

Comparative Evaluation of Push-Out Bond Strength of Bulk-Fill versus Dual-Cure Resin Composites in Root Canals

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Abstract

Purpose: The aim of this study to evaluate the bond strength of bulk-fill and dual-cure resin composites to root canal dentin at coronal, middle and apical levels. **Materials and Methods:** Forty four extracted single-rooted teeth were removed 12 mm from the apex and a root canal treatment was performed. The post spaces were prepared to a depth of 8 mm using a Cytec Blanco pilot bur. Then, the roots were randomly divided into four groups according to the restoration protocols: Fiber post + Panavia F, Clearfil DC Bond + Bulkfill composite (SonicFill), Clearfil DC Bond + Bulkfill composite (Clearfil PhotoCore), and Clearfil DC Bond + Dual-cure composite (Clearfil DC CorePlus). For the push-out test, the roots were embedded in acrylic and sectioned using a water-cooled diamond coated saw. Three slices (coronal, middle, and apical) were obtained from each root. **Results:** The SonicFill group had the lowest push-out bond strength values, while the Fiber post + Panavia F group had the highest median MPa levels for the coronal, middle, and apical levels ($p < 0.001$). In all groups, the apical third section had a lower push-out bond strength compared with the middle and coronal levels. **Conclusion:** The bond strength of a sonic activated bulk-fill composite in root canals is lower than that of other conventional methods.

Key Words: Fiber post, Sonicfill, Clearfil DC Core Plus, Clearfil Photo Core

Introduction

Following an endodontic treatment, if the remaining tooth structure is not adequate for the stable retention of a direct core build-up material, insertion of post into the canal is a treatment option to retain the core [1]. The post can be metal, fiber, or ceramic. Metallic posts have poor stress distribution due to differences in the elastic modulus of metal and dentin, which can occasionally cause root fracture and the potential discoloration of surrounding soft tissue [2]. The use of glass fiber posts has advantages, such as more rapid treatment and better biocompatibility, aesthetics, corrosion resistance, and similar biomechanical properties to dentin [3-5]. When loaded, adhesively luted endodontic reinforced with glass or quartz lead to better homogeneous tension distribution than rigid metal or zirconium oxide ceramic. Moreover, it has been reported that, compared with traditional metallic cast posts, glass fiber posts decrease the likelihood of irreparable root fractures [6-8]. To prevent cohesive failure of the material that enhances the retention of root dentin, the use of resin composites should be evaluated. Low elastic modulus (with respect to fiber posts) and direct bonding to the root dentin are advantages of resin composites.

Recently, several new restorative materials have been advertised as “bulk-fill” composites, which can be applied in bulk amounts of 4 mm, or even 5 mm, without requiring a prolonged curing time or a light-curing unit with increased irradiance [9]. One such bulk-fill composite is SonicFill, which can be applied in a manner similar to a flowable composite because it is activated sonically, even though it has high filler content (wt%: 83.5).

Many dual-cure resin composite materials, which can also be used in a deep post space or as a luting material, are available. However the effect of their use in deep post spaces is still unknown. In the coronal region, dual-cure resin composite will polymerize through photo-initiated chemical

reactions, while in the apical region this will occur via chemically initiated polymerization. It has been reported that the mechanical properties of dual-cure resin composites are better after photo activation than with chemical activation alone [10]. Therefore, the properties of dual-cure resin composites may be different at any levels of the post cavity because of the reduction of light energy in the deeper regions of the post cavity, and this may also affect regional bond strengths. Although the mechanical properties of dual-cure resin composite have been evaluated, studies on regional mechanical properties and regional bond strengths using various dual-cure resin composites are very limited. The aim of this study was to compare the bond strength of dual-cured resin cement with a fiber post, two brands of light-cured bulk-fill resin composites, and a dual-cured resin composite to the root dentin, at a depth of 8 mm, using the in vitro push-out test method.

Materials and Methods

A total of 44 extracted human maxillary incisors were selected. The teeth were stored in 0.1% thymol solution at 4°C and used within 3 months after extraction. This study was approved by the University of Cukurova Institutional Review Board. Inclusion criteria were the absence of caries, root cracks, restorations, and previous endodontic treatments. Teeth with open apices and larger apical size than 35 were excluded from the study. The entire length of the root was calibrated at 12 mm from the apex, and the teeth were decoronated using a water-cooled diamond bur. The root canal was treated using a TF Adaptive system (SybronEndo, USA), and the canal was irrigated respectively with 4 cc 2.5% Sodium hypochlorite and 2 cc saline solution between each instrument. The apical master file was size #35. The root canals were then filled using Gutta-percha points (President Dental, Duisburg, Germany), utilizing a lateral compaction technique with Sealapex cement (SybronEndo, USA). Finally,

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the post spaces were prepared to a depth of 8 mm (± 0.2 mm) using a Cytac Blanco pilot bur (E Hahnenkratt GmbH, Königsbach-Stein, Germany) and enlarged using the post system's drills, up to size 4, according to the sequence.

The roots were randomly assigned to four groups ($n = 11$) according to the restoration protocol used. Test materials and their properties and manufacturers are provided in *Table 1*.

- Clearfil DC Bond + Clearfil PhotoCore (CPC)
- Clearfil DC Bond + Clearfil DC Core Plus (DCC-Plus)
- Clearfil DC Bond + SonicFill (SF)
- ED primer + Panavia F + Composite fiber post (FP)

Clearfil DC Bond—a dual-cure, one-step, self-etch adhesive system—was used for bonding the composite to the root canal dentin for the CPC, DCC-Plus, and SF groups.

Equal amounts of liquids A and B were mixed for 5 s, and the mixture was applied to root canal dentin in the post space for 20 s using a micro-brush disposable applicator (Microbrush, Grafton, WI, USA). The adhesive was air-dried for 5 s, and a paper point was used to remove excess adhesive resin that had accumulated at the bottom of the canal. Next, high-pressure airflow was used for an additional 5 s to dry the adhesive.

For the Clearfil DC Bond, 20 s light curing was applied according to the manufacturers' instructions. Post spaces were filled with three dental composites (Clearfil DC Core Plus, Clearfil PhotoCore, and SonicFill). Light exposure was performed for 40 s using an LED curing light for 4-mm thickness of resin. The post spaces were filled totally with two increments, and each increment was condensed with a plugger.

Table 1: Data according to manufacturer information

Material	Formulation	Polymerization mode	Manufacturer
Clearfil DC Core Plus	A paste: Bis-GMA, hydrophilic aliphatic dimethacrylate, hydrophobic aliphatic dimethacrylate, hydrophobic aromatic dimethacrylate, silanized barium glass filler, silanized colloidal silica, colloidal silica, chemical-initiator, photo-initiator, pigments	Dual-curing	Kuraray Noritake Dental Inc., Japan
Clearfil PhotoCore	Bis-GMA, TEGDMA, colloidal silica, di-camphorquinone, filler content: 83 wt.%, 68 vol.%	Light-curing	Kuraray Europe GmbH
SonicFill	Bis-GMA, bis-EMA, TEGDMA, Filler 83 vol%	Light-curing	Kerr Corporation, USA
Clearfil DC Bond	A liquid: MDP, hydrophobic dimethacrylates, HEMA, photoinitiator, chemical catalyst; nanofiller B liquid: Water, ethanol, chemical catalyst	Dual-curing	Kuraray Medical Inc., Japan
Panavia F2.0	Sodium fluoride, 10-methacryloyloxydecyl, dihydrogen phosphate, hydrophobic aromatic dimethacrylate, hydrophilic aliphatic dimethacrylate, silanated silica filler, silanated colloidal silica, di-camphorquinone, initiators, silanated barium glass filler	Dual-curing	Kuraray, Medical Inc., Japan
ED primer	2-Hydroxyethyl methacrylate, 10-methacryloyloxydecyl, dihydrogen phosphate (10-MDP), N-methacryloyl-5-aminosalicylic acid, water accelerators	Dual-curing	Kuraray, Medical Inc., Japan

Bis-GMA bisphenol-A-dimethacrylate, UDMA urethane dimethacrylate, TEGDMA triethyleneglycoldimethacrylate, DDDMA dodecanedioldimethacrylate.

In the FP group, the adhesive system (ED Primer A + ED Primer B, Kuraray, Tokyo, Japan) was applied inside the root canal and onto the post surface for 20 s, the adhesive was air dried for 5 s, and excess adhesive resin in the apical canal was removed using a paper point. The resin posts (E Hahnenkratt GmbH, Königsbach-Stein, Germany) were covered with a resin-luting agent (Panavia F 2.0, Kuraray) and fixed inside the root canal with rotating movements. Excess material was removed, and the resin-luting agent was light-cured for 40 from all directions with an LED light-curing unit (3M Espe Elipar Freelight 2, Germany). All specimens were then stored at 95% humidity for 48-h at 37°C.

Push-out testing

After the 48-h storage period, all specimens were embedded into acrylic blocks. The first 1-mm-thick slab was excluded from the coronal part, and then three 2-mm-thick slabs were serially cut perpendicular to the long axis of the root with a low-speed diamond coated saw under water cooling (Exakt 400 cs Apparatebau, Norderstedt).

A universal testing machine (Testometric Company Ltd, Rochdale, Lancashire, England), operating at a crosshead speed of 1 mm/min, was utilized. A stainless steel device was used to place the aligned specimen onto a bar with a diameter of 1 mm and a length of 4 mm. The unit of force was the Newton (N), and bond strength was calculated according to the formula Force (F)/Area (A) and recorded in megapascals (MPa). Each slice's thickness was measured with calipers. Calculation of the bonding surface area (A) was performed with the conical frustum area formula: $A = \pi(R_2 + R_1)(h_2 + (R_2 - R_1)^2)^{0.5}$, where R_1 = base radius, R_2 = top radius, and h = height of the frustum [11].

Following the push-out test, the failure mode was identified by examining each specimen under a stereomicroscope (Olympus SZ61, Tokyo, Japan) at 40x magnification. The specimens from the FP group were divided into four subgroups according to failure mode: (i) adhesive failures between post and cement; (ii) adhesive failures between dentin and cement; (iii) mixed failures; and (iv) cohesive failures inside the post. For other resin-based composite groups, the failure mode was classified according to the fracture pattern as adhesive, cohesive, or mixed.

Statistical Analysis

Statistical analyses were performed using the statistical package SPSS v. 20. The normality of the distribution of each continuous variable was determined. Since the data were not distributed normally, an appropriate non-parametric test was used. The groups were compared using the Kruskal–Wallis test. The Mann–Whitney U test was used post hoc to evaluate differences within the groups. Bonferroni's correction was applied ($p < 0.05/n$; where n = number of comparisons) for multiple comparisons, and a p -value < 0.008 was considered to indicate significance. The results are presented as means \pm SD and medians (min–max).

Results

The push-out strength values for the displacement of filling material at the coronal, middle, and apical levels are presented in Table 2. There were significant differences among the groups ($p < 0.05$). The FP group had the highest median MPa value for all three levels ($p < 0.001$). The SF group had the lowest push-out bond strength values at the coronal and apical levels. The DCC-Plus values were lower than the CPC values in the coronal level; however, in the middle and apical levels, the DCC-Plus values were higher than the CPC values, though the differences were not statistically significant. The apical level of all groups demonstrated lower push-out bond strengths than the middle and coronal levels. The adhesive failure pattern was most common in all groups, but in the FP group cohesive failures were observed in 45% of specimens.

Discussion

The effectiveness of light-cured composites in root canals for strengthening tooth structure is highlighted in some reports [12,13]. Thus, the present study evaluated the bond strength to root dentin with three dental composites rather than employing dual-cured resin cement and a fiber post. The bond strength of the SF group was considerably lower than that of the resin-based composites and FP. SF had the highest filler content of all the materials used in this study. This filler content might reduce light transmission as it lowers the probability of light scattering at the resin-filler interface (for particles smaller than the wavelength of the incident blue light), thus making nanoparticles unable to scatter blue light [14].

The push-out bond strength values of all groups at the coronal level were higher than those at the middle and apical levels in the present study. Similarly, Aksornmuang et al. [15] indicated that, within the same resin composite, the properties of the material in the coronal portion were better than in the apical portion. The regional push-out bond strength values may have been influenced by regional differences in polymerization.

Dual-cure resin composite in the coronal region may have polymerized through photo activation, resulting in higher push-out bond strength values, whereas resin composite in the apical region could have polymerized mainly through

chemical activation. Previous studies employing the push-out bond strength test have reported that photo-activated composite possessed superior push-out bond strength to chemically activated composite [10,16]. In the middle and apical levels, both light-curing resin composite groups (CPC and SF) showed lower bond strength values than the tested dual-curing resin composites in the present study.

The reason for these lower bond strength values might be related to the structural differences of the root dentin in the apical third, depth of curing, and insufficient polymerization [17]. While the DCC-Plus showed significantly higher bond strength values than CPC at the middle and apical levels, at the coronal level, DCC-plus values were lower than those of CPC, though the difference was not significant.

This result may be attributable to the properties of dual-cure composites (i.e., the greater chemical polymerization that takes place with limited or no contribution from the light source in the apical portions of the canals). Additionally, the speed of the polymerization reaction is strongly influenced by the inhibitor concentration in unfilled light-cured methacrylate-based systems [18].

Bucuta et al. [19] evaluated the curing behavior of high viscosity bulk-fill composites, demonstrating that SF had the lowest depth of cure at 20 s standard curing mode. However, it has been reported that the amount of light transmitted through SF specimens is lower than with other bulk-fill resin-based composites and is rather comparable to regular nano and microhybrid resin-based composites [19]. Thus, the polymerization at a certain depth depends not only on the amount of photons reaching that depth but also on the polymerization process already initiated in the upper layers, which propagates in depth. Kim et al. [20] found similar shrinkage values among all high-viscosity composites (conventional: Filtek Z250; bulk-fill: SonicFill, Tetric N-Ceram), which demonstrated significantly less shrinkage than low-viscosity composites. However, despite the low shrinkage stress of the SonicFill, the materials in this study were used in a post space high C-factor design. This could create the formation of internal and external marginal gaps, resulting in debonding from the dentin surface and weakening the bond strength.

The bonding strategy used in the current study might also have affected the outcome. Irradiation of dual-cure adhesives with sufficient light energy in the apical level of the post spaces is important for minimizing the adverse effects of uncured acidic resin monomers of one-step self-etch adhesives [21]. Clearfil DC Bond, a one-step self-etch adhesive that contains acidic resin monomers, an organic solvent, and water, is used for self-cure polymerization in the deeper region when the post space is filled with resin core material. The initial microtensile bond strength achieved with a dual-cure one-step self-etch adhesive was evaluated by Aksornmuang et al. [22], who identified the optimal curing time for such adhesive applied to an 8-mm-deep root canal dentin surface as 20 s utilizing a high-intensity curing unit (Hyperlightel). Thus, a

dual-cure one-step self-etch adhesive system was light-cured for 20 s using an LED-curing unit in the present study.

Table 2: Distribution of the push-out bond strength values in MPa for the displacement of filling material obtained from specimens in the coronal, middle, and apical thirds of each group. p^* Kruskal–Wallis Test, p^{**} Mann–Whitney U between 2 groups

Groups	Localization, Mean \pm SD, Median (Min–Max)		
Grp1 (CPC)	Coronal	Middle	Apical
	11.09 \pm 2.49	5.41 \pm 2.30	4.08 \pm 1.43
	10.83(7.41–16.67)	4.40(2.85–9.53)	3.52(2.83–7.53)
Grp2 (DCC-Plus)	10.55 \pm 2.15	7.23 \pm 2.07	6.45 \pm 1.89
	9.88(7.17–14.43)	7.08(4.71–10.38)	5.71(4.43–10.63)
Grp3 (SF)	6.94 \pm 1.85	6.33 \pm 2.60	3.12 \pm 1.47
	6.76(4.59–10.90)	6.11(2.73–12.46)	2.70(1.21–6.08)
Grp4 (FP)	16.09 \pm 4.77	11.73 \pm 3.84	8.51 \pm 3.43
	16.92(9.74–23.54)	10.66(5.35–18.12)	6.75(4.95–15.43)
p (Comparisons between 4 groups)*	0.0001	0.0001	0.0001
p (Multiple comparisons between 2 groups)**			
p Grp 4 vs Grp 3	0.0001	0.001	0.0001
p Grp 4 vs Grp 2	0.004	0.003	0.094
p Grp 4 vs Grp 1	0.017	0.001	0.001
p Grp 1 vs Grp 2	0.45	0.028	0.001
p Grp 2 vs Grp 3	0.001	0.25	0.001
p Grp 1 vs Grp 3	0.001	0.279	0.094

To interpret our results, it must be recognized that many factors affect the integrity of the bond between root dentin and the material filling. In addition to polymerization shrinkage, the C-factor, application method, and polymerization of the composite resin play significant roles [23]. Future studies should examine different bonding strategies and incremental techniques in post space.

Conclusion

Based on the methodology and results of the present study, it can be concluded that the bond strength of the recently introduced sonically activated bulk-fill composite in root canals is lower than that of other conventional methods.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

1. Schwartz RS, Robbins JW. Post placement and restoration of endodontically treated teeth: a literature review. *Journal of Endodontics* 2004; **30**: 289–301.
2. 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 post-and-core systems. *Journal of Prosthetic Dentistry*. 1999; **81**: 262–269.

3. Maccari PC, Conceição EN, Nunes MF. Fracture resistance of endodontically treated teeth restored with three different prefabricated esthetic posts. *Journal of Esthetic and Restorative Dentistry*. 2003; **15**:25-30.

4. Asakawa Y, Takahashi H, Iwasaki N, Kobayashi M. Effect of ultraviolet light irradiation period on bond strengths between fiberreinforced composite post and core build-up composite resin. *Dental Materials – Journal*. 2014; **33**: 133–140.

5. Chieruzzi M, Pagano S, Pennacchi M, Lombardo G, D'Errico P, Kenny JM. Compressive and flexural behaviour of fibre reinforced endodontic posts. *Journal of Dentistry*. 2012; **40**: 968-978.

6. Chieruzzi M, Rallini M, Pagano S, Eramo S, D'Errico P, Torre L, Kenny JM. Mechanical effect of static loading on endodontically treated teeth restored with fiber-reinforced posts. *Journal of biomedical materials research part b applied biomaterials*. 2014; **102**: 384-394.

7. Salameh Z, Sorrentino R, Ounsi HF, Sadig W, Atiyeh F, Ferrari M. The effect of different full-coverage crown systems on fracture resistance and failure pattern of endodontically treated maxillary incisors restored with and without glass fiber posts. *Journal of Endodontics*. 2008; **34**:842-846.

8. Maccari PC, Cosme DC, Oshima HM, Burnett LH Jr, Shinkai RS. Fracture strength of endodontically treated teeth with flared root canals and restored with different post systems. *Journal of Esthetic and Restorative Dentistry*.2007;**19**: 30-36.

9. Ilie N, Hickel R. Investigations on a methacrylate-based flowable composite based on the SDR technology. *Dental Materials* 2011; **27**: 348–355.

10. Hofmann N, Papsthart G, Hugo B, Klaiber B. Comparison of photo-activation versus chemical or dual-curing of resin-based luting

cements regarding flexural strength, modulus and surface hardness. *Journal of Oral Rehabilitation*. 2001;28:1022–1028.

11. Baldea B, Furtos G, Antal M, Nagy K, Popescu D, Nica L. Push-out bond strength and SEM analysis of two self-adhesive resin cements: An in vitro study. *Journal of Dental Sciences*. 2013; **8**: 296-305.

12. Anic I, Shirasuka T, Matsumoto K. Scanning electron microscopic evaluation of two compaction techniques using a composite resin as a root canal filling material. *Journal of Endodontics*. 1995; **21**: 594-8.

13. Alaçam T, Uzun O, Kivanç BH, Yoldaş O, Görgül G. Microhardness of packable composites used as posts condensed with different methods. *Journal of Endodontics*. 2003; **30**: 51-53.

14. Fujita K, Ikemi T, Nishiyama N. Effects of particle size of silicafiller on polymerization conversion in a light-curing resin composite. *Dental Materials*. 2011; **27**: 1079–1085.

15. Aksornmuang J, Nakajima M, Foxton RM, Tagami J. Mechanical properties and bond strength of dual-cure resin composites to root canal dentin. *Dental materials*. 2007; **23**:226–234.

16. Braga RR, Cesar PF, Gonzaga CC. Mechanical properties of resin cements with different activation modes. *Journal of Oral Rehabilitation*. 2002; **29**:257–262.

17. Yoshida K, Meng X. Influence of light-exposure methods and depths of cavity on the microhardness of dual-cured core build-

up resin composites. *Journal of Applied Oral Science*. 2014; **22**: 44-51.

18. Rosentritt M, Shortall AC, Palin WM. Dynamic monitoring of curing photoactivate resins: a methods comparison. *Dental Materials*. 2010; **26**: 565-70.

19. Bucuta S, Ilie N. Light transmittance and micro-mechanical properties of bulk fill vs. conventional resin based composites. *Clinical Oral Investigations*. 2014; **18**: 1991-2000.

20. Kim RJ, Kim YJ, Choi NS, et al. Polymerization shrinkage, modulus, and shrinkage stress related to tooth-restoration interfacial debonding in bulk-fill composites. *Journal of Dentistry*. 2015; **43**: 430-439.

21. Isidor F, Odman P, Brondum K. Intermittent loading of teeth restored using prefabricated carbon fiber posts. *The International Journal of Prosthodontics*. 1996; **9**: 131–136.

22. Aksornmuang J, Nakajima M, Panyayong W, et al. Effects of photocuring strategy on bonding of dual-cure one-step self-etch adhesive to root canal dentin. *Dental Materials – Journal*. 2009; **28**: 1331-141.

23. Orłowski M, Tarczydło B, Chalas R. Evaluation of Marginal Integrity of Four Bulk-Fill Dental Composite Materials: In Vitro Study. *The Scientific World Journal*. 2015; 701262.