ORIGINAL RESEARCH

Effect of Different Resin Cements on the Bond Strength of Custom-made Reinforced Glass Fiber Posts—A Push-out Study

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Abstract

Aim and objective: This study aims to evaluate the effect of different resin cements on the bond strength (BS) of custom-made glass fiber posts (GFPs) using the push-out test.

Materials and methods: Twenty-four uniradicular bovine teeth were selected. The crowns were sectioned at the cementoenamel junction, and the root canals were treated. The post spaces of the teeth were prepared to a length of 12 mm to receive a GFP. The specimens were randomly assigned to three experimental groups ($n = 8$), according to the resin cement used to fix the GFPs: RelyX U200 (U200), Allcem Core (ACC), and Allcem Dual (ACD). Each specimen was sectioned into six slices per root third (cervical, middle, and apical), which were subjected to the push-out test. BS values were calculated and compared using the Kruskal–Wallis and Friedman tests.

Results: There were significant differences in the middle third, according to the resin cement type used ($p < 0.05$). ACD showed lower BS values ($p < 0.05$). Significant differences were observed for ACD among the thirds of the slices, with the lowest values also observed for the middle third ($p < 0.05$).

Conclusion: The present study shows that ACC and U200 showed higher BS values compared with ACD, and were also less influenced by the depth of the root dentin.

Clinical significance: The restoration of endodontically treated teeth is a challenge in dentistry, and, in most cases, will require installation of fiberglass pins. In this respect, several types of resin cements are indicated for cementation of these pins; for this reason, their adhesiveness must be adequately investigated. Conventional cements and self-adhesive cements have shown satisfactory performance in cementing the custom-made GFPs, thereby making these cements satisfactory clinical choices. The present study suggests that ACD had lower performance than the other two cements evaluated.

Keywords: Bond strength, Endodontically treated teeth, Glass fiber post, Push-out, Resin cements.

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Introduction

The prosthetic rehabilitation of endodontically treated teeth is considered a challenge due to the considerable loss of dentinal structure involved. Root fractures in these teeth have been a cause of recent concern in dentistry since they compromise treatment prognosis.[1,2] A root fracture can be defined as an unpleasant and devastating clinical event and has been identified as one of the main reasons for tooth loss.[3,4] Over the years, several restorative materials have been developed with minimal flaws to rehabilitate fractured teeth. The primary goal of these materials is to retain the restorative material or prosthetic rehabilitation; for this reason, their adhesive properties are important to guarantee success and improve the longevity of the treatment.[3-5]

Glass fiber posts (GFPs) are usually recommended to restore endodontically treated teeth. They are easy to use and reduce the risk of root fracture because they have an elasticity module, similar to that of dentin.[5-8] Furthermore, GFPs adhere to dentin, allowing an adequate amount of dentin to be conserved in post space preparation.[1] Custom-made fiber-reinforced (CMFR) posts can be reinforced with a composite resin, and are indicated to reconstruct teeth with extensive coronary losses and excessively enlarged iatrogenically conical or elliptical canals.[9,10] These CMFR posts facilitate adaptation and, consequently, mechanical retention. This helps reduce both the volume of the needed resin cement and the resultant stress on the adhesive interface during polymerization contraction.[11,12]

Regarding cementation, several adhesive cementation techniques have been proposed, and a wide-ranging variety of resin cements are indicated for the post fixation procedure.[13-15] Thus, the type of adhesive system used to fix GFPs can also influence the success of restorations with the posts. Self-adhesive cements were recently launched to overcome some of the limitations of conventional and self-etching resin cements. Self-adhesive cements

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do not require any pretreatment of the dental substrate; they are applied in a single clinical step.[15] However, only a few studies have been conducted on this issue, in comparison with many studies on conventional cements.

In this respect, the present study aims to evaluate the effect of different resin cements—two conventional and one self-adhesive type—on the bond strength (BS) of reinforced GFPs, by using the push-out test.

Materials and Methods

The study protocol was approved by the institutional ethics board (protocol #0289). The teeth were donated by the Tooth Biobank of the State University of Montes Claros, Montes Claros, MG. Twenty-four lower uniradicular bovine teeth were selected. Digital radiographs (DRs) were obtained. Teeth with internal resorption, open apex, excessive curvature, calcifications, and pathologies were excluded. The samples were stored in a 0.1% thymol solution in an incubator at 37°C and 100% relative humidity.

Standardization and Sample Preparation

All the teeth were standardized at a length of 17 mm. The crowns were sectioned at the cementoenamel junction, using Isomet 1000 precise cutting machine (Buehler, Lake Forest, Illinois, USA), under abundant refrigeration. Afterward, the root canals were shaped using the ProTaper rotatory system (Dentsply, Ballaigues, Swiss). Then, apical patency and the length of root canal patency were obtained with a #15 K-file. The working length was established at 1 mm beyond the root apex, confirmed using DRs. The teeth were shaped with manual and rotatory files, and copiously irrigated with 5.25% sodium hypochlorite solution, and the final irrigation was carried out with 5 mL of saline solution. Afterward, the canals were dried with absorbent paper points (Dentsply, Petropólis, Brazil).

The root canals were filled using gutta-percha cones R50 (VDW, Munich, Germany) and AHPlus (Dentsply, Ballaigues, Swiss), epoxy resin-based root canal sealers, by the lateral condensation technique. The specimens were kept in an incubator at a constant temperature of 37°C for 7 days. Subsequently, the roots were prepared with a 12-mm deep canal space for pin insertion, using a diamond instrument (H250 033, HORICO, Berlin, Germany) with a water coolant. This procedure initially used #2 broad drill (Dentsply, Ballaigues, Swiss), followed by #3 broad drill and, lastly, #2 Whitepost drill (FGM, Joinville, Brazil), at low speed, thus allowing the remaining 5 mm of the gutta-percha to stay in the apical third.

Next, a space was created for a 9-mm long irregularly shaped core, using a 720F handpiece drill (KG Sorensen, São Paulo, Brazil), to simulate excessive dentine wear, similarly in all specimens. This preparation was further refined with a 720G drill (KG Sorensen, São Paulo, Brazil). The root was constantly irrigated with water during these procedures.

Glass Fiber Post Cementation

The # 2 white fiberglass post (FGM, Joinville, Brazil) was selected with the following characteristics: tapered, cervical diameter of 1.8 mm, apical diameter of 1.05 mm, total length of 20 mm, translucent, and radiopaque. First, the fiber post was cleaned with gauze smears dipped in 70% alcohol, according to the manufacturer's guidelines. Then, 37% phosphoric acid (FGM, Joinville, Brazil) was applied for 1 minute to the pin and was then washed off for the same amount of time. After application and cleaning of the post with the acid, a silane layer of Prosil (FGM, Joinville, Brazil) was applied on the entire surface of the post with a disposable brush (Cavibrush, FGM, Joinville, Brazil) for 1 minute. Subsequently, the post was subjected to hot-air jets for 1 minute. Then, Ambar APS adhesive (FGM, Joinvile, Brazil) was applied with a disposable brush, a drop of liquid was reproduced on the post for 10 seconds, and the adhesive was reapplied for 10 seconds followed by the application of an air jet for 10 seconds. Lastly, the adhesive was photoactivated by light curing (KaVo Dental, Biberach an der RiB, Germany) for 10 seconds. After preparing the fiberglass post, the root canal was lubricated with a water-soluble lubricant agent (KY, Johnson and Johnson, São Paulo, Brazil) using an extra-fine disposable brush to prepare it for making the CMFR fiber post. To this end, a portion of Vittra APS composite resin, color EA1 (FGM, Joinville, Brazil) was applied in a single increment to the surface of the fiberglass post. A fine layer of Vittra APS composite resin was also placed at the entrance of the canal, and the post/resin set was taken to the canal and photoactivated for 10 seconds as prepolymerization. Then, the prefabricated GFP/resin set was removed from the canal to be photoactivated again on each of its surfaces (buccal, lingual, mesial, and distal) for 20 seconds, thus producing the CMFR post. The water-soluble gel was removed by irrigating the post with water followed by aspiration with an endodontic cannula, and drying with absorbent paper points (Dentsply, Petropólis, Brazil).

The CMFR GFPs were divided into three groups to be cemented according to the resin cement used: RelyX U200 (3M ESPE, St. Paul, USA), Allcem Dual (FGM, Joinville, Brazil), and Allcem Core (FGM, Joinville, Brazil).

Cementing of GFP with RelyX U200 Self-adhesive Cement

The first procedure was to clean the GFP with gauze dipped in 70% alcohol. Afterward, a layer of silane was applied to the entire surface of the post for 1 minute followed by drying with hot air for 1 minute. Then, the resin cement was manipulated, applied to the fiberglass post, and inserted into the conduit with a long, thin metal Centrix tip (DFL, Taquara, Rio de Janeiro, Brazil). The post was then placed inside the conduit, and the excess cement was removed with a disposable brush to prepare for subsequent photoactivation, lasting 40 seconds, according to the manufacturer's instructions.

Cementing of the GFP with Allcem Core and Allcem Dual Cements

The fiber post was cleaned with gauze dipped in 70% alcohol, and then air-dried. Afterward, a layer of silane was applied for 1 minute over the entire surface of the post and dried with hot-air jets for 1 minute.

After these procedures, Ambar APS adhesive was applied by rubbing a drop of the liquid on the post with a disposable brush for 10 seconds. Then, the adhesive was reapplied for 10 seconds, and air jets were applied for 10 seconds. Photoactivation was performed by light curing (KaVo Dental, Biberach an der RiB, Germany) for 10 seconds. Once the chemical preparation of the fiberglass post was completed, the preparation of the root canal began. The post was acid-conditioned with 37% phosphoric acid (FGM, Joinville, Brazil) for 15 seconds followed by washing with abundant water for 1 minute and drying with absorbent paper tips. Then, Ambar APS adhesive was applied with a disposable brush followed by a new application of the adhesive for 10 seconds, and an air jet for 10 seconds. Lastly, photoactivation was performed by light curing (KaVo Dental, Biberach an der RiB, Germany) for 20 seconds.

The cementation procedures were completed by taking Allcem Dual or Allcem Core cement into the canal, using self-mixing tips. Then, the post was taken to the root canal, and all excess materials were removed with a disposable brush followed by photoactivation for 60 seconds. After cementation, the specimens were stored in a moist environment at 37°C for 7 days before being prepared for mechanical testing.

Push-out Test

The push-out test was conducted as described in previous studies.[12,15] The roots were fixed in acrylic plates and sectioned transversely with a precision saw (IsoMet 1000, Buehler; Lake Bluff, Illinois, USA) to obtain two 1.0-mm-thick slices of each root third. The first slice of each root, 0.5-mm thick, was discarded. Each slice of the specimen was attached to a stainless steel base, which was attached to the bottom of the Instron 2519-106 universal machine (Instron, Norwood, Massachusetts, USA). This base contained a hole of 2.5 mm in diameter in the central region, under which the portion of the slice related to the post was positioned, with its apical portion facing upward. Then, a metal rod attached to the upper portion of the universal machine was placed under the area of root reinforcement. A metallic stem was selected according to the diameter of the root canal filled with the reinforcement (2.5, 2.0, 1.5, and 0.5 mm). The metal rod had to be positioned under the post area. Then, the load cell (2000 N) was activated and the compressive load was balanced. The metal rod was activated with a crosshead speed of 0.5 mm/minute, exerting compressive force in the apex–cervical direction, until the restorative material was displaced. The force required to displace the post was measured in newton (N), and converted into megaPascal (MPa) using a table. The lateral area of the post (AL) was initially calculated to determine BS, using the following formula (Fig. 1), where "*R*" is the largest radius of the post in its coronary portion, "*r*" is the smallest radius of the post in its apical portion, and "*h*" is the thickness of the post/height of the slice. The measurements of "*R*", "*r*", and "*h*" were obtained by visual examination of each slice using a digital caliper. Then, the force needed to displace the restorative material (*F*) was divided by its AL to determine the BS in MPa.

$$A = \pi(R + r)\sqrt{h^2 + (R - r}$$

Fig. 1: Formula for determining bond strength values

Statistical Analysis

Two factors were considered in this experimental push-out study: the cement type used (RelyX U200, Allcem Core, and Allcem Dual) and the slice root thirds (cervical, middle, or apical). Mean values, standard deviations, and median were calculated for each group. The Kruskal–Wallis test was used to compare the BS of the three types of cement in the root thirds. The Friedman's test (nonparametric) was applied to compare the measurements performed in the same sample unit in order to compare third slices. In both cases, Dunn's test was used for multiple comparisons. All statistical analyses were performed using SPSS (IBM® Statistical Package for Social Studies) version 20 (Armonk, New York, USA), at a level of significance of $p > 0.05$.

Results

The results of the Kruskal–Wallis test showed a statistical difference in the BS of different cements when the same root thirds were compared ($p < 0.05$). The three cements presented a similar performance in the apical and cervical thirds, whereas ACD cement presented lower mean values, and lower median values in the middle third, compared with ACC and U200 cements ($p = 0.006$). The Friedman test showed statistical differences among the root thirds in all the cements ($p < 0.05$). In this comparison, U200 and ACC cements performed similarly in the three root thirds. ACD cement showed different means and medians among the thirds, with the middle third presenting lower values than the other two ($p = 0.01$) (Table 1).

Table 1: Values of push-out bond strength (MPa) of three cements in different thirds of intraradicular dentin

	Root third			*"p"*
Cement	*Cervical*	*Middle*	*Apical*	*value**
U200	60.99 ± 21.31 Aa Md = 59.76	77.43 ± 24.12 Aa Md = 70.49	75.00 ± 22.47 Aa Md = 61.12	0.09
ACC	66.17 ± 31.66 Aa Md = 50.25	65.37 ± 16.84 Aa Md = 60.68	95.09 ± 37.43 Aa Md = 90.08	0.08
ACD	73.62 ± 24.96 Aa Md = 60.18	51.48 ± 23.91 Bb Md = 40.66	74.72 ± 25.43 Aa Md = 70.44	0.01
p value#	0.31	0.006	0.13	

p value obtained by the Kruskal–Wallis test for comparison among different cements in the same root third. * *p* value obtained by Friedman's test to compare the performance of the same cement in different root thirds. Different uppercase letters represent statistically different results among the cements (column). Different lowercase letters represent statistically different results among the root thirds for the same cement (line)

Discussion

GFPs have been widely indicated to rehabilitate endodontically treated teeth that have extensive coronary destruction.[1-4] Prefabricated posts are used traditionally, but a more current trend favors CMFR posts because they adapt better to the anatomy of the root canals, especially in broad/flared roots.[2] However, these rehabilitations have failures, the most frequent of which is debonding of a post at the resin cement/dentin interface. Therefore, this study evaluated the BS of two etch-and-rinse prefabricated cements, Allcem Dual and Allcem Core, to the root dentin, and compared them with a self-adhesive resin cement, RelyX U200, in their use with CMFR GFPs.

The adhesive systems used in total conditioning do not seem to fill the open interfibrillar spaces, resulting in reduced adhesive strength.[12,14] However, although resin cements do not form a hybrid layer or resinous tags, they have shown good adaptation and continuity in root dentin, as reported by pertinent studies.[15-17]

The configuration factor (C-factor) is defined as an indicator that reproduces the generation of polymerization shrinkage stresses, owing to the constraint of cavity configuration.[17,18] Regarding the C-factor inside the root canal, where it is very high, resin cements with different polymerization methods may present different stress values at the bonding interface.[12,13] Hence, the three evaluated cements presented the same dual polymerization mechanism.

Based on the results obtained in the push-out test, the null hypothesis that there is no difference in BS between resin cements was rejected concerning root thirds. Therefore, a lower BS was identified when the Allcem Dual cement was used in the middle root third. Although previous studies have shown that self-adhesive resin cements present better results than conventional ones, the U200 and ACC cements used in the present study showed a performance similar to that of these studies, namely with higher BS values.[15,17] This result can be credited to the immediate analysis adopted in the methodology. Studies show that values of immediate adhesion of self-adhesive cements, such as U200 cement, may be higher than those observed later.[15] Moreover, conventional cements have shown higher adhesion strength compared with self-adhesive cements.[18] In this respect, the studies that evaluated BS after thermocycling of the samples can be recommended in simulating aging.[19]

In this study, superior BS values were observed for the cervical and apical thirds and lower values for the middle third. These findings corroborate those of a previous study, in which the comparison of the regions according to each cement type showed that there was a significant difference between the cervical and middle third regions, and the apical and middle regions, in total-etch resin cements.[15] The best results for the apical third can be explained by the lower tubular density in its root dentin, which increases significantly in the middle and apical thirds.[20] The results of the previous studies reported higher BS values in the apical third than in other parts of the root canal.[21-24] Therefore, the cement BS to root dentin in self-adhesives seems to be related more to the regions of solid dentin than to the density of the dentinal tubules.[15,24] On the contrary, higher BS values in the cervical region can be attributed to the conditioning of phosphoric acid being more effective in highly tubular areas of cervical root dentin, and to a higher light range during photoactivation.[25-27]

One of the limitations of current *in vitro* studies involving human teeth is the difficulty in obtaining these teeth, and in standardizing them anatomically. In this respect, the present study chose to use bovine teeth, whose properties are similar to those of human teeth. A systematic review of the literature analyzed publications that compared the BS values of human and bovine teeth reported in *in vitro* studies. One of the main results of the present review was that no significant difference was found between human and bovine teeth, either in regard to enamel or dentin substrates. Low-to-moderate heterogeneity was found in the meta-analysis.[28] Despite these findings, more studies must be carried out on an ongoing basis to evaluate the best clinical procedures, and to monitor and follow the evolution of restorative materials.

Conclusion

Based on the findings of this study, it can be concluded that Allcem Core and RelyX U200 resin cements showed higher BS values when associated with custom-made reinforced GFP, compared with Allcem Core and Allcem Dual cements. Additionally, both cements were less influenced by the depth of the root dentin.

Clinical Significance

Restoration of endodontically treated teeth is a challenge in dentistry and, in most cases, will require installation of fiberglass pins. In this respect, several types of resin cements are indicated for cementation of these pins; for this reason, their adhesiveness must be adequately investigated.

Authors' Contributions

All the authors contributed to performing the research, and have read and approved the final version of the manuscript.

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