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Original Article

Comparative Analysis of Push-Out Bond Strength Between Prefabricated Solid Glass Fiber Post and Bundled Glass Fiber-Reinforced Resin Post

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CLINICAL SIGNIFICANCE

The Rebilda post GT system, requiring less dentin removal and simpler preparation, provides a comparable bond strength to the Reforpost, making it a preferable choice for minimizing tissue loss and simplifying the procedure.

ABSTRACT

Objectives: The objective of this study was to conduct a comparative analysis of the push-out bond strength between a prefabricated solid glass fiber post and a bundled glass fiber-reinforced resin post at the coronal, middle, and apical thirds.

Materials and Methods: The crowns of twenty extracted human mandibular premolars were removed to obtain the root length of 17 mm. After canal extension and fillings were completed, two groups were prepared from roots randomly: bundled fiber (Rebilda Post GT-RB) and solid fiber (Reforpost-RF). The canal preparation was made for the Reforpost with its own drill. Posts were cemented into root canals with dual-cure resin cement. The roots were embedded in cylindrical acrylic blocks. Six sections were obtained from a root. A push-out test was applied to the post surface by a universal test machine. The debonding value between the post and dentin surface was recorded in Newton and converted to MPa using the formula.

Results: The push-out bond strength values displayed no significant variance among the post systems across all root thirds ($p>0.05$). Nonetheless, a notable distinction was noted between the root regions of RF ($p=0.032$), with the middle third demonstrating higher bond strength values compared to the coronal third. Conversely, for RP, no significant variance was observed between root regions ($p>0.05$).

Conclusion: Rebilda Post GT showed similar results to those of Reforpost in terms of push-out bond strength between post and root canal dentin. It has not been found to have an advantage over solid fiber posts.

1. Introduction

Dental caries, substantial material loss, or the creation of an access cavity for endodontic therapy can lead to substantial loss of tooth structure. Intraradicular posts are utilized to provide support for crown restorations[1] in order to reconstruct endodontically treated teeth with significant coronal destruction and to minimize stress transferred to the tooth.[2] The fragility of pulpless teeth is primarily attributed to the loss of supporting tissues due to various factors. As a result, the risk of fracture significantly increases following endodontic treatment.[3]

Coronal preservation of tooth tissue, selection of posts with elastic properties similar to dentin, and effective post adhesion are critical determinants for the successful clinical outcome of restored endodontically treated teeth.[1] In the restoration of pulpless teeth, custom or prefabricated posts may be employed. Fiber posts, due to their mechanical properties resembling those of natural tooth structure, offer a more uniform distribution of stress within the root, thereby reducing the likelihood of failure. Consequently, they represent a viable alternative[1,2], characterized by favorable aesthetics, cost-effectiveness, and similarity in properties to dentin, particularly in terms of flexural strength and elasticity modulus.[4]

Teeth restored with glass fiber posts demonstrate a lower susceptibility to fracture in comparison to those restored with metal or zirconia posts. This is attributed to the incomplete transfer of forces to the root, and the capacity of polymerized resin cement to reinforce the root.[1,5] However, prefabricated posts may not perfectly conform to root canal preparation, leading to variations in cement thickness.[6,7] The primary reported failure associated with such restorations is loss of retention. The survival rate of posts is significantly influenced by their adaptation to the root canal's anatomy.[8] Challenges arise from the relatively low bond strength achieved during cementation procedures.[9] An inherent limitation of glass fiber posts is their standardization of post diameters, which may result in poor adaptation to the root canal and necessitate additional canal preparation or the use of smaller diameter posts.[10,11]

Reforpost (RF) is a prefabricated post designed as a single-piece, parallel, serrated, and conically shaped glass fiber system with three different thicknesses. It exhibits a modulus of elasticity similar to dentine and presents good retention, facilitating adaptation to the root canal. It is asserted that its reduced removal of tooth tissue in the apical third provides protection to the dentin in this area and diminishes the risk of root fracture. The post's parallel structure facilitates mechanical interlocking with the root canal walls.[12]

The Rebilda Post GT (RB) constitutes a glass fiber reinforced composite post system, encompassing four distinct post sizes distinguished by color codes, each comprising a specific number of posts. The blue-coded posts consist of four 0.8 mm diameter posts, the red-coded posts comprise six posts with a 1 mm diameter, the green-coded posts entail nine 1.2 mm diameter posts, and the black-coded posts encompass twelve 1.4 mm diameter posts. This assembly of slender posts facilitates effortless insertion into various root canal morphologies. The system is designed to reduce the requirement for mechanical preparation of root canals, thus preserving the integrity of the tooth structure and enhancing retention values through increased surface area in restorations.[13]

While several existing studies[14,15] have examined the impact of solid and bundled posts on bond strength, it is crucial to validate these findings through further research. This research project aimed to conduct a comprehensive comparison of the push-out bond strength between a standardized prefabricated glass fiber post and a bundled glass fiber-reinforced resin post. The objective is to assess the bond strength across all root thirds. The null hypotheses (H0) of the study are as follows: 1) Post systems have similar bond strength values, 2) Different root regions have similar bond strength values.

2. Materials and Methods

2.1. Study design

The study was conducted in accordance with the approved protocol by the Yıldırım Beyazıd University Ethics Committee with decision number 2019-235. A total of 20 human mandibular premolar teeth were utilized for the study. The teeth were divided into two groups: one treated with RF and the other with RB (n=10 for each group). The crowns were removed under water cooling, ensuring a root length of 17 mm, and the working length was determined as 16 mm.

Initial access to the canal was established using a #15 K-file and an Endo-Mate TC2 (NSK, Frankfurt, Germany) endodontic motor. The root canals were shaped with a OneShape (MicroMega, Besançon, France) ISO 25 tip and a 6% taper file as per the manufacturer's recommendations. Throughout the shaping process, the canals were irrigated with 1 ml of 2.5% NaOCl using 2 ml injectors with 27-gauge needles. Final irrigation of the root canals was performed using 2 ml of 17% EDTA (pH 7.6, 3 minutes), followed by 2 ml of 2.5% NaOCl (1 minute), and 5 ml of distilled water. The canals were subsequently dried with paper points.

For filling, a 25 tip and 6% taper master gutta-percha cone, along with #20-#25 cones and sealer (AH 26, Dentsply, Sirona, USA) were used. Access cavities were temporarily restored using CavitG (3M ESPE, Seefeld, Germany). The treated teeth were stored at 37°C and 100% humidity for 7 days. Post space was prepared for Reforpost (Angelus, Brazil) using #2 Largo drills, while no mechanical preparation was made for RB (VOCO, Cuxhaven, Germany).

Following post space preparation, the canals were irrigated with 2 ml of 17% EDTA (pH 7.6, 3 minutes), 2 ml of 2.5% NaOCl (1 minute), and 5 ml of distilled water. Paper points were utilized for drying the canals.

The posts were affixed to the root canals using dual cure resin cement (Panavia SA Cement Plus, Kuraray Inc., New York, USA). The resin cement was dispensed from a syringe onto the tube end and then distributed over the canal surfaces using a #40 lentulo. Once the post was inserted into the canal with finger pressure, the cement was cured using a light-curing device (Elipar, 3M ESPE, Seefeld, Germany) for 40 seconds.

The tooth roots were encased in acrylic within round acrylic blocks measuring 20 mm in diameter. Six 1 mm-thick sections, two from each of the coronal, middle, and apical thirds of the root, were obtained using a precision cutting device (Metkon Micracut Precision Cutter, Metkon, Bursa, Turkey) with water cooling.

A universal test device (Lloyd LR10K Plus, Ametek Inc., United Kingdom) was employed to conduct push-out tests at a crosshead speed of 0.5 mm/min. The 1 mm diameter pin was positioned at the center of the force application surface, and the measured bond strength values were recorded in Newton (N) and subsequently converted to megapascal (MPa) units using the formula $MPa = N/A$, where $A = 2\pi rh$, with π being 3.14, r representing the radius of the intraradicular space, and h denoting the disc height.

Table 1. Mean push out bond strengths (MPa) with standard deviations.

Material/Root level	Coronal third	Middle third	Apical third	p-value
RB	4.398±2.120[a]	5.211±3.049[a]	5.273±3.382[a]	0.085[2]
RF	3.802±1.706[a]	6.157±3.395[b]	5.331± 3.701[ab]	**0.032**[2]
p-value	0.479[1]	0.363[1]	0.445[1]	

[1] independent student's t-test, [2] One-way ANOVA Tukey-post hoc test

2.2. Scanning electron microscopy analysis

The failure type of each specimen was determined using a stereomicroscope (Leica S8 APO, Leica Microsystems, Wetzlar, Germany). Adhesive failure was characterized into three categories: cement-dentin adhesion failure, post-cement failure, and mixed-type failure. Cement-dentin adhesion failure refers to the separation of cement from dentin, while post-cement failure involves the separation of cement from the post. Mixed-type failure was defined as the concurrent occurrence of these bond failures. Subsequently, one sample from the coronal in each group underwent scanning electron microscopy (SEM) analysis (FEI Quanta 450 FEG, FEI, Oregon, USA) both before and after the push-out test.

2.3. Statistical analysis

The statistical analysis was conducted using the SPSS 21.00 software (SPSS Inc, Chicago, USA). To validate normality and homogeneity across groups, the Shapiro-Wilk test and Levene's test were performed. Normal distribution and homogeneity were confirmed. When comparing the push-out bond strength values between the coronal, middle, and apical thirds, a one-way ANOVA and Tukey post-hoc test were utilized. For the comparison of push-out bond strength values between different post systems, an independent student's t-test was employed. The significance level was set at $p<0.05$.

3. Results

The push-out bond strength values showed no significant difference between the post systems in all root thirds ($p>0.05$). However, a significant difference was observed between the root regions of RF ($p=0.032$), with the middle third exhibiting higher bond strength values than the coronal third. For RP, no significant difference was found between root regions ($p>0.05$) (Table 1).

Following the bond strength test, the SEM examination revealed inhomogeneous areas in the resin cement (Fig. 1). In the RF group, mixed failure and cement-dentin failures were equally prominent. In contrast, the RB group exhibited mix-type failure as the most common and cement-post interface failures as the least common (Fig. 2).

Samples of one coronal section from both post materials were examined by SEM before and after the push-out test. Unlike the distribution of fine fibers of the RB in the resin cement, the resin cement surrounding the surface of the RF did not exhibit splitting, although surface separations were observed after the push-out bond strength test (Fig. 3).

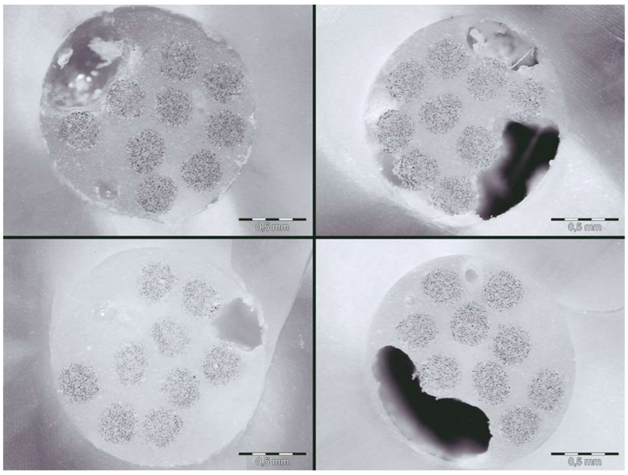

Fig. 1. Inhomogenities in the resin cement.

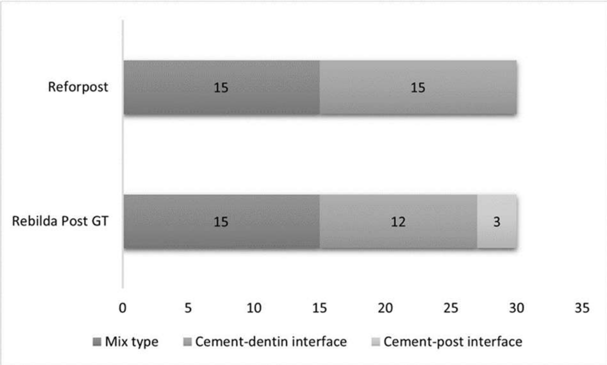

Fig. 2. Failure types of the post specimens. (Failure of dentin adhesion, separation of cement from dentin; failure of post adhesion, separation of cement from post; mixed type failure was evaluated as the coexistence of the mentioned bonds.)

4. Discussion

Solid and bundled post systems are crucial in the restoration of endodontically treated teeth, providing necessary support and stability for subsequent restorative procedures. Solid post systems, often made of metals or carbon fibers, offer high strength and durability but may require more extensive tooth preparation and can sometimes compromise the remaining tooth structure. Bundled post systems, typically composed of fiber-reinforced composites, offer advantages such as better adaptation to the canal morphology, preservation of more tooth structure, and improved aesthetics. They distribute stress more evenly and have a modulus of elasticity similar to dentin, which reduces the risk of root fractures. However, the choice of post system depends on various factors including the extent of tooth damage, aesthetic requirements, and the specific clinical situation.[16-18]

In this study, solid (RF) and bundled (RB) post systems were compared for their bonding ability to the root canal systems. The results indicated that both bundled glass fiber-reinforced resin post (RB) and glass fiber post (RF) demonstrated similar bond strength values, leading to the acceptance of the first null hypothesis. This finding aligns with previous research by Alves et al.[15], which evaluated the bond strength of single prefabricated glass fiber posts and bundled glass fiber-reinforced resin posts in weakened roots. Their results showed that while the individual prefabricated and bundled systems had distinct characteristics, their bond strength values were comparable, supporting the notion that both systems can be effective in clinical applications.

Additionally, a study by Abreu et al.[14] focused on the bond strength of cemented fiber posts in teeth with simulated internal root resorption, further supporting the conclusion that the bonding performance of different fiber post systems can be quite similar under various conditions. They found that both single prefabricated and bundled posts showed adequate bonding strength, suggesting that either system can be chosen based on clinical preference and specific case requirements.

The design of a post can significantly impact its bond strength and retention in the root canal. Research indicates that parallel posts are more conservative in nature compared to tapered and double-tapered posts. In the current study, we utilized a parallel structure serrated post (RF). Surface modifications applied to the post can enhance post retention.[19] Literature suggests that the serrated form of RF enhances the bonding between the resin cement and the post, thereby increasing retention.[20]

The production of prefabricated glass fiber posts adheres to

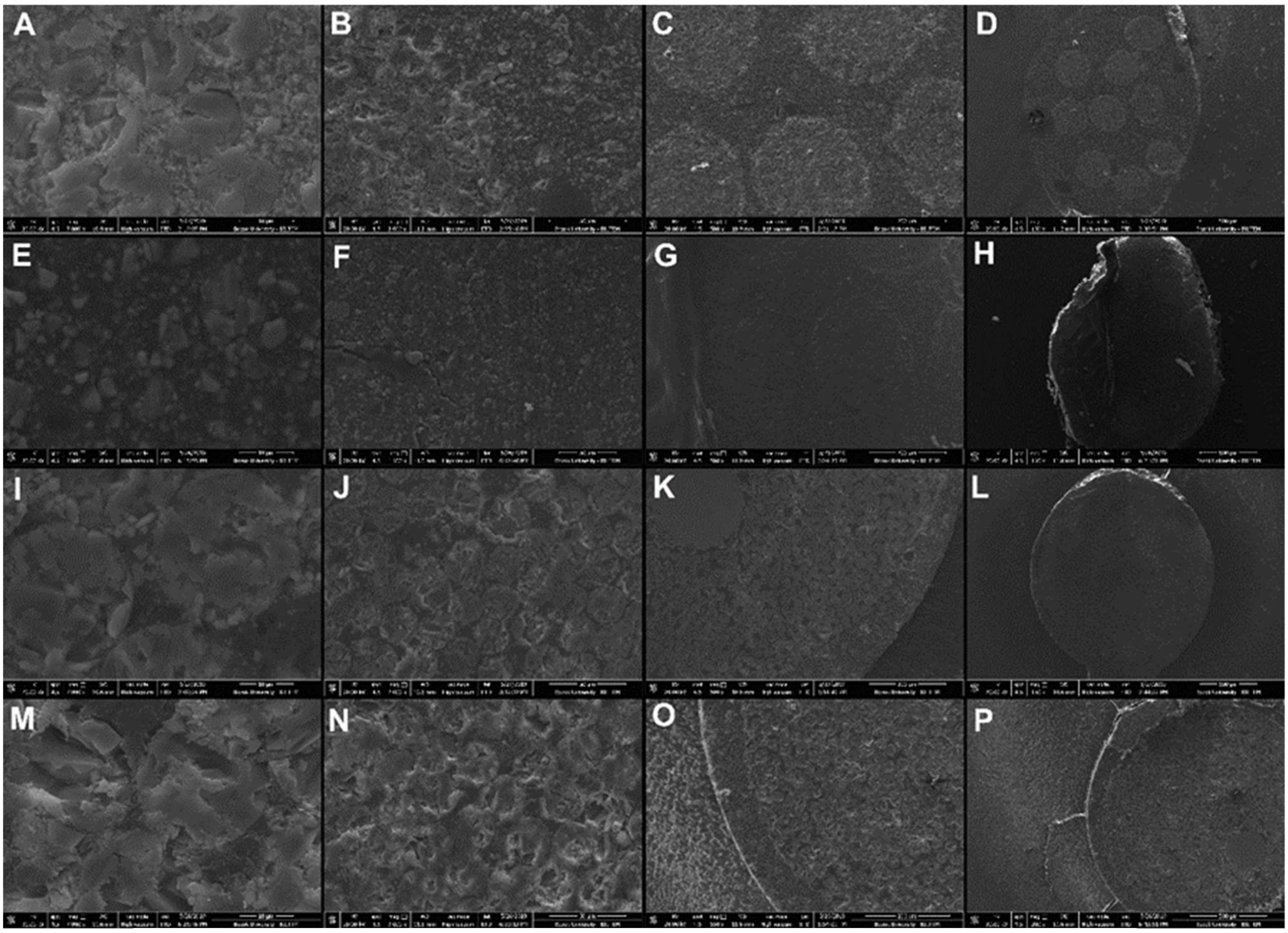

Fig. 3. SEM images of RB (A-H) and RF (I-P) coronal slices before (A-D; I-L) and after (E-H; M-P) push out strength tests.

The production of prefabricated glass fiber posts adheres to specific standards, necessitating adaptation to the root canal through mechanical preparation or selection of the closest post diameter.[10] Cast metal posts are manufactured to conform to the root canal shape using direct or indirect techniques.[21] CAD/CAM milled glass fiber posts demonstrate superior adaptability to root canals compared to prefabricated fiber posts, reducing cement thickness.[22] Glass fiber and cast metal posts produced with CAD/CAM exhibit better bond strength than prefabricated glass fiber posts due to their compatibility with the root canal. The bundled glass fiber-reinforced resin post utilized in our study can be conveniently inserted into the root canal without requiring special post preparation. Post adaptation to the root canal is believed to positively impact bond strength, making the RB bundled fiber post advantageous in root canal compatibility. We compared the push-out bond strengths of RB bundled fiber post and RF solid prefabricated glass fiber post, yielding similar values. Notably, a separate study comparing solid glass fiber posts and bundled glass fiber-reinforced resin posts also produced similar results.[23] However, variations in luting agents, adhesives, and test conditions may influence the attainment of lower bond strength values. Inhomogeneous distribution of the resin cement, as observed in this study, and varying fiber numbers and insertion processes into the root canal could lead to void formation and differing bond strength results. Kharouf et al.[24] reported similar risks of void formation for solid fiber and bundled fiber, contrasting Bitter et al.[23], who indicated that bundled fiber contains more voids than the solid post. Additionally, the presence of six or twelve fiber bundles in the RB post did not significantly affect bond strength, producing comparable values to the solid post.

In the context of post placement, dual cure resin cements are considered a highly reliable option for ensuring thorough polymerization across the entire post area. Although they are capable of polymerizing in the absence of light, their mechanical properties are significantly enhanced when light curing is incorporated. Hence, the usage of light curing in conjunction with dual cure cements is commonly recommended.[1] Studies have indicated that dual cure resin cement can effectively enhance the degree of polymerization, particularly in areas like the apical third where polymerization is challenging due to moisture and contamination. This is attributed to the elimination of the detrimental effects caused by these factors in the apical region.[25] In current research, dual cure resin cement was employed for both posts. Discrepancies may exist in the occupied area between the RB and RF post in the root compared to the canal volume, as well as in the amount of remaining cement between these posts and the dentin surface. Nevertheless, it has been reported that the enlargement of post space and the subsequent increase in cement thickness do not compromise the push-out bond strength of fiber-reinforced composite resin posts to root dentin.[25]

In the present investigation, it was observed that the coronal third of the RF demonstrated significantly lower bond strength compared to the middle third. Conversely, Bitter et al.[23] noted a significantly lower bond strength in the apical third of the RB post. Another study[27] utilizing translucent fiber posts found no statistically significant variations in push-out bond strength values across different thirds. Duarte Santos et al.[27] conducted a study employing two different resin cements and determined that resin cement and root thirds did not significantly impact push-out bond strengths and failure modes. The current research yielded similar bond strength results across various root thirds solely for RB. It is important to note that the moisture present in the apical region under in vivo conditions was not simulated in the present study. The primary limitation lies in the inability of in vitro test conditions to effectively replicate natural conditions.

Research suggests that the quantity of fibers in the composite fiber bundle utilized in this investigation may influence the thickness of the resin cement. Unlike solid posts, where the post is entirely surrounded by a layer of cement, the cement application around bundled fibers is disrupted due to the presence of fibers in the resin cement. Studies have demonstrated that variations in cement thickness can significantly affect bond strength. For instance, a study by Marcos et al.[28] showed that customized posts with a thicker cement layer had higher bond strength compared to posts with thin or very thick cement layers. Similarly, D'Arcangelo et al.[29] found that the highest bond strength was achieved with an intermediate cement thickness, indicating that overly thick or thin cement layers can reduce bond strength.

Moreover, the operator is believed to be a significant factor in the proper placement of the RB post in the root canal. The potential impact of air bubbles, which may form during the insertion of the bundled fiber post, on the fracture strength of the restoration and root, as well as on the stress exerted on the root surface, should be carefully considered. Air bubbles and voids can compromise the mechanical integrity and bond strength, as highlighted by Grandini et al.[30], who observed gaps and bubbles within the cement layer when fiber posts were not properly adapted.

It is suggested that further research would be beneficial in evaluating resin cement thickness, the quantity of fibers within the fiber bundle, stresses on the root surface, and fracture strength. Additionally, comparing the influence of adapting the RB post to the canal on bond strength with CAD-CAM milled fiber posts and cast posts is crucial to determine the efficacy of chairside application. Studies by Farid et al.[31] have shown that increasing cement thickness can reduce bond strength with self-adhesive cements, while self-etch adhesives are less affected.

5. Conclusion

The bundled fiber post demonstrated comparable push-out bond strength to the solid fiber post across all thirds of the root. It was observed that the bundled fiber post did not present an advantage over the solid fiber post in this regard. However, the parallel form of the RF post necessitates more extensive root canal preparation to achieve a parallel form within the root canal space. Conversely, RB post only requires the removal of the root canal filling material for intracanal placement. Furthermore, the insertion of an RF post into the root canal results in greater tissue loss compared to the placement of an RB post. Both systems exhibited similar push-out bond strength to the root canal walls. Consequently, the RB post offers an advantage over the RF post as it requires no dentin removal from the root canal walls.

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Conflict of Interest

The authors declare that no conflict of interest is available

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