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# Effect of Chlorhexidine Treatment Prior to Fiber Post Cementation on Long-Term Resin Cement Bond Strength

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### Clinical Relevance

The addition of chlorhexidine application prior to adhesive cementation appears to be effective in enhancing the long-term push-out strength with glass fiber posts in all root thirds *in vitro*.


## SUMMARY

**The purpose of this study was to evaluate the push-out bond strength of two different adhesive cements (total etch and self-adhesive) for glass fiber post (GFP) cementation in simulated, long-term service (thermocycling) when the root canal is treated with chlorhexidine before cementation. One hundred twenty premolar specimens with a single root canal were selected, endodontically treated, and shaped for GFP cementation (n=120). The specimens were randomly placed into one of 12 groups (10 specimens each) according to cement (T = total-etch RelyX ARC or S = self-adhesive RelyX Unicem), treatment with chlorhexidine (N or Y: without or with), and number of thermal cycles (00, 20, or 40: 0, or 20,000 or 40,000 cycles): 1. TN00, 2. TN20, 3. TN40, 4. TY00, 5. TY20, 6. TY40, 7. SN00, 8. SN20, 9. SN40, 10. SY00, 11. SY20, 12. SY40. The root of each specimen was cut perpendicular to the vertical axis, yielding six 1.0 mm-thick sections. A push-out bond strength test was performed followed by statistical analysis using a factorial analysis of variance. Pairwise comparisons of significant factor interactions were adjusted using the Tukey test. Significant differences of push-out bond strengths were found in the four main effects (resin cement [*p*<0.0001], treatment with chlorhexidine [*p*<0.0001], number of cycles [*p*<0.0001], and root third [*p*<0.0001]) and all interactions (*p*<0.05 for**



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**all). Both resin cements produced higher bond strength in the cervical third followed by the middle third, and lower values were detected in the apical third. Additionally, the results suggest that the use of an additional disinfection treatment with chlorhexidine before the cement application produced the highest push-out bond strength regardless of root third. Further, the thermocycling simulation decreased the bond strength for both resin cements long-term when the chlorhexidine was not applied before cementation. However, when the root canal was treated with chlorhexidine and the fiber post was cemented with self-adhesive cement, the bond strength increased after 0, 20,000 and 40,000 cycles.**

## INTRODUCTION

The cement preferred for glass fiber post (GFP) cementation is dual-cured resin cement. In addition to having the advantages of light-cure activation, dual-cured cements also contain chemical initiators for deep areas where light access is difficult to achieve.[1,2] However, there have been some problems (incomplete post seating, debonding,[3,4] and defects such as pores, voids, and cracks[5,6]) reported regarding the complicated technique. To decrease the number of steps and simplify the cementation process, self-adhesive dual-cured cement was developed. This cement has one step (no need for conditioning or bonding system) and has demonstrated similar[2,7] or better[8] bonding performance compared with other resin-based cements.

Current literature has suggested that the decrease in adhesive bond strength might be caused by the degradation of the exposed collagen fibrils due to incomplete resin-infiltrated acid-etched dentin.[9] This degradation is induced by an endogenous proteolytic mechanism involving the activity of matrix metalloproteinases (MMPs).[10] Nevertheless, 2% chlorhexidine has been shown to inhibit intrinsic factors such as MMPs.[11,12] Elimination of MMPs can stabilize the composite-dentin hybridization.[13] However, there is no consensus if chlorhexidine treatment before cementation improves the bond strength or for how long. Thermocycling simulates the aging process, and it has been suggested that 10,000 cycles is comparable to 1 year of temperature changes in the mouth.[14] The literature indicates that a wide range of cycles (4000-40,000) has been used.[15] A decrease,[16] increase,[17] or no change[18] in long-term bond strength has been reported but not with the chlorhexidine interaction.

The aim of this study was to evaluate the push-out bond strength of two different adhesive cements (total etch and self-adhesive) for GFP cementation in long-term (after thermocycling simulation of 2 and 4 years = 20,000 and 40,000 cycles) when the root canal is treated with or without chlorhexidine prior to cementation.

The null hypotheses tested were: (1) there will be no statistically significant difference in GFP push-out strength between the total-etch and the self-adhesive resin cements, (2) there will be no statistically significant difference between the different resin cement GFP push-out strengths among different root thirds, (3) there will be no statistically significant difference between root canals treated without or with chlorhexidine, (4) there will be no difference in GFP push-out bond strength in long-term simulation comparing 0, 20,000 and 40,000 cycles, and (5) there will be no statistically significant difference in GFP push-out strength after the interaction of all variables.

## METHODS AND MATERIALS

One hundred twenty human premolars (n=120) meeting the inclusion criteria with a ≥18-mm single root canal were selected for the study. Exclusion criteria were the presence of resorption, caries, root fractures, or previous endodontic treatment. The teeth were numbered, radiographed, and stored in 0.1% thymol.

The root canal systems were accessed through the occlusal surface under copious amounts of water and located using a K#15 file (Senseus K-Flexofile, Dentsply, Maillefer, Switzerland). Working length of the root system was determined to be 1 mm from the root apex and verified with an apex locator. The root canals were shaped by rotary instruments (ProTaper system, Dentsply) and sequenced in order (SX, S1, S2, F1, F2), applying the crown-down technique. Irrigation was performed with 1 mL of 6% sodium hypochlorite (NaOCl) solution (Vista Dental, Racine, WI, USA) using a syringe and a 27-gauge needle throughout progression of file sizes. Final irrigation was done with 17% ethylene diamine tetra acetic acid (EDTA) (Vista Dental) for 1 minute followed by 6% NaOCl solution for 1 minute. The root canals were obturated using a warm vertical condensation technique performed with gutta percha cones (Protaper F2, Dentsply DeTrey Gmbh, Konstanz, Germany) and root canal sealer (AH-Plus, Dentsply DeTrey).

A careful demineralization and tubule opening of the root dentin, with ultrasonic instrumentation in

Table 1: *Groups, Composition, Root Canal Treatment and Techniques of the Cement Application for All Materials Used in the Present Study*

| Adhesive Cement | Cement Composition | Treatment with 2% Chlorhexidine | Procedures | Cement Application | Thermocycling |
|---|---|---|---|---|---|
| RelyX ARC (T) 3M ESPE, St Paul, MN, USA | HEMA, bisGMA, dimethacrylate resins, methacrylatemodified polycarboxylic acid copolymer, photoinitiator/water, ethanol | Yes group<br>No group | Etching with 37% phosphoric acid for 15 s. Rinsing with 10 mL distilled water. Removing water excess with paper point #80 Application of multisteps adhesive system (Single Bond—3M) | Application of the adhesive cement into the root canal with a cylindrical tip microbrush. Application of the adhesive cement on the post. Insertion of post into the root canal. Light cure for 60 s. | 0 cycles<br>20,000 cycles<br>40,000 cycles |
| RelyX Unicem **(S)** 3M ESPE, St. Paul, USA | Methacrylated phosphoric esters, dimethacrylates, acetate, initiators, stabilizers, glass fillers, silica, calcium hydroxide | Yes group<br>No group | Rinsing with 10 mL distilled water. Removing water excess with paper point #80. Capsule activation. | Application of the adhesive cement into the root canal with an elongated tip. Insertion of post into the root canal. Light cure for 60 s. | 0 cycles<br>20,000 cycles<br>40,000 cycles |

association with EDTA, was performed. Post spaces were prepared to depths of 10 mm, leaving an apical seal of 5 mm of gutta-percha in the canal space. A series of sequential reamers provided for the GFP No. 2 (Rely-X Fiber Post, 3M ESPE, St Paul, MN, USA) were used for this process. The specimens were randomly placed into one of 12 groups (10 specimens per group) according to cement (T or S: total etch RelyX ARC or self- adhesive RelyX Unicem, respectively), treated with chlorhexidine (N or Y: without or with), and number of thermal cycles (00, 20 or 40: 0, 20,000, or 40,000 cycles) as follows: 1.TN00, 2.TN20, 3.TN40, 4.TY00, 5.TY20, 6.TY40, 7.SN00, 8.SN20, 9.SN40, 10.SY00, 11.SY20, 12.SY40.

All GFP surfaces were cleaned with 70% isopropyl alcohol (Cumberland Swan, Smyrna, TN, USA) and air-dried. Half the groups were not treated with chlorhexidine before cementation. The root canals of the other groups were treated with a 2% chlorhexidine solution (VEDCO, St Joseph, MO, USA), which was used to irrigate the post space using a syringe and a 27-gauge needle, and left for 60 seconds. After the waiting time, the root canal was irrigated with water and slightly dried before cementing. All manufacturer recommendations were followed for each material according to Table 1. After cementation, all teeth were light-cured for 60 seconds (Optilux 500, Kerr, Orange, CA, USA) from the occlusal direction. Thermocycling was used to simulate the aging process. The groups subjected to the 2- and 4-year aging simulation were held in 5°C cold water and then in 55°C hot water, 30 seconds in each bath, for 20,000 and 40,000 cycles.

The roots of each specimen were immediately sectioned perpendicular to the vertical axis by means of a low-speed diamond saw (Isomet, Bueher, Lake Buff, IL, USA) under copious amounts of water. Six 1.0-mm slices for each root were obtained, which were then separated into three subgroups according to specimen area (two cervical, two middle, and two apical; Figure 1).

The push-out test for each specimen section was performed with a universal testing machine (No. 8841, Instron, Canton, MA, USA) at a crosshead speed of 0.5 mm/min. The push-out test load was applied in an apical-to-cervical direction until the post became dislodged from the specimen. The push-out strength values were measured at failure and recorded in MPa ± standard deviations. A mean average for each section tested was recorded for each of the subgroups.

### Statistical Analysis

The push-out strengths were measured at failure and recorded in MPa ± standard deviation. Inferential statistical analysis of the data was evaluated using factorial analysis of variance (ANOVA) and the Tukey test ($\alpha$=0.05) to compare resin cement, treatment with chlorhexidine, number of cycles, and root third (SPSS version 20.0, SPSS, Chicago, IL, USA).

## RESULTS

When comparing different resin cements (total-etch and self-adhesive), we found a significant difference ($p<0.05$), independent of treatment with chlorhexi-

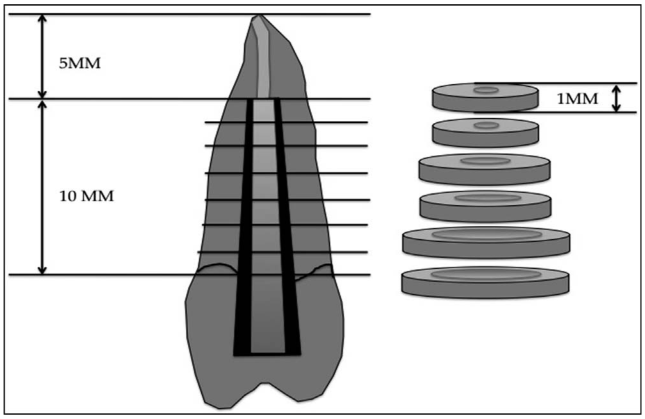


Figure 1. *Sectioning of the cemented glass fiber posts into six slices (two cervical, two middle, and two apical).*

dine and thermocycling. The self-adhesive cement had higher bond strengths than did the total-etch resin cement in all thirds (Figure 2).

When we evaluated root thirds (cervical, middle, and apical), a significant difference was determined ($p<0.05$), independent of cement, treatment with chlorhexidine, or thermocycling. The cervical third displayed the highest push-out strength, followed by the middle third, and the apical third showed the lowest push-out strength.

When comparing the chlorhexidine treatment (without and with), we found a significant difference ($p<0.05$), independent of cement, thirds, or thermocycling. The push-out strength was generally higher for both the total-etch and self-adhesive resin cement when the chlorhexidine was applied in the root canal before cementation.

In evaluating thermocycling, we found a statistically significant difference ($p>0.05$) for the self-adhesive resin cement. For this cement, thermocycling increased bond strength after 20,000 and 40,000 cycles. On the other hand, no significant statistical difference was found for the total-etch resin cement after thermocycling ($p>0.05$).

The factorial ANOVA comparing multiple independent and dependent variables showed statistically significant differences among all groups independent of cement type, root third, treatment with chlorhexidine, or thermocycling ($p<0.05$). Descriptive statistics are given in Table 2 with statistical differences noted by different uppercase letters in columns and different lowercase letters in rows.

## DISCUSSION

The teeth were stored in 0.1% thymol, which has no effect on either the organic or inorganic content of dentin,[19] during the study for sterilization/disinfection purposes, and to prevent dehydration.

This research included a meticulous analysis of many factors that can improve the long-term bond strength of GFP cementation and increase the retention of the future restoration[20] of a tooth with considerable loss of coronal structure.[21]

Prefabricated GFPs were used in this study because of their lower modulus of elasticity and inherent flexibility, which help distribute stress

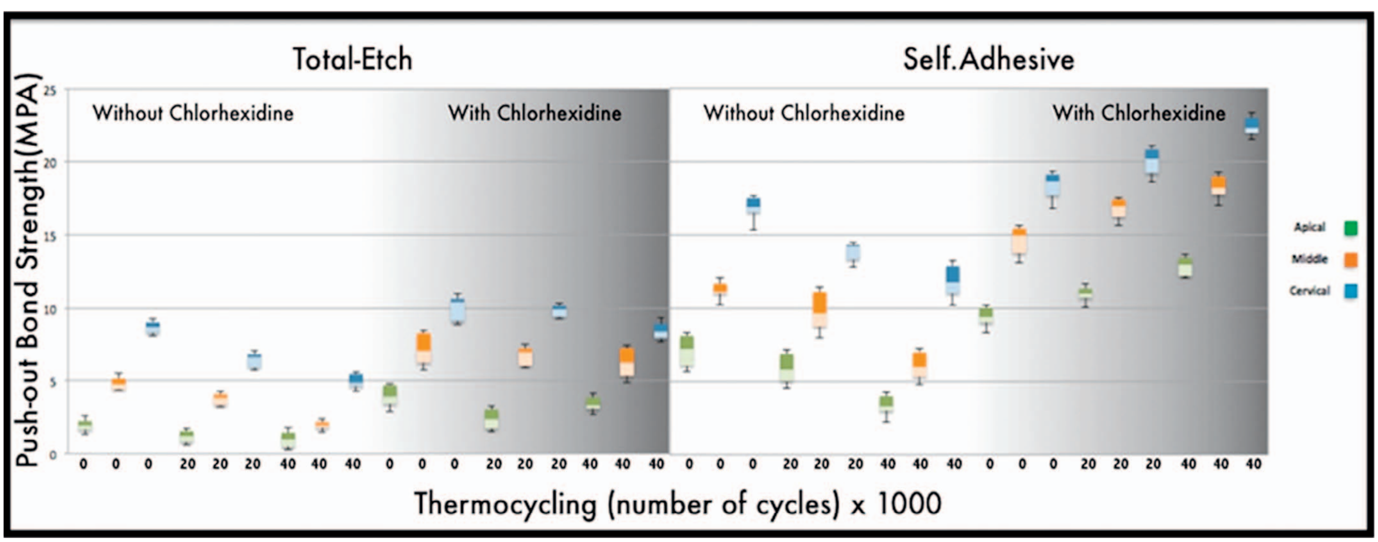


Figure 2. *Push-out bond strength means (MPa) with standard error bars of the total-etch and self-adhesive resin cements, chlorhexidine treatment, and thermocycling stratified by root thirds.*

Table 2: *Descriptive Statistics (Mean Group Push-Out Strength [MPa] ± Standard Deviation [MPa]) With Statistical Differences Noted by Different Uppercase Letters in Columns and Different Lowercase Letters in Rows*[a]

| | Root Third | | |
|---|---|---|---|
| | **Apical Third** | **Middle Third** | **Cervical Third** |
| Total-etch | | | |
| 0 Cycles (n = 20) | | | |
| Without chlorhexidine | 2.14 ± 1.09 Kc | 5.55 ± 1.27 Lb | 8.71 ± 0.91 La |
| With chlorhexidine | 3.95 ± 1.82 Kc | 7.09 ± 2.06 Kb | 10.44 ± 1.89 Ka |
| 20,000 cycles (n = 20) | | | |
| Without chlorhexidine | 1.22 ± 0.88 Jc | 3.87 ± 0.79 Jb | 6.64 ± 1.15 Ja |
| With chlorhexidine | 3.10 ± 1.23 Ic | 6.99 ± 1.29 Ib | 9.93 ± 0.95 Ia |
| 40,000 cycles (n = 20) | | | |
| Without chlorhexidine | 1.01 ± 0.96 Hb | 2.00 ± 0.92 Hb | 4.39 ± 1.12 Ha |
| With chlorhexidine | 3.33 ± 1.15 Gc | 6.29 ± 2.02 Gb | 8.38 ± 1.11 Ga |
| Self-adhesive | | | |
| 0 Cycles (n = 20) | | | |
| Without chlorhexidine | 7.23 ± 1.60 Fc | 11.14 ± 0.99 Fb | 16.91 ± 1.72 Fa |
| With chlorhexidine | 9.42 ± 1.21 Ec | 14.97 ± 1.94 Eb | 18.68 ± 2.01 Ea |
| 20,000 cycles (n = 20) | | | |
| Without chlorhexidine | 5.81 ± 1.33 Dc | 8.67 ± 0.76 Db | 14.23 ± 1.48 Da |
| With chlorhexidine | 11.00 ± 1.00 Cc | 16.98 ± 1.43 Cb | 20.20 ± 1.66 Ca |
| 40,000 cycles (n = 20) | | | |
| Without Chlorhexidine | 3.31 ± 1.19 Bc | 6.00 ± 1.26 Bb | 11.76 ± 1.67 Ba |
| With Chlorhexidine | 12.99 ± 0.92 Ac | 18.22 ± 1.28 Ab | 22.31 ± 0.86 Aa |

[a] *Groups connected by different uppercase letters in columns and different lowercase letters in lines represent statistical differences ($p<0.05$).*

more uniformly to the entire root surface.[22] A double-tapered GFP system was the shape selected. Schmage and others reported that precise fitting of the tapered GFP into the endodontic canal avoids the need of a wider preparation, which preserves dental hard structure in the apical third where the anatomical root form narrows the most.[23]

A careful removal of gutta-percha and tubule opening of the root dentin with ultrasonic instrumentation in association with EDTA was performed.[24] Aggressive removal of the gutta-percha during the post-space preparation often leads to an oversized post-space and can be a cause of adhesive or cohesive failure.[23] Final irrigation was performed with a 2% chlorhexidine solution, which has demonstrated antibacterial properties in the current literature, restricting microbial ingress into dentinal tubules.[25] Chlorhexidine has been shown to have the property of inhibiting matrix metalloproteinase (MMP), preserving composite-dentin hybridization over time.[26] Chlorhexidine in this study, was used in a manner similar to other antimicrobial agents, which are rinsed after use to avoid possible interference with the resin's ability to micromechanically bond to dentin. A prior study tested the chlorhexidine application and did not find any statistical difference between investigators that rinsed and those who did not rinse the solution.[27] GFPs were disinfected with alcohol before cementation to reduce the likelihood of surface damage to the glass fibers, which would have affected the integrity of the post.[26]

Considering the structural variability of the dentinal substrate inside the root canal, the push-out strength test allows for a more accurate analysis of the overall bonding mechanism and the ability to better simulate a clinical scenario.[26] Bond strength longevity can be measured after a thermocycling simulation. Thermocycling simulates the aging process, and it has been suggested that 10,000 cycles is comparable to 1 year clinically.[14] This process imitates the thermal changes that occur inside the mouth by drinking, eating, and breathing. The international standard for testing bond strength long-term stipulates an aging procedure in which test specimens are held in 5°C cold water and then in 55°C hot water, 30 seconds in each bath, for a large number of cycles. Investigators have used between 4000 and 40,000 cycles.[15] In our study, 20,000 and 40,000 cycles were used to simulate 2 and 4 years, respectively.

Considering the push-out strength of the two different resin cements, the first null hypothesis was rejected. The results showed that the total-etch adhesive cement (T) had lower push-out strength values to dentin compared with the self-adhesive cement (S), similar to the findings of previous studies.[28-31] However, other studies have reported higher bond strengths for the total-etch adhesive cement compared with the self-adhesive cement.[32-34] Conflicting results between the various luting cements might be explained by variability in research methodology.[7] Additionally, the complexity of clinical technique using multiple steps may cause inherent problems including the incorporation of air trapped in the cement layer. The self-adhesive cements are only mildly acidic, resulting in limited demineralization and hybridization of the root dentin.[35] However, even with limited hybridization,[36] the push-out strengths in this study for self-etching cement are statistically higher than those of the total-etch adhesive cements. These results may be explained by the fact that the chemical interactions between the adhesive cement and hydroxyapatite are more important for root dentin bonding than is the ability to hybridize dentin.[28] Published in the current literature, this interaction is based on calcium ion chelation by acidic groups from the self-adhesive cements, producing a chemical interaction with the dentin hydroxyapatite.[37] Despite the fact that the hybrid layer makes an important contribution to micromechanical bonding, the chemical interaction and the simplicity of application may contribute to the success of self-adhesive cements.

Considering the push-out strength between the different root thirds, the second null hypothesis for this study was rejected. The total-etch and the self-adhesive resin cement showed higher cervical third values compared with the middle third, while the apical third presented significantly lower push-out strength. The results agree with those reported in the current literature.[31,38] However, some investigators found equal bond strength values for the total-etch and self-adhesive cements in different root thirds.[39,40] Additionally, some researchers disagree, reporting higher push-out strengths in the apical third for the self-adhesive cements.[39,41] The lower push-out bond strength in the apical third, compared with the middle and cervical thirds, can be explained. Some explanations are: (1) difficulty accessing the narrow and deep areas, (2) incomplete removal of the smear layer before cementation, and (3) poor cement penetration into the root canal dentin.[7] Factors that should also be considered are the difficulty of phosphoric acid demineralization in deep areas and maintenance of ideal moisture before cementing.[37] In addition, those regions farthest from the curing light access likely affect the degree of conversion of the resin cement. Dual polymerization has better conversion values when light activation is used during polymerization.[7,42] Goracci and Ferrari used a tapered, translucent GFP to improve light penetration in the apical third of the adhesive cement.[43]

Considering the push-out strength between a root canal treated without or with chlorhexidine, we rejected the third null hypothesis. The results obtained in this study, for both cements, indicate that the immediate push-out strength is lower for the groups treated without chlorhexidine compared with those treated with chlorhexidine. For some authors, in general, the chlorhexidine method either did not demonstrate a significant difference among groups[44] or it negatively affected the bond strength of the adhesive systems to dentin.[45] These findings are supported by the fact that the antibacterial effects of the chlorhexidine solution alone does not seriously affect the bond strength of resin cements. The higher push-out strengths obtained in this study for both the total-etch and self-adhesive, when the root canal was treated with chlorhexidine prior the cementation, may be explained by the fact that other irrigating solutions were used in combination with the chlorhexidine. Sodium hypochlorite (NaOCl), the first solution used, can dissolve organic tissue for its antimicrobial properties. However, because NaOCl influences only the organic components of the smear layer, a demineralizing agent such as EDTA is indicated to supplement the NaOCl action. The 2% chlorhexidine, which has been recommended as an irrigant in endodontic treatment, is also indicated as an additional step because of its antibacterial properties.[11] When a NaOCl + EDTA combination supplemented with chlorhexidine is employed, a higher bond strength between the root canal dentin and the resin cement can be achieved.[46] Another possible explanation is that the adsorption of chlorhexidine by dentin favors the resin's infiltrating into the dentinal tubules, which might explain the high bond strengths obtained in this study. Certain properties of chlorhexidine (a strong positive ionic charge, ready binding to the phosphate groups, a strong affinity to tooth surfaces that are increased by acid etching, and increases in the surface-free energy of enamel and perhaps that of dentin) could lead to the assumption that its application after dentin acid etching will increase the dentin-wetting ability of primers, thus improving adhesion.[27]

In considering the push-out, long-term bond strength of 0, 20,000 and 40,000 cycles, we rejected the fourth null hypothesis. The literature reports a decrease in bond strength after thermocycling simulation.[15] A possible explanation for the lower bond strength of the resin cement after thermocycling is the hydrolysis effect at the cement interface. One reason might be the lack of treating the root canal with 2% chlorhexidine, whose action, when applied before bonding, inhibits the MMPs,[12] preserving the composite-dentin hybridization long-term.[13] This action can be verified by the presence of "water trees," which is the water path inside the hybrid layer. Studies have shown that the hybrid layer is conserved for up to 12 months[16] but is decreased after this period of time. The lower long-term bond strength values for the total-etch cements might be explained by the complexity of the clinical technique, which has multiple steps. This complexity may cause inherent problems, including incorporation of air in the cement layer and gaps,[8] creating access to the water trees. On the other hand, the increase in bond strength of the self-adhesive found in this study might be explained by the calcium ion chelation by acidic groups, which produces a very close chemical interaction with the dentin hydroxyapatite. As a result, a homogenous interface is produced between the GPF and the dentin in the root canal, blocking the water trees' access.

A limitation in this study was using root thirds as testing specimens. Although we determined the weakest link of the individual root thirds, a collective bond strength was not determined. Due to the taper of the canal and post, one would have to push from the apex toward the crown. A pilot study is currently under way for this type of analysis. In this study, unfortunately, simply adding the three mean root thirds together to obtain a full root push-out would produce erroneous data.

## CONCLUSIONS

Within the limitations of this *in vitro* study, the results suggest that the self-adhesive cement has higher push-out strengths in all thirds compared with total-etch cement, and when treated with chlorhexidine before cementation, these numbers are greater, immediately and in long term.

### Regulatory Statement

This study was conducted in accordance with all the provisions of the human subjects oversight committee guidelines and policies of the University of Louisville. The approval code for this study was IRB Exempt 14.1063.

### Conflict of Interest

The authors of this article certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company presented in this article.

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