Intraradicular posts are often necessary for the restoration of endodontically treated teeth because of extensive carious lesions, endodontic access cavity preparation, previous restorations, and fractures. Common complications of radicular posts include debonding, root fracture, and endodontic lesions.

Fiber posts frequently fail because of debonding. When fiber posts are attached with a resin cement, 2 interfaces are formed: the dentin-resin cement and the resin cement fiber post. The weak point is the dentin-resin cement at either side of the interface. This interface could be affected by factors such as dentin conditions, orientation of dentinal tubules, irrigation solutions, depth of the intraradicular area, type of adhesive system, and endodontic sealer.

Different adhesive systems are currently used to lute fiber posts: total-etch and self-etch (as well as conventional adhesive techniques) and self-adhesive systems. Self-adhesive resin cement (SARC) was introduced in 2002 and, unlike conventional adhesives, has no pretreatment requirements for the tooth surface and no negative effects on the root canal resulting from either chemical or micromechanical retention to the tooth surface. When the bond strength of SARC was compared with that of conventional adhesive techniques, the results were contradictory.

Drilling during post preparation creates a smear layer consisting of gutta percha remnants and the root canal

ABSTRACT

Statement of problem. The effects of different post space irrigation procedures on the bond strength of a self-adhesive resin cement to the root canal dentin are still unclear.

Purpose. The purpose of this in vitro study was to evaluate the effects of alternative post space irrigation procedures on the cement strengths of posts attached with a self-adhesive resin cement.

Material and methods. Forty single-rooted teeth were selected, and after root canal preparation and obturation, post spaces were prepared. The teeth were divided into 4 groups corresponding to the post space irrigation procedure and treated as follows: the distilled water (DW) group (control) received 15 mL of distilled water; the NaOCl+ethylenediaminetetraacetic acid (EDTA) group was treated with 5 mL of 5.25% NaOCl, 5 mL of 17% EDTA, and 5 mL of distilled water; the chlorhexidine (CHX) group was treated with 15 mL of 2% chlorhexidine solution; and the phosphoric acid (PA) group treatment consisted of etching the walls of the prepared post holes with 35% phosphoric acid. Fiber posts were attached with a self-adhesive resin cement, and specimens were cut horizontally for push-out testing. The statistical evaluation consisted of 1-way ANOVA with the post hoc Tukey honest significant differences test ($\alpha=.05$).

Results. The NaOCl+EDTA treatment yielded a significantly higher bond strength than those used in the other 3 groups ($P=.003$). No statistically significant differences were found among any of the other groups, as different root regions showed similar bond strength values ($P>.05$).

Conclusions. The results showed that EDTA in combination with NaOCl could be advantageous for post space irrigation when fiber posts are bonded with a self-adhesive resin cement. (J Prosthet Dent 2016;115:601-605)
sealer, and this smear layer that covers the root canal dentin surface directly affects the bond strength of the dentin-resin cement interface. SARC is unable to etch the root canal dentin through the smear layer or to form a hybrid layer and resin tags. SARC adhesion is based on the chemical interactions between monomeric acidic groups and hydroxyapatite and on micromechanical retention.

Post space irrigation (PSI) may influence the strength of the cement bond with the root canal dentin. Although some manufacturers recommend sodium hypochlorite (NaOCl) for post space preparation, this procedure may adversely affect the resin cement bond strength. The application of NaOCl and ethylenediaminetetraacetic acid (EDTA) may remove the smear layer completely, increase the penetration of the adhesive, and accordingly, increase the resin bond strength. Chlorhexidine (CHX) also has been used as an irrigant in PSI because of its antibacterial activity, substantivity, and biocompatibility and the inhibition of the collagen-degrading enzyme matrix metalloproteinase. Additionally, studies have shown that CHX did not negatively affect the fiber post bond strength. Most studies of fiber post bond strength in PSI procedures have used conventional adhesive systems. Only a few studies have evaluated the bond strength of SARC with different irrigation solutions. Scanning electron microscopy indicated that phosphoric acid application for 15 seconds can reduce the smear layer, although this is less effective than applying EDTA and/or NaOCl. The influence of phosphoric acid on the bond strength of SARC has not been previously evaluated.

The purpose of this in vitro study was to compare the effects of different PSI procedures on the bond strength of fiber posts attached with SARC. The null hypotheses were that different irrigation procedures would not alter the bond strength at the SARC-dentin interface and that different root regions would exhibit similar bond strength values.

MATERIAL AND METHODS

Forty mandibular premolar teeth were selected. Inclusion criteria were a single canal and absence of internal resorption (confirmed from buccolingual and mesiodistal radiographs), absence of caries, absence of root cracks, and a root length greater than 15 mm. Teeth were maintained in distilled water and decoronated with a diamond disk (Isomet 2000; Buehler Ltd) below the cement and enamel junction. The working length (root canal length of 1 mm) was measured with a number 10 K-file visible from the apical foramen. A rotary system (ProTaper NiTi; Dentsply Intl) was used to apply the crown-down technique for the endodontic preparation procedure, and the apical preparation was extended with a file (ProTaper F3; Dentsply Intl). The root canal was irrigated with 5 mL of 5.25% NaOCl between instrument changes and subsequently with 5 mL of 17% EDTA solution for 1 minute, 5 mL of 5.25% NaOCl, and a final rinse with distilled water (5 mL). The root canals were completely dried with absorbent paper after the final irrigation. The root canals were obturated with gutta percha points and a sealer (AH Plus; Dentsply DeTrey GmbH) by cold lateral compaction. An interim filling material was used to seal the endodontic access cavities (Cavit G; 3M ESPE).

After 7 days of storage at 37°C and in 100% humidity, the interim filling was removed. The root canal filling was removed at a 10-mm depth with a number 1 Peeso reamer (Mani Inc), and preparation of the post was completed with a number 1 drill (DT Light-Post System; Bisco Inc). The post space was viewed with a stereomicroscope to completely remove the root canal filling. After post space preparation, the specimens were divided into 4 groups according to the PSI procedure: DW group root canals were irrigated with 15 mL of distilled water; NaOCl+EDTA group root canals were irrigated with 5 mL of 5.25% NaOCl (CHLORAXiD 5.25%; Cerkamed), then 5 mL of 17% EDTA (MD Cleanser; Metabiomed) for 1 minute, and 5 mL of distilled water; the CHX group root canals were irrigated with 15 mL of a 2% CHX solution (Gluko-Chex 2%; Cerkamed), and the PA group was treated with 35% phosphoric acid (3M ESPE) applied to the walls of the prepared root canal with a syringe for 15 seconds; and the root canals were irrigated with 15 mL of distilled water.

After PSI, absorbent paper points were used to dry the root canals, and a SARC (Relay U200; 3M ESPE) was applied to the root canal with a Lentulo spiral according to the manufacturer’s instructions. Fiber posts were seated with slight finger pressure, and the SARC was polymerized with a light-emitting diode unit (Elipar FreeLight 2; 3M ESPE). Specimens were subsequently maintained in 100% humidity at 37°C for 24 hours.

After 24 hours of incubation, the specimens were embedded in an autopolymerizing acrylic resin and sectioned horizontally with a water-cooled, low-speed diamond disk (Isomet 1000; Buehler Ltd). Six slices were obtained, and each slice was approximately 1 mm thick. The first 2 slices were termed coronal, the second 2 middle, and the third 2 apical. A push-out test was applied to slices 2, 4, and 6 at 0.5 mm/min with a...
1-mm-diameter metallic plunger from the apical to the coronal direction until the post was dislodged. Figure 1 shows the specimen preparation and push-out test apparatus. The push-out bond strength was measured with a universal testing machine (Instron). The maximum load required for failure was measured in newtons (N). The maximum failure load was converted to megapascals (MPa) for each slice and adjusted for the total bonding area (mm²) of each segment. The post diameter was measured with a digital caliper at both the coronal and apical posts and the dentin surface sections. The total bonding area was calculated as $\pi [R+r] \left [ h^2+(R-r)^2 \right ]^{0.5}$, where $R=$post radius, $r=$apical post radius, and $h=$slice thickness. A 1-way ANOVA with a post hoc Tukey honest significant differences (HSD) test was used to evaluate statistical differences among the experimental groups ($\alpha=.05$). Differences in the frequency of various failure modes between the groups were evaluated.

RESULTS

Because no statistically significant differences were found among the regions ($P=.583$), the mean of the 3 regions of each tooth was calculated and tested for differences with 1-way ANOVA. Data in Table 1 are means ±SD. Significant differences among the PSI procedures were found (between groups df=3, $F=5.532$, $P=.003$). The NaOCl+EDTA treatment yielded a significantly higher bond strength than those in the other 3 groups. No significant differences were found in the mean bond strength among the CHX, PA, and DW groups ($P>.05$). Different root regions (coronal, middle, apical) showed similar bond strength values ($P>.05$) (Table 2).

The frequency of each type of bond failure mode is given in Table 3. The most common failure mode was mixed, followed by adhesive failure between the dentin and resin cement and cohesive failure in the resin cement. No cohesive failures were found in the post or within the dentin. In addition, no failure was observed at the resin-post interface.

DISCUSSION

The role of different PSI procedures in determining fiber post bond strength after the use of a SARC was evaluated. Results demonstrated that different irrigation procedures affect fiber post bond strength. Different root regions exhibited similar bond strengths.

After post space preparation, scanning electron microscopy revealed the presence of a layer containing sealer, gutta percha remnants, and other debris in the root canal dentin. Previous research has shown that the use of EDTA in combination with NaOCl irrigation for smear layer removal is effective. A 1-minute 17% EDTA irrigation ensured adequate elimination of the smear layer, but the application of EDTA for more than
1 minute could result in excessive dentinal erosion. In the present study, the use of EDTA was limited to a 1-minute application. Removing the smear layer is essential to achieve a complete hybrid layer with etch and rinse systems. Irrigation procedures may have contradictory results regarding the bond strength when self-etching adhesive systems are applied. Although a previous study encouraged the removal of the smear layer with NaOCl and EDTA, this may cause excessive etching and decreased bond strength; another study indicated no negative effects of self-etching adhesive systems on bond strength; yet another paper indicated no negative effects of self-etching adhesive systems are applied. Although a previous study encouraged the removal of the smear layer with NaOCl and EDTA, this may cause excessive etching and decreased bond strength; another study indicated no negative effects of self-etching adhesive systems on bond strength; yet another paper concluded that self-etching adhesives increased dentin bond strength when PSI was performed with NaOCl and EDTA.

Only a few studies have evaluated the effects of irrigation procedures on the bond strength of SARC. Bitter et al concluded that the use of NaOCl irrigation in conjunction with EDTA increased the SARC bond strength. Our results are in accordance with this study regarding the use of irrigation with NaOCl+EDTA, which was associated with a significantly increased push-out bond strength. This may be attributed to the insufficient dissolution of the smear layer with the use of SARC. The use of the EDTA+NaOCl combination for PSI improves penetration into the dentinal tubules by removing the smear layer.

CHX was used as a PSI because of its antimicrobial effects, substantivity, and biocompatibility. Another reason to use CHX for PSI is that inhibition of the enzyme matrix metalloproteinase may lead to decomposition of the hybrid layer and decalcification of the root canal dentin. Lindblad et al investigated the efficacy of CHX in increasing the resin cement bond strength, generally indicating that no negative effects were observed. In the present study, no significant differences in bond strength between the CHX and DW groups were observed. In accordance with our results, Bitter et al reported that CHX had no significant effect on bond strength relative to irrigation with distilled water.

No detrimental effect associated with the application of phosphoric acid was observed in this study. This result could be explained by the lesser effectiveness of phosphoric acid on the removal of the smear layer in comparison with the EDTA+NaOCl combination.

Different root regions may exhibit variable bond strengths after the application of resin cement during root canal procedures. These differences could have resulted from different tubule densities of dentin, technical sensitivity, the difficulty of applying an adhesive in a narrow post space, and limited light transmission to the apical region. A decreased bond strength is expected from the coronal to the apical regions. Our results indicate that different root regions exhibit comparable bond strengths. Different bonding mechanisms related to a SARC (either micromechanical or chemical) could contribute differently in different root regions. Another possible explanation could be the light transmission of the DT Light-Post (Bisco), which is greater than that of other glass fiber posts. This could improve polymerization in the apical region. Future studies should be conducted to examine the long-term effects of various PSI methods on the bond strength of SARC.

### CONCLUSIONS

Based on the results of this in vitro study, the PSI procedure influences the SARC bond strength. The NaOCl+EDTA combination positively affected bond strength; however, no differences were found among the CHX, PA, and DW groups. Different root regions exhibited similar bond strength values.

### REFERENCES


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**Table 1.** Mean (±SD) bond strength according to post space irrigation procedure

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean (±SD) (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distilled water</td>
<td>7.62 (1.88)</td>
</tr>
<tr>
<td>NaOCl + EDTA</td>
<td>9.69 (2.50)</td>
</tr>
<tr>
<td>CHX</td>
<td>6.35 (1.02)</td>
</tr>
<tr>
<td>Phosphoric acid</td>
<td>7.26 (1.87)</td>
</tr>
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</table>

**Table 2.** Mean ±SD bond strength according to root region

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean (±SD) (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronal</td>
<td>8.12 (3.19)</td>
</tr>
<tr>
<td>Middle</td>
<td>7.46 (2.93)</td>
</tr>
<tr>
<td>Apical</td>
<td>7.6 (2.90)</td>
</tr>
</tbody>
</table>

*Similar superscript letters show no statistical differences observed among different root regions (P>0.05).*

**Table 3.** Mode failure percentages with respect to post space irrigation protocols

<table>
<thead>
<tr>
<th>Mode of Failure</th>
<th>Distilled Water (%)</th>
<th>NaOCl + EDTA (%)</th>
<th>CHX (%)</th>
<th>Phosphoric Acid (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adhesive between dentin-cement</td>
<td>50</td>
<td>26.7</td>
<td>33.3</td>
<td>16.7</td>
</tr>
<tr>
<td>Cohesive within cement</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>Mixed failure</td>
<td>50</td>
<td>73.3</td>
<td>66.7</td>
<td>73.3</td>
</tr>
</tbody>
</table>

CHX, chlorhexidine.


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