The Effect of Dowel Space on the Bond Strengths of Fiber Posts

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Purpose: The purpose of this study was to evaluate the effect of the degree of mismatch between post space and post diameters on the bond strength of a fiber-reinforced resin post.

Materials and Methods: Thirty-two extracted human maxillary central incisors and canines were endodontically treated and assigned to four groups: Group 1 - Canal prepared with a D.T. Light Post #1 drill (control); Group 2 - Canal prepared with a D.T. Light Post #2 drill; Group 3 - Canal prepared with a D.T. Light Post #3 drill; Group 4 - Canal prepared with a Gates Glidden #6 drill. A D.T. Light Post size 1 was then luted into the canal using One-Step Adhesive and Post Cement Hi-X. A push-out test was performed on three sections of each root to measure push-out bond strengths. Data were analyzed with ANOVA and Bonferroni's test at $p < 0.05$. Two extra teeth for each group were restored in the same fashion and processed for SEM observation.

Results: (in MPa): Group 1: 15.7 ± 6.9; Group 2: 14.7 ± 6.5; Group 3: 14.0 ± 5.0; Group 4: 14.0 ± 5.1. The variable "post space" resulted in no statistically significant difference in mean bond strengths ($p > 0.05$). For the variable "root region," the *coronal* third (17.5 ± 6.0) resulted in statistically greater mean bond strengths than the *apical* third (12.3 ± 6.0) at $p < 0.008$. The *middle* third (14.0 ± 5.3) resulted in no statistically significant different mean bond strengths from the *coronal* third at $p > 0.119$ and from the *apical* third at $p > 0.999$. Under the SEM, some areas of the canal system still displayed residual gutta-percha, which resulted in debonding of the interface between the resin cement and dentin. Areas with incomplete dentin hybridization were observed in localized areas of all groups.

Conclusions: The diameter of the post space did not affect the push-out bond strengths. Bonding at the coronal level of the root canal is more reliable than bonding at the apical level. The presence of residual gutta-percha and the deficient dentin hybridization may result in deficient seal of the resin–dentin interface.

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THE RESTORATION of endodontically treated teeth is often complicated because of the loss of tooth structure by caries, restorative procedures, fractures, and endodontic access preparations. The use of posts in endodontically treated teeth with insufficient coronal tooth structure is a universally accepted procedure. Posts provide retention for the core and increase the resistance form of the tooth.[1]

The use of fiber-reinforced resin posts (fiber posts) to restore endodontically treated teeth has gained popularity in the last few years. Most fiber posts consist of a resin matrix with reinforcing quartz or glass fibers.[2] Quartz fibers have a higher tensile strength than do glass fibers.[2] The microstructure of each fiber post is based on the diameter and density of the individual fibers and on the quality of adhesion between the fibers and resin matrix.[2] Fiber posts are made in preshaped molds in which fibers are prestressed and resin, as a filler, is injected under pressure to fill the spaces between the fibers, giving them solid cohesion. In most posts, the resin matrix is made of epoxy resin or its derivatives. Important characteristics of fiber posts include a modulus of elasticity similar

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to that of dentin[3] and their ability to be cemented using an adhesive technique.[4,5]

One of the clinically relevant problems dentists face when restoring endodontically treated teeth is the mismatch between the diameter of the post space and that of the post.[6] The retention of prefabricated metal posts cemented with nonadhesive techniques is inversely proportional to the mismatch between the diameter of the post and that of the canal.[6,7] With the advent of dentin bonding, composite resin cement is now used to improve the retention strength of posts, compared with the retention strength provided by conventional luting materials such as zinc phosphate cement.[8,9] When composites are used to retain metal serrated posts, increasing the post space results in similar or greater resistance to dislodgement than when posts are cemented in well-fitting canals.[8-11]

The push-out bonding test was first described in dentistry in 1970[12] and for studying bonding to root canal dentin in 1996.[13] The push-out test provides a better estimation of the bond strength than the does the conventional shear test, because with the push-out test, the fracture occurs parallel to the dentin–adhesive interface, which makes it a true shear test.[14] Additionally, the push-out test has been considered more dependable than the microtensile test for bonded posts.[15]

The scientific literature is scarce on the correlation between post space and retention strength of fiber posts, and since the most frequent cause of failure of bonded fiber posts is debonding,[16] the purpose of this study was to evaluate the effect of the degree of mismatch between post space and post diameters on the push-out bond strength of a fiber post bonded to root canal dentin with a total-etch adhesive technique. The null hypotheses tested in this study were: (1) The accuracy of fit between the post and post space does not influence bond strengths; (2) there is no difference in bond strength at different levels of the root for a given post.

Materials and Methods

The sample size was determined from data of previous studies carried out in our laboratory[17], which used the same push-out setup shown in Figure 1. Thirty-two extracted human maxillary central incisors and canines stored in 0.2% chloramine at 4°C up to 3 months were endodontically treated. The crown of each tooth was removed 2 mm coronal to the CEJ with a 0.15 diamond-wafering blade (Buehler, Lake Bluff, IL) in an Isomet 1000 slow-speed saw (Buehler).

Endodontic access was carried out with a tapered fissure bur (Brasseler USA, Savannah, GA) with a high-speed handpiece and water spray. Working length was calculated by subtracting 1 mm from the total length of the file inside the root canal. A crown down technique (instrumentation of the coronal aspect of the canal first, and then moving towards the apical foramen with progressively smaller files) was used for instrumentation with Gates Glidden (Union Broach, York, PA) #2 to #4 drills, and then rotary files (Profile .06 Taper Series 29, Dentsply Maillefer, Tulsa, OK) were used incrementally up to a #35 file/.06 taper. A solution of 5.25% sodium hypochlorite (The Clorox Co, Oakland, CA) was delivered with a Monoject (Sherwood Medical Co, St. Louis, MO) syringe and 27-gauge needle as a root canal irrigant during instrumentation. Following the final irrigation, the canal spaces were completely dried with absorbent paper points (Dentsply Maillefer). The prepared canals were then coated with AH26 (Dentsply Caulk, Milford, DE) root canal sealer using paper points. The lateral condensation technique was accomplished with Obtura II (Texceed Corp, Costa Mesa, CA), gutta-percha, and AH26 (Dentsply Caulk) sealer. After endodontic treatment was completed, teeth were stored in 100% humidity in black film containers for 7 days. Gutta-percha was removed with a warm plugger (Union Broach) to the appropriate depth. Post spaces were prepared to depths of 8 mm from the CEJ, leaving a minimum apical seal of 4-5 mm of gutta-percha.

The teeth were randomly divided into four groups of eight specimens each. Post spaces were prepared using drills corresponding to each group (Table 1).

The canals were etched with 32% phosphoric acid (Uni-Etch, Bisco, Schaumburg, IL) for 15 seconds, rinsed with water for 10 seconds, and then blot-dried with paper points to leave the dentin moist. Two consecutive coats of One-Step Adhesive (Bisco) were brushed into the root canal with a microbrush (Endo White Applicator, Bisco). The excess adhesive was then absorbed with paper points until a paper point returned dry from the canal. After completing the application of the adhesive, the light guide of a Curing Light 2500 (3M ESPE, St. Paul, MN) was placed on the canal opening and activated for 40 seconds. A fiber post (D.T. Light Post size 1, Bisco) with a diameter of 1.50 mm at the coronal end and 0.90 mm at the apical end was then coated with One-Step Adhesive (Bisco). Equal amounts of Post Cement Hi-X Self-Cured Resin Cement (Bisco) base and catalyst were mixed for 15 seconds into a uniform paste. Cement was loaded into a Unit-Dose Needle Tip (Bisco) and injected into the canal. The posts were placed into the canal with light pressure, and

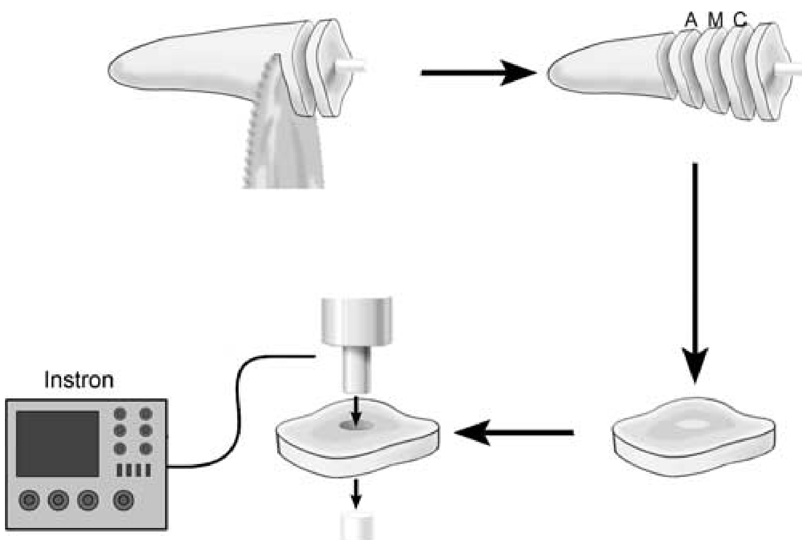

Figure 1. Preparation and testing of specimens for push-out bond strength.

excess luting material was removed with a disposable brush. After 4 minutes, the roots with their cemented posts were stored in sterile water in a black film canister for 1 week at 37°C.

The specimens were fixed to 1″ wide phenolic rings (Buehler) filled with acrylic resin (Trayresin, Dentsply/Trubyte, York, PA). The posts were kept parallel to the surface of the acrylic[17] and fixed with sticky wax. Three segments per root (Fig 1) apical to the CEJ were obtained by sectioning the root under distilled water coolant with an Isomet saw (Buehler). The sections were 2.0 ± 0.1 mm thick. Each specimen was marked on its coronal side with an indelible marker, and specimen thickness was measured with a Mitutoyo absolute digital caliper (Mitutoyo, Kanogawa, Japan) with an accuracy of 0.001 mm. The sections (total = 96 sections) were stored individually in black film canisters with sterile water.

Each section was attached to the push-out jig (Fig 1) with cyanocrylate adhesive (ZapIt, Dental Ventures of America, Corona, CA), ensuring that the coronal surface faced the jig and the post was centered over the hole in the jig. The push-out jig was placed on an Instron 4204 (Instron, Canton, MA) universal testing machine. The jig's 0.90 mm wide stainless steel pin was aligned with the center of the post, and the crosshead was lowered at 1.0 mm/min until the post was dislodged. Push-out bond strengths were calculated for each section by using the following formula:

$$\text{Debond stress} = \frac{\text{Debonding force (Kg)}}{A}$$

where A = area of the interface between the post/cement and dentin. Debond stress values were converted to MegaPascals (MPa). The area of the post/dentin interface was measured using the formula of the surface area of a conical frustum,[17] considering the top and bottom circles of the dislodged bonded assembly along with the height of the slice.

Data were analyzed with ANOVA using the SPSS 11.5 for Windows (SPSS, Chicago, IL) statistical software. *Post-hoc* tests were calculated using the Bonferroni's multiple comparison test at $p < 0.05$.

Table 1. Materials Used

Groups (coronal/apical drill diameters) n = 8	*Post (coronal/apical drill diameter)*	*Dentin Adhesive*	*Resin Luting Agent*
1 DT drill #1 (1.64/0.92 mm) 2 DT drill #2 (1.92/1.05 mm) 3 DT drill #3 (2.20/1.30 mm) 4 Gates Glidden #6 (1.40 mm)	D.T. Light Post #1 (1.50/0.90 mm), Lot 400001142 Bisco Inc. (Schaumburg, IL)	One-Step Adhesive, Lot 400000437 Bisco Inc.	Post Cement Hi-X Base, Lot 300014553 Post Cement Hi-X Catalyst, Lot 300014554 Bisco Inc.

Two additional teeth were prepared for each group and sectioned as described for the push-out bond strength testing. A vinyl polysiloxane impression (Imprint II Light-Body, 3M ESPE) was taken of the coronal surface of each section to control for artifacts during specimen preparation for SEM and poured in epoxy resin (Epo-Thin, Buehler). The root sections were fixed in 2.5% glutaraldehyde/2% paraformaldehyde in 0.1 M sodium cacodylate buffer at pH 7.4 for 12 hours at 4°C. After fixation, the sections were rinsed with 20 mL of 0.1 M sodium cacodylate buffer at pH 7.4 for 1 hour with three changes, followed by distilled water for 1 minute. They were then dehydrated in ascending grades of ethanol (25% for 20 minutes, 50% for 20 minutes, 75% for 20 minutes, 95% for 30 minutes, and 100% for 60 minutes). The sections were then demineralized in 6 N HCl for 30 seconds, and deproteinized in 1% NaOCl for 10 minutes to visualize the hybrid layer.[18] After drying, the specimens were mounted on aluminum stubs (Ted Pella, Redding, CA) with adhesive carbon disks (Ted Pella) and colloidal quick-drying silver paint (Ted Pella). The specimens were then sputter-coated with gold-palladium in an E-5100 sputter-coater (Polaron, Watford, England) at 20 mA for 90 seconds. They were observed under a Field-Emission SEM (Hitachi S-4700, Hitachi High Technologies America, Pleasanton, CA) at an accelerating voltage of 5 kV and a working distance of 13-14 mm. The epoxy replicas were compared with the corresponding root sections only if the original sections showed interfacial gaps under the SEM.

Results

There were no statistically significant differences in mean bond strengths (MPa) at $P < 0.05$ (Table 2): Group 1: 15.7 ± 6.9, Group 2: 14.7 ± 6.5, Group 3: 14.0 ± 5.0, Group 4: 14.0 ± 5.1. For the variable "root region" (Table 3), the *coronal* third (17.5 ± 6.0) had significantly greater bond strength than the *apical* third (12.3 ± 6.0) ($P < 0.008$). The *middle* third (14.0 ± 5.3) was not significantly different from the *coronal* third ($P > 0.119$) or the *apical* third ($P > 0.999$).

The SEM findings (Figs 2-5) were similar for all groups, regardless of the cement thickness. Residual gutta-percha was found in some sections, which were associated with areas of debonding at the interface around the gutta-percha (Figs 2A, 3E, and 5A). In spite of long and abundant resin tags in the coronal and middle thirds, hybridization of root dentin was deficient in localized areas. Figures 3B, 3C, 3D, and 3F show a "ghost" hybrid layer[18,19] or "hybridoid" region,[20] which is a misinfiltrated hybrid layer in which the adhesive did not envelop the collagen fibers exposed by acid etching. Figures 2D, 2E, 5B, and 5C show areas of separation between the adhesive/cement layer and dentin substrate. Resin tags were not abundant in the apical third of the root in which areas of the interface did not display any resin tag formation (Fig 4C). Voids in the body of the resin cement layer were observed in all groups. The presence of wider voids near the resin-dentin interface (Fig 2E) was noted in proximity to tightly sealed resin-dentin interfaces. In one specimen in Group 4, there was an interfacial gap that did not match the image of the epoxy replica. Therefore, this specimen was discarded.

Table 2. Push-out Bond Strengths by Drill Size and Location of Root Section (MPa)

Groups	*Root Section*	*Mean ± SD*	*N*
	Coronal	15.9 ± 5.6	8
DT drill # 1	Middle	16.0 ± 6.6	8
	Apical	15.1 ± 7.1	8
	Mean	15.7 ± 6.9	24
	Coronal	19.3 ± 6.1	8
DT drill # 2	Middle	12.5 ± 5.8	8
	Apical	11.7 ± 5.1	8
	Mean	14.7 ± 6.5	24
	Coronal	17.8 ± 4.0	8
DT drill # 3	Middle	11.5 ± 3.6	8
	Apical	12.9 ± 5.8	8
	Mean	14.0 ± 5.0	24
	Coronal	16.6 ± 5.2	8
Gates Glidden #6	Middle	15.7 ± 5.2	8
	Apical	9.6 ± 4.7	8
	Mean	14.0 ± 5.1	24

For each drill size, combined means were not statistically different at $p < 0.05$

Table 3. Combined Mean Push-Out Bond Strengths by Root Section (MPa)

Region of Root	*N*	*Mean ± SD*
Coronal	32	$17.5^{a} \pm 6.0$
Middle	32	$14.0^{ab} \pm 5.3$
Apical	32	$12.3^{b} \pm 6.0$

Means with same superscript letter are not statistically significantly different ($p < 0.05$).

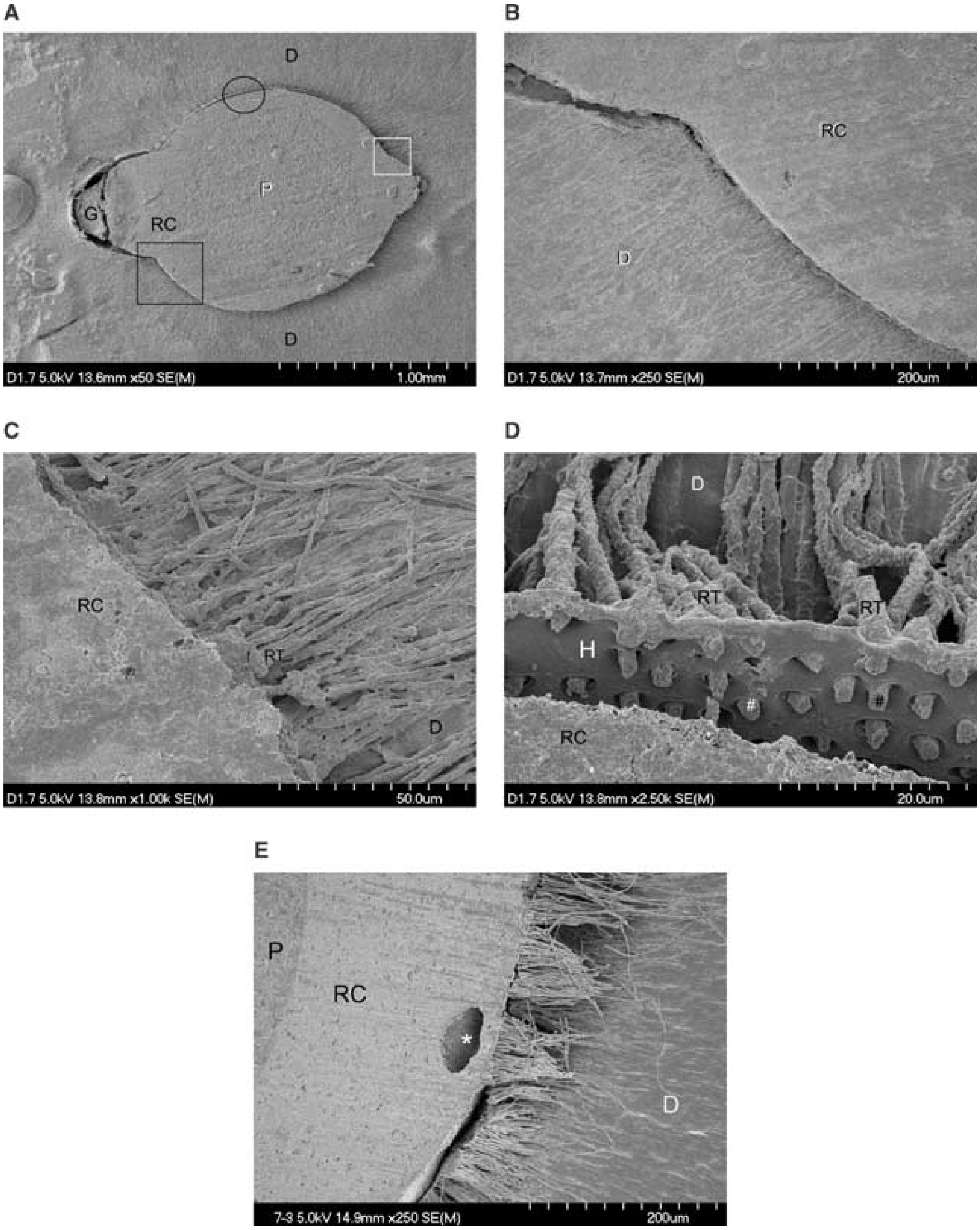

Figure 2. SEM micrographs of specimens in Group 1 (control) - canal prepared with the D.T. Light Post size 1 drill. *(A)*. General view of specimen in Group 1, middle third, at ×50 magnification. Note the residual gutta-percha (G) that caused a gap between the dentin and the resin cement. The thickness of the resin cement varies from 100 to 200 μm. *(B)*. Close-up view (×250) of area within the dark square in Figure 2A. Note that the resin–dentin interface is open only in the area in the vicinity of the residual gutta-percha. *(C)*. Close-up view (×1000) of the area within the white square in Figure 2A. Note the abundant resin tag formation and a tight interfacial seal. *(D)*. Close-up view (×2500) of area within the dark circle in Figure 2A. Note that the resin–dentin interface is open in spite of the formation of a hybrid layer. This hybrid layer does not show the characteristic reticular pattern of adhesive resin intermingled with the collagen fibers. Resin tags fractured immediately above this misinfiltrated hybrid layer (#). *(E)*. Interface showing an air bubble in the core of the resin cement. In the area of the dentin–resin interface corresponding to the air bubble (asterisk), there is no separation between the substrate as opposed to the remaining of the interface where a gap is observed. D = Dentin; RC = Resin cement; P = Post; H = Hybrid layer; RT = Resin tag(s); G = Residual gutta-percha.

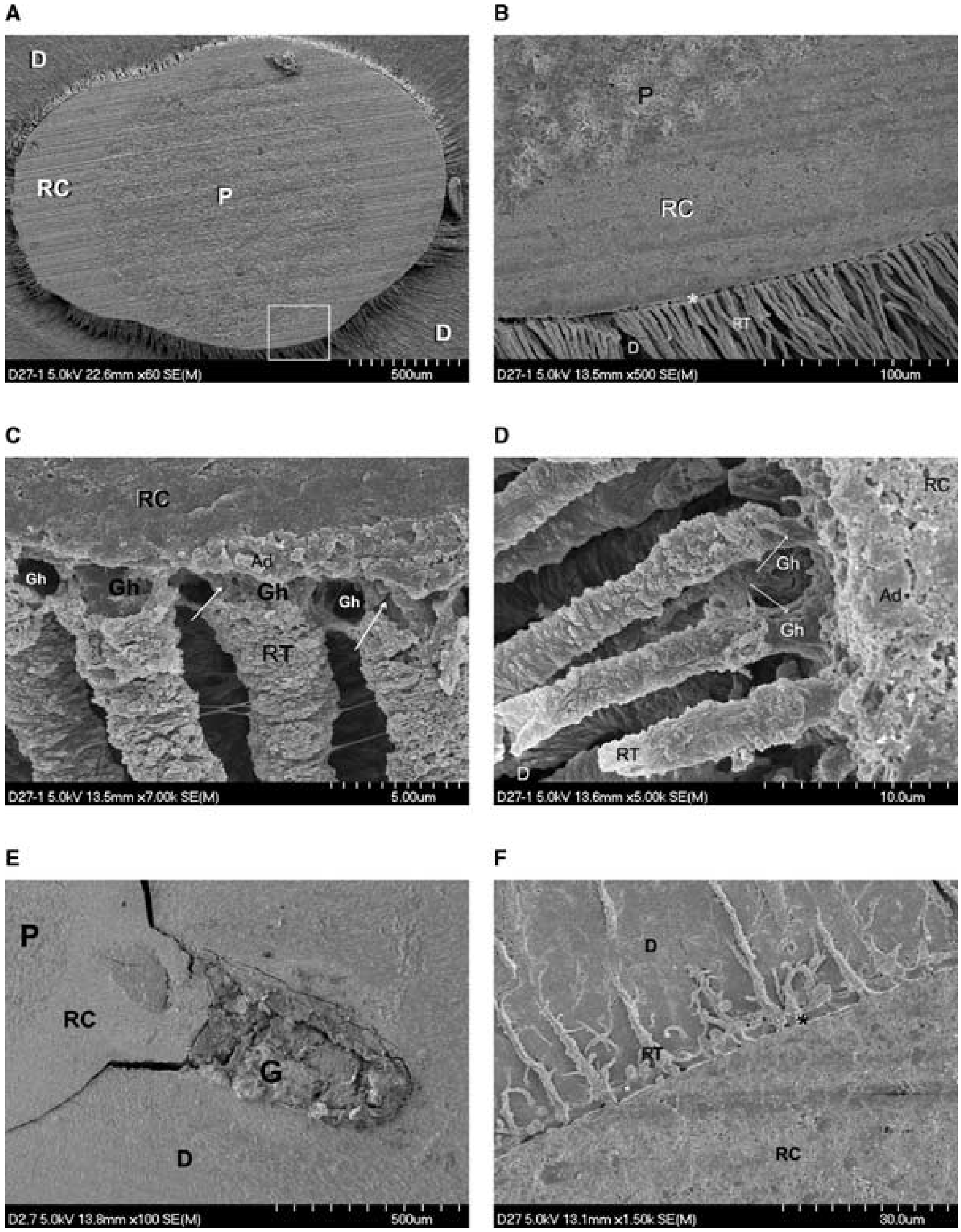

Figure 3. SEM micrographs of specimens in Group 2 (canal prepared with the D.T. Light Post size 2 drill) *(A)*. General view of specimen in Group 2, coronal third, at ×60 magnification. The thickness of the resin cement reached 370 μm. *(B)*. Close-up view (×500) of area within the white square in Figure 3A. Note the morphology of the area of the resin–dentin interface marked with an asterisk, suggesting an open area; however, the details of the hybrid layer are not readily assessable at this low magnification. *(C)*. Close-up view (×7000) of the resin–dentin interface shown in Figure 3B. Ad = Adhesive; Gh = Ghost hybrid layer or hybridoid region. The adhesive did not properly infiltrate the collagen network exposed by phosphoric acid etching. The HCl and NaOCl dissolved the unprotected collagen fibers resulting in an empty space. Note that the resin tags show a very rough surface morphology (peritubular hybridization), except in the area corresponding to the ghost hybrid layer (arrows). Note the tubule anastomosis. *(D)*. Another area of the resin–dentin interface (×5000) showing the ghost hybrid layer or hybridoid region. Note that the resin tags show a very rough surface morphology (peritubular hybridization), except in the area corresponding to the ghost hybrid layer (arrows). *(E)*. Another specimen in Group 2, middle (×100). In this section the width of the residual gutta-percha reached 0.6 mm and caused an interfacial gap. (*F*). The interface corresponding to the specimen in Figure 3E (×1500) showed a very sparse resin tag formation and incomplete dentin hybridization. Note the tubule anastomosis. D = Dentin; RC = Resin cement; P = Post; H = Hybrid layer; RT = Resin tag(s); G = Residual gutta-percha.

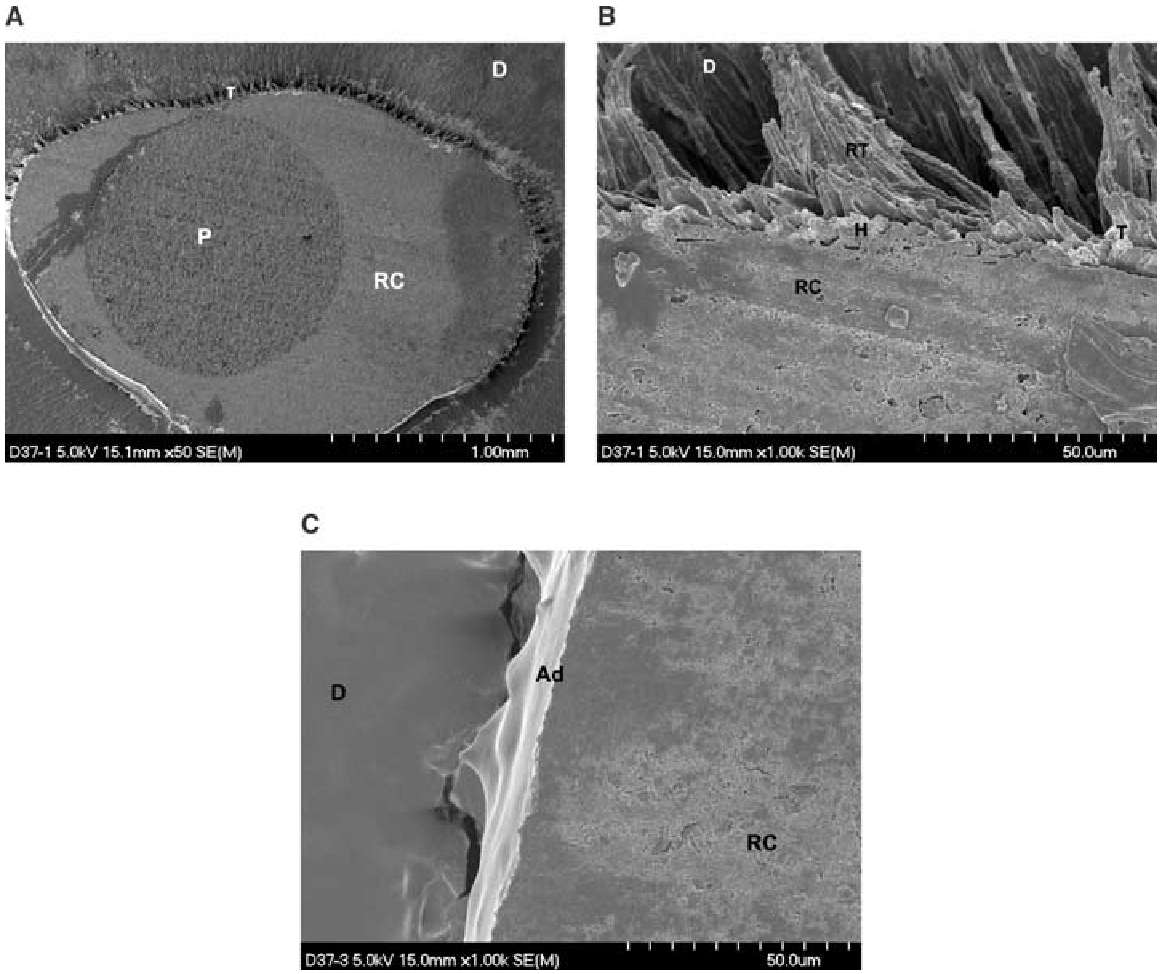

Figure 4. SEM micrographs of specimens in Group 3 (canal prepared with the D.T. Light Post size 3 drill) *(A)*. General view of specimen of coronal third, at ×50 magnification. The thickness of the resin cement reached 850 μm. *(B)*. Area of the interface of specimen in Figure 4A. In this case the resin–dentin interface is sealed without signs of gap formation. *(C)*. Apical third showing a resin–dentin interface without resin tags (×1000). D = Dentin; RC = Resin cement; P = Post; H = Hybrid layer; RT = Resin tag(s); G = Residual gutta-percha.

Discussion

For metal posts luted with resin cements, increasing the post space results in similar or greater retention than when the posts fit the post space tightly.[8-11] In our study, the thickness of the resin cement did not have any influence in the push-out bond strengths. Taking into consideration that manufacturers recommend the use of a calibrated drill to prepare a post space slightly wider than the corresponding post, the results of the present study do not totally support the manufacturers' recommendations. This apparent contradiction may be a result of the wide variations in root canal morphology. In spite of the careful preparation of the canal spaces, some canals showed an elliptical shape in cross-section, while others still had residual gutta-percha in areas that the preparation drill would not reach. The unpredictable variation in morphological features may also explain the relatively high standard deviations for some of the groups.

The modulus of elasticity of fiber posts is similar to the modulus of elasticity of dentin.[21] The similarity in physical properties between dentin and fiber posts may result in lower prevalence of catastrophic clinical failures as the post may fracture prior to the tooth. Zirconia posts and stainless steel posts are much stiffer than the quartz-fiber post used in the present study. Stiffer

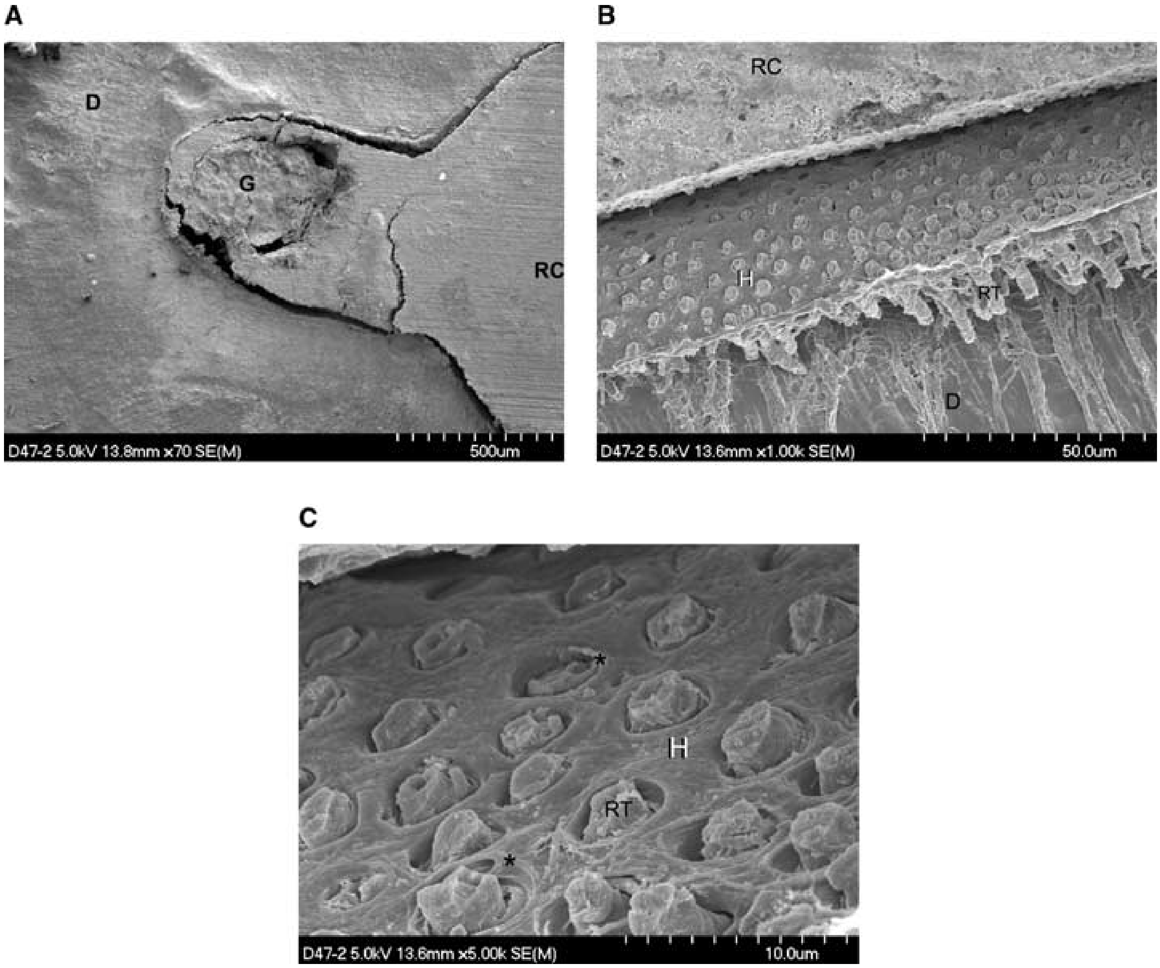

Figure 5. SEM micrographs of Group 4 (canal prepared with a # 6 Gates Glidden drill) *(A)*. General view of specimen of medium third, at ×70 magnification. Residual gutta-percha also caused interfacial debonding. *(B)*. Close-up view (×1000) of the interface showing a wide area of separation between the hybrid layer and the adhesive resin. Note the tubule anastomosis. *(C)*. At ×5000, the debonded area shows fractured resin tags. The asterisks point to partially dissolved collagen fibers. D = Dentin; RC = Resin cement; P = Post; H = Hybrid layer; RT = Resin tag(s); G = Residual gutta-percha.

posts result in catastrophic irreparable fractures as opposed to D.T. Light-Post (DT), a double-tapered quartz-fiber post, which displays more favorable fractures.[22] In fact, DT has a higher fracture resistance than both a zirconia post and another glass-fiber post.[23] This fracture resistance may be a result of the number of fibers per surface area in the structure of the DT post.[2] DT ranked first among eight posts in fiber density (32 fibers/mm^2).[2] DT also ranked first in resistance to mechanical fatigue in the same study. Forces in the tooth restored with a fiber post are apparently absorbed by the core and post and not transferred to the vulnerable root structure. Another study found that a fiber post resulted in the lowest stress inside the root.[24] The metal post tested in the same study transferred greater stresses to the root which could cause higher incidence of vertical root fractures.

Compared with confined dentin areas, flat dentin surfaces result in increased bond strength of resin-based materials.[25] Although confined dentin areas, such as prepared root canals used in the present study, are more clinically relevant, these restrained areas are mechanically less favorable to the establishment of a stable bonding as a result of a high ratio of bonded surfaces to unbonded surfaces, or C-factor.[26] The resin material has an opportunity to flow when more free surfaces are available, which results in relaxation of stresses that develop within the polymerizing resin.[26,27] The accumulated stresses may explain not only the localized debonding observed under the SEM, but also the relatively low bond strengths of fiber posts to root canal dentin. While the bond strengths to root canal dentin are in the magnitude of 12-15 MPa,[17] the bond strengths to a flat dentin surface with One-Step Adhesive are in the range of 22-27 MPa.[28] This reduction may be caused by internal stresses resulting from polymerization shrinkage that pulls the bonded restoration away from the dentin walls. The C-factor associated with a thickness of 150 μm of resin cement around the post may reach a value of 200, which is 40× higher than the C-factor of an occlusal composite restoration.[29]

In the present study we used hand-mixed resin cement, Post Cement Hi-X (Bisco). Some voids were observed in the cement layer, which is in agreement with a study that used the same resin cement.[5] The use of a lentulo spiral might have reduced the prevalence of voids.[5] The incorporation of air into the cement mix may inhibit the polymerization of the resin cement around the minuscule air bubbles.[30] The deleterious effect of a high C-factor may actually be compensated by the stress relaxation provided by the air in the structure of the cement. To illustrate this phenomenon, Figure 2E shows an interface with a wide air bubble in the core of the resin cement. In the area of the dentin-resin interface corresponding to the air bubble, there is no separation between the substrate as opposed to the remaining of the interface where a gap is observed. Consequently, we may speculate that the use of hand-mixed resin cements to lute fiber posts may be of some benefit for the mechanical integrity of the resin–dentin interface as it provides an opportunity for the stresses accumulated in the resin cement to dissipate, at least partially. When the cement layer is thicker, more air is incorporated by surface area; therefore one can expect the relaxation to be more efficient. There is, however, a trade-off between incorporation of air and physical properties of composite materials.[31] Air bubbles may weaken the composite substantially, which may explain in part the debonding between the resin cement and the root dentin.

Because One-Step Adhesive is a light-polymerized adhesive, its performance was expected to be compromised at the medium and apical thirds of the root where the curing light might not reach. A previous study demonstrated that One-Step Adhesive performs well at any level of the root.[27] As opposed to other light-polymerized one-bottle dentin adhesives, the acetone-based One-Step Adhesive is compatible with self-cured composites.[32] A clinical study showed that the two-year clinical performance of DT bonded with One-Step Adhesive was excellent and comparable to the clinical performance of another fiber post bonded with a dual-cure adhesive, Excite DSC.[16] In an in vitro study,[33] several dentin adhesives were used. The hybrid layer formed by a dual-cure adhesive system was shown to be more uniform in the apical third than that formed with the light-cured version of the same adhesive, Excite.[33]

This study also evaluated the bond strength at each section of the post. Because the post retains and stabilizes the core, it is important to evaluate different levels of adhesion of the post. It has been shown that the number of dentinal tubules decreases moving from the crown to the root apex.[34] There is a reduced infiltration of adhesive into the tubules (resin tags) in the apical third for light-cured adhesives, such as One-Step Adhesive.[5,33] Because adhesion is enhanced by penetration of resin into the tubules,[35] the difference in the number of tubules may explain why the strongest adhesion occurred in the most coronal sections where there is a greater number of tubules per square mm. Additionally, the coronal portion of the canal is the most accessible part of the canal space, making it easier to etch and more thoroughly apply the adhesive agents than in deeper areas of the canal. Besides, light curing is more effective close to the light guide.

The specimens in the present study were not subjected to thermal fatigue or to mechanical fatigue. It has been shown that thermocycling results in a significant decrease in the flexural strength of fiber posts.[14] Also, mechanical fatigue increases the microleakage for all types of posts;[36] however, it has also been demonstrated that mechanical fatigue does not change the bond strengths for fiber posts.[37,38]

Adhesive failures between dentin and resin cement have been reported clinically with fiber posts.[16,21] In our study, several areas of the dentin–cement interface showed debonding under the SEM as opposed to the post–cement interface, which did not show any separation. These findings are in agreement with those of Ferrari et al, who observed a discontinuous gap between resin cement and dentin in all groups tested, but a good adaptation between the fiber posts and respective resin cements.[33]

Additional retention and hermetic sealing may be provided by the formation of hybridized resin tags in the lateral canals that radiate from the main tubules (Figs 3C, 3D, 3F, and 5B). The hybridization of such microscopic tags in lateral tubule branches was previously described as lateral tubule hybridization.[18] As seen in micrographs of Figures 3C and 3D, the permeation of adhesive resin into the intertubular dentin parallel to the tubule axis was compromised and may have resulted in the formation of a "ghost" hybrid layer,[18,19] also referred to as "hybridoid" region.[20] This deficient infiltration of the adhesive into etched dentin may have been caused by overdrying the dentin with paper points prior to the application of the adhesive. It has been shown that the application of an acetone-based adhesive on dried dentin results in the "ghost" hybrid layer phenomenon.[18] Dried dentin is not totally infiltrated by the adhesive, leaving collagen fibers unprotected. The subsequent immersion in HCl and NaOCl during specimen preparation for SEM may be sufficiently severe to dissolve the collagen proteins resulting in an empty space (ghost hybrid) that in normal circumstances is occupied by a mesh of collagen fibers intermingled with the polymerized adhesive resin.[18] This weak area of the interface raises the question whether the use of fiber posts bonded with resin-based cements in root canals seals the pathway for bacteria leakage into the periapical region.

Despite the newest technology, the amount of remaining tooth structure after endodontic therapy and post preparation is a concern, and the strength of an endodontically treated tooth is directly related to the thickness of remaining dentin.[39] Consequently, the use of post spaces of smaller diameter is recommended because it may reduce the stress applied on the dentin when the corresponding post is inserted and limits the amount of tooth structure removed, therefore increasing its resistance to fracture.[39,40]

The first null hypothesis was accepted, as the accuracy of the fit between the post and the root canal did not influence bond strengths. The second null hypothesis was rejected, as the apical third of the root canal dentin bonded less reliably to the post than either the middle or the coronal thirds. Further studies should compare the long-term survival rate of current fiber post systems.

Conclusions

1. The diameter of the post space did not affect the push-out bond strengths.
2. Bonding at the coronal level of the root canal was more reliable than bonding at the apical level.
3. Residual gutta-percha and deficient dentin hybridization may compromise the bonding to root canal dentin.

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