ORIGINAL ARTICLE

Fracture resistance of three post and core systems in endodontically treated teeth restored with all-ceramic crowns

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Abstract The restoration of endodontically treated teeth requires the fabrication of a post and core to provide retention and support for the final crowns. The objective of this study was to compare the fracture resistance of endodontically treated teeth restored with glass fiber post and composite resin cores, customized zirconia posts, and cast metal post and cores. A total of 40 human extracted mandibular first premolars were used for the study. The teeth were randomly divided into four groups. Group A represented a control group that did not receive any posts and was filled with core material only; Group B comprised cast metal posts and cores; Group C comprised custom milled zirconia posts and cores; and Group D comprised glass fiber posts. All groups were prepared to receive all ceramic crowns. All samples were subjected to compressive testing with an Instron machine (Universal Testing Machine) and fracture loads and failure patterns were analyzed. The findings indicated a statistically significant difference between the failure loads in the groups studied. The mean load required to fracture the zirconia custom posts was higher (765.1 ± 48.5 N) than the fiber posts and the cast posts and cores (P < 0.001). The fiber posts resisted a mean load of...
1. Introduction

Endodontically treated teeth with insufficient tooth structure are often restored with crowns (Carter et al., 1983; Sorensen and Martinoff, 1984). In teeth with substantial hard tissue loss resulting from cavities or trauma, posts are often necessary for providing sufficient retention for the core material (Perez et al., 2005). Although posts have been recommended to strengthen the teeth, several investigators have cautioned that posts with inadequate resistance to rotational forces can weaken the teeth (Zhi-Yue and Yu-Xing, 2003).

The fracture susceptibility of teeth restored with posts may be related to factors such as the amount of remaining tooth structure, which provides resistance to the fracture of the tooth (Ng et al., 2006), as well as the characteristics of the post, such as the material composition, modulus of elasticity, diameter, and length (Fokkinga et al., 2006). A Root fracture is the most serious type of failure in post-restored teeth (Testori et al., 1993; Wu et al., 2004). To avoid root fractures, a post having a modulus of elasticity similar to that of dentin helps in distributing the stress of occlusal load in a uniform pattern (Akkanay and Gulmez, 2002).

The cast gold post and core has been regarded as the "gold standard" in post-and-core restorations because of its superior success rate (Bergman and Lundquist, 1989; Creugers et al., 1993). Alternatives to cast metal posts and cores have been developed. The use of prefabricated posts and custom-made buildups with amalgam or composite resin has simplified the restorative procedure because all steps can be completed chairside with acceptable clinical success (Linde, 1984). The choice of an appropriate restoration for endodontically treated teeth is guided by strength and esthetics. The restoration of teeth with adhesively cemented internal restorations offers improved mechanical stability over cemented restorations (Trope and Tronstad, 1991).

The development of tooth colored posts has improved the esthetics of teeth restored with posts and cores (Sidoli et al., 1997; Mannocci et al., 1999; Rosentritt et al., 2000). Zirconium dioxide and glass fiber-reinforced composite resins (FRC), in particular, are the foundation of many modern post-and-core concepts (Qing et al., 2007). Several studies have investigated the fracture resistance of fiber posts since their introduction and compared it with that of the metal posts. Unfortunately, the results have not been consistent, with some authors reporting that endodontically treated teeth restored with fiber posts showed lower fracture resistance than that of teeth restored with metal posts (Martinez-Insua et al., 1998; Newman et al., 2003). Other authors, however, indicated the fracture resistance of fiber post–restored teeth to be equal to or greater than that of teeth restored with metal posts (Rosentritt et al., 2000; Raygot et al., 2001). Zirconia posts were first introduced by Meyenberg et al. (1995) who reported that the flexural strengths (900–1200 MPa) of these posts was comparable to that of cast gold or titanium, and that it is possible to have the same post dimensions as high gold alloys or titanium. Zirconia is a widely used material because of its good chemical stability, high mechanical strength, high toughness, and a Young’s modulus similar to that of stainless steel alloy (Piconi and Maccauro, 1999). Apart from its favorable chemical and physical properties, it has the esthetic advantage of having a color similar to that of natural teeth (Ahmad, 1998; Vichi et al., 2000). The high elastic modulus of elasticity of zirconia posts at 200 GPa (Guazzato et al., 2004) causes stress to be transferred to the less rigid dentin, thereby resulting in root fractures (Bateman et al., 2003). However, there is little consensus with regard to their mechanical behavior and reliability and other factors which would contribute to their optimal performance. Therefore the objective of the study was to compare the fracture resistance of endodontically treated teeth prepared with a 2 mm ferrule restored with a cast post and core, a glass fiber post with a composite resin core, and a customized zirconia post restored with an all-ceramic crown.

2. Materials and methods

2.1. Specimen preparation

A total of 40 sound, single-rooted mandibular first premolars with similar size and shape were collected. Root lengths were measured from apex to tip of the cusps, together with the buccolingual and mesiodistal dimensions at the highest bulge with a digital caliper (Schnitttaster, Dentsaurum, Germany). The specimens were stored in a solution of 0.9% saline at room temperature. Selection criteria also included the absence of root caries, restorations, or previous endodontic treatment. The teeth were divided into 4 groups of 10 specimens each. All teeth underwent root canal treatment. The root canals were instrumented manually in a step-back technique to an apical size of ISO 40. The canals were dried with absorbent paper points and obturated with gutta-percha (Roeko, Langenau, Germany) and sealer (AH plus, Dentsply DeTrey, Konstanz, Germany) with cold lateral condensation. After endodontic treatment, each root was thinly covered with a silicone impression material to simulate the thickness of the periodontal ligament (Imprint II Garant light-body by 3M ESPE). All teeth were embedded in an acrylic resin cube (RAPID REPAIR, Dentsply, Germany). The acrylic resin blocks were shaped to fit into a retentive device for fracture testing (Fig. 1).

2.2. Post space preparation

Post space preparation for all teeth was initiated after 7 days from obturation by the use of a universal starter drill at a
speed of 5000 rpm to a depth of 9 mm for the post space. The post space for all the groups was prepared with Gates Glidden size 1 up to size 4 (1.1 mm) (and size 5 to enlarge the canal orifice), keeping 4 to 5 mm as an apical seal (Fig. 1).

2.2.1. Teeth preparation before post cementation
All teeth were prepared to receive an all-ceramic crown with a finish line of 0.5 mm above the CEJ. The axial reduction was done with an MRD gauged diamond (Lot-NR 1599, DFS Dental and Technical Products, GmbH, Germany) which was attached to the milling machine (K9 Milling Apparatus-990, Kavo, Germany) for every group. The MRD gauged diamond had a self-limiting tip, which produced a 1 mm deep chamfer, and the margins and the angle of convergence were standardized. Each tooth after preparation had dentin support of 2 mm. The buccolingual and mesiodistal widths were measured with the calibrated gauge caliper to be approximately in the same range (Table 1). The ferrule used in this study was 2.0 mm. The occlusal surface of the prepared teeth was flattened to ensure the accurate fit of the posts.

2.3. Post and core fabrication
2.3.1. The control group
The gutta-percha was removed from the pulp chambers to 3-4 mm in depth. The dentine was etched for 15 seconds with 37 percent phosphoric acid gel (Total Etch). The surface was rinsed with water and dried with paper points. The bonding agent EXCITE F (Ivoclar, Vivadent) was applied and the multicore material was injected into the etched chambers. The core was then built with the same material to the desired dimensions.

2.3.2. Glass fiber post group
The glass fiber posts (RelyX, Fiber 3 M ESPE) were cemented and the core was built up with MULTICORE FLOW system (Ivoclar Vivadent). The dentin was etched for 15 seconds with 37% phosphoric acid gel (Total Etch). The surface was rinsed with water and dried with paper points. The bonding agent EXCITE F (Ivoclar, Vivadent) was applied and the multicore material was injected into the etched roots. Each post was placed to its full depth, and the core was contoured to the desired dimensions.

2.3.3. Cast post and core
Cast posts and cores were fabricated with Duralay (Reliance Dental Manufacturing, Worth, IL). Plastic Para-post systems were covered with Duralay, and an impression of the canal was made. The core was also built with the same material. All of the specimens were then prepared to final premeasured dimensions. Posts and cores were invested in Beauty-Cast (Whip Mix Corp., Louisville, KY) without a ring liner. After casting, each post and core was tried to verify the fit and cemented with zinc phosphate cement (Mizzy Inc., Cherry Hill, NJ).

2.3.4. Zirconia post and core group
The same technique for fabricating the cast post and core was used, except that the Duralay buildup of the post and cores was scanned and the presintered Y-TZP Cercon Base blanks were milled with the Cercon brain unit (DeguDent, Hanau, Germany) according to the manufacturer’s instructions. The Zirconia posts were cemented with glass ionomer cement GIC (GC Fuji I by GC America) and seated for 7 min with finger pressure.

2.4. Restorative procedures
1. Group A (Control). No post was placed. Only the core material was placed and served as the control group for comparison of the results.
2. Group B (Cast Post and Core).
3. Group C (Fiber post).
4. Group D (Customized zirconium post)

2.5. Crown fabrication
After post and core cementation and finalization of the tooth preparation, the distance from the finish line to the occlusal surface of the preparation was 4 mm. Each tooth preparation from all the groups was measured with a digital caliper to ensure similar dimensions both mesiodistally and buccolingually. Final impressions were made for all the specimen with a polyvinylsiloxane impression material (Elite by Zhermack), and the master die was fabricated with die Stone (Heraeus Kulzer, Hanau, Germany).

Table 1  
Dimension of prepared tooth.

<table>
<thead>
<tr>
<th></th>
<th>Buccolingual</th>
<th></th>
<th>Mesiodistal</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Mean (mm)</td>
<td>Range (mm)</td>
<td>Mean (mm)</td>
<td>Range (mm)</td>
</tr>
<tr>
<td>Control group (A)</td>
<td>3.38</td>
<td>3–3.7</td>
<td>5.2</td>
<td>5–5.4</td>
</tr>
<tr>
<td>Cast post-core (B)</td>
<td>4.3</td>
<td>3.7–4.81</td>
<td>5.46</td>
<td>4.75–5.87</td>
</tr>
<tr>
<td>Glass fiber post (C)</td>
<td>3.34</td>
<td>3.2–3.54</td>
<td>4.8</td>
<td>4.34–5.3</td>
</tr>
<tr>
<td>Zircon (D)</td>
<td>3.2</td>
<td>3.00–3.60</td>
<td>5.16</td>
<td>5–5.25</td>
</tr>
</tbody>
</table>

Figure 1  Line diagram showing tooth preparation and embedding in acrylic resin for testing in Instron machine.
Zirconia copings were made by scanning the master die. The presintered Y-TZP Cercon base blanks were milled with the Cercon brain unit (DeguDent, Hanau, Germany) according to the manufacturer's instructions. All the copings were steam cleaned, and porcelain veneering was done and measurements were made after ceramic application to maintain the same thickness of ceramic for all the specimens.

The crowns were cleaned with ethanol, dried, and cemented with glass ionomer cement (GC Fuji I by GC America). The restorations were kept on the prepared samples under finger pressure for 30s, and excess cement was removed with a sharp instrument after 10 min. After the cementation procedures, the samples were again maintained in a wet condition. Calibration for each step and procedure in this study was done by the same examiner for each specimen.

2.6. Fracture strength test

The specimens were tested with a universal testing machine (Instron 8500 Plus, 100 Royal St. Canton, USA), set to deliver an increasing load until fracture. The specimens were placed at an angle of 45 degree to the long axis of the tooth, with the application point midway between the lingual slope of the buccal cusp, and between the central fissure and the cusp tip (Figs. 2 and 3). The crosshead speed of 0.01 cm/min was used, and the load was applied at an angle of 45 degrees to the long axis of the tooth. The force applied was recorded in newtons. After loading, the mode of failure was recorded for each specimen and classified as either a favorable fracture above the cementoenamel junction (repairable) or a catastrophic fracture of the root below the cementoenamel junction (nonrepairable) (Table 2). These inspections were made with a stereomicroscope (Stereoscopic zoom microscope, SMZ-1000, Nikon, Japan).

2.7. Statistical analysis

The fracture resistance (maximum load-to-failure) after loading was compared among the 3 post types with a 1-way analysis of variance (ANOVA). Comparisons among the pairs were performed with a Student-Newman-Keuls Multiple Comparisons Test exhibiting a $P$-value of $<0.05$, which was significant.

3. Results

3.1. Fracture strength test

The mean and standard deviations for failure loads were shown in Fig. 4. A statistically significant difference was observed among the failure loads in the groups studied. The load required to fracture the zirconia custom post was higher ($765.1 \pm 48.5$ N) than the fiber post and cast post and core ($P < 0.001$). The fiber post resisted a load of $561.4 \pm 37.2$ N, which was higher than the cast post and core (Fig. 4). However, the values were not statistically significant within these 2 groups.

4. Discussion

The task of restoring endodontically treated teeth is encountered almost daily in prosthodontic practice. Leempoel et al. (1987) evaluated a large sample of teeth with single crown...
restorations and found that 39% were nonvital and had received some type of post restoration. In an effort to improve the fracture resistance of endodontically treated teeth restored with a post-and-core system, research has focused on post materials, post designs, luting agents, and ferrule effect (Mendoza et al., 1997; Martinez-Insua et al., 1998; Akkayan, 2004).

In the current study, all specimens were restored and tested with complete-coverage of crowns to ensure standardization. The placement of a crown during endodontic restoration testing has been questioned, as this practice may obscure the effects of different buildup techniques (Sorensen and Engelman, 1990; Libman and Nicholls, 1995). It is true that a crown creates a ferrule effect and variation in the load distribution when placed over a core buildup if the margins encircle a sound dentin collar (Butz et al., 2001). However, testing post and core preparations without placement of a crown would not have reflected clinical practice.

The current study attempted to compare the conventional metal post and core with fiber post and custom-milled zirconia posts. It has been reported that more rigid reconstructions are unable to absorb stress and are therefore susceptible to failure (Sidoli et al., 1997; Mannocci et al., 1999). The observations in the present study may be attributed to the fact that zirconia posts had the highest modulus of elasticity among the post types tested. Higher modulus of elasticity results in less bending of the post/core unit under load; consequently, less stress is exerted on the tooth (Butz et al., 2001). The failure pattern between the custom milled zirconia post and the conventional cast post and core were similar (Table 2) and were classified as a nonrestorable fracture, which may be attributed to the rigidity of the post.

Available prefabricated fiber posts may be too wide for some canals, especially mandibular incisors, and may exhibit poor adaption to noncircular canals. Their use is limited when there is insufficient coronal tooth structure (ferrule less than 2 mm) because of their lower modulus of elasticity, and they may undergo flexure under functional stress and produce micromovement at the core, producing decementation of the crown (Ng et al., 2006). The fracture resistance of this group was comparable with that of the custom cast post and core (Fig. 2). With regard to the failure pattern, the fiber post group exhibited more favorable fracture patterns (restorable) above the cementoenamel junction than the cast post and core group (Table 2).

Fracture strength values from other studies were not comparable with the results of the present study because of differences in research design. Moreover, in the present study, the zirconia posts were custom milled unlike other studies which used prefabricated zirconia posts (Sorensen and Engelman, 1990; Butz et al., 2001). The results of this study suggest that custom milled zirconia posts and cores can be used when esthetics are important, and when the anatomy of the root canal combined with the extensive loss of coronal tooth structure requires the use of a custom post.

5. Conclusions

1. All 3 post and core systems performed favorably under compressive testing.
2. The load required to fracture the zirconia custom post was higher compared to the fiber post and cast post and core.
3. The fiber post resisted a load higher than the cast post and core.
4. The fracture patterns of the teeth restored with fiber posts were favorable (70%).
5. Multiple cracks were seen with the zirconia post group within the root body (90% nonrestorable).

References


