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Push-Out Bond Strength of Fiber Posts to Overflared Root Canals in Different Root Regions: Effect of Reinforcement Techniques

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ABSTRACT

Objectives: This study aimed to investigate the effect of different reinforcement techniques on the push-out bond strength of fiber posts to over-flared root canals.

Materials and Methods: Forty-eight extracted human single-canal premolars were endodontically treated, over-flared, and randomly divided into four groups (N=12) including SARC: luting with self-adhesive resin cement, DCC: luting with dual-cure core build-up resin composite, CRR: relining root canal walls with bulk-fill resin composite, and DAP: relining fiber post with bulk-fill resin composite. After 24 hours, the roots were sectioned to obtain three cervical, middle, and apical 3mm slices. The push-out test was performed and failure pattern was examined. Kruskal-Wallis and post-hoc Dunn-Bonferroni tests were used for statistical analysis (P<0.05).

Results: In all three regions, the lowest and highest bond strength was found in the SARC and DAP groups, respectively. In the middle region, there was a statistically significant difference between the bond strength of the SARC group and that of the DCC (P=0.044), CRR (P=0.021), and DAP (P<0.001) groups. There was no significant difference in the apical region. The lowest bond strength was observed in the apical region, and the highest was related to the cervical region. Adhesive failure was the most common failure pattern in all groups.

Conclusion: Based on our results DCC, CRR and DAP methods increased bond strength in the middle and cervical sections of over-flared root regions. Considering that DCC is the easiest and most practical method, we propose that CRR and DAP can be replaced with this method in clinical procedures.

Keywords: Resin Cements; Post and Core Technique; Lightpost; Composite Resins; Dentin-Bonding Agents

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INTRODUCTION

Endodontically treated teeth are often structurally compromised due to extensive caries, fractures, and previous restorations or root canal treatment itself. Post and cores can be used to provide retention of restoration and support of the teeth. Today, fiber posts are widely used due to their similar elasticity modulus to that of dentin. By forming monoblocks, they distribute stresses more evenly and prevent vertical root fractures. The main reason for the failure of fiber post restorations is the debonding of fiber posts due to failure in the cementing stage or throughout the removal of temporary restoration [1].

One reason for debonding is the mismatch between the internal shape of the root canal and the diameter of the fiber post [2,3]. Prefabricated fiber posts are round in cross-section and do not adequately match the oval or overflared root canals caused by the caries progression, trauma, internal root resorption, or iatrogenic injuries. In such cases that the posts do not adapt well [4], the cement layer may become too thick, and more bubbles and defects are created inside it [5]. One method to overcome this problem is to anatomically shape prefabricated fiber posts with resin composite directly or indirectly [6]. In addition to increasing post adaptation to the root canal, this technique reduces the thickness of the resin cement and improves its mechanical properties and retention [7]. Increasing the fiber post adaptation to the root canal walls also enhances the bond strength [8-12]. Another method to reduce the thickness of cement is to reduce the inner diameter of the overflared root canal by reinforcing the walls using resin composite before luting the prefabricated fiber posts [13-16]. Some studies showed that using bulk-fill resin composites for this purpose increases the bond strength [13,14].

We introduce a one-step method for reinforcing attenuated walls in overflared root canals and simultaneous luting of fiber posts using dual cure core build-up resin composite material and compares its push-out bond strength with previous techniques. In this method the dual-cure core build-up flowable resin composite is placed inside the root canal, the salinized fiber post is placed immediately inside the canal and light cured. This method is simpler and more practical due to its one-step design and use of dual-cure resin composite. Therefore, this study examined the validity of the following two hypotheses: 1- the push-out bond strength of fiber posts is not significantly different in various reinforcement techniques and 2- the push-out bond strength of fiber posts is not significantly different in different parts of the root canal.

MATERIALS AND METHODS

The protocol of this study was approved by the ethics committee of Tabriz University of Medical Sciences (R.TBZMED.REC.1398.1198). Forty-eight single canal premolars with healthy roots extracted due to periodontal reasons were collected. They were cleaned of visible particles with a wet gauze and were kept in 0.5% chloramine T solution (Merck, New York, USA) up to 3 months until use [17]. After cleaning the root surfaces and removing the crowns, the length and morphology of the root canals were determined by preapical radiography. Teeth with any calcification within the root canals, severely curved roots, root length outside the range of 14±1mm measured from the cementoenamel junction, and history of previous endodontic treatment or post cementation were excluded from the study. The crown down technique was used to prepare the canal space [18]. The coronal and middle regions of the root canals were enlarged using Gates-Glidden burs (MANI) #2 to #4. Then, the root canals were prepared up to the working length using K-files (MANI Tochigi, Japan) #15 to #40 and a master apical file #30 [10]. In all preparation steps, 0.9% normal saline was used for irrigation [7]. The prepared canals were finally obturated with the lateral technique by gutta-percha (Ariadent, Tehran, Iran) and AH26 sealer (Dentsply, Konstanz, Germany) up to one millimeter of the working length. Periapical radiographic images were taken to ensure the quality of the obturations. The samples were then placed in 100% humidity at 37°C for 72 hours to let the sealer set [10]. In the next step, 10mm of the gutta-percha was removed using No. 3 peeso reamers (Mani, Tochigi, Japan) to prepare the post space so that at least 4mm of gutta-percha remained at the end of the canal. After this step, a short-tapered diamond bur (Diaswiss, Geneva, Switzerland) 2.6mm in diameter was used in a low-speed handpiece to create overflared root canals [14]. The teeth were then randomly divided into four groups (Table 1).

After24 hours and keeping the samples at 100% humidity (Eppendrof tubes with gauze soaked in distilled water) [7], the roots were cut perpendicular to the longitudinal axis of the tooth using a microtome (Fanavaranpars, Tehran, Iran) under water cooling. Three 3mm slices were obtained from each root. Measurements were conducted by a digital

Table 1. Experimental groups and mode of application (N=12)

Group	Application steps
SARC (control)	All Bond universal adhesive was applied to the root canal, solvent was evaporated by air syringe, fiber post was salinized using silane coupling agent and luted with GC Link Ace self-adhesive resin cement, light curing was carried out for 30 seconds
DCC	All Bond universal adhesive was applied to the root canal, solvent was evaporated by air syringe, Luxa-core Z flowable Dual-cure composite resin was placed inside the root canal, light curing was carried out for 30 seconds
CRR	All Bond universal adhesive was applied to the root canal, solvent was evaporated by air syringe, Opus bulk-fill composite resin was placed inside the root canal, fiber post lubricated with a water-soluble gel, Light curing was performed for 60 seconds
DAP	A water-soluble gel was used as inside the root canal, fiber post was silanized using silane coupling agent, A layer of Opus bulk-fill resin composite was placed on it, post-composite resin set was removed, curing was completed for 20 seconds, All Bond universal adhesive was applied to the root canal, solvent was evaporated by air syringe, fiber post was cemented with GC Link Ace self-adhesive resin cement

caliper The maximum force at failure (N) and the bonding surface area (A) were calculated as:

$$A=2r\pi\times h$$

Where, π=3.14, r was the radius of the fiber post and h was the section thickness in millimeters. Bond strength (MPA) was calculated by dividing force by the surface area (A).

Failure pattern analysis

A Nikon stereomicroscope (SMZ1000, Tokyo, Japan) with a magnification of ×40 was used to examine failure patterns, which were divided according to the following classification: 1. cohesive in tooth or post; 2. mixed (combination of cohesive and any type of adhesive failure); 3. adhesive between cement and dentin; 4. adhesive between cement and fiber post; 5. adhesive between composite and fiber post; 6. adhesive between composite and dentin; and 7. adhesive between composite and cement [19].

Statistical Analysis

Normality of data distribution was tested with Shapiro-Wilk test. Non-parametric Kruskal-Wallis test and a post-hoc Dunn-Bonferroni test were used for statistical analysis. Descriptive statistics were used to describe qualitative findings of the failure pattern. Significance level was set at P<0.05.

RESULTS

The results of the Shapiro-Wilk test showed that the assumption of normality was not valid for the bond strength data (P<0.05).

Table 2 shows the descriptive statistics for bond strength in the three root regions among the four study groups with the Kruskal-Wallis test.

Further analysis with Dunn-Bonferroni test showed a statistically significant difference between the bond strength of the SARC group with CRR (P=0.009) and DAP groups (P=0.007) in the cervical region. The paired comparisons of the other groups were not statistically significant (P>0.05). Also, in the middle region, there was a statistically significant difference between the bond strength of the SARC group with DCC (P=0.04), CRR (P=0.02), and DAP groups (P<0.001). The paired comparisons of other groups were not statistically significant (P>0.05).

Table 2. Descriptive statistics of bond strength in the study groups based on root region

Groups	**Root Region**		
	Cervical	**Middle**	**Apical**
SARC	59.73 ± 45.06^{A}	28.83 ± 27.62^{A}	37.68 ± 19.11^{A}
DCC	114.68 ± 83.65^{C}	91.54 ± 46.98^{B}	44.54 ± 17.36^{A}
CRR	143.28 ± 60.24^{BC}	96.91 ± 45.51^{B}	36.09 ± 14.5^{A}
DAP	165.77 ± 106.15^{BC}	168.78 ± 75.39^{B}	61.75 ± 57.83^{A}
	P=0.01	**P<0.001**	**P=0.57**

* Different letters indicate statistically significant differences

Table 3 shows the descriptive statistics of the bond strength among the three tested groups without considering root regions (Kruskal-Wallis test). The lowest bond strength was found in the apical region, and the highest was related to the cervical region. Figure 1 shows the frequency distribution of failure patterns among the four study groups.

Table 3. Descriptive statistics of the bond strength between three root regions (N=48)

Root Region	Bond strength (Mean+SD)	P
Cervical	120.87±84.8[A]	
Middle	96.51±70.85[A]	<0.001
Apical	40.15±18.32[B]	

SD: standard deviation

*Different letters indicate statistically significant differences

DISCUSSION

The mismatch between the walls of endodontically treated teeth and prefabricated fiber posts can lead to debonding of the fiber posts due to the increased thickness of the cement and the associated polymerization stresses [2,3]. Therefore, one of the primary objectives of the methods employed in this study was to minimize polymerization stress at the cement-dentin and cement-post interfaces. This was achieved in the CRR group by relining the root canal with composite resin and decreasing the canal width. In the DAP group, it was accomplished by relining the fiber posts and reducing the resin cement thickness. In the DCC group, this goal was met by replacing the resin cement with a dual-cure resin composite containing a higher filler content. [20].

In the present study, self-adhesive cements were considered as the control group. They are dual cured resin cements and unlike other resin cements, a separate adhesive bonding agent is not necessary [21]. Self-adhesive resin cements have higher bond strength to dentin than self-etching cements or cements that need pre-etching. This can be due to several reasons including the difference in the number of diluting monomers, higher amount of filler by weight than conventional cements, lack of acid-etching step and less complexity and technical sensitivity [22].

Another factor contributing to the increased bond strength in the DAP technique is the application of high hydraulic pressure to the cement against the canal walls. This pressure improves the contact between the cement, post, and dentin assemblies, leading to better integration. Additionally, it reduces the formation of bubbles in the cement, eliminating potential cracking sites and enhancing the penetration of resin into the demineralized dentin. This results in a more uniform hybrid layer with longer resin tags and more adhesive lateral branches [9,23,24]. Rocha et al. [12] also demonstrated that customizing fiber posts significantly reduces bubble formation in the cement layer.

Bulk-fill composites offer an increased depth of cure due to their enhanced translucency and optimized photoinitiators [25]. These composites exhibit low polymerization shrinkage stress while maintaining good mechanical properties due to their high filler content [15]. Silva et al. [26] investigated the use of bulk-fill and regular composite resin for relining glass fiber posts. Both types of composites increased bond strength, similar to our study, although their results did not show a statistically significant difference between the two types of composite resin. Consequently, they concluded that bulk-fill composite can be a viable alternative to regular composite for the customization of fiber posts.

In the present study, the CRR technique utilized a regular bulk-fill resin composite. Similarly, Chidoski-Filho et al. [14] employed the CRR technique and compared the performance of bulk-fill and conventional resin composites in both flowable and regular forms. Their results indicated that bulk-fill composites, in both forms, exhibited higher bond strength and lower nanoleakage compared to conventional composites. There were no significant differences between the bond strength of flowable and regular forms of bulk-fill resin composites in the cervical and middle regions of the root. Consequently, using bulk-fill resin composite, whether flowable or regular, instead of conventional resin composite, leads to higher bond strengths, consistent with our study's findings. Lins et al. [27] used flowable and regular bulk-fill resin composites instead of

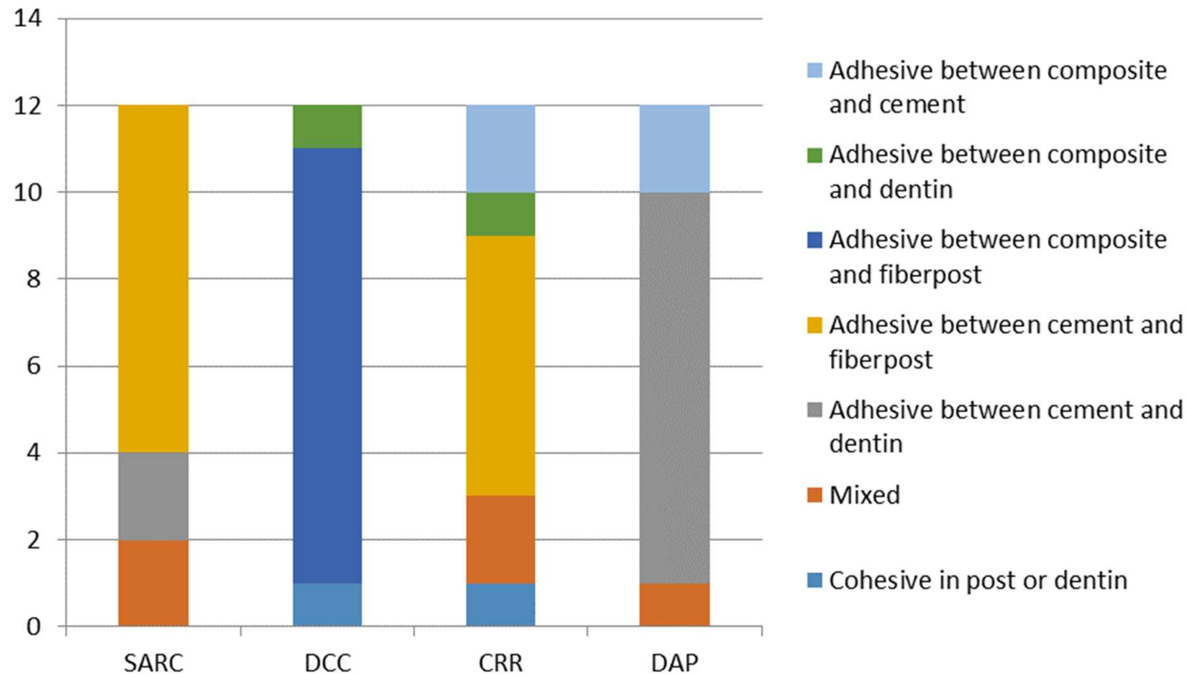

Fig 1. Frequency distribution of fracture patterns

resin cement for luting the fiber posts. They demonstrated that in flowable bulk-fill resin composites, bond strength was similar to DAP in different root regions.

Braz et al. [15] reinforced flared root canals with flowable bulk-fill resin composites but they were uncertain about polymerization of composite in apical regions of the root canal. So, in the present study, in the DCC group, Luxa-core Z flowable dual-cure core build-up resin composite was used for simultaneous reinforcement and cementation of fiber post to overflared root canals. Dual cure core buildup resin composites have been used to achieve the fast setting of light-curing materials, as well as self-cure characteristics in order to compensate for the lack of accessibility of photons for example in the root canal when placing a post [28].

Our results indicated no significant difference in bond strength between DCC, CRR, and DAP groups in any of root regions; hence, we can use any of these methods to achieve the desired bond strength. CRR and DAP techniques have several steps for relining and luting fiber posts, which can be time-consuming and confusing and demand a high level of skill and expertise from the operator. So, they need to be replaced with simpler, more practical, and more effective methods [29,30]. Among these methods, DCC is the easiest and most practical technique. It can be considered an effective and straightforward method that requires minimal chair time, especially in cases with internal root resorption and undercuts inside the root canal.

Evaluation of the bond strength of fiber posts to different root regions is possible with different mechanical tests. In the present study, a push-out bond strength test was used, which is the most common method used in in-vitro studies [31-32]. Bond strength analysis based on different root regions showed that the highest bond strength was related to the cervical and middle areas, which was significantly higher than the bond strength in the apical region. Therefore, the second hypothesis of the study is also rejected, which is consistent with previous studies [33,34].

Apical region is the most undesirable part for hybridization purposes for many reasons including decrease in density and diameter of dentinal tubules from cervical to apical, reduced light penetration, increased light source distance, and decrease in the degree of conversion of resin monomers, difficulty to access and flow of cement in the apical. These are reasons why the lowest strength was seen in the apical area in our study [32,35].

In our study, cohesive failure at the post was rare due to its similar mechanical properties to dentin [36]. The highest failure rates among all four groups were adhesive failures, consistent with previous studies [37,38]. In the SARC and CRR groups, the highest failure rate was adhesive failure between the cement and fiber post. In the DCC group, it was adhesive failure between the composite and fiber post, and in the DAP group, it was adhesive failure between the cement and dentin. Consequently, further studies are necessary to enhance the adhesive bond between these different layers. Due to the diversity in the layers across these four groups, no further comparisons were possible.

Additionally, in this study, following methods from previous laboratory studies, temporary restorations were not used for sealing roots, and no thermal cycling or aging was applied. These factors should be considered when generalizing these results to clinical practice[7,14,15,20].

CONCLUSION

According to the results of this study, the application of different reinforcement techniques increased bond strength compared to using self-adhesive resin cement in the overflared root canal region. Among these techniques, using dual-cure core build-up composite resin to attach the fiber post without relining it proved to be the easiest and most practical method. Therefore, other reinforcement techniques can be replaced with this method in clinical procedures.

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CONFLICT OF INTEREST STATEMENT

None declared.

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