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Research Article

Evaluation of Bond Strength to Root Canal Dentine for Ready-Made Glass Fiber Post and Custom-Made Composite Resin Post (An *In-vitro* study)

Nofal A[1]*, Elbasty R[2] and Zaki AA[3]

[1]Fixed Prosthodontics Department, Faculty of Dentistry, Cairo University, Cairo, Egypt and A. Lecturer, Fixed Prosthodontics Division, School of Dentistry, Newgiza University, Giza, Egypt

[2]A. Professor, Fixed Prosthodontics Department, Faculty of Dentistry, Cairo University, Cairo, Egypt and Head of Fixed Prosthodontics Division, School of Dentistry, Newgiza University, Giza, Egypt

[3]Professor and Head of Fixed Prosthodontics Department, Faculty of Dentistry, Cairo University, Cairo, Egypt.

***Corresponding Author:** Nofal A, Fixed Prosthodontics Department, Faculty of Dentistry, Cairo University, Cairo, Egypt and A. Lecturer, Fixed Prosthodontics Division, School of Dentistry, Newgiza University, Giza, Egypt.

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Abstract

Aim: The aim of this in-vitro study was to evaluate the bond strength of ready-made glass fiber post and custom-made composite resin posts to root canal dentin.

Methodology: The present study was conducted using 24 extracted human maxillary incisors which were decapitated, root canal treated and prepared to receive a post. Teeth were then divided into 2 equal groups (n = 12): Group (FP) received a ready-made glass fiber post (RelyX Post) and Group (CP) received a custom-made composite resin post. Posts were cemented using self-adhesive resin cement (RelyX U200). Teeth were then mounted in acrylic blocks and sectioned horizontally perpendicular to their long axis to obtain a coronal, middle and apical section from each root. Specimens were then subjected to the push-out test using a universal testing machine at a cross-head speed of 1mm/min.

Results: For both groups, there was no significant difference between the mean push-out bond strength of the coronal, middle and apical sections (Apical > Middle > Coronal). The custom-made composite resin post showed significantly higher mean push-out bond strength than the ready-made glass fiber post in the coronal, middle and apical segments (Apical > Middle > Coronal).

Conclusions: Within the limitations of this in-vitro study, it can be concluded that the technique followed for the fabrication of the custom-made composite resin post might be considered as a promising technique in terms of enhancing the bond strength of the resulted post to the root canal dentine. The composite resin material used for the fabrication of the custom-made composite resin post achieved satisfactory bond strength values to the root canal dentine when combined with the investigated self-adhesive resin cement.

Keywords: Push-Out; Bond Strength; Fiber Post; Resin Cement; Custom-Made Post; Ready-Made Post

Introduction

Badly decayed root canal treated teeth have compromised mechanical properties, few remaining tooth structure, no neurosensory feedback and less proprioceptive response. These qualities make root canal treated teeth at risk of failure during function more than vital healthy teeth. Therefore, proper restoration of such teeth is mandatory to keep relying on them being valuable elements of the dentition.

Materials and Methods

24 freshly extracted maxillary incisors with average root length of 13 mm (± 1 mm) were decapitated 2 mm coronal to the cemento-enamel junction from their mesial aspect. Root faces were then flattened using a high-speed wheel diamond.

Root canal treatment of the teeth

Root canal treatment was done using rotary endodontic files (MPro, Seeddent, China). Obturation was done using the single cone technique and resin sealer (ADSEAL, Meta Biomed Co., Korea). Universal bonding agent (Single Bond Universal Adhesive, 3M, USA) was applied and light cured (Bluephase N, Ivoclar Vivadent, Switzerland) then a small amount of flowable composite (G-aenial Universal Flo, GC, USA) was applied and light cured to establish coronal seal. Teeth were then stored in 0.9% saline solution in a clean glass container and the glass container was stored in an incubator at 37o C for one week to ensure complete setting of the resin sealer.

Post space preparation

Radicular preparation was done using gates glidden (Mani, Italy) for removal of the gutta percha then RelyX fiber post drills (3M, USA) were used in sequential order (size 0-1-2-3) to prepare the post space inside the root canals. All rotary instruments introduced inside the canal were mounted on a low-speed handpiece with internal coolant and were set to a standardized length of 10 mm to ensure at least 3 mm apical seal of gutta percha.

Sample grouping

The samples were numbered from 1 to 24 then randomly and equally divided into 2 groups (n = 12) according to the type of post that will be used; Group (FP) received a ready-made glass fiber post and Group (CP) received a custom-made composite resin post.

For Group (FP) samples

Irrigation of the root canals was done using 3 ml NaOCl (2.5%) followed by 3ml EDTA sol. (17%) with a saline flush in between. Root canals were then dried using paper points and filled with self-adhesive resin cement (Rely X U200, 3M, USA) using the endo tip then a finger spreader size 30 was introduced in the canal with a brushing motion on the canal walls to ensure that no air bubbles are entrapped within the resin cement. The stopper on the post was set to 10 mm and the post was inserted in the root canal until the stopper reached the root face, then 360 o rotation of the post inside the root canal was done to ensure complete wetting of the post with resin cement. Tack curing for 2 seconds was done to remove the excess cement at the root face then full curing was done for 20 seconds. Universal bonding agent was then applied to the root face then light cured for 20 seconds. Flowable composite was then injected around the post and cured for 20 seconds to establish a coronal seal. Teeth were then stored in 0.9% saline solution in a clean glass container and the container was stored in an incubator at 37o C for one week to ensure complete setting of the resin cement.

For Group (CP) samples

The first step in the custom-made composite resin post fabrication was the fabrication of the composite carrier, an empty gutta-percha vial with square cross-section was sprayed on the inside with lubricating oil as a separating medium, then transparent silicone impression material (DENU Trans Sil, HDI, Korea) was extruded inside the empty vial. While the impression material was still soft, a medium sized ready-made fiber post (FiberKleer, Pentron, USA) was inserted in the impression material and centralized within the square cross section of the vial (Figure 1), with its long axis parallel to the long axis of the vial, then the impression material was left to set for 2.5 minutes.

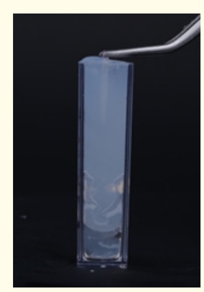

Figure 1: Fiber post inserted into the soft impression material.

After the impression material had set, the ready-made fiber post was removed from the impression and the empty mold was removed from the vial, sliced halfway through the square cross section of the vial using a surgical blade no. 15 with the slice passing through the center of the fiber post mold in a manner that allows stretching the two halves of the mold apart (Figure 2).

The mold was re-inserted in the empty gutta-percha vial, and a posterior composite (CLEARFIL MAJESTY Posterior, Kuraray Noritake Dental Inc., Japan) increment was added to the empty mold

Figure 2: Slice passing through the center of the fiber post mold.

and pushed to the apical end of the mold using a hand endodontic plugger (Figure 3).

Figure 3: Packing of composite inside the transparent mold.

The last step was repeated until the mold was completely packed with composite, and light curing of the composite through the transparent impression material and the transparent gutta-percha vial was done for 20 seconds on each surface of the mold. The mold was then removed from the vial and the cured composite was removed from the mold and checked for voids and flashes. This composite replica of the medium sized fiber post would serve as a carrier (Figure 4).

Figure 4: Finished composite carrier

The second step in the custom-made composite resin post fabrication was the customization of the composite carrier, the root canal was lubricated using KLY gel (Reckitt Benckiser, USA) on a paper point, then the carrier was relined with the same composite and slowly introduced inside the root canal until the apical end of the carrier reached a definite vertical stop. Tack curing was done on the coronal end of the post for 5 seconds then the post was removed from the canal and curing was continued outside the canal for 20 seconds on each surface of the post, the post was then checked for voids and irregularities and checked for fit. The labial surface of the post was marked with a red permanent marker to guide the post insertion inside the root canal during the cementation procedures (Figure 5).

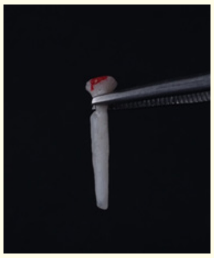

Figure 5: Finished custom-made composite resin post.

Cleaning, irrigation of the root canals and resin cement application were done using the same protocol applied for Group (FP) samples, then the post was inserted slowly inside the root canal to allow excess cement to easily flow out of the canal. Once the post was completely seated, slight taps on the head of the post were done using the handle of a size 5 dental mirror to vibrate the cement line and help get rid of the excess resin cement and the air bubbles at the interface between the post and the canal walls. Light curing, coronal seal and storage of the samples were performed using the same protocol followed for Group (FP) samples.

Sample preparation for the push-out test

Teeth were mounted in acrylic resin blocks using a dental surveyor (BEGO GmbH and Co. KG, Germany) as a paralleling device then samples were sectioned horizontally perpendicular to their long axis using a precision saw (IsoMet 4000, Buehler, USA). Three post/dentine sections: coronal (c), middle (m), and apical (a) of 2 mm thickness each were obtained from each root. Each specimen was marked on its coronal surface with a permanent marker. According to the position of the section, a color was adopted: Red color "Coronal", Blue color "Middle", and Black color "Apical". The thickness of the specimens was confirmed using a digital caliper.

The push-out test

Each specimen was secured in a custom-made loading fixture (push-out jig) after making sure that the coronal surface faced the jig, and the post was centered in the hole of the jig. The push-out test was performed by applying a compressive load to the apical aspect of each slice via a 1.2 mm diameter cylindrical punch (plunger) mounted on a universal testing machine (Instron 3345, INSTRON, USA). The tip was positioned to contact only the post surface, without contacting the surrounding cement or root canal walls. The load was applied apico-coronally (towards the larger part of the root slice) on the apical surface of the slices with a crosshead speed of 1 mm/min until bond failure occurred (Figure 6), as manifested by the extrusion of the post segment from the root.

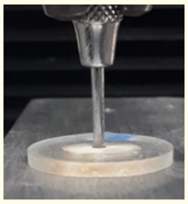

Figure 6: The push-out test.

The maximum load applied before dislodgment of the post from the test specimen (debonding force) was recorded using a computer software in Newton (N), which was considered the point of bond failure, then converted into megapascals (MPa). Statistical analysis was performed using IBM SPSS 20®, Graph Pad Prism® and Microsoft Excel 2016. Data was represented as mean and standard deviation.

Results

Exploration of the given data was performed using Shapiro-Wilk test and Kolmogorov-Smirnov test for normality. It was revealed that no significant difference was noted at P-value > 0.05 which indicates that the concluded data originated from normal distribution (parametric data) resembling normal bell curve.

Intra-group comparison

In both groups, no significant difference was found in the push-out bond strength values between the three root sections as shown in (Table 1 and Figure 7) (P > 0.05, Apical > Middle > Coronal).

Variable		Coronal	Middle	Apical	P Value
Mean ± SD	Group (FP)	18.22 ± 2.72	18.84 ± 5.18	20.45 ± 3.2	0.43
	Group (CP)	20.69 ± 2.91	23.71 ± 6.42	24.32 ± 5.2	0.22

Table 1: Intra-group comparison showing means, standard deviations, and P values of the push-out bond strength (MPa) for both groups.

*: significant (P ≤ 0.05)

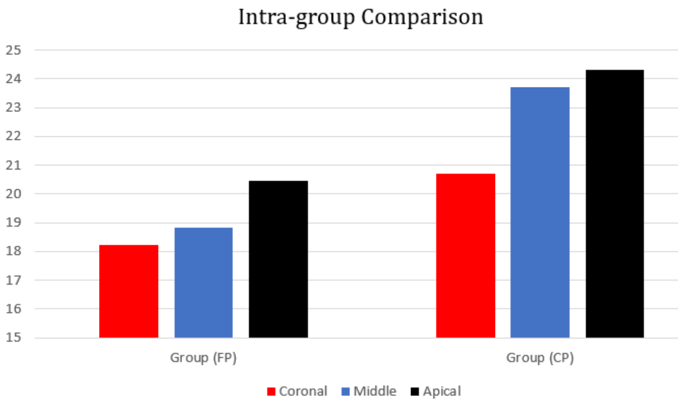

Figure 7: Intra-group comparison of the push-out bond strength (MPa) for both groups.

Inter-group comparison

Comparison between Group FP (ready-made glass fiber post) and Group CP (custom-made composite resin post), regarding the coronal, middle and apical sections, was performed using independent t-test which revealed that the push-out bond strength for Group CP was significantly higher (P ≤ 0.05, Apical > Middle > Coronal) than Group FP in all root sections as shown in (Table 2 And Figure 8).

Discussion

It is critical to properly restore endodontically treated teeth as it affects their service life. Endodontically treated teeth are mostly badly broken down due to previous restorations, trauma, decay, and access cavity preparation. This leads to compromised resistance and retention form of such teeth and, consequently, probability of failure during function. Therefore, the use of posts is mostly recommended for endodontically treated teeth [3].

Variable		Coronal	Middle	Apical
Mean ± SD	Group (FP)	18.22 ± 2.72	18.84 ± 5.18	20.45 ± 3.2
	Group (CP)	20.69 ± 2.91	23.71 ± 6.42	24.32 ± 5.2
P Value		0.04*	0.05*	0.037*

Table 2: Inter-group comparison showing means, standard deviations and P values of the push-out bond strength (MPa) for coronal, middle and apical sections.

*: significant (P ≤ 0.05).

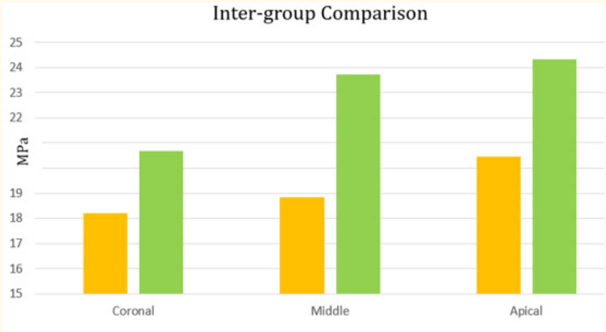

Figure 8: Inter-group comparison of the push-out bond strength (MPa) for the coronal, middle and apical sections.

Failure of systems restored with glass-fiber posts is attributed to the post-cement de-bonding rather than cement-dentine de-bonding or cohesive failure of cement. This can be due to various causes; fiber posts are fabricated from highly cross-linked epoxy resin which hinders its chemical bond with resin cement monomer [1]. Also, there is a strong correlation between the resin cement film thickness and the bond strength of the fiber posts [4], The irregular film thickness and the high c-factor inside of the root canal can lower the bond strengths of posts to resin cements [2].

The intervention in the present study was the novel custom-made composite resin post, which may have several advantages over the ready-made glass fiber post, including superior adaptation to the root canal walls, as a composite carrier was customized inside the root canal, this would yield a uniform minimum cement gap. Also, Better support to the cervical part of the root (the neck of the tooth), as the diameter of the post preparation reaches it maximum at the orifice of the root canal due to the uniform taper of the drill. Lack of adaptation of the post in this area will result in lower fracture resistance of the system and higher cement film thickness, which may lead to debonding as previously discussed. Another advantage is having less interfaces than the silanated ready-made glass fiber post; as the glass fiber post achieves tertiary monoblock through 3 interfaces (post-silane, silane-cement, cement-dentine), on the other hand, the custom-made composite resin post achieves secondary monoblock through 2 interfaces only (post-cement, cement-dentine). Finally, the chairside technique of the custom-made composite resin post may provide the dentist with an economical, easier and less time-consuming alternative to the indirect custom-made post and core, as the resulting post is a single-phase custom-made post that requires only one visit similar to the ready-made glass fiber post.

In other words, the custom-made composite resin post may combine the advantages of both the ready-made glass fiber post and the custom-made post and core. Therefore, the aim of this study was to evaluate the bond strength to root canal dentine for ready-made glass fiber post and custom-made composite resin post.

Root canal treatment was done by the same operator for standardization. Also, Manufacturer instructions were followed for all materials used and investigated in the present study [5]. ADSEAL resin sealer has been used because eugenol containing sealer might alter the polymerization of resin cement and interfere with the adhesive properties of the resin-based cement [6].

Removal of gutta percha and drilling in sequential drill order (0-1-2-3) during the post space preparation were done using a low-speed handpiece with internal coolant mounted on an electric micro-motor with built-in coolant to minimize the heat generation during drilling and prevent the denaturation of the dentine collagen, which may affect the bond strength [7,8].

The size of the fiber post used to fabricate the composite carrier mold was medium sized to have enough space around the carrier inside the root canal for customization with composite resin, since the size of the final drill used for post space preparation is standardized for both groups to be the largest drill of RelyX Post, simulating a clinical situation requiring a custom-made post.

Fabrication of the composite carrier and its customization were done using CLEARFIL MAJESTY™ Posterior. It was the material of choice in this study as it was intentionally created as a posterior filling material, thus its compressive strength is relatively higher than other name brands and, more importantly, its modulus of elasticity is similar to dentine (20-22 GPa). [9]. So, the use of CLEARFIL MAJESTY Posterior in the fabrication of the custom-made composite resin post can help achieve a true monoblock.

NaOCl and EDTA were used as post space irrigants, following the manufacturer's instructions of the self-adhesive resin cement and because using NaOCl and EDTA in succession, with a saline flush between both irrigants, removes the organic part of the smear layer and the inorganic part of the smear layer respectively, thus opening the dentinal tubules which might have been clogged during post space preparation and preparing the dentine for bonding the post using self-adhesive resin cement [5,10].

The combination of Rely-X post and Rely-X U200 was used as a comparator to conduct the present study, as it yielded higher mean push out bond strength compared to glass-fiber posts from other manufactures. [11-13].

A Push-Out (PO) approach has been used to dynamically test the shear bond strength of adhesive-dentine bonds. This method is very useful in testing the adhesion of root canal sealers and retention of posts luted in root canals. The PO test is based on generating shear stress at the interface between dentine and cement, as well as between post and cement [14].

In the light of the push-out test results, the null hypothesis of this study (*i.e.*, The bond strength of the custom-made composite resin post to root canal dentin would be equal to that of the ready-made glass fiber post) was rejected.

The results of the push-out test revealed that for the ready-made glass fiber post group, no significant difference was found between coronal, middle and apical root thirds, mean values respectively are (18.22, 18.84, 20.45). The same was found for the custom-made composite resin post group, mean values were (20.69, 23.71, 24.32) for the coronal, middle and apical root thirds respectively.

This was in agreement with Elkhodary and Elbasty [5]. On the other hand, the results were in contrast with Elbanna., *et al.* [15] who explored the push-out bond strength of oval posts in oval canals. This may be due to the fact that Elbanna., *et al*. used premolar teeth with oval canals for the push out test while in the present study, maxillary incisors with circular canal cross section were used.

The push-out test results for the coronal, middle and apical segments were significantly higher for the custom-made composite resin post group than for the ready-made glass fiber post group. Mean values were 18.22 and 20.69 respectively for the coronal third, 18.82 and 23.71 respectively for the middle third and finally, 20.45 and 24.32 respectively for the apical third. The higher mean push-out bond strength of the custom-made composite resin post group may be explained by the fact that the immediately fabricated custom-made composite resin post bond chemically to the self-adhesive resin cement through the residual monomer in the relining composite material [16].

Additionally, the cement gap in the custom-made composite resin post group is minimal compared to the ready-made glass fiber post group, which decreases the polymerization shrinkage stresses and the voids within the cement line and therefore, the higher push-out bond strength values [17].

The results can also be explained by the higher pressure within the resin cement during the bonding of the custom-made composite resin post compared to the conventional glass fiber post, which suppresses water sorption and results in a better contact between the cement/post assembly and the dentine. This was in accordance with Faria-E-Silva [18] and Al-Assar [19]**.** The results can also be attributed to the closer contact of the custom-made composite resin post with dentine, which can promote higher retention forces through higher frictional retention and thus, higher push-out bond strength [20].

In the current study, test specimens were not completely restored, and neither thermal cycling nor mechanical stressing were applied. These factors, according to some studies, may limit the direct application of study results to clinical situations, however, some authors [19,21-23] found no significant difference between the push-out bond strength of fiber posts before and after thermocycling and mechanical stressing.

Conclusion

Within the limitations of this in-vitro study, the following can be concluded

- The technique followed for the fabrication of the custom-made composite resin post might be considered as a promising technique in terms of enhancing the bond strength of the resulted post to the root canal dentine.
- The composite resin material used for the fabrication of the custom-made composite resin post achieved satisfactory bond strength values to the root canal dentine when combined with the investigated self-adhesive resin cement.

Conflict of Interest

The authors have no conflict of interest to disclose.

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