In Vitro Comparison of the Mechanical Strength of Carbon Fiber and Zirconia Ceramic Posts and Cores

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Ten similarly sized extracted maxillary central incisors were treated endodontically; carbon fiber posts were fit to five specimens and zirconia ceramic posts were fit to the other five. The same cement was used for fixation and core reconstruction. The purpose of this study was to test the strength of the two groups of specimens via a static strain test. The carbon fiber posts were seen to have greater elasticity but were subjected to such stresses so as not to recommend their use in single-rooted teeth with no clinical crowns. Their use may be recommended in other clinical situations. Zirconia ceramic posts were more reliable and stronger above all for single-rooted teeth with no crowns. (Int J Periodontics Restorative Dent 2012;32:e75–e81.)

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In routine practice, the clinician has always had to deal with the restoration of teeth that have been treated endodontically. In general, these restorations do not give rise to undue concern. Nevertheless, a correct initial diagnosis may guard against future difficulties, such as detachment of endocanal posts or, in more serious cases, fracture of the teeth themselves.

The cast post and core cemented within the root canal is a technique that has been tested through many decades of use. Historically, it derived from the Richmond crown technique, now in disuse since it does not contain the necessary precision or biomechanical characteristics required in the field of prosthodontics.[1] There are two techniques used to fabricate cast posts and cores: the direct and indirect techniques. The direct technique entails fabricating the post and core in a fusible material directly on the tooth after suitable preparation, while the indirect technique entails taking an impression in silicone, developing a plaster cast, and then fabrication of the

Table 1 Characteristics of the posts and cores

	Fracture diameter (mm)	Area (mm²)	Length beyond root (mm)
Zirconia ceramic post			
Zir 1	1.10	0.95	5.50
Zir 2	1.10	0.95	4.10
Zir 3	1.19	1.11	5.80
Zir 4	1.20	1.13	5.00
Zir 5	1.18	1.09	5.00
Zir 6	1.56	1.91	5.20
Carbon fiber post			
Carb 1	1.25	1.23	5.50
Carb 2	1.34	1.41	5.00
Carb 3	1.27	1.27	6.00
Carb 4	1.24	1.21	6.00
Carb 5	1.24	1.21	5.20
Carb 6	1.26	1.25	5.00

artifact in the laboratory.[2] If properly executed, both techniques yield good results.

In recent years, alternative methods based on the adhesion of composite resin cements to dental tissues (enamel and dentin) have been proposed alongside the traditional techniques; the properties of these cements have opened new doors in reconstructive dentistry.[3–5] Such cements have replaced the zinc oxyphosphate cements generally used in the past, and have made possible a valid alternative to the cast post-and-core technique in the form of nonmetallic posts and cores.[1] According to the manufacturers, the new materials proposed for posts and cores also have moduli of elasticity that are closer to that of the tooth, reducing the risk of root fracture. Their simplicity of use, with the elimination of laboratory steps, means that excellent results with a good degree of precision may readily be achieved.[3]

The aim of this research was to determine the breaking point of carbon fiber and zirconia ceramic posts with composite resin cores[6] using a static strain test. The results were compared with data reported in the literature concerning posts and cores usually used for anterior tooth restorations.

Method and materials

Ten maxillary central incisors extracted for periodontal reasons were selected; they were similar in shape, length, and mesiodistal width of the crown and root (Table 1). Specimens were fixed in formaldehyde, and the root canal was reamed and obturated with gutta percha. After completing endodontic treatment, the root of each tooth was immersed in a matrix of inorganic resin (Orthocryl, Dentaurum) (Fig 1).

Specimens were then prepared by a single operator using the same preparation technique and the same type of bur (North-Bel M122) as that for a normal prosthetic preparation. Dies were made on the prepared tooth with 0.5-mm sheets of heat-shrinking material using a mini-vacuum molding machine (BREGA EFFEGI BB85), from which 10 tooth stumps of similar sizes were produced (Fig 2). Each incisor had the same size base, which was then perfectly adapted to the machine support. Once this phase was complete, the crown of each specimen was removed from the root using a carburundum disk of 0.2-mm diameter (Rascodent).

The root canals were then reamed using reamers 0.70- to 0.90-mm wide, and the final bur was that provided with the post kit and was specific to each size post. To conclude this phase, all root canals were reamed and cleansed with an ethylenediaminetetraacetic acid–based solution (neoTUbulicid, Simit Dental).[4] The specimens obtained were divided into two groups:

Fig 1 *The root of each tooth was immersed in a matrix of inorganic resin.*

Fig 2 *On the prepared tooth, dies were made with 0.5-mm sheets of heat-shrinking material using a mini-vacuum molding machine.*

carbon fiber posts of 1.2-mm diameter were inserted into the specimens of the first group (Tech.2000, Isasan), and zirconia ceramic posts of the same diameter were inserted into those of the second group (Komet).

The cementing procedure was accomplishing using the same cement (Panavia 21, Kuraray) and following the manufacturer's instructions. Zirconia ceramic posts were first conditioned (Monobond-s, Vivadent) to ensure adhesion of the cement to the ceramic. The caps of the heat-molded material, already perforated at the tip to allow passage of the endocanal post, were then tested. The caps, which were coated with Vaseline (Farmalabor), were filled with a self-hardening composite resin cement reinforced with titanium (Ti-Core Core Material, Essential Dental Systems), which was chosen because its physical characteristics are similar to those of dentin.[7]

The specimens were then ready for mechanical testing (Figs 3 and 4) to verify the following mechanical characteristics:

- Static strength of the bond between post and root
- Transmission of stress from posts to the surrounding cement
- Location and type of fractures
- Analysis of the fracture surface

Static testing

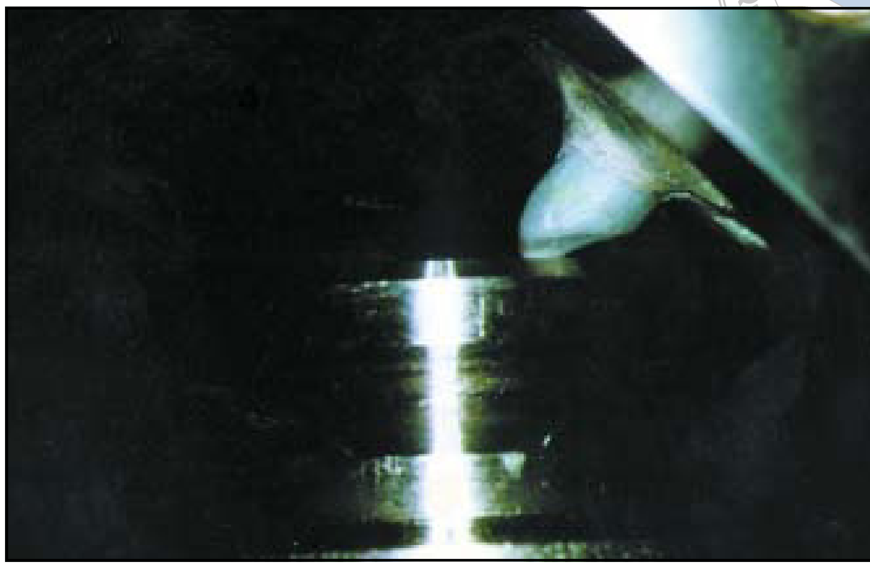
Tests of combined compression and bending on teeth prepared with the post-and-core technique were performed using a dynamometric machine (INSTRON 8501) (Fig 5) for mechanical static strain tests using a 1-kN load cell and special accessories comprising a cylindric support to anchor the post-root system to be tested for combined compression and bending strength, a cylindric tool via which the machine's actuator depresses the core and post vertically, and cold polymethyl methacrylate resin to embed the root and the system to be tested.

Preparation methods and assembly

A stainless steel body was prepared that enabled the root to be fixed at an inclination of 45 degrees to horizontal (Fig 6). The elastic deformation of stainless steel is held to be negligible compared to the system being tested.

Test parameters

Strain tests were performed at set deformations in a controlled position. Six test runs were performed for each type of post (Zir 1 to 6 and Carb 1 to 6). The actuator was lowered using a special cylindric tool at a speed of 1 mm/min. The ambient conditions (25°C, 48% to 50% humidity) were the same for all tests.



Figs 3 (left) **and 4** (above) *Specimens obtained were at this point ready for mechanical testing.*

Fig 5 *Compression and bending tests performed on teeth prepared using the post-and-core technique were done using a dynamometric machine.*

Fig 6 (right) *A stainless steel body was prepared that enabled the root to be fixed at an inclination of 45 degrees to the horizontal.*

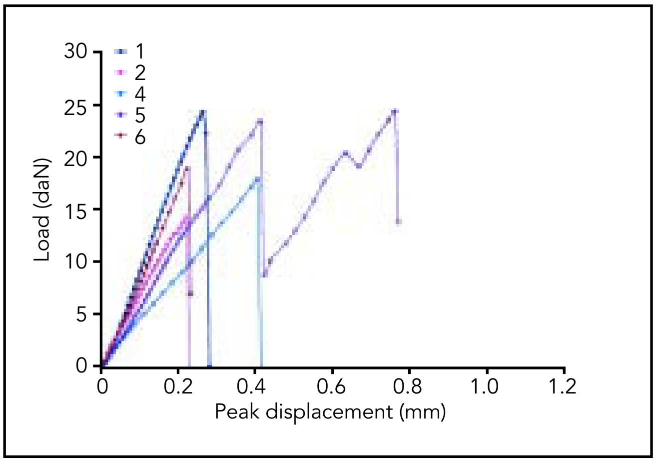


Fig 7 *Load versus peak displacement for zirconia ceramic post-and-core specimens.*

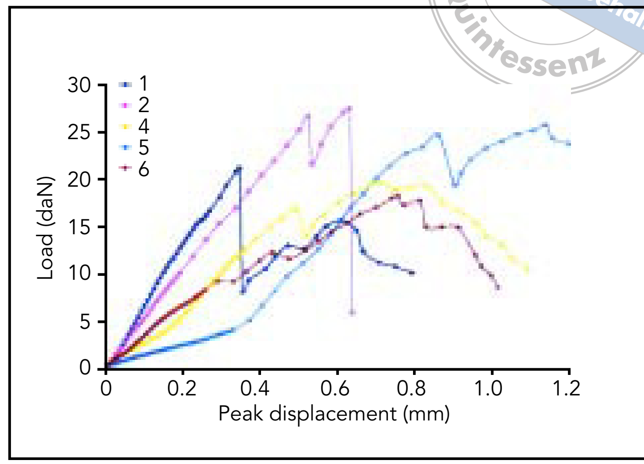


Fig 8 *Load versus peak displacement for carbon fiber post-and-core specimens.*

Results

For each system tested, the following parameters were analyzed: maximum stress and peak displacement, stress required to fracture the post and core, and the location of the fracture or deformation of the post and core (Table 2). Load versus displacement for the individual systems and the values of peak load and peak displacement are shown in Figs 7 and 8. Table 2 summarizes the results.

The behavior of the zirconia ceramic posts and cores luted with composite resin cement reinforced with titanium was similar for each of the six test runs (Fig 7). The peak loads varied between 15 and 25 daN. For each post, the fracture was located slightly below the cement-root interface. There was a good bond between the post and composite resin cement until fracture occurred. This may be explained by the fact that the bonding was located between rigid materials that maintain their rigidity until fracture.

Table 2 **Load, peak displacement, and location of fracture**

	Load (daN)	Peak displacement (mm)	Fracture location
Zirconia ceramic post			
Zir 1	24.4	0.333	Below cement-root interface
Zir 2	14.5	0.222	Below cement-root interface
Zir 4	18.2	0.409	Below cement-root interface
Zir 5	24.6	0.765	Below cement-root interface
Zir 6	19.6	0.230	Below cement-root interface
Carbon fiber post			
Carb 1	21.3	0.346	Above cement-root interface
Carb 2	27.5	0.627	Above cement-root interface
Carb 3	19.7	0.711	Above cement-root interface
Carb 4	25.8	1.139	Above cement-root interface
Carb 6	18.2	0.751	Above cement-root interface

Regarding the second system (ie, carbon fiber post and core luted with composite resin cement reinforced with titanium powder), even if the peak loads came close to those recorded with the zirconia ceramic posts, a fundamental aspect emerged. In all tests, maximum load was reached after micro- and macrofractures had affected the composite resin titanium-reinforced cement. This aspect has clinical repercussions and explains the nonlinearity of the initial part of the graphs, whose irregular shape is characterized by frequent yielding of the external part of the cement, corresponding to continual load recoveries (Fig 8).

Discussion

Unlike the zirconia ceramic posts, the carbon fiber posts were seen to fracture above the cement-root interface. In some cases, only the external part of the cement fractured with the intact post remaining in place, indicating that the carbon fiber post was more flexible than the structure in which it was embedded. There were no fractures of the roots in which the posts were fixed. With regard to the maximum loads reached, it should be noted that although both systems passed the threshold of 15 daN, in several cases, the carbon fiber posts showed microfractures of the composite resin cement below 10 daN, undoubtedly a less acceptable performance than the compound fractures of the zirconia ceramic posts.

Though routine in clinical practice, restoration of an endodontically treated tooth using endocanal posts is not always complication-free. First and foremost, good canal therapy that obturates the apex and adequate compaction of the gutta percha are required. This also makes possible a correct knowledge and diagnosis of the root anatomy, which is particularly important in the use of canal posts. Various root shapes, including ribbon-shaped roots, anomalous curvature, invagination, and abnormally thin or highly tapered roots, may predispose the root to poor results with the application of posts.[8]

Many studies are reported in the literature concerning the strength of teeth treated endodontically with endocanal posts versus vital teeth, with some of the principles outlined as follows:

- The endodontically treated tooth loses approximately 9% of its water content.[9]
- The areas to which most load stress is distributed lie in the cervical (cementoenamel interface) and apical zones. On the basis of these criteria, we must decide the section and length of the posts to be used.[10]
- Threaded posts, therefore, cause further stress and may determine fractures. Thus, their use is not recommended; passive posts are preferable.[11]
- The material used to fabricate the posts is extremely important since it must have a modulus of elasticity as close as possible to that of root dentin (18 GPa).[12,13]

In light of these considerations, the use of posts made of alternative materials cemented with adhesive techniques may be considered a step forward in the routine application of the post-and-core technique. Carbon fiber posts and those of zirconia ceramic may best meet the needs of resistance to load, while respecting the above principles.

From the in vitro tests, some considerations may be made:

- The tests made it abundantly clear that carbon fiber posts do not achieve an optimal bond with the composite resin cements used to reconstruct the core. The fractures in the specimens with carbon fiber posts were located above the cement-root interface. In some cases, however, a fracture was only observed in the cement portion, with the post intact and in place, pointing out the greater flexibility of the carbon fiber post/composite core combination than the more rigid supporting structure. This problem has a parallel in clinical practice. In anterior segments, detachment of the composite resin core from the carbon fiber post was observed. Therefore, the use of such posts in anterior teeth without clinical crowns is not recommended. Instead, carbon fiber posts are recommended in cases of partial loss and, above all, in multirooted teeth where the application of two or more posts allows mechanical as well as chemical adhesion. This method would appear to be a successful replacement for metal posts cast in more than one part, a method that is time-consuming and rather laborious.
- Carbon fiber posts applied to ribbon-shaped roots may undergo decementation because of the discrepancy in the

shape between the post and root canal lumen. To obviate this difficulty, some researchers suggest preventive rebasing of the post using composite resin and subsequent cementing.[7] The authors recommend the use of alternative techniques in cases where the taper of the chosen post is not the closest to that of the canal lumen, bearing in mind that technically the thickness of the canal cement should be maintained between 200 and 300 µm. Further advantages of carbon fiber posts include ease of removal and low cost.

- Zirconia ceramic posts have a high rigidity and may thus be harmful in cases of severe trauma. Their worst disadvantage during the present tests was that of fracturing at the level of the crown. This disadvantage may be reduced by the use of posts cast in a single piece with the core, as in the Empress IPS technique (Ivoclar Vivadent). If this method is combined with a chamfered post margin, results from the clinical standpoint are decidedly better, even if costs increase considerably. The use of zirconia ceramic posts is undoubtedly preferable in all-ceramic restorations because of their ability to transmit light. Unfortunately, removal and the working procedure are very laborious.

No fractures of the roots in which the posts were fixed were recorded in either group of specimens (carbon fiber or zirconia ceramic posts). For the maximum loads reached, it should be noted that even though both systems passed the threshold of 15 daN, the carbon fiber posts showed microfractures of the composite resin cement below 10 daN, a less acceptable performance than the compound fractures occurring in the specimens with zirconia ceramic posts.

Knowledge of the properties of these materials in clinical practice helps the clinician to successfully treat patients by producing predictable and long-lasting results, provided that the choice of material is made based on its characteristics and limitations in relation to the requirements of the individual case.

Acknowledgment

The authors would like to dedicate this work to colleague and friend Aldo Carano. He is no longer with us, but his love and his professional and human generosity are alive, and the authors would like them to be an example for all those who think only in terms of feeling to an end, forgetting that what remains of us is affected, and how much we loved is perhaps the truest sense of immortality.

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