Retentive Force of Three Fiber-reinforced Resin Composite Posts and a Zirconia Post Cemented with Two Adhesive Luting Agents: In Vitro Study

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By means of a pull-out test, this study compared the retentive force of three fiber-reinforced resin composite posts and a zirconia post. These posts were cemented using two different dual-polymerizing adhesive resin luting agents.

Forty freshly extracted canines were selected for the study. All tooth root were endodontically treated and the post spaces prepared. The posts were luted using luting agents according to the manufacturers’ guidelines. A tensile force was applied, and all data were collected and analyzed statistically. Glass fiber posts that were luted with Panavia F (Group 3) had the highest median load (3.610 N), while zirconia posts that were luted with RelyX ARC (Group 6) had the lowest median load (0.926 N). Among the different post systems that were luted with Rely X ARC, significant differences were observed in their median tensile loads (p<0.047). When comparing between Panavia F and RelyX ARC of each post system, a significantly higher tensile load was seen with zirconia posts luted with Panavia F (Group 7) (p<0.032).

Keywords: Ceramic posts, Adhesive luting agent, Pull-out test

INTRODUCTION

Posts were originally designed to retain coronal restorations when inadequately tooth structure remained10. They were later viewed as a method of reinforcing endodontically treated teeth10. Some clinicians have advocated rigid cast metal posts and cores as the restorative method of choice for endodontically treated teeth10. However, the growing demand for esthetic restorations in dentistry has led to the development of tooth-colored, metal free post and core systems9. Moreover, while posts and cores used to restore endodontically treated teeth should be strong, it is also now preferable for the post to fail in response to mechanical stress before the remaining dental structure did10. This is a preferred failure mode as it is protective to the remaining dental structure.

Heydecke et al.10 reported that the choice of an appropriate restoration for endodontically treated teeth is guided by strength and esthetics. With recent advances in ceramic technology, all-ceramic crowns have become more popular. Still on this issue about esthetics, Sorensen and Mito9 suggested that a post-core restoration supporting a translucent all-ceramic crown should not adversely affect the esthetic qualities of the definitive restoration. On this account, new tooth-colored posts can potentially improve the esthetics of teeth restored with dowels and cores9,20.

Zirconia posts were developed in the late 1980s in response to the need for a post that possessed optical properties compatible with an all-ceramic crown11,12. The post was made from fine-grained, dense tetragonal zirconia polycrystals (TZP), and zirconia posts are reported to possess high flexural strength and fracture toughness11,13,16. Glass and quartz fiber-reinforced post systems, with elastic moduli comparable to that of dentin, were subsequently introduced14,15. Freedman10 reported that the types of failure that occurred with these post systems were primarily post-and-core fractures that could potentially allow retreatment of the tooth. Of late, translucent quartz fiber post systems were introduced as a means to achieve optimal esthetics.

With regard to factors that influence restoration survival, post retention is believed to be a major factor. To achieve adequate retention, posts are bonded to the root canal with cement. Therefore, the cement with the greatest retention should perform the best. With ceramic posts, the use of light-polymerized luting agents has been recommended9.

The objective of this study, therefore was to compare the retentive force of three different fiber-reinforced resin composite posts and a zirconia post cemented with two different dual-polymerizing adhesive resin luting agents. A pull-out test was used to measure the retentive strength, revealing the maximum and minimum pull-out failure loads.

MATERIALS AND METHODS

Tooth specimens
Forty freshly extracted canines free of cracks, caries, fractures, and restorations were selected for the study. All external debris was removed using an ultrasonic scaler (Mini Piezon, EMS Piezon Systems, Nyon, Switzerland), and the teeth were stored in 37°C saline solution until use. The anatomic crowns

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of all teeth were removed perpendicular to the long axis of the tooth, from the most incisal point of the proximal cementoenamel junction (CEJ), using a water-cooled diamond bur (R837,014; Diatech, Geneva, Switzerland) and an air turbine (Midwest 8000, Dentsply, York, PA) at 300,000 rpm. Root length were measured from the CEJ on the facial surface, and the widest faciolingual and mesiodistal dimensions of each specimen were determined using digital calipers accurate to 1 μm (Digimatic Caliper Model 500-196, Mitutoyo, Aurora, IL).

Eight experimental groups were formed due to the different combinations of post systems and dual-polymerizing adhesive resin luting agents used in this study (Table 1). Prepared tooth specimens were assigned randomly to these eight groups, with five teeth in each group (Table 2). Root dimensions were assessed using two-way analysis of variance (ANOVA), and no significant differences in dimensions were found across the groups (α = .05).

Table 1 Post systems and luting agents used in this study

<table>
<thead>
<tr>
<th>Product</th>
<th>Manufacturer</th>
<th>Composition*</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-T Light Post</td>
<td>Recherches Techniques Dentaires, St. Egreve, France</td>
<td>Quartz fiber</td>
</tr>
<tr>
<td>Snow Post</td>
<td>Kuraray Dental, Osaka, Japan</td>
<td>Glass fiber</td>
</tr>
<tr>
<td>Easy Post</td>
<td>Dentsply Maillefer, Ballaigues, Switzerland</td>
<td>Glass fiber + zirconia</td>
</tr>
<tr>
<td>Cosmo Post</td>
<td>Ivoclar Vivadent, Schaan, Liechtenstein</td>
<td>Zirconia</td>
</tr>
<tr>
<td>Panavia F</td>
<td>Kuraray Dental, Osaka, Japan</td>
<td>Bis-GMA with 10-methacryloyloxydecyl dihydrogen phosphate (MDP)</td>
</tr>
<tr>
<td>Rely-X ARC</td>
<td>3M Dental Products, St Paul, MN</td>
<td>Bis-GMA, TEGDM, zirconia, silica filler dimethacrylate polymer, amine</td>
</tr>
</tbody>
</table>

*According to manufacturer

Table 2 Experimental groups of this study

<table>
<thead>
<tr>
<th>Group</th>
<th>Post system (mm)</th>
<th>Cement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>D-T Light Post (0.9)</td>
<td>Panavia F</td>
</tr>
<tr>
<td>Group 2</td>
<td>D-T Light Post (0.9)</td>
<td>Rely X ARC</td>
</tr>
<tr>
<td>Group 3</td>
<td>Snow Post (1.0)</td>
<td>Panavia F</td>
</tr>
<tr>
<td>Group 4</td>
<td>Snow Post (1.0)</td>
<td>Rely X ARC</td>
</tr>
<tr>
<td>Group 5</td>
<td>Easy Post (1.0)</td>
<td>Panavia F</td>
</tr>
<tr>
<td>Group 6</td>
<td>Easy Post (1.0)</td>
<td>Rely X ARC</td>
</tr>
<tr>
<td>Group 7</td>
<td>Cosmo Post (1.4)</td>
<td>Panavia F</td>
</tr>
<tr>
<td>Group 8</td>
<td>Cosmo Post (1.4)</td>
<td>Rely X ARC</td>
</tr>
</tbody>
</table>

Post insertion
Each post system was luted with two different dual-polymerizing adhesive resin luting agents (Rely X ARC, 3M Dental Products, St. Paul, MN; Panavia F, Kuraray Dental, Osaka, Japan) according to the manufacturers’ guidelines. A thin layer of cement was also inserted into the canal, and any excess cement was removed. The coronal end of the post was positioned in direct contact with the tip of a light unit (Pololit Lux Halogen Light; VOCO, Cuxhaven, Germany) and was polymerized for 40 seconds. Light intensity produced was 800 mW/cm², and was calibrated using a built-in digital radiometer on the light unit before each exposure to ensure accuracy.

Pull-out test
The specimens were secured in an Instron universal testing machine (Testometric Micro 5000, High Wycombe, UK), whereby a device that loaded the tooth vertically. A tensile force was then applied at a crosshead speed of 1 mm/min (Figs. 1 and 2). Pull-out threshold was defined as the point at which the specimen could no longer withstand the increasing
Comparison in retentive force of posts

Fig. 1 A view of the specimen with pull-out test.

Fig. 2 A view of the specimen with pull-out test.

Fig. 3 A view of the specimen with pull-out test.

load, and whereby the post was pulled out of the tooth (Fig. 3).

Statistical analysis
All data were collected and analyzed statistically using non-parametric methods that have no assumptions about the underlying distribution of the data. In particular, Kruskal-Wallis and Mann-Whitney tests were used to analyze the data. Median values were calculated for each group of variables, because a median is more appropriate for small sample size.

Two-sided p-values were considered statistically significant at p<0.05. Statistical analyses were carried out using a statistical package, SPSS 12.0 for Windows (SPSS Inc., Chicago, IL, USA).

RESULTS
Median failure loads for the eight groups are listed in Table 3. Group 3 had the highest median load (3,610 N), while Group 8 had the lowest median load (0.926 N).

To evaluate the post systems, Groups 1, 3, 5, and 7 - which used the Panavia F luting agent - were analyzed using the Kruskal-Wallis Test. No significant differences were observed among the groups.

In addition, Groups 2, 4, 6, and 8 - which used RelyX ARC luting agent - were analyzed using the Kruskal-Wallis test. This time, significant differences were observed among the groups (p<0.047).

Mann-Whitney test was used to analyze the data between the luting agent groups for each post system. According to Mann-Whitney test, the difference between Group 7 and Group 8 was significant (p<0.032). Group 7 withstood a significantly higher median load (1.836 N) than Group 8 (0.926 N).

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Median failure load (Newton)</th>
<th>Minimum failure load (Newton)</th>
<th>Maximum failure load (Newton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>5</td>
<td>1.846</td>
<td>0.622</td>
<td>2.663</td>
</tr>
<tr>
<td>Group 2</td>
<td>5</td>
<td>1.224</td>
<td>0.515</td>
<td>4.704</td>
</tr>
<tr>
<td>Group 3</td>
<td>5</td>
<td>3.610</td>
<td>1.130</td>
<td>5.408</td>
</tr>
<tr>
<td>Group 4</td>
<td>5</td>
<td>1.782</td>
<td>1.313</td>
<td>2.294</td>
</tr>
<tr>
<td>Group 5</td>
<td>5</td>
<td>2.010</td>
<td>0.612</td>
<td>2.924</td>
</tr>
<tr>
<td>Group 6</td>
<td>5</td>
<td>0.933</td>
<td>0.622</td>
<td>2.533</td>
</tr>
<tr>
<td>Group 7</td>
<td>5</td>
<td>1.836</td>
<td>1.542</td>
<td>3.877</td>
</tr>
<tr>
<td>Group 8</td>
<td>5</td>
<td>0.926</td>
<td>0.627</td>
<td>1.561</td>
</tr>
</tbody>
</table>
DISCUSSION

In this in vitro study, teeth were carefully selected for standardized size and quality. Nevertheless, considerable variation in the resistance to fracture and dowel pullout was observed. However, a similar variation trend occurred in all of the experimental groups. Based on the statistical analysis of the results, the use of extracted teeth for this study appeared valid.

The mean root size was 15.41 ± 1.18 mm in length and 6.29 ± 0.45 mm in mesiodistal width. Conscientious attempts were made to calibrate the canal preparations. To prepare the post space, special size-matching preparation burs of 1.6 mm diameter for the post systems were used. Post preparation terminated at 7 mm coronal to the root apex for each tooth; therefore, the post length varied with root length. To minimize the variation in post length, teeth were selected carefully to ensure a similar root length.

Access opening and root canal instrumentation were simulated. However, owing to the large number of samples in this study, canal obturation procedure was expeditiously omitted. This was because canal obturation has little or no effect on root strength\(^{16,20}\). However, if the obturation procedure had been performed using endodontic sealer containing eugenol, the eugenol might affect the setting characteristics and bonding properties of the resin cement. It should also be mentioned that thermocycling procedures were not used in this study, as these simulated clinical conditions might affect the results. As such, further studies that better simulate the oral environment are recommended.

In this study, the load at which the post was pulled out of the root canal or when the post failed was recorded. One goal in the restoration of an endodontically treated tooth is to preserve the remaining tooth structure if the restoration fails. Post fracture might allow retreatment, although retrieving a broken post without irreversibly damaging the tooth is a considerable challenge.

Retention of prefabricated posts in the root canal is affected mostly by post dimensions, shape, and surface roughness. Each prefabricated post system is manufactured in various widths and lengths to enable a selection to fit a given clinical situation. It should be highlighted that in the present study, the effect of post length was not considered as a research variable.

In this in vitro study, Snow Post luted with Panavia F (Group 3) had the highest median load (3.610 N). Snow Post used a silanation mechanism to produce chemical bonding between the bonding cement and the post. Silane is a coupling agent that promotes adhesion by causing a chemical reaction on the surfaces of minerals (such as glass or ceramic) and polymers (such as epoxy, polyester, or methacrylate resins). With the minerals, this reaction is a condensation reaction. With the polymers, it is an addition reaction and a copolymerization reaction with terminal groups, as well as grafting with free radical sites.

When freshly mixed self-etching ED Primer (of Panavia F) was applied to the tooth surface, the activated primer dissolves the smear layer and penetrated the microstructure of enamel or dentin. Simultaneously, dissolved calcium ions neutralize the acidity of the primer, stopping the decalcification process at an approximate depth of 1 μm after a precise hybrid layer has been created. As for Snow Post, glass fibers and epoxy resin matrix resulted in a greater resistance to acids and alkalis, to hydrolysis in wet environments, and to fatigue compared with typical glass fibers. Therefore, when Snow Post was used in conjunction with Panavia F, the highest median load was achieved.

Based on Mann-Whitney test, there was a significant difference between Group 7 and Group 8 (p<0.032). Group 7 withstood a higher median load (1.836 N) than Group 8 (0.926 N). In Group 7, the zirconia posts (Cosmo Posts) were luted with Panavia F. Panavia F contained MDP (10-methacryloyloxydecyl dihydrogen phosphate) monomer. Based on theoretical derived from the chemical formula of 10-MDP, the ratio of C–C/H/C–H/C=C bonds to C–O bonds to –COO– bonds was 11 : 2 : 1. This special molecular structure of MDP enabled the bonding agent to decalcify, penetrate, and create a chemical bond with calcium ion and hydroxyapatite simultaneously. MDP-calcium ion and MDP-apatite are very stable in water.

Yoshida et al.\(^{20}\) reported that upon investigating the chemical bonding efficacy of three functional monomers, quantitative determination of carbon concentration on hydroxyapatite revealed that the bonding potential of 10-MDP to hydroxyapatite was significantly stronger than the others.

Further, Atsu et al.\(^{20}\) reported that the bond strength was significantly higher in zirconium oxide ceramic surface applied with a phosphate monomer-containing bonding/silane coupling agent mixture than with a luting agent that contained no phosphate monomer. Hense, results of this study agreed with the results of previous studies, whereby it was demonstrated that MDP monomer increased the bonding strength with calcium ion and hydroxyapatite and zirconia.
CONCLUSIONS

By means of a pull-out test, this in vitro study evaluated the retentive force of three fiber-reinforced resin composite posts and a zirconia post cemented with two different dual-polymerizing adhesive resin luting agents. Within the limitations of this study, the following conclusions were drawn:

1. Highest mean tensile load was achieved by endodontically treated teeth of Group 3 using Snow Post with Panavia F (3.610 N).
2. In the comparison of Panavia F and RelyX ARC, a significantly higher tensile load was achieved by zirconia posts luted with Panavia F (p<0.032).

REFERENCES