SUMMARY

Ceramic root-canal posts offer potential advantages over other types with respect to aesthetics and biocompatibility. Any post must be sufficiently rigid and retentive to withstand functional forces. Ceraposts (1.2 mm coronal diameter, ceramic, tapering, smooth posts) and Paraposts (1.25 mm, stainless-steel, parallel, serrated posts) were tested for rigidity by means of a three-point bending test. To test retention in roots, ceramic posts were cemented using one of three protocols: (1) glass-ionomer cement, (2) silane coupling agent and resin cement, or (3) sandblasted post surface, silane coupling agent, and resin cement. Stainless-steel posts were cemented with resin. The tensile force required to dislodge the posts, following four weeks of storage in water, was recorded. Data were compared using Student’s t-test and Mann-Whitney U analysis. Ceraposts were significantly more rigid than Paraposts (p<0.001). Paraposts cemented with resin were significantly more strongly retained than Ceraposts following any cementation protocol (p<0.001). Retention of the ceramic posts was significantly greater with a silane coupling agent and resin cement than with glass-ionomer cement (p<0.001). Sandblasting the ceramic posts produced variable results and needs further investigation before it could be recommended.

INTRODUCTION

Parallel-sided, serrated, stainless-steel posts, typified by the Parapost, have a long record of clinical success, and in many countries represent the industry standard for prefabricated posts (Schwartz, Summitt & Robbins, 1996; Torbjörner, Karlsson & Ödman, 1995). Issues of aesthetics and biocompatibility have led dentists and patients to increasingly demand metal-free restorations. Consequently, there has been progress in the search for durable, aesthetic, biocompatible ceramic and resin restorations.

The excellent biocompatibility of ceramics has been established for some time. In addition, many ceramic restorative materials have a high degree of translucency (Anusavice, 1996). This can allow light transmission into the underlying tooth tissue, thereby avoiding the root darkening that commonly occurs in teeth restored with opaque materials. Historically, the disadvantage of ceramic materials has been their low flexural strength compared with metals.
In function, ceramic restorations have a record of frequent failure in high-stress situations (Anusavice, 1996). Recently developed ceramic materials consisting of zirconium dioxide stabilized with small amounts of yttrium oxide offer high flexural strength and toughness (Christel & others, 1989; Shimizu & others, 1993). Root-canal posts made of these materials are commercially available and offer the potential for post and core restorations with adequate strength for normal function and the advantage of superior aesthetics to current alternative systems. A clinical trial has been reported in which 80 ceramic posts with composite resin or ceramic cores were observed over 16.6 ± 9.1 months. No posts were fractured and none were lost to debonding (Kern, Simon & Strub, 1998).

Although the ceramic and stainless steel posts are quite different products, either post could be chosen in a given clinical situation, making comparisons between the two clinically relevant. Therefore, the purposes of this study were (1) to compare the rigidity of ceramic root-canal posts with stainless-steel posts of similar size, and (2) to compare the retention in roots of ceramic posts using three different cementation regimens with the retention of stainless-steel posts.

METHODS AND MATERIALS

Rigidity Test
The ceramic posts tested (Cerapost; Gebr Brasseler, Lemgo, Germany) are made of 94.9% zirconium dioxide (ZrO₂), stabilized with 5.1% yttrium oxide (Y₂O₃). Ten size 50 ceramic posts, which measure 0.5 mm in diameter at the apical tip and 1.2 mm in diameter in the coronal portion, were tested for rigidity using a three-point bending test in a Universal Testing Machine (Instron, High Wycombe, UK). The test is a variation of the ASTM standard method, designation E 855-84. The posts were supported as shown in Figure 1 with the parallel-sided coronal portion spanning the test jig, and the load applied at the midpoint. The crosshead speed of the testing machine was 5 mm per minute, and the load was applied until the posts fractured. Ten 1.25 mm stainless-steel, serrated posts (Parapost; Coltène/Whaledent Inc, Mahwah, NJ 07430) were tested in a similar manner. Loading of these posts continued until they reached their yield point, as indicated by the force/deflection curve becoming nonlinear.

All of the data were recorded in an Apple Macintosh computer using MacLab Chart software. A plot of force (N) versus deflection (µm) was made for each post. The gradients of the plots for the two groups of posts were compared using Student’s t-tests. The mean gradient for each post type was calculated and used for graphic depiction of the comparison.

Retention Test
Forty single-rooted human teeth, free of defects or restorations in the roots and with narrow, unfilled root canals, were selected for use in the study. The teeth were sectioned horizontally 1 mm above the labial cemento-enamel junction. The roots were grooved on their outside surfaces using a diamond bur in a high-speed handpiece, embedded in individual acrylic blocks with the root face exposed, and stored in sterile, deionized water at room temperature until tested.

The root canals were prepared using the step-down method (Goerig, Michelich & Schultz, 1982) with 2.5% sodium hypochlorite irrigation. This is a modification of the step-back technique, resulting in a flared preparation with minimal apical enlargement. The canals were filled with laterally-condensed gutta-percha and AH26 sealer (Dentsply DeTrey Division, Dentsply Ltd, Weybridge, Surrey, UK). The roots were randomly assigned to four groups of 10. For all groups post-canal preparations were made to a depth of 10 mm by removing gutta-percha with Gates-Glidden drills (Dentsply Maillefer, Ballaigues, Switzerland) and preparing the canals with the post-hole drills supplied by the manufacturer of the posts to be cemented.

In Group 1 the dentin of the post canals was etched for 15 seconds with 37% phosphoric acid gel, rinsed with water for 30 seconds, and dried with paper points. The stainless-steel posts were cleaned with isopropyl alcohol and air dried. Each post was cemented to full depth with freshly mixed resin cement (Flexi-Flow Natural; Essential Dental Systems, Hackensack, NJ 07606) introduced into the canal by a Pastinject spiral filler (Micro Mega, Besancon, France), and held in position for 15 minutes.

Groups of ceramic posts were cemented using one of the three alternative cementing regimens suggested by the manufacturer.

In Group 2 the root portion of the ceramic posts was sandblasted by rotating the post for 10 seconds in a stream of 50 µm aluminium oxide. They were cleaned with isopropyl alcohol, air dried, and coated with silane primer (3M Scotchbond Ceramic Primer; 3M Dental Products, St Paul, MN 55144) used according to the manufacturer’s instructions. The dentin of the post canal was instrumented with the diamond roughening instrument supplied by the manufacturer. Dentin etching, rinsing, drying, and cementation were the same as for Group 1.

In Group 3 the ceramic posts were cleaned with isopropyl alcohol, air dried, and silane coated. Dentin roughening was the same as for Group 2. Etching, rinsing, drying, and cementation were the same as for Groups 1 and 2.

In Group 4 the dentin of the post canals was rinsed with water and dried with paper points. The ceramic posts were cleaned with isopropyl alcohol, air dried, and cemented to full depth with freshly mixed capsulated glass-ionomer cement (Fuji 1; GC Corp, Tokyo, Japan) and held in place for 15 minutes.

Following storage of all specimens in sterile, deionized water at room temperature for four weeks, the portions of the ceramic posts extending from the roots had pieces
of close fitting, stainless-steel tube cemented to them to provide protection from crushing in the vice of the testing machine. Each specimen was then placed into a retention device and mounted in the testing machine. Figure 2 shows the arrangement of post, root, acrylic block, and retention testing device. A universal coupling in the testing machine ensured that the load was directed axially along the post. The crosshead speed of the testing machine operated at 5 mm per minute, and the tensile force (N) required to remove the post from the root was recorded using the computer software as described above. The data for each group were statistically compared with the other groups using Student’s t-tests and Mann-Whitney U tests.

The ceramic posts were inspected visually after testing to determine the mode of failure, by looking for traces of cement on their surfaces.

**Electron Microscopy**

Scanning electron microscopy (SEM) was used to examine the surface topography of the posts as supplied by the manufacturer, following sandblasting, and the fractured surfaces of five posts chosen at random following the three-point bending tests. Specimens were mounted onto SEM stubs with silver paste and prepared for examination by gold coating in a Poloron E5100 coating unit (Poloron Equipment Ltd, Watford, UK). Representative black-and-white photographs were taken at various magnifications when viewed with a Cambridge stereoscopic 360SEM (Cambridge Instruments Co, Cambridge, UK).

**RESULTS**

**Rigidity Test**

The force versus deflection gradients for the 10 ceramic posts and the 10 stainless-steel posts (Table 1) were compared using Student’s t-test. This revealed that the ceramic posts were significantly more rigid than the stainless-steel posts (p<0.001). Figure 3 shows the mean gradient for the ceramic posts (1.96 ± 0.2) and for the stainless-steel posts (0.18 ± 0.03). The highest points on the two plots represent the force and deflection values at the yield points of the posts. At these points the ceramic posts fractured and the stainless-steel posts became permanently deformed.

**Retention Test**

The mean retention values for the four groups of posts are shown in Table 2. Stainless-steel posts cemented with resin cement were more strongly retained than ceramic posts following any cementation protocol (p<0.001). The only other significant result was that the ceramic posts cemented with glass-ionomer cement were less strongly retained than when cemented with resin (p<0.001). Some of the sandblasted posts fractured during the retention tests.

<table>
<thead>
<tr>
<th>Table 1: Rigidity of Posts Determined by Force/Deflection (Gradient)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ceramic Posts</strong></td>
</tr>
<tr>
<td>force (N)</td>
</tr>
<tr>
<td>268.8</td>
</tr>
<tr>
<td>237.8</td>
</tr>
<tr>
<td>249.0</td>
</tr>
<tr>
<td>140.5</td>
</tr>
<tr>
<td>250.3</td>
</tr>
<tr>
<td>221.1</td>
</tr>
<tr>
<td>246.0</td>
</tr>
<tr>
<td>204.8</td>
</tr>
<tr>
<td>264.8</td>
</tr>
<tr>
<td>287.8</td>
</tr>
</tbody>
</table>

Student’s t-test revealed that ceramic posts were more rigid than stainless steel posts (p<0.001).
Visual examination of the ceramic posts revealed that in Group 4 (glass ionomer) all of the posts were clean after the retention test, indicating that the mode of failure was adhesive at the interface of the glass-ionomer cement and the posts. In Groups 2 and 3 traces of resin cement were found adhering to all of the posts, suggesting a partly cohesive mode of failure.

**Electron Microscopy**

Electron microscopic examination of the ceramic posts, as supplied by the manufacturer, revealed a rough, granular surface texture with no pattern (Figure 4A). Following sandblasting for 10 seconds with 50 µm alumina, the surface assumed a more regular pattern with parallel, circumferential corrugations approximately 4 µm in width (Figure 4B).

The fractured surfaces of the posts used in the bending tests were all of similar appearance (Figure 5). The portion of the post in compression, namely the half of the post adjacent to the moving head of the testing machine, suffered a fracture at right angles to its long axis, leaving a rough surface. From about midway through the post, the path of fracture deviated, turning 90 degrees to run along the long axis of the post, then turned abruptly again to exit the surface in tension at an oblique angle. The fractured surface of the portion in tension was smoother than that in compression.

**DISCUSSION**

As predicted from the results of other studies (Christel & others, 1989; Shimizu & others, 1993), the rigidity of the ceramic posts was very high. Ichikawa and others (1992) demonstrated that zirconia has twice the rigidity of polycrystalline aluminous ceramic. In the present study the zirconia posts exhibited higher resistance to bending than stainless steel, and also the typically brittle behavior of all ceramics, that of low ability to tolerate strain before fracture.

The high retention value of the serrated stainless-steel posts and the relatively low retention of the ceramic posts with glass-ionomer cement is consistent with previous work on the effects of shape and surface texture (Standlee, Caputo & Hanson, 1978). High retention can be predicted for parallel, serrated posts, and low retention can be predicted for tapered, smooth posts. Jørgensen and Holst (1967) demonstrated that cements with higher compressive strength produce a proportionally greater retention. This would partly explain the stronger retention of the ceramic posts with resin cement than with glass-ionomer cement. The silane coupling agents may have enhanced the bond between resin and post, as these materials are proven mediators of adhesion between resins and some ceramics (Eames & others, 1977). This may account for the retention of fragments of cement on ceramic posts after retention testing. However, the durability of bonds between silanated zirconia ceramic and BIS-GMA resin has been questioned by Kern and Wegner (1998), who found that the bond failed spontaneously after 150 days of water storage with thermocycling.

Sandblasting the ceramic posts could be predicted to enhance retention by improving mechanical interlocking of the cement and post. The regular pattern of grooves produced by the sandblasting reflected the way in which the posts were rotated in the stream of particles. The sandblasted group showed a trend towards improved retention. However, the retention of a number of specimens in this group was strong enough to result in fracture of the posts before the retention failed. The sandblasting process could have weakened the ceramic by introducing surface flaws that acted as crack initiation sites, or alternatively, the energy imparted by sandblasting may have modified the crystalline structure of the surface. A third possibility is

<p>| Table 2: Comparison of the Mean Force (N) to Cause Retentive Failure of Group* with Other Groups |</p>
<table>
<thead>
<tr>
<th>Group</th>
<th>Force (N)</th>
<th>t test</th>
<th>Mann-Whitney U</th>
</tr>
</thead>
<tbody>
<tr>
<td>1*</td>
<td>394±23</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>2</td>
<td>190±95</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>3</td>
<td>118±21</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>4</td>
<td>54±90</td>
<td>&gt;0.05</td>
<td>&gt;0.1</td>
</tr>
<tr>
<td>2*</td>
<td>190±95</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>3</td>
<td>118±21</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>4</td>
<td>54±90</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Group 1: stainless steel post, resin cement
Group 2: sandblasted ceramic post, resin cement
Group 3: ceramic post, silane, resin cement
Group 4: ceramic post, glass ionomer cement
simply that the ceramic was not weakened, but its tensile strength was exceeded during the retention test.

CONCLUSIONS

The ceramic root-canal posts (Cerapost) were significantly more rigid than the stainless-steel posts (Parapost).

The serrated, parallel, stainless-steel posts were significantly more retentive in roots than the smooth, tapering, ceramic posts.

A silane coupling agent and resin cement produced significantly stronger retention of the ceramic posts than that produced by glass-ionomer cement.

Sandblasting of the ceramic posts produced variable results and needs further investigation before it can be recommended.

(Received 4 January 1999)

References


