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# Effect of Endodontic Retreatment on Push-out Bond Strength and Quality of Fiber Postbonding Interface of Resin Cements

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## ABSTRACT

**Aim:** The aim of this study is to evaluate the impact of endodontic retreatment on push-out bond strength and dentin interface of two resin cements used for fiber postcementation during endodontic retreatment.

**Materials and methods:** The root canals of 40 extracted human canines were prepared, obturated and divided into four groups (n = 10). Gutta-percha was partially removed and fiber posts were immediately cemented in groups 1 and 2 using Panavia F with ED Primer and RelyX™ U200, respectively. In groups 3 and 4, the root canal access was sealed with temporary restorative cement, specimens were stored for 30 days, endodontically retreated, and fiber posts were cemented using the resin cements applied to groups 1 and 2, respectively. Push-out tests and scanning electron microscopy analyses of different areas were performed. Data from push-out bond strengths were analyzed by one-way analysis of variance and Tukey's tests.

**Results:** Higher bond strength values were detected in the apical third for group 1 than group 3 ($p < 0.05$). No differences were observed in other comparisons between the same third of different groups ($p > 0.05$). Comparisons between different thirds in the same group revealed a higher bond strength in the apical third for group 1. Scanning electron microscopy showed formation of hybrid layer and extensive resin tags in group 1. No hybrid layer was observed in groups 2 and 4.

**Conclusion:** Endodontic retreatment had adverse effects on the push-out bond strength and dentinal interface of Panavia F with ED Primer when used for fiber postcementation specifically in the apical third, but not on RelyX™ U200.

**Clinical significance:** A significant interaction was detected between endodontic retreatment and resin cement, which indicated that endodontic retreatment might adversely affect the push-out bond strength and dentinal interface of Panavia F with ED Primer when used for fiber postcementation specifically in the apical third.

**Keywords:** Bond strength, Fiber post, Laboratory research, Push-out testing, Retreatment.

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## INTRODUCTION

Post-and-core systems are widely used in endodontically treated teeth that have insufficient coronal structure,[1] and frequently improve retention of coronal restorations.[2] Fiber posts offer some advantages over metallic posts, because their physical properties are similar to those of dentin;[3] thus, they allow balanced distribution of masticatory forces[1] and reduce the risk of radicular fracture.[4]

Resin cements are commonly used to bond fiber posts, but achieving effective adhesion is challenging, considering the unfavorable geometry and inherent limitations caused by the physicochemical properties of adhesives.[5] Many of the constraints are related to polymerization shrinkage, which reduces bond strength and creates gaps along debonded surfaces.[6,7] Conventionally, for optimal bonding and sealing, adhesives should completely diffuse across and into etched dentin. Further, the diffusion of adhesive would enable the encapsulation and protection of collagen fibrils, fill interfibrilar spaces and promote a physical interaction with underlying dentin.[8] Consequently, debris-free surfaces are imperative for successful mechanical retention of fiber posts.

Nonsurgical endodontic retreatment is the first choice for resolving endodontic failures caused primarily by persistent root infections.[9-12] However, the action of the drills used to remove the root filling material produces a new smear layer rich in sealer and gutta-percha remnants plasticized by the friction heat,[13] that mixed with inorganic components, can occlude dentinal tubules.[14] Furthermore, solvents are often used as an aid for removing gutta-percha[15] and result in the deposition of a thin layer of gutta-percha on root canal walls i.e., difficult both to detect and remove.[16,17]As well, there is no established retreatment protocol that ensures complete removal of these materials and the smear layer.[18,19]

The aim of this study was to evaluate the influence of endodontic retreatment on the push-out bond strengths and dentinal interfaces of two resin cements used for fiber postcementation. The null hypothesis was that neither endodontic retreatment nor the resin cements would influence retention of fiber posts.

## MATERIALS AND METHODS

### Specimen Preparation

The local ethics committee approved the study protocol (n = 450,480). Forty freshly extracted human canines with similar root dimensions and morphology were selected by measuring the buccolingual and mesiodistal widths (in mm) using a digital caliper, allowing a maximum deviation of 10% from the determined mean.[20] The teeth were stored in 0.1% thymol solution for up to 4 months. Soft tissue deposits were removed with periodontal scalers and the roots were sectioned transversally, 17.0 mm from the apex, using a low-spead diamond saw (Isomet 1000, Buehler, Lake Bluff, IL).

A size 15 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was then placed in the canal until it was visible at the apical foramen. The working length was determined by subtracting 1 mm from this measurement. The root canals were prepared with the crown-down technique using the ProTaper Universal rotary system (Dentsply Maillefer, Ballaigues, Switzerland), and a progressive series of integrated files up to the Finishing-3 (F3) file, at the manufacturer-recommended torque and speed settings. During preparation, all of the root canals were irrigated with 20 ml of 2.5% sodium hypochlorite (NaOCl). Afterwards, passive ultrasonic irrigation was performed as previously reported[21] using a CPR-6 ultrasonic tip (Obtura Spartan Endodontics, Algonquin, IL) with 5 ml of 2.5% NaOCl for 1 minute, followed by 5 ml of 17% ethylenediaminetetraacetic acid for 1 minute, and 5 ml of 2.5% NaOCl for 1 min. The root canals were dried with F3 paper points and obturated with F3 gutta percha cones (Dentsply Maillefer, Ballaigues, Switzerland) and AH Plus sealer (Dentsply DeTrey, Konstanz, Germany), using a McSpadden compactor (Dentsply Maillefer, Ballaigues, Switzerland).

### Experimental Groups

Using a computerized algorithm (http://www.random.org), the specimens were randomly divided into four equal groups (n = 10): 1, Panavia F/ED Primer treatment group; 2, RelyX™ U200 treatment group; 3, Panavia F/ED Primer retreatment group; and 4, RelyX™ U200 retreatment group.

The gutta-percha in groups 1 and 2 was immediately removed using a number 3 Largo drill (Dentsply Maillefer, Ballaigues, Switzerland) up to a depth of 12 mm. The post spaces were irrigated for 1 minute with 1.0 ml of 0.9% sodium chloride (NaCl) to remove debris and sealer remnants, and were then dried with paper points. Fiber posts (Reforpost RX no. 1; Angelus, Londrina, Brazil) were immersed in 70% alcohol for 60 seconds to remove residues and oils, and etched for 15 seconds with 37% phosphoric acid (FGM Dentscare, Joinville, Brazil). Group 1 posts were then silanized with Clearfil Porcelain Bond Activator (Kuraray, Tokyo, Japan) and Clearfil SE Primer (Kuraray Noritake Dental, Okayama, Japan), and group 2 posts were silanized with Ceramic Primer (3M ESPE, St. Paul). After 60 seconds, the posts were dried with a light jet of air.

ED Primer (Kuraray) was applied to the dentinal surface of each group 1 post space for 20 seconds using a microbrush, and excess primer was removed with paper points. Panavia F (Kuraray Noritake Dental, Okayama, Japan) was manipulated according to the manufacturer's instructions and was injected into the spaces using a syringe with a needle tip (Centrix, Shelton, CT). The posts were positioned and photopolymerized at the cervical orifice for 60 seconds at 1200 mW/cm$^2$ using a Radii-Cal unit (SDI, Bayswater, Australia). The same postcementation procedure was repeated for group 2 posts using RelyX™ U200 (3M ESPE, Seefeld, Germany).

In groups 3 and 4, access to the root canal was sealed with Cavit-G (3M ESPE, Seefeld, Germany), and the roots were stored under 100% humidity at 37°C for 30 days to allow the sealer to set completely. D1, D2 and D3 files (ProTaper Universal Retreatment; Dentsply Maillefer, Ballaigues, Switzerland) were used sequentially with the crown-down technique at the torque and speed settings recommended by the manufacturer until the required depth in an 'in and out' movement was achieved. After application of the D1 file, 0.1 ml of chloroform was applied to soften the gutta-percha. The walls of the root canals were examined under an operative microscope at 12.5× magnification (DF Vasconcelos, São Paulo, Brazil). If remnants of the root canal filling were visible, a smooth ultrasonic tip (SP1 fine; NSK, Tochigi, Japan) was used to remove any residual filing. Finally, the root canals were prepared using the ProTaper Universal rotary system (Dentsply Maillefer, Ballaigues, Switzerland) and a progressive series of integrated files up to the Finishing-3 (F3) file, at the manufacturer-recommended torque and speed settings. During retreatment, the specimens were irrigated with 20 ml of 2.5% NaOCl. Obturation and postspace preparation was completed using the same protocol as described for the first intervention, and fiber postcementation was performed as described for groups 1 and 2 respectively. A summary of the 'step-by-step' procedures employed for fiber postcementation is detailed in Table 1.

## Push-out Tests

All specimens were stored at 37°C in a humid environment for 7 days[22] prior to testing. Following storage, the specimens were sectioned transversely into six 1.0 mm thick slices from the cervical, middle and apical thirds of the post spaces. One slice from each area was subjected to compressive loads applied in the apicocoronal direction to avoid any interference caused by the root canal taper, using a universal testing machine (D5000 EMIC, São José dos Pinhais, Brazil) operated at a speed of 0.5 mm/min.

Push-out bond strengths (MPa) were calculated by dividing failure load (N) by area (mm$^2$). Area ($S_L$) was estimated from the formula for calculating the lateral surface area of a truncated cone: $S_L = \varpi\ (R + r)\ [h^2 + (R - r)^2]^{0.5}$, where $\varpi$ represents the constant (3.14), $R$ is the coronal post radius, $r$ is the apical post radius and $h$ is the slice thickness. The radii and thickness were measured individually using a digital caliper.

**Table 1:** Summary of the 'step-by-step' manufacturer procedures employed for fiber postcementation

| *Panavia F/ED Primer* | | *RelyX U200* | |
|---|---|---|---|
| *Group 1 (Treatment)* | *Group 2 (Retreatment)* | *Group 3 (Treatment)* | *Group 4 (Retreatment)* |
| 1. Postsilanization: mix Clearfil Porcelain Bond Activator (Kuraray, Okayama, Japan) with SE Primer (Kuraray, Okayama, Japan), apply to the Reforpost and dry after 60s<br>2. Mix ED Primer A + B (Kuraray, Okayama, Japan) and apply with a microbrush for 20s in the post space<br>3. Remove excess with paper points<br>4. Inject Panavia F resin cement (Kuraray, Okayama, Japan) into canal space<br>5. Insert the Reforpost into canal and light-cure with output intensity of 1200 mW/cm$^2$ for 60s | | 1. Postsilanization: apply Ceramic Primer (3M ESPE, St. Paul, USA) to the Reforpost and dry after 60s<br>2. Inject the self-adhesive resin cement RelyX U200 (3M ESPE, MN, USA) into canal space<br>3. Insert the Reforpost into canal and light-cure with output intensity of 1200 mW/cm$^2$ for 60s | |

## Failure Analysis

The failure mode of each debonded slice was assessed using a dental operative microscope (DF Vasconcelos) at 12.5× magnification, and was classified as follows: (1) adhesive failure between post and resin cement, (2) adhesive failure between dentin and resin cement, (3) cohesive failure in resin cement and (4) cohesive failure in dentin. Because no mixed failure occurred, this failure mode was not included in the classification.

## Scanning Electron Microscopy (SEM)

The remaining slices from each postspace third were examined for nanoleakage by conventional ammoniacal silver nitrate, and prepared for SEM.[23] After 24 hours, the slices were removed from the tracer solution, rinsed in deionized water, immersed in photo-revealed solution and polished using wet silicon carbide paper of decreasing abrasiveness (up to 1200 grit), and 1.0 and 0.3 µm alumina polishing pastes. The slices were then demineralized in 85% phosphoric acid for 10 seconds, immersed in 2% NaOCl for 10 minutes and dehydrated in an ascending series of ethanol (25, 50, 75 and 100%). Lastly, the slices were sputter-coated with a carbon layer (Bal-Tec SCD 050; Bal-Tec AG, Balzers, Liechtenstein), and observed under a field-emission scanning electron microscope (Phenom-World BV, Eindhoven, The Netherlands) operating at 10.0 kV under 2500× magnification. The micrographs were subsequently used for qualitative examination of the bonding interfaces.

## Statistical Analysis

The push-out bond strengths were tabulated and analyzed using one-way analysis of variance and Tukey's test of multiple comparisons. All statistical analyses were performed using Biostat 4.0 software (AnalystSoft Inc, Alexandria). A p-value less than 0.05 was considered statistically significant.

## RESULTS

Means and standard deviation of push-out strength (in MPa) are summarized in Table 2. Higher push-out bond strength values were detected in the apical third for group 1 than for group 3 ($p < 0.05$). No statistically significant differences were observed in other comparisons between the same third of different groups ($p > 0.05$). Comparisons between different thirds in the same group revealed a higher bond strength in group 1 of the apical third than in the cervical third of the same group. In other comparisons between different thirds of the same group, no statistically significant differences were observed. Operative microscope examination of the samples revealed that the most frequent type of failure was cohesive in dentin in group 1 and adhesive between dentin and cement in the other groups. No mixed failures were observed. The failure mode distribution is described in Table 3.

Scanning electron microscopy revealed numerous long resin tags that were apparently well hybridized with the intratubular dentine in group 1 (Figs 1A to C). However, the hybridized resin tags were not observed in group 3, which exhibited differences in resin tag density, and a considerable amount of noninfiltrated dentinal tubules, mainly in the apical portion (Figs 1G to I). No resin tags or hybrid layer was observed in groups 2 and 4 (Figs 1D to F, J to L).

## DISCUSSION

The results of the current study demonstrated that the endodontic retreatment and the type of resin cement influenced fiber postretention. Consequently, the null hypothesis that endodontic retreatment and resin cements would not influence fiber postretention was rejected.

Many endodontic procedures performed before fiber postcementation might interfere with the strength of the bond between resin cements and root canal dentin.[24-28] However, the effect of retreatment has not been so documented. Few studies have assessed the influence of

**Table 2:** Mean and standard deviation of push-out bond strength (MPa) according to different groups and post/canal third

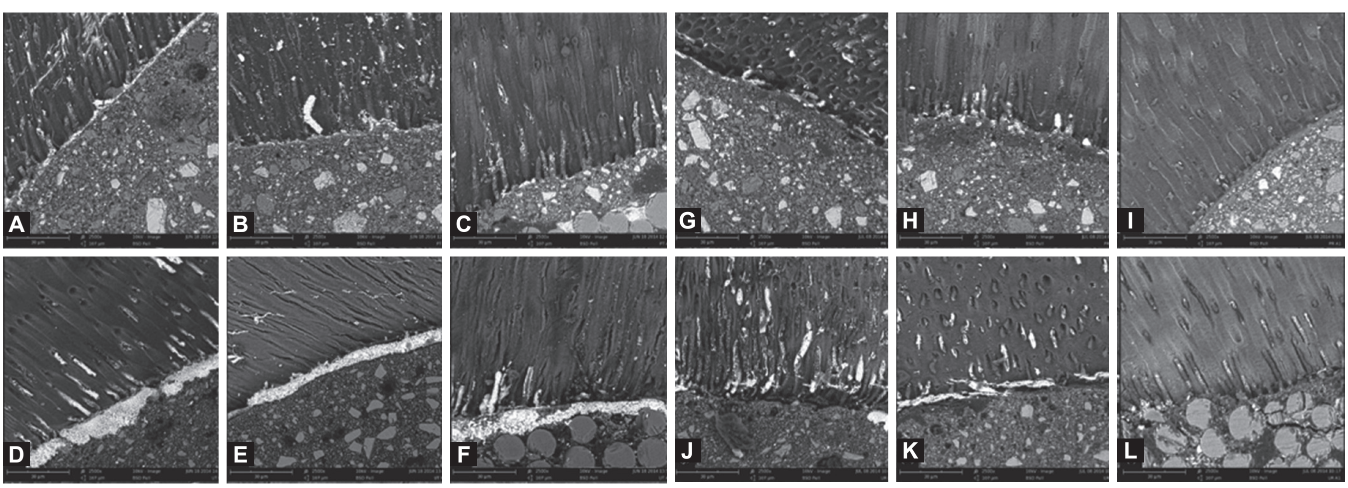
| | *G 1 Panavia F treatment* | *G 2 RelyX U200 treatment* | *G 3 Panavia F retreatment* | *G 4 RelyX U200 treatment* | *p* |
|---|---|---|---|---|---|
| Coronal | 8.32 (4.74)$^{a,1}$ | 7.72 (3.48)$^{a,1}$ | 6.72 (1.87)$^{a,1}$ | 10.04 (4.76)$^{a,1}$ | 0.3452 |
| Middle | 10.41 (3.36)$^{a,1,2}$ | 9.45 (3.86)$^{a,1}$ | 8.44 (2.82)$^{a,1}$ | 8.83 (4.44)$^{a,1}$ | 0.6719 |
| Apical | 15.05 (5.33)$^{a,2}$ | 10.95 (4.57)$^{a,b,1}$ | 8.82 (3.16)$^{b,1}$ | 10.52 (5.11)$^{a,1}$ | 0.0380 |
| p | 0.0086 | 0.2140 | 0.2270 | 0.7492 | |

*Within each line, different letters mean statistically significant difference; within each column, different numbers mean statistically significant difference ($p < 0.05$)

**Table 3:** Failure modes of specimens after push-out test

| | *G1* | | | *G2* | | | *G3* | | | *G4* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *C* | *M* | *A* | *C* | *M* | *A* | *C* | *M* | *A* | *C* | *M* | *A* |
| Adhesive (post/cement) | | | | | | | 11 | | | 11 | | |
| Adhesive (dentin/cement) | 20 | | 10 | 80 | 70 | 40 | 89 | 89 | 11 | 67 | 78 | 44 |
| Cohesive in cement | | | | | | | | | | 11 | | |
| Cohesive in dentin | 80 | 100 | 90 | 20 | 30 | 60 | | 11 | 89 | 11 | 22 | 56 |

*Percentage of failure mode in the groups




**Figs 1A to L:** Representative SEM micrographs of the resin-dentine interface at coronal, middle and apical areas of the groups (original magnification × 2500, bar = 107 μm) this procedure on the bonding process,[29,30] despite the fact that retreatment is indicated when the initial procedure fails,[11,12] and therefore merits attention. Shokouhinejad et al[29] demonstrated that the chloroform used in retreatment had an adverse effect on the bond strength of Resilon/Epiphany SE. Guedes et al[30] reported that the use of eucalyptol significantly decreased the bond strength between fiberglass posts and root canal dentin. Further, after endodontic retreatment, the postspace could contain a greater amount of debris than after the initial treatment.

Different adhesive materials are used with post-and-core systems, such as etch-and-rinse, self-etching and self-adhesive cements, and in some cases, the results obtained with the different adhesives are conflicting.[31] In this study, self-etching and self-adhesive resin cements were used to simplify bonding in the root canal system. Because of inadequate access and visibility, intracanal adhesive techniques are predominantly unfavorable. As well, remnants of phosphoric acid may remain within the root canal when conventional three-step adhesive systems are used.[32] Furthermore, the difficulties encountered in moisture control after rinsing may result in overdrying or overwetting.[33]

Various experimental setups have been described for evaluating bond strength, which is the force per unit area required to break the bond between adhesives and dentin.[26] The push-out test is commonly employed and is considered a valid method because it is less sensitive to variations in stress distribution during loading than the microtensile test.[34] In this study, the push-out test revealed a significant adverse impact of endodontic retreatment on Panavia F with ED Primer bond strength specifically in the apical third. Lower bond strength values were probably due to the increased difficulty in removing remaining filling material in this root area. Further, self-etching adhesives do not remove the smear layer; conversely, self-etching adhesives dissolve the smear layer and infiltrate underlying dentin.[24] Consequently, smear plugs remain on the conditioned dentinal surface and are incorporated into the remaining filling material. According to previous publication,[17] the use of chloroform probably resulted in a thin layer of gutta-percha deposited on canal walls that impregnated the root dentin and damaged the formation of the hybrid layer and consequently the bonding mechanism of Panavia F with ED Primer.

Conversely, the RelyX™ U200 mechanism does not involve formation of a hybrid layer and resin tags;[35,36] thus, the adhesive was probably not influenced by endodontic retreatment. As well, RelyX™ U200 does not require surface treatment of dentin, and its mechanism of action is based on chemical interaction with hydroxyapatite. Calcium ions in hydroxyapatite act as electron receptors and promote a chemical bond between acid monomers and hard tissues that result in the formation of calcium phosphates.[37] No interaction was observed between the RelyX™ U200 groups and the endodontic procedures, and remaining filling material into the dentinal tubules did not seem so relevant in this group.

Different thirds compared with the same group revealed a higher bond strength in endodontic treatment on Panavia F with ED Primer of the apical third compared with the cervical third of the same group. Retentive strength of a bonded post can be considered to be the combined result of micromechanical interlocking, chemical bonding and sliding friction.[38] The largest adjustment of fiber posts in apical third contributes to the frictional retention and consequently increases the resistance to dislocation. This fact combined with ED Primer bonding mechanism results in the formation of the hybrid layer and resin tags providing micromechanical interlocking.

A minimum number of dentin and resin cement adhesive failures occurred in the Panavia F with ED Primer treatment group compared with the high percentage of failures observed in the Panavia F with ED Primer retreatment group. The finding suggested that the effects of endodontic retreatment are relevant on self-etching adhesives. Adhesive failure between the post and resin cement were rare. The silanization of the postsurface, as well as proper postconfiguration, which was parallel to the apical conicity and the undercuts along the entire length, potentially contributed to the lower frequency of failure between the post and resin cement. Cohesive failures in dentin occurred most frequently in the Panavia F with ED Primer treatment group, which suggested that the bond strength exceeded cohesiveness in this group.

Scanning electron microscopy was conducted to determine the quality of the bonding surface and revealed resin tags with an evident hybrid layer in the Panavia F with ED Primer treatment group, which supported the bonding mechanism of this system. However, differences in the resin tag density were found in the Panavia F with ED Primer retreatment group, most likely due to remnants of root canal fillings. According to previously published data,[39] smear layer density might compromise bonding to dentin compared with smear layer thickness, especially for self-etch adhesives. The RelyX™ U200 groups did not display resin tags or the hybrid layer as reported in other studies, which supported the theory that self-adhesive resin cements interact superficially.[35-37]

The adverse effect of residual filling material on the bond strength of resin cement has been explained by the fact that longer endodontic sealer contact time with the dentin promotes high penetration of harmful agents through the dentinal tubules.[40,41] Postspace preparation might remove part of the dentin surface, but probably not enough to eliminate the excess cement from the dentinal tubules, especially in the apical third. Further, a heavy smear layer covering the tubules might adversely affect the formation of resin tags that are essential for adhesion of self-etching systems.

## CONCLUSION

Endodontic retreatment had adverse impacts on the push-out bond strength and dentinal interface of Panavia F with ED Primer when used for fiber postcementation specifically in the apical third, but not on RelyX™ U200.

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