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Effect of root canal filling techniques on the bond strength of epoxy resin-based sealers

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Abstract: The aim of this study was to evaluate the effects of different root canal filling techniques on the bond strength of epoxy resin-based sealers. Sixty single-rooted canines were prepared using ProTaper (F5) and divided into the following groups based on the root filling technique: Lateral Compaction (LC), Single Cone (SC), and Tagger Hybrid Technique (THT). The following subgroups (n = 10) were also created based on sealer material used: AH Plus and Sealer 26. Two-millimeter-thick slices were cut from all the root thirds and subjected to push-out test. Data (MPa) was analyzed using ANOVA and Tukey's test ($\alpha = 0.05$). The push-out values were significantly affected by the sealer, filling technique, and root third ($p < 0.05$). AH Plus (1.37 ± 1.04) exhibited higher values than Sealer 26 (0.92 ± 0.51), while LC (1.80 ± 0.98) showed greater bond strength than THT (1.16 ± 0.50) and SC (0.92 ± 0.25). The cervical (1.45 ± 1.14) third exhibited higher bond strength, followed by the middle (1.20 ± 0.72) and apical (0.78 ± 0.33) thirds. AH Plus/LC (2.26 ± 1.15) exhibited the highest bond strength values, followed by AH Plus/THT (1.32 ± 0.61), Sealer 26/LC (1.34 ± 0.42), and Sealer 26/THT (1.00 ± 0.27). The lowest values were obtained with AH Plus/SC and Sealer 26/SC. Thus, it can be concluded that the filling technique affects the bond strength of sealers. LC was associated with higher bond strength between the material and intra-radicular dentine than THT and SC techniques.

Keywords: Dental Materials; Root Canal Obturation; Dental Bonding.

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Introduction

Root canal filling during endodontic treatment can be performed by cold lateral compaction or by different thermoplastic filling techniques. Cold lateral compaction is a widely used technique[1] that allows precise material handling[2,3] but requires greater working time than thermoplastic filling techniques.[4]

In the last decade, there has been a tendency to simplify the root canal preparation with the introduction of mechanized systems that reduce the number of files used or even with a single file to clean and shape the root canal.[5] Accordingly, the single-cone filling technique has been proposed, and it includes the use of a master cone having the same volume as the instrumented root canal. This allows the filling material to be completely filled into the canal, thus reducing the working time.[5]

Thermoplastic filling techniques allow the condensation of warm gutta-percha (GP) cones in all the root canal irregularities, reducing the empty spaces.[1,6,7,8] However, the heat required to plasticize GP cones promotes the degradation of its components[9] and alteration of the chemical composition of epoxy-based sealers.[10]

The bond strength of the filling material to the radicular dentin is primarily the result of physicochemical interactions across their interface.[11] Furthermore, the mechanical adhesion provided by filling materials within the root canal irregularities and dentin tubules can also contribute to the bond strength of the filling material.[12] Therefore, as the heat provided by thermoplastic filling techniques may alter the sealer's physicochemical properties[10] and the pressure applied can directly influence the mechanical interlocking between the filling materials and the radicular dentin, it is essential to evaluate the influence of different root canal filling techniques on the root canal bond strength.

The aim of this study was to evaluate the impact of different filling techniques on the bond strength between a sealer-based epoxy resin and the radicular dentine.

Methodology

This study protocol was approved by the Institutional Ethics Committee (Process no.461.870). The sample consisted of 60 single-rooted human mandibular canines with completely formed apices, no calcifications, and roots with curvature angles ≤ 10° (mild curvature according to Schneider's method). The tooth crowns were removed, and the roots were trimmed coronally to a standardized length of 16 mm. The working length (WL) was fixed at 1 mm from the root apex.

The canals were instrumented with the ProTaper Universal system (Dentsply Maillefer, Ballaigues, Switzerland) using the crown-down technique. The instruments were attached to a 64:1 gear reduction hand-piece (Anthogyr, Sallanches, France) powered by an electric motor (Endo Plus VK Driller, São Paulo, Brazil) and used in the following sequence: SX, S1, S2, F1, F2, F3, F4, and F5. The canals were irrigated after each file change with 2 mL of 1.0% sodium hypochlorite. After preparation, the canals were filled with 5 mL of 17% ethylenediaminetetraacetic acid for 5 min, flushed with 5 mL of distilled water, and dried with absorbent paper points (Dentsply Ind. e Com. Ltda., Petrópolis, Brazil).

Sixty root canals were filled using three techniques: Cold lateral compaction (LC; n = 20), Tagger's hybrid technique (THT; n = 20), or single cone (SC; n = 20). Within each group, either AH Plus® (Dentsply DeTrey, Konstanz, Germany) with GP cones (Dentsply Ind. e Com. Ltda.) (n = 10), or Sealer 26 (Dentsply Ind. e Com. Ltda.) with GP cones (n = 10) was used as the filling material. In the specimens filled using the LC technique, a #40 lentulo spiral was used to apply the sealer in the canal, followed by introduction of a ProTaper GP cone F5 (Dentsply Maillefer, Ballaigues, Switzerland) up to the WL. This was followed by the vertical insertion of a #25 finger spreader (Dentsply Maillefer) to create space for the accessory GP cones. In the specimens filled using THT, a medium GP cone was measured with a ruler and used as the main cone up to WL. Two accessory GP cones coated with sealer were introduced into the canal immediately after removal of the #25 finger spreader. Thereafter, a #70 McSpadden compactor (Dentsply Maillefer) attached to a low-speed hand-piece was used in a clockwise direction apically up to a point 1.5 - 2.0 mm short of the WL. Brushstroke movements were used with amplitude of approximately 1 mm, and contact was maintained between the instrument and the cones at the canal orifice. In the SC group, the sealer was applied to the canal with a #40 lentulo spiral, followed by introduction of a ProTaper GP cone F5 (Dentsply Maillefer, Ballaigues, Switzerland) up to the point of biomechanical preparation.

The sealers were mixed according to the manufacturer's instructions. Excess sealer was removed with cotton pledgets, and the canal entrance was sealed with a quick-setting temporary filling (Cimpat; Septodont Brazil Ltda., Barueri, Brazil).

The teeth were placed at 37°C and 95% humidity after a time period three times greater than the regular setting time of the sealer (24 h for AH Plus and Sealer 26) and then subjected to the bond strength test. The roots were then fixed on acrylic plates with wax (Kota Import, São Paulo, Brazil) and sectioned with a precision cutting machine

(Isomet 1000; Buehler, Lake Forest, USA) at 300 rpm. One slice from each third was selected for the push-out test in an Instron 4444 universal testing machine (Instron Corp., Canton, USA) at a crosshead speed of 0.5 mm/minutes. A stainless steel support was used to hold the specimens such that the side of the root canal with a smaller diameter faced upwards and was aligned with the shaft that would exert pressure load on the sealer (apico-coronally). Four-mm-long shafts with tip diameters of 1 mm, 0.6 mm, and 0.4 mm were used in the coronal, middle, and apical thirds, respectively.

Tension (r in MPa) was calculated by dividing the force needed to dislodge the filling material (F in kN) of sealer bonding area (SL in mm^2), using the following equation: r = F/SL. The sealer bonding area (SL) was calculated using the following equation: SL = p (R + r) g, where p = 3.14, R = mean radius of the coronal canal in mm, r = mean radius of the apical canal in mm, and g = height relative to the tapered inverted cone in millimeters. The mean values of push-out bond strength were analyzed statistically. The Kolmogorov–Smirnov test showed that the data followed the normal distribution. Therefore, the statistical analysis was carried out using a parametric three-way analysis of variance (root canal filling technique, filling material, and root third) and post-hoc Tukey's test with the significance level fixed at 5% (SPSS 17.0; SPSS Inc., Chicago, USA).

After completion of the push-out test, the specimens were examined with a stereomicroscope (Stemi 2000-C; Carl Zeiss, Jena, Germany) at 25 × magnification and the failure modes (adhesive, cohesive, or mixed) that occurred because of displacement of the sealer from the specimen were evaluated. Failure was considered adhesive if the sealer was totally separated from dentine (dentine surface without sealer), cohesive if the fracture occurred within the sealer (dentine surface totally covered by the sealer), and mixed, when a combination of adhesive and cohesive modes (dentine surface partially covered by the sealer) occurred.

Results

When considering the root canal filling techniques, the bond strength (MPa) of LC (1.80 ± 0.98) ($p < 0.05$) was significantly higher than that of THT (1.16 ± 0.50) and SC (0.92 ± 0.25). Tukey's test demonstrated that AH Plus/LC (2.26 ± 1.15) showed the highest values for the interaction between techniques and sealers and was statistically different from the others ($p < 0.05$). Sealer 26/LC (1.34 ± 0.42) showed intermediate values and was similar ($p > 0.05$) to AH Plus/THT (1.32 ± 0.61), which in turn was similar to Sealer 26/THT (1.00 ± 0.27) (Table 1). The SC technique exhibited the lowest values for bond strength with AH Plus (0.48 ± 0.13) and Sealer 26 (0.30 ± 0.12), which were similar to each other ($p > 0.05$). The comparison between the root canal thirds revealed a significantly higher bond strength in the coronal third (1.45 ± 1.14) ($p < 0.05$) than in the middle (1.20 ± 0.72) and apical thirds (0.92 ± 0.81).

The analysis of the failure modes (Table 2) showed that, regardless of the sealer used, the specimens

Table 1. Bond strength mean values and standard deviations (in MPa) according to the filling technique and sealer used.

Filling technique	Sealer Material	Bond Strenght*
Cold lateral compaction (LC)	AH Plus	2.26 ± 1.15 a
	Sealer 26	1.34 ± 0.42 b
Tagger's hybrid technique (THT)	AH Plus	1.32 ± 0.61 b
	Sealer 26	1.00 ± 0.27 b
Single-cone technique (SC)	AH Plus	0.48 ± 0.13 c
	Sealer 26	0.30 ± 0.12 c

* Different letters indicate statistical significance ($p < 0.05$).

Table 2. Distribution of failure modes (%) after the push-out test for each type of root canal filling technique/sealer.

Filling Technique / Sealer	AH Plus			Sealer 26		
	Failure Mode			Failure Mode		
	Adhesive	Cohesive	Mixed	Adhesive	Cohesive	Mixed
Cold lateral compaction (LC)	0	70	30	0	60	40
Tagger's hybrid technique (THT)	20	30	50	30	30	40
Single-cone technique (SC)	80	0	20	80	0	20

filled by LC predominantly demonstrated cohesive failure; specimens filled by THT and SC showed mixed failure and adhesive failure, respectively.

Discussion

During obturation, the sealer penetrates into the dentinal tubules and gives rise to a mechanical interlocking between the sealer and dentin.[13] The ability of root canal sealers to penetrate to dentinal tubules is related to their physical and/or chemical properties.[14,15] Therefore, various techniques have been studied in order to identify the optimal root canal obturation system, of which LC, SC, and THT present good standards for clinical use.

The bond strength of the filling material was evaluated using the push-out test. This test represents a reliable and reproducible method that simulates clinical conditions, i.e., the failure occurs parallel to the dentin/material interface.[16,17] In the present study, to evaluate the material dislocation resistance, three points with different diameters were used. The point's diameter was slightly smaller than each root canal third slice, which allowed the point to be fitted to the filling material, leading to more accurate results. The epoxy-based sealers used here were previously shown to have satisfactory physicochemical properties[15,18,19] and root canal bond strength.[20]

In the present study, cold lateral compaction had the highest bond strength. These results could be related to the pressure provided by the spreaders over the master and accessory cones, which can create forces in lateral and apical directions and can favor the sealer interlocking with the dentin irregularities and/or tubules. Alternatively, the single-cone technique probably generates forces mainly in the apical direction. Corroborating this hypothesis, this technique had the lowest bond strength values. Furthermore, the root canal anatomy variations can overlap the files' shaping ability, which can negatively affect the cone adaptation.[5] However, the evaluation of this condition wasn't included in our aims and should be further evaluated with different methods.

The thermoplasticized GP cones negatively affected the root canal bond strength of epoxy-based sealers. The flowability and longer polymerization time of epoxy resin-based sealers allow them to penetrate deeper into the irregularities,[1,6,8] thus enhancing the mechanical interlocking between the sealer and dentine.[11] However, our results showed a significantly lower dentin bond strength with Sealer 26. These results could be related to the sealer's composition. Sealer 26 has calcium hydroxide, which reduces its flowability[21] and the capacity to fill dentin irregularities,[22] and the bond strength as shown in the present study. Differently, AH Plus has a hard polymeric chain formed by diepoxy molecules and polyamines,[18,19]which increases its bond strength to the radicular dentin even upon cold lateral compaction.

Regardless of the sealer type and properties, thermoplastic filling techniques allow the filling of irregularities in the root canal wall with minimal amount of sealer mixed in the filling material.[6,23] However, the frictional heat generated during THT alters the physicochemical properties of epoxy-based sealers and resin organic matrix,[10,24] thus, negatively affecting the bond strength of the filling material to the radicular dentin. Additionally, GP cones may cool faster than the sealer, creating gaps in the filling mass and union interface.[8] This may have contributed to the results, unlike what occurred in the LC technique where there is no heating of the filling mass.[3]

The root thirds may differ structurally with respect to canal geometry and collagen/mineral content.[25] In this study, a higher bond strength was observed in the cervical third than in the middle or apical thirds, regardless of the filling technique and/or sealer used. This could be associated with the higher sealer volume and/or penetration into the less mineralized cervical dentin.[25] Our results also showed a direct relation between the filling technique and the sealer bond strength. Further studies are necessary to elucidate the effects of root canal filling techniques on sealer penetration and its relation to dentin bond strength.

Conclusion

Our results indicate that the filling technique affects the bond strength of epoxy resin-based sealers, with the single-cone technique being associated with lower bond strength of the materials to intra-radicular dentine.

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