In Vitro Evaluation of a Carbon Fiber Post

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The purpose of this study was to evaluate the influence of endodontic and restorative procedures on fracture resistance of teeth, and to compare the incidence of root fracture in teeth with clinical crowns removed that were restored with three different types of post and a composite core build-up. Seven groups of 10 extracted maxillary canines were used. A control group had only a crown preparation, but no endodontic treatment. Three groups had endodontic treatment, crown preparation, and the access restored. Three groups had endodontic treatment, the crown totally removed, a tapered, parallel, or carbon post placed, and a composite build-up. All specimens were subjected to a 45-degree load at 0.5 mm/min until failure occurred. The force at failure and the location of fracture were recorded. The groups with post and composite build-ups failed at significantly lower force than the teeth in which the crowns had not been removed. There were no significant differences in the amount of force required to produce failure among the three groups with different posts and a composite build-up. The group restored with the carbon post had no root fractures, whereas there were five fractures in each of the parallel and tapered post groups.

A variety of post systems exist for the restoration of endodontically treated teeth that have inadequate remaining tooth structure. Caputo and Standlee (1) stated that posts are needed to allow the clinician to rebuild enough tooth structure to retain restorations. Posts do not strengthen teeth, and the loss of tooth structure from preparation weakens the root, leading to an increased incidence of root fracture. These authors stated that, “the price for more retention is the increasing risk of damaged tooth structure.”

Common prefabricated post designs include the tapered, parallel, and threaded designs. Tapered posts follow the prepared canal shape and conserve tooth structure, but they are less retentive and have been shown to cause nonrestorable root fractures (2-4). Parallel posts are more retentive, but more tooth structure must be removed that may result in a higher incidence of perforation failure (5, 6). Threaded posts are the most retentive and distribute stresses better in short roots, but the incidence of vertical root fracture is increased with the use of these posts (3, 6). In a retrospective study, Sorensen and Martinoff (6) demonstrated vertical root fracture to be a common mode of failure in teeth restored with posts, especially teeth restored with threaded or tapered posts.

Recently, a carbon fiber post has become available in the United States (C-Post, BISCO, Itasca, IL). Carbon fiber has certain properties that make it potentially useful in dentistry. It is biocompatible (7), corrosion-resistant (8), and strong (9). Most reports of potential uses of carbon fiber in dentistry are limited to reinforcement of existing restorative materials and as a possible post (10-13). The carbon fiber post is reported to have a modulus of elasticity that is nearly identical to that of dentin, so that it causes less tooth stress, resulting in fewer root fractures. By comparison, the modulus of elasticity for stainless steel is roughly 20 times greater than dentin; for titanium, the modulus of elasticity is 10 times greater than dentin (14). Posts with a high modulus of elasticity do not flex with the tooth under loading and are empirically believed to cause root fracture.

The purpose of this study was to: evaluate the influence of endodontic and restorative procedures on fracture resistance of teeth; and compare the incidence of root fracture among teeth restored with three different types of posts, each supporting a composite core build-up.

MATERIALS AND METHODS

Seventy extracted maxillary canines, free of cervical caries, were used for this study. All teeth were stored in a 0.01 M phosphate-buffered saline solution (Sigma Chemical Co., St. Louis, MO) before and during experimental storage times. Teeth were randomly divided into 7 groups of 10.

Ten teeth were not prepared endodontically to serve as controls (group 1). The other 60 teeth were endodontically instrumented at a working length 1 mm from the apex to a #35 master apical file. A step-back technique was used with stainless-steel K-files (Union Broach, New York, NY), Gates Glidden drills #2 to #4 (Union Broach), and 2.5% sodium hypochlorite irrigation. The prepared teeth were obturated with thermoplasticized, injectable gutta-percha (Obtura, Texceed Corp., Costa Mesa, CA) and resin sealer (AH-26, DeTrey, Zurich, Switzerland).
Groups were prepared and/or restored as follows.

**Group 1 (Coronally Prepared Control)**

Specimens were flattened occlusally with a fine-grit, diamond wheel, perpendicular to the long axis to a standardized length of 24 mm. A simulated crown preparation, 8 mm from incisal edge to cervical region, was made. The preparation was tapered from the cervical region to produce a 4 mm × 3 mm rectangle at the incisal edge. To ensure even distribution of force, a 2-mm, 45-degree, incisal-lingual bevel was placed.

**Group 2 (Endodontically/Coronally Prepared Control)**

The endodontic access of each tooth was entirely filled with gutta-percha. Samples were prepared coronally as in group 1.

**Group 3 (Composite-Restored Access)**

Gutta-percha was removed to a depth of 6 mm from the incisal edge with a hot instrument (Touch ‘n Heat, Analytic Technology, Redmond, WA). The chamber was restored with composite after etching for 15 s with 32% phosphoric acid and air drying for 5 s. Five coats of primers A and B (BISCO) were applied and air-dried for 5 s. All-Bond 2 resin (BISCO) was applied and light cured for 20 s. The access was filled in two increments of Bis Core base material (BISCO), which was light-cured for 20 s after each increment. Specimens were prepared coronally as for group 1.

**Group 4 (Carbon Fiber in Access)**

Post space was prepared by removing gutta-percha to a depth of 16 mm from the incisal edge using a hot instrument (Touch ‘n Heat) and C-Post pilot and finishing drills (BISCO). Post space was etched for 15 s, rinsed, and dried with paper points. Two coats of primers A and B (BISCO) and then one coat of Pre-Bond resin (BISCO) were applied to the post space and dried with a paper point. The C-Posts were lightly sand-blasted and coated with primer B. Posts were cemented with C & B luting cement (BISCO). The access was restored with composite as for group 3, and specimens were prepared coronally as for group 1.

**Group 5 (Carbon Fiber Post/Composite Core Restoration)**

Clinical crowns were removed with a fine-grit, diamond wheel, perpendicular to the long axis of the root. Remaining tooth length was standardized at 18 mm. Gutta-percha was removed to a depth of 14 mm from the incisal edge with a hot instrument (Touch ‘n Heat). Posts were cemented as in group 4, and a core restoration (BisCore, BISCO) of the same dimensions as the crown preparation in group 1 was placed using a custom-made acrylic jig.

**Group 6 (Tapered Stainless-Steel Post/Composite Core Restoration)**

Specimen preparation was similar to group 5, except #1 PD Post (Union Broach) was placed.

**Group 7 (Parallel Stainless-Steel Post/Composite Core Restoration)**

Specimen preparation was similar to group 5, except #1 ParaPost (Whaledent Int., NY, NY) was placed.

After preparation, each tooth was mounted in an aluminum sample well with epoxy resin (Buhler, Lake Bluff, IL). Samples were stored in aqueous-buffered phosphate solution until testing. A custom aluminum sample holder was used to position the specimens in the universal testing machine (model MTS-810; Materials Testing Systems, Inc., Minneapolis, MN) so that the load was directed at a 45-degree angle (Fig. 1). Samples were loaded at a rate of 0.5 mm/min until fracture occurred. The force at failure was measured in kilograms, and the type of fracture was recorded as the core debonded, the post fractured, or the tooth fractured.

Duncan’s multiple range test was used to determine the influence of preparation procedures or post type on resistance to fracture.

**RESULTS**

Results are summarized in Table 1. Sixty-nine specimens were available for statistical analysis. One sample from group 4 was omitted due to a recording error during testing. Mean values for fracture resistance were highest in the control group (189.4 kg) and lowest for the decoronated C-Post group (107.4 kg) (Fig. 2). Statistical analysis revealed that groups with intact crowns (groups 1 to 4) were significantly more fracture-resistant than groups with crowns removed and restored with a post and composite core.
TABLE 1. Specimen preparation and mean loads at fracture

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Endo</th>
<th>Post Type</th>
<th>Restoration</th>
<th>Load at Fracture</th>
<th>(SD kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>No</td>
<td>None</td>
<td>None</td>
<td>189.4</td>
<td>(33.7)</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>Yes</td>
<td>None</td>
<td>Gutta-percha</td>
<td>187.2</td>
<td>(59.1)</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>Yes</td>
<td>C-Post</td>
<td>Composite</td>
<td>182.1</td>
<td>(48.1)</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>Yes</td>
<td>Composite</td>
<td>Composite</td>
<td>163.8</td>
<td>(37.5)</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>Yes</td>
<td>PD Post</td>
<td>Composite core</td>
<td>107.4</td>
<td>(26.3)</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>Yes</td>
<td>ParaPost</td>
<td>Composite core</td>
<td>111.6</td>
<td>(19.0)</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>Yes</td>
<td></td>
<td>Composite core</td>
<td>107.8</td>
<td>(17.5)</td>
</tr>
</tbody>
</table>

![Fig 2. Mean loads at fracture.](image1)

build-up (groups 5 to 7). No significant differences in fracture resistance were noted among the four groups with crowns not removed. No significant differences in fracture resistance were noted among the three groups with crowns removed. The two groups restored with stainless-steel posts (groups 6 and 7) demonstrated a 50% incidence of root fracture, whereas the group restored with a carbon fiber post and composite core (group 5) had no root fractures (Figs. 3 and 4).

DISCUSSION

The loads at failure were significantly higher in the groups that did not have crowns removed. These specimens also had the greatest amount of intact tooth structure. This finding agrees with Trabert et al. (15), who found that the amount of remaining tooth structure was the most influential factor in predicting fracture resistance.

There was no significant difference between the groups with intact crowns restored with carbon posts (group 4) and those with intact crowns restored without a post (groups 1 to 3). This observation is in agreement with Guzy and Nicholls (16), who found no significant differences in endodontically treated teeth restored with or without a post. The values obtained for load at fracture in this study are greater than those in the Guzy and Nicholls study. This could be due to the load rate used; Guzy and Nicholls used 5 cm/min, whereas this study used 0.5 mm/min or 100 times lower/slower. Research by Espevik (17) demonstrated that materials undergo more plastic deformation at lower load rates leading to an increase in strength values.

This study obtained a load at fracture of 107 kg for groups without crowns and restored with either a ParaPost or C-Post and composite core. This finding agrees with a recent study by Cohen et al. (18) that demonstrated a load at fracture of 216.7 lb (98.2 kg) and 169.7 lb (77.1 kg) for teeth restored with TiCore (Essential Dental Systems, South Hackensack, NJ) and a C-Post or ParaPost, respectively. Their samples were loaded directly on the core material. Consequently, 79% of the samples failed by core fracture. Samples in this study were loaded directly on the core and post interface. This type of loading attempts to increase the load directed on the post. As a consequence, one specimen failed due to post fracture, whereas Cohen et al. (18) observed no post failures.

The design used in this study would also seem to increase the root stress due to post loading and increase the chance of root fracture. The rate of root fracture for this study for the groups restored with a post and core was 50% for the stainless-steel posts and 0% for the C-Post group.

Our finding of no root fractures in teeth restored with the C-Post and composite core is of interest when compared with a recent study by Isidor et al. (19) that evaluated cyclic loading of bovine
teeth restored with a C-Post, composite core, and crown. They found no failures of C-Post restored teeth after 260,000 cycles and no complete root fractures, but 4 of 14 specimens had incomplete longitudinal fractures. This compares with a 100% incidence of root fracture in teeth restored with a cast post and core and an 81% rate of root fracture in teeth restored with a ParaPost and subjected to identical cyclic loading conditions (20).

The design of this study did not include the fabrication of cast crowns for the specimens to place the posts in the restored specimens under maximum shear stress. Placement of cast crowns would give a more realistic picture of in vivo performance.

This study was supported by grants from the American Association of Endodontists Foundation and the Louisiana State University School of Dentistry. This study received further support from BISCO in the form of donated materials.

The authors thank Dr. Diana Gardiner for her statistical analysis of data and Dr. Xiaoming Xu for his assistance in sample testing.

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References