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Push-out bond strengths: the Epiphany–Resilon endodontic obturation system compared with different pairings of Epiphany, Resilon, AH Plus and gutta-percha

M. Ungor[1], E. O. Onay[1] & H. Orucoglu[2]

[1]Department of Endodontics, Faculty of Dentistry, Baskent University, Ankara; and [2]Department of Endodontics, Faculty of Dentistry, Selcuk University, Konya, Turkey

Abstract

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Aim To assess the bond strength of the new resin-based Epiphany–Resilon root canal filling system, and to compare this with bond strengths of different pairings of AH Plus, gutta-percha, Epiphany and Resilon.

Methodology A total of 65 extracted human single-rooted teeth were used. All teeth were instrumented using a set of ProTaper rotary instruments. Irrigation was performed with 15 mL of 1.25% NaOCl between each instrument and the smear layer was removed during and after instrumentation with 5 mL of 17% EDTA. The canal spaces were filled with different combinations of core and sealer using lateral condensation, as follows: group 1, AH Plus + gutta-percha; group 2, AH Plus + Resilon; group 3, Epiphany + Resilon; group 4, Epiphany + gutta-percha; group 5 (control), gutta-percha only. Cylinders of root dentine 1.13 (0.06)-mm long were prepared from the coronal sections of the 65 teeth. The test specimens were subjected to the push-out test method. After adhesion testing, the remaining sections were examined under a stereomicroscope at × 25 magnification to determine the nature of bond failure. The values of bond strength were analyzed by one-way analysis of variance (ANOVA) and the *post hoc* Tukey's test, with significance set at $P < 0.05$.

Results The respective mean push-out test values for groups 1–5 were: 2.000 ± 0.369, 1.380 ± 0.154, 1.706 ± 0.340, 2.857 ± 0.523 and 0.078 ± 0.027 MPa. Significant difference ($P < 0.001$) occurred between the groups. Multiple paired comparisons (Tukey's test) revealed that group 4 (Epiphany + gutta-percha) had significantly ($P < 0.001$) greater bonding strength than all the other groups; group 1 (AH Plus + gutta-percha) had significantly ($P < 0.05$) greater bonding strength than group 2 (AH Plus + Resilon); and group 5 (control) had significantly ($P < 0.05$) lower bonding strength than all the other groups. Inspection of the surfaces revealed the bond failure to be mainly adhesive to dentine for all groups.

Conclusions The Epiphany–Resilon combination (group 3) was not superior to that of the AH Plus-gutta percha combination (group 1).

Keywords: AH Plus, bond strength, Epiphany, push-out, Resilon.

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Correspondence: Emel Olga Onay, DDS, Department of Endodontics, Faculty of Dentistry, Baskent University, 11. sok. No: 26 06490 Bahcelievler, Ankara, Turkey (Tel.: +90 312 2151336; e-mail: eonay@baskent.edu.tr).

Introduction

The bond strength of root canal sealers to dentine is important for maintaining the integrity of the seal in root canal filling (Tagger *et al.* 2002). Anusavice

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(1996) defines adhesion as the force that binds two substances that are brought into intimate contact, and specifies that adhesion is the result of attraction amongst molecules. A better term for this process might be 'mechanical bonding', which implies that the attachment between the substances is not caused by molecular attraction but by mechanical interlocking.

The materials and techniques currently used for adhesive bonding to dentine in restorative dentistry have been developed over many years. The latest-generation dentine bonding systems achieve high bond strength and reduced microleakage by micromechanical bonding or by forming a hybrid layer between the dentine and the resin (Nakabayashi 1985). Studies have examined the potential of adhesive resins as root canal filling materials (Leonard *et al.* 1996, Ahlberg & Tay 1998). According to the findings, all bonding agents and resins that have been investigated as root filling materials have deficiencies related to working properties, radiopacity and lack of removability (Zidan & ElDeeb 1985, Leonard *et al.* 1996, Ahlberg & Tay 1998).

Recently, Resilon Research LLC (Madison, CT, USA) introduced Resilon obturating points and resin sealer. This product is used in combination with a self-etching primer to create a solid monoblock. Resilon is a thermoplastic synthetic resin material that is based on polymers of polyester and contains a bifunctional methacrylate resin, bioactive glass and radiopaque fillers (Shipper *et al.* 2004). The resin sealer, Epiphany Root Canal Sealant (Pentron Clinical Technologies, Wallingford, CT, USA), contains bisphenol-A diglycidyl dimethacrylate (BisGMA), ethoxylated BisGMA, urethane dimethacrylate, hydrophilic difunctional methacrylates, silane-treated barium borosilicate glasses, barium sulfate, silica, calcium hydroxide, bismuth oxychloride with amines, peroxide, photo initiator, stabilizers and pigment (Teixeira *et al.* 2004). The primer is an aqueous solution of an acidic monomer. The system also includes pellets that can be used for backfilling in thermoplasticized techniques.

The purpose of this study was to assess the bond strength of the new resin-based Epiphany–Resilon root canal filling system, and to compare with bond strengths of different pairings of AH Plus, gutta-percha, Epiphany and Resilon. The null hypothesis tested was that there is no difference in the bond strength of Epiphany–Resilon combination and AH Plus-gutta percha combination to dentine.

Materials and methods

A total of 65 extracted human single-rooted teeth were used. Each tooth was placed in sodium hypochlorite for 2 h for surface disinfection, and then stored in distilled water until use. The crown of each tooth was sectioned at the amelo-cemental junction using a water-cooled diamond disk. The working length was determined visually by subtracting 1 mm from the length of a size 10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) at the apical foramen. The middle and coronal thirds were prepared using ISO size 50, 70, 90 and 110 Gates Glidden drills (Produits Dentaires S.A., Vevey, Switzerland) with a low-speed handpiece to a depth of 5 mm.

All teeth were instrumented using a set of ProTaper rotary instruments (Dentsply Maillefer) including S1, S2, F1, F2 and F3. Fifteen millilitres of 1.25% NaOCl was used for irrigation between each instrument. The smear layer was removed during and after instrumentation with 5 mL of 17% EDTA (pH 7.4). Finally, the root canals were flushed with 3-mL distilled water and dried with paper points before filling.

The roots were divided randomly into five groups (four experimental groups of 15 roots each and one control group of five roots) and filled as follows:

Group1: The roots were filled with AH Plus sealer (Dentsply De Trey GmbH, Konstanz, Germany) and 0.04 taper gutta-percha (Diadent, Chongju, Korea) using the cold lateral condensation technique.

Group2: The roots were filled with AH Plus sealer and 0.04 taper Resilon points (Pentron) using the cold lateral condensation technique.

Group3: After instrumentation, a self-etching primer (Epiphany Primer; Pentron) was placed into the canal with a syringe. The primer was allowed to remain for 30 s and the excess was removed with paper points. Roots were filled with Epiphany sealer (Pentron) and 0.04 taper Resilon points using the cold lateral condensation technique.

Group4: The roots were prepared with the primer as in group 3 and then filled with Epiphany sealer and .04 taper gutta-percha using the cold lateral condensation technique.

Control group: The roots were filled with 0.04 taper gutta-percha using the cold lateral condensation technique.

The roots in groups 3 and 4 were light-cured for 40 s to create a coronal seal according to manufacturer's recommendations. All 65 roots were stored in gauze

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dampened with sterile saline and enclosed in sealed tubes for 7 days to allow the sealer to set.

Preparation of roots for push-out bond strength testing

The coronal portion just below the amelo-cemental junction of each root was sectioned perpendicular to its long axis to create 1.13 (0.06)-mm slices using a water-cooled diamond blade on an Isomet machine (Buehler, Lake Bluff, IL, USA). The apical portion of each root was preserved for measurement of apical microleakage in another investigation.

After measuring the thickness of each slice with digital calipers, the filling material was loaded with a 1-mm diameter cylindrical plunger. The plunger tip was sized and positioned such that it touched only the filling material and did not stress the surrounding root canal walls (Fig. 1). Loading was performed on a testing machine (Bencor-Multi T, Danville Engineering Co., Danville, CA, USA) at a speed of 1 mm min^{-1} until bond failure occurred. The bond was considered to have failed when filling material was extruded from the root section.

To express the bond strength in MPa, the load at failure recorded in Newtons was divided by the area of the bonded interface [as calculated by the following formula (Goracci *et al.* 2004): $A = 2\pi\, r \times h$, where π is the constant 3.14, r is the root canal radius, and h is the thickness of the slice in millimetres].

After adhesion testing, the remaining sections were split longitudinally in buccolingual direction using a diamond disk and dentine surfaces were examined under a stereomicroscope at $\times$ 25 magnification to determine the nature of bond failure: cohesive within the filling material or adhesive at the filling material–dentine interface.

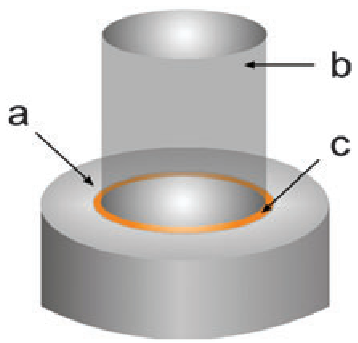

Figure 1 Schematic representation of the push-out test. (a) Root dentine cylinder. (b) Cylindrical plunger. (c) Root canal sealer and core material.

The values of bond strength were analyzed by one-way analysis of variance (ANOVA) and the *post hoc* Tukey's test, with significance set at $P < 0.05$.

Results

The mean push-out test values for each group were as follows: group 1 (AH Plus + gutta-percha) 2.000 ± 0.369 MPa; group 2 (AH Plus + Resilon) 1.380 ± 0.154 MPa; group 3 (Epiphany + Resilon) 1.706 ± 0.340 MPa; group 4 (Epiphany + gutta-percha), 2.857 ± 0.523 MPa; group 5 (gutta-percha control), 0.078 ± 0.027 MPa. ANOVA revealed a significant difference amongst the groups ($P < 0.001$). Multiple paired comparisons (Tukey's test) showed that group 4 (Epiphany + gutta-percha) had significantly greater ($P < 0.001$) bonding strength than all the other groups; group 1 (AH Plus + gutta-percha) had significantly greater ($P < 0.05$) bonding strength than group 2 (AH Plus + Resilon); and group 5 (control) had significantly lower ($P < 0.05$) bonding strength than all the other groups.

Inspection of the surfaces revealed that the bond failure was mainly adhesive to dentine for all groups meaning that the dentine surface appeared clean and devoid of sealer.

Discussion

Adhesion of root canal filling material to dentinal walls is important in both static and dynamic situations. In a static situation, it should eliminate any space that allows the percolation of fluids between the filling and the wall (Ørstavik *et al.* 1983). In a dynamic situation, it is needed to resist dislodgement of the filling during subsequent manipulation (Stewart 1958).

Bond-strength testing has become a popular method for determining the effectiveness of adhesion between endodontic materials and tooth structure. There are many methods for measuring the adhesion of endodontic root canal sealers, but none has yet been widely accepted (Gogos *et al.* 2004). The tensile strength test is sensitive, with the result that small alterations in the specimen or in stress distribution during load application have a substantial influence on the results (Van Noort *et al.* 1991). On the other hand, a major problem with shear testing is that it is difficult to closely align the shear-loading device with the bond interface. The load is offset at some distance from the bonded

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interface, resulting in unpredictable torque loading on the specimen (Watanabe *et al.* 2000).

In this study, the push-out test method was used to test the dentine bond strengths of different root canal sealers. Extrusion testing in dentistry was first described by Roydhouse (1970). Kimura (1985) concluded that push-out testing tended to reduce the values for bond strength to dentine. Haller *et al.* (1991) re-introduced the push-out test and the testing procedure selected for the present investigation used that model. The model has been shown to be effective and reproducible (Haller *et al.* 1993). Another advantage of this method is that it allows root canal sealers to be evaluated even when bond strengths are low.

During chemo-mechanical preparation, a layer of debris, the smear layer, is formed. Current theories of dentine bonding mechanisms involve either chemical modification of the smear layer and bonding directly to it, or removal of the smear layer and bonding to subjacent tooth structures (Yu *et al.* 1993). Some studies have shown that removal of the smear layer enhances the adhesion of sealers to the root canal wall (De Gee *et al.* 1994, Pecora *et al.* 2001).

The smear layer can act as a reservoir or substrate for microorganisms (Pashley 1984), and can also block the extension of sealer tags into the dentinal tubules, thereby decreasing micromechanical adhesion (Kouvas *et al.* 1998). In the current study, 17% EDTA was used during and after instrumentation to remove the smear layer.

All five of the groups tested showed measurable adhesive properties. The Epiphany sealer and gutta-percha core combination (group 4) had the highest bond strength, whereas the AH Plus sealer and Resilon core combination (group 2) had the lowest values. Interestingly, the Epiphany sealer and Resilon core combination (group 3) showed lower bond strength values than expected. One possible explanation is that gutta-percha is a more compactable than Resilon, and thus helps resist dislodgment.

The bond strength of the AH Plus sealer and gutta-percha core combination (group 1) showed higher bond strength than the Epiphany sealer and Resilon core combination (group 3). The result is similar to the findings of Gesi *et al.* (2005) who used the same methodology.

When the results for groups with the same core material were compared (Table 1), the Epiphany sealer and gutta-percha core combination had significantly higher bond strength than the AH Plus sealer and gutta-percha core combination. In line with this, the Epiphany sealer and Resilon core combination had higher bond strength than the AH Plus sealer and Resilon core combination; however, this difference was not significant.

Table 1 Mean push-out bond strengths (MPa) (+ SD) for the experimental and control groups. Groups identified with the same superscript letters (a,b,c) are not statistically significant ($P > 0.05$)

Material	n	Mpa (mean values) ± SD
Group II AH Plus + Resilon	15	$1.3800^{a} \pm 0.154$
Group III Epiphany + Resilon	15	$1.7059^{a,b} \pm 0.340$
Group I AH Plus + gutta-percha	15	$2.0004^{b} \pm 0.369$
Group IV Epiphany + gutta-percha	15	$2.8569^{c} \pm 0.523$
Controls (gutta-percha only)	5	0.778 ± 0.027

After adhesion testing, the remaining sections were split longitudinally in a buccolingual direction using a diamond disk and were examined under a stereomicroscope at × 25 magnification to determine the nature of bond failure. Inspection of the surfaces revealed that the bond failure to be mainly adhesive to dentine for all groups meaning that the dentine surface appeared clean and devoid of sealer. In general, high bond strengths of materials that are weakly adhesive to dentine exhibit cohesive failures (Lee *et al.* 2002). Based on the results of this study, it is reasonable to speculate that the Epiphany sealer bonded more strongly to Resilon than it did to dentine.

Numerous investigations have shown that the resin-based sealer AH Plus has higher bond strength than most other sealers (Wennberg & Ørstavik 1990, Gettleman *et al.* 1991, Pecora *et al.* 2001). In the present study, the AH Plus sealer and gutta-percha core combination (group 1) also showed good adhesion properties.

Adhesive strength is only one aspect of the quality of root canal sealing. Further investigation of other features of root canal sealers is required. In most cases, the results of laboratory experimental studies cannot be directly transposed to the clinical situation. However, they do provide reproducible and reliable means for comparing and testing new and prospective sealers, and for establishing international standards (Tagger *et al.* 2002).

Conclusions

Within the limits of the push-out test method, the Epiphany sealer and Resilon core combination was not superior to that of the AH Plus sealer and gutta-percha core combination.

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