



ORIGINAL ARTICLE

Effect of calcium silicate-based endodontic sealer on the retention of fiber posts cemented at different time intervals

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KEYWORDS

AH Plus;
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Bond strength;
Pull-out

Abstract Objective: To evaluate the effect of BC HiFlow, a new calcium silicate-based endodontic sealer, compared with a resin epoxy-based sealer after 2 different times of cementation on the pull-out bond strength of glass-fiber-reinforced composite posts cemented with a self-adhesive resin cement (RelyX Unicem).

Methodology: Sixty human maxillary central incisors were decoronated, prepared and obturated with gutta-percha and sealer. Roots were distributed into 5 groups according to the sealer and time of post cementation: (1) AH Plus sealer with immediate post fixation, (2) BC HiFlow with immediate post fixation, (3) AH Plus and post fixation after 7 days, (4) BC HiFlow and post fixation after 7 days, and (5) fiber post fixation in canals obturated with gutta-percha only (no sealer). After 1 week of post cementation, the pull-out test was performed and the failure mode was examined under a digital microscope. Data were analyzed using ANOVA followed by Tukey's post hoc and *t* tests ($p < .05$).

Results: With immediate post cementation, AH Plus group showed significantly higher pull-out retentive strength than the BC HiFlow and control groups ($p = .009$ and $p < .001$, respectively). There was no significant difference between the groups when the posts were cemented 7 days after obturation ($p = .726$). The time of post cementation had a significant influence on the canals obturated with AH Plus ($p = .003$). The time did not significantly affect the canals obturated with BC HiFlow ($p = .289$). The prominent type of failure was mixed mode in all groups.

Conclusion: BC HiFlow sealer did not affect the pull-out bond strength of glass-fiber-reinforced composite posts cemented with a self-adhesive resin cement immediately after or 7 days after obtu-

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ration. For immediate post cementation, AH Plus increased the pull-out bond in comparison to BC HiFlow.

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1. Introduction

The success of root canal treatments depends on the quality of the endodontic treatment and coronal restoration performed afterwards (Gillen et al., 2011). In teeth with extensive loss of coronal structure, the use of intraradicular posts may be required for the support and retention for the restoration (Morgano, 1996). Posts can be made of different metallic and nonmetallic materials. Prefabricated glass-fiber-reinforced composite posts have been widely used in recent years due to their advantages, such as the presence of adhesive bonding to the tooth structure, improved restoration esthetics, and a modulus of elasticity that is comparable to dentin (Santos-Filho et al., 2014). For fiber post cementation, either conventional dual-cured or self-adhesive resin cement are available. The advantage of self-adhesive resin cement is that it decreases the sensitivity of the technique and clinical time for the cementation procedure by eliminating the pretreatment step of tooth surface. It has been shown that fiber posts cemented with self-adhesive resin cement have a similar level of retention to posts cemented with a conventional dual-cured resin cement (Macedo et al., 2010). The excellent mechanical properties of the resin cement are related to its chemical interaction with the hydroxyapatite in the tooth structure. This interaction is based on chelation of the calcium ions by acid groups in the self-adhesive cements (Gerth et al., 2006). Furthermore, the particles of the cement can penetrate into dentin, resulting in micromechanical interlocking (Bitter et al., 2009). However, debonding is the most common cause of failure of fiber posts (Monticelli et al., 2003). Therefore, the retention of fiber posts is an essential property for clinical success.

Different factors have been reported to interfere with the bonding of the posts to the dentin (Macedo et al., 2010). One of these factors is the type of root canal sealer that is used for obturation (Teixeira et al., 2008). Eugenol-containing sealers have a negative influence on the fiber posts retention (Menezes et al., 2008; Cecchin et al., 2011) due to the interference of the hydroxyl group in the sealers with the polymerization reaction of the resin cements (Paul and Schärer, 1997). However, resin- and calcium hydroxide-based endodontic sealers do not affect the retention of fiber posts (Cecchin et al., 2011). Therefore, it is important that the type of final restoration is considered before the sealer to be used for obturation is selected.

Bioceramics are ceramic materials designed for the repair and reconstruction of diseased or damaged parts of musculoskeletal system (Hench 1991). Calcium silicate-based sealers are bioceramic sealers that were introduced as a new generation of endodontic sealers. Endosequence BC sealer (Brasseler USA, Savannah, GA, USA) is based on a calcium silicate composition. BC sealer is a biocompatible sealer (Zhou et al., 2015) that has antibacterial property (Alsubait et al., 2019). A significant advantage of bioceramic sealers is the bioactive property, which is not found in eugenol- or resin-based endodontic seal-

ers (Giacomino et al., 2019). The manufacturer recommends the use of Endosequence BC sealer with the single cone filling technique. However, many practitioners still prefer to use continuous wave filling technique. The application of heat during the downpack might affect the chemical and physical properties of the root canal sealer (Camilleri, 2015; Atmeh and AlShwaimi, 2017). Therefore, a new Endosequence BC Sealer, BC Sealer HiFlow, was recently introduced to the market for warm obturation techniques. According to the manufacturer, it exhibits a lower viscosity when heated compared to the original BC sealer.

Different methods have been used to assess the bond strength of fiber posts to radicular dentin, including the push-out (Vilas-Boas et al., 2018), microtensile (Yaman et al., 2014) and pull-out tests (Borges et al., 2020). A recent study reported that BC sealer decreases the push-out bond strength between fiber posts and dentin (Vilas-Boas et al., 2018). However, no research studies have used the pull-out test, which more closely simulates the most common clinical failure cause of fiber posts (Monticelli et al., 2003). Therefore, the aim of the present study was to evaluate the effect of a new calcium silicate-based endodontic sealer (BC HiFlow) compared with a resin epoxy-based sealer after 2 different times of cementation on the retention strength of glass-fiber-reinforced composite posts cemented with a self-adhesive resin cement. The following null hypotheses were tested: 1) no difference in the mean values of pull-out bond strength of fiber posts cemented in canals filled with the calcium silicate-based endodontic sealer or the epoxy resin-based endodontic sealer; 2) no difference in fiber post retention would be found when cemented immediately or 7 days after root filling.

2. Materials and methods

2.1. Specimen selection and preparation

The current study protocol was reviewed and approved by the Institutional Review Board at King Saud University in Riyadh, Saudi Arabia (E-19-3887) and the College of Dentistry Research Center at King Saud University in Riyadh, Saudi Arabia (FR 0504). Sixty human maxillary central incisors with completely formed apices, with a root length of 14 ± 1 mm, and approximately the same dimensions at the cement-enamel junction (6 ± 0.5 mm mesiodistally and buccolingually) that were extracted for reasons unrelated to the present study were used. The teeth were assessed using a dental operating microscope (OPMI pico, Carl Zeiss, Thonwood, NY). Teeth without any caries, restorations, craze lines, cracks, or dental abnormalities were selected. The soft tissues covering the root surface were removed with hand scalers. Buccolingual and mesiodistal radiographs were taken for each tooth. Teeth with a single, straight (Schneider, 1971), noncalcified canal were selected. The teeth were kept in saline at room temperature until the start of the study.

The crowns were sectioned using a saw machine (Isomet, Buehler Ltd., Lake Blu, NY, USA) to obtain a standardized root length of 13 mm. Working length (WL) was established by visualizing the tip of a size 10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) at the root canal terminus and subtracting 1 mm from this measurement. The root canal was prepared using the ProTaper rotary system (Dentsply Maillefer) at 300 revolutions per minute up to size 30, with a 0.09 taper (F3). Irrigation was carried out with 2 mL 2.5% sodium hypochlorite (NaOCl) after each instrument. For smear layer removal, 2 mL 17% EDTA solution (Pulpdent Corp, Watertown, MA) was used for 1 min followed by 2 mL 2.5% NaOCl. Sterile saline was used for the final flush and the canal was dried with paper points (Dentsply Maillefer). Specimens were randomly distributed into 5 groups ($n = 12$ each) according to the endodontic sealer and time of fiber post cementation:

- Group (AH-0): canals were filled with gutta-percha/AH Plus Jet sealer (Dentsply DeTrey, Konstanz, Germany) and immediately cemented with a fiber post.
- Group (BC-0): canals were filled with gutta-percha/BC HiFlow and immediately cemented with a fiber post.
- Group (AH-7): canals were filled with gutta-percha/AH Plus Jet sealer and cemented with a fiber post 7 days after obturation.
- Group (BC-7): canals were filled with gutta-percha/BC HiFlow and cemented with a fiber post 7 days after obturation.
- Group (Control): fiber post was cemented in canals obturated with gutta-percha without an endodontic sealer.

For root canal obturation, ProTaper F3 gutta-percha cone (Dentsply Maillefer) was coated with sealer and seated to the WL. For the BC groups, the sealer was injected to the coronal third of the canal, and then, the sealer-coated cone was inserted slowly into the canal. Afterward, for all specimens, the cone was seared off at the level of the orifice with a heat carrier that was attached to a size 40.04 plugger and was set at 200 °C (alpha II, B&L Biotech USA, Bala Cynwyd, PA), and the canal was condensed with a hand plugger (Buchanan, Kerr, USA). The plugger was introduced into the canal until reaching 4 mm of the WL. In the AH-7 and BC-7 groups, the middle and coronal portions of the canals were back-filled with gutta-percha (Beta, B&L Biotech USA) and compacted with hand pluggers. Temporary filling material (Coltosol F, Coltène, Altstätten, Switzerland) was used to seal the access cavities. The specimens in the AH-7 and BC-7 groups were then stored in an incubator at 95% humidity and 37 °C for 1 week to ensure full setting of the sealer.

2.2. Fiber post cementation

Glass-fiber posts (size 2, RelyX, 3 M ESPE, St. Paul, MN, USA) were cemented immediately after the downpack in specimens from the AH-0, BC-0 and Control groups. Fiber post cementation in the samples from the AH-7 and BC-7 groups was performed 7 days after obturation. In these specimens, the temporary filling was removed. Gates Glidden drills (Dentsply Maillefer) #1, 2 and 3 were used to remove the first 9 mm of the canal filling material. In all specimens, the post and root canals were prepared according to the manufacturer's

instructions. Briefly, a 9-mm-deep post space was prepared with a matching drill (3 M ESPE) attached to a low-speed handpiece. Posts were inserted into the canal and checked for fitting, were disinfected with alcohol and were thoroughly air-dried. The prepared post space was rinsed with 2.5% NaOCl followed by distilled water. Finally, the post space was dried with paper points. After the application of the cement (RelyX Unicem) in the prepared post space, the post was seated, and the extra cement was removed with a cotton pellet. The cement was light cured (EliparTM S10, 3 M ESPE) for 40 s. All specimens were stored at 37 °C and 95% humidity for 1 week before the pull-out test was performed. All procedures were performed by a single operator under a dental operating microscope.

2.3. Pull-out test

Each specimen was embedded vertically in an epoxy resin with 2 mm of the root left uncovered. Thereafter, the specimens were secured in the Instron testing machine (Model 5965, ITW, MA, USA) for the pull-out testing along the long axis of the post. A constant loading rate of 0.5 mm/min was applied and the forces were recorded at the point of extrusion of the posts in newtons (N). The operator who made the tests was not aware of the allocation of the samples to the groups.

2.4. Evaluation of failure modes

A digital microscope (KH-7700, Hirox, Japan) at a magnification of 50X was used to examine the debonded posts and identify the type of failure: adhesive failure with no cement on the post surface, cohesive failure of the cement on the post or mixed failure, which is the combination of the adhesive and cohesive failure modes (Saridaga et al., 2016). The operator who examined the slices was not aware of the allocation of the samples to the groups.

2.5. Statistical analysis

Statistical analysis was performed using SPSS software (SPSS 22; IBM Corp., New York, NY, USA). According to the Shapiro–Wilk normality test, the data were normally distributed in all groups. Two-way analysis of variance (ANOVA) was used to detect interactions between the type of sealer and time of post cementation. If a statistically significant interaction was found, one-way ANOVA followed by Tukey post hoc tests and *t* tests were performed for multiple comparisons. The level of significance was set at 0.05.

3. Results

The mean values and standard deviations of the pull-out strength are displayed in Table 1. Based on two-way ANOVA, there was a significant interaction between the type of sealer and time of post cementation ($p = .007$). For the type of sealer used for obturation, one-way ANOVA revealed significant differences between groups when the posts were cemented immediately after obturation ($p < .001$). The canals obturated with AH Plus showed significantly higher bond strength than the canals obturated with BC HiFlow and the canals in the control

Table 1 Mean and standard deviation (SD) of pull-out strength for each group.

Sealer	Post Cementation	N	Mean \pm SD
AH Plus	Immediate	12	194.1 \pm 36.9 ^{A, a}
	7 days after obturation	12	142 \pm 39.6 ^{C, b}
BC HiFlow	Immediate	12	157.1 \pm 8.7 ^{B, d}
	7 days after obturation	12	147.8 \pm 28.5 ^{C, d}
Control (no sealer)		12	136.8 \pm 31.5 ^{B, C}

Groups with the same superscripts are not significantly different ($P > .05$). The uppercase superscript letters correspond to a comparison of the means across the AH Plus, BC HiFlow and control groups for each time point. The lowercase superscript letters correspond to a comparison of the means within each sealer group at different times.

group ($p = .009$ and $p < .001$, respectively). There was no significant difference between the canals obturated with BC HiFlow and the canals in the no sealer group ($p = .202$). Furthermore, there was no significant difference between the groups when posts were cemented 7 days after obturation ($p = .726$).

For the timing of post space cementation factor, the pull-out fiber post strength in the canals filled with AH Plus was significantly higher with immediate post cementation than with cementation after 7 days ($p = .003$). The time was not a significant factor for the canals obturated with BC HiFlow ($p = .289$).

Fig. 1 presents the results of a microscopic analysis of the fiber posts after the pull-out test. In all groups, the mixed mode of failure was the predominant type of failure.

4. Discussion

The effect of the chemical composition of endodontic sealers on bond strength of post to root dentin has been reported pre-

viously (Teixeira et al., 2008). In this experiment, the influence of a new calcium silicate-based endodontic sealer on fiber post bond strength was evaluated. AH Plus is a widely used resin epoxy-based sealer against which new sealers have been compared (Brackett et al., 2006; Loushine et al., 2011); therefore, it was included for comparison. Human teeth with relatively equal dimensions were used to mimic clinical conditions and to prevent root size differences from affecting the results. The pull-out test has been selected to assess the bond strength of fiber post to dentin. This method allows comprising the whole length of the root canal without root sectioning, so potential artifacts caused by cutting process of the specimens could be avoided (Perdigão et al., 2007; Ebert et al., 2011). Posts can be placed after the completion of root canal treatment immediately or at a subsequent visit after the sealer is completely set. Despite the large number of studies on this topic in the literature, there is lack of consensus regarding the best time for post cementation. Therefore, post retention was evaluated after cementation at two different times, immediately after and 7 days after canal obturation, to determine whether unset BC sealers compared with set sealers have an effect on fiber post retention.

In the present study, it was shown that the pull-out bond strength of fiber posts was significantly higher in canals obturated with AH Plus than canals obturated with BC HiFlow when cemented immediately after obturation. However, there was no significant difference in the post retention between AH Plus and BC HiFlow when cemented 7 days after obturation. Furthermore, the timing for cementation significantly affected the bond strength of posts in canals filled with AH Plus but did not influence the pull-out strength in canals filled with BC sealer. Hence, the two null hypotheses tested in the present study had to be partially rejected.

AH Plus sealer and RelyX Unicem are both resin-based cements that have similar chemical compositions. This similarity might explain the absence of an AH Plus negative influence on the bond strength of fiber posts. These results are in line with those presented in previous studies (Cecchin et al., 2011; Vano et al., 2008). However, when posts were cemented immediately after obturation, the unset resin-based sealer

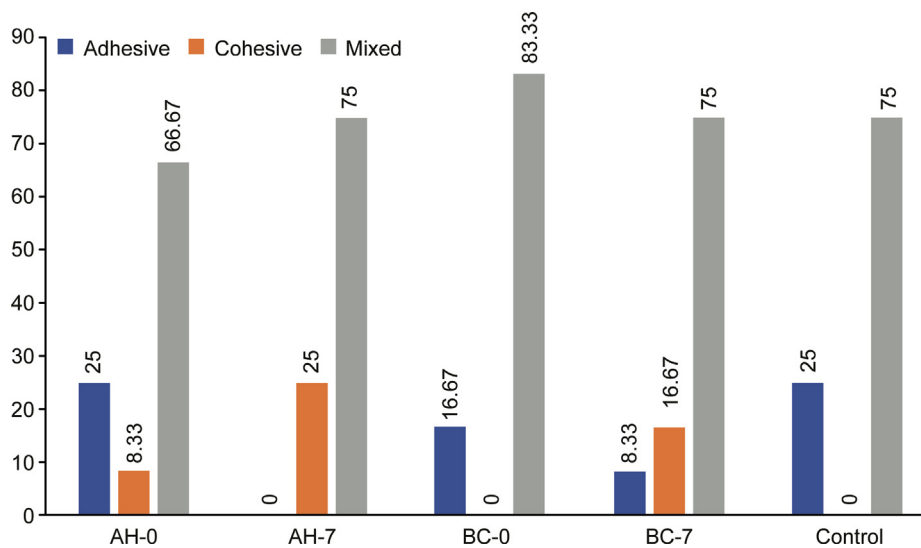


Fig. 1 Percentage of the types of bond failures that occurred in each group.

improved the bond strength value of the fiber posts. This finding is in accordance with a finding in a recent study (Vilas-Boas et al., 2018) but is inconsistent with a finding in an earlier study that reported significantly lower bond strength values when post was placed immediately (Vano et al., 2008). The discrepancies may be related to differences in methodology. Vano et al. (2008) used 3 different types of post systems that require pretreatment of the root with an adhesive system before post cementation is performed. Unset sealers might cause unavoidable contamination in the post space, which might interfere with the luting steps. The RelyX Unicem used in the present study is less technique sensitive to luting procedures.

When cementation was performed in canals obturated with gutta-percha and BC HiFlow, the bond strength values were similar to those in the control group. Furthermore, the timing for post cementation did not influence the pull-out bond strength of the fiber post to root dentin. This result can be attributed to the composition of the sealer. BC HiFlow is a new premixed bioceramic sealer. Its setting reaction is initiated by the moisture present in the dentin. The main products of the setting reaction are calcium silicate hydrogel and calcium hydroxide. Calcium hydroxide reacts with phosphate to obtain hydroxyapatite and water (Camilleri, 2007). The hydroxyapatite chemically interacts with RelyX Unicem to form a chemical adhesion (Gerth et al., 2006). A literature review revealed that no previous studies assessed the pull-out bond strength of fiber posts to dentin in canals obturated with gutta-percha and BC sealer. The BC sealer effect has been evaluated using the push-out test, but conflicting results have been reported. Özcan et al. (2012) stated that calcium silicate-based sealer did not affect the fiber posts retention and that its effect was equivalent to that of resin-based sealer. On the other hand, Dibaji et al. (2017) showed that BC sealer decreased the bond strength of fiber posts to radicular dentin. Self-adhesive resin cement was used for fiber post fixation in the present study and in the study conducted by Özcan et al. (2012), while dual-cure resin was used in the Dibaji et al. (2017) study. However, the current results cannot be compared with the results in these studies due to the differences in the methodology used for the bond strength measurements.

AH Plus and BC sealer penetration into dentinal tubules have been reported previously (El Hachem et al., 2019). Sealer penetration improves retention of the root filling (Kokkas et al., 2004). In this study, the post space was prepared after obturation in all groups. The mechanical removal of the dentin impregnated with sealer during this step, which has been reported as an important factor for achieving fiber post retention (Vano et al., 2008), might have contributed to the results of this study.

The analysis of the failure modes showed that the mixed mode of failure was the predominant type of failure in all groups. Similar observations were reported in earlier studies (Teixeira et al., 2008; Dimitrouli et al., 2011). This suggests that the bond between the cement and radicular dentin was not affected by AH Plus or BC HiFlow sealers.

It should be stressed that the *in vitro* method used in the present study cannot fully represent an *in vivo* environment. However, these results might provide information that can help clinicians in selecting the appropriate type of sealer for clinical practice.

5. Conclusion

Within the limitations of the present *in vitro* study, the following can be concluded:

1. BC HiFlow sealer did not affect the pull-out bond strength of glass-fiber-reinforced composite posts that were cemented with a self-adhesive resin cement immediately after ($p = .202$) or 7 days after obturation ($p > .05$).
2. For immediate post cementation after obturation, the pull-out bond strength of glass-fiber-reinforced composite posts in the canals filled with AH Plus was significantly higher than those filled with BC HiFlow sealer ($p = .009$).
3. There was no significant difference in the pull-out bond strength of glass-fiber-reinforced composite posts between canals obturated with AH Plus and BC HiFlow when posts were cemented 7 days after obturation ($p > .05$).

Ethical statement

Approval of the study protocol was obtained from the Institutional Review Board at King Saud University in Riyadh, Saudi Arabia (E-19-3887) and the College of Dentistry Research Center (CDRC) at King Saud University in Riyadh, Saudi Arabia (FR 0504). The project was carried out in the Physical Research Laboratory, CDRC, King Saud University in Riyadh, Saudi Arabia.

CRedit authorship contribution statement

Sara Abdulrahman Alsubait: Conceptualization, Methodology, Data curation, Writing.

Declaration of Competing Interest

The author has no conflict of interest to declare.

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