Original Article

Comparative evaluation of push-out bond strength of single and multiple fiber-reinforced posts cemented with dual-cure resin cement using different adhesive strategies: An *in vitro* study

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ABSTRACT

Aims: The aim of the present study was to evaluate and compare the push-out bond strength of single and multiple fiber-reinforced posts cemented with dual-cure resin cement using total-etch and self-etch adhesive systems.

Methods: Sixty single-rooted maxillary permanent incisors were decoronated and endodontically treated. Following post space preparations, the roots were divided into four groups (n = 15); Group 1: single fiber-reinforced composite post with the total-etching agent, Group 2: single fiber-reinforced composite post with the self-etching agent, Group 3: multiple pin posts with the total-etching agent, and Group 4: multiple pin posts with the self-etching agent and then cemented using dual-cure resin cement. The samples were then sectioned to obtain approximately 2-mm disks, and a push-out test was performed. Data obtained were statistically analyzed using analysis of variance, *post hoc* Tukey, and unpaired t-test.

Results: The mean push-out bond strength values showed that Group 3 had significantly higher bond strength as compared to the other groups ($P < 0.05$).

Conclusions: Dentapreg multiple pin posts with total-etching agents resulted in higher push-out bond strength as compared to single fiber-reinforced posts and self-etching agents.

Keywords: Dentapreg multiple pin posts, fiber-reinforced posts, push-out bond strength, self-etch, total-etch

INTRODUCTION

Postendodontic restoration of structurally compromised teeth represents a challenging task for the complete success of endodontic treatment. Thus, the restoration of an endodontically treated tooth before prosthetic therapy is of utmost importance, especially when the remaining coronal tooth structure is inadequate to provide both resistance and retention form.[1] Hence, in the last few years, with a plethora of newer materials and advanced technologies, fiber-reinforced composite posts are being used lately.[2]

Clinical studies have reported a success rate of 95%–99% for teeth restored with Fiber reinforced composite

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(FRC) posts.[3] These posts have attracted attention due to their esthetic enhancement, dentin-like physical properties, and better biomechanical performance. However, when the treated root canal cavity is large and irregular, these posts cannot exactly complement the tapered shape of the root canal cavity and hence large amount of cement is required to fill the space between the post and residual dentin. This could lead to inhomogeneities between the post and residual dentin.[4]

Several methods were introduced to overcome these drawbacks. These included canal reinforcement with composite resins, accessory fiber posts, woven bondable fibers, and constructing direct or indirect anatomic fiber posts.[5] Recently, a multiple pin post approach is introduced to enhance the adaptation of posts to the root canal.

Dentapreg® (Dentapreg; ADM, Brno, Czech Republic) has introduced completely new, minimally invasive, fast, and risk-free pin posts for the reconstruction of teeth after endodontic treatment. The pins are flexible and can anatomically conform to the curvature of the root without the need for additional instrumentation. The concept of flexible pins respects the original biomechanics of the tooth and consequently avoids the risk of root fracture.[6]

The use of adhesive systems along with FRC posts offers new prospects for the restoration of endodontically treated teeth. Both FRC and pin posts are compatible with Bis-GMA bonding techniques, allowing chemical and micromechanical bonding to the root dentin that leads to a more uniform stress distribution than metal posts.[5] However, the most frequent cause of failure in FRC posts is adhesive or cohesive debonding, which occurs primarily at the cementodentinal interface.[7] Hence, the selection of appropriate dental adhesive and luting procedures is important.

Recently, dental adhesives use one of two strategies, i.e., the total-etching technique or the self-etch technique. In total-etching techniques, it is well known that a wet-bonding technique is essential for achieving optimal bond strength. However, control of surface wetness is difficult to achieve in the deep and narrow post space within a root canal. Hence, self-etching techniques can be used, as they can be applied to both wet and dry dentin.[8] However, the infiltrating efficiency of self-etch systems at the thick smear layer on the post space dentin still remains a concern. According to Martinho (2014), in a self-etch adhesive system, primary acidic material is ineffective in demineralizing radicular dentin; consequently, affecting the bond strength between the radicular dentin and fiber posts.[9]

Based on these considerations, the purpose of this research was to investigate the push-out bond strengths of single fiber-reinforced posts and multiple fiber-reinforced pin posts cemented using dual-cure resin cement along with two different adhesive systems. The null hypothesis tested was that the push-out bond strengths would be unaffected by the type of posts and adhesive systems.

MATERIALS AND METHODS

Sixty single-rooted human maxillary incisors with fully developed apices, extracted for periodontal and orthodontic purposes were the inclusion criteria for the study. Moreover, teeth with the presence of caries, root cracks, and previous endodontic treatments were not selected for the study. Later, the teeth were cleaned of any soft tissues with ultrasonics and kept in 3% sodium hypochlorite (NaOCl) (Prime Dental Products Pvt Ltd., Mumbai, India) for 2 h for surface disinfection and then stored in normal saline (Swaroop Pharmaceuticals Pvt Ltd., Uttar Pradesh, India) until further use.

Sample preparation

All the teeth were decoronated at a level of 1.5–2.0 mm coronal to the cementoenamel junction with a diamond disk. The pulp tissue was extirpated, and the working length was established 1 mm short of the apical foramen with a size 10 K-file (Mani Inc., Tochigi, Japan). Following the crown-down technique, the root canals were cleaned and shaped using the Universal ProTaper rotary system (Dentsply Maillefer, Ballaigues, Switzerland*)* up to F3 (size 30, 0.09 taper). After each instrumentation, the canals were passively irrigated with 2 ml of 5.25% NaOCl and normal saline, using a 30-gauge side-vented needle for over 1 min. Final irrigation was done with 2 ml of 5.25% NaOCl, followed by normal saline for 1 min, and then 2 mL of 17% ethylenediaminetetraacetic acid (Prime Dental Products Pvt Ltd., Mumbai, India), followed by normal saline for 1 min to facilitate removal of the smear layer. Later, the canals were dried with paper points (Dentsply Maillefer, Ballaigues, Switzerland). The root canals were then obturated using F3 (size 30.,09 taper) gutta-percha cones (Dentsply Maillefer, Ballaigues, Switzerland) along with AH-Plus sealer (Dentsply, De Trey Konstanz, Germany) using a single-cone obturation technique. After the completion of endodontic treatment, root canals were sealed coronally with provisional restorative material, Cavit-G (3M ESPE, Seefeld, Germany), and the teeth were stored in 100% humidity at 37°C for 24 h for the complete setting of sealers.

Post space preparation

The post space preparation was initiated with the sequential use of Peeso Reamers up to size 2. Due care was taken to maintain a minimum of 5-mm gutta-percha obturation in the apical region. The post space was irrigated with normal saline and dried thoroughly with paper points. The roots were now randomly divided into four groups of 15 samples each as follows,

- Group 1: Single-glass fiber-reinforced composite post along with the total-etching agent
- Group 2: Single-glass fiber-reinforced composite post along with the self-etching agent
- Group 3: Multiple-glass fiber pin posts along with the total-etching agent
- Group 4: Multiple-glass fiber pin posts along with the self-etching agent.

In groups, where a single fiber-reinforced composite post (Selfpost, Medicept UK Ltd., UK) and total-etching agent were used, the walls of the post space were acid etched with 37% phosphoric acid (Scotchbond Etchant, 3M ESPE, St. Paul, USA) by introducing it throughout the entire length of the post space by endodontic syringe and endodontic tips for 15 s, water rinsed for 30 s, and gently dried with absorbent paper points. Further Scotchbond Universal Adhesive (3M ESPE, St. Paul, USA) was applied to the post space with a micro brush for 15 s, gently air-dried, and then light cured for 20 s with the tip directed toward the post space opening.[10] Dual-cure adhesive resin cement RelyX Ultimate (3M ESPE, St. Paul, USA) was filled directly into the post space through a premixed syringe, and a single FRC post was seated immediately to its full depth with finger pressure; excess luting cement was removed, and the cement was allowed to autocure for 5 min for chemical curing. Light curing was then performed through the posts as previously described for 30 s. Later, the excess parts of the posts were sectioned through diamond disks, and the samples were sealed with glass ionomer cement coronally (Fuji IX, GC Corp., Tokyo, Japan), and incubated at 37°C for 7 days.

In the self-etching group, the walls of the prepared post space were rinsed thoroughly with water and dried lightly with paper points, without desiccating the dentin. Two consecutive coats of the Scotchbond Universal Adhesive were applied to the post space and light cured for 20 s.[10] Later, the resin cement was filled into the post spaces and the posts were adapted as described previously.

Whereas, in the case of, multiple fiber pin posts (Dentapreg; ADM, Brno, Czech Republic), the total-etching and self-etching criteria were repeated as described earlier. The dual-cure resin cement was filled into the post spaces and then depending upon the width of the post space, the pin posts were placed directly into the post space until its full depth according to the manufacturer's instructions. They were then light cured for 20 s; the excess was sectioned off using diamond disks and sealed.[6]

Push-out bond strength tests

The middle portion of each root was sectioned perpendicular to the long axis of the tooth with a diamond disk to get 2 ± 0.05-mm thick slices. The push-out bond test was performed with a cross-head speed of 1 mm/min under a universal testing machine (Asian Test Equipments, India). Care was taken to center the push-out pin of diameter 1.0 mm on the post surface without causing stress on the post space walls. The load was applied to the apical side of the root slice to avoid resistance to movement of the post due to the post space taper. The peak force that caused extrusion of the post segment from the slice was considered a bond failure and was then recorded in Newton (N). To express bond strength in megapascals (MPa), the value recorded in Newton was divided by the area of the bonded interface. This was calculated as follows: $A = 2\pi rh$ where, "π" is constant (3.14), "r" is the post radius, and "h" is the thickness of the slice.

Statistical analysis

Data were collected and subjected to analysis using the Statistical Package for the Social Sciences Software version 21, (SPSS v11.0, SPSS Corp., IBM, Chicago.). Descriptive statistics for mean force (MPa) were expressed as mean ± standard deviation for each group. Two groups were compared by the unpaired *t*-test and four groups were compared for force by analysis of variance followed by Tukey's *post hoc* test for pairwise comparison. Simple and multiple bar charts were used for graphical representation. *P* value was considered statistically significant when it was <0.05.

RESULTS

The mean push-out bond strengths achieved in each group are tabulated in Table 1. There was a statistically significant difference in mean force among all four groups with $P < 0.05$. Group 3 (0.44595 ± 0.106120) showed the highest bond strength values as compared to Group 1 (0.37876 ± 0.069242), whereas Group 2 (0.22876 ± 0.028894) showed the lowest bond strength values. On comparison with the unpaired *t*-test, it was found that the mean difference for force (MPa) between single post (0.26607 ± 0.061246) and multiple posts (0.41236 ± 0.094762) was 0.146286 which was found to statistically significant. Similarly, the mean difference for force (MPa) between total-etch (0.37467 ± 0.112316) and self-etch (0.30376 ± 0.092259) was 0.070907 which was also statistically significant. These results are tabulated in Table 1, respectively.

Table 1: Comparison of forces among all the groups and Intergroup comparison of forces between the groups

Comparison of force (MPa) between all the four groups by ANOVA			
Groups (*n*=15)	**Force (MPa), mean±SD**		***P***
Group 1	0.37876±0.069242		<0.05*
Group 2	0.22876±0.028894		
Group 3	0.44595±0.106120		
Group 4	0.30338±0.062721		
Intergroup comparison of force (MPa) between single post and multiple pin posts by unpaired *t*-test			
Groups	**Force (MPa), mean±SD**	**Mean difference**	***P***
Single post	0.26607±0.061246	0.146286	<0.05*
Multiple posts	0.41236±0.094762		
Intergroup comparison of force (MPa) between total-etch and self-etching agent by unpaired *t*-test			
Groups	**Force (MPa), mean±SD**	**Mean difference**	***P***
Total-etch	0.37467±0.112316	−0.070907	<0.05*
Self-etch	0.30376±0.092259		

*$P<0.05$=Statistically significant. ANOVA: Analysis of variance, SD: Standard deviation, MPa: Megapascals

DISCUSSION

In the present study, push-out bond strengths of two different post systems using two different adhesive systems were evaluated and compared. The push-out bond strength test was first advocated by Roydhouse.[11] Goracci *et al*. noticed that it is a more reliable method for determining bond strengths, as it results in shear stress that is comparable with the stress under clinical conditions.[12] Therefore, a push-out bond strength test was performed in the present research.

Different authors have recommended different thicknesses of disks for the push-out test. In the present study, the disk thickness was 2 ± 0.5 mm, which was commonly used.[13] Furthermore, to centralize the force advocated during push-out testing and to avoid friction with the dentin wall, the pin diameter of the push-out jig was standardized to 1 mm, which was smaller than the diameter of the post.[14]

Since the introduction of FRC posts, the restoration of a structurally compromised endodontically tooth is no more a challenge. It has been reported, that the glass and polyethylene in FRC posts reinforce the resin restorations, and have an elastic modulus similar to dentin, which causes better bonding, thereby, reinforcing the structurally compromised roots as well.[5] In addition, the light-transmitting capacity of the FRC post has allowed for curing the luting material throughout the length of the tooth, resulting in significantly higher push-out bond strength.[15]

According to the results of the present study, the bond strength was significantly higher in the multiple fiber pin posts compared to a single FRC post. This might be because the multiple fiber pin posts may have promoted better post adaptation by creating a homogeneous unit between the post, dentin, and cement. The multiple pin posts with smaller cross-section areas and similar lengths have more modulus of elasticity compared to a single wide post. The distribution of multiple posts in a larger surface area helps to limit the propagation of cracks by spreading the tensile stress on a wider surface of luting cement or dentin.[16]

Furthermore, an intergroup comparison using an unpaired "*t*" test between single and multiple post systems presented statistically significant results in the present study. These results were in agreement with the findings of Li *et al*. and Fráter *et al*. that multiple FRC posts have a positive effect on structurally compromised roots as compared to single fiber posts.[17,18]

Dentapreg multiple fiber pin posts were used in the present study. Dentapreg pin posts reinforce the tooth structure by creating a monoblock. They are light-cured firm, yet flexible and thin glass-fiber pins, composed of unidirectional glass fiber of S-type, originally developed for the strength requirements of a space shuttle with a diameter of 0.45 mm. They conform to the curvature of the root canal so there is no need for additional instrumentation. These fiber pin posts offer multi-scale retention such as first, macromechanical retention due to the increase in the number of pin posts, and second, micromechanical retention to root dentin due to the use of adhesives agents.[6]

The retention of fiber posts to the root canal wall is most likely to be affected by different adhesive strategies. The Scotchbond Universal Adhesive used in this study functions as both self-etch and total-etch adhesive. The chemistry of Scotchbond Universal Adhesive includes Vitrebond™ Copolymer, MDP, HEMA, and water which allows using the adhesive both with additional phosphoric acid etching in a total-etch approach and as self-etch adhesive, depending on the clinical situation and personal preference.[19]

Self-etch adhesives do not require a separate etching step, as they contain acidic monomers that simultaneously "condition" as well as "prime" the dental substrate, thus demineralization and resin infiltration occur simultaneously.[20] Consequently, this approach has been claimed to be more user-friendly and less technique-sensitive.[21] However, in the present study, self-etch adhesives demonstrated statistically insignificant results as compared to total-etching adhesives. This might be justified due to the inability of self-etching adhesives in infiltrating thick smear layers, such as those produced during post space preparations.[22] It was also reported that the smear layer hybridized by the self-etching adhesive includes a hybrid layer that contains disorganized collagen fibrils that degrade over time, thus resulting in a weak interface between the post space and radicular dentin.[23]

Furthermore, in the present study, an intergroup comparison between total-etching and self-etching adhesives using the unpaired "*t*" test revealed statistically significant results. This might be attributed to the probability that the phosphoric esters in the self-etch adhesives cannot penetrate adequately through the retained partly dissolved smear layer on the root canal walls, resulting in interfacial gaps and lower bond strengths.[12]

Another important phenomenon to be taken into consideration, a high configuration factor, is generated within the post spaces because of rapid shrinkage with reduced flow relief during polymerization of luting cement, leading to numerous interfacial gaps. Thus, the cement used for luting of posts plays an important role. A chemically activated dual-catalyst cement has been proposed to overcome this shrinkage caused due to rapid polymerization.[24] In the present study, RelyX Ultimate was used as a luting cement. According to manufacturers, it ensures results that are uncompromising and guarantees high bond strength and, long-lasting esthetics.

Finally, it should be pointed out that *in vitro* studies have limitations and cannot completely replace clinical trials. Further clinical investigations would contribute toward more promising outcomes.

CONCLUSIONS

Within the limitations of this study, it can be concluded that Dentapreg multiple pin posts were significantly more retentive than single-glass fiber-reinforced composite posts. In addition, it was found that irrespective of the type of glass fiber-reinforced composite post used employing a separate total-etching adhesive was also significantly more retentive than a self-etching adhesive.

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Conflicts of interest

There are no conflicts of interest.

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