Comparison of fracture resistance of fiber-reinforced post and core with different cementation techniques: *in vitro* study

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Abstract. – OBJECTIVE: The current study aimed to inspect the fracture resistance of fiber post to canal dentin using a different technique of cementation.

MATERIALS AND METHODS: 60 sound single-rooted central incisors with comparable size and length were stored in normal saline. Each tooth was immersed in 5% sodium hypochlorite (NaOCl). The specimens were randomly divided into 6 groups of 10 specimens each. All included specimens received root canal treatment (RCT). Post-space preparation was done using Gates Glidden drills. Post space was standardized with 10 mm length, keeping 3 to 5 mm as an apical seal. Based on the cementation technique samples were divided into six study groups. Group A: One step-Monoblock; Group B: One step-Monoblock-NA-FP; Group C: One step-Monoblock-RX-MC; Group D: Two-step- RX-MC; Group E: Two-step- RX-FZ; Group F: Two-step- RX-FZ-Custom post. Following cementation, all teeth will be prepared to receive a monolithic zirconia crown with a finish line of 1 mm above the CEJ. Each specimen was mounted in auto-polymerizing clear acrylic resin using a preformed tube. All samples were subjected to pushing forces to measure the fracture strength of the specimen using a universal testing machine. To compare the means among different experimental groups Post-Hoc Tukey multiple comparison tests and analysis of variance (ANOVA) were adopted.

RESULTS: The highest fracture resistance was observed in group A. Whereas, the lowest fracture resistance was observed in group D samples. Fracture strength in group A samples showed significantly higher fracture resistance values compared to all other groups ($p < 0.05$). Fracture resistance values in group F specimens were significantly higher than specimens in groups B, C, D, and E. respectively ($p < 0.05$).

CONCLUSIONS: Monoblock technique using single cementation and core material (Multicore Flow) when polymerized simultaneously exhibited the highest fracture resistance of glass fiber post compared to other cementation techniques.

Key Words:

Fracture resistance, Monoblock technique, Two-step technique, Cementation technique.

Introduction

Endodontic infection is caused by dental caries and trauma, leading to tooth loss or compromised tooth structure after endodontic treatment[1]. With endodontically treated teeth, there is a loss of water content, as well as a change in the physical and esthetic properties of the remaining tooth structure[2]. For these reasons, a full coverage coronal restoration is clinically required[3]. However, due to the severe coronal structure loss and a need for retention and resistance form of the tooth preparation, a post and core system is needed to restore these endodontically treated teeth.

With changed physical features, dehydration, and decreased neurosensory feedback system, the endodontically treated tooth poses a challenge to dental practitioners[4]. The type of final restoration is determined by the amount of remaining coronal tooth dentin and the number of remaining walls[5]. Since endodontic treatment predisposes the tooth to fracture, it is recommended to utilize different techniques to form a retentive tooth core, including inter radicular post, auxiliary retentive techniques (groove, pins, boxes, or undercuts), and adhesives[6]. Intra radicular post fabricated with zirconia, composite fibers, and metals is the most commonly used method for core retention[7,8]. Previous studies[9,10] have reported up to 99% success rate for teeth restored with post and core retention.

The main objective of inter radicular post is to provide retention when the remaining tooth structure is insufficient and to retain the core restoration in place[11]. When restoring an endodonti-

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cally treated tooth with a considerable loss of tooth structure, a fiber post is recommended to prevent catastrophic failures by reducing gap advancement, improving fracture resistance, and preventing catastrophic failures. Glass fiber posts (GFP) have less stiffness and modulus of elasticity similar to dentin[12]. They are more esthetically pleasing and present better resistance to mechanical failure due to adhesive resin dentin bonding[13,14]. Evidence[15,16] advocates that the use of GFP improves fracture resistance and lowers non-restorable fractures in all specimens by 20% to 30%.

Multiple factors affect fracture resistance of endodontically treated teeth. These aspects may range from the type of post material, design, diameter, adaptability, post length, available tooth structure, post material biocompatibility, load experienced by tooth structure, ferrule effect, fracture resistance of constructed tooth, and cementation technique[17]. Cementation of GFP to dentin is a critical aspect that influences the fracture resistance of the post, microleakage, and finally tooth prognosis[18]. To improve adhesion of post to dentin various cementation techniques are recommended. The monoblock one-step technique is based on the application of a single material system[7]. The technique is advantageous as it limits procedural steps, and is less time-consuming and cost-effective. Aesthetically the technique is more pleasing for anterior and posterior teeth[19]. Similarly, a modern two-step cementation technique also recognized as an incremental technique is practiced clinically[20]. The procedure is useful as it lowers stress generation and reduces the C-factor of the radicular canal which indirectly improves bond integrity and influences fracture resistance[21]. Jongsma et al[20] in their recent work, praise the two-step technique whereas, Reis and his colleagues highlight the importance of the monoblock technique[19].

Based on the currently available literature, the effect of different cementation techniques on fracture resistance of fiber-reinforced posts is dubious with the heterogeneous outcome. Most of the evidence is available on the push-out bond strength (PBS) of GFP using diverse cementation techniques[6]. Hence, the current study aimed to inspect the fracture resistance of fiber post to canal dentin using a different technique of cementation.

Materials and Methods

60 sound single-rooted central incisors of comparable size and length were stored in normal saline. Each tooth was measured from the incisal edge to the root apex. And the teeth were divided into six groups (A, B, C, D, E, F). The included teeth were free of caries, restorations, and endodontic treatment. Teeth which were excluded were abnormal, defective, and pathological. The present study follows a checklist for reporting *in vitro* study CRIS guidelines.

Specimens Preparation

Each tooth was immersed in 5% sodium hypochlorite (NaOCl) (Sigma Aldrich, Merck, Germany) for 15 minutes to remove all residual organic materials from the root surfaces. Each tooth was inspected for any residual soft tissue and was carefully cleaned using a periodontal curette (Hufriedy, Rockwell, Chicago, US) following storage of specimens in 0.9% saline solution at room temperature. The specimens were randomly divided into 6 groups of 10 specimens each. All included specimens received root canal treatment (RCT). A straight-line access cavity was established followed by negotiation and creating a glide path with hand files (15-20) K files (Maillefer, Tulsa, USA) to the full working length. Instrumentation was carried out using a crown down technique with a ProFile System to the full working length up to size 40 (0.04) preparing the canal mechanically. The canal was irrigated constantly using 1% NaOCl during shaping. About 17% Ethylene diamine tetraacetic acid (EDTA) solution was used to remove the smear layer, each for 180s. The final rinse was done with 10 ml of sterile water. After chemical-mechanical preparation, canals were dried using absorbent paper points (Gapa Dent, Zhengzhou Smile Dental Equipment, Henan, PRC) and then obturated using gutta-percha (Roeko; Langenau, UK) and sealer (AH Plus, Dentsply, Konstanz, Germany) with cold lateral compaction technique.

Post-Space Preparation

Post-space preparation for all teeth was done after 7 days from the RCT using Gates Glidden drills (Mani, ZZlinker, Shingai, PRC) size 1 (0.5 mm) up to size 3 (0.9 mm) and 4 (1.1 mm) to enlarge the canal orifice. Post-space was standardized with 10 mm length, keeping 3 to 5 mm as an apical seal. A yellow fiber post drill (RelyX™ Fiber Post 3M ESPE) was used to shape the canals while keeping the same working length. Each tooth was thoroughly cleaned using air and water spray and then dried using paper points.

Study Groups and Cementation Techniques

Group A: One step-monoblock

The dentin was etched for 20 seconds using 37% phosphoric acid gel (Total Etch - Ivoclar; Vivadent). The surface was rinsed with saline and dried with paper points. A dual-cure bonding agent (EXCITE F DSC- Ivoclar; Vivadent) was applied to the post space and coronal part of the tooth and on the fiber post (RelyX™ Fiber Post 3M ESPE) with a micro brush, the air thinned and then cured for 20s. Then a dual-cure polymerizing resin build-up material (Multicore) was used as cement, for the fiber post (RelyX™ Fiber Post 3M ESPE), and core build-up simultaneously (one step). This was done under finger pressure followed by a light cure for 40s.

Group B: One step-monoblock-NA-FP

The dentin was etched for 20 seconds using 37% phosphoric acid gel Total Etch (Ivoclar; Vivadent). The surface was rinsed with saline and dried with paper points. A dual-cure bonding agent EXCITE F DSC (Ivoclar; Vivadent) was applied to the post space and coronal part of the tooth only with a micro brush, the air thinned and then cured for 20s. Then a dual-cure polymerizing resin build-up material (Multicore, Ivoclar; Vivadent) was used as cement, for the fiber post (RelyX™ Fiber Post 3M ESPE), and core build-up simultaneously. This was done under finger pressure followed by a light cure for 40s.

Group C: One step-Monoblock-RX-MC

The dentin was etched for 20 seconds using 37% phosphoric acid gel Total Etch (Ivoclar; Vivadent). The surface was rinsed with saline and dried with paper points. A dual-cure bonding agent EXCITE F DSC (Ivoclar; Vivadent) was applied to the coronal part of the tooth and on the fiber post (RelyX™ Fiber Post 3M ESPE) only with a micro brush, air thinned, and then cured for 20s. Then a self-adhesive dual-cure resin cement was used to fill up the post space up to the orifice (RelyX Unicem; 3M ESPE) simultaneously followed by dual-cure polymerizing resin build-up material (Multicore, Ivoclar; Vivadent) for the rest of the coronal part. Then under finger pressure, the fiber post (RelyX™ Fiber Post 3M ESPE), was placed through the buildup into the canal and cemented. This was then followed by a light cure for 40s.

Group D: Two-step-RX-MC

The dentin was etched for 20 seconds using 37% phosphoric acid gel Total Etch (Ivoclar; Vivadent). The surface was rinsed with saline and dried with paper points. A dual-cure bonding agent (EXCITE F DSC- Ivoclar; Vivadent) was applied to the coronal part of the tooth, and on the fiber post (RelyX™ Fiber Post 3M ESPE) with a micro brush, the air thinned and then cured for 20s. Then the fiber post (RelyX™ Fiber Post 3M ESPE) was cemented under finger pressure using a self-adhesive dual-cure resin cement (RelyX Unicem; 3M ESPE) as the first step. Then the core build-up was done separately (second step) using a dual-cure polymerizing resin build-up material (Multicore, Ivoclar; Vivadent). This was then followed by a light cure for 40s.

Group E: Two-step-RX-FZ

The dentin was etched for 20 seconds using 37% phosphoric acid gel Total Etch (Ivoclar; Vivadent). The surface was rinsed with saline and dried with paper points. A dual-cure bonding agent (EXCITE F DSC- Ivoclar; Vivadent) was applied to the coronal part of the tooth, and on the fiber post (RelyX™ Fiber Post 3M ESPE) with a micro brush, air thinned and then cured for 20s. Then the fiber post (RelyX™ Fiber Post 3M ESPE) was cemented under finger pressure using a self-adhesive dual-cure resin cement (RelyX Unicem; 3M ESPE) as step one, t hen the core build-up was done separately using packable composite (Filtek z350 XT). This was then followed by a light cure for 40s.

Group F: Two-step-RX-FZ-Custom post

Fiber post (RelyX™ Fiber Post 3M ESPE) bonded with a dual-cure bonding agent EXCITE F DSC (Ivoclar; Vivadent) then cured for 20sec. Petroleum jelly was used inside the canal as a lubricant agent then the post was covered with composite material (Filtek z350 XT) and inserted in the canal to adapt to the root canal anatomy. The post cured along with the composite material inside the canal for 20s then outside for 20sec. Dentin etched for 20 seconds using 37% phosphoric acid gel Total Etch (Ivoclar; Vivadent). The surface was rinsed with saline and dried with an air syringe. A bonding agent (EXCITE F DSC- Ivoclar; Vivadent) was applied inside the canal with a micro brush and then cured for 20s. The post was cemented using dual-cure polymerizing resin cement (RelyX Unicem; 3M ESPE) following manufacturer instructions. The core build-up was done using packable composite (Filtek z350 XT) and then light-cured for 40s.

Teeth Preparation for Crowns

All teeth with a finish line of 1 mm received a monolithic zirconia crown. The axial reduction

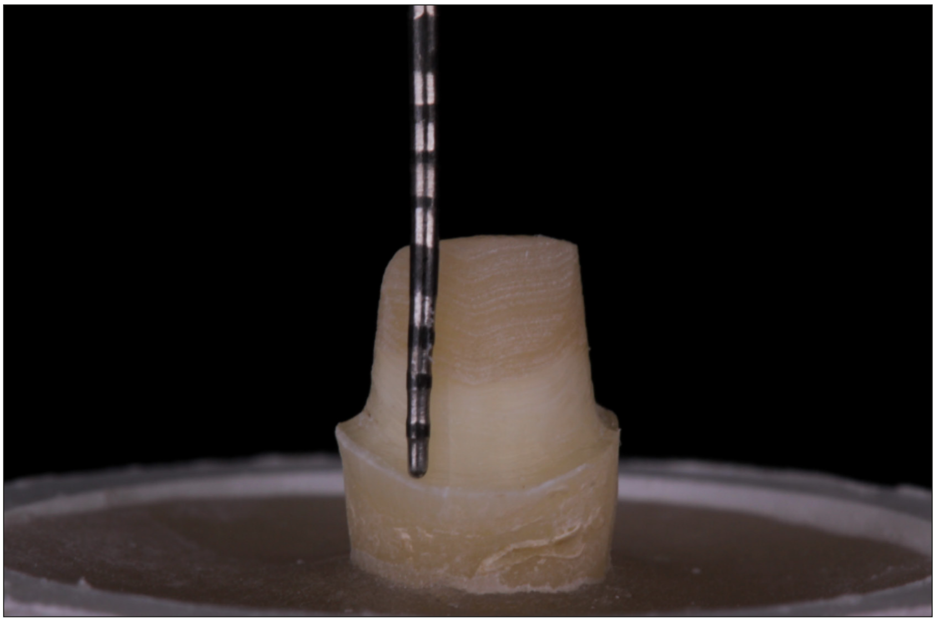

Figure 1. The total occluso-gingival height for the preparation.

will be done with an MRD gauged diamond (Lot-NR 1599, DFS Dental and Technical Products, GmbH, Germany) which will be attached to the milling machine (K9 Milling Apparatus-990, Kavo, Germany) for every group. The MRD gauged diamond had a self-limiting tip, which produced a 1 mm deep chamfer, and the margins and the angle of convergence were standardized. Each tooth after preparation had dentin support of 2 mm. And that was measured after axial reduction and then measured from the finish line to the incisal surface of the prepared teeth. The faciolingual and mesiodistal widths were measured with the calibrated gauge caliper to be approximately in the same range. The ferrule used in this study was 2.0 mm. The incisal surface of the prepared teeth will be flattened to ensure the accurate fit of the posts[25]. The total occlusogingival height for the preparation was 5 mm. **(**Figure 1)

Crown Fabrication and Cementation

All teeth were scanned using (Ceramill map 600; Amann Girrbach) and monolithic zirconia crowns were designed and milled for each tooth using CAD/CAM (Mulling ceramill motion 25X; Amann Girrbach), with all crowns (Sirona disk XT ML; Dentsply) having a 1.5 mm thickness at the cingulum area for the crown to withstand compression forces and 1.0 mm thickness at the cervical area. All crowns were cemented using dual-cure polymerizing resin cement (RelyX Unicem; 3M ESPE), excess cement was removed before light cure, and crowns were light-cured 20s for each surface according to the manufacturer instructions (Figures 2 and 3).

Specimen Mounting and Testing

Each specimen was mounted in auto-polymerizing clear acrylic resin (manufacturer) using a preformed tube formed (cylindrical tube) with standardized dimensions and a 30-degree angle, to serve as a cylindrical test tube (CTT). Each specimen held 3 mm below the cementoenamel junction (CEJ). Positioning of each tooth was performed using a surveyor to standardize the angulation of the specimen while pouring the auto-polymerizing acrylic resin in the preformed tube former. While the polymerization of the acrylic resin was active, the CTT block was immersed in a cool water bath to prevent dehydration of the specimen teeth. The specimen was positioned on a prefabricated CTT using the positioning surveyor. The CTT was fabricated to fit into a custom holding device (CHD) to standardize the test for each specimen. All specimens were subjected to pushing forces to measure the fracture strength of the specimen using a universal testing machine (Instron-5965) at a crosshead speed of 0.5

mm\min. A maximum load of 100N was applied which caused the fracture of the tooth recorded in mega-pascal (MPa) (Figure 4).

Statistical Analysis

To compare the means among different experimental groups Post-Hoc Tukey multiple comparison tests and analysis of variance (ANOVA) were adopted. Differences in fracture resistance of fiber-reinforced post and core with different cementation techniques were assessed by ANOVA. The mean comparison was evaluated using Post-Hoc Tukey multiple comparison *t*-tests. The level of significance was maintained at ($p < 0.05$).

Results

The highest fracture resistance was observed in group A specimens (23.07 ± 7.11) MPa, however, the lowest fracture resistance was observed in group D samples (9.52 ± 2.83) (Table I). A statistically significant difference was observed in the fracture resistance among the compared groups ($p<0.05$).

Fracture strength in group A samples showed significantly higher fracture resistance values compared to all other groups ($p<0.05$). Specimens in groups B (13.63 ± 4.02) and C (15.58 ± 3.68) showed comparable fracture resistance outcomes, which were lower than group A ($p>0.05$). Similarly samples in-group E (16.40 ± 3.77) showed comparable ($p>0.05$) fracture resistance outcomes, to fracture resistance values in groups B and C respectively ($p>0.05$). The fracture resistance of samples in group D (9.52 ± 2.83) was significantly lower than in all study groups ($p<0.05$). Fracture resistance values in group F specimens (18.05 ± 3.76) were significantly higher than specimens in groups B, C, D, and E respectively ($p<0.05$).

Discussion

The purpose of the present study was to evaluate the effect of different fiber post cementation and core build-up techniques on the fracture resistance of endodontically restored teeth. The highest fracture resistance value was observed in One-step Monoblock-MC and the least fracture resistance was demonstrated in One-step-Monoblock-NA-FP specimens. Monoblock, a single-step technique with Multicore, for post and bulk fill core material was polymerized simultaneously and achieved the best fracture resistance of fiber-reinforced post and core compared to other methods.

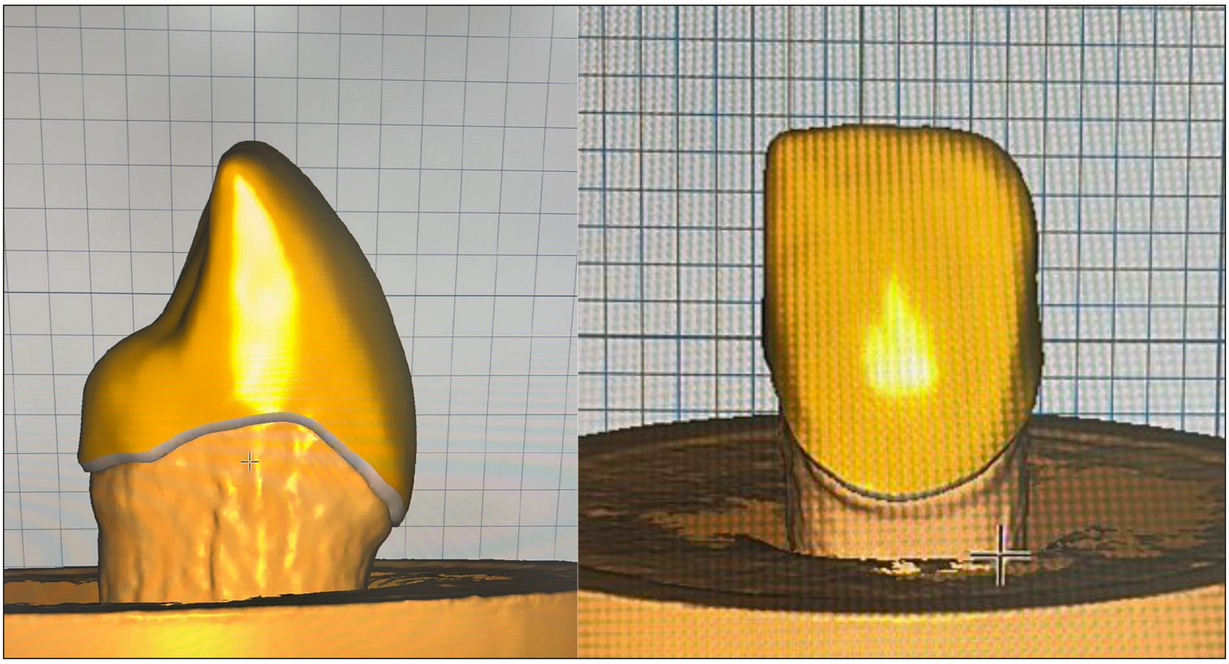

Figure 2. Monolithic zirconia crowns designed and milled for each tooth using CAD/CAM has a 1.5 mm thickness at the cingulum area and 1.0 mm thickness at the cervical area.

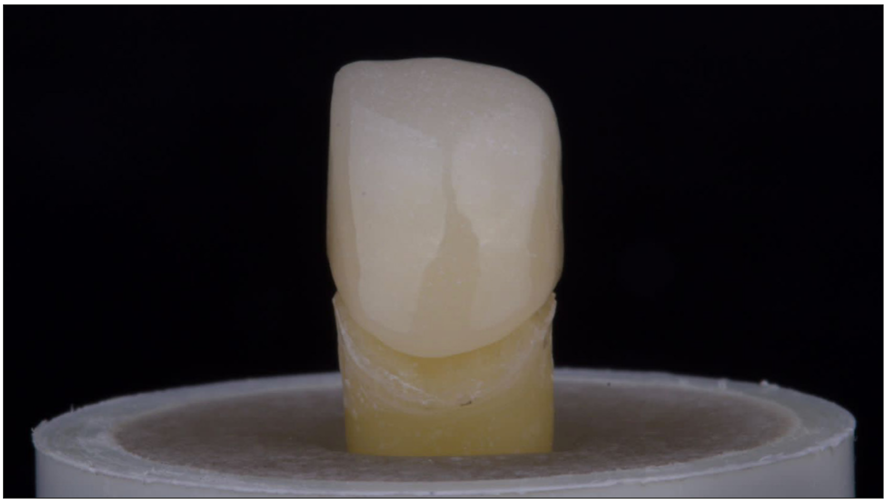

Figure 3. Monolithic zirconia crown cemented using dual-cure polymerizing resin cement.

For a standard methodology, the length and diameter of the posts were kept constant. Previous studies have suggested that fiber post monoblock cementation to root dentin can be assessed using an *in vitro* design[19,22]. The post size used in the study was passively fitting in the root canal preparations for allowing cement for luting and minimizing stress exertion on dentin when inserting post[14]. A resin-based cement (Rely X or Multicore) was employed in contrast to acid-base cement, as they provide greater bond strength than conventional cement[23]. The strength of specimens was evaluated using a universal testing machine as the technique is consistent, cost-effective, and provides comparative analysis against multiple assessment groups[24,25].

The lowest fracture resistance was found in one step-Monoblock-NA-FP group in which no bonding agent was applied to the root dentin. Adhesive bonding agents are critical for reliable

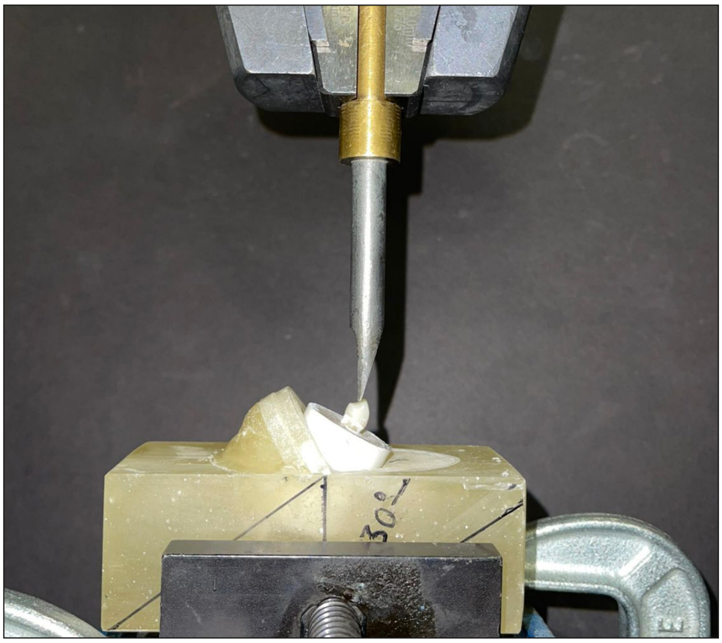

Figure 4. Sample positioned on Universal testing machine at a crosshead speed of 0.5 mm\min

dentin bonding and the lack of bonding agent in samples of the One-step- Monoblock-NA-FP group showed a reduction in fracture resistance properties[26]. It is suggested in previous studies that the lack of resin tag formation between the cement and dentin surface contributes to a decrease in post retention[27]. Resin tags within dentin are formed due to permeation and polymerization of adhesive resin in intratubular dentin and are responsible for better bond integrity[28]. However, this was not achieved in One step- Monoblock-NA-FP group specimens. Hence lower fracture resistance values were gained.

The composition of fiber posts has a methacrylate matrix which bonds well with the dentin adhesive[29]. Within the specimens of group F (Two-step RX-FZ custom) posts were customized with composite resin, and post strength was significantly higher than in other groups, except for group A. The addition of composite resin to the structure of the fiber post due to post relining is a possible reason for superior fracture resistance in this group (Two-step RX-FZ custom)[6,30]. In addition, customized posts result in standardization of cement thickness, causing a decrease in cohesion and increase in adhesive forces within the resin cement, leading to superior fracture resistance[31]. An adhesive bond provides superior bond integrity compared to cohesive failures, therefore improving the post retention in the group samples (group F -Two-step RX-FZ custom)[20]. In addition, thin cement layers show a higher degree of monomer to polymer conversion, which subsequently affects the physical properties of the relined post[6]. Therefore, it is imperative to further investigate the bond between the post reline material, glass fiber post, and the effect on fracture resistance.

In the present study, the highest fracture resistance values were observed in One-step Monoblock (group A) specimens. Among all study groups, an adhesive bond was applied to root dentin, post space only in group A. Also, the crown design, the material of fabrication, and the cementation process were the same. Therefore it is the application of adhesive bonding agents which caused the increased post strength in group A samples[6]. In addition, improved fracture resistance in one step-Monoblock specimen was due to the simultaneous polymerization and application of the same material for post cementation and core. Minimizing the chances of void formation and debris contamination between the cement and the core material and intimate contact[30,32].

Interestingly, the study by Jongsma et al[20] showed that contraction of polymeric materials in the two-step technique (groups D, E, and F) is lower compared to One-step (groups A, B, and C) methods. Lower stress at the cement-dentin interface prevents debonding of cement improving the prognosis of post-treatment[33]. It also reduces the chances of microleakage, secondary caries, and endodontic failure[34]. By contrast in the one-step technique, the polymerization stresses cause cement shrinkage away from the dentin and increase the C-factor[30]. But in the case of two-step methods, the C-factor is minimized as the cement contracts towards the dentin[20]. However, in the present study, this did not influence fracture resistance of the restored teeth samples and showed similar fracture resistance outcomes.

Within the limitations of the present study, microleakage represents a critical aspect of post-treatment and tooth prognosis was not assessed in the present study. The study was performed in *in vitro* settings without the specimens undergoing thermocycling, however, exposure to intra-oral stresses and temperature changes significantly influences fracture resistance. In addition, the anatomical variations in root dentin of endodontic treated teeth are also a possible limitation of the existing study. Therefore, further randomized control trials,

Table I. Means and standard deviations of fracture strength among the study groups.

Study group	Treatment Means	Std Deviations	p-value[ǀ]	
A	One step- monoblock-MC	20.07[a]	4.11	< 0.05
B	One step- Monoblock-NA-FP	9.52[b]	3.83	
C	One step monoblock- RX-MC	19.05[c]	3.76	
D	Two-step RX-MC	18.63[d]	3.77	
E	Two-step RX-FZ	17.21[e]	4.03	
F	Two-step RX-FZ- customized	17.93[f]	3.68	

MC, multicore, FP, fiber post, RX, Rely X Unicem, FZ, Filtek Z. *Different superscript small alphabets denote statistically significant differences (Tukey multiple comparison tests). ǀShowing significant differences among study groups (ANOVA).

assessing the clinical success of different post cementation and core build-up materials, including mechanical longevity and microleakage, are recommended.

Conclusions

The application of adhesive agent with a Monoblock technique using single cementation and core material (Multicore Flow) when polymerized simultaneously exhibited the highest fracture resistance of glass fiber post compared to other cementation techniques.

Conflict of Interest

The authors declare that they have no conflict of interest

Authors' Contribution

Conceptualization, A.A. AlHelal and S.A. AlObaid; Methodology, A.A. AlHelal, and S.A. AlObaid; Software, A.A. AHelal and S.A. AlObaid; Validation, S.A. AlObaid, A.A. AlHelal, and A.A. AlHelal; O.Y. Bakhsh Formal analysis, O.Y. Bakhsh; Investigation, H.N. Alsaiari; O.Y. Bakhsh Resources, H.N. Alsaiari; data curation, H.N. Alsaiari; O.Y. Bakhsh writing—original draft preparation, A.S. AlQahtani, and T.M. AlNassar; writing—review and editing, A.S. AlQahtani; visualization, T.M. AlNassar; supervision, T.M. AlNassar, H.D. Alsayed and H.D. AlSayed; project administration, H.D. Alsayed; funding acquisition, T.M. AlNassar. All authors have read and agreed to the published the version of the manuscript.

Ethical Statement

The study was approved by the Ethical Board of King Saud University.

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