Original Article

Evaluation of bond strength in customizing fiber post using translucent resins photoactivated by different light-emitting diodes

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Abstract

Aims: The objective of the study was to evaluate two translucent resin composite systems for customizing light-polymerized fiber posts with light-emitting diode (LED) curing units regarding adhesion using conventional cement at 24 h and 6 months.

Settings and Design: This was an experimental *in vitro* study.

Methods: Forty roots were prepared and divided into four groups ($n = 10$): ZV-Z350 resin and LED Valo; ZR-Z350 resin and LED Radii-Cal; OV-Opallis resin and LED Valo; and OR-Opallis resin and LED Radii-Cal. The fiber post was customized and cemented with conventional resin cement and was photoactivated by two different sources.

Statistical Analysis Used: The data were subjected to two-way ANOVA and Tukey's *post hoc* tests ($P = 0.05$). The data regarding the pattern of adhesive failures were described in terms of the frequency of occurrence in each third of the postspace.

Results: Both at 24 h and 6 months, bond strength among groups was similar, regardless of the analyzed postspace 3rd ($P > 0.05$). Adhesive failure Type 4 was the most frequent in all thirds.

Conclusions: Customizing the fiber post with Z350 and Opallis has the same effect on bond strength and adhesive failure pattern, regardless of the LED curing units used for photopolymerization.

Keywords: Adhesives; bond strength; cement; light-emitting diode; resin

INTRODUCTION

The need for customization of the fiber post for better adaptation in excessively wide canals has led to several studies in the literature.[1-3] Resin composite is material used in this technique,[4,5] allowing its execution by clinicians. However, even after the benefits of postcustomization, other problems continued to persist in treatment, such as the difficulty of light passage from the light-emitting diode (LED) device in the deeper regions of the canal.

It is known that the efficacy of intraradicular restorations depends on the properties of the material, specifically a good bond strength.[6] Currently, what has been observed in the literature are investigations of different methods of cleaning residues in the postspace resistance of the post, cement, and dentin assembly.[7-13] Evaluations of different

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Date of submission : 08.01.2024
Review completed : 15.02.2024
Date of acceptance : 26.02.2024
Published : 05.04.2024

Access this article online	
Quick Response Code:	Website: https://journals.lww.com/jcde
	DOI: 10.4103/JCDE.JCDE_14_24

How to cite this article: Barros AP, Costa JL, de Melo AC, Galvani LD, Dantas AA, Kuga MC. Evaluation of bond strength in customizing fiber post using translucent resins photoactivated by different light-emitting diodes. J Conserv Dent Endod 2024;27:408-13.

resinous materials, specifically translucent resins for postcustomization, are still not extensively addressed. Therefore, the authors were encouraged to conduct this *in vitro* assay in an attempt to investigate whether the translucency of different resins influences the bond strength and adhesive failure pattern.

In a previous study,[14] the authors assessed the bond strength of the customized fiber post with Z350 and Opallis resins. However, it is important to note that a self-adhesive resin cement was employed. The continuation of the current research holds significant clinical relevance due to the widespread adoption of the customization technique by clinicians. The investigation using a different resin cement becomes of utmost importance to determine whether the results are similar to or divergent from those found previously,[14] even when using the same LED devices and resin composites.

Thus, the objective was to evaluate two translucent resins (Z350 and Opallis) for customizing the fiber post and light-polymerizing with LED curing units (Valo or Radii-Cal) on the bond strength and adhesive failure pattern to the intraradicular dentin of the post space, using a conventional resin cement (RelyX Ultimate). The null hypothesis tested was that the resin and the photopolymerization device did not influence the bond strength or adhesive failure pattern at 24 h or 6 months of observation.

METHODS

Specimens' preparation

Forty bovine incisors were selected and preserved in thymol solution (0.1%; pH 7.0) at a temperature of 4°C ± 1°C for 7 days. On the 8th day, the roots were cross-sectioned at the level of the cementoenamel junction using a double-sided diamond disc (KG Sorensen, São Paulo, SP, Brazil), standardizing the sample length by 15 mm from the root apex.[9] Subsequently, the canal was prepared similarly to Leandrin *et al*.[3] Following the instrumentation, irrigation was carried out with 3 mL of 17% ethylenediaminetetraacetic acid (Biodinâmica, Ibiporã, PR, Brazil) for 3 min, followed by 5 mL of 2.5% sodium hypochlorite (Asfer, São Caetano do Sul, SP, Brazil). The root canals were dried with absorbent paper points and filled with epoxy resin-based sealer (AH Plus; Dentsply DeTrey, Konstanz, Germany) and a single F5 gutta-percha cone (ProTaper; Dentsply Maillefer, Petrópolis, RJ, Brazil).

For the preparation of the post space, a Largo #2 drill (Dentsply, Petrópolis, RJ, Brazil) was used to a length of 11 mm, followed by a specific drill (#2 White Post DC System; FGM, Joinville, SC, Brazil) at low rotation speed (NSK, Shinagawa, Tokyo, Japan), without water cooling as recommended by the manufacturer. Subsequently, the canal was irrigated with 5 mL of distilled water, and drying of the canal was performed using absorbent paper points.[3]

Customization of the fiber post and cementation

The preparation (White Post DC #2; FGM, Joinville, SC, Brazil) began with cleaning their surface with 70% ethanol, followed by the application of silane (Prosil; FGM, Joinville, SC, Brazil) and drying with an air jet for 1 min at a distance of 2 cm. Subsequently, a universal adhesive (Scotchbond Universal™; 3M/ESPE, St. Louis, Missouri, USA) was used on the post's surface, followed by photoactivation for 20 s.[3] Next, the specimens were randomly divided into four groups ($n = 10$), according to the resin and the evaluated LED curing units:

- Group ZV (Filtek Z350 resin and Valo photopolymerizer): In this group, the fiber posts were customized with the translucent resin Filtek Z350 (XT CT; 3M/ESPE, St. Louis, MO, USA). To achieve this, the post space was previously lubricated with water-soluble gel (KY; Johnson and Johnson, SP, Brazil). Subsequently, the resin-coated post was inserted into the canal and photopolymerized for 5 s using an LED device (Valo; Ultradent, South Jordan, UT, USA), with an irradiance of 1000 mW/cm^2. Later, the customized post was removed, and photoactivation was completed across its entire surface for 20 s. The customized post was treated with 37% phosphoric acid (Condac, FGM, Joinville, SC, Brazil) for 1 min, washed and dried, followed by the application of silane (Prosil; FGM, Joinville, SC, Brazil). Subsequently, a universal adhesive (Scotchbond Universal™; 3M/ESPE, St. Louis, Missouri, USA) was actively applied to the post's surface

Concurrently, the post space was irrigated with 10 mL of distilled water to remove the water-soluble gel, followed by drying with paper points and application of 37% phosphoric acid (Condac, FGM, Joinville, SC, Brazil) on all intraradicular dentin for 15 s. Next, the canal was rinsed with distilled water for 30 s and dried with absorbent paper points. Afterward, the universal adhesive system (Scotchbond Universal™; 3M/ESPE, St. Louis, Missouri, USA) was actively applied with a microbrush over the entire dentin surface

Finally, conventional resin cement (RelyX Ultimate; 3M/ESPE, St. Louis, MO, USA) was manipulated and inserted into the post space with the aid of a precision syringe (Precision; Maquira, Maringá, PR, Brazil), and the post was placed into the canal, removing excess cement. Photoactivation was performed with an LED device (Valo; Ultradent, South Jordan, UT, USA) for 40 s

- Group ZR (Filtek Z350 resin and Radii-Cal photopolymerizer): The fiber posts were anatomized with the translucent resin composite Filtek Z350 (XT CT; 3M/ESPE, St. Louis, MO, USA), in the same way as the ZV group, however, their polymerization was performed using the LED device (Radii-Cal; SDI, Itajaí, SC, Brazil) was used with an irradiance of 1200 mW/cm², for 5 s. The fiber posts were then removed from the post space and photoactivation was completed on each face for 10 s on each side. Cementation occurred in the same manner as mentioned above, however using LED curing units (Radii-Cal; SDI, Itajaí, SC, Brazil) for 30 s on the specimen's cervical face

- Group OV (Opallis resin and Valo photopolymerizer): The fiber posts were anatomized with the translucent resin composite Opallis (T-Neutral; FGM, São Paulo, SP, Brazil) inserted in the post space previously lubricated with water-soluble gel (KY; Johnson and Johnson; São Paulo, SP, Brazil), and were then light cured for 5 s using an LED device (Valo; Ultradent, South Jordan, UT, USA), with an irradiance of 1000 mW/cm². The fiber posts were then removed from the post space and photoactivation was completed on each face for 20 s on each side. The customized post was treated with 37% phosphoric acid (Condac, FGM, Joinville, SC, Brazil) for 1 min, washed and dried, followed by the application of silane (Prosil; FGM, Joinville, SC, Brazil). Subsequently, a universal adhesive (Scotchbond Universal™; 3M/ESPE, St. Louis, Missouri, USA) was actively applied to the post's surface. Concurrently, the post space was irrigated with 10 mL of distilled water to remove the water-soluble gel, followed by drying with paper points and application of 37% phosphoric acid (Codac, FGM, Joinville, SC, Brazil) on all intraradicular dentin for 15 s. Next, the canal was rinsed with distilled water for 30 s and dried with absorbent paper points. Afterward, the universal adhesive system (Scotchbond Universal™; 3M/ESPE, St. Louis, Missouri, USA) was actively applied with a microbrush over the entire dentin surface. Finally, conventional resin cement (RelyX Ultimate; 3M/ESPE, St. Louis, MO, USA) was manipulated and inserted into the post space with the aid of a precision syringe (Precision; Maquira, Maringá, PR, Brazil), and the post was placed into the canal, removing excess cement. Photoactivation was performed with an LED device (Valo; Ultradent, South Jordan, UT, USA) for 40 s
- Group OR (Opallis resin and Radii-Cal photopolymerizer): The procedure was similar to the one described for OV, except that the LED (Radii-Cal; SDI, Itajaí, SC, Brazil) at a constant power of 1.200 mW/cm² for 30 s.

Push-out analyses and failure mode were performed in 24 h and in 6 months after fiber postcementation. In sequence, 40 specimens ($n = 10$, each group) were submitted to push out bond strength analysis after 24 h, and other specimens were immersed in distilled water for 6 months, at 38°C. The distilled water was changed every 3 days.

Pushout bond strength test

After 24 h and 6 months, the roots were vertically positioned within a PVC matrix (22.3 mm diameter × 21.0 mm length) and assessed using a parallelometer (BioArt B2, São Carlos, SP, Brazil). Subsequently, the specimens were removed from the matrices and sectioned perpendicular to their longitudinal axis using a diamond disk attached to a hard tissue cutting machine (Isomet 1000; Buehler Ltd, Lake Bluff, IL, USA) with water cooling.

Three sections, each with a thickness of 1.9 mm ± 0.2 mm, were obtained from the apical, middle, and cervical thirds of the post space. The cervical, middle, and apical sections were obtained, respectively, from 1.0 mm, 5.0 mm, and 9.0 mm apically to the cervical face of the root. Subsequently, the specimens underwent ultrasonic cleaning with distilled water for 1 min. The apical, middle, and cervical thirds were marked, and the specimens were subjected to the push-out bond strength test using an electromechanical testing machine (EMIC, São José dos Pinhais, PR, Brazil), applying a 5 kN load cell at a speed of 0.5 mm/min, until complete displacement of the fiber post and/or the cementation system occurred.

Punches with diameters of 1.2 mm, 0.9 mm, and 0.5 mm were used for the cervical, middle, and apical thirds of the post space, respectively. The force (F) required for specimen displacement was measured in Newtons (N) and converted into bond strength (MPa) using the formula: MPa = F/AD.[15]

Failure mode

After push-out test, the slices were analyzed in stereomicroscope Leica DFC295 attached to a Leica S8 APO (Leica Microsystems, Wetzlar, Hesse, Germany), with ×10 magnification, to evaluate the failure mode pattern. The failure mode was classified according to Ramos *et al*.[16]

Statistical analysis

The Shapiro–Wilk test was used to verify the data normality. Once the normality of the bond strength results was confirmed, the data were subjected to two-way ANOVA and Tukey's *post hoc* tests ($P = 0.05$). The data regarding the pattern of adhesive failures were described in terms of the frequency of occurrence in each third of the post space.

RESULTS

Bond strength in 24 h

The bond strength was the same among the evaluated groups; regardless of the post space third analyzed [$P > 0.05$, Table 1]. In the comparison between thirds, the bond strength in the cervical third, regardless of the analyzed group, was higher than that demonstrated in the other thirds [$P < 0.05$, Table 1]. There was no difference between the results demonstrated between the middle and apical thirds of the post space [$P > 0.05$, Table 1].

When comparing the thirds, the bond strength of the cervical third, regardless of the group analyzed, was higher than that demonstrated in the other thirds [$P < 0.05$; Table 1]. There was no difference between the results demonstrated between the middle and apical thirds of the post space [$P > 0.05$; Table 1].

Bond strength in 6 months

The bond strength values between groups were similar to those demonstrated in the 24 h and evaluation, regardless of the material used for customizing the fiber post and the photoactivation system employed [$P > 0.05$, Table 2]. In the comparison between thirds within the same group, the bond strength values of the cervical third, regardless of the analyzed group, were higher than those demonstrated in the other thirds [$P < 0.05$, Table 2]. There was no difference between the results demonstrated between the middle and apical thirds of the post space [$P > 0.05$, Table 2]. These results coincide with those observed at the 24 h mark.

Failure pattern

In 24 h, adhesive failure Type 4 was the most frequent in all thirds, regardless of the evaluated group [Figure 1].

Table 1: Arithmetic mean and standard deviation of bond strength values for the universal adhesive cementation system (Scotchbond Universal) and conventional resin cement (RelyX Ultimate), depending on the resin used for customizing the fiber post and the equipment for photopolymerization of the cementation system, after 24 h

	ZV	ZR	OV	OR
Cervical third	10.69a,A (0.71)	10.01^{a,A} (0.71)	10.22^{a,A} (0.79)	10.14^{a,A} (0.71)
Middle third	9.71^{a,B} (0.57)	9.14^{a,B} (0.47)	9.41^{a,B} (0.43)	9.41^{a,B} (0.69)
Apical third	9.33^{a,B} (0.49)	8.91^{a,B} (0.64)	9.31^{a,B} (0.71)	8.99^{a,B} (0.58)

^{a}Similar letters in the same row indicate similar results ($P>0.05$), ^{A,B}Different letters in the same column indicate significant differences ($P<0.05$).
ZV: Customization with Z350 XT resin and photoactivation with Valo,
ZR: Customization with Z350XT resin and photoactivation with Radii-Cal,
OV: Customization with Opallis resin and photoactivation with Valo,
OR: Customization with Opallis resin and photoactivation with Radii-Cal

Table 2: Arithmetic mean and standard deviation of bond strength values for the universal adhesive cementation system (Scotchbond Universal) and conventional resin cement (RelyX Ultimate), depending on the resin used for customizing the fiber post and the equipment for photopolymerization of the cementation system, after 6 months

	ZV	ZR	OV	OR
Cervical third	9.74^{a,A} (0.77)	9.71^{b,A} (0.51)	9.62^{a,A} (0.76)	9.68^{b,A} (0.63)
Middle third	9.01^{a,B} (0.34)	9.02^{a,B} (0.57)	9.01^{a,B} (0.32)	9.05^{a,B} (0.49)
Apical third	8.64^{a,B} (0.38)	8.54^{a,B} (0.43)	8.59^{a,B} (0.51)	8.51^{a,B} (0.52)

^{a}Similar letters in the same row indicate similar results ($P>0.05$), ^{A,B}Different letters in the same column indicate significant differences ($P<0.05$).
ZV: Customization with Z350 XT resin and photoactivation with Valo,
ZR: Customization with Z350 XT resin and photoactivation with Radii-Cal,
OV: Customization with Opallis resin and photoactivation with Valo,
OR: Customization with Opallis resin and photoactivation with Radii-Cal

At 6 months, similarly to what was observed in the 24 h and evaluation, the most frequent failure pattern was Type 4, regardless of the analyzed third of the post space [Figure 2].

DISCUSSION

This study evaluated two translucent resins composite (Z350 XT and Opallis) for customizing the fiber post, polymerized with LED curing units (Valo or Radii-Cal), regarding bond strength and adhesive failure pattern in a conventional cementation system to intraradicular dentin. There was no statistically significant difference in bond strength among the evaluation groups at 24 h and 6 months of follow-up. Furthermore, the incidence of the failure pattern was the same for all groups, regardless of the resin composite or LED used, accepting the null hypothesis.

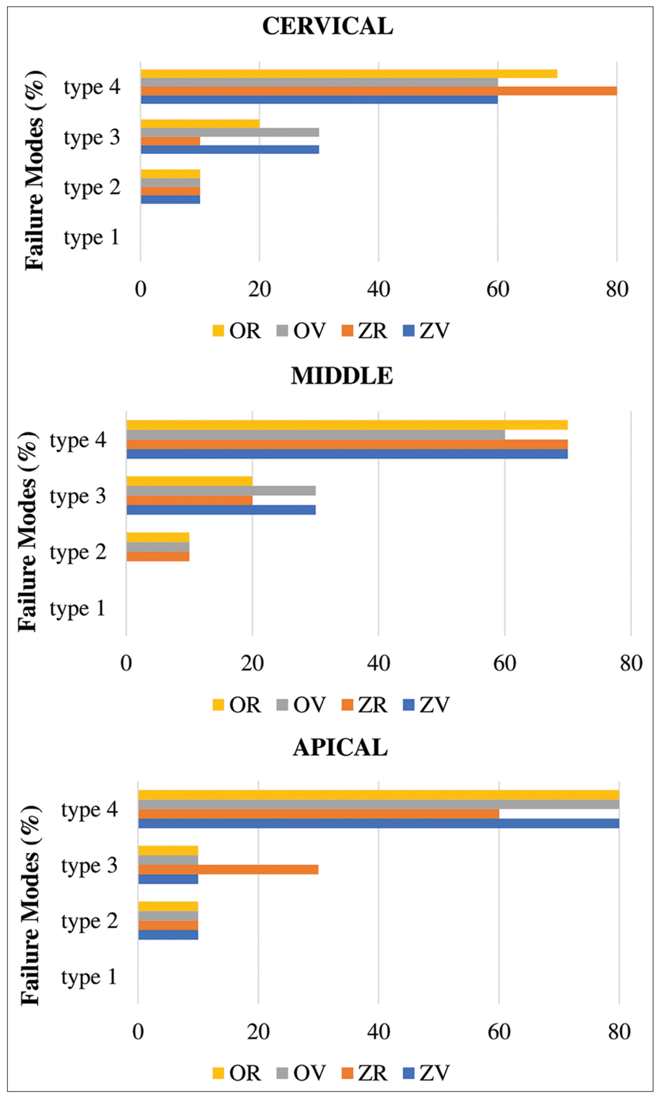

Figure 1: Failure modes found (%) in the space thirds cervical, middle, and apical at 24 h of evaluation, in the different evaluation groups

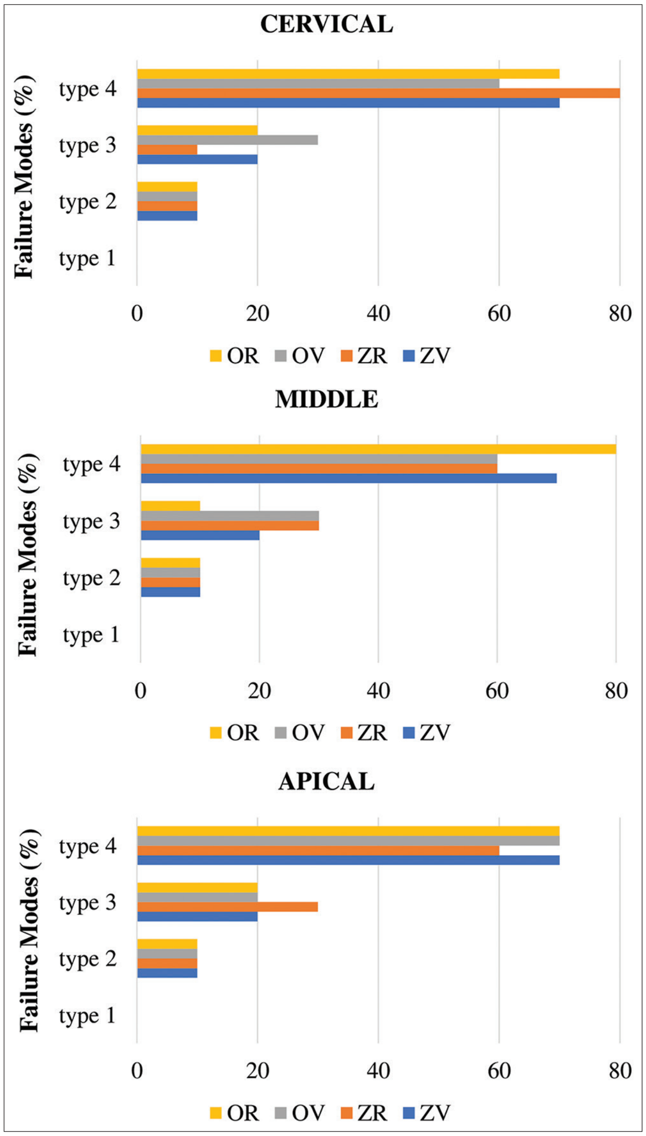

Figure 2: Failure modes found (%) in the space thirds cervical, middle, and apical at 6 months of evaluation, in the different evaluation groups

The present study utilized the conventional resin cement RelyX Ultimate to investigate whether the outcomes would be similar to those of a previous study[14] conducted by the authors. In the earlier research, the same methodology was employed: Customizing the post with Z350 and Opallis resins, albeit with the use of self-adhesive resin cement, RelyX U200. It is well-established that conventional and self-adhesive resin cement exhibit distinct mechanisms of action within intraradicular dentin, which further underscores their relevance in the investigation of this study.

Some factors mentioned in the previous literature may interfere with the adhesion and, consequently, the strength of the fiber post, such as ineffective cleaning of the intraradicular dentin,[7,9] a thick layer of cementation material, and incomplete polymerization of the resin cement.[17-19] Another issue relates to irregularities and a lower number and diameter of dentinal tubules in the apical third,[20] which can also affect bond strength. This is due to the resin tags decreasing in deeper regions of the canal due to these anatomical changes.[21]

The evaluated bond strength was consistent among the analyzed groups in all thirds, both at 24 h and at 6 months, contrasting with the results of a previous study.[14] It is worth noting that in this study, a conventional resin cement was used, in contrast to the previous methodology. However, in the comparison between thirds, the bond strength in the cervical third was higher than in the other thirds, regardless of the analyzed group. We know that a significant factor that can lead to restoration defects concerns the C-factor (cavity configuration factor), especially in the deeper thirds of the post space, creating high contraction stress at the post/cement/dentin bonding interface,[22] justifying the results obtained in the comparisons between the different thirds.

A relatively common difficulty during the cementation of the post is the photoactivation of dual-cure cements.[23] Incomplete polymerization of the material promotes its degradation and detachment from the root canal.[23] The result of this is the formation of potential adhesive failures in intraradicular restorations. As demonstrated in our results, both at 24 h and at the 6-month follow-up, Type 4 failures were observed with a frequency of incidence ranging from 60% to 80%, regardless of the resin material and LED device used [Figures 1 and 2]. Type 4 adhesive failures, known as mixed failures, occur in the presence of one or more failures simultaneously.[16] These failures were also reported in previous studies.[24-26]

This assay used only two resin composite systems, which limits our results. Therefore, we encourage further research comparing a greater number of resins to complement the findings obtained in this study. In addition, the authors suggest conducting long-term clinical trials to validate the findings of this investigation.

CONCLUSIONS

Customizing the fiber post with the translucent resins Z350 and Opallis has the same effect on bond strength and adhesive failure pattern, regardless of the LED curing units used for photopolymerization when using the conventional resin cement RelyX Ultimate.

Acknowledgment

This study was financed in part by the Coordination for the Improvement of Higher Education Personnel (CAPES) – Finance code 001.

Financial support and sponsorship

Coordination for the Improvement of Higher Education Personnel (CAPES) – Finance code 001.

Conflicts of interest

There are no conflicts of interest.

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