EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org

Vol. 68, 2487:2495, July, 2022

Print ISSN 0070-9484 • Online ISSN 2090-2360

Fixed Prosthodontics and Dental Materials

Submit Date : 19-03-2022 • Accept Date : 31-05-2022 • Available online: 30-06-2022 • DOI : 10.21608/edj.2022.128297.2030

EFFECT OF CAD-CAM AND PREFABRICATED GLASS FIBER POST ADAPTATION ON THE PUSH-OUT BOND STRENGTH TO ROOT CANAL DENTIN

Abdelraheem Mohamed Abdelkader*

ABSTRACT

Objectives: The aim of this study was to evaluate the effect of adaptation of glass fiber post on Push-out bond strength to root canal dentin.

Materials and Methods: Thirty human single-rooted premolar teeth were endodontically treated. The specimens were divided into 3 groups: First group, positive control group n=10 the post space was prepared with the #0.8 drill to receive a #0.8 prefabricated glass fiber post. The second group, Negative control group n=10 post space were prepared to simulate an oversized root canal and then #0.8 prefabricated glass fiber post was used. Third group, CAD-CAM glass fiber post group n=10 Post space was prepared in the same way like negative control group but CAD –CAM post was used. All posts were cemented to their corresponding roots using self adhesive resin cement. All root with the posts were sectioned transversely into 2.0 mm thick slices and the push-out test was done. Results were analyzed by two-way ANOVA followed by a Tukey's post hoc test, p= 0.05.

Results: Push out bond strength was significantly higher in CAD-CAM post group in comparison with Negative control group and positive control group. No significant differences was observed in Push out bond strength between positive control and negative control groups. The bond strength was higher for coronal third than middle and apical third.

Conclusions: CAD-CAM post is an effective treatment for flared root canals. The bonding strength of the coronal third of the root dentin was significantly greater than the middle and apical third.

KEYWORDS: Fiber-reinforced post, Push-out bond strength, CAD-CAM post, self-adhesive resin cement

* Assistant Professor, Fixed Prosthodontics Department, Faculty of Dentistry, Mansoura University

INTRODUCTION

Despite recent advances in dentistry, there are still major challenges in restoring teeth that have undergone root canal treatment. The remaining tooth structure, the supporting tissues condition and the restoration aesthetics all play a role in the effective rehabilitation of teeth that have undergone endodontic treatment. [1]

Root post systems are frequently used to restore teeth that have been endodontically treated and have a weakened dental crown structure. The purpose of the post is to offer retention and strength for prospective prosthetic restorations that will reconstruct the missing coronal tooth structure.[2] Prefabricated or cast metal posts have been frequently utilized for many years. However, in addition to not being aesthetically pleasing, these posts have certain limitation inherent to root fracture because of the metal's greater modulus of elasticity as compared to root dentin. [3]

Because of the limitations of metal posts, researchers and developers have been working to produce new types of post materials having modulus of elasticity and optical qualities comparable to those of tooth structure.[4] prefabricated glass fiber posts have appeared with promising properties, which has an elastic modulus close to root canal dentin, leading to a more homogeneous distribution of masticatory load than metal posts, decreasing the risk of root fracture. Among other advantages of fiber post, superior biocompatibility, easy handling, corrosion resistance, easier removal, good aesthetics and bonding to root canal dentin when used in conjunction with resin cements [5,6]

However, prefabricated fiberglass posts do not always match the shape of the root canal, especially for non-circular or extremely tapered root canals. Thus, the root canal wall should be prepared to match the size of the post. This can make the tooth even weaker and reduce post adaptation to the prepared root canal space which affects the post retention .[7, 8] If adequate adaptation is not present, the resin cement will be thick, which may reduce bond strength because a larger volume of cement causes higher shrinkage stress at the dentin/cement and post/cement contacts, causing more gaps to develop inside the root canal .[9, 10]

Custom post have been introduced to improve the adaptation of fiber post. One of the suggested techniques is the construction of anatomically adapted posts by direct technique, where the shape of the post space is acquired by directly applying composite resin to the fiberglass post, or through indirect technique, where the post is produced in the laboratory. [11,12] Fiberglass post customization allows for greater adaptability to the prepared post space and the creation of thin cement layers, resulting in improved post retention. [13]

Digital dentistry was created to improve workflow precision and speed up the manufacturing process. [4] Today, computer-aided design, computer-aided manufacturing (CAD/CAM) technique enables the construction of a fiberglass post and core in one piece instead of relining prefabricated fiberglass posts with composite resin, reducing the number of interfaces between the fiberglass post and resin cement.[15]

The most common reason for fiber post loss is post debonding or loss of adhesion at the post/resin cement or resin cement/dentin junction. [16,17] As a result, for improved adhesion, tight contact of all components included in the adhesive interface (post / root canal dentin /resin cement) is important, which might increase the clinical outcome of endodontically treated tooth restorations. [18.]

Previous researches on the influence of fiber post adaptation on the bonding strength of prefabricated and customized glass fiber posts have reported conflicting results. Non adapted post has been demonstrated in certain studies to increase the displacing of fiber posts [10-11, 19-20], while other researches have indicated that well-adapted posts have little influence on bond strength.[21, 22] The goal of this research was to evaluate how CAD-CAM and prefabricated glass fiber posts affected the push-out bond strength to root canal dentin.

The hypotheses were

i. The bond strengths of CAD-CAM and prefabricated fiber posts cemented with the same self-adhesive resin cement are significantly different.

ii. There is a significant difference in the bond strength between glass fiber post and different root canal thirds.

MATERIALS AND METHODS

Teeth selection and preparation

The ethics committee of Mansoura University approved this work. For this study, thirty extracted single-rooted human premolars were chosen. The root length was equal or more than 13 mm from root apex to cement-enamel junction. The collected teeth had no caries, root cracks, or severe root curvature. Ultrasonic scalar was used to remove all the external debris of the collected teeth. Then the collected teeth were kept in distilled water, which was changed each two days.

Under water cooling, all teeth were sectioned at the cement-enamel junction (CEJ) with a low-speed diamond disc to standardize all the specimen lengths to approximately 13 mm and afterword kept in distilled water until the time of use.

Each root working length was determined by inserting a K file #10 (Mani Inc, Japan) into the root canal until the file tip is just visible at the apical foramen, then reducing 1 mm from the recorded length. All the root canal preparations were done by the same operator with rotatory ProTaper NEXT files (Dentsply Maillefer, Ballaigues, Switzerland) till the X4 file. 2.5 % NaOCl and17% Ethylenediamine Tetraacetic Acid (EDTA) (MD-cleanser, Meta Biomed) were used as irrigating solutions. After final rinsing with distilled water the canals were dried with paper points (Coltène / Whaledent, Langenau, Germany) and filled with gutta-percha (Coltène /Whaledent, Langenau, Germany) using the lateral condensation technique and Adseal sealer (Meta Biomed Co, Cheongju, Korea). After obturation was completed, glass ionomer cement (Riva, SDI, Victoria, Australia) was used for restoration of the access cavity. After that, all specimens were kept in an incubator for a week at 37° C with 100% humidity.

Post space preparations and grouping

After storage of specimens for one week, the gutta-percha was cut until a depth of 9 mm using size 2 Gates Glidden Drills (Dentsply, Maillefer, Ballaigues, Swizerland), leaving 4 mm of gutta-percha to maintain the apical seal. The specimen were classified into 3 groups, each with ten teeth;

Group (1) positive control group

Post space was performed with a drill corresponding to the #0.8 post to receive a #0.8 mm (1.35mm coronal and 0.8 mm apical) prefabricated glass fiber post (Easy post; DENTSPLY Mailer, Switzerland), simulating a perfect post adaptation into the root canal.

Group (2) Negative control group

In order to simulate flared root canals, the post spaces were enlarged gradually with peeso reamers (Dentsply, Maillefer, Ballaigues, Swizerland) size 1–3 to standardize the form and eliminate remaining gutta-percha. After finishing preparation of flared post space, prefabricated fiberglass posts #0.8 were used to simulate an insufficient adaptation of the post into the root canal.

Group (3) CAD-CAM post group

Post space preparation was done like Negative control group but CAD/CAM glass fiber posts (Trilor, Bioloren, Sarrono, Italy) were used.

Fabrication of CAD/CAM glass fiber post

Intraoral scanner Medit i500 scanner (MEDIT corp, Seongbuk-gu, Seoul, Korea) was used to scan the post space. Then the data were transferred from the scanner to the software (exocad GmbH, Darmstadt, Germany). After that, the digitized data was sent to dental CAM software (Ceramill Motion 2) (Amann Girrbach, Koblach, Austria) to mill the CAD CAM glass fiber post and core (Trilor Bioloren, Saronno, VA, Italy). After milling, the CAD CAM posts were inserted in their corresponding canals with no need for modification.

Posts cementation

Before cementation, the post spaces were cleaned with distilled water and dried with paper points. All posts were soaked in 24% H_2O_2 (Luna for Perfumes and Cosmetics, Egypt) for 60 seconds, then water rinsed (30 seconds) and air dried (30 seconds). Each post surface was then covered with silane (Ultradent Silane, Ultradent Products Inc, USA) for 1 minute followed by air drying. All posts were cemented with self-adhesive resin cement (G-CEM LinkAceTM, GC Corp, Tokyo, Japan). Using a paste carrier tip, cement was placed on the post surface and into the root canal space then the post was fixed in position under finger pressure for 5 seconds. Following removal of the extra cement, light-curing was done using a LED-curing unit (HILUX, BENLIOGLU DENAL INC, Ankara, Turkey) for 60 seconds. The specimens were then kept for 24 hours in distilled water at 37° C.

Samples Preparation for Push-out Test

All Samples were inserted in acrylic resin blocks and then under water cooling, transversally sectioned perpendicular to the long axis using a diamond disk IsoMet 4000 microsaw (Buehler USA). The first 1 mm apical to CEJ was cut and discarded (so the length become 12 mm ,4 mm apical gutta-percha and 8mm post), then samples were cut into 2.0 mm thick slices. In this way 4 slices were produced per root. The first slice was used to represent the coronal thirds, the third slice represented the middle thirds, and the forth slice represented the apical thirds.The second slices was not used. Thus, ten specimens were selected per root thirds for each group. A waterproof marker was used to mark the apical side of each slice and its thickness was measured with 0.01 mm precision using a digital caliper (Electronic digital caliper, Minova Co, Japan).

Using a Pin mounted on a universal testing machine (Instron universal testing machine model 3345 England), push out forces were transmitted to each slice in an apical to coronal direction at a crosshead speed of 0.1 mm/minute until dislodgment of the post, Figure (1). The maximum failure load was measured in Newtons (N), and the applied force was divided by the bonded area to be converted to MPa. The formula for calculating the bonded area was: [6, 10, 11]

$$A = \pi (r_1 + r_2)\sqrt{(r_1 + r_2)^2 + h^2}$$

where π was the constant 3.14, r_1 was the radius of cervical post, r_2 was the radius of apical post and h was the slice thickness in millimetres.

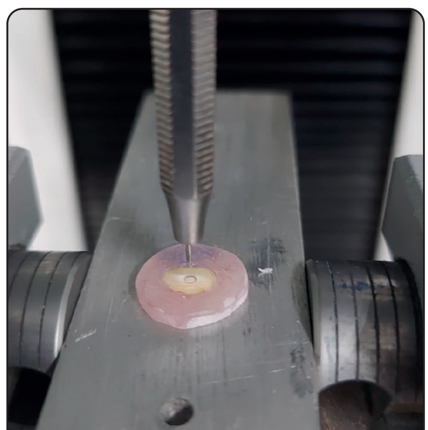

Fig. (1) Push-out test for sectioned specimen positined in universal testing machine

Mode of failure

To analyze the fracture pattern, failed specimens were viewed using a stereomicroscope (Olympus SZ61, Tokyo, Japan) at 20 x magnification. The failure modes were categorized as: 1) Adhesive failure between post and resin cement 2) Adhesive failure between resin cement and root dentin 3) mostly cohesive inside resin cement; 4) mixed.[18]

Statistical analysis

Using IBM SPSS software package version 20.0 (Armonk, NY: IBM Corp), data was loaded into the computer and statistically evaluated. Shapiro Wilk test was performed to confirm the normality of the distribution and Levene's test was used for homogeneity of variances. For descriptive statistics, the data on push-out bond strength were normally distributed and reported as means ± standard deviation. For comparison of data of Push-out bond strength between different groups and different root thirds, a two-way ANOVA was utilized and if significant differences were detected, Tukey's multiple comparisons test was used. The significance of the collected results was considered at a 5% level.

RESULTS

Two-way ANOVA test showed that, there was a significant difference in Push-out bond strength among groups ($p< 0.001$), root thirds ($p<0.001$), and the interaction groups* (root thirds ($p = 0.039$) (Table 1). To compare overall push-out bond strength among groups, a post-hoc test (Table 2) was utilized. The CAD-CAM post group had the highest push-out bond strength, followed by the positive control group, while the negative control group had the lowest. Between the CAD-CAM post group and the other groups, there was a significant difference in push-out bond strength. However, there was no significant difference in Push-out bond strength between negative and positive control groups.

For the effect of the root third, the coronal third had the highest push-out bond strength, followed by the middle third, while the apical third had the lowest. Between every two thirds, there was a significant difference in push-out bond strength. (Table 3) The result showed that there was a significant difference in push-out bond strength across groups for all root thirds. The push-out bond strength of the CAD-CAM post was significantly greater than the positive and negative control groups for all root thirds. (Table 4, Figure 2)

Stereomicroscopic examination of the debonded area revealed two modes of failure: adhesive failure occurs when no resin cement remnants are left on the post surface or root dentin, and mixed failure occurs when resin cement remnants are left on the post or dentin surface. There was no evidence of cohesive breakdown in any of the specimens. In the Negative control and positive control groups, the failures were mostly adhesive, however in the CAD-CAM post group mixed failures were seen, Figure (3).

TABLE (1) Two-way ANOVA of the effect of group, root third, and their interaction on the push-out bond strength

	Type III Sum of Squares	df	Mean Square	F	P-value
Corrected Model	49.475a	2	23.606	10.806	0.002
Intercept	1.732	1	1.732	1.860	0.139
Group	55.510	1	55.510	59.620	<0.0001
Root third	50.910	1	50.910	54.680	<0.0001
Group*Third	17.851	4	17.851	18.302	0.039
Error	26.216	12	0.931		
Total	996.824	15			
Corrected Total	73.428	14			

TABLE (2) Post hoc test (Tukey) comparing all groups

	(J) group	Mean Difference (I-J)	Std. Error	P-value	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
Negative Control	Positive Control	-0.65	0.609	0.2953	-1.8984	0.5984
	CAD CAM POST	2.82	0.777	0.0011*	1.2292	4.4108
Positive Control	Negative Control	0.65	0.609	0.2953	-0.5984	1.8984
	CAD CAM POST	3.47	0.684	<0.0001*	2.0694	4.8706
CAD CAM POST	Positive Control	-2.82	0.777	0.0011*	-4.4108	-1.2292
	Negative Control	-3.47	0.684	<0.0001*	-4.8706	-2.0694

. The mean difference is significant at the .05 level.

TABLE (3) Post hoc test (Tukey) comparing all root thirds

	(J) group	Mean Difference (I-J)	Std. Error	P-value	95% Confidence Interval for Difference [a]	
					Lower Bound	Upper Bound
Coronal	Middle	-1.79	0.761	0.0259*	-3.3482	-0.2318
	Apical	-3.84	0.663	<0.0001*	-5.1983	-2.4817
Middle	Coronal	1.79	0.761	0.0259*	0.2318	3.3482
	Apical	-2.05	0.581	0.0015*	-3.2398	-0.8602
Apical	Coronal	3.84	0.663	<0.0001*	2.4817	5.1983
	Middle	2.05	0.581	0.0015*	0.8602	3.2398

. The mean difference is significant at the .05 level.

TABLE (4) Comparison of push-out bond strength between levels of groups and root thirds

	Coronal	Middle	Apical	P-value	Statistically significant
	X±SD	X±SD	X±SD		
Negative Control	5.63±0.95 A,a	4.5±0.83 A,b	3±0.52 A,c	<.001*	Sig.
Positive control	6.99±1.22 A,a	5.05±1.38 A,a	3.06±0.47 A,b	0.001*	Sig.
CAD CAM POST	10.27±1.12 C,a	7.96±1.11 C,b	5.31±0.63 C,c	<.001*	Sig.
P value	<.001*	<.001*	<.001*		
Statistically significant	Sig.	Sig.	Sig.		

X; mean, SD standard deviation,*p is significant at 5%. In the same column, different capital letters revealed significant differences across groups. The presence of different small letters in the same raw showed significant difference between root thirds. No significant difference between the same letters.

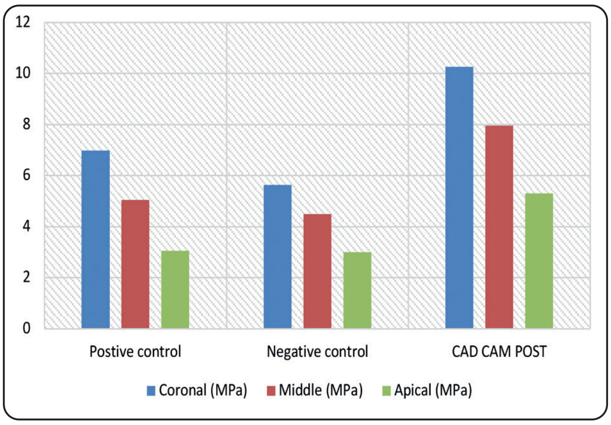

Fig. (2) Comparison of push-out bond strength between root thirds for each group

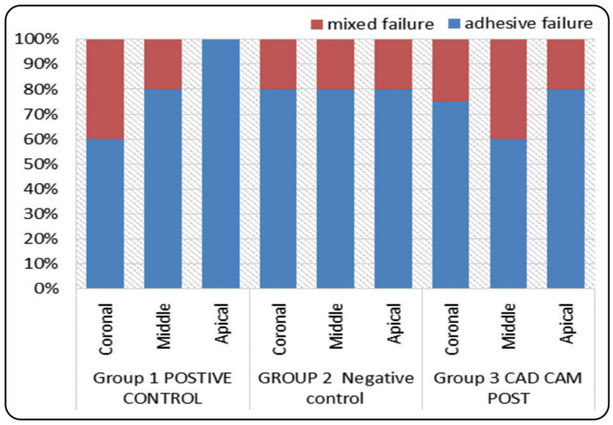

Fig. (3) Mode of failure

DISCUSSION

Various customization strategies to improve post adaption were documented in the literature, such as the use of composite resin to cover a prefabricated fiberglass post. This approach has various advantages, such as the use of currently accessible materials in the dental office, reduced clinical time, no need for specialized technology, such as CAD-CAM, and no need to take impressions. However, this method has the disadvantage of forming an adhesive interface between the glass fiber post and the covering composite resin, which might lead to failure. The customized post in this study was constructed of unidirectional glass fiber that was created using CAD-CAM technology without any extra interfaces, which might favour the stress distribution to the root.[1,11]

The first hypothesis was accepted after it was demonstrated that well-adapted CAD-CAM glass fiber posts had significantly superior bond strength to root canal dentin in comparison to the prefabricated post cemented with the same self-adhesive resin cement. This may be due to the CAD-CAM post group's good adaption, which results in a thin and homogeneous resin cement coating with fewer voids and gaps between the cement and the root dentin.[23] This finding is inconsistent with earlier in vitro studies [6, 8,11,15,24] that investigated the push-out bond strength and found that customization of fiber post by relining or digitalization improved the retention when compared to prefabricated fiber posts.

However, Bakaus et al[25] examined the impact of relining prefabricated posts with composite materials against well-adapted prefabricated fiber posts and found that the well-adapted prefabricated posts had a much greater push-out bond strength to root canal dentine than the relined posts. This decrease in bond strength may be due to poor polymerization of the light-cured resin utilized for relining the prefabricated fiber post.

In terms of enhancing the retention between both the glass fiber post and resin cement, surface treatment of the fiber post by the application of 24% H_2O_2 for 60 sec was used. Earlier research has shown that this method of surface treatment, at this concentration and time, will partly remove the epoxy resin covering of the glass fiber post, uncovering the glass fibers (without harming the post architecture), allowing for silanization and resin cement bonding. [1,26,27]

In the current study, we used a self-adhesive resin cement because of the less clinical time required and also less sensitive technique than traditional resin cements, which required the use of adhesive systems. It also had superior dentin retention due to chemical reactions between both the functional methacrylate phosphoric acid esters and the hydroxyapatite present in the dentin .[24, ,28, 29]

Different methods can be used to evaluate post retention to root dentin. In the current study, we used the push out bond strength, which is among the most acceptable in vitro methods for evaluating retention of the glass fiber post.[30] This methodology has several advantages such as fewer pre-test failures due to sectioning procedures, reduced data inconsistency and creation of homogeneous shear stress at the post-cement interface, imitating stresses associated with clinical conditions.[31]

Regarding root canal regions, the findings of this study revealed a significant difference in bond strength for different root canal regions, with greater bond strength values in the coronal third in comparison to the other thirds. As a result, the second hypothesis has been accepted. These findings are consistent with those of previous investigations.[1,11,13] This is due to increased light curing penetration in the coronal third in comparison to the middle and apical thirds, differences in densities and dentinal tubules orientation toward to the apical third of the root canal and restrictions in the flow of the resin cement toward the apical third of the root canal, which may cause more bubbles and voids in the luting cement.[1]

The analysis of failure modes revealed the presence of adhesive and mixed failure modes for all tested groups. The prefabricated post groups (positive control and negative control groups) had a higher rate of adhesive failure, which confirms the result of push-out bond strength where the lowest bond strength value present in the prefabricated post groups. On the other hand, mixed failure was found more frequently in CAD-CAM post group, which supports the result where the highest bond strength value was present in the CAD-CAM post group.

CONCLUSIONS

Prefabricated glass fiber posts have a lower bonding strength to root canal dentine than CAD-CAM fabricated glass fiber posts.

The various root canal regions influenced the bond strength between fiber post and root canal dentine, which was greater in the coronal third.

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