

ORIGINAL ARTICLE

Thermocompaction decreases long-term push-out bond strength of methacrylate-based sealers

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Abstract

Purpose. The purpose of this study was to evaluate the immediate and long-term bond strengths to root dentin of Epiphany/Resilon and AH Plus/gutta-percha fillings, after using either lateral condensation or Tagger's hybrid thermomechanical compaction techniques. **Materials and methods.** Eighty human single-rooted teeth were used. The root canals were prepared by means of hand crown-down technique up to a #45 K-file and irrigation with 1% sodium hypochlorite was performed. Samples were randomly divided into eight ($n = 10$) experimental groups divided according to filling material (gutta-percha/AH Plus and Resilon/Epiphany), obturation technique (Lateral compaction and Tagger's hybrid thermomechanical compaction) and storage time (24 h and 6 months). During storage, the samples were kept at 37°C and 100% humidity. After the two experimental periods, each root was sectioned perpendicular to its long axis into three serial slices and push-out tests were carried out using a universal testing machine. Statistical significant differences were set by ANOVA and Tuckey *post-hoc* ($p < 0.05$). **Results.** Using thermocompaction technique, the samples filled with Epiphany/Resilon decreased significantly the bond strength after a 6 months storage-period ($p < 0.05$) and the ones filled with AH Plus/gutta-percha presented a tendency to lower values of the push-out test, although not statistically significant. For both materials, dentin bond strength of the specimens filled by means of lateral condensation remained stable throughout the experimental periods. **Conclusion.** Under the limitations of the current study, it can be concluded that the thermocompaction technique and the storage time can influence push-out bond strength when used with methacrylate-based sealers.

Key Words: bond strength, endodontics, push-out test, root canal filling materials

Introduction

A successful endodontic treatment basically depends on the adequate management of intra-canal infection. Thus, after cleaning and shaping procedures, a complete and three-dimensional sealing of the root canal system is critical to prevent oral pathogens from colonizing and re-infecting the endodontic space [1–3]. For root canal obturation, the sealer—usually employed in conjunction with a thermoplastic core material—has a role in preventing gaps and voids and in providing hermetic fillings.

In order to achieve these goals, endodontic sealers should ideally assemble flow, dimensional stability and adhesion properties [4]. Moreover, especially when the placement of an intra-canal retainer is required, the sealer should bond with the dentinal walls and to the core material. In this regard, sealers with high bond strengths improve the tooth resistance to fracture [5,6] and avoid root canal fillings to be dislodged during post space preparation, favoring the maintenance of the sealing quality [7].

To cope with the features cited above, a range of endodontic materials has been developed. Amongst

them, the epoxy-resin-based sealer AH Plus (Dentsply-Maillefer, Ballaigues, Switzerland) is used in conjunction with gutta-percha cones and appears to provide long-term dimensional stability and improved adhesion to root canal walls when compared to other commonly employed endodontic sealers [8–10]. Nevertheless, some authors pointed out that AH Plus presents low adherence to gutta-percha [9,10].

Differently, the dual-curing dimethacrylate-resin-based sealer Epiphany (Pentron Clinical Technologies, Wallingford, CT) was developed to be associated with a self-etching primer and with a dimethacrylate-containing polycaprolactone-based thermoplastic core material (Resilon Research LLC, Madison, CT). Epiphany adjunctive use with Resilon purportedly creates a monoblock between root canal dentin and the root-filling material [6,11–13], which is claimed to enhance sealing. On the other hand, long-term dimensional stability of these obturation materials has been questioned [14]. Considering that methacrylate resin-based sealers are hydrophilic, the issue of water sorption became a concern and some studies have reported that polymers degrade over time through physical and chemical processes [6,14].

Apart from the filling materials, several techniques have been developed for root canal obturation. Cold lateral condensation is the most taught and practiced filling technique [15]. However, its ability to adjust to the root canal system is questionable, since the occurrence of voids, spreader tracts and incomplete cones fusion has been reported [16,17]. A large range of techniques for thermoplastification of filling materials has been suggested [18]. Besides providing increased volumetric changes and a better adaptation of root canal fillings, these techniques appear to reduce sealer to gutta-percha ratio in the root canal filling which could promote the long-term seal [19]. Among these techniques, Tagger's hybrid thermomechanical compaction is one of the most propagated, enabling both gutta-percha and Resilon to be plasticized through heating, with similar melting points [2,3].

Recently, the effect of thermomechanical compaction in the ability to bond to dentin has been considered as a matter of concern for endodontic filling materials [20]. Moreover, to the best of the authors' knowledge, no study compared the long-term push-out bond strength of different sealers, core materials and obturation techniques. Therefore, the aim of this study was to evaluate Epiphany/Resilon and AH Plus/gutta-percha bond strengths to dentin, observing the influence of obturation technique (cold lateral condensation or Tagger's hybrid thermomechanical compaction) and time (24 h and 6 months after root canal fillings) on the push-out test outcomes.

Materials and methods

This study was approved by ethics and research committees (20620) of the Federal University of Rio Grande do Sul (UFRGS). Eighty human single-rooted premolar mandibular teeth, provided by UFRGS institutional bank of teeth, were selected. Buccolingual and mesiodistal radiographs were obtained to ensure the presence of a single root canal. Teeth presenting previous endodontic manipulation, incomplete root formation, calcifications and/or root resorption were excluded. The selected teeth were immersed in 5.25% sodium hypochlorite for 2 h and then dental crowns were sectioned below the cementum–enamel junction.

Root canal preparation

A single trained operator performed the canals instrumentation. The teeth were placed in a metallic device to ensure standardized manipulation. After defining apical patency with a #15 K-file (Dentsply Maillefer, Ballaigues, Switzerland), the working length (WL) was visually established, being set at 1 mm from the apical foramen. In all samples, the root canals were prepared with hand crown-down technique. The adopted technique allowed the standardization of the apical enlargement (up to a #45 endodontic file). During preparation, at each change of instrument, root canals were irrigated with 2 ml of 1% NaOCl (Biodinâmica Quim. Farm. LTDA, Ibioporã, Brasil). A final rinse with 2 ml of 17% ethylenediaminetetraacetic acid (EDTA) (Biodinâmica Quim. Farm. LTDA) for 3 mins was performed. Then, the root canals were flushed with saline and dried using paper points. For Epiphany/Resilon groups, only excess of saline was removed.

Root canal fillings

For root canal fillings, samples were randomly divided into eight ($n = 10$) experimental groups, according to the obturation materials (AH Plus/gutta-percha or Epiphany/Resilon), technique employed (lateral compaction or Tagger's hybrid thermomechanical compaction) and to the storage time after obturation (assessment of push out bond strengths 24 h or 6 months post-endodontic fillings) (Figure 1).

A pre-fitted master cone coated with sealer (prepared as recommended by the manufacturer) was inserted into the root canal until being adapted at the entire WL. For the Epiphany system, prior to the master cone placement, the primer (Epiphany Primer, Pentron) was placed into the canal with a syringe, it remained for 30 s and the excess was removed with paper points.

For the groups in which lateral compaction was employed, canal fillings were achieved using

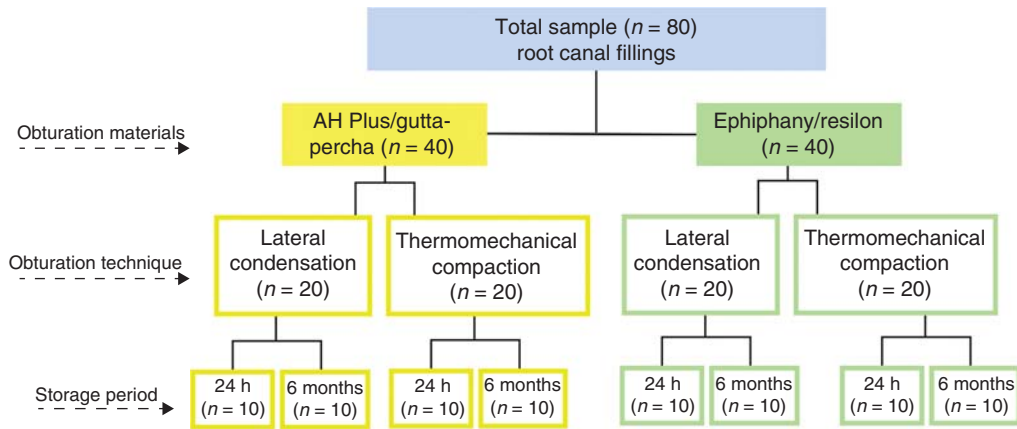


Figure 1. Flow chart of procedures.

accessories cones coated in sealer and size B endodontic finger spreaders (Dentsply-Maillefer, Ballaigues, Switzerland). A heated instrument was used to cut the coronal surplus and the filling was vertically compacted.

For the groups in which Tagger's hybrid thermomechanical compaction was used, after the placement of a master apical cone, two accessories cones coated with sealer were introduced into the root canal to fill the canal apical third. Then, the middle and cervical thirds were filled using #55 thermomechanical compactors (Dentsply-Maillefer, Ballaigues, Switzerland) coupled to a low-speed handpiece. The compactor was used in a clockwise direction and with brush-stroke movements toward the apical third, 3 mm short of the apical stop [21].

Furthermore, for the samples obturated with Epiphany/Resilon, a LED curing light with 950 mW/cm² (SmartliteTM PS, De Trey-Dentsply, Konstanz, Germany) was applied after root canal fillings, to create an immediate coronal seal. The light guide tip was kept for 40 s in contact with the coronal portion of the root.

After obturation, buccolingual and mesiodistal radiographs were taken to evaluate the quality of the filling. Homogeneity and apical extension were considered. If voids, gaps or incomplete root canal fillings were detected, the samples were excluded.

Push-out bond strength

Following canals obturation, the samples were placed at 37°C and 100% humidity. After the pre-determined experimental times (24 h or 6 months) each root was sectioned perpendicular to the long axis into three serial slices with nearly 0.7 mm thickness, using a low-speed saw under water cooling (Isomet, Buehler Ltd., Lake Bluff, IL). Thirty slices per group (three per sample) were obtained from the cervical/middle thirds. The apical and cervical diameter, as well as the filling material thickness, was measured with a digital caliper.

The micro push-out tests were performed at a cross-head speed of 1 mm/min and 500 N load using a universal testing machine (DL-2000, EMIC, São José dos Pinhais, Brazil). The plunger tip was sized and positioned to touch only the filling material, without contacting the canal walls. The load was applied on the apical aspect of the root slice to avoid any limitation to filling material movement because of the canal taper. The peak force, at the point of extrusion of the root filling from the slice, was taken as the point of bond failure and recorded in Newtons (N). To express the bond strength in MPa, the load value was divided by the area of the bonded interface. The interfacial area of the root filling was approximated by the following formulae, where g was the taper, R was the radius in mm, h was the root slice thickness in mm and A was the area in mm². The bond was considered to have failed when filling material was extruded from the root section.

$$g = \left(h^2 + (R_2 - R_1)^2 \right)^{1/2}$$

$$A = \pi \cdot g (R_1 + R_2)$$

Values of bond strength were analyzed by one-way analysis of variance and the post-hoc Tukey's test, with significance level of 5%.

After the test, the samples were verified under a 20× magnification stereoscope (Carl Zeiss, Oberkochen, Germany) to observe the failure modes (cohesive, adhesive and mixed).

Results

Push-out test mean values and standard deviations for each group are given in Table I. The results indicated that thermocompaction filling technique decreased push-out bond strength after 6 months of storage when used with methacrylate-based sealers

Table I. Push-out bond strength mean and standard deviation, in MPa, of the groups.

Groups	24 h	6 months
Resilon/Epiphany L	7.56 (± 5.31) ^{AB}	5.59 (± 4.48) ^{AB}
Gutta-percha/AH Plus L	4.63 (± 4.32) ^{AB}	5.29 (± 2.94) ^{AB}
Resilon/Epiphany T	9.78 (± 6.05) ^A	1.74 (± 2.52) ^B
Gutta-percha/AH Plus T	7.12 (± 3.36) ^{AB}	3.61 (± 2.75) ^B

Values with the same superscript letters are not statistically different. ANOVA ($p = 0.005$), Tukey ($p < 0.05$). L, Lateral compaction; T, Tagger's hybrid thermomechanical compaction.

($p < 0.05$) and the samples filled with AH Plus/gutta-percha, although not statistically significant.

For both materials, dentin bond strength of the specimens filled by means of lateral condensation remained stable throughout the experimental periods.

Regardless of the technique and experimental period, mixed failures (cohesive and adhesive) predominated in most samples (Figure 2). At the 6 months experimental period, six samples of Epiphany/Resilon presented pre-testing failures when used thermocompaction filling technique and, in these cases, the bond strength were taken as 0 MPa.

Discussion

The present study points out a clinically relevant, but often forgotten, issue: apart from the filling materials, the obturation technique and the period elapsed after root canal fillings have an influence on bond strength to dentin. According to the current results, after thermomechanical compaction, there is a tendency to progressive reduction of bond strength to dentin and a more striking influence of time was observed for Epiphany/Resilon than to AH Plus/gutta-percha fillings.

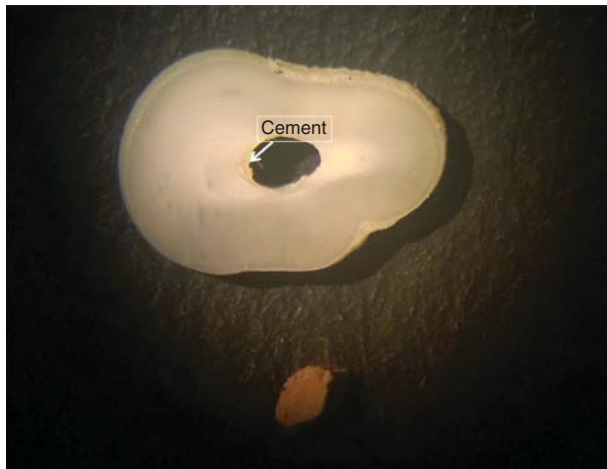


Figure 2. Representative image of a mixed failure.

On the other hand, in specimens filled by means of lateral condensation, dentin bond strength remained stable when AH Plus/gutta-percha were used, while for Epiphany/Resilon a less pronounced reduction occurred over time compared to the thermomechanical technique.

Regarding the influence of obturation techniques on the values of push-out test, a recent study [20] also revealed that lateral condensation is associated with higher bond strengths of the materials to intraradicular dentine than a hybrid technique using thermomechanical compaction.

The poor dimensional stability of the Epiphany system has already been claimed to explain its reduced sealing capacity in long-term evaluations [22] and probably have also influenced the reduction in bond strength to dentin over time. Previous studies showed that a progressive degradation of interface occurs in Epiphany/Resilon fillings due to unbound water entrapped at the bulk of material [23]. Hydrophilic monomers are incorporated in methacrylate resin-based sealers to facilitate resin penetration into dentinal tubules. These materials absorb water and release unreacted monomers, resulting in deterioration of their physical/mechanical properties, which leads to a decreased life expectancy of interfaces through hydrolysis and microcrack formation [13,24,25]. These features promote high values of the sealer solubility [25,26], which, together with the requirement of using a hydrophilic primer prior to endodontic fillings, partially explain the current results.

Two forms of heat generation are applied when the Tagger hybrid technique is used for Epiphany/Resilon fillings. Beyond photoactivation for immediate coronal sealing, which already promotes heat, it is well established that warm obturation techniques can also accelerate polymerization of sealers [23].

In this way, the purpose for incorporating a delayed polymerization mechanism to prevent relief of polymerization stresses by slow flow [6,27] is not respected with the thermomechanical compaction technique. Accordingly, Nagas et al. [28] suggested that reduced polymerization time adversely affects methacrylate-based sealers' bond strength to dentine, leading to an interface more prone to degradation. The photoactivation withholds the resin viscous flow and increases polymerization stress [29], which is already very high due to the C-factor and geometric shape of root canals [30–33]. This can also explain the reason for premature failure (obturation mass displaced before testing) in some samples of Epiphany/Resilon using thermomechanical compaction. Similar aspects occurred in the study of Gesi et al. [34] after 24 h of setting.

On the contrary, AH-Plus is reported to present adequate long-term dimensional stability, because this sealer suffers expansion over time [9], which

may have contributed to a less expressive reduction of bond strength in samples filled by means of after 6 months when compared to the Epiphany system.

The push-out test can be used to measure the interfacial shear strength developed between different surfaces, providing additional information on the evaluation of adhesion properties [8]. In this test, failure occurs parallel to the sealer–dentin interface, estimating bonding effectiveness in such a way that is similar to clinical conditions [12,35,36]. In this regard, during post-space preparation, endodontic fillings bond strength can affect the resistance to displacement, creating voids in the obturation and compromising the maintenance of sealing integrity [7,37,38].

In addition, according to Pane *et al.* [39], the plunger tip can also compromise the standardization of the push-out test. The variations of specimen geometry and the decreasing canal diameter from coronal to apical may influence the results. The punch needs to match the canal diameter, being only slightly smaller, to ensure the biomechanical behavior of bond strength tests [39].

Conclusion

Under the limitations of the current study, it can be concluded that the thermocompaction technique and the storage time can influence push-out bond strength when used with methacrylate-based sealers.

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