Bonding of Self-adhesive (Self-etching) Root Canal Sealers to Radicular Dentin

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Abstract

The latest generation of methacrylate resin–based sealers has eliminated the use of separate self-etching primers by incorporating acidic resin monomers in the sealers to render them self-adhesive to dentin. This study examined the adhesive strengths, interfacial ultrastructure, and tracer penetration of a nonetching (EndoREZ; Ultradent, South Jordan, UT) and two self-adhesive methacrylate resin–based sealers (MetaSEAL; Parkell, Farmington, NY, and RealSeal SE; SybronEndo, Orange, CA) when they were applied to radicular dentin following the manufacturers' recommended use of EDTA as the active final rinse. A modified push-out testing design was used to evaluate the dislodgement of core-free sealers. The mixed sealers were placed in dimensionally identical, artificially created canal spaces prepared in the coronal, middle, and apical thirds of radicular dentin. After setting, each sealer-filled cavity was subjected to compressive loading until failure. Additional specimens were prepared for transmission electron microscopy to examine the ultrastructure and nanoleakage within the sealer-radicular dentin interface. The two self-adhesive sealers MetaSEAL and RealSeal SE exhibited higher push-out strengths than the nonetching sealer EndoREZ when EDTA was used as the active final rinse. All three sealers showed a 1- to 1.5-μm thick zone of partially demineralized dentin, with the EDTA dentin demineralization effect masking the true self-etching potential of MetaSEAL and RealSeal SE. The true self-etching potential of self-adhesive sealers is a clinically important attribute that should be further investigated. Incomplete smear layer removal from the apical third of instrumented canal walls may jeopardize the performance of self-adhesive sealers should they fail to self-etch without the adjunctive use of calcium chelating irrigants. *(J Endod 2009;35:578–582)*

Key Words

Adhesion, dislocation resistance, EDTA, hybrid layer, nanoleakage, push-out test, root canal sealers

Interests in adhesive endodontics (1) have led to the introduction of three generations of methacrylate resin–based root canal sealers. EndoREZ (Ultradent, South Jordan, UT), the first generation (2–4), uses nonacidic, hydrophilic resin monomers to enhance sealer penetration into dentinal tubules after the removal of canal wall smear layers (5, 6). The second generation (7–9) (eg, RealSeal; SybronEndo, Orange, CA) is technologically analogous to those resin-based luting cements that use separate self-etching primers (10, 11) before the application of flowable composites to the primed dentin. The use of self-etching primers reintroduces the concept of incorporating smear layers created by hand/rotary instruments in the sealer-dentin interface (12). Provided that they are aggressive enough to etch through thick smear layers (13), the technique sensitivity of bonding to root canals may be reduced when smear layers are inadvertently retained in the apical third of instrumented canal walls.

The third generation of methacrylate resin–based sealers (eg, MetaSEAL; Parkell, Farmington, NY, and RealSeal SE) (14, 15) is comparable to self-adhesive resin luting cements (16) in that both were designed with the intention of combining a self-etching primer and a moderately filled flowable composite into a single product. They represent a milestone in bonding step reduction, in that acidic resin monomers that are originally found in dentin adhesive primers are now incorporated into the resin-based sealer/cement to render them self-adhesive to dentin substrates.

There have been concerns regarding the limited aggressiveness of self-adhesive resin cements in creating micromechanical retention via dentin hybridization (17). This probably accounted for their weaker adhesive strengths and poorer marginal integrity when compared with conventional resin cements that use etch-and-rinse or self-etch adhesives for bonding (18–20). In theory, the bonding mechanism of self-adhesive sealers is similar to self-adhesive resin cements. However, the latter are used on smear layer–covered dentin, whereas the former are presumably applied to smear layer–depleted dentin after irrigation with EDTA. As EDTA demineralizes radicular dentin apart from removing smear layers (5, 6, 21), the adhesive mechanism of self-adhesive sealers may be different from the limited dentin hybridization observed for the self-adhesive resin cements. Thus, the objective of this study was to examine the adhesive strengths, interfacial ultrastructure, and tracer penetration of two self-adhesive methacrylate resin–based sealers when they are applied to radicular dentin following the manufacturers' recommended use of EDTA as the active final rinse.

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Materials and Methods

Simulated Canal Spaces

Forty-two human canine teeth were used in this study. A 0.90 ± 0.05-mm thick longitudinal tooth slice was prepared from each tooth using an Isomet saw (Buehler, Lake Bluff, IL) under water cooling. Simulated canal spaces were prepared in the coronal, middle, and apical thirds of the radicular dentin using the protocol introduced by Huffman et al (22). Briefly, a minidrill press was used to generate vertically oriented truncated cavities (Fig. 1*A*) that were enlarged with size 40, 0.04 taper ProFile rotary instruments (Dentsply Tulsa, Tulsa, OK) to their D_{16} diameter. Each cavity had standardized diameters of 0.94 mm and 1.04 mm along its top and base. The experimental design also ensured that the artificial canal spaces were devoid of calcospherites (23) that could have augmented a sealer's retention from the noninstrumented parts of a true root canal. Tooth slices were randomly divided into three groups. For each sealer, 20 simulated canal spaces from 10 slabs were used for evaluating the push-out strengths at three radicular dentin locations ($N = 20$).

Specimen Preparation

Two self-etching, dual-curable, methacrylate resin-based sealers were investigated. MetaSEAL uses 4-methacryloyloxyethyltrimellitate anhydride, and RealSEAL SE uses a polymerizable methacrylate carboxylic acid/anhydride as the respective acidic resin monomer. EndoREZ, a dual-curable sealer that contains nonacidic diurethane dimethacrylate and triethyleneglycol dimethacrylate, was used as the "nonetch" sealer for comparison.

Tooth slices were ultrasonicated in 6.15% sodium hypochlorite (NaOCl), 17% EDTA, and sterile distilled water for 2 minutes each to remove organic debris and smear layers. En masse cleaning ensured that potential differences in push-out strength at the three dentin locations were not caused by inadequate cleaning of the apical dentin. The cavities were bulk filled with sealer without a main thermoplastic core material, according to the method invented by Jainaen et al (24). The sealer-filled, glass slide–covered cavities were stored in light-protected humidors for 3 days until the sealers had completely set in the self-cured mode, simulating the curing condition encountered in the middle and apical thirds of true root canals.

Push-out Strength

Bonding of the set sealers to radicular dentin was evaluated with a thin-slice push-out test design (25, 26) using a custom-built, light-illuminated, Plexiform push-out device (Fig. 1*B*). The use of high-intensity fiberoptic illumination greatly enhanced the alignment of a 0.7-mm diameter plunger with the inverted truncated cavities, with a 0.1-mm clearance from either side of the dentinal wall (Fig. 1*C*). The fiberoptic illumination ensures that the sealer may be dislodged into the underlying cylindrical well without the plunger touching the cavity walls. Each sealer-filled cavity was subjected to compressive loading via a Vitrodyne universal testing machine (Liveco Inc, Burlington, VT) at a cross-head speed of 10 μm/sec until failure.

The circumferences of the coronal (C) and apical aspects (A) of each cavity were measured using image analysis software (Scion Corp, Frederick, MA). The sealer-dentin interfacial area was approximated by $0.5(C + A)h$, where h represents the tooth slice thickness. Push-out strength was computed by dividing the maximum load at failure by the interfacial area. Failure modes were classified as adhesive failure along the sealer-dentin interface, cohesive failure within the sealer, or mixed failure.

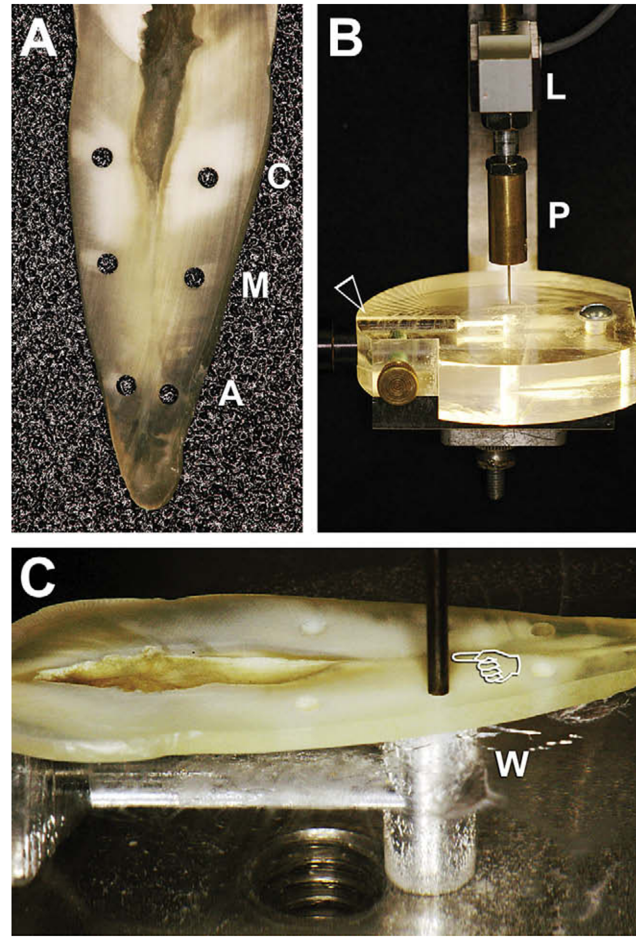

Figure 1. (*A*) Preparation of truncated cavities of uniform dimensions in radicular dentin. As slanted preparations are not amendable to push-out tests, a minidrill press was used for the preparation of a pilot hole and subsequently the attachment of rotary nickel titanium instruments to ensure that all cavities were created perpendicular to the tooth slice. Two tapered cavities each were prepared in the coronal (C), middle (M), and apical (A) thirds of a root slice. (*B*) Fiberoptic light-illuminated push-out testing device. A plunger (P), connected to a 10-kg load cell (L), is set up over the cylindrical well of a custom-built Plexiglas stage. The stage has a side channel (open arrowhead) for the insertion of a fiberoptic light guide. (*C*) Light illumination greatly simplifies the task of plunger (pointer) alignment with the center of an inverted truncated cavity in the tooth slice.

Statistical Analysis

Each sealer-filled hole was treated as a statistical unit. Because the normality and homoscedasticity assumptions of the push-out strength data appeared to be valid, they were analyzed using two-way analysis of variance, with sealer type and dentin location as independent variables. Post hoc comparisons were performed by using a Tukey test. Statistical significance was set at $\alpha = 0.05$.

Transmission Electron Microscopy

The remaining four slabs from each sealer group were filled with sealer as previously described. After setting, excess sealers were polished off to expose the sealer-dentin interfaces. For each sealer, two slabs were processed for examination of the ultrastructure of the sealer-dentin interface. They were fixed in Karnovsky's fixative and osmium tetroxide, dehydrated in an ascending ethanol series, transferred to propylene