Comparison of the fracture resistances of pulpless teeth restored with a cast post and core or carbon-fiber post with a composite core

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Statement of problem. The survival of pulpless teeth restored with a post and core system is a controversial issue.

Purpose. This study compared the fracture resistance of 2 types of restorations: teeth restored with prefabricated carbon-fiber posts and composite cores to cast dowel-core restored teeth.

Material and methods. A total of 44 recently extracted sound premolars were randomly distributed into 2 equal groups: group I, restored with prefabricated carbon-fiber post and a composite core; and group II, with custom-cast type III gold alloy post and cores. The size and shape of the posts were identical in the 2 groups. All teeth were fully covered with a nonprecious cast crown. Fracture resistance was measured by applying a point force at 45 degrees to the long axis of the tooth.

Results. Mean fracture threshold was 103.7 ± 53.1 kg for group I versus 202.7 ± 125.0 kg for group II (differences significant with P<.003). In group II, however, fracture nearly always affected the tooth itself, whereas in group I, the post-core nearly always failed first.

Conclusions. Significantly higher fracture thresholds were recorded for the cast post and core group. Teeth restored with cast posts typically showed fracture of the tooth, although at loads rarely occurring clinically. (J Prosthet Dent 1998;80:527-32.)

CLINICAL IMPLICATIONS

Post and cores used for the restoration of pulpless teeth should be strong; nevertheless, the post should fail before the remaining dental structure in response to mechanical stress. In this study, the failure threshold of carbon-fiber posts was significantly lower than the threshold for cast posts. Cast posts commonly resulted in tooth fracture at failure.

The likelihood of survival of a pulpless tooth is directly related to the quantity and quality of remaining dental tissue.1-3 A post is commonly placed in an attempt to strengthen the tooth. However, dentin must be removed during preparation of the post hole and the consequent reduction in fracture resistance may outweigh any likely gains. The post does not actually strengthen the root, but rather serves to improve retention of the core.2-5

Of the various post and core designs available, the most widely used can be classified into 2 basic types: metal posts and cores that are custom cast as a single piece, and 2-element designs comprising a commercial prefabricated post to which a silver amalgam or composite core is subsequently adapted. Cast posts and cores are commonly advocated for teeth with little remaining coronal structure6,7 or for uniradicular teeth with small coronal volume.6,8,9 In such situations, the use of an alloy with high gold content, and thus high biocompatibility, high corrosion resistance, and low rigidity appear most appropriate.10 In contrast, prefabricated posts appear to be most useful in teeth that retain considerable coronal dentin; in these situations, the core can be made from materials that adhere to dental tissues.5,9

In recent years, carbon-fiber materials have come into use for prostodontic applications.11-13 The use of such materials for prefabricated posts offers a number of advantages, including biocompatibility, resistance to corrosion and fatigue, mechanical properties that closely match those of the tooth,5,14 and the option of easy removal of the post from the root canal.13,15-18 Once cemented, metal posts are considerably more difficult to remove.

McDonald et al.19 compared the fracture resistance of (a) teeth restored with a steel post, (b) teeth restored with a carbon-fiber post, and (c) intact root-treated teeth (controls), and found no significant differences among the 3. Assif et al.20 compared the fracture resistance of teeth restored with cast dowel cores with vari-
ous post designs and did not detect any significant differences.

The purpose of this study was to compare the fracture resistance of extracted premolars restored with carbon-fiber posts and composite cores and cast gold posts and cores. All samples were also restored with cast complete crowns.

MATERIAL AND METHODS

The experiments were performed with a homogeneous sample of 44 similarly sized premolars, all recently extracted from adolescents who were receiving orthodontic treatment. After extraction, the teeth were placed in an aqueous buffered solution of formalin (5%) for 24 hours. The teeth were then cleaned and transferred to tap water at 5°C to prevent desiccation for storage. Before the experiments, all teeth were endodontically treated by the mutual lateral condensation method. AH Plus root canal sealer (batch no. 9711003576, Dentsply-DeTrey, Konstanz, Germany) was used as an endodontic sealer. In addition, the dental crown was seated with an Isomet 2600 saw, 2 mm coronal to the dentinoenamel junction. A chamfered shoulder of 1 mm in width and depth was then made at this level around the entire circumference of the tooth. A counterbevel of 1 mm was also prepared, as a ferrule of the core (Figs. 1 and 2). The post hole was drilled first with a 10 mm Composipost preparation drill (medium size, no. 2 ref. 622, Composipost Rhd., Meylan Cedex, France), then its final shape was developed with a Composipost definitive drill (medium size, no. 2, ref. 632, Composipost Rhd.). The 44 teeth were randomly assigned to group I (carbon-fiber posts and composite cores) or group II (cast post and core).

For teeth in group 1, a carbon-fiber post with an epoxy resin matrix (batch no. 061021970328, Composipost Rhd.) with 2 diameters, a thinner apical section (1.2 mm) and a wider coronal section (1.8 mm), both cylindrical, was used (Fig. 1). It also had 2 tapered areas, one at the tip and the other at the interface between the 2 diameters. The posts were cemented with a resin cement (Panavia 21, Kuraray Co. Ltd., Osaka, Japan), and the corresponding dentin adhesive, a Bis-GMA/MDP resin cement that is compatible with the epoxy resin (RTD, Meylan-Cedex, France) that binds the carbon fibers together. The composition and identification of this resin is protected by a patent. The core was prepared to a height of 3 mm by using an autopolymerizing composite (Cavex Clearfill Core, batch no. 43260, Cavex Holland, Haarlem, Holland) with adhesive (Clearfill New Bond Cavex Holland) using a steel matrix.
Fracture Curves: CFP & composite core

![Fracture Curve Diagram](image)

Fracture Curves: Cast-post & core (gold)

![Fracture Curve Diagram](image)

Fig. 3. Fracture curves in group I more inelastic behavior, despite results obtained in group II.

Group II teeth were prepared as in group I, with a 1 mm wide chamfer and a counterbevel to achieve the ferrule effect.\textsuperscript{21,22} A pattern for the post and core was made with Duralay (Reliance Dental Mfg. Co., Worth, Ill.) in a height of 3 mm coronal to the gingival margin. The resin patterns were invested with a phosphate-bonded investment material (GC Fujiwet, GC Co.-Belgium, Leuven, Belgium) and burned out in a furnace (Type 5635, Kavo Ewl, Leutkirch, Germany) in accordance with manufacturer’s directions. The induction apparatus used for casting at 1070°C was a multitheatrical (F. LLI. Manfredi, Pinerolo, Italy). Casting was conducted by using a standard lost wax technique with type III gold alloy (Dentozam-M, Sempsa, Madrid, Spain). The cast posts and cores were air abraded with 50 μm aluminum oxide powder and ultrasonically treated in neutral detergent solution for 10 minutes to improve adhesion of the resin.\textsuperscript{23} At this stage, the cast posts were cemented in place with the same resin used in group I (Panavia 21, ID primer A and B, Kuraray Co. Ltd.).

For all specimens, the core and tooth were machined to provide the space for the crown (Figs. 1 and 2). The final counterbevel in the core (fitting against the bevel in the enamel) was approximately 0.5 mm high and 0.5 mm deep. The crown, custom-cast with a Ni-Cr alloy (Wiron 99, Bego, Bremen, Germany) was then cemented onto the tooth/core with a glass ionomer cement (Ketac-Cem, Espe, Seefeld, Germany). The restored teeth were mounted so they were perpendicular...
lat to the face of the resin prism (Formatray, Kerr UK Ltd., Peterborough, U.K.), at a depth of 2 mm below the dentinoenamel junction, for fracture resistance testing.

Fracture resistance testing

Immediately after mounting, fracture resistance was determined with an Instron universal testing machine (model 1114, Instron Corp., Canton, Mass.). Testing conditions were adjusted to simulate the in vivo situation. The force was applied at 45 degrees to the long axis of the tooth (simulating the angle of occlusion of the cusps of the opposing premoval), and crosshead speed was slow (1 cm/min). For all specimens, both peak load at failure (fracture resistance) and mode of failure were recorded.

Statistical analysis

The fracture resistance data showed approximately normal distributions in both groups; however, variance was considerably higher in group I. Therefore the Mann-Whitney test was used to compare the 2 groups. Unless otherwise stated, statistical significance was at P<.05.

RESULTS

The value of mechanical failure for group I (restored with a carbon-fiber post) was 103.7 kg (SD, 53.1), whereas for group II (teeth restored with a gold post-core), it was 202.7 kg (SD 125).

Given that the values obtained showed considerable dispersion, it was necessary to consider the median and range values found in each group. Thus, in group I, the median was 95.5 and the maximum and minimum values were 260 and 34, respectively. For group II, the median was 151.5 and the maximum and minimum values were 458 and 54, respectively. Fracture curves in group I indicated less elastic behavior, despite the results obtained for group II (Fig. 3).

The results revealed that teeth restored with a cast gold post and core recorded a higher fracture threshold than teeth restored with a carbon-fiber post and composite core (Table I). The between-group difference in fracture resistance was statistically significant (Mann-Whitney U test, P<.003).

The mode of failure was also different for the 2 groups. Of the 22 teeth in group I, 13 specimens (59%) showed failure of the tooth/post core interface and of the post, 4 (18%) displayed a similar response but the post remained intact, and the core fractured in 4 (18%) specimens. Failure of the tooth was observed for only 1 specimen (5%) (Fig. 4). Of the 22 teeth in group II, 20 (91%) demonstrated cervical root fracture (13/22, 59%) or cervical fissuring (7/22, 32%). Failure was the result of dislodgment of the cast restorations in only 2 specimens (9%) (Fig. 5).

DISCUSSION

In this study, only 1 (5%) of the 22 teeth restored with carbon-fiber posts resulted in fracture of the tooth itself. In a study of similar restorations by Cohen et al., fractures of the tooth were likewise observed in only 21% of the specimens. In a study of the fracture resistance of teeth restored with Composiposte carbon-fiber
posts, Purton and Payne\textsuperscript{13} reported that tooth fractures were uncommon and that the most frequent site of failure was the post and core interface. By contrast, in teeth restored with a cast-post and core, fracture of the tooth was observed in 91\% of the specimens, albeit in response to loads that rarely occur in vivo.

Because the post hole was prepared to the same shape as the prefabricated post used in group 1, post shape and length were identical in the 2 groups. Particular advantages of the design used in this study (Figs. 1 and 2) are the (1) beveling of edges and the apex to reduce concentration of stresses in these areas,\textsuperscript{4} and (2) relatively narrow diameter of the lower portion of the post to reduce the amount of tooth structure that must be removed.\textsuperscript{2,5,21}

There are 3 possible explanations for the observed differences in fracture resistance and mode of fracture between restorations of the 2 groups. Breakage of the post at the point of insertion into the core (Fig. 4, A) appeared to occur before fracture for the restorations in group I (carbon-fiber post). This phenomenon reduced the incidence of the types of fractures illustrated in Figures 4, D and 5, A and B. However, in restorations with cast-posts and cores, the post did not break and the force was transmitted to the "shoulder" of the tooth. Also, breakage of the core itself (Fig. 4, C) may occur when the core is resin, again reducing the incidence of tooth fractures. Finally, the longitudinal arrangement of fibers in the carbon-fiber post and the modulus of elasticity of the post, which is less than or equal to that of dentin,\textsuperscript{14} may redistribute stress into the tooth and away from the chamfered shoulder to increase the likelihood of failure of the post/tooth union instead of tooth fractures.

Counterbevels thus have both advantages and disadvantages. Because the tooth is elliptical (not circular) in cross-section, the counterbevel redistributes rotational stresses throughout the tooth. This clearly improves fracture resistance.\textsuperscript{6} However, if the structure is strong and a heavy load is applied, the counterbevel may favor fracture of the shoulder of the tooth before failure of the tooth-core union and post (Fig. 3, A), the tooth core union and tooth post union (Fig. 3, B), or the core itself (Fig. 3, C). Previous studies have concluded that this effect of counterbevels argues against their use in cast post and cores.\textsuperscript{5,7} The results of our study support this view, particularly in patients in whom high stresses are developed during mastication.

In this study, teeth were fully restored with a cast crown, as occurs in clinical practice. In one study, it was reported that crowns act to distribute applied loads more evenly over the core,\textsuperscript{21} and that they concentrate forces in the outer regions of the coronal third of the root, especially at the interfaces of materials with different moduli of elasticity.\textsuperscript{1,7} It has also been suggested that cemented crowns alter the distribution of forces so markedly that post and core design is irrelevant.\textsuperscript{20} However, the differences between the 2 post and core designs tested in this study suggested that this latter assertion may be incorrect.

There was considerable within-group variability as has been noted in previous studies of this type.\textsuperscript{17,19,20} Such variability may be attributable to normal variation among teeth, such as the position of the root canal, or the distance between the coronal surface and the dentinoenamel junction,\textsuperscript{20} or to variation introduced during extraction\textsuperscript{9} and/or during storage. The greater variability in fracture resistance observed in group II (cast post and core) may be attributable to the number of steps in the process of preparation of such devices that increased the number of variables.

Also, the results obtained in vitro, as in this study, may not accurately reflect the situation in vivo. For example, fracture resistance was determined by applying a heavy load to a single point; by contrast, in vivo failure typically occurs in response to light or moderate...
loads applied repeatedly over a long period. Furthermore, the long-term efficacy of carbon-fiber posts and composite cores is strongly influenced by long-term performance of the cements used at the post/tooth and post/core interfaces.

CONCLUSIONS

The following conclusions were drawn from this study:

1. Significantly higher fracture-threshold values were obtained in the cast-post and core group.
2. Teeth restored with carbon-fiber posts and composite cores typically showed failure of the post/core interface before the fracture of the tooth occurred. This failure occurred in response to acceptably high loads. By contrast, teeth restored with cast posts and cores typically showed fracture of the tooth, albeit in response to loads that rarely occur in vivo.

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REFERENCES


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