An In Vitro Study on the Adhesion of Quartz Fiber Posts to Radicular Dentin

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Purpose: To evaluate in vitro the bond strength at the adhesive interface between a quartz fiber post, different adhesive systems, and different composite cements.

Materials and Methods: Thirty extracted single-rooted teeth were endodontically treated and divided into three groups (n = 10). Quartz fiber posts (DT Light-Post) were cemented with the following materials: group I: Prime & Bond NT + Self Cure Activator, and Calibra as luting cement; group II: Prime & Bond NT + Self Cure Activator, and UniFil Core; group III: UniFil Bond in combination with Unifil Core. The specimens were processed for the push-out test to evaluate bond strength at the root dentin-cement-post interface. They were sectioned along the long axis of the post into 1-mm-thick slices. A total of 60 sections was obtained from group I. Group II provided 67 slices, while group III provided 69. Loading was performed at a crosshead speed of 0.5 mm/min until the post segment was dislodged from the root section.

Results: There was no statistically significant difference between the three experimental groups. The mean bond strength obtained for group I was 9.81 ± 5.40 MPa. For group II it was 12.06 ± 6.25 MPa, and 9.80 ± 5.01 MPa for group III.

Conclusion: All the materials tested were similar in terms of providing satisfactory bond strength when used for luting fiber posts. However, Unifil Core may be advantageous since it can also be used as a core buildup material, which simplifies the clinical procedures.

Keywords: dental adhesives, resin cements, fiber posts, bond strength, push-out test.

J Adhes Dent 2007; 9: 463-467. *Submitted for publication: 09.11.05; accepted for publication: 31.10.06*

Endodontically treated teeth are often considered weaker than vital teeth due to the reduction of the coronal portion as a consequence of traumas or extensive caries. Post-endodontic restorations using endo-canal posts for the retention of the core followed by onlays, crown veneers, or metal-ceramic crowns are advisable in many clinical situations.[26] In the past, metal posts were mainly employed. However, the excessive rigidity of these posts has been proven to cause stress under function, non-uniformly transmitted to residual dentin, often resulting in irreversible tooth fracture.[1,25]

Epoxy resin-based fiber posts reinforced with carbon fibers were introduced back in 1990; they allow a more uniform stress distribution to the surrounding tooth structure because their modulus of elasticity is close to that of dentin.[7] Ideally, the remaining tooth, the fiber post and the composite cement create a "monoblock" in which the loads are uniformly dissipated, ensuring a behavior similar to healthy teeth with a lower risk of root fractures.[3,25]

The use of newly developed adhesive systems for restoring endodontically-treated teeth is also beneficial in terms of providing a coronal seal and thus reducing the risk of microleakage.[8,9] Because of the numerous treatment alternatives available, there is confusion regarding the choice of the most suitable material. The combination of an adhesive system and resin cement recommended by the manufacturer is thought to be an important factor for achieving good clin-

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Table 1 Chemical composition and application mode of the tested materials

Group I	Group II	Group III
Prime&Bond NT **Adhesive:** di-and trimethacrylate resins, PENTA (dipentacrythritol penta acrylate monophosphate), photoinitiators, stabilizers, nanofillers, amorphous silicone dioxide, cetylamine hydrofluoride, acetone. Self-curing activator: aromatic sodium sulfinate (self-curing initiator), acetone, ethanol.	**Prime&Bond NT**	**Unifil Bond** 4-MET, ethanol, water, methacrylate monomer, photo/chemical initiators
Calibra Esthetic Resin Cement **Base:** dimethacrylate resins, camphorquinone (CQ) photoinitiators, stabilizers, glass filler, fumed silica, titanium dioxide, pigments. **Catalyst:** dimethacrylate resins, catalyst, stabilizers, glass filler; fumed silica.	**Unifil Core** UDMA, dimethacrylates, fluoroaminosilicate glass, photo/chemical initiators	**Unifil Core**
Etch dentin for 40 s with 37% phosphoric acid, rinse with water. Dry with air jet and paper points. Apply adhesive for 20 s with a microbrush. Light air stream to evaporate the solvent. Light cure for 10 s. Apply silane on the post, heat for 30 s with a halogen light. Apply adhesive on the post.	Etch dentin for 40 s with 37% phosphoric acid, rinse with water. Dry with air jet and paper points. Apply adhesive for 20 s with a microbrush. Light air stream to evaporate the solvent. Light cure for 10 s. Apply silane on the post heat for 30 s with a halogen light. Apply adhesive on the post.	Etch and prime dentin for 20 s with Unifil Bond 1. Dry gently with air juet. Apply adhesive for 20 s with a miscrobrush. Apply gentle air stream. Light cure for 10 s. Apply silane on the post, heat for 30 s with a halogen light. Apply adhesive on the post.
Mix base and catalyst on a glass plate slab; the resin cement is carried inside the root canal with lentulo drill. Insert the post into the root canal, removing the excess of cement. Light cure for 20 s.	Mix resin cement and fill a CENTRIX syringe (Hawe Neos, Kerr) Fill the root canal and insert the post, removing excess of cement Light cure for 20 s.	Mix resin cement and fill a CENTRIX syringe (Hawe Neos, Kerr) Fill the root canal and insert the post, removing excess of cement Light cure for 20 s.

ical results. However, clinically different types of adhesive systems and resin composites can be used. The push-out test has been considered a suitable method for assessing bond strength at the interfacial level between the fiber post and the root canal walls.[3,5]

In this in vitro study, quartz fiber posts were tested in combination with different adhesive systems and resin cements. In particular, a resinous material that can be used for luting as well as for building up the core was tested and compared to conventional resin cement. The purpose was to evaluate the bond strength at the interface between the fiber post, the adhesive system, and the composite cement used for restoring endodontically treated teeth. The null hypothesis is that the use of different combinations of adhesives and luting cements produces different bond strength at the interface between radicular dentin and fiber post.

MATERIALS AND METHODS

Thirty single-rooted teeth, extracted for periodontal or orthodontic reasons, were stored in 0.9% sodium chloride solution for an average period of 4 months before testing. The crown of each tooth was removed 2 mm beneath the cementoenamel junction using a high-speed diamond saw (Isomet, Buehler; Lake Bluff, IL, USA) under water cooling. Root segments approximately 17 mm long were obtained. The working length was established 1 mm short of the apex. Instrumentation of the root canals was performed with a crown-down technique, using stainless-steel K-files and Gates Glidden burs. All canals were prepared to ISO size 35. Each canal was irrigated in between instrumentation with 17% ethylene diamine tetra-acetic acid (EDTA) and 5.25% sodium hypochlorite (NaOCl), dried with paper points, and

Fig 1 1-mm-thick root slices containing the bonded fiber post prior to push-out testing.

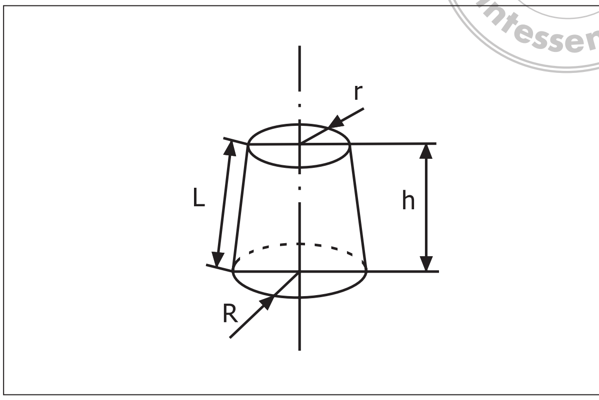

Fig 2 Schematic drawing of the mathematical formula used to measure the area at the post/root interface of push-out prepared specimens.

obturated with non-standard gutta-percha cones and CRS endodontic cement. Down-packing was performed using the continuous wave warm vertical compaction technique (System B, SybronEndo; Orange, CA, USA). Backfilling was performed with Obtura II (Spartan; Fenton, MO, USA).

Access to the canal system was temporarily sealed with Cavit (3M ESPE; St Paul, MN, USA) and teeth were stored in physiological saline solution at 37°C for two weeks. Then the gutta-percha was removed from the coronal and middle thirds of each root with Gates-Glidden drills (#3 and #4, Union Broach; York, PA; USA). At least 5 mm of intact gutta-percha and sealer was left behind to preserve the apical seal.

A dowel space was then prepared by enlarging the canal with larger Gates Glidden and Largo drills used with a very light brushing movement on the canal walls. The canals were rinsed with hydrogen peroxide using a syringe and an endodontic irrigation needle, and an air scaler was employed to eliminate gutta-percha residue from root canal walls (SONICFlex LUX, KaVo; Genova, Italy). Translucent quartz fiber posts with a coronal diameter of 1.5 mm and an apical diameter 0.9 mm (DT Light-Post size 1, RTD; St. Egeve, France) were tried into the root canal before luting.

The teeth were randomly divided into 3 experimental groups (n = 10), depending on the type of adhesive (self-etching vs total-etch) and resin cement system employed for post cementation.

In Group I, the adhesive system Prime & Bond NT + Self Cure Activator (DeTrey Dentsply; Kostanz, Germany) was used in combination with Calibra, a dual-curing resinous cement (DeTrey Dentsply). In Group II, Prime & Bond NT + Self Cure Activator (DeTrey Dentsply) was used with Unifil-Core, a dual-curing resin cement/core material (GC; Tokyo, Japan). In Group III, UniFil Bond, a self-etching adhesive system (GC) was used with UniFil Core dual-curing composite (GC). The luting procedures performed in each experimental group and the chemical composition of the tested materials are reported in Table 1. The root canal orifice was sealed with the hybrid composite Ceram-X Duo in Group I and Unifil Core in Groups II and III.

Push-out Test

After storing in distilled water for 24 h, each post-cemented root was sectioned transversally into 6 or 7 1-mm-thick slices containing cross sections of the fiber post, using the Isomet saw under water cooling to yield 60 to 69 slices for each subgroup (Fig 1). From 10% to 15% of the sections were lost while cutting in all the experimental groups. The overall number of sections obtained in the three groups is reported in Table 2.

After measuring the thickness with a pair of digital calipers, each slice was glued with cyanoacrylate (Zapit, Dental Ventures of America; Corona, CA, USA) to a loading fixture. A compressive load was applied to the slice via a 1-mm-diameter cylindrical punch attached to a universal testing machine (Controls; Milano, Italy), with the apical aspect of the slice (ie, an inverted cone-shaped posthole) facing the punch tip. The punch was aligned so that it only contacted the post upon loading. Loading was applied at a crosshead speed of 0.5 mm/min until the post segment was dislodged from the root slice. Interfacial bond strength was calculated by dividing the maximum failure load by the area of the bonded interface. The value (N/mm^2) that produced failure was shown on the digital display of the machine and recorded; the bond strength (in MPa) was calculated by dividing the load (in Newtons) at failure by the interface area of the bond (S_L), which was calculated with the following formula:

$$S_L = \pi(R+r)\sqrt{h^2+(R-r)^2}$$

where π is the constant 3.14, R is the larger radius of the post, r is the smaller radius, and h is the thickness of the section (Fig 2).

Dislodged specimens were examined at 40X magnification under a stereomicroscope (Olympus SZ-CTV, Olympus; Tokyo, Japan) to determine the failure mode. Failures were classified as adhesive (at the post/cement or cement/dentin interface), cohesive (in the cement or dentin), or mixed.

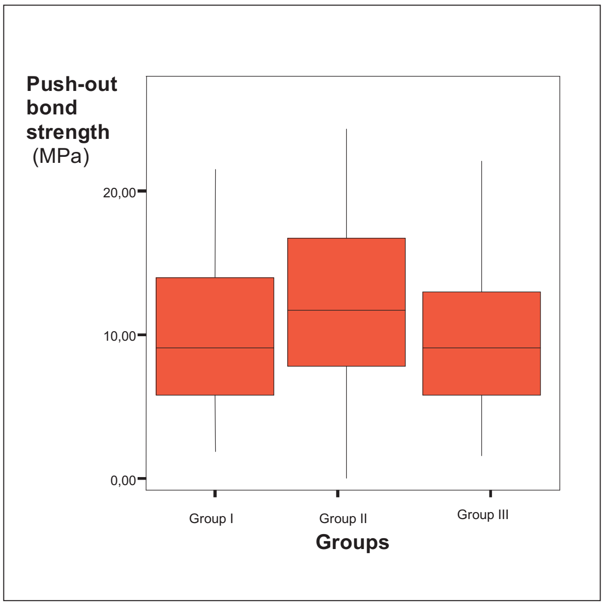

Fig 3 Mean values and standard deviation of the push-out bond strength values in MPa. In the chart, the length of each box represents the interquartile range of bond strength data for the tested materials.

Statistical Analysis

For each data series, the coefficient of variation (the ratio between standard deviation and mean value) was calculated as a parameter of consistency or reproducibility of bond strength. The Kolmogorov-Smirnov test was applied to check for normal data distribution. A regression analysis was used to ensure that the root of origin was not a significant factor for differences in the strength measurements. To evaluate the significance of the differences among the three groups, one-way analysis of variance (ANOVA) was employed, followed by the Tukey test for multiple comparisons. Statistical significance was set at the 0.05 probability level.

RESULTS

The results obtained in the experimental groups are reported in Table 2 and Fig 3. Excluding "zero bond" data from the statistical analysis, bond strength values were normally distributed, as determined by the Kolmogorov-Smirnov test. The variances in the three groups were uniform. One-way ANOVA and Tukey test revealed no significant differences among the three groups ($p = 0.261$). The mean bond strength obtained in group I was 9.81 ± 5.40 MPa. For group II, it was 12.06 ± 6.25 MPa, and 9.80 ± 5.01 for group III. The failure mode recorded in all experimental groups was mixed in nature: although residual luting agent (adhesive and cement) was visible on both the bonded interfaces (cement/post and cement/dentin), a more frank detachment occurred from the post surface.

Table 2 Mean values (MPa) and standard deviation recorded in each experimental group

	No. of specimens	Mean (MPa)	Standard deviation
Group I	60	9.81[a]	5.40
Group II	67	12.06[a]	6.25
Group III	69	9.80[a]	5.01

Same superscript letter meens no significant difference.

DISCUSSION

Similar bond strength results were achieved in all groups. Thus, the null hypothesis that there is a difference in the efficacy of the three luting systems for bonding quartz fiber posts to intraradicular dentin must be rejected.

Taking into account the relative weakness of the post-root bond, the push-out test has been considered the most appropriate method to assess the adhesion of luted posts to root canal dentin. The use of thin (ca 1 mm) sections of the restored root segment for testing allows a more uniform distribution of the load applied throughout the bonded interface. Moreover, it permits the evaluation of the pattern of bond failure in loaded specimens.[5,14]

In the study, an etch-and-rinse bonding agent was applied in combination with two luting cements and compared in efficacy to a self-etching adhesive system. Total-etch adhesives require smear layer dissolution and partial demineralization of the root dentin, exposing a fine network of collagen fibers. The infiltration of such a network by resin monomers allows the formation of a resin-dentin interdiffusion zone or hybrid layer.[8,9,27] It has been reported that self-etching adhesives respond variably to smear layer as a consequence of their aggressiveness.[21,22] The self-etching primer tested gave results that were not dissimilar from the total-etch approach.

Recent studies reported that fiber-post luted restorations can fail as a consequence of debonding of the post from the root canal.[14,17] This may occur either along the cement/dentin or the cement/post interfaces. A pretreatment of the post surface with a coupling agent (silane and/or adhesive) has been recommended to strengthen adhesion.[2,12,13] This procedure is required especially in the case of epoxy-resin–based fiber posts, due to the differences in chemistry with methacrylate-based resins.[18] Adhesion relies on the silanization of the glass/quartz fibers of the post: in this way, the free radicals exposed on the post surface can link with the resin cement components.

Bonding to intraradicular dentin presents several challenges to clinicians. Heterogeneity of the substrate[24] and exposure of root dentin to sodium hypochlorite, hydrogen peroxide,[19,20] eugenol-containing sealers, and heat generated from warm compaction[23] may impair optimal dentin hybridization.

The accessibility of the root canal during handling of the materials and the peculiar conditions of moisture in the root canal are other factors that can possibly influence the quality of adhesion.[4] The poor correspondence of circular prefabricated posts to irregular post spaces may effect a nonuniform adaptation of the luting material to root canal walls with excessive film thickness, thus losing its function of "stress breaker" at the interfacial level.[11,15,28] Furthermore, a high, unfavorable C-factor has been recently reported for the root canal, which may contribute to maximizing the polymerization stress of resin-based materials along the root canal walls.[4,23] The choice of slow-setting dual-polymerizing resin materials like the ones tested in the present study may prevent curing stress generation and interfacial stress formation.

Dual-polymerizing resin materials contain a photosensitizer like camphoroquinone (CQ) and catalytic components normally employed for chemical polymerization. Camphoroquinone requires a co-initiator for effective polymerization to occur, such as sodium salts of sulphinic acid.[6,16] Although these agents enhance resin polymerization in dual-curing resin systems, the combination of different adhesives and resin cements may affect bond strength.

Clinicians are often faced with advertisements that suggest the use of adhesives and luting systems from the same manufacturer. Even if care should be taken when drawing conclusions from bond strength data, the combination of the adhesives/cements tested here provided satisfactory results.

CONCLUSION

The choice of a luting agent also suitable for core buildup may represent a promising alternative to conventional resin cements, simplifying the clinical procedures and reducing the risk of incompatibility. Nevertheless, it would be desirable to seek ways to improve bonding to radicular dentin. Further research may elucidate suitable combinations of adhesives/luting agents for cementing fiber posts, and clinical data are advisable for supporting the experimental data.

ACKNOWLEDGMENTS

The fiber posts, adhesives, and composites employed in this study were generously sponsored by DeTrey Dentsply and GC.

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Clinical relevance: This in vitro work provides evidence that the different combinations of adhesive/luting agents tested to cement quartz fiber posts, when carefully used in accordance with correct post space preparation and the manufacturer's instructions, can be clinically successful because they all demonstrate satisfactory bond strength to radicular dentin.