The Influence of Operator Variability on Adhesive Cementation of Fiber Posts

Marco Simonetti[a]/Ivana Radovic[a,b]/Michele Vano[a,f]/Nicoletta Chieffi[c]/Cecilia Goracci[d]/
Francesco Tognini[a]/Marco Ferrari[e]

Purpose: The aim of this study was to evaluate the influence of the operator's experience on the outcome of fiber post cementation using an etch-and-rinse acetone-based adhesive.

Materials and Methods: Fifteen human anterior teeth were used in the study. One trained operator performed the endodontic procedures and prepared the roots for the insertion and cementation of the posts. At this point, teeth were divided into 3 groups and distributed to 3 operators to lute the posts: an expert operator (EO), a moderately experienced operator (ME), and an operator with a low level of experience (LE). Quartz fiber posts (DT Light Post #1 or #2, RTD) were used. Posts were cemented using Prime&Bond NT Dual Cure adhesive system (Dentsply Caulk) in combination with the dual-curing resin cement Calibra (Dentsply Caulk). The post retention was assessed with the "thin-slice" push-out test. One-way ANOVA was performed to examine the effect of the operator on push-out strength, followed by post-hoc multiple comparisons using Tukey's test, with the significance level set at $\alpha = 95\%$.

Results: The results of push-out strength testing were as follows: EO (12.44 ± 3.63 MPa), ME (11.68 ± 2.64 MPa), LE (11.18 ± 3.12 MPa). No statistically significant differences were determined among the three groups.

Conclusion: There was no statistically significant difference in the retention measured for fiber posts luted by operators with different levels of clinical experience. Given the parameters of this investigation, the level of operator experience in luting fiber posts does not affect post retention under laboratory conditions.

Keywords: operator, variability, bonding, fiber posts.

J Adhes Dent 2006; 8: 421-425. *Submitted for publication: 10.01.06; accepted for publication: 04.05.06.*

In the past 10 to 15 years, the method of reconstructing endodontically treated teeth by the use of fiber post and core systems has gained acceptance among clinicians. A well-known characteristic of fiber posts is a modulus of elasticity that is in accordance with dentin, resin cements, and resin core materials.[2] Laboratory studies have shown that this feature results in beneficial properties, such as lower occurrence of root fractures.[28] More importantly, fractures observed with fiber posts were most commonly of a nature allowing repair, unlike the ones seen with conventional cast posts.[1,5,19,23,30]

In clinical trials, lower occurrence of root fractures was noticed in general, along with the high survival rate of fiber posts combined with full crowns.[8,21] Recent data have confirmed the good clinical performance of endodontically treated teeth restored with fiber posts and direct composite restorations.[13]

In terms of bond strength of fiber posts to root canal dentin, the best results in short-term laboratory investigations have been achieved with the etch-and-rinse systems in combination with dual-cured resin cements.[10] However, etch-and-rinse systems are considered to be technique sen-

[a] PhD Student, Department of Dental Materials and Restorative Dentistry, Policlinico Le Scotte, University of Siena, Siena, Italy.

[b] Clinical Assistant, Clinic for Pediatric and Preventive Dentistry, Faculty of Dentistry, University of Belgrade, Beograd, Serbia.

[c] Dentist in private practice, Siena, Italy.

[d] Assistant Professor, Department of Dental Materials and Restorative Dentistry, Policlinico Le Scotte, University of Siena, Siena, Italy.

[e] Dean and Professor, Department of Dental Materials and Restorative Dentistry, Policlinico Le Scotte, University of Siena, Siena, Italy.

[f] Resident, Department of Oral Surgery, University of Pisa, Pisa, Italy.

Reprint requests: Dr. Ivana Radovic, Clinic for Pediatric and Preventive Dentistry, Faculty of Dentistry, University of Belgrade, Dr. Subotica 11, Beograd 11000, Serbia and Montenegro. Tel: +38-111-268-4581, Fax: +38-111-268-5361, e-mail: ivana.radovic@iritel.com

Table 1 Composition of the materials used in the study

Material	Composition/Batch No.	Manufacturer
34% Tooth Conditioner Gel	Phosphoric acid, highly dispersed silicon dioxide, colorant, water/ 0405000944	Dentsply Caulk
Prime & Bond NT Dual Cure adhesive	Adhesive: di- and trimethacrylate resins, PENTA (dipentaerythritol penta acrylate monophosphate), photoinitiators, stabilizers, nanofillers, amorphous silicone dioxide, cetylamine hydrofluoride, acetone/0501002323 Self-curing activator: aromatic sodium sulfinate, (self-curing initiator), acetone, ethanol/040901	Dentsply Caulk
Calibra Esthetic Resin Cement (dual curing resin cement)	Base: dimethacrylate resins, camphorquinone (CQ) photoinitiator, stabilizers, glass fillers, fumed silica, titanium dioxide, pigments/ 040916 Catalyst: dimethacrylate resins, catalyst, stabilizers, glass fillers, fumed silica/0506142	Dentsply Caulk
DT Light Post	quartz fiber post/35003180409 A	RTD

sitive,[7] especially if the wet bonding method is followed, as with acetone-based systems.[25,31] Moreover, root canal dentin is different in nature than coronal dentin, and in clinical situations, it is usually additionally altered by endodontic procedures which involve the use of different irrigants.[6,14,24] The shape of the root canal itself is another factor that influences adhesive procedures. Tay et al have shown that C-factors in bonded root canals are fairly high, exhibiting a negative correlation with resin sealer thickness.[32] In contrast, the volumetric shrikage is reduced as the cement layer is reduced, which results in reduction of shrinkage stress (called also the S-factor). However, it was concluded that the complex interaction of C- and S-factors in root canals can result in highly unfavorable conditions when compared with indirect intracoronal restorations with a similar resin film thickness.[32] In accordance with these findings, it has been demonstrated that stresses from polymerization shrinkage which occur in the dowel space complicate the formation of high-strength bonds when cementing endodontic posts with resin cements.[4] Therefore, it may be questioned whether the favorable results obtained in previous laboratory studies can be repeated in everyday practice performed by clinicians with different levels of knowledge and experience.

The aim of this study was to evaluate the influence of the operator's experience on the success/outcome of fiber post cementation using an etch-and-rinse acetone-based adhesive. The null hypothesis tested was that the efficacy of adhesive cementation of fiber posts to root canal dentin is not influenced by the operator.

MATERIALS AND METHODS

Fifteen anterior human teeth, recently extracted for periodontal reasons, were used in this study. They were stored in 0.5% chloramine-T until use. One trained operator performed the endodontic procedures and prepared the roots for the insertion and bonding of the posts. The crown portion of each tooth was removed by cutting with a diamond blade, under copious water cooling, perpendicular to the long axis of the tooth. The roots were endodontically instrumented at a working length of 1 mm from the apex to a #35 master apical file. A step-back technique was used with stainless-steel K-files (Union Broach; New York, NY, USA), Gates-Glidden drills #2 to #4 (Union Broach), and 2.5% sodium hypochlorite irrigation. The roots were obturated with thermoplasticized injectable gutta-percha (Obtura, Texceed; Costa Mesa, CA, USA) and a resin sealer (AH-Plus, Dentsply DeTrey; Konstanz, Germany). Then, part of this filling material was removed with burs, and the canal wall of each specimen was enlarged with low-speed post drills provided by the manufacturer, in order to create a 9-mm-deep post space, as measured from the cementoenamel junction on the buccal aspect of the tooth. At this point, the specimens were randomly divided into 3 groups of 5 teeth each and distributed to 3 operators with different levels of experience to perform the luting of the posts. None of the three operators were involved in the previous endodontic and post space preparation procedures.

Group 1: expert operator (EO). At the time of this investigation, the expert operator had been placing fiber posts routinely for 10 years and had placed at least 1000 posts.

Group 2: moderately experienced operator (ME). The second operator (postgraduate student) had placed approximately 200 fiber posts within 2 years of clinical experience.

Group 3: operator with a low level of experience (LE). The third operator was an undergraduate student that had placed approximately 10 fiber posts prior to the present investigation.

Post Cementation

In all three groups, Prime&Bond NT Dual Cure adhesive system was used (Dentsply Caulk; Milford, DE, USA) in combination with the dual-curing resin cement Calibra (Dentsply

Caulk) (Table 1). Each operator received written information on how to use the materials, and the information was written strictly according to the manufacturer's instructions. The luting procedure was also calibrated among the three operators. The post space was rinsed and thoroughly dried using air and paper points. Caulk 34% Tooth Conditioner Gel (34% phosphoric acid) was applied to the post space through a needle, and after 15 s it was completely rinsed off with water injected into the canal with an endodontic syringe. Excess water was removed from the post space with a gentle air blast. Paper points were used to remove residual moisture, but without desiccating the etched dentin surface. One to two drops of Prime&Bond NT adhesive were placed into a clean plastic mixing well, and were immediately mixed with an equal number of drops of Self-Cure Activator for 1 to 2 s with a clean, unused brush tip. The adhesive/activator mixture was applied to the post preparation with a microbrush, being certain to apply generous amounts to the preparation orifice. The contact of adhesive/activator with tooth structure was maintained for 20 s. The post preparation was dried with an air syringe, and the excess adhesive/activator solution was absorbed from the post space by a paper point. A single coat of mixed adhesive/activator was applied to the post with the same brush, followed by gentle air drying. If any dull areas appeared on the treated post, mixed adhesive/activator was reapplied, and immediately air dried for 5 s. DT Light Posts (RTD; St Egrève, France) were used. Depending on the size and the shape of the root specimens, #1 and #2 posts were used. Resin cement components were mixed and spread on the surface of the post and into the post preparation with a lentulo spiral. The post was seated immediately and the excess was removed. Light curing was performed through the post for 10 s with a high-power LED curing light (SmartLite PS, Dentsply Caulk). The intensity of the light was 950 mW/cm^2. All the post-cemented roots were placed in water at room temperature. After one week, specimens for push-out strength testing were prepared by the operator that was not involved in the luting procedures.

Preparation of Specimens for the Push-out Strength Test

The portion of each root that contained the bonded fiber post was sectioned into 5 to 6 1-mm-thick serial slices with the Isomet saw (Buehler; Lake Bluff, IL, USA) under water cooling. Five bonded roots were used for each group, resulting in 25 to 30 slices per group for push-out strength evaluation. The thickness of each slice was measured with a digital caliper, and then firmly fixed with cyanoacrylate glue to a loading fixture. The push-out load was applied by a universal testing machine (Controls; Milano, Italy) equipped with a 1-mm-diameter cylindrical plunger. The plunger was positioned so that it only contacted the bonded post upon loading, introducing shear stresses along the bonded interfaces. The apical aspect of the slice was facing the punch tip, so the loading force was introduced in an apical-coronal direction, moving the post towards the larger part of the root slice. Loading was performed at a speed of 0.5 mm/min. Bond failure was manifested by the extrusion of the post from the root section. Push-out strength (in MPa) was calculated by dividing the load in N at debonding by the bonded surface area (SL, mm^2). SL was calculated as the lateral surface area of a truncated cone with the formula: $S_L = \pi\ (R+r)[(h2 + (R-r)^2]^{0.5}$, where R represents the coronal post radius, r the apical post radius, and h the thickness of the slice.

Table 2 Push-out strength

DT Light Post Prime & Bond NT Calibra	Number of specimens	Push-out strength (MPa) mean [SD]
Group 1 (expert operator)	31	12.44 [3.63][a]
Group 2 (moderately experienced operator)	28	11.68 [2.64][a]
Group 3 (operator with low experience)	27	11.18 [3.12][a]

Same superscript letter indicates no significant difference.

Statistical Analysis

As strength data were normally distributed (Kolmogorov-Smirnov test), and group variances were homogeneous (Levene's test), one-way ANOVA was applied to assess the significance of the differences in push-out strengths among the three experimental groups. The significance level was set at $\alpha = 95\%$.

RESULTS

The mean and standard deviation of push-out strength values for the three experimental groups are shown in Table 2. In Fig 1, the length of each box represents the range of the push-out strengths measured in three groups. The highest values of push-out strength were recorded in group 1 (expert operator), while the variability of the data was the lowest in group 2 (medium experience). The one-way ANOVA revealed that no statistically significant differences in push-out strengths existed among the three groups ($p > 0.05$).

DISCUSSION

Prior to luting the posts, endodontic procedures and preparations of dowel spaces were performed by the operator that was afterwards not involved in the cementation procedures. In this way, differences between three operators could have been related only to their diverse abilities to handle the adhesive cementation of the posts in the root canals.

In order to determine the retentive strength of fiber posts, microtensile[4,17,22] and push-out[3,10,16] tests have been used.

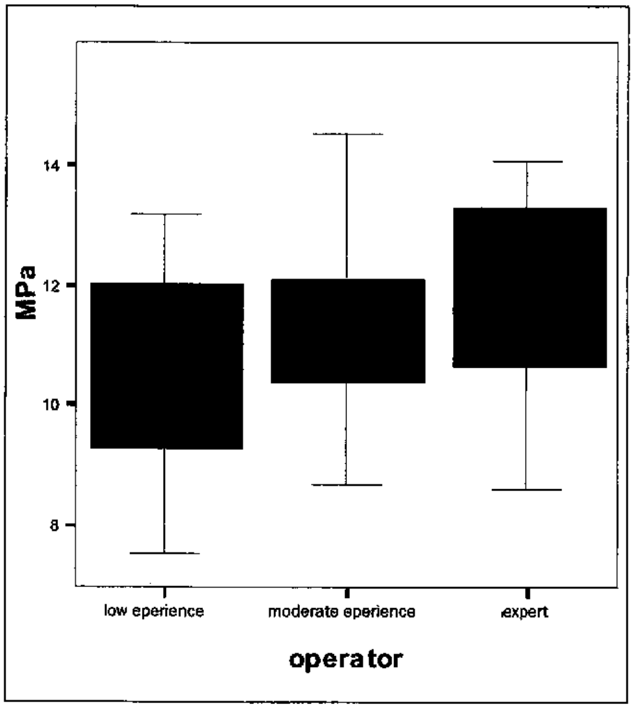

Fig 1 Push-out strengths measured for the posts luted by operators with different levels of clinical experience.

In the present study, the thin-slice push-out strength test was performed, since it has been shown to be more reliable than the microtensile technique for measuring the retentive strength of fiber posts to root canal walls.[11] No aging was performed prior to the push-out test, in order to simulate clinically relevant conditions of loading at the early stage of a restoration's lifetime. Moreover, if an adhesive restoration is placed coronally, it can be assumed that a fiber post luted in the root canal should not be exposed to degradation processes.

No studies that investigated bond strength of Calibra resin cement to root canal dentin have been published so far. However, push-out strength values recorded in this study were in accordance with those reported by Goracci et al[10] for other adhesive cements. From the results of this investigation, no influence of the operator on the retentive strength of luted fiber posts could be determined, which lead to the acceptance of the null hypothesis.

The possible variability in the outcome of bonding procedures that may be induced by the operator was investigated in several studies. Sano et al[29] and Miyazaki et al[20] showed that the clinical experience of the operator influences bond strength to coronal dentin. The operator-related variability was shown to be a more important consideration than the material when gap formation was observed in a study by Jacobsen et al.[15] Peschke et al investigated the consequences of misinterpreting manufacturers' instructions. A significantly higher amount of marginal openings was seen in groups where one of the steps in the application procedure was performed incorrectly.[26]

However, information on how the operator's expertise can influence the success of a procedure of adhesive post cementation was missing in the literature. Since bonding to intraradicular dentin is generally considered to be more technique-sensitive than adhesion to coronal tissues, the fact that strength values in this study were not different regardless of the clinician's level of experience could be viewed as highly beneficial from the clinical stand point. DT Light Post posts cemented with dual-curing resin cement had shown favorable results in terms of 2-year clinical survival.[21] These posts also performed very well when in vitro fatigue resistance was assessed.[12] Therefore, it would be reasonable to expect high survival rate and satisfactory clinical behavior of restorations placed with quartz fiber posts. On the other hand, clinical studies that investigated fiber posts reported that along with the general success of this treatment option, debonding of posts was occasionally noticed.[8,21]

Mannocci et al investigated resin-dentin interfaces in teeth that were restored in vivo with adhesively cemented carbon fiber posts. Teeth needed to be extracted after 6 months to 6 years of service, and the interfaces were then examined. Debonding of the adhesive from the resin-infiltrated dentin area and debonding of the composite cement from the adhesive were the most frequently observed failure modes and were observed in one-third of the examined interfaces.[18] Two recently published studies questioned the thought that the retention of adhesively bonded fiber posts in root canals is purely the result of resin infiltration and micromechanical interlocking. Pirani et al reported the universal occurrence of interfacial gaps along the hybrid layer surface or the post-cement interface, and speculated that the clinical success of adhesively cemented fiber posts may be explained predominantly by frictional retention.[27] In a study by Goracci et al, it was shown that friction is the chief factor contributing to the retention of bonded fiber posts.[9]

The present investigation is the first one in the literature that shows the absence of any influence of the operator's experience on the adhesive procedure. The authors are aware that the specific choice of materials might have influenced the results. It is possible that with a different fiber post, different adhesive approach, and/or a different resin cement, the operator's experience in adhesive cementation procedures could be crucial to the outcome in terms of post retention. Therefore, it would be of interest to acquire deeper and more detailed insight into the long-term clinical performance of fiber posts before directly applying the in vitro results to the clinical situation.

CONCLUSION

There was no statistically significant difference in the retention measured for fiber posts luted by operators with different levels of clinical experience. Under the parameters of this study and using the materials specified, the operator's experience in luting fiber posts into root canals does not affect post retention in vitro.

REFERENCES

1. Akkayan B, Gulmez T. Resistance to fracture of endodontically treated teeth restored with different post systems. J Prosthet Dent 2002;87:431-437.
2. Asmussen E, Peutzfeldt A, Heitmann T. Stiffness, elastic limit, and strength of newer types of endodontic posts. J Dent 1999;27:275-278.
3. Bell AM, Lassila LV, Kangasniemi I, Vallittu PK. Bonding of fibre-reinforced composite post to root canal dentin. J Dent 2005;33:533-539.
4. Bouillaguet S, Troesch S, Wataha JC, Krejci I, Meyer JM, Pashley DH. Microtensile bond strength between adhesive cements and root canal dentin. Dent Mater 2003;19:199-205.
5. Cormier CJ, Burns DR, Moon P. In vitro comparison of the fracture resistance and failure mode of fiber, ceramic, and conventional post systems at various stages of restoration. J Prosthodont 2001;10:26-36.
6. Erdemir A, Ari H, Gungunes H, Belli S. Effect of medications for root canal treatment on bonding to root canal dentin. J Endod 2004;30:113-116.
7. Ferrari M, Tay FR. Technique sensitivity in bonding to vital, acid-etched dentin. Oper Dent 2003;28:3-8.
8. Ferrari M, Vichi A, Mannocci F, Mason PN. Retrospective study of the clinical performance of fiber posts. Am J Dent 2000;13:9B-13B.
9. Goracci C, Fabianelli A, Sadek FT, Papacchini F, Tay FR, Ferrari M. The contribution of friction to the dislocation resistance of bonded fiber posts. J Endod 2005;31:608-612.
10. Goracci C, Sadek FT, Fabianelli A, Tay FR, Ferrari M. Evaluation of the adhesion of fiber posts to intraradicular dentin. Oper Dent 2005;30:627-635.
11. Goracci C, Tavares AU, Fabianelli A, Monticelli F, Raffaelli O, Cardoso PC, et al. The adhesion between fiber posts and root canal walls: comparison between microtensile and push-out bond strength measurements. Eur J Oral Sci 2004;112:353-361.
12. Grandini S, Goracci C, Monticelli F, Tay FR, Ferrari M. Fatigue resistance and structural characteristics of fiber posts: three-point bending test and SEM evaluation. Dent Mater 2005;21:75-82.
13. Grandini S, Goracci C, Tay FR, Grandini R, Ferrari M. Clinical evaluation of the use of fiber posts and direct resin restorations for endodontically treated teeth. Int J Prosthodont 2005;18:399-404.
14. Hayashi M, Takahashi Y, Hirai M, Iwami Y, Imazato S, Ebisu S. Effect of endodontic irrigation on bonding of resin cement to radicular dentin. Eur J Oral Sci 2005;113:70-76.
15. Jacobsen T, Söderholm KJ, Yang M, Watson TF. Effect of composition and complexity of dentin-bonding agents on operator variability – analysis of gap formation using confocal microscopy. Eur J Oral Sci 2003;111:523-528.
16. Kurtz JS, Perdigao J, Geraldeli S, Hodges JS, Bowles WR. Bond strengths of tooth-colored posts, effect of sealer, dentin adhesive, and root region. Am J Dent 2003;16(special number):31A-36A.
17. Mallmann A, Jacques LB, Valandro LF, Mathias P, Muench A. Microtensile bond strength of light- and self-cured adhesive systems to intraradicular dentin using a translucent fiber post. Oper Dent 2005;30:500-506.
18. Mannocci F, Bertelli E, Watson TF, Ford TP. Resin-dentin interfaces of endodontically-treated restored teeth. Am J Dent 2003;16:28-32.
19. Martinez-Insua A, da Silva L, Rilo B, Santana U. Comparison of the fracture resistances of pulpless teeth restored with a cast post and core or carbon-fiber post with a composite core. J Prosthet Dent 1998;80:527-532.
20. Miyazaki M, Onose H, Moore BK. Effect of operator variability on dentin bond strength of two-step bonding systems. Am J Dent 2000;13:101-104.
21. Monticelli F, Grandini S, Goracci C, Ferrari M. Clinical behavior of translucent-fiber posts: a 2-year prospective study. Int J Prosthodont 2003;16:593-596.
22. Monticelli F, Osorio R, Albaladejo A, Aguilera FS, Ferrari M, Tay FR, et al. Effects of adhesive systems and luting agents on bonding of fiber posts to root canal dentin. J Biomed Mater Res B Appl Biomater 2006;77:195-200.
23. Newman MP, Yaman P, Dennison J, Rafter M, Billy E. Fracture resistance of endodontically treated teeth restored with composite posts. J Prosthet Dent 2003;89:360-367.
24. Nikaido T, Takano Y, Sasafuchi Y, Burrow MF, Tagami J. Bond strengths to endodontically-treated teeth. Am J Dent 1999;12:177-180.
25. Pereira GD, Paulillo LA, De Goes MF, Dias CT. How wet should dentin be? Comparison of methods to remove excess water during moist bonding. J Adhes Dent 2001;3:257-264.
26. Peschke A, Blunck U, Roulet JF. Influence of incorrect application of a water-based adhesive system on the marginal adaptation of Class V restorations. Am J Dent 2000;13:239-244.
27. Pirani C, Chersoni S, Foschi F, Piana G, Loushine RJ, Tay FR, et al. Does Hybridization of Intraradicular Dentin Really Improve Fiber Post Retention in Endodontically Treated Teeth? J Endod 2005;31:891-894.
28. Rosentritt M, Sikora M, Behr M, Handel G. In vitro fracture resistance and marginal adaptation of metallic and tooth-coloured post systems. J Oral Rehabil 2004;31:675-681.
29. Sano H, Kanemura N, Burrow MF, Inai N, Yamada T, Tagami J. Effect of operator variability on dentin adhesion: students vs. dentists. Dent Mater J 1998;17:51-58.
30. Sirimai S, Riis DN, Morgano SM. An in vitro study of the fracture resistance and the incidence of vertical root fracture of pulpless teeth restored with six post-and-core systems. J Prosthet Dent 1999;81:262-269.
31. Tay FR, Gwinnett AJ, Wei SH. The overwet phenomenon: an optical, micromorphological study of surface moisture in the acid-conditioned, resin-dentin interface. Am J Dent 1996;9:43-48.
32. Tay FR, Loushine RJ, Lambrechts P, Weller RN, Pashley DH. Geometric factors affecting dentin bonding in root canals: a theoretical modeling approach. J Endod 2005;31:584-589.

Clinical relevance: Retention of adhesively cemented fiber posts was not influenced by the operator's level of experience.