ORIGINAL RESEARCH

Influence of Adaptation and Adhesion on the Retention of Computer-aided Design/Computer-aided Manufacturing Glass Fiber Posts to Root Canal

Rita Eid[1], Khaled Azzam[2], Hasan Skienhe[3], Hani Ounsi[4], Marco Ferrari[5], Ziad Salameh[6]

Abstract

Aim: The study aimed to assess the effect of friction and adhesion on the pushout bond strength of CAD/CAM fiber-reinforced composite (FRC) post and cores in comparison to prefabricated fiber posts.

Materials and methods: Thirty extracted single-rooted premolars were divided into three groups ($N = 10$): CP: CAD/CAM FRC posts (Trilor, Bioloren) cemented with self-adhesive resin cement (Rely X U200, 3M) as control group. CPL: CAD/CAM FRC composite posts cemented with the same self-adhesive resin cement after lubricating the root canal with petroleum jelly (Vaseline, Unilever) to prevent adhesion. RXP: prefabricated posts cemented with self-adhesive resin cement. Specimens were subjected to thermal cycling and then to pushout tests. The mode of failure was observed using a stereomicroscope. Results were analyzed by two-way ANOVA followed by a Tukey's *post hoc* test for comparison, $p = 0.05$.

Results: Push-out bond strength was significantly lower in the RXP group (8.54 ± 3.35 MPa) in comparison to CP (12.10 ± 1.38 MPa), while no significant differences were concluded between the other groups. Failure was mostly adhesive for CPL and RXP and adhesive and mixed for CP.

Conclusion: Custom made CAD/CAM posts have a positive effect on the retention of FRC posts to root canal walls while adhesion between self-adhesive cement and root dentin did not influence significantly the pushout bond strength of CAD/CAM posts to root canal.

Clinical significance: The friction of well-adapted CAD/CAM fiber post and cores plays a predominant role in the success of post restorations of endodontically treated teeth.

Keywords: Adhesion, Computer-aided design/computer-aided manufacturing fiber post, Friction, Pushout strength, Self-adhesive cement.

The Journal of Contemporary Dental Practice (2019): 10.5005/jp-journals-10024-2654

Introduction

Fiber-reinforced composite (FRC) posts have been frequently used in the restoration of teeth with extensive loss of structure.[1] They are known for their elastic modulus close to dentin[2] and uniform stress distribution along the root canal.[1,3] Clinical trials[4–6] have concluded deboning as the main cause for failure of fiber posts. Several *in vitro* studies[7–9] reported a positive effect on the fit of the post and the cement thickness on the retention of fiber posts to root dentin. Recently, computer aided design/computer aided manufacturing (CAD/CAM) fiber post and cores were proposed to create customized intraradicular posts with a better adaptation to the root canal walls.[8] In addition, adhesive failure between cement and dentin was reported as the most type of observed failure pattern which occurs mainly because of the difficulties in achieving proper adhesion to intraradicular dentin.[1,3] In fact, the luting process of a glass fiber post to root dentin remains a complex process[6] due to the presence of several challenges as: the unfavorable cavity configuration,[10] the presence of a thick smear layer with remnants of endodontic materials,[1,3] the sensitivity of the adhesive luting technique in the canal, the reduced polymerization of dual-cure cements in apical region. Different adhesive systems have been used to cement fiber posts to root canal. Self-adhesive resin cement has the advantage of requiring no previous dentin treatment[11] and reliable bond strength to root dentin in comparison with the other bonding techniques.[12] According to Sarkis-Onofre et al.,[13] the use of self-adhesive resin cement could improve the retention of glass fiber posts into root canals in comparison to total-etch and self-etch adhesive systems. Therefore, the aim of this study was to evaluate by using the pushout test, the relevance of adaptation of CAD/CAM fiber posts with the presence or the absence of a proper adhesion to root dentin. The null hypotheses tested were (1) that there is no significant difference in the bond strength between customized fiber posts and prefabricated fiber posts luted with the same self-adhesive resin cement and (2) that the interfacial adhesion between the self-adhesive resin cement and the root dentin does not improve significantly the bond strength of customized fiber posts to root canals.

[1,3]Department of Prosthodontics, Faculty of Dental Medicine, Lebanese University, Beirut, Lebanon

[2]iDent Lab, Cluj-Napoca, Romania

[4]Department of Restorative Dentistry and Endodontics, Faculty of Dental Medicine Lebanese University, Beirut, Lebanon

[5]Department of Medical Biotechnologies, Division of Fixed Prosthodontics, University of Siena, Siena, Italy

[6]Department of Research, Faculty of Dental Medicine, Lebanese University, Beirut, Lebanon

Corresponding Author: Rita Eid, Department of Prosthodontics, Faculty of Dental Medicine, Lebanese University, Beirut, Lebanon, Phone: +961 3695576, e-mail: ritayeid@yahoo.com

How to cite this article: Eid R, Azzam K, *et al.* Influence of Adaptation and Adhesion on the Retention of Computer-aided Design/Computer-aided Manufacturing Glass Fiber Posts to Root Canal. J Contemp Dent Pract 2019;20(9):1003–1008.

Source of support: Nil

Conflict of interest: None

© The Author(s). 2019 Open Access This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by-nc/4.0/), which permits unrestricted use, distribution, and non-commercial reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated.

Materials and Methods

Sample Preparation

This study was conducted at the Lebanese University, School of Dental Medicine, and was approved by the ethical committee of the Lebanese University (124/112018). Thirty single-rooted mandibular premolars free of cracks and caries, extracted for periodontal or orthodontic reasons, were cleaned with an ultrasonic scaler (Mectron S.P.A, Carasco, Italy) and stored in 0.5% chloramine solution (Chloramine-T, Honeywell Riedel-de-Haen, Germany) for less than 2 months before testing. The root length of each tooth was measured from the cementoenamel junction (CEJ) to the apex on the buccal side, with an average of 14 mm. The diameter of the teeth was measured buccolingually and mesiodistally at the CEJ using a vernier caliper (Insize, Sao Paulo, Brazil). Teeth with more than 2 mm variations in terms of length, mesiodistal diameter, or buccolingual diameter were discarded. Teeth were decoronated with a water-cooled low-speed diamond saw (IsoMet Low-Speed Precision Cutter, Buehler, Lake Bluff, IL, USA), and root canal treatments were performed using nickel-titanium rotary instruments (ProTaper NEXT, Dentsply Sirona, Ballaigues, Switzerland) to an apical size of 30 and a 0.07 taper at a working length of 0.5 mm from the apex with 5.25% sodium hypochlorite irrigation. Canals were then obturated with gutta-percha points (DiaDent Group International, Burnaby, Canada) and canal sealer (AH Plus, Dentsply-De-Trey, Konstanz, Germany) using warm vertical compaction. Then, the post space preparation was performed at a depth of 9 mm from the sectioned surface with the use of size 2 Gates Glidden Drills (Dentsply, Sirona). Peeso reamers (Dentsply, Sirona) were then used gradually (size 1–3) to homogenize the shape and remove residual gutta-percha. The canal spaces were rinsed with distilled water and dried with paper points (DiaDent group international). The specimens were prepared by one operator and divided into three groups ($n = 10$) as described in Table 1.

CP: CAD/CAM FRC post and cores (Trilor, Bioloren, Sarrono, Italy) cemented with self-adhesive resin cement (Rely X U200 automix, 3M ESPE, St Paul, MN, USA) used as the control group.

RXP: prefabricated fiber posts (RelyX fiber post, 3M ESPE, St Paul, MN, USA) cemented with self-adhesive cement (Rely X U200 automix, 3M).

CPL: CAD/CAM FRC posts and cores (Trilor, Bioloren) cemented with self-adhesive resin cement (Rely X U200 automix, 3M) after canal lubrication with petroleum jelly (Vaseline, Unilever, Australia).

Posts Fabrication and Cementation

For the prefabricated posts (RXP) group, the post that reached the working length with a mild friction was selected. Self-adhesive resin cement (RelyX U200 Automix, 3M ESPE, St Paul, MN, USA) was used to cement the posts, and elongation tips were used to place the cement in the canal to avoid air bubbles as per the manufacturer's instructions. The excess cement was removed prior to 40-seconds polymerization (Elipar S10 LED curing light, 3M-ESPE) from the tip of the post (Fig. 1A).

For the customized posts groups (CP and CPL), direct resin patterns were fabricated (Pattern Resin, GC America, Alsip, Il, USA). The resin patterns were sprayed with a scan powder (IPS Contrast Spray, Ivoclar Vivadent, Schaan, Liechtenstein) and scanned with a laboratory scanner (Imetric 1041, Imetric 3D, Courtenay, Switzerland), and then the data were imported from the scanner to CAD construction software (DentalCad, Exocad, Darmstadt, Germany) to clean substantial noises and undercuts. The digitized data were then transmitted to dental CAM software (WorkNC Dental, Hexagon, Neu-Isenburg, Germany) to develop the milling sequence. The cement space size was regulated to 80 μm in the WorkNC Dental CAM software to compensate for the antireflective spray thickness and ensure the passive fit of the post. The posts in group CP and CPL were milled using a 5-axis computer numerical control (CNC) milling machine (D5, Datron, Darmstadt, Germany) (Fig. 2A). The posts were passively fitted in their correspondent canals without any need for adjustment after milling.

The post in groups CP and CPL were coated with silane (RelyX Ceramic Primer, 3M) as per the manufacturer's recommendations and cemented in the canal spaces (Fig. 2B) using the same self-adhesive resin cement as the prefabricated group. Excess cement was removed, and posts were polymerized (Elipar S10) for 40 seconds on each axial wall of the tooth.

Fatigue Simulation

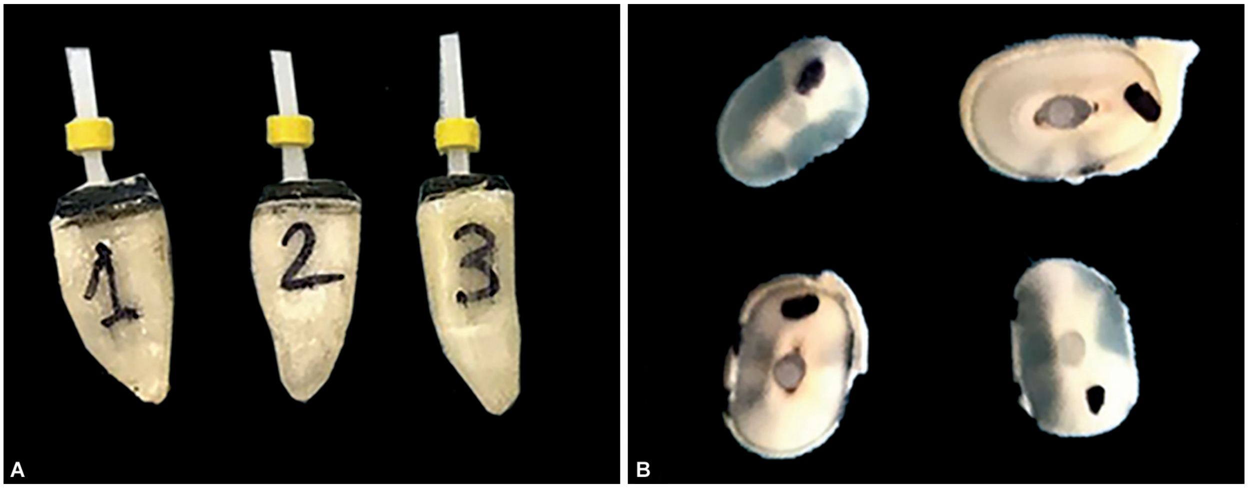
All specimens were subjected to thermocycling (thermocycler THE-1200, SD Mechatronik, Feldkirchen-Westerham, Germany) in distilled water for 5,000 cycles at 5°C and 55°C, with 30 seconds of dwell time and 5 seconds of transfer time to simulate aging.

Samples Preparation for Pushout Test

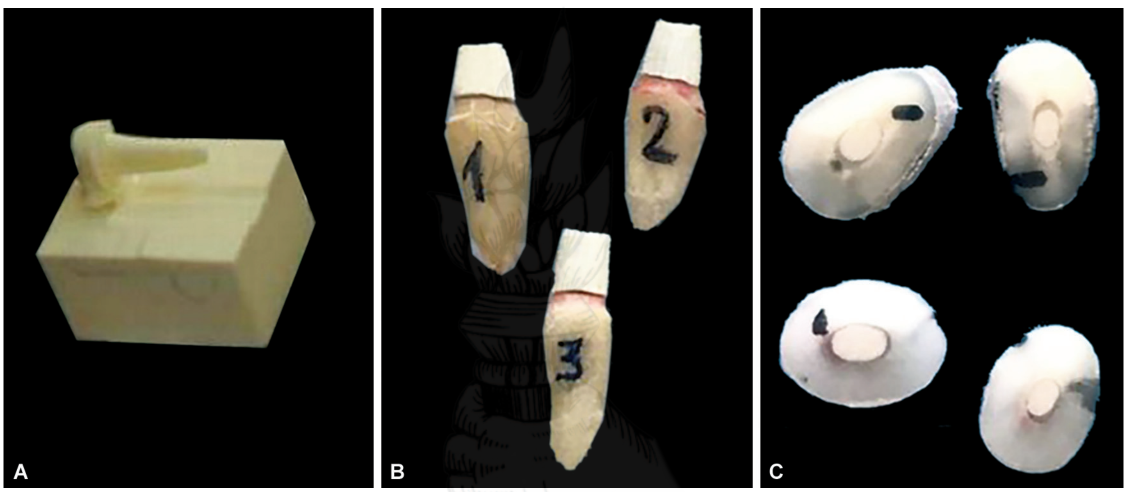
The roots of each tooth were cut with a low-speed diamond saw underwater, cooling into 1 mm-thick slices and making a total of six slices per root (IsoMet 1000 Precision Cutter). Each slice was marked on its apical side with a waterproof marker (Figs 1B and 2C). The diameters of the post from coronal and apical sides along with the thickness of each slice were measured using a digital caliper with 0.01 mm accuracy (Insize Co). Then, pushout forces were applied on each slice in an apical-coronal direction using 1.2- and 0.76 mm-diameter custom stainless-steel cylindrical plungers mounted on a universal testing machine (Triax Digital 50, Controls, Milan, Italy) at a crosshead speed of 0.5 mm/minute. The sizes of the plungers were chosen to match the diameter of the post at the different root thirds. Each slice was oriented to ensure that the apical surface faced the plunger and the plunger was centralized to avoid contact with

Table 1: Composition of the investigated materials within the groups

Group	*Material*	*Manufacturer*	*Composition*
CP (control)	Trilor®	Bioloren, Saronno, Italy	Epoxy resin matrix (25% vol), multi directional glass fiber reinforcement (75% vol)
RXP	Rely X® fiber Post	3M-ESPE, St Paul, MN, USA	Epoxy resin matrix:32% glass fibers:67%, zirconium and strontium fillers
CPL	Trilor®	Bioloren, Saronno, Italy	Epoxy resin matrix (25% vol), multi directional glass fiber reinforcement (75% vol)
	Vaseline®	Unilever, Sydney, Australia	Semi solid mixture of hydrocarbons



Figs 1A and B: Representative photograph of the specimen's preparation in group RXP; (A) Cementation of the prefabricated posts; (B) Root slices of 1 mm thickness prepared for the push-out test



Figs 2A to C: Representative photograph of specimen's preparation in groups CP and CPL; (A) Milling of customized post and cores; (B) Cementation of the milled posts; (C) Root slices prepared for the push-out test

JAYPEE

dentin. Micro pushout testing was performed, and shear stress was applied along the bonded interfaces until failure occurred. The load of failure was recorded in Newtons (N), and the bond strength was calculated in megapascals (MPa), dividing the failure load by the surface of the bonded area.

Outcome Measurements

For RXP group, the bonded area was considered as the lateral surface of a truncated cone and calculated using the formula: $\pi \times (R + r) \times [(h^2 + (R - r)^2] \times 0.5$ where R is the coronal post radius, r is the apical post radius, and h is the thickness of the slice.[14] For the groups CP and CPL, the bonded area was calculated by a special numerical computing program (MATLAB, MathWorks, Natick, MA, USA) that can produce three-dimensional graphics based on the different measurements of each slice. The mode of failure was assessed at 45× magnification in a stereomicroscope (AmScope, Irvine, CA, USA), and failures were classified in three groups: adhesive failure (post-cement or the dentin-cement), cohesive failure (within the resin cement), and mixed failure (adhesive–adhesive or adhesive–cohesive).

Statistical Analysis

The Kolmogorov–Smirnov test was used to check homogeneity and normal distribution. The p value was 0.033, which confirmed the normality distribution. The two-way analysis of variance (ANOVA) was used, followed by Tukey's *post hoc* test for multiple comparisons to determine the statistical significance of the mean differences among groups. All statistical analyses were performed at a 0.05 level of significance.

Results

The mean values of pushout bond strength were obtained with the three groups are shown in Figure 3. The highest mean bond strength was recorded for the CP group (12.10 ± 1.38 MPa), while the lowest bond strength was recorded for the group RXP (8.54 ± 3.35 MPa). The two-way ANOVA, showed no significance between groups ($p = 0.057$) as shown in Table 2. *Post hoc* was used to evaluate pairwise differences among groups with the use of Tukey's test and concluded a significant lower bond strength for group RXP

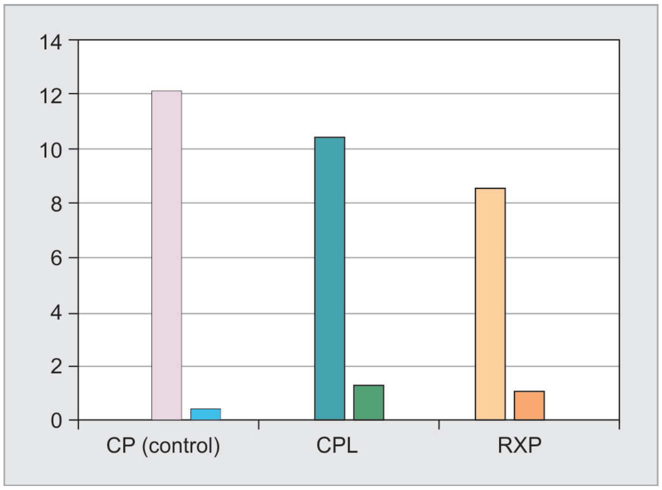


Fig. 3: Mean and standard deviations of different groups

compared to CP. No significant differences in bond strength were observed between the groups CP and CPL and between the groups CPL and RXP (Table 3).

The prefabricated fiber posts (RXP) exhibited lower pushout strength compared with customized posts (CP), whereas the presence of lubricant didn't affect the pushout bond strength of customized posts.

The most frequent type of failure in all groups was adhesive between the post and the dentin, as shown in Table 4. Mixed failures, mostly adhesive–cohesive, were also observed in group CP.

Discussion

In the present study, it was shown that custom milled FRC post and cores showed a significantly better pushout bond strength to root canal in comparison with prefabricated FRC posts luted with the same self-adhesive cement, thus the first null hypothesis was rejected.

The group RXP showed the lowest bond strength values compared to the control group (CP). This is probably related to the digital manufacturing of post and cores in groups CP and CPL, which allows a well-adapted post unit with a thinner cement layer known to cause less voids and gaps between the cement and the root dentin when compared with prefabricated posts in group RXP[15]

Table 4: Percentage of failure mode found in different groups

Group	*Adhesive*	*Cohesive*	*Mixed*
Group CP (control)	64	2	34
Group CPL	98	0	2
Group RXP	80	0	20

(Fig. 4). As a result, the bonding area of the adapted posts seems to increase, resulting in better retention.[14] In addition, the adaptation of post and cores in the canal generates additional pressure during cementation leading to better contact between the cement/post assembly and the dentin and better retention.[16] Regarding the effect of posts adaptation on bond strength to root canal, the results of the present study align with several *in vitro* studies,[7–9,17] that investigated the pushout bond strength of adapted post and cores obtained by relining or digitization and concluded better retention to root canal compared to prefabricated fiber posts. Tsintsadze et al.[8] compared the retention of CAD/CAM fiber-reinforced composite posts with prefabricated fiber posts and cast post and cores and concluded an increased bond strength in both CAD/CAM and cast groups compared with the prefabricated ones. This study diverges from the present study by the type of used adhesive cement where the self-etch adhesive was used and by the fact that specimens were not subjected to fatigue simulation.

In the present study, a one-piece, well-adapted post and core was fabricated using the CAD/CAM technology in groups CP and CPL which differs from the previous studies[7,9,11] where composite relining materials were added to prefabricated posts to enhance their adaptation. The main advantage relies on eliminating the factors related to the composite relining materials in terms of polymerization shrinkage and degree of conversion.[7] These factors may influence the pushout bond values irrelatively from the adaptation variable. This was observed by Bakaus et al.[7] who compared relined posts with reinforcement composite materials to well-adapted prefabricated posts and concluded a better push out bond strength of the well-adapted posts to root canal in comparison with the relined posts. In fact, the poor polymerization of light-cured resin used for relining affected its hardiness,[18] and may have been responsible for the low bond strength values reported in that study.[19]

The customized posts cemented with self-adhesive resin cement in lubricated canals (CPL) did not present a significant

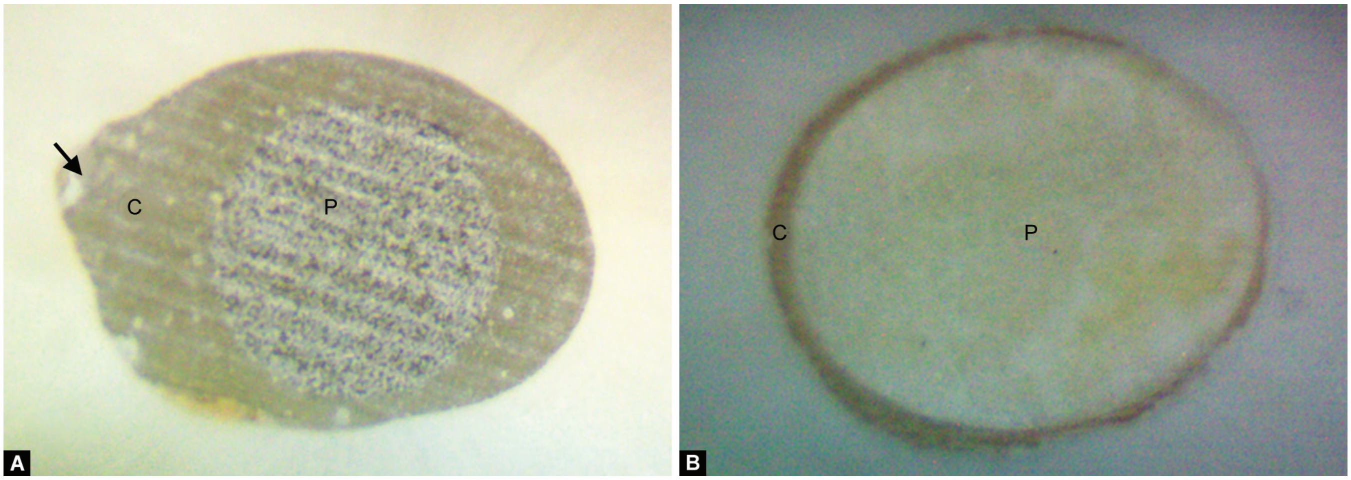
Table 2: ANOVA tests between and within groups dependent variable

	Sum of squares	*df*	*Mean square*	*F*	*Sig.*
Between groups	63.64	2	31.82	3.188	0.057
Within groups	269.503	27	9.982		

Table 3: Multiple comparisons test showing significance between groups

					95% confidence interval	
(I) SET		*Mean difference (I–J)*	*Std. error*	*Sig.*	*Lower bound*	*Upper bound*
Control	CPL	1.64552	1.41291	0.484	−1.8577	5.1487
	RXP	3.56415*	1.41291	0.046	0.0609	7.0673
CPL	Control	−1.6455	1.41291	0.484	−5.1487	1.8577
	RXP	1.91862	1.41291	0.377	−1.5846	5.4218
RXP	Control	−3.56415*	1.41291	0.046	−7.0673	−0.0609
	CPL	−1.9186	1.41291	0.377	−5.4218	1.5846

*The mean difference is significant at the 0.05 level



Figs 4A and B: Representative stereomicroscope photograph (45× magnification) of (A) a prefabricated fiber post (P) characterized by the presence of a thick cement layer (C) and air bubbles (arrow), and of (B) a customized post (P) characterized by the perfect adaptation of the post with a very thin uniform cement layer (C)

decrease in bond strength to root canal in comparison with the control (CP). Therefore, the second null hypothesis was accepted as interfacial adhesion between the self-adhesive resin cement and the root dentin did not improve significantly the bond strength of customized fiber posts to root canals. In the present study, self-adhesive resin cement was used because of its reduced technique-sensitivity and the chemical interaction between the functional methacrylate phosphoric acid esters and the hydroxyapatite present on dentin surface, resulting in superior retention of fiber posts to dentin compared with total and self-etch adhesive systems.[9,12] It can be concluded that despite the favorable adhesive properties of self-adhesive cement, the high contraction stress at the bonding surface caused by the enormously increased C-factor in the canal results in impairing the bond strength to root canal dentin with post-insertion.[21] The present results corroborate with the results of Goracci et al.,[20] who examined the "fixation strengths of prefabricated fiber posts that were cemented with either resin cements only, or in conjunction with a self-etch and a total-etch dentin adhesive" and concluded that the use of dentin adhesives produces no improvement on the fixation of fiber posts with resin cements to dentin and that sliding friction is the predominant factor for retention.

The pushout bond strength test is a common *in vitro* method to evaluate the retention of posts and different adhesive cementation protocols to root dentin.[22,23] This methodology represents the advantages of homogeneous shear tensile stress, less premature failures caused by sectioning procedures,[23] and reduced data inconsistency.[24]

Regarding the fracture analysis, adhesive failure between cement and dentin was the most frequent type of failure observed in all groups, which is consistent with previous studies.[16,25,26]

In the RXP group, adhesive failures are mostly related to the thick cement layer that generates bubbles and pores and compromises adhesion, as mentioned above.[15] In addition, the bond between the luting cement and the radicular dentine is sometimes unable to withstand curing shrinkage.[1]

In the CPL group, all failures were adhesive as a result of the lack of adhesion between cement and dentin due to the presence of petroleum jelly.

As for the control group CP, mixed failures (adhesive between cement-dentin and cohesive in cement) were also observed. Cohesive failures may be explained by the insufficient light transmission in case of customized posts leading to a decrease degree of conversion.[27] In addition, the quality of bonding between cement and root dentin in the case of well-adapted posts is superior, which will transmit the curing stress to the cement.

The present study presents essential limitations relative to an *in vitro* study, where all procedures are done by one operator in extraoral conditions. Therefore, it could not completely simulate *in vivo* conditions. The pushout test is considered as an effective method to test the bond strengths of fiber posts to root canal dentin.[22] However, the exposure of the fiber post to the displacing forces during the pushout test cannot simulate functional forces during clinical service.[28]

Conclusion

Within the limitations of this *in vitro* study, it can be concluded that the use of CAD/CAM customized FRC posts have a positive effect on the bond strength to root canal walls in comparison with prefabricated fiber posts. The adhesion of self-adhesive resin cements to the root dentin did not improve significantly the pushout bond strength of custom fit post and cores to root canal where the friction seems to play a predominant role in the retention of posts.

References

1. Bru E, Forner L, et al. Fibre post behaviour prediction factors. a review of the literature. J Clin Exp Dent 2013 Jul;5(3):e150–e153. DOI: 10.4317/jced.50619.
2. Kensche A, Dähne F, et al. Shear bond strength of different types of adhesive systems to dentin and enamel of deciduous teeth *in vitro*. Clin Oral Investig 2016 May;20(4):831–840. DOI: 10.1007/s00784-015-1560-y.
3. Goracci C, Ferrari M. Current perspectives on post systems: a literature review. Aust Dent J 2011 June;56(1):77–83. DOI: 10.1111/j.1834-7819.2010.01298.x.
4. Mancebo JC, Jiménez-Castellanos E, et al. Effect of tooth type and ferrule on the survival of pulpless teeth restored with fiber posts: a 3-year clinical study. Am J Dent 2010 Dec;23(6):351–356.

5. Marchionatti AME, Wandscher VF, et al. Clinical performance and failure modes of pulpless teeth restored with posts: a systematic review. Braz Oral Res 2017 July;31:e64. DOI: 10.1590/1807-3107bor-2017.vol31.0064.
6. Naumann M, Koelpin M, et al. 10-year survival evaluation for glass-fiber-supported postendodontic restoration: a prospective observational clinical study. J Endod Apr 2012;38(4):432–435. DOI: 10.1016/j.joen.2012.01.003.
7. Bakaus TE, Gruber YL, et al. Bond strength values of fiberglass post to flared root canals reinforced with different materials. Braz Oral Res 2018 Mar;32:e13. DOI: 10.1590/1807-3107bor-2018.vol32.0013.
8. Tsintsadze N, Juloski J, et al. Performance of CAD/CAM fabricated fiber posts in oval-shaped root canals: An *in vitro* study. Am J Dent 2017 Oct;30(5):248–254.
9. Farina AP, Chiela H, et al. Influence of Cement Type and Relining Procedure on Push-Out Bond Strength of Fiber Posts after Cyclic Loading. J Prosthodont 2016 Jan;25(1):54–60. DOI: 10.1111/jopr.12271.
10. Davidson CL, de Gee AJ, et al. The competition between the composite-dentin bond strength and the polymerization contraction stress. J Dent Res 1984 Dec;63(12):1396–1399. DOI: 10.1177/00220345840630121101.
11. Llena C, García-Gallart M, et al. Root canal adaptation and intra-tubular penetration of three fiber-post cementation systems. J Clin Exp Dent 2018 Dec;10(12):1198–1204. DOI: 10.4317/jced.55208.
12. Ubaldini ALM, Benetti AR, et al. Challenges in luting fibre posts: adhesion to the post and to the dentine. Dent Mater 2018 Jul;34(7):1054–1062. DOI: 10.1016/j.dental.2018.04.001.
13. Sarkis-Onofre R, Skupien JA. The role of resin cement on bond strength of glass-fiber posts luted into root canals: a systematic review and meta-analysis of *in vitro* studies. Oper Dent 2014 Jan-Feb;39(1):E31–E44. DOI: 10.2341/13-070-LIT.
14. Falcão Spina DR, Goulart da Costa R, et al. CAD/CAM post-and-core using different esthetic materials: Fracture resistance and bond strengths. Am J Dent 2017 Dec;30(6):299–304.
15. Da Silva NR, Aguiar GC, et al. Effect of Resin Cement Porosity on Retention of Glass-Fiber Posts to Root Dentin: An Experimental and Finite Element Analysis. Braz Dent J 2015 Nov–Dec;26(6):630–636. DOI: 10.1590/0103-6440201300589.
16. Chieffi N, Chersoni S, et al. The effect of application sustained seating pressure on adhesive luting procedure. Dent Mater 2007 Feb;23(2):159–164. DOI: 10.1016/j.dental.2006.01.006.
17. Faria-e-Silva AL, Pedrosa-Filho Cde F, et al. Effect of relining on fiber post retention to root canal. J Appl Oral Sci 2009 Nov–Dec;17(6):600–604. DOI: 10.1590/S1678-77572009000600012.
18. Teixeira CS, Silva-Sousa YC, et al. Effects of light exposure time on composite resin hardness after root reinforcement using translucent fibre post. J Dent 2008 Jul;36(7):520–528. DOI: 10.1016/j.jdent.2008.03.015.
19. Gomes GM, Gomes OM, et al. Evaluation of different restorative techniques for filling flared root canals: fracture resistance and bond strength after mechanical fatigue. J Adhes Dent 2014 Jun;16(3):267–276. DOI: 10.3290/j.jad.a31940.
20. Goracci C, Fabianelli A, et al. The contribution of friction to the dislocation resistance of bonded fiber posts. J Endod 2005 Aug;3(8):608–612. DOI: 10.1097/01.don.0000153841.23594.91.
21. Aksornmuang J, Nakajima M, et al. Effects of C-factor and resin volume on the bonding to root canal with and without fibre post insertion. J Dent 2011 Jun;39(6):422–429. DOI: 10.1016/j.jdent.2011.03.007.
22. Boschian Pest L, Cavalli G, et al. Adhesive post-endodontic restorations with fiber posts: push-out tests and SEM observations. Dent Mater 2002 Dec;18(8):596–602. DOI: 10.1016/S0109-5641(02)00003-9.
23. Soares CJ, Santana FR, et al. Finite element analysis and bond strength of a glass post to intraradicular dentin: comparison between microtensile and push-out tests. Dent Mater 2008 Oct;24(10):1405–1411. DOI: 10.1016/j.dental.2008.03.004.
24. Castellan CS, Santos-Filho PC, et al. Measuring bond strength between fiber post and root dentin: a comparison of different tests. J Adhes Dent 2010 Dec;12(6):477–485. DOI: 10.3290/j.jad.a17856.
25. Zicari F, De Munck J, et al. Factors affecting the cement-post interface. Dent Mater 2012 Mar;28(3):287–297. DOI: 10.1016/j.dental.2011.11.003.
26. D'Arcangelo C, Cinelli M, et al. The effect of resin cement film thickness on the pullout strength of a fiber-reinforced post system. J Prosthet Dent 2007 Sep;98(3):193–198. DOI: 10.1016/S0022-3913(07)60055-9.
27. Arrais CA, Chagas CL, et al. Effect of simulated tooth temperature on the degree of conversion of self-adhesive resin cements exposed to different curing conditions. Oper Dent 2014 Mar-Apr;39(2):204–212. DOI: 10.2341/13-091-L.
28. Radovic I, Mazzitelli C, et al. Evaluation of the adhesion of fiber posts cemented using different adhesive approaches. Eur J Oral Sci 2008;116(6):557–563. DOI: 10.1111/j.1600-0722.2008.00577.x.

JAYPEE