Fracture resistance of teeth restored with different post systems: in vitro study

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Objectives. The objective of this study was to investigate fracture resistance and mode of failure of teeth restored with different prefabricated post systems.

Study design. Thirty teeth were collected, sectioned 15 mm from the apex, root canal prepared, and randomly allocated into 3 groups as follows: glass fiber posts (group 1), carbon fiber posts (group 2), and Radix-Anchor titanium posts (group 3). Teeth were then restored with a composite core and tested using a universal testing machine at 10 mm/min cross-head speed. Mode of failure was identified as either reparable or irreparable (catastrophic).

Results. Mean values of fracture forces (N) for teeth restored with Radix posts (571.6) were statistically significantly higher than teeth restored with either carbon fiber (420.6) or glass fiber posts (393.9). There were 86.67% of fractures that were catastrophic in nature.

Conclusions. Teeth restored with Radix-titanium posts were more resistant to fracture than those restored with either carbon or glass fiber posts. Most of the fracture modes were catastrophic in nature. **(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;106:e77-e83)**

The restoration of endodontically treated teeth frequently poses a challenge for the clinician. In cases of considerable hard tissue loss, posts are used as an element supporting core foundation when there is insufficient coronal tooth structure.[1] The literature shows that there is no consensus regarding the ideal endodontic post and core system. Clinicians usually choose the post and core system that provides best retention, support, and reduces the possibility of root fracture.[2,3]

Generally, posts and cores may be fabricated using indirect or direct techniques. Indirect techniques require an impression and cast during the preparatory stages to produce a cast metal post-core build-up. Direct techniques involve the use of a prefabricated post in a radicular preparation.[4] Cast endodontic posts are indicated if significant amount of tooth structure is lost where maximum retention is required.[5] They are versatile and allow best fitting to the root canal.[6] They have been proven to be satisfactory in many long-term clinical studies and show good adaptability to the configuration and angulations of root canal walls as well as an ideal connection to the core with no possibility of separation.[7]

Nevertheless, metal posts and cores are associated with inferior aesthetics, as they do not allow light transmission,[8] might corrode causing gingival and tooth discoloration,[7,9] and have possible biocompatibility concerns.[10] Some may encounter difficulty in fabrication and fitting, and retrieval is difficult and might lead to tooth and/or root fracture.[7]

Nonmetal posts were developed as a result of advances in biomaterials, development in bonding and adhesive systems, and enhancement of aesthetic characteristics of dental restorations.[7] Nonmetal posts include composites and ceramics. Composite posts include carbon fiber, silica fiber, ribbon fiber, and light-transmitting posts.

Nonmetal posts have superior aesthetics,[11,12] are biocompatible, more color stable, corrosion free, and some have similar stiffness to dental tissues thus improving stress distribution.[11,13-15]

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Clinical studies have demonstrated satisfactory initial results for using ceramic post and fiber posts.[16] Boschian et al.[17] concluded that using fiber posts and resin composite cements might reinforce the remaining tooth structure and reduce root fracture and post debonding. Such effects may be attributed to the chemical bonding between the post and the cement and to the similarity in the elasticity modulus between the post and dentin. Resin-bonded nonmetal posts might reinforce the weakened teeth but not to a degree that matches sound teeth.[7,18]

As the aesthetics provided by all ceramic restorations is dependant on endodontic post-and-core materials, and shade and color of luting cement,[7] colored endodontic post-and-core systems along with the development of zirconia and glass fiber endodontic posts have enhanced the light transmission characteristics of restorations.[19]

Clinical failure of posts might be attributed to many factors such as caries, periodontal disease, root fracture, post fracture, post distortion, loss of crown retention, and loss of post retention.[20] Reasons behind the failure of post-retained restorations were documented in the literature as post loosening; the use of short, tapered, and threaded posts; and lack of ferrule effect.[21,22]

Ready-made or prefabricated metal posts are associated with higher risk of root fracture[23] due to the high stiffness and modulus of elasticity of the metal when compared to tooth structure, which might lead to increased stress concentration.[24,25] A high rate of ceramic post fracture was reported in the literature.[13,26] This was due to their high stiffness and low plastic deformation.[27] Furthermore, the existence of surface flaws and defects weaken ceramics under stress.[25] Mechanical properties of ceramic posts were found to be superior to those of carbon fiber and titanium posts.[27] They have similar survival rates to those of cast metal and core systems.[28] Nevertheless, teeth resorted with ceramic posts have had higher failure potential than those restored with carbon fiber posts.[29] Some studies have reported that teeth restored with metal posts had less fracture potential than those restored with carbon fiber posts.[30,31] Other studies have demonstrated similar levels of fracture potential when metal and carbon fiber posts were compared.[13] Some studies have shown that fracture resistance was not significantly different when ceramic post, carbon fiber post, and prefabricated metal posts were used to restore endodontically treated teeth.[13,32]

Mannocci et al.[33] arranged the fiber posts in terms of flexural strength in the following descending order: carbon fiber Carboteck posts, carbon fiber Composipost, quartz fiber Aesthetic plus posts, and finally silica fiber Snow posts. In a comparable study, and based on post fracture strength, Butz et al.[34] arranged investigated endodontic post and core system in the following descending order: cast post and core, titanium post and composite core, zirconia post and ceramic core, and zirconia post and composite core. The survival rates of teeth restored with the above systems were 94%, 94%, 100%, and 63%, respectively. Their study indicated that associating zirconia posts and composite cores for restoring endodontically treated teeth was not recommended.

A systematic review was conducted by the Cochrane Library in 2007. The main objectives of the review were to assess the effectiveness of different post and core systems for the restoration of endodontically treated teeth and to compare the clinical failure rates of the different types of posts. As only randomized clinical trials were included in the systematic review, only 2 trials were found appropriate and only 1 compared metal to nonmetal posts. Although the review study showed a higher risk of failure associated with metal posts compared to carbon fiber posts, there was a high risk of bias and the results were deemed unreliable. It was concluded that more research was needed.[35]

The aim of this study was to investigate the fracture resistance and mode of failure of teeth restored with prefabricated posts including glass fiber, carbon fiber, and Radix Anchor titanium posts, along with use of resin composite core. The null hypothesis stated that there was no significant difference in fracture resistance of teeth restored with the above-mentioned post systems.

MATERIALS AND METHODS

Thirty single-rooted anterior teeth were collected, cleaned, and stored in 5% thymol at room temperature. Teeth were examined under ×2 magnification using a magnifying lens (Kavo EWL, D.88299, Leutkirch, Germany) to ensure they were free of caries, restorations, or cracks. The mesiodistal and buccolingual dimensions of the teeth were recorded at the cervical margins using digital caliber (Anglia, ST Microelectronics, Edinburgh, UK) to standardize dimensions of the tested teeth.

All teeth were accessed and the root canal prepared using hand files to a master apical file size of 40. Sodium hypochlorite irrigation was used during the cleaning and shaping. The canals received a final wash with EDTA to remove any traces of sodium hypochlorite. Then, teeth were sectioned 15 mm from the apex, 2 mm coronal to the amelocemental junction, at a level corresponding to the clinical gingival margin, using a diamond bur (Dentsply, Maillefer, Switzerland) with continuous water coolant. Then the roots were embedded in die stone (Begostone, BEGO Bremer Goldschlgereiaeilh, Bermen, Germany) leaving 3 mm above the stone surface to mimic the position of the root within the alveolar bone. Teeth were randomly allocated into 3 groups and each group was restored with a different post type, as follows (diameter of all posts was 1.5 mm):

- Group 1: Teeth restored with glass fiber posts (GF, J. Morita, Irvine, CA, USA).
- Group 2: Teeth restored with carbon fiber posts (C-Post, Bisco Inc., USA).
- Group 3: Teeth restored with Radix prefabricated titanium metal posts (Radix Ker-Standard, Dentsply).

In each group a post space length of 10 mm was prepared, according to the manufacture's instructions, then irrigated with saline, dried with paper points (Absorbant Paper Points, Dream Dental Co., Seoul, South Korea), etched with 30% phosphoric acid solution (Gluma, Dormagen, Germany) for 30 seconds and irrigated again, and finally dried.

The 3 types of the prefabricated posts were cemented inside the post channels using adhesive resin cement (Bistite II DC, J.Morita). The cement was prepared following the manufacturers' instructions and applied to the post and post space, excess cement was removed and a water-based air barrier was applied to the margins of the canal orifice to prevent air from inhibiting setting of the cement. In addition, light-curing (Degulux, Degussa, Germany) for 20 seconds was carried out coronally. The cement was allowed to cure for 3 minutes, then the air barrier was removed by copious water irrigation and the tooth was dried by gentle air blowing. Cores were built up using a hybrid composite core (Shade A 3.5, Estelite composite, J.Morita). The coronal root surface was acid etched and a ready-made cellulose mold (Dentaurum-Gruppe TurnstraBe 31, Ispringn, Germany) was used to build up the resin composite core. At the fitting surface of each mold, a small mark was placed at the coronal third of the buccal surface, to standardize the point of load application during mechanical testing.

Each specimen was fixed in a specially fabricated stainless steel tube, which was used to hold the specimen during testing. A surveyor (Degussa, Geschaftsbereich Dental, Frankfort II, Germany) aided in the alignment of the teeth in the steel tube. The stainless steel tube containing the specimen was mounted on an in-house designed retaining jig (Mechanical Engineering Laboratories, Jordan University of Science and Technology, Irbid, Jordan), which was fixed to the lower member of the universal testing machine (Instron 1195, Instron Limited, Buckinghamshire, England). The retaining jig was used to tilt and hold specimens at 130° from the horizontal plane. A steel rod was fixed to the upper member of the testing machine, and compressive load was applied on specimens at a 10 mm/min crosshead speed (Fig. 1). The specimens were loaded to fracture and force at failure (N) was recorded. Mode of failure of each specimen was categorized as core failure only, root fracture only, or core and root fracture. The last 2 failure modes were considered catastrophic (irreparable), while core fracture was considered repairable.

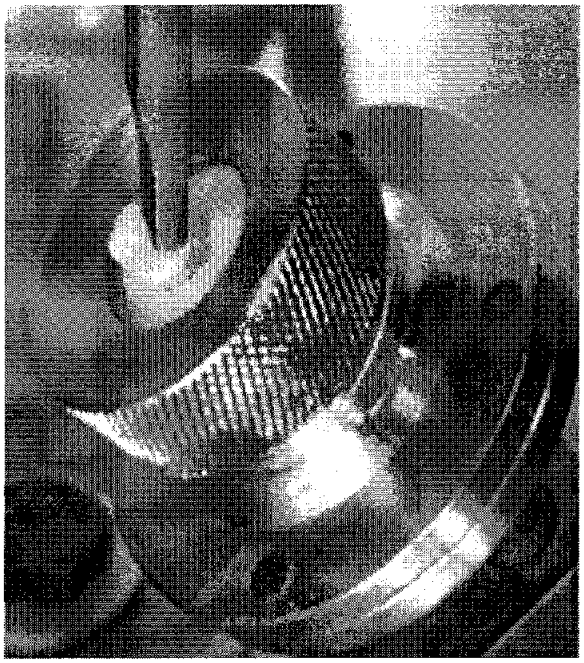

Fig. 1. A specimen under loading.

RESULTS

Statistical analysis of the data was carried out using SPSS package (release 11.0, SPSS Inc., Chicago, IL). One-way analysis of variance (ANOVA) and post hoc Protected Least Significant Difference (PLSD) tests were carried out ($P < .05$). There were no statistically significant differences ($P > .05$) between the mesiodistal and the buccolingual dimensions of the teeth among the tested groups (Table I).

Fracture loads are shown in Fig. 2. Teeth restored with Radix titanium posts demonstrated the highest mean fracture load (571.6 N), whereas teeth restored with glass fiber posts showed the lowest mean fracture load (393 N); there was a statistically significant difference between the 2 groups ($P = .004$). Also there was a statistically significant difference between the Radix titanium post group and the carbon fiber post group ($P = .014$). There was no statistically significant

Table I. Mean (SD) values (in mm) of MD and BL dimensions of the teeth.

Group	*MD Dimension*	*BL Dimension*
Glass fibre post	5.60 (0.52)	7.10 (0.46)
Carbon fibre post	5.59 (0.46)	7.10 (0.44)
Radix post	5.87 (0.53)	7.60 (0.60)

Values indicate homogeneous subsets ($P > .05$) within each dimension

MD, meio-distal; BL, bucco-lingual.

Table II. Failure mode of the specimens. Group 1 = Glass fiber; Group 2 = Carbon fiber; Group 3 = Radix post.

Fracture mode	*Fracture frequency number (%)*	*Fracture frequency (by group)* 1	2	3
Only core fracture	4 (13.33)	0	4	0
Only root fracture	5 (16.67)	1	4	0
Core and root fracture	21 (70)	9	2	10

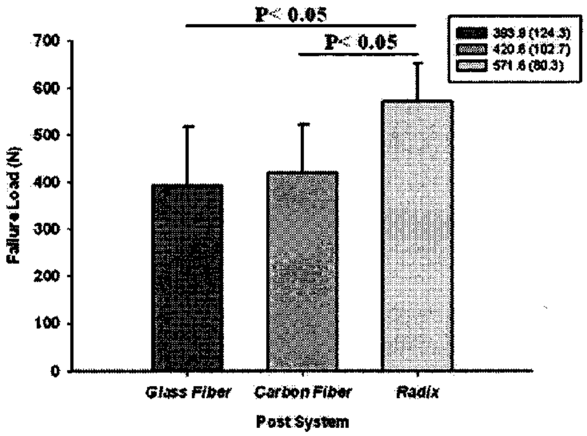

Fig. 2. Fracture loads of teeth in the 3 groups. Mean (SD) values were indicated in the figure legend. Statistical significant differences were present between groups ($P < .05$).

difference in forces between glass fiber posts group and carbon fiber posts groups.

Regarding failure modes (Table II), combined core and root was the most common exhibited (70%) followed by root fracture (16.67%) then core fracture (13.33%).

DISCUSSION

Posts should have the ability to allow force and stress transfer and distribution to prevent root fracture. The literature lacks reliable long-term clinical studies that provide accurate conclusions regarding post type to be used, and reports conflicting in vitro results about the ability of the new posts and adhesive systems to reinforce weakened teeth. This study compared the fracture resistance of natural teeth restored with 3 different types of post systems: glass fiber, carbon fiber, and Radix titanium. Results showed statistically significant differences between teeth restored with radix post and teeth restored with either glass fiber or carbon posts. Accordingly we rejected our hypothesis.

To simulate clinical conditions, natural teeth were used in this study, since artificial teeth do not simulate natural dentin, and they unrealistically adhere to the post, which does not resemble the clinical situation.[18] Natural teeth differ in length, width, size, and location of root canal, and presence of cracks and surface defects.[25,30,36,37] Thus, in this study, the mesiodistal and buccolingual dimensions of each tooth were recorded at the level of the cervical margin to ensure that each experimental group contained teeth of similar dimensions. Teeth were sectioned 15 mm from the apex, 2 mm coronal to the amelocemental junction, at a level corresponding to the clinical gingival margin. This method was adopted in many studies.[38-40]

The roots were embedded in die stone leaving 3 mm above the stone surface to mimic the position of the root within the bone in clinical situations and allow visualization of mode of failure during testing.[38,39] In agreement with previous studies,[5,41] the periodontium resilient effect was disregarded by embedding the specimens in stone without periodontal simulation, which would prevent any dislodgement of the teeth from the stone mold during testing. However, some studies have used silicon to simulate the periodontal ligament, and to provide a cushioning effect that would resemble clinical conditions.

Similar studies to the present study have used several types of cements including zinc phosphate cement,[38,42,43] Panavia-Ex,[39] dual-polymerizing adhesive resin adhesive cement.[44] Adhesive resin cement was used to cement the posts, since they have the ability to bond to both the radicular dentin and post allowing the use of conservative post insertion techniques as well as reducing potential stress.[45,46]

Composite was the material of choice for core build up because of its good bond strength, controlled and quick setting, good aesthetics, and adequate compressive strength.[3] Moreover, composite core materials have a higher fracture resistance than amalgam and glass ionomer materials.[47,48] A cellulose mold was used to build up the composite core standardizing the size of the core for all specimens.

Specimens were tilted at a 130° angle from the horizontal, and continuous compressive loading was applied, as it was shown to be the most clinically comparable angle of loading in anterior teeth.[38,42,46,49] However, other studies used different angulations from horizontal, as 60° angle,[18] and 45° angle.[5] A cross head speed of 10 mm/min was used in this study. A wide range of cross head speed was reported in the literature, ranging from 0.5 mm/min[50] to 10 mm/min.[51] However, one of the limitations of this study is the use of the continuous loading instead of the more clinically relevant cyclic loading. The continuous loading method has been adopted by many studies in this field and is easy to perform in comparison to the cyclic loading method. However, results obtained in this study were well within results reported in the literature.

Statistical analysis revealed that teeth restored with Radix posts had statistically significantly higher fracture resistance than teeth restored with Glass fiber posts. This was in agreement with Mitsui et al.[52] but disagreed with another study.[53] Similarly, statistical analysis revealed that teeth restored with Radix posts had statistically significantly higher fracture resistance than teeth restored with carbon fiber posts, which disagreed with the other study[52]; accordingly the null hypothesis was rejected. This could be because Radix posts have a high flexural strength and high modulus of elasticity. High modulus of elasticity would allow the post to withstand large amounts of stress before bending and transmitting the load to the root. This mechanism makes the tooth more resistant to fracture. However, when a fiber post is used it will bend at lower loads thus allowing transmission of the force to the tooth sooner. Consequently, the tooth will fail at lower values of stress. There was no statistically significant difference between forces required to fracture glass fiber and carbon fiber posts. Glass and carbon fiber posts have the same rigidity because both have fibers arranged longitudinally within the epoxy resin, which decreases stress by changing orientation within the post under load.[24,25] The fracture force of teeth restored with the glass fiber post systems exhibited a large standard deviation, which might be due to preexisting cracks and the low fracture toughness of glass fiber posts.

In this study, teeth were restored by a post and core without a crown. Previous research showed that placement of a crown may obscure the effect of different post and core buildup techniques.[42,54] However, the fracture loads recorded for teeth restored with the different post types were in the range of 390 to 570 N, which was in harmony with other studies.[1,55]

According to manufacturers' claims, resin-reinforced endodontic posts (carbon and glass fiber posts) were introduced to the dental profession in order to allow homogeneous mechanical and chemical bonding between the post and dental tissues to reinforce the tooth.[56] Restoration with endodontic posts must aim to decrease the levels of dentin stress within the root and keep it at the lowest level. Some researchers have adopted the idea that the stiffer the post the more even the stress distribution.[56-59] Others have supported the view that the less stiff the post the better the stress distribution.[15,31]

The use of an endodontic post inside the canal transforms the forces from compressive stress (resisted by the dental tissues) to tensile stress (less resisted by the dental tissues). Consequently, the tooth fracture resistance will be reduced.[60] However, fiber posts flexibility lead to stress direction toward the core or the post-tooth interface (luting cement) leading to an increased failure rate.[56]

Conflicting reports about ability of post systems to resist fracture were reported in the literature. Some studies have reported that teeth restored with metal posts had less fracture potential than those restored with carbon fiber posts.[30,31] Other studies have demonstrated similar levels of fracture potential when metal and carbon fiber posts were compared.[13,32] However, the use of a carbon fiber post did not significantly alter the fracture resistance or fracture patterns of endodontically treated incisor teeth when compared to cast post and core systems and prefabricated stainless steel post systems.[61] Furthermore, using fatigue testing, failure of teeth restored with carbon fiber posts were reported less than those restored with ceramic or metal posts.[29,62] However, teeth restored with fiber posts were associated with lower failure loads than those restored with metal posts in the case of using progressive loading.[31] The former situation is similar to the in vivo situations. The conflicting results of the above studies might be because of different experimental protocols followed under various testing conditions.

In this study, the mechanical test was conducted after 24 hours of preparing the specimens, since the dentin resin layer will degredade with time in the presence of moisture. Walker et al.[63] showed that this poorly infiltrated area has clinical implications as postoperative sensitivity, and premature degradation of the dentin/resin cement interface over time, although, it is yet to be investigated if the layer of poorly infiltrated collagen matrix would affect the bond strength of the post to the root. However, results obtained in this study were well within results reported in the literature.

Regarding mode of failure, combined core and root fractures were the most common exhibited (70.00%) followed by root fracture (16.67%), and then core fracture (13.33%). Teeth restored with Radix and glass fiber posts showed almost entirely core and root fracture (100% and 90% respectively), which is likely attributed to the high bending resistance of such post systems.

CONCLUSIONS

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

(1) teeth restored with titanium posts demonstrated higher resistance to fracture when compared to carbon fiber post and glass fiber post; (2) there is no statistically significant difference between forces required to fracture teeth restored with glass fiber posts and carbon fiber posts; and (3) most of the failure modes were catastrophic in nature with the teeth being nonrestorable.

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