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RESEARCH AND EDUCATION

Pull-out retentive strength of fiber posts cemented at different times in canals obturated with a eugenol-based sealer

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ABSTRACT

Statement of problem. Currently, no standard luting protocol exists for fiber posts. In addition, no agreement has been reached on the time interval between canal obturation and post space preparation and cementation.

Purpose. The purpose of this in vitro study was to evaluate the retention of fiber posts cemented with 3 different types of cement: Paracore, Variolink II, and RelyX Unicem cement after 24 hours or 2 weeks in root canals obturated with gutta percha and a eugenol-based sealer.

Material and methods. Seventy-two caries-free, freshly extracted, single-rooted human mandibular first premolar teeth with straight root canals were prepared and obturated with gutta percha and Endofil sealer. Specimens were divided into 2 groups (n=36): post spaces prepared 24 hours after obturation and post spaces prepared 2 weeks after obturation. Posts in both groups were luted with 1 of 3 different luting agents (n=12), ParaCore, Variolink II, or RelyX Unicem cement. Each tooth specimen was vertically secured in a universal testing machine, and a constant pull-out loading rate of 0.5 mm/min was applied until cement failure occurred. Data were statistically analyzed with 2-way and 1-way ANOVAs and *t* tests.

Results. Two-way ANOVA indicated statistically significant differences in mean post retention among the 3 cement types ($P<.001$) and among the means of the different time intervals investigated ($P<.001$). Significant differences were noted among all cement types tested between the 24-hour and 2-week time intervals ($P<.05$).

Conclusions. Time elapsed between canal obturation and post cementation significantly influenced fiber post retention, regardless of the type of resin cement. Fiber posts showed significantly higher retention if cemented after 24 hours of obturation than if cementation occurred after 2 weeks. (J Prosthet Dent 2016;116:85-90)

The use of intraradicular posts in endodontically treated teeth may be required to promote retention between the artificial crown and the remaining radicular tooth structure.[1] The success of endodontically treated and restored teeth depends on post space preparation,[2-4] physicochemical properties of the luting agent,[5] and selection of appropriate root canal sealers.[6,7] Fiber-reinforced composite resin (FRC) posts were introduced as an alternative to cast metal posts.[8] Their modulus of elasticity is closer to that of dentin, which may reduce the risk of root fracture.[9] FRC posts also have an esthetic advantage.[10]

The adhesion of resin cement to the radicular dentin and post retention can be affected by the type of endodontic sealer used. Resin-based sealers and adhesive systems have been recommended for the cementation of FRC posts because of their favorable physical properties and adequate biologic performance in tests evaluating adhesion, resistance to removal by traction, and decrease in coronal leakage.[11] Calcium hydroxide-based endodontic sealers may stimulate a sterile biological closure of the apical region, increasing the potential for treatment success.[12] Eugenol-containing sealers are the most widely used by endodontists worldwide because of the sealers' long history of clinical success.[13] However, eugenol is known to interfere with polymerization of resin compounds, altering different physical and mechanical

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Clinical Implications

The time elapsed between canal obturation and post cementation significantly influenced fiber post retention, regardless of the type of resin cement. Cementing fiber posts as soon after canal obturation as possible would be prudent.

properties.[14] Nevertheless, studies disagree on whether this interaction is clinically relevant or not.[14] However, recent in vitro studies have concluded that eugenol-based sealers significantly reduced pull- and push-out bond strength of fiber posts luted with resin cement.[15-18]

The influence of dental cement on post retention has been investigated.[19] Fiber posts are commonly bonded to root canals with the use of dual-polymerizing or auto-polymerizing resin-based cement. Self-adhesive resin cement does not require pretreatment of the tooth structure. Cementation is a single-step procedure. RelyX Unicem (3M ESPE) cement was the first product in this class of self-adhesive cement marketed. Its multifunctional monomers with phosphoric acid groups simultaneously demineralize and infiltrate enamel and dentin.[20] The dominant setting reaction is the radical polymerization that can be initiated by light exposure or through the self-polymerization mechanism. This process results in extensive cross-linking of the cement's monomers and the formation of high molecular-weight polymers.[19]

The level of polymerization in composite resins is expressed as the degree of conversion of monomeric C=C bonds to polymeric C-C bonds. The extent of conversion affects both the physical and mechanical properties of the polymer.[20]

A number of studies have demonstrated that, although autopolymerizing and light-polymerizing methods of activation are unrelated, light activation is still essential for some dual-polymerized resin cement to ensure an adequate degree of conversion.[21] As a consequence, the degree of conversion decreased as the distance from the polymerization tip increased and was probably the result of a considerable reduction in light intensity within the post space.[20]

The effect of immediate versus delayed post space preparation on leakage has been investigated in a number of studies with controversial results.[22-24] Some authors demonstrated no differences in leakage between immediate and delayed gutta percha removal for post space preparation,[20] whereas others reported that immediate post space preparation resulted in less leakage than with delayed preparation.[23] In addition to apical leakage, in the case of immediate post cementation, the unset sealer may interfere with the setting of the luting resin cement and negatively affect post retention.[24]

Currently, no standard luting protocol exists for fiber posts. In addition, there is no agreement on the time interval between canal obturation and post space preparation and cementation. Therefore, the purpose of this study was to evaluate the retention of fiber posts cemented with 3 different types of cement: Paracore, Variolink II, or RelyX Unicem cement after 24 hours or 2 weeks in root canals obturated with gutta percha and a eugenol-based sealer. The null hypothesis tested was that no differences in fiber post retention would be found among the 3 different resin luting agents cemented either 24 hours or 2 weeks after obturation with eugenol sealer.

MATERIAL AND METHODS

Seventy-two caries-free, freshly extracted, single-rooted human mandibular first premolar teeth were used in this study. The teeth were subjected to radiographic examination from both the buccolingual and mesiodistal directions. Teeth with a single, noncalcified, and straight canal were selected according to the Schneider method.[25] The teeth were stored in an antimicrobial preservative container (0.5% chloramine-T; Delchimica Scientific Glassware) at 4°C and used within 6 weeks of extraction. Teeth were sectioned 2 mm coronally to the midfacial of the cementoenamel junction by using a low-speed diamond saw (Isomet 2000; Buehler Ltd) under copious water irrigation. Pulpal tissues were removed with a barbed broach (Dentsply Maillefer). To determine the working length, a size 10 K-file (Maillefer) was placed in the canal until it was visible at the apical foramen. Then 1 mm was subtracted from this measurement. The canals were prepared with K-file sizes 15 and 20, followed by Protaper Ni-Ti rotory instruments (sizes S1, S2, F1, and F2; Dentsply Maillefer) in a high torque motor (X-Smart, REF A 1004; Dentsply Maillefer) at 350 rpm by using the crown-down technique to the full working length.[26]

Three milliliters of 5.25% sodium hypochlorite (NaOCl) were introduced into the canals after every instrument with a 10-mL syringe with a 27-gauge tip. Root canals were obturated with laterally compacted gutta percha (Kerr Dental) and Endofil sealer (Promedica). Coronal gutta percha was compacted with vertical condensation with a heated endodontic plugger (no. 911; Moyco Union Broach). Subsequently, a 3-mm-deep space was prepared in the coronal gutta percha to provide space for an interim restoration. An interim material (Cavit; 3M ESPE) was placed in the access cavity of all obturated teeth, which were then stored in 100% relative humidity at room temperature. Specimens were divided into 2 groups (n=36) according to the different times (24 hours or 2 weeks) between post space preparation and cementation. Gutta percha was removed, and post spaces were prepared with a no. 5 Peeso reamer

Table 1. Resin luting agents used in this study

Luting Agents	Manufacturer	Composition*
Variolink II	Ivoclar Vivadent AG	Monomer matrix composed of Bis-GMA, urethane dimethacrylate, and triethylene glycol dimethacrylate. Inorganic fillers are barium glass, ytterbium trifluoride, Ba-Al-fluorosilicate glass, and spheroid mixed oxide. Additional contents include catalysts, stabilizers, and pigments.
RelyX Unicem	3M ESPE	Resin matrix consists of specially designed multifunctional, phosphoric acid modified methacrylate monomers. These monomers form highly cross-linked cement matrix during radical polymerization. Phosphoric acid groups of methacrylate monomers interact with tooth surface and facilitate self-adhesion. Amount of inorganic fillers contained approximates 70 percent by weight, the grain particle size (d[90] =90% of the fillers) is <12.5 μm. Portion of fillers is silanated to chemically bond to methacrylate monomers; another portion is alkaline (basic) and neutralize remaining phosphoric acid groups of methacrylate monomers.
ParaCore	Coltèene/ Whaledent Inc	Methacrylates, fluoride, barium glass, amorphous silica

*Information supplied by manufacturers.

(Pulpdent Corp) at low speed to a depth of 8 mm with a minimum length of apical gutta percha of 5 mm for all specimens; this procedure was followed by a no. 6 parallel-sided Parapost twist drill (Parapost Black P-42; Coltène/Whaledent Inc) at low speed. Post spaces were prepared to a diameter of 1.5 mm and a depth of 8 mm under NaOCl irrigation.

Parallel-sided, prefabricated fiber posts (ParaPost Fiber Lux; Coltène/Whaledent Inc) were used. Parapost posts were passively fitted in their respective canals before luting. To maintain moistness, teeth were held in a gauze sponge soaked in saline whenever they were handled. To increase retention of the roots in the acrylic resin block during the pull-out test, each root was notched on the buccal and lingual surfaces with a tungsten carbide bur. The specimens were then mounted with autopolymerizing resin (Ortho Resin; Dentsply DeTrey) in a short length of polyvinyl chloride pipe, and a dental surveyor (J.M. Ney Co) was used to align the post space with the long axis of the tooth. After canal irrigation with NaOCl and drying with absorbent paper points, the posts were luted with 1 of 3 different luting agents (Table 1).

For ParaCore posts (Parapost; Coltène/Whaledent Inc), the ParaBond (Coltène/Whaledent Inc) nonrinse conditioner was applied to the canal with a thin microbrush, which was moved up and down for 30 seconds. Excess conditioner was removed with paper points and dried with a light jet of air for 2 seconds. A mixture of ParaBond adhesive A/B (Coltène/Whaledent Inc) was applied to the canal with a thin microbrush and rubbed in for 30 seconds. Excess adhesive was removed by paper points and dried with a light jet of air for 2 seconds. Finally, cement material was applied directly from the tip of the syringe into the prepared post space in the root canal. The fiber post was also coated with cement and then inserted into the canal with slight pressure. Excess cement was removed, and the cement was then light polymerized (XL 2500; 3M ESPE) for 40 seconds.

For Variolink II (Ivoclar Vivadent AG) dual-polymerizing resin cement, acid-etch gel (phosphoric acid gel 37%; Ivoclar Vivadent AG) was applied to the tooth for 15 seconds. The canal was rinsed immediately with water and dried with paper points. The adhesive (Excite DSC; Ivoclar Vivadent AG) was applied to the canal with a microbrush, and excess adhesive was removed with paper points. The cement was mixed in a 1:1 ratio on a mixing pad for 10 seconds. The cement was applied to the bonding surface of the canal. The posts were also coated with the cement and inserted in the prepared canals with finger pressure; excess cement was removed flush with the top of the tooth. The light activation (XL 2500; 3M ESPE) was performed for 40 seconds.

For RelyX Unicem (3M ESPE) dual-polymerizing self-adhesive resin cement, the cement capsule was activated for 2 seconds and automixed in a high-speed triturator (Rotomix; 3M ESPE) for 10 seconds. Then the resin cement was placed in the root canals with an elongation tip (3M ESPE). Posts were then coated with cement and inserted in the prepared canals with finger pressure. Excess cement was removed, and the polymerization light (XL 2500; 3M ESPE) was applied for 40 seconds.

Specimens were stored in 100% relative humidity at room temperature for 24 hours before testing. Each tooth specimen was vertically secured in the universal testing machine (Instron, model 8500 Plus; Dynamic Testing System; Instron Corp). A tensile force was applied to dislodge the post by using pneumatic grips that grasped the post head and pulled the post along its long axis. A constant loading rate of 0.5 mm/min was applied until cement failure occurred. The peak force recorded at the point of extrusion of the post from the tooth was considered the point of bond failure. Force was recorded in newtons (N).

Data were statistically analyzed with statistical software (SPSS v16.0; SPSS Inc). A 2-way analysis of variance (ANOVA) was applied to the mean retentive strengths of time interval, cement materials, and combinations. When a significant cross-product interaction was found, 1-way ANOVA and the *t* test were applied to the combinations. After 24 hours, 1-way ANOVA was used to evaluate the retention of fiber posts among the 3 different cement. There was significant difference; therefore, the Tukey honest significant differences multiple comparisons test was performed to determine which cement was significantly different. The same analysis was accomplished for the second time point (after 2 weeks; α=.05 for all analyses).

Table 2. Forces required for post dislodgment after different time intervals between canal obturation and post cementation with 3 brands of cement (n=12)

	Cement forces (N)		
Time	**Variolink II**	**Paracore**	**RelyX Unicem**
24 h	60.4 ±24.9^{aA}	69.6 ±25.2^{aA}	119.1 ±47.2^{bA}
2 wk	32 ±18.5^{cB}	43.7 ±23.4^{c,dB}	61.8 ±24.7^{dB}

Values are means ±SD. Groups with same superscripts are not significantly different (P>.05). Uppercase superscript letters compare means across time rows for each cement. Lowercase superscript letters compare means along cement columns for each time period.

Table 3. Summary of 2-way ANOVA of cement types and time interval and their interaction for post retention

Source	Sum of Squares	*df*	Mean Square	F	*P*
Cement	25702.346	2	12851.173	15.469	<.001
Time	24951.918	1	24951.918	30.035	<.001
Cement×time	3658.421	2	1829.210	2.202	.119
Error	54830.285	66	830.760		
Total	408094.308	72			

RESULTS

Means and standard deviations (SD) of the post retention data are presented in Table 2. Two-way ANOVA indicated statistically significant differences in mean post retention among the 3 cement types (P<.001) and among the means of the different time intervals investigated (P<.001) (Table 3). Moreover, 2-way ANOVA indicated no interaction between cement type and time interval (P=.119). The 1-way ANOVA revealed statistically significant differences in mean post retention among the different types of cement in the 24-hour groups (P<.001) and in the 2-week groups (P=.009). Multiple comparisons test results indicated that the Paracore and Variolink II groups were significantly different from the Unicem group (P<.001). In addition, they were not significantly different from each other (P=.427). Furthermore, the Student t test revealed significant differences among all cement types tested between the 24-hour and 2-week time intervals (P<.05).

DISCUSSION

This study was designed to evaluate retention of fiber posts cemented with 3 different brands of dual-polymerizing resin cement because clinicians are using different brands of resin cement with fiber posts. Data from the present study support the partial rejection of the null hypothesis. At the 2 different times included in this study, the fiber posts luted with RelyX Unicem cement exhibited significantly higher retention than those luted with Variolink II cement. However, at 2 weeks, no significant differences were found in the retention of fiber posts cemented with Paracore or RelyX Unicem resin cement.

RelyX Unicem self-adhesive cement was significantly more effective than the multistep composite resin cement Variolink II. The bonding mechanism of the self-adhesive cement RelyX Unicem is reported to be based on a combination of micromechanical retention and chemical adhesion.[27]

The extent of polymerization in composite resin is expressed as degree of conversion of monomeric C=C bonds to polymeric C–C bonds. The lower values for Variolink II cement after 24 hours may be explained by the incomplete polymerization at the apical area. This incomplete polymerization may affect both the physical and mechanical properties of the polymer.[28]

The reduced conversion of Variolink II cement in the apical third may be the result of decreased transmission of light as the depth increases.[29] Light activation is still necessary for many dual-polymerizing resin cement to ensure complete polymerization, even though the auto-polymerizing and light-polymerizing modes of activation are independent. Therefore, the degree of polymerization can decrease when the distance from the polymerization tip increases.[30,31]

The predictable placement of etching gel and adhesive materials into the apical region of the post space is a challenge. The inability to develop a completely etched surface of the dentin in the post space, combined with problems of obtaining access to uniformly coat the adhesive material in the apical portion of the post preparation, can affect the bond strength of these cement.[32]

Unset adhesive solution can pool, limiting solvent volatilization, interfering with the polymerization process,[33] and thus predisposing the resin cement in this region to incomplete setting.[34] The shape and dimension of commonly used disposable bristle brush tips could be responsible for this pooling affect.[35]

ParaCore is a dual-polymerized, glass-reinforced composite resin cement with an integrated bond and cement system. The ParaBond cement consists of a nonrinse conditioner and a chemically activated adhesive, which is more favorable in situations where the light activation is restricted, such as during the cementation of a post. In addition, ParaCore cement's long, narrow mixing tip allows the cement to be directly injected into the root canal, facilitating the cementation process and ensuring a void-free cement film.[36] However, self-adhesive cement do not require any pretreatment of tooth structure, allowing a 1-step cementation process. RelyX Unicem cement, with its multifunctional monomers containing phosphoric acid groups, simultaneously demineralizes and infiltrates enamel and dentin. The dominant setting reaction is the radical polymerization that can be initiated by exposure to a light source or through the auto-polymerization mechanism. This process results in the extensive cross linking of cement monomers and the production of high molecular weight polymers.[37]

Phosphoric acid groups also react with the tooth apatite. Water formed in these neutralization processes contributes to the cement's initial hydrophilicity, which improves adaptation to the tooth structure and moisture tolerance. Subsequently, the water produced reacts with acidic functional groups during the cement reaction with ion-releasing basic filler particles. Such a reaction would finally result in a conversion to a hydrophobic matrix. The adhesion obtained relies on the micromechanical retention and chemical interaction between the acidic groups in the monomer and hydroxyapatite.[38] In addition, RelyX Unicem cement was injected into the post space, eliminating air entrapment and the formation of bubbles and ensuring a high quality cement film that is free of voids. This high quality cement film may explain the high retentive strength for fiber posts in the present study.[39]

Posts may be placed immediately after completion of endodontic treatment or at a later stage after obturation. However, the immediate placement of the intraradicular post has a significant disadvantage. Post space preparation is performed when the remaining apical 4 to 5 mm of sealer and gutta percha are not fully hardened, which may disrupt the apical seal.[40] Therefore, in the present study, the post space was prepared either after 24 hours (early) or after 2 weeks (delayed).

A wide variety of sealers is available. Endofil, a eugenol-based sealer, was chosen in the present study because it is one of the most widely used sealers. Eugenol is a phenol that acts as a scavenger of free radicals. This scavenger activity is thought to inhibit resin polymerization.[41] However, opinions diverge regarding the influence of eugenol-based endodontic sealers on the polymerization of resin cement used for the cementation of intraradicular posts. Teixeira et al[42] reported that Endofil sealer reduced the bond strength of carbon fiber posts in the coronal and middle portions of the root more than EndoREZ sealer. However, other studies reported no differences between the effects of a eugenol and noneugenol sealer on a post's retention.[40]

Results of the present study indicated that the elapsed time between canal obturation and post cementation significantly influenced fiber post retention, regardless of the type of resin cement used. Fiber posts cemented 24 hours after obturation recorded significantly higher retention than those cemented after 2 weeks. This result can be explained by the greater penetration of eugenol into the dentinal tubules over time.[38]

Differences in results of the 3 brands of resin cement may have been caused by the handling characteristics of the adhesive system, light polymerization technique, and experience and skill of the operators. However, all possible measures were taken to ensure standardization.[36]

Artificial aging could have altered the results, so further studies that include artificial aging are suggested. To eliminate the factor of the differences in the sizes of the teeth, the post spaces were prepared with parallel ParaPost drills. In this way, post spaces were uniformly cylindrical throughout their length and were of similar dimensions.[43]

Future studies might examine the dislodged posts and teeth under magnification to determine whether the cement is retained on the post, in the prepared post space, or in a combination of the 2 locations. Recording the number and size of any voids present in the cement would also be of interest.

CONCLUSIONS

Within the limitations of this in vitro study, the following may be concluded:

1. Early (after 24 hours) preparation and cementation of fiber posts in canals obturated with eugenol-based sealers produced higher retentive values than delayed (after 2 weeks) cementation ($P<.001$).
2. At 24 hours, fiber posts luted with RelyX Unicem cement exhibited significantly higher retention than those luted with Variolink II or Paracore cement ($P<.001$).
3. At 2 weeks, fiber posts luted with RelyX Unicem cement exhibited significantly higher retention than those luted with Variolink II cement ($P=.009$).

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