Comparison of adhesive bond strength among fiber reinforced post and core with different cementation techniques: In vitro study

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Abstract
Aim: To investigate push-out bond strength (PBS) of fiber post to radicular dentin after using different cementation techniques.

Material and methods: Sixty single-rooted premolars were disinfected and cleaned by mechanical instrumentation. S1, S2, and SX were used for canal shaping and finishing of the canal was carried out using F1 and F2. This was followed by constant irrigation and smear layer removal using 17%EDTA. The canal was dried filled with gutta-percha and canal space was prepared using a peso reamer. Based on cementation techniques, samples were randomly allocated into six groups. Group 1: One-step Monoblock MC; Group 2: One-step, Monoblock MC-NA (no adhesive) GFP; Group 3: One-step, RX-MC-Monoblock; Group 4: Two-step, RX-MC; Group 5: Two-step, RX-FZ; and Group 6: Two-step RX-FZ-custom post. All specimens were mounted in polyvinyl pipes using acrylic resin up to cement enamel junction. All specimens were mounted in a universal testing machine subjected to push-out forces at a speed of 0.5 mm/min. Five samples from each group were sputter-coated with 6 nm gold thickness for 300 s at 250 mA. The coated specimens were assessed under the scanning electron microscope (SEM). Analysis of variance (ANOVA) and Tukey Kramer multiple comparisons tests were performed to compare means among groups maintaining the level of significance at (p<0.001).

Results: The highest PBS was displayed in RX-MC-Monoblock (199.020 ± 21.432 MPa). Whereas, lowest PBS was found in Monoblock MC-NA (no adhesive)-GFP (76.440 ± 9.468 MPa). Among one-step groups, RX-MC Monoblock exhibited the highest PBS (199.020 ± 21.432 MPa) comparable to one-step Monoblock MC (134.28 ± 19.37 MPa) (p > 0.05). Similarly, among two-steps groups, two-step RX-MC demonstrated significantly higher PBS values than two-step RX-FZ (143.340 ± 23.68 MPa) and RX-FZ-custom post (86.90 ± 7.41 MPa) (p < 0.05).

Conclusion: One-step RX-MC-Monoblock technique using self-adhesive cement and core foundation composite resin material multicore flow when cured simultaneously exhibited the highest bond integrity of post retention compared to other cementation technique.

Keywords
One-step cementation, two-step technique, push-out bond strength, scanning electron microscopy

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Introduction

Teeth with an endodontic treatment are at increased risk of failures and fractures due to compromised structure. Furthermore, a large access cavity design and mechanical preparation of the canals during an endodontic treatment further weaken the tooth. This may be due to loss of remaining dentinal thickness (RDT) of root canal walls along with dentin desiccation and loss of collagen crosslinking. All these factors contribute to the reduced stiffness and fracture resistance of the tooth. Therefore, restoring and retaining such compromised structure necessitates the post-placement for retention and adhesion of coronal restorations.

Traditionally, cast metal posts are used to retain core buildup on root canal treated teeth (RCT). It exhibits a higher elastic modulus than dentin, which might be the reason for root fracture and failure. However, metal posts display less corrosion resistance along with poor esthetics. Therefore, to overcome the limitations of metal post, glass fiber posts (GFP) with less stiffness and comparable modulus of elasticity to dentin are being commonly used. They are more esthetically pleasing and present better resistance to mechanical failure due to adhesive resin dentin bonding. Previous studies have reported up to 99% success rate for teeth restored with GFP along with compatibility with BIS-GMA-containing adhesives. Cementation of GFP to the radicular dentin and the coronal restoration is considered as the most critical step influencing post retention and microleakage along with the post-retoration interface. A good dentinal seal prevents the development of recurrent caries, reduces bacterial invasion, and strengthens the tooth to resist mechanical failure. In the available literature, multiple studies have adopted different cementation techniques to enhance the adhesion between GFP posts, root dentin, and core buildups. The one-step cementation technique is also known as the monoblock technique is a classical technique based on the application of a single material system. This method reduces the number of interfaces between different materials, minimizes procedural steps, consumes less time, and saves material. It provides better esthetics and can be used for both posterior and anterior teeth. A contemporary two-step post cementation technique, also known as incremental technique, is employed in clinical practice. This results in lower stress generation and reduces the canal C-factor which improves the bond integrity of fiber post with the root dentin and core. Both the techniques have their advantages and disadvantages. A recent study by Jongsma et al. highlights the advantage of the two-step technique whereas, a clinical case report by Reis et al. outlines and supports better bond integrity of GFP restored by monoblock technique. Hence, due to heterogeneous outcomes of both restoring techniques further investigation is indispensable.

Currently, available literature demonstrated that data related to the effect of the one-step and two-step cementation techniques for GFP cementation and core buildup is limited. It is hypothesized that the two-step technique will display comparable PBS of GFP with root dentin to that of the one-step restoring technique. Hence, the purpose of the present study was to investigate PBS of fiber post to radicular dentin after using different cementation methods.

Material and methods

Criteria of selection of specimens

Sixty sound single-rooted premolars were extracted due to orthodontic reasons for 3 months. Root lengths were recorded from the apex to the buccal cusp tip occluso-apically. Buccolingual and mesiodistal dimensions were measured from the highest contour with a calibrated digital caliper. Hypoplastic, teeth with fracture and cracked lines, and other abnormalities were excluded with the help of a radiograph. Teeth with no caries, previous restorations, or endodontic treatment, clinically and radiographically sound were included in the study.

Preparation of specimens

Each tooth was immersed in 5% sodium hypochlorite (NaOCl) (Sigma Aldrich, Merck, Germany) for 15 min for disinfection. Residual organic and inorganic debris was removed using a periodontal curette (Hufriedy, Rockwell, Chicago, US) following storage of specimens in 0.9% saline solution at room temperature. A straight-line access cavity was established in all specimens and a glide path was formed using a 10K file (Maillefer, Tulsa, USA) to full working length, confirmed by radiograph.

Instrumentation was carried using a crown down technique with a pro-taper universal NiTi system (Dentsply Maillefer, Switzerland) to the full working length up to size 40K preparing the canal mechanically. The canal was irrigated constantly using 1% NaOCl during shaping (S1, S2, SX) and finishing (F1, F2). About 17% Ethylene diamine tetraacetic acid (EDTA) solution was used to remove the smear layer, each for 180s. The final rinse was done with 10ml of sterile water. After chemical-mechanical preparation, canals were dried using absorbent paper points (Gapa Dent, Zhengzhou Smile Dental Equipment, Henan, PRC) then obturated using gutta-percha (Roeko; Langenau, UK) and sealer (AH Plus, Dentsply, Konstanz, Germany) with cold lateral compaction technique.

Preparation of post space

Post-space preparation for all teeth was done after 7 days. Gates Glidden drills (Mani, ZZlinker, Shingai) size #1 up to size #3 (0.9 mm) and size #4 (1.1 mm) were used.
sequentially to enlarge the canal orifice. Post space was standardized with 10 mm length, keeping 2–3 mm as an apical seal. Each canal space was thoroughly cleaned using air and water spray and then dried using paper points. The samples were distributed randomly using the probability sampling technique into six groups (n = 10) according to the cementation technique.

Methods of cementation

**Group 1: One-step (Monoblock MC)**

The radicular canal space was etched for 20 s using 37% phosphoric acid gel (Ho Dental, Las Vegas NV). The post space was rinsed with saline and dried with paper points. A dual-cure bonding agent Excite F DSC adhesive (Ivoclar; Schaan, Liechtenstein) having a photopolymer camphorquinone was applied in the canal space, coronal part of the tooth and on the GFP (RelyX™ Fiber Post 3M, ESPE) with a micro brush in a single stroke, the air thinned and then cured for 20 s (Bluephase C8, Ivoclar Vivadent, Schaan, Liechtenstein). A dual-cure polymerizing resin material Multicore (Ivoclar; Vivadent, Schaan, Liechtenstein) was used as cement. Under finger pressure, the fiber post was placed through the cement. Multicore was used as a build-up material simultaneously followed by light cure for 40 s.

**Group 2: One-step (Monoblock MC-NA (no adhesive)-GFP)**

The process of etching, rinsing, and drying of canal space was similar as discussed in One-step group 1. Dual-cure bonding agent Excite F DSC adhesive (Ivoclar; Schaan, Liechtenstein) was applied to the post space and coronal part of the tooth only with no application on fiber post. The remaining restorative protocols using Multicore for core buildup and cementation were the same as discussed in One-step group 1.

**Group 3: One-step (RX-MC-Monoblock)**

The canal space was etched, rinsed, and dried similar to methods reported in One-step group 1 and group 2. On the coronal part of the tooth and fiber post, dual-cure bonding agent Excite F DSC (Ivoclar Vivadent Schaan, Liechtenstein) was applied with a micro brush, the air thinned, and then cured for 20 s.

A self-adhesive dual-cure resin cement was used to fill up the post space up to the orifice (RelyX Unicem; 3M, ESPE) removing excess cement. Dual-cure polymerizing resin build-up material Multicore for the rest of the coronal part. Then under finger pressure, the fiber post was placed through the buildup into the canal and cemented. The complete unit was light-cured for the 40 s.

**Group 4: Two-step (RX-MC)**

Etching, rinsing, and drying of canal space were similar to all one-step groups. Dual-cure bonding agent Excite F DSC (Ivoclar Vivadent, Schaan, Liechtenstein) was applied to the coronal part of the tooth and fiber post. A self-adhesive dual-cure resin cement was used to fill up the post space up to the orifice (RelyX Unicem; 3M ESPE). Under finger pressure, the fiber post was placed through the cement into the canal cured for 20 s. Core build-up was done separately (second step) using a dual-cure polymerizing resin build-up material (Multicore, Ivoclar Vivadent, Schaan, Liechtenstein) following light cure for 40 s.

**Group 5: Two-step (RX-FZ)**

Using etchant, drying of canal space and rinsing was similar to groups discussed previously. Dual-cure bonding agent Excite F DSC adhesive (Ivoclar Vivadent, Schaan, Liechtenstein) was applied to the coronal part of the tooth and on the fiber post. A self-adhesive dual-cure resin cement (RelyX Unicem; 3M, ESPE, India) was used to fill up the post space up to the orifice. A fiber post under finger pressure was cemented in the canal space. Excess cement was removed and cured 20 s. Followed by dual-cure polymerizing resin restorative material (Filtek z350 XT, 3M, India) for core buildup of the rest of the coronal part. The buildup was cured for 40 s.

**Group 6: Two-step (RX-FZ-custom post)**

Dentin etched for 20 s using 37% phosphoric acid gel, rinsed, and dried. Application of dual-cure adhesive Excite F DSC (Ivoclar Vivadent, Schaan, Liechtenstein) was applied on the fiber post cured for 20 s. Petroleum jelly (Vaseline, petroleum, India) was used inside the canal as a lubricant. The post was covered with composite material (Filtek z350 XT) and inserted in the canal. The fiber post was cured along with the composite material inside the canal for 20 s. Between post and canal wall dual-cure polymerizing resin, cement was injected (RelyX Unicem; 3M ESPE) up to the orifice and cured 20 s. Core build-up was done using packable composite (Filtek z350 XT, 3M, India) then light-cured for 40 s (Figure 1).

**Specimen mounting push-out bond strength (PBS) testing**

Each specimen was mounted in auto-polymerizing clear acrylic resin (Astra Chemtech, Dehli, India) using a pre-formed polyvinyl tube with standardized dimensions. Each specimen was positioned at a level of cementoenamel junction (CEJ). The homogeneity was achieved by using a pre-designed 3-D printed centralizing positioning jig. All specimens were positioned on a metallic mold of
Sixty premolar tooth selected and disinfected

Chemomechanical preparation of root canal

Shaping and cleaning of canal

Canal space prepared with reamers and further disinfected

Core buildup using composite material

Placement of fiber post

Cementation of post (Monoblock or RX-FZ-custom)

SEM analysis

Specimen failure analysis

Statistical analysis

Result

SEM analysis

Figure 1. A schematic flow diagram showing steps adopted in the material and method section.

A universal testing machine (Instron 5965) subjected to pull-out forces at a speed of 0.5 mm/min. The maximum load caused by dislodgment of the post from the root canal was recorded in megapascal (MPa).\textsuperscript{2,19–21}

Specimen failure analysis

Five pairs of samples from each group were sputter-coated with 6 nm gold thickness for 300's at 250 mA by a single investigator. The coated specimens were assessed under the scanning electron microscope (SEM) (Thermo-Fisher Scientific, USA). The images were captured under a wide field mode at 10 kV 500× magnification. The failure analysis was performed using SEM and digital microscope (Hirox KH 7700, Tokyo, Japan).\textsuperscript{4} The failure were classified as adhesive, cohesive, or admixed.

Statistical analysis

The data were analyzed with IBM SPSS Version 25.0 software (IBM, Armonk, NY, USA). Analysis of variance (ANOVA) and Tukey Kramer multiple comparisons tests were performed to compare means among groups. ANOVA was used to analyze differences in retention of posts with different cementation techniques and core material used among the six groups. Comparisons of means were assessed using Tukey Kramer multiple comparisons tests maintaining the level of significance at (p < 0.001).

Result

The highest PBS was displayed in RX-MC-Monoblock (199.020 ± 21.432 MPa). Whereas, lowest PBS was found in Monoblock-MC-NA (no adhesive)-GFP (76.440 ± 9.468 MPa).

ANOVA showed that all investigated groups were significantly different from each other (p < 0.05). Moreover, individual comparison using Tukey Kramer post hoc test showed that Monoblock MC (134.28 ± 19.37 MPa) demonstrated significantly higher PBS of GFP to Monoblock MC-NA (no adhesive)-GFP (0.024) and RX-FZ-custom post (p = 0.013) (p < 0.05). Similarly, Monoblock MC-NA (no adhesive)-GFP, demonstrated significantly lower PBS values to RX-MC Monoblock (p = 0.011) RX-FZ (p = 0.032) and RX-FZ-custom post (p = 0.021) specimens (p < 0.05). Furthermore, Group 3: One-step RX-MC Monoblock exhibited significantly higher PBS (199.02 ± 21.43) to group 4-Two-step RX-MC (0.033) and RX-FZ-custom post (0.041) (p < 0.05). Group 4, RX-MC displayed PBS values (158.38 ± 25.78 MPa) significantly higher than group 5 RX-FZ (p = 0.011) and RX-FZ-custom post (p = 0.047). Whereas, group 6, RX-FZ custom post specimens demonstrated PBS (86.90 ± 7.41 MPa) significantly lower compared to all investigated groups (p < 0.05) (Table 1).

Among one-step groups, RX-MC Monoblock (group 3) exhibited highest PBS (199.020 ± 21.432 MPa) compared to Monoblock MC (group 1) (134.28 ± 19.37 MPa) (p > 0.05). Similarly, among two-step groups, RX-MC (group 4) demonstrated significantly higher PBS values than RX-FZ (143.340 ± 23.68 MPa) (group 5) and RX-FZ-custom post (86.90 ± 7.41 MPa) (group 6) (p < 0.05) specimens respectively.

The qualitative analysis of SEM imaging revealed adhesive penetration into dentinal tubules (Figure 2). Whereas, Figure 3 showed a difference between adhesive interface and fiber penetration into dentinal tubules (Figure 2). Whereas, Figure 3 showed a difference between adhesive interface and fiber penetration into dentinal tubules.
post at the coronal section. The images display irregular distribution of cement along with the presence of micro gaps and the juxtaposition of resin cement and root dentin.

Discussion

The purpose of the existing study was to evaluate the effect of six different cementation and core build-up techniques on fiber post retention. The hypothesis was accepted as the highest bond value was observed in One-step RX-MC Monoblock specimen (199.020 ± 21.43) followed by two-step RX-MC (158.386 ± 25.78), two-step RX-FZ (143.340 ± 23.68), and One-step Monoblock MC (134.280 ± 19.375) specimens. The length and the apical diameter of the post were kept constant. Monoblock, single step technique with rely X cement for post and bulk fill core material polymerized simultaneously, achieved better retention of fiber post compared to other techniques.

Table 1. Descriptive statistics ANOVA and Tukey Kramer post hoc test amongst different experimental groups.

| Experimental groups                       | Mean (MPa) | Standard deviation | ANOVA p-value | Multiple comparison |
|-------------------------------------------|------------|--------------------|---------------|---------------------|
| Group 1: One-step Monoblock MC           | 134.280    | 19.375             |               |                     |
| Group 2: One-step Monoblock MC-NA (no adhesive)-GFP | 76.440    | 9.468              | 0.024*        | Group 1             |
| Group 3: One-step RX-MC-Monoblock       | 199.020    | 21.432             | 0.001§        | 0.503               |
| Group 4: Two-step RX-MC                 | 158.380    | 25.784             | 0.044*        | 0.825               |
| Group 5: Two-step RX-FZ                 | 143.340    | 23.688             | 0.896         | 0.032*               |
| Group 6: Two-step RX-FZ-custom post     | 86.900     | 7.415              | 0.013*        | 0.021*               |

FZ: Filtek z350 XT; GFP: glass fiber post; MC: multicore; RX: RelyX Unicem.
*Statistically significant difference using Tukey Kramer post hoc test.
§Statistically significant difference using ANOVA.

Figure 2. Photomicrograph of the interface between dentin and adhesive. Penetration of adhesive within radicular dentin (magnification ×500). Adhesive penetration (yellow arrow). RD: root dentin.

Figure 3. Cross-section of the cervical section of root showing bonded post specimens using SEM: (a) Group 1: One-step Monoblock MC: Adhesive interface showing micro-gaps (yellow arrows), juxtaposition between cement and dentin (asterisks) (magnification ×16) and (b) Group 3: Two-step RX-MC: Adhesive interface showing micro-gaps (yellow arrows), juxtaposition between cement and dentin (asterisk) (magnification ×22).
An ex-vivo study design was adopted, as available evidence suggests that fiber post–root dentin monoblock can be validated independently using an in-vitro design. To comply, with the oral environment the posts used in the existing study were passive as their retention relies mostly on the cement used for luting, with minimum stress exertion on root structure when inserting post. Furthermore, since it’s advocated that resin-based cement has greater bond strength than conventional cement that is, zinc phosphate, hence resin-based cement was utilized in all investigated groups. PBS of specimens was evaluated using a universal testing machine as the technique is consistent, cost-effective, and provides comparative analysis against multiple assessment groups.

Post decementation is one of the most common causes of post-failure. The lowest PBS was found in one-step Monoblock MC-NA (no adhesive) GFP (76.44 ± 9.468 MPa). It is anticipated that the lack of bonding agent in samples of this group showed a significant reduction in retention properties. The absence of resin tag formation between the cement layer and dentinal surface may have contributed to a decreased post retention. The permeation of resin into intratubular dentin is responsible for better bond integrity, which was not achieved, in the present group specimens. Based on the composition of GFP, the methacrylate matrix bonds well with the bonding agent improving mechanical retention to radicular dentin. In specimens of group 6 customized posts with composite, a significantly lower PBS (86.90 ± 7.41 MPa) compared to all groups except Monoblock MC-NA (no adhesive) GFP was observed. The level of polymerization in composite resins is expressed as the degree of conversion of monomeric C=C bonds into polymeric C-C bonds. The extent of conversion affects both physical and mechanical properties of composite.

The author’s opinion, low thickness of cement could be a reason due to the relining of post to the shape of canal. The surface of GFP is rough and the relined customized post is smooth. Composite use to reline post can leave voids between post and composite surface, so the failure is at the GFP and composite interface and not at the relining material and the dentin cement interface. Therefore, for this technique, further investigations are needed to explore the bond between the relining composite material and the fiber post surface. Moreover, highly cross-linked polymer matrix of GFP is difficult to bond with resin luting cement adding to low bond values in this group.

The highest bond value was observed in One-step RX-MC Monoblock specimen (199.020 ± 21.43) followed by two-step RX-MC (158.386 ± 25.78), two-step RX-FZ (143.340 ± 23.68), and One-step Monoblock MC (134.280 ± 19.375) specimens. The author speculates that irrespective of the techniques used (One-step or two-step) the application of bonding agent on post provides an effective adhesion along with satisfactory clinical outcome. Additional reasoning of improved bond integrity in One-step RX-MC Monoblock specimen was due to the simultaneous application and curing of the two materials together. This reduces the void formation and debris contamination between the cement and the core material resulting in homogenous contact between the two layers. In addition, since both materials are polymeric simultaneous polymerization allows for a strong bond and cross linking. This outcome is supported by work by Marigo et al. and Sterzenbach et al.

The findings of the present study contradict the outcome of work already published by Jongsma et al. The study by Jongsma et al. establishes that in the two-step technique the contraction stresses are lower in the restoration compared to One-step. This prevents debonding of post cement and cement dentin interface providing sustainable clinical outcome and better tooth prognosis. In addition, the technique minimizes the chances of microleakage, secondary caries, and endodontic failure. Polymerization stress in one-step technique pulls the cement away from dentin contributing to high C-factor. Whereas, in the case of a two-step procedure the cement shrinks in the direction of dentin with minimum C-factor. In addition, the use of material used for restorative procedures may also contribute toward the success of both techniques.

It would be interesting to perform microleakage studies assessing both one-step and two-step techniques. Since work on this restorative clinical technique is very limited. More clinical studies, including randomized control trials, are recommended to extrapolate the conclusions of the present study. The findings of the present study should be adopted with caution as the study was performed in an in-vitro setting without the specimens undergoing thermocycling. Specimens not undergoing thermocycling along with anatomical variations in radicular dentinal structure can be attributed to possible limitations of the existing study.

Conclusion

Monoblock technique using self-adhesive cement and core foundation composite resin material Multicore Flow when polymerized simultaneously exhibited the highest bond integrity of post retention compared to other cementation techniques. Moreover, the use of bonding agents significantly increased post retention irrespective of one-step or two-step restorative techniques.
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