxillary central incisors) restored with carbon fiber posts, glass fiber posts, and everStick posts. The objectives of this study were to check the fracture resistance of the everStick post and compare it with glass fiber posts and carbon fiber posts and evaluated their modes of failure.

Materials and methods: An estimated 80 freshly extracted human maxillary central incisors were collected for this study. The coronal portions of 60 teeth were sectioned 4 mm incisal to the cemento-enamel junction (CEJ) and 20 teeth were left intact to be used as controls. All the samples were embedded vertically in acrylic resin blocks and the groups were divided as follows. I—control group, II—carbon fiber group, III—glass fiber group, and IV—everStick (E-glass) group. Root canal treatment was completed in all the 80 teeth of 4 groups. Control group teeth were restored with a composite. In all other teeth, post and core placement was carried out. All specimens were mounted on a test block and subjected to static loading until fracture and the mode of fracture was recorded. Statistical analysis was carried out using ANOVA to calculate the mean values of all groups. An intergroup comparison was carried out using Tukey's *post hoc* test.

Results: The study showed that group I showed the highest fracture resistance followed by group IV, which is everStick post group under static loading. There was a significant difference among test groups. The main mode of fracture was repairable as there was debonding of the core in all the fiber posts.

Conclusion: Teeth of the control group showed highest fracture resistance and teeth restored with everStick posts showed higher fracture resistance than those restored with glass fiber or carbon fiber posts under static loading ($p < 0.05$). The principal mode of fracture was debonding of core and remaining root. Teeth restored without application of a post showed the highest fracture resistance than all other groups.

Clinical significance: EverStick/E-glass fiber posts showed significantly higher fracture resistance than the other fiber posts and can be suggested for clinical use.

Keywords: Carbon fiber, Fracture resistance, Glass fiber post, Post and core, Static loading.

The Journal of Contemporary Dental Practice (2019): 10.5005/jp-journals-10024-2668

Introduction

Teeth requiring endodontic treatment are weak as they show extensive loss of the tooth structure owing to caries, repetitive restorations, and/or fracture; such teeth are further weakened by endodontic procedures. Endodontically treated teeth (ETT) are hollow cylinders; their strength and bending fracture resistance is proportional to the difference between their outer and inner diameters. The resultant loss of structural integrity necessitates special considerations such as adequate resistance and retention features, which may be collectively termed as anchorage. The most accepted method of providing coronal and radicular reinforcement to grossly destructed teeth is the placement of posts in root canals. A post's primary purpose is to retain the final restoration and distribute occlusal stresses along the tooth structure, and multiple factors such as post length, diameter, remaining dentin thickness, and post adaptation determine its effectiveness.[1,2]

Earlier cast posts were most commonly used, but because of the disadvantages associated with them such as high cost, higher removal of dentin, loss of retention of the post or the crown; potential for root fractures with resultant catastrophic failures and the risk of corrosion, prefabricated metal posts have been developed, which are available in various designs and tapers and have the advantage of being directly placed into the prepared canal.[3] A desirable quality of posts is its elasticity, which should be similar to dentin to reduce stress concentration at the dentin–post interface so that forces are more evenly transferred to the root, and the incidence of root fracture decreases. Therefore, various types of fiber posts have been developed such as carbon fiber posts, glass fiber posts, and everStick posts. All available fiber-based posts are basically composite materials composed of fibers of carbon or silica surrounded by a matrix of polymer resin, usually an epoxy resin. Different fiber types such as glass fibers, carbon fibers, Kevlar

[1,2]Department of Conservative Dentistry and Endodontics, College of Dental Sciences and Hospital, Amargadh, Bhavnagar, Gujarat, India

[3]Department of Periodontology and Implantology, College of Dental Sciences and Hospital, Amargadh, Bhavnagar, Gujarat, India

[4]Department of Oral Surgery, College of Dental Sciences and Hospital, Amargadh, Bhavnagar, Gujarat, India

Corresponding Author: Prerak Doshi, Department of Conservative Dentistry and Endodontics, College of Dental Sciences and Hospital, Amargadh, Bhavnagar, Gujarat, India, Phone: +91 9705031428, e-mail: Prerakdoshi25@gmail.com

How to cite this article: Doshi P, Kanaparthy A, Kanaparthy R, *et al.* A Comparative Analysis of Fracture Resistance and Mode of Failure of Endodontically Treated Teeth Restored Using Different Fiber Posts: An *In Vitro* Study. J Contemp Dent Pract 2019;20(10):1195–1199.

Source of support: Nil

Conflict of interest: None

fibers, vectran fibers, and polyethylene fibers have been added to composite materials. A wide variety of postdesigns are available and include parallel-sided, tapered, smooth and serrated forms. The mechanical properties of fiber posts depend on the type of fibers, the type of matrix, the fiber content, and the direction of the fibers. The fibers contribute stiffness and strength to the usually elastic resin matrix.[4,5] To sum up, fiber posts are provided with a micro-retentive surface so that the bonding is more efficient; they require minimum tooth preparation and are esthetic, sufficiently radiopaque, and exhibits good fatigue resistance and can flex slightly.[6]

The carbon-fiber-prefabricated post, introduced in the early 1990s, is composed of longitudinally aligned carbon fibers embedded in an epoxy resin matrix. The disadvantages of this type of post are that it has no radiopacity and is black in color, leading to the development of esthetic silica fiber posts. Glass-fiber-reinforced posts have less stiff fibers than carbon fiber posts. They are therefore more flexible than both metal and carbon-fiber posts. They have flexural strength more close to the dentin than carbon fiber posts and may be made up of quartz or silica fibers.[3] The E-glass fiber or everStick post is a resin-impregnated un-polymerized glass fiber structure and appears to be superior to the glass and carbon fiber posts in terms of tooth preparation, bonding ability, flexibility, flexural strength, and esthetics.[8] Hence, the objective of this study was to compare the fracture resistance of this E-glass fiber post system with glass fiber posts and carbon fiber posts and to check their modes of failures.

Materials and Methods

Source of Data

For this study, 80 freshly extracted human maxillary central incisors (extracted for periodontal reasons) with completely formed apices, similar root diameter, absence of caries, and visible fracture lines or cracks were collected from the department of oral and maxillofacial surgery, College of Dental Sciences and Hospital, Bhavnagar.

Sample Processing and Storage

The teeth were rinsed under tap water in order to remove blood and tissue debris. Soft tissue tags, bone, or calculus was removed with the help of an ultrasonic scaler. The selected teeth were disinfected in 0.2% thymol solution and stored in normal saline at 37°C and were placed in a humidor until they were required for the study.

Preparation of Samples

The teeth were divided into four groups as follows. Group I (control group)—teeth with intact coronal tooth structures that were subjected to root canal treatment and post endodontic composite restorations as intact crowns do not require posts.

Groups II to IV

All the 60 incisors were sectioned perpendicular to the long axis, 4 mm incisal to the cement-enamel junction to simulate the loss of coronal tooth structure, which necessitates the use of a post and core.

The following post placements were carried out: II—carbon fiber group, III—glass fiber group, IV—everStick post group. Mounting the specimen: an aluminum foil was covered on root surfaces within 1 mm of the CEJ and the samples were embedded vertically in acrylic resin blocks. After resin polymerization, the teeth were removed from the blocks and the foil was removed from the root surface, creating a space in the resin blocks. Polyvinyl siloxane impression material (Impregum F, 3M/ESPE, Europe) was mixed and placed in the space created in the resin blocks to simulate the effect of the periodontal ligament. The teeth were reinserted into the cylinders and the excess material removed with a scalpel blade. The sectioned surfaces of the specimens were hand polished with a fine (400-grit) silicon carbide abrasive paper to adjust the height of the remaining root. Root canal treatment was carried out as follows:

In all the 80 teeth, root canals were accessed and working length determined. The canals were cleaned and shaped using a step-back technique and irrigated using 27-gauge Endo-Eze irrigator tips (Ultradent Products Inc, South Jordan, UT). The irrigants used were 3% sodium hypochlorite and 17% ethylene-diamine-tetraacetic acid and the final rinse was done using saline. The canals were dried using paper points and obturated with gutta-percha and AH Plus endodontic sealer following the cold lateral compaction technique.

Group I (control group) samples did not undergo any post placement (as their coronal tooth structures were intact) and were restored with composite. In the remaining 60 samples, post spaces (10-mm long) were prepared with gates glidden drills and peeso reamers up to the size of 1.1 mm and rinsed with 0.2% chlorhexidine for 10 seconds. For teeth of groups II, III, and IV, scotchbond universal adhesive was then applied in the canals and light-cured followed by cementation of posts using dual-cure Rely X Ultimate adhesive universal resin cement (3M ESPE, St. Paul, USA). The complete procedure was carried out according to the manufacturer's instructions.

For teeth of group II, carbon fiber posts (Angelus, Londrina, Brazil) were tried and fitted into the prepared post spaces. They were cut 3 mm above the sectioned tooth surface to retain a composite core. For group III, glass fiber posts (Coltene Whaledent, OH, USA) were cemented and similarly cut 3 mm above the sectioned tooth surface. For group IV, the ever Stick post (GC, Europe) foil bag was opened and the posts cut from the silicone strip using scissors. The measured length of the post was marked on the protective paper and the post cut together with the silicone to a suitable length. The post was removed from the silicone with tweezers and its length and suitability was checked by inserting it into the root canal. Additional posts were shaped and attached tightly to the main post both coronally and inside the root canal by means of lateral condensation. The condensed posts were light cured in the canal for 20 seconds, removed and again light cured for 20 seconds (Fig. 1).

Composite core build-up in all teeth of groups II, III, and IV was carried out. The composite (Filtek Z250 XT, 3M ESPE, St. Paul, USA) was placed in 1-mm increments and each increment was light cured for 20 seconds. Moreover, a 3-mm core buildup was done.

Static Loading Analysis

All the 80 specimens of groups I, II, III, and IV were subjected to static loading using a universal testing machine (Instron 3382, Instron Corp., Memmingen, Germany) on the basis of pneumatic pressure control and programmed by the Instron Bluehill 2 software.

The compressive load was applied on the palatal aspect 2 mm below the incisal surface at an angle of 135° to the long axis of the tooth at a crosshead speed of 2 mm/minute. The loading angle of 135° from palatal to labial was selected on the basis that it simulates the average angle of contact between\maxillary and mandibular incisors in class I occlusion and is a test of function. A crosshead speed of 2 mm/minute was selected to allow time for distribution of the force from the point of application, i.e., from the core to throughout the post. Failure threshold is the maximum loading force at which the

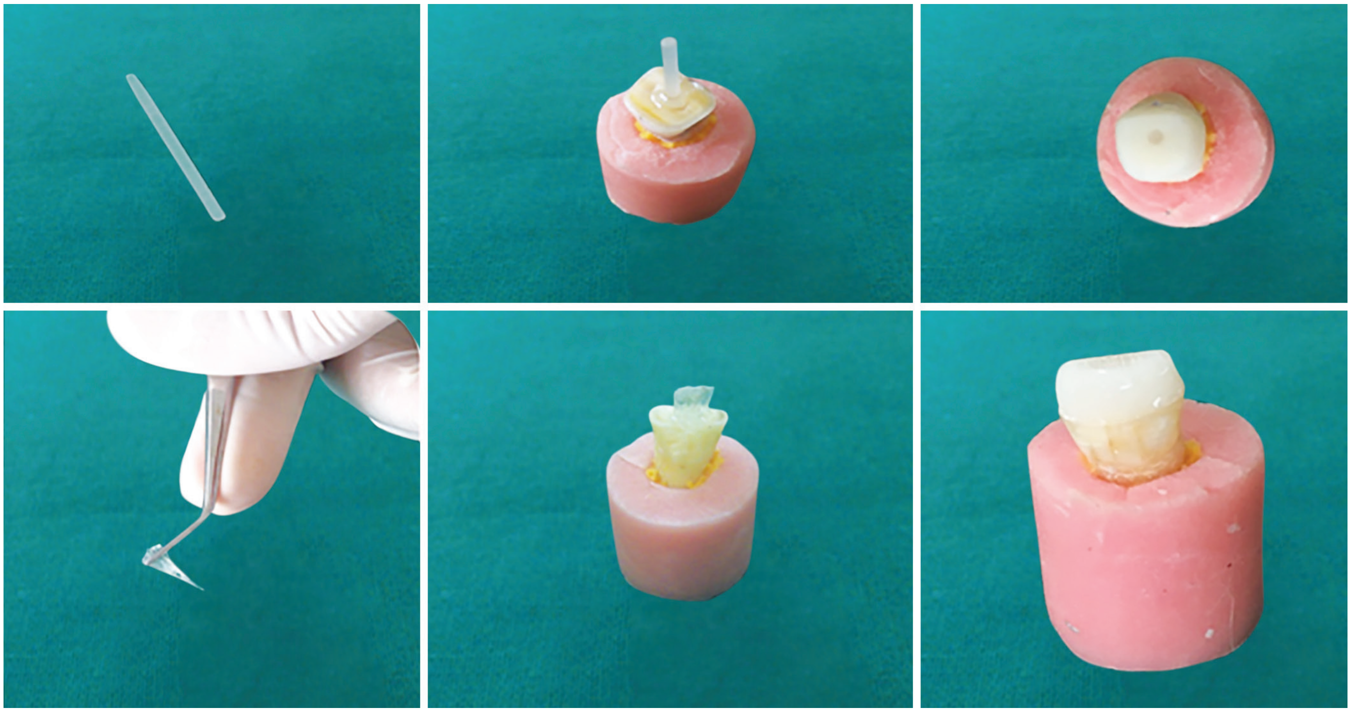

Fig. 1: Placement of an ever Stick post. Analysis of variance (ANOVA)

tooth fractures. The modes of fractures were recorded. Except for one sample each in groups II and III, all the failures occurred by debonding of composite cores. Statistical analysis was carried out using ANOVA to calculate the mean values of all groups. An intergroup comparison was carried out using Tukey's *post hoc* test.

Results

The results of the study were statistically significant. The mean failure load value of group I was 576.52 N, that of group II was 281.26 N, for group III it was 343.89 N and for group IV it was 452.32 N.

The average failure load of the control group I was significantly higher than the other post groups. A comparison of mean values of all groups showed significant differences between the groups, as seen in Tables 1 and 2. The predominant mode of failure was debonding of the core. One sample each from group II and III showed a catastrophic mode of failure in which the roots fractured while there was no root fracture in group IV. The remaining samples showed debonding of the composite cores.

Discussion

This *in vitro* study was carried out using 80 extracted human teeth collected from the department of oral surgery. The teeth were extracted as they were mobile owing to chronic periodontal disease and belonged to patients who were above 40 years of age. The teeth were divided into 4 groups of 20 each. The crowns of teeth under control group I were left intact and subjected to root canal treatment, whereas the crowns of teeth of groups II, III, and IV were sectioned 4 mm incisal to the cement-enamel junction, and they received carbon fiber, glass fiber, and everStick fiber posts respectively after root canal treatment, followed by fracture testing. Results of fracture tests showed highest fracture resistance of the samples of group I, which can be explained by the greater amount of remaining tooth structure, thus proving that it is a critical factor in the fracture resistance of the tooth. Among the groups II, III, and IV, where post and cores were placed, the highest fracture resistance was shown by teeth under group IV, in which everStick posts were used. This difference in the fracture resistance could be because the everStick fibers are fanned out in the coronal aspect, which increases the area of adhesion with the core and other unique features seen with this post.

An everStick post was used in this study as it is a recent post with unique properties. It is a soft, flexible, and un-polymerized glass fiber post consisting of a unidirectional fiber bundle with diameter ranging from 0.9 to 1.2 mm or from 0.9 to 1.5 mm, impregnated with polymethylmethacrylate (PMMA) and 2,2-bis-(4-[2-hydroxy-3-methacryloyloxypropoxy]phenyl)-propane (bis-GMA) with an

Table 1: Mean values for all groups

					95% confidence interval for mean	
	n	*Mean*	*Std. dev.*	*Std. error*	*Lower bound*	*Upper bound*
I	20	576.52	20.38901	4.55912	566.9842	586.0688
II	20	281.26	10.80920	2.41701	276.2066	286.3244
III	20	343.89	10.44282	2.33509	339.0036	348.7784
IV	20	452.32	14.35235	3.20928	445.6089	459.0431
	80	413.50	113.8750	12.73161	388.1606	438.8439

Tukey's *post hoc* test

Table 2: A comparison for mean value for all groups

(I) group	*(J) group*	*Mean difference (I–J)*	*Std. error*	*Sig.*
I	II	295.2610(*)	4.60324	0.00 (<0.05)
	III	232.6355(*)	4.60324	0.00 (<0.05)
	IV	124.2005(*)	4.60324	0.00 (<0.05)
II	III	−62.6255(*)	4.60324	0.00 (<0.05)
	IV	−171.0605(*)	4.60324	0.00 (<0.05)
III	IV	−108.4350(*)	4.60324	0.00 (<0.05)

*Mean difference is significant at the 0.05 level

interpenetrating polymer network (IPN), which strengthens the bond between the post and the resin, creating a monoblock ensuring that adhesive failures and microleakage are minimized. Everstick fibers can be individually adapted to the shape of the root canal. Additional strips of the post can be added in a lateral-condensation-like technique to completely fill and adapt to the canal. The fibers in the coronal part are flared to provide better bonding to the core. This unique technique of this post enables its use in large, oval, or even curved canals. It also reinforces the root, thus increasing fracture resistance. The flexural strength and elasticity of these posts is similar to dentin, due to which stresses are evenly distributed throughout the length of the root. Adhesive bonding to the resin cement used for cementation, and the composite core increases the bond strength to the root and the core and reduces the chances of debonding.[9]

Finite element analysis studies by Pegoretti et al. observed that cast post-and-cores produced the greatest stress concentration at the post–dentin interface in the root, while the glass fiber composite shows low stresses inside the root, thus indicating that glass fiber induces a stress field similar to that of the natural tooth.[9] Silva et al. carried out studies using a finite element analysis, which indicate that fiber-reinforced composites are better materials for dental posts, since they show a homogeneous stress distribution when compared to the metallic posts.[10]

Dean et al. carried out an *in vitro* comparison of carbon fiber with conventional cast posts and concluded that there were no root fractures with carbon fiber posts, unlike cast posts.[11]

A clinical study by Preethi and Kala, on the comparative evaluation of a cast post and core, a carbon-fiber-reinforced post with a composite core, and a glass-fiber-reinforced post with a composite core showed that the glass fiber group exhibited a higher success rate.[12]

Another clinical study conducted by Ferrari et al. concluded that composiposts (carbon fiber) performed better than cast posts. He also compared the clinical performance of composiposts with Aestheti (carbon fibers surrounded by quartz fibers) posts and Aestheti Plus (post made entirely of quartz fibers') posts and found no significant differences between the groups.[13]

An *in vitro* study showed that the everStick posts showed a higher fracture resistance when compared to the cast posts.[14]

A clinical study by Chunawalla et al. using the everstick fiber post showed promising results and they concluded that this fiber post provides homogeneous mechanical and chemical bonding of all components, reduces the risk of root fracture, since its modulus of elasticity is similar to that of root dentine and its diametric tensile strength is low and presents no potential hazards of corrosion and hypersensitivity.[15]

Limitations of the Study

All the teeth used in the study belonged to older individuals as the teeth were extracted because of a periodontal disease. The fracture resistance of such teeth is less compared to young teeth owing to occlusion of dentinal tubules, thereby reducing the overall content of water and so may affect the results of load testing. Also, intra-oral conditions such as dynamic loading and temperature changes should have been replicated in this study, which would make it more relevant to the clinical scenario.

In this study, samples were not fitted with crowns so that the influence of the properties of the post material could be established without being obscured by other factors. Since it is only an *ex vivo* study, clinical studies are required to come to a definite conclusion and the results of this and other such studies can be taken as suggestions.

Conclusion

The E-glass fiber post showed a significantly higher fracture resistance than the glass fiber or carbon fiber posts, which may be attributed to its minimal preparation of post space, lower modulus of elasticity, and the unique technique of placement and bonding. There was no catastrophic failure in this group. The mode of failure of the samples was due to debonding of composite cores, which is considered favorable as it can be repaired.

Clinical Significance

Studies using E-glass fiber post are showing promising results as they are performing better than other posts. Hence it can be suggested as a suitable alternative to glass fiber and carbon fiber posts.

References

1. McComb D. Restoration of the Endodontically Treated Tooth. Ensuring Continued trust, dispatch, february/march 2008.
2. Haralur SB, Al Ahmari MA, et al. The Effect of Intraradicular Multiple Fiber and Cast Posts on the Fracture Resistance of Endodontically Treated Teeth with Wide Root Canals. Biomed Res Int 2018;2018:1671498. DOI: 10.1155/2018/1671498.
3. Torbjorner A, Fransson B. A literature review on the prosthetic treatment of structurally compromised teeth. Int J Prosthod 2004;17:369–376.
4. Bateman G, Ricketts DNJ, et al. Fibre-based post systems: a review. Br Dent J 2003;195:43–48. DOI: 10.1038/sj.bdj.4810278.
5. Bonchev A, Radeva E, et al. Fiber Reinforced Composite Posts - A Review of Literature. Int J Sci Res October 2017;6(10):1887–1893.
6. Fischer DE. Benefits of Fiber Posts: Clinical Application of a New Post System | Dentistry Today February;2008. pp. 1–9, https://www.dentistrytoday.com/endodontics/1024--sp-835130998?tmpl=component&print=1.
7. https://www.gcindiadental.com/wp-content/uploads/brochures/Everstick_Booklet.pdf.
8. Vats A, Srivastava S, et al. High strength and bonding achieved with new flexible EverStick posts: A case report. Endodontology 2016;28:188–191. DOI: 10.4103/0970-7212.195429.
9. Pegoretti A, Fambri L, et al. Finite element analysis of a glass fibre reinforced composite endodontic post. Biomaterials 2002;23(13):2667–2682. DOI: 10.1016/S0142-9612(01)00407-0.
10. Silva NR, Castro CG, et al. Influence of different post design and composition on stress distribution in maxillary central incisor: Finite element analysis. Indian J Dent Res 2009;20(2):37.
11. Dean JP, Jeansonne BG, et al. *In vitro* evaluation of a carbon fiber post. J Endod 1998;24:807–810. DOI: 10.1016/S0099-2399(98)80007-1.

12. Preethi GA, Kala M. Clinical evaluation of carbon fiber reinforced carbon endodontic post, glass fiber reinforced post with cast post and core: A one year comparative clinical study. J Conserv Dent 2008;11(4):162–167. DOI: 10.4103/0972-0707.48841.
13. Dikbas I, Tanalp J. An Overview of Clinical Studies on Fiber Post Systems. Sci World J 2013;2013:171380. DOI:10.1155/2013/171380.
14. Chauhan P, Miglani A, et al. A comparative evaluation of fractured resistance of custom made Post and everStick post system in endodontically treated teeth- An *in vitro* study. Int J Appl Dent Sci 2017;3(1):78–80.
15. Chunawalla YK, Zingade SS, et al. Glass Fibre Reinforced Composite Resin Post & Core In Decayed Primary Anterior Teeth – A Case Report. Int J Clin Dent Sci 2011;2(1):55–59.