REVISTA DE ODONTOLOGIA DA UNESP
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Original Article

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Influence of customization and light-curing device on the bond strength of glass fiber posts - *in vitro* study

Influência da reanatomização e do aparelho fotopolimerizador na resistência de união de pinos de fibra de vidro - estudo *in vitro*

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How to cite: Schoenhals GP, Chaves LP, Naufel FS. Influence of customization and light-curing device on the bond strength of glass fiber posts - *in vitro* study. Rev Odontol UNESP. 2022;51:e20210058. https://doi.org/10.1590/1807-2577.05821

Resumo

Introdução: Dentes com extensa perda de estrutura podem comprometer a retenção das restaurações ao remanescente dental, onde pinos intraradiculares são indicados. **Objetivo:** Avaliou-se *in vitro* a união de pinos de fibra de vidro à dentina radicular em função de diferentes modos de reanatomização, fotopolimerizadores e regionalização radicular. **Material e método:** Noventa (n=10) raízes bovinas uniradiculares foram usadas num estudo fatorial 3 x 3 x 3 com parcelas subdivididas: Reanatomização do pino, variando a presença e tipo de resina (Sem reanatomização, Resina Convencional e Resina Bulkfill); Fotopolimerizador (Valo, Radii-cal, Rainbow); e Terço radicular (cervical, médio e apical). **Resultado:** O teste de Tukey (5%) evidenciou para o Fator Reanatomização superioridade dos grupos BulkFill (8.16MPa) e Z350 (7.40MPa) ao grupo Controle (4.92MPa), sem diferirem entre si. Todos os fotopolimerizadores diferiram entre si, com superioridade de Valo (9.36MPa), Radii (6.96MPa) intermediário, e inferioridade de Raiwbow (4.17MPa). O terço radicular cervical (7.81MPa) foi superior e o apical inferior (5.80MPa), com o terço médio (6.88MPa) intermediário e sem diferir dos demais. **Conclusão:** Conclui-se que a reanatomização de pinos de fibra de vidro aumenta a resistência de união à dentina radicular, independentemente da resina utilizada, havendo prejuízo no terço apical e quando são empregados fotopolimerizadores com menor intensidade luminosa.

Descritores: Cimentos de resina; fotoiniciadores dentários; fotopolimerização de adesivos dentários; pinos de retenção dentária; técnica para retentor intrarradicular.

Abstract

Introduction: Endodontically treated teeth are usually affected by extensive structure loss requiring the use of intraradicular posts to provide retention and restoration. **Objective:** An *in vitro* assessment was performed on the bonding of glass fiber posts to the root dentin. **Material and method:** Ninety (n = 10) single bovine roots were used in a 3 x 3 x 3 factorial study with subdivided plots: post customization varying the presence and type of resin (without customization, conventional resin, and Bulk Fill resin), light-curing device (Valo, Radii-Cal, Rainbow), and root third (cervical, middle, and apical). **Result:** For the customization factor, Tukey's test (5%) showed the superiority of the Bulk Fill (8.16 MPa) and Z350 (7.40 MPa) groups compared to the control group (4.92 MPa), without differing from each other. All light-curing devices differed, showing the superiority of Valo (9.36 MPa), Radii (6.96 MPa) as an intermediate, and the inferiority of Rainbow (4.17 MPa). The cervical root third (7.81 MPa) was superior, the apical third was inferior (5.80 MPa), and the middle third (6.88 MPa) was an intermediate without differing from the others. **Conclusion:** The customization of glass fiber posts increases the bond strength to the root dentin, regardless of the resin used. There was a compromise in the apical third and when using light-curing devices with lower light intensity.

Descriptors: Resin cement; dental photoinitiators; light-curing of dental adhesives; dental retention posts; intraradicular retainer technique.

INTRODUCTION

Endodontically treated teeth are usually affected by extensive structure loss due to caries disease, cavity preparations, invasive procedures, and the removal of mineral tissues in the root canal access[1]. This may compromise the retention of restorations because of the reduced amount of tooth remnants, requiring the use of intraradicular posts to provide retention and restoration[2,3].

Glass fiber posts are one of the options to restore endodontically treated teeth and, when compared to cast metal retainers, present a modulus of elasticity close to dentin and higher flexural strength, reducing intraradicular stress[4]. They also associate esthetic properties such as translucency, whiteness, and opacity, which facilitates mimicking the tooth[5]. These posts also demand a shorter treatment time for the ability to be cemented in one single session and bonding to resin cement, which bonds to dentin, through adhesive techniques[6,7].

However, there is not an optimal prefabricated post for each canal due to the unique morphology of each tooth, resulting in maladjustment of the post to the canal, thick cementation line, and penetration failures of cementing agents, which has led to the alternative of customizing intraradicular posts with composite resins for better adaptation to the canal[8]. The literature is still unclear regarding the materials and protocols for post customization. This is due to the complex procedure of intraradicular adhesion, justified by the unpredictable variation of morphological characteristics of the canal, such as reduced density and diameter of dentinal tubules in the apical regions and difficult moisture control along the root canal[9]. There is also difficult access of the light emitted by light-curing devices in the deepest areas of the canal, which do not allow light energy to reach the entire root length, decreasing restorative success[10].

Therefore, this *in vitro* study aimed to assess the bond strength of glass fiber posts for different types of customization, light-curing devices, and root regions.

The null hypotheses tested are:

1- There is no difference in the bond strength of glass fiber posts without customization or customized with different types of resin;

2- There is no difference in the bond strength of glass fiber posts using different light-curing devices;

3- There is no difference in the bond strength of glass fiber posts in the different regions of root dentin.

MATERIAL AND METHOD

Experimental Design

This *in vitro* study presented a factorial experimental design with subdivided plots, including three factors: 1- Customization of glass fiber posts in three levels: A- Post without customization; B- Post customized with conventional resin (Z350-3M); and C- Post customized with Bulk Fill resin (3M) (Chart 1); 2- Light-curing in three levels: I- VALO; II-Radii-Call; and III- Rainbow model LY-A180 (Chart 2); and 3- Root region in three levels with subdivided plots: i- cervical; ii- middle; and iii- apical. The outcome variable was the push-out bond strength test.

Chart 1. Distribution in the experimental groups (n=10)

CUSTOMIZATION	LIGHT-CURING DEVICE
Without customization (n=30)	Valo (Ultradent, South Jordan, USA)
	Radii-Call (SDI, Cologne, Germany)
	Rainbow (OSAKA, Guangdong, China)
Customization with Bulk Fill resin (n=30)	Valo (Ultradent, South Jordan, USA)
	Radii-Call (SDI, Cologne, Germany)
	Rainbow (OSAKA, Guangdong, China)
Customization with conventional resin (n=30)	Valo (Ultradent, South Jordan, USA)
	Radii-Call (SDI, Cologne, Germany)
	Rainbow (OSAKA, Guangdong, China)

Chart 2. Light-curing devices tested

	Valo	Radii-Call	Rainbow
Manufacturer	(Ultradent, South Jordan, USA)	(SDI, Cologne, Germany)	(OSAKA, Guangdong, China)
Power density	1400 mW/cm^2	1200 mW/cm^2	900 mW/cm^2
Wavelength	380-480 nm	440-480 nm	450-470 nm

Root Selection

Recently extracted bovine incisors were subjected to an analysis of mesiodistal dimensions and original length, allowing the selection of similar units with cylinder canals. From these, 90 (n=10) were selected and maintained in chloramine T for one week for disinfection. After cutting the cervical region perpendicular to the long axis of the tooth with a double-sided diamond disc, under constant irrigation in a Labcut 1010 precision cutting device (Extec, São Paulo, SP, Brazil), the crown portions were discarded. This resulted in roots with a standardized length of 16 mm, which were stored in distilled water in a refrigerator for up to one month to prevent losses of histological properties of the bovine roots.

Root Canal Preparation

The roots were endodontically treated with Kerr files (Maillefer-Dentsply, Ballaigues, Switzerland) up to size 80 memory file, with a standardized working length of 16 mm. The canals were irrigated with distilled water and dried with absorbent paper cones. Then, they were filled with gutta-percha cones and calcium hydroxide-based cement (Sealer 26 - Dentsply, Rio de Janeiro, RJ, Brazil) using the lateral condensation technique.

After one month of storage in artificial saliva at 37°C in an oven, 12 mm of the filling material was removed from the canals with a series of Gates drills (up to #6) to cement the post, which consisted of a #1 conical post with a rough and grooved surface (Reforpost, Angelus, Londrina, PR, Brazil).

Distribution of Treated Roots in the Groups

Next, the roots were randomly distributed in nine groups according to the customization and curing unit, as described in Chart 1.

The samples of each group were subdivided into three groups according to root region: cervical, middle, and apical (n=10).

Post and Canal Preparations

The glass fiber posts were etched for one minute with 37% phosphoric acid (Condac 37, FGM, Joinville, SC, Brazil), washed with water from the triple syringe, air-dried, and silanized (Primer silane - Angelus, Londrina, PR, Brazil). They were dried for one minute and received the application of Scotchbond hydrophobic adhesive (3M ESPE, Saint Paul, Minnesota, USA) and light-cured. All steps were performed according to the manufacturer's instructions. Charts 2 describe the characteristics of light-curing devices, following these cementation protocols respectively:

- Without customization:

A. Glass fiber post

1) 37% phosphoric acid for one minute;
2) Washing for one minute and drying;
3) Silane with microbrush and evaporating for one minute;
4) Adhesive with microbrush and light-curing for 20 seconds;

B. Canal

1) Irrigation with 0.9% saline solution;
2) Drying with absorbent paper;
3) Self-adhesive cement directly on the canal;
4) Positioning the post without customization;
5) Light-curing for 40 seconds, root wrapped in aluminum foil.

- With customization:

A. Glass fiber post

1) 37% phosphoric acid for one minute;
2) Washing for one minute;
3) Silane with microbrush and evaporating for one minute;
4) Adhesive with microbrush and light-curing for 20 seconds;
5) Composite resin modeled to the post and positioned on the canal;
6) Initial light-curing for three seconds;
7) Removal from the canal and light-curing for 40 seconds;
8) 37% phosphoric acid for 15 seconds for decontamination;

B. Canal

1) Irrigation with 0.9% saline solution;
2) Drying with absorbent paper;
3) Self-adhesive cement directly on the canal;
4) Insertion of the customized post;

5) Light-curing for 40 seconds, root wrapped in aluminum foil.

The specimens identified were maintained in distilled water in an oven at 37°C. After one week, the roots were sectioned with a diamond disc in a Labcut 1010 precision cutting machine (Extec, São Paulo, SP, Brazil), under constant refrigeration, perpendicular to the long axis, and in slices with 1±0.2 mm of thickness. For each root (specimen/sample), nine slices (specimens) were obtained, corresponding to three slices for each root third. The slices were individually identified, maintained in distilled water, and immediately subjected to the mechanical test.

Bond Strength Test (*push-out*)

The adhesive interfaces of the specimens have a conical and truncated shape and their areas were obtained by measuring canal diameters on the coronal and apical sides of each slice. Their thickness was obtained with the help of a digital caliper (Mitutoyo Sul Americana Ltda, Suzano, SP, Brazil) and the total area, in mm^2, was calculated with the following formula: A = π (R2+R1) [h2 + (R2-R1)2]0,5, where π= 3.14; R2= crown radius of the cementation area; R1= apical radius of the cementation area; h= height of the slice.

The specimens were subjected to the push-out test and positioned in a stainless steel metal support with a central perforation with a slightly larger diameter than the adhesive interface (2.0 to 3.8 mm). Due to the conical shape of the posts, the load was applied in the apical-crown direction, from the surface with the smallest diameter, with the post being pushed toward the wider portion of the canal.

The load was applied on a post surface with a tip (diameter varying from 1.3 mm to 0.8 mm) coupled to a universal testing machine (EMIC DL 2000; EMIC, São José dos Pinhais, PR, Brazil) with a cell load of 500 KgF (50 N), at speed of 1.0 mm/min, so it would not contact the adhesive interface.

Conversion of Values

The values obtained during the push-out test were registered in N and converted to MPa with the formula α= F/A, where F, in N, is the maximum force registered at the time of post displacement and A is the adhesive interface area.

Fracture Type Analysis

After the push-out test, the slices were analyzed with light microscopy (DINOLITE plus digital microscope, AnMo Electronics Corporation, Hsinchu, China), with a magnification of 200x, and were classified as: 1- A P/C (adhesive failure between cement/resin and post); 2- A C/D (adhesive failure between cement and dentin); 3- CC (cohesive failure of the cement); 4- CD (cohesive failure in dentin); and 5- M (mixed failure).

Statistical Analysis

The factors of customization, light-curing devices, and root thirds were considered. The SigmaPlot 11.0 software was used for the analyses. Normal distribution and homogeneity of variances were verified with the Kolmogorov-Smirnov analyses and Levene test, respectively. The data were processed with three-way ANOVA with subdivided plots and multiple comparisons with Tukey's test, both at $p<0.05$.

RESULT

There were significant differences between the factors of customization (p<0.001), light-curing device (p<0.001), and root third (p=0.003), but no differences between double (p=0.264; p=0.993; and p=0.779) and triple (p=0.984) interactions. The differences were identified with Tukey's complementary test (5%), showing in the customization factor the superiority of Bulk Fill (8.16 Mpa) and Z350 (7.40 Mpa) groups compared to the control group (4.92 Mpa), without differing from each other. For the light-curing device factor, all groups differed, showing the superiority of Valo (9.36 Mpa), Radii as an intermediate (6.96 Mpa), and the inferiority of Rainbow (4.17 Mpa). For the root third factor, the cervical third (7.81 Mpa) was superior, the apical third was inferior (5.80 Mpa), and the middle third (6.88 Mpa) showed intermediate values without significantly differing from the cervical and apical thirds (Chart 3).

Chart 3. Adhesive bond strength of the experimental groups tested

		ROOT THIRD	Light-curing device			Mean ROOT THIRD
			VALO (F1) 9.36(5.48) a	**RADII (F2) 6.96(3.66) b**	**RAINBOW (F3) 4.17(2.70) c**	
Customization	**CONTROL (R1) 4.92(3.24) B**	**CROWN**	7.49 (2.95)	6.22 (2.53)	4.25 (2.27)	**CROWN 7.81(4.59) ∞**
		MIDDLE	6.38 (2.54)	5.64 (4.33)	2.50 (2.38)	
		APICAL	5.43 (2.90)	4.16 (2.80)	2.23 (1.43)	
	Z350 (R2) 7.40(4.89) A	**CROWN**	12.07 (4.49)	8.65 (1.68)	4.77 (3.01)	**MIDDLE 6.88(5.12) ∞β**
		MIDDLE	10.54 (7.34)	6.88 (4.87)	4.71 (3.86)	
		APICAL	8.17 (3.74)	6.41 (3.74)	4.41 (2.09)	
	BULK FILL (R3) 8.16(4.90) A	**CROWN**	12.15 (6.95)	9.58 (3.46)	5.13 (2.03)	**APICAL 5.80(3.85) β**
		MIDDLE	11.79 (5.83)	8.53 (2.39)	4.94 (1.90)	
		APICAL	10.19 (4.86)	6.59 (2.58)	4.57 (2.80)	

Different capital letters indicate statistically significant differences for the customization factor. Different lower-case letters indicate statistically significant differences for the light-curing device factor. Different symbols indicate statistically significant differences for the root third factor.

The ACD failure was prevalent for the customization with Bulk Fill and Z350, showing that failure occurs between the cement and dentin, where there is a closer contact. However, the predominant failure mode in the control group was APC, failing the adhesion between post and cement. The CD failures prevailed for the Valo light-curing device due to the extensive conversion potential presented. Radii was an intermediate and Rainbow had the lowest number of cement-dentin failures. The opposite to the conversion degree of light-curing devices causes CC failures, with the highest rates for Rainbow, intermediate for Radii, and Valo with the lowest rates, which confirms the bond strength data (Figure 1).

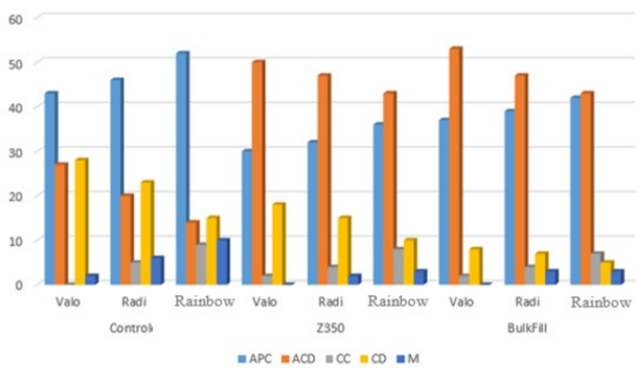

Figure 1. Failure mode analysis (APC, ACD, CC, CD, and M) for each group.

DISCUSSION

The procedures involving the rehabilitation of dental elements after endodontic treatment with the fixation of posts include several variables susceptible to failures, which may compromise the bond strength of posts to the canal and result in restorative failure[11-15]. Some of these aspects were assessed in the present study, which showed that the best bond strength results occurred in the cervical region of the canal whose posts had been adapted by the customization procedure (R2 and R3), using the light-curing device with the highest power density (F1) and with the inferiority of the apical third.

The first null hypothesis tested was rejected because there were significant statistical differences between the types of customization. The groups customized with composite resins (R2 and R3) had the highest bond strength results when compared to posts cemented without customization. The best results might be attributed to the close contact of the composite resin modeled to the inner root surface and the consequent smallest thickness of the resin cement required for cementation, reducing polymerization shrinkage stress. This result corroborates studies showing that post retention within root canals is not exclusively adhesive, but also frictional[15-19].

The composite resins used for customization, either conventional or Bulk Fill, did not differ regarding dentin bond strength, suggesting that the better adaptation to the canal is more important than the material used[18,20]. The C-factor of polymerization was reduced in this technique because photoactivation occurs outside the canal, having the post as the only adhesion surface, therefore not presenting polymerization shrinkage stress, following the same principles of indirect crown restorations[12]. Different results are found in the literature, justified by materials (fluid resins and cement) and customization techniques (directly to the canal), considering that material insertion and light-curing directly to the canal involves two adhesive surfaces (post and canal wall), producing stress in the adhesive interface[21-23].

The push-out test was used in the present study for being the most reliable test to assess the bond strength of glass fiber posts to the root dentin because the fracture pattern occurs parallel to the cement/root dentin interface[23].

The second null hypothesis was also rejected because there was a significant difference between the groups light-cured with different equipment. The Valo group (F1) showed the highest bond strength means, the Radii group (F2) presented an intermediate value, and the Rainbow group (F3) had the lowest bond strength. This may be justified by the power density of each light-curing device and the different light spectrum. The Valo provides a power density of 1400 mW/cm^2, Radii-Call has 1200 mW/cm^2, and Rainbow has 900 mW/cm^2. This corroborates the principle that the more intense the light, the more photons are available for absorbing photosensitizers, which can then be elevated to the excited state, helping to form more free radicals and initiating and propagating the polymerization process[21,22].

It should also be noted that the light potential of a curing unit reduces intensity with depth and does not reach the same absorption level after passing through some structures[10,23,24]. This is why there were differences in bond strength for the root thirds. The cervical third presented the best results, the middle third was an intermediate, and the apical third had the lowest results, which rejects the third null hypothesis. This may be explained by the insufficient arrival of light to allow the conversion of monomers into polymers[1,23]. Moreover, light-curing devices with a power of 1500 mW/cm^2 presented higher bond strength results, especially in the cervical third[22,23]. These results agree with previous studies that show that dual resin cement depends on photoactivation to achieve better mechanical properties, recommending the use of translucent glass fiber posts to minimize the issue of light transmission throughout the root extension. They conclude that the ability to transmit light was not significant to obtain an appropriate degree of conversion for the cement, especially in the apical region[10,16,20].

Additionally, the morphology along the root presents histological differences, whereas, apically, the dentinal tubules reduce in size and present greater moisture. Residual gutta-percha and insufficient hybridization may also occur[24,25]. This is seen in the study by Calixto et al.[13] in which the lowest bond strength results are found in the apical third for both the morphological factor that reduces the size of dentinal tubules in the root apex and the light potential that decreases along the root length.

Some methodological limitations allow a restricted interpretation of the results, considering that even with the standardization of the root length, variances along the root canal present histological differences. Therefore, further studies are required to assess the relationship between the adjustments of glass fiber posts to the root dentin (canal walls).

CONCLUSION

The customization of glass fiber posts with composite resin increases the bond strength to the root dentin, regardless of the resin used. There was a compromise for bonding on the apical root third and when using light-curing devices with lower light intensity.

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CONFLICTS OF INTERESTS

The authors declare no conflicts of interest.

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Received: November 16, 2021
Accepted: March 9, 2022