Alternative Adhesive Strategies to Optimize Bonding to Radicular Dentin

Serge Bouillaguet, DMD, PhD, Bruno Bertossa, DMD,* Ivo Krejci, DMD, PhD,* John C. Wataha, DMD, PhD,[†] Franklin R. Tay, DMD, PhD,[†] and David H. Pashley, DMD, PhD[†]*

Abstract

This study tested the hypothesis that bond strengths of filling materials to radicular dentin might be optimized by using an indirect dentin bonding procedure with an acrylic core material. Roots of human teeth were endodontically prepared and obturated with EndoREZ, Epiphany, or the bonding of an acrylic point with SE Bond by using a direct or an indirect bonding technique. Bond strengths of endodontic sealers to radicular dentin were measured with a thin slice push-out test. Push-out strengths of EndoREZ and Epiphany to radicular dentin were less than 5 megapascals (MPa). The direct bonding technique with acrylic points and the self-etching adhesive had push-out strengths of 10 MPa, increasing to 18 MPa with the indirect technique. The use of the indirect bonding protocol with an acrylic point to compensate for polymerization stresses appears to be a viable means for optimizing bond strengths of endodontic filling materials to radicular dentin. *(J Endod 2007;33:1227–1230)*

Key Words

Bonding, monoblock, push-out test, root strengthening

From the *Department of Cariology and Endodontology, University of Geneva, Geneva, Switzerland; and [†]Department of Oral Biology and Maxillofacial Pathology, Medical College of Georgia, Augusta, Georgia.

Address requests for reprints to Dr Serge Bouillaguet, Department of Cariology and Endodontology, School of Dental Medicine, University of Geneva, 19 rue B. Menn, 1205 Geneva, Switzerland. E-mail address: serge.bouillaguet@medecine.unige.ch.

0099-2399/$0 - see front matter

doi:10.1016/j.joen.2007.05.016

Vertical root fractures of endodontically treated teeth are frequently encountered in the dental practice (1). Removal of tooth structure during endodontic and restorative treatments increases the risk of tooth fracture, with fatigue mechanisms mediating the fracture of root tissues over time (2). Recently, the use of "monoblocks" created by bonding root filling materials to radicular dentin has been proposed as a means to strengthen roots (3, 4). However, bonding to root dentin is compromised by volumetric changes that occur in methacrylate resin–based sealers during polymerization (5). Polymerization shrinkage stresses developed along the root dentin-sealer interface might result in debonding of the sealer (6). These stresses are exacerbated inside the root canal because the bonding area is high relative to the volume of canal filling materials; canal walls cannot compensate for shrinkage stresses by elastic deformation (7).

A material must also exhibit sufficient strength and modulus of elasticity to contribute significantly to root strengthening, even if it is securely bonded to the dentin. Because the moduli of elasticity of gutta-percha or Resilon (Pentron Clinical Technologies, Wallingford, CT) are approximately 100 megapascals (MPa), which is 100,000-fold less than that of dentin (8), they are unlikely to be potential root strengthening materials.

A recent review on adhesive endodontics suggests that root dentin-sealer bonds are often inadequate and that the inferior mechanical properties of current materials contribute to their suboptimal performance (9). Thus, the objective of this study was to examine the use of alternative adhesive strategies to optimize bonding to radicular dentin. The hypothesis tested was that bonding to radicular dentin might be enhanced by adopting indirect bonding procedures that compensate for polymerization stresses. With an indirect bonding procedure, a first step coats the canal walls with hybridized resins, and then a second step bonds the core material to the cured resin film. Thus, the polymerization shrinkage that occurs during the initial adhesive coating step will reduce the effects of stress imposed when the core material polymerizes, thereby preserving the bond integrity.

To test this hypothesis, a self-etching adhesive was used in conjunction with an acrylic core as a root filling material. These materials were bonded to radicular dentin by using either a direct bonding technique or an indirect bonding procedure. Dentin-resin bond strengths were assessed at 3 levels of the root canal space with a thin slice push-out test (10).

Materials and Methods

Twenty-four single-rooted human teeth were collected after patients' informed consent was obtained under a protocol approved by the Human Assurance Committee of the University of Geneva, Switzerland. Each tooth was sectioned below the cementoenamel junction to obtain a 12-mm long root. The canal space was mechanically prepared with Hero nickel titanium rotary instruments (Micro-Mega, Geneva, Switzerland) under constant irrigation with 3% sodium hypochlorite (NaOCl). Working length was established 1 mm short of the root apex. The final preparation had a 6-degree taper and a diameter of 0.30 mm at the apical end. On completion of instrumentation, 1 mL of 17% ethylenediaminetetraacetic acid was used to remove the smear layer. The canals were rinsed with distilled water, dried with 95% ethanol (11) and multiple paper points, and divided into 4 groups (n = 6).

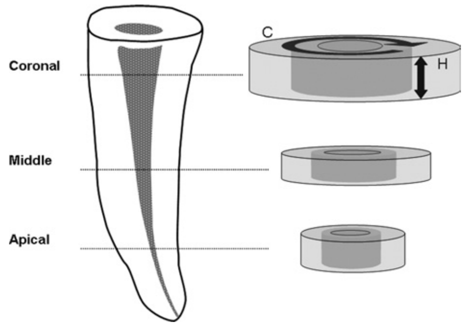

Figure 1. The roots were sectioned and ground to 0.7-mm-thick slices located at 3 different levels (coronal, middle, apical) inside the root. Each slice was placed in an apical-coronal orientation under the testing device to avoid the effect of variation in specimen conicity on the resistance to dislodgment. The push-out bond strength of each section was calculated as the force at failure divided by the bonded cross-sectional surface area (circumference [C] multiplied by height [H]).

Specimens in Group 1 were filled with Epiphany (Pentron Clinical Technologies) sealer and Resilon points. As specified by the manufacturer's instructions, the self-etching primer was introduced into the canal for 1 minute (Appli-Brush) before excess primer was removed with paper points. The Epiphany sealer was then introduced into the canal space with a lentulo spiral. A Resilon point, previously tried-in with tug back, was coated with the Epiphany sealer, inserted to the working length, compacted by using a warm vertical compaction technique with a System B heat source (SybronEndo, Orange, CA), and back-filled by using Obtura II (Spartan, Fenton, MO).

Specimens in Group 2 were filled with EndoREZ (Ultradent Inc., South Jordan, UT) according to manufacturer's instructions. The 2 components of the EndoREZ sealer were mixed and introduced into the root canal via a 30-gauge NaviTip (Ultradent Products). A calibrated 0.06-taper resin-coated gutta-percha master cone (Ultradent Inc) was then inserted into the canal. The canal orifice was exposed to blue light (Elipar FreeLight 2; 3M ESPE, St Paul, MN) for 40 seconds to polymerize the coronal part of the sealer.

A direct bonding technique was used for Group 3, with Clearfil SE Bond (Kuraray Medical Inc, Tokyo, Japan) combined with translucent, stiff but flexible endodontic acrylic points (Produits Dentaires SA, Vevey, Switzerland). The root canals were conditioned with Clearfil SE Bond Primer for 20 seconds by using a 27-gauge needle (BD Microlance 3, Drogheda, Ireland), before excess primer was removed with paper points. Clearfil SE Bond Resin was then introduced (Appli-Brush) into the root canal before the placement of a 0.06-taper acrylic point covered with Bond Resin. The adhesive resin was light-cured for 120 seconds through the acrylic point. The light guide was in direct contact with the coronal part of the root to maximize delivery of light energy through the translucent acrylic point and into the dentin.

An indirect bonding procedure was adopted for Group 4. Clearfil SE Bond Primer was similarly applied as in Group 3. Clearfil SE Bond Resin was applied to the canal walls, forced into the primed dentin with a 0.06-taper Teflon plugger, and light-cured. Because there was no bonding of Teflon to methacrylate-based resins, the Teflon plugger was easily withdrawn. The SE Bond Resin–coated acrylic point was inserted and bonded in situ by light-curing for 120 seconds through the acrylic point. This procedure simulates the reduction of polymerization shrinkage stresses in indirect bonding of composite inlays to coronal cavities (12).

The specimens were stored at 37°C and 95% relative humidity for 1 week. Each specimen was then sectioned perpendicular to the longitudinal axis of the root by using a low speed diamond-coated saw (Isomet; Buehler Ltd, Lake Bluff, IL) under water cooling. Three sections were produced along the apical, middle, and coronal parts of the each root (Fig. 1). Each section was wet ground (silicon carbide paper 500–4000 grit) to a thickness of 700 μm by using a LaboPol-2 polishing machine (Struers, Birmensdorf, Switzerland). The thickness of each section was carefully monitored with a digital caliper to minimize the effect of variation in specimen thickness on the frictional resistance to dislodgment of the material (13).

For the thin slice push-out test, each section was fixed in an apical-coronal orientation with sticky wax to a custom-made aluminum stub with a central opening, over which the filling material was centered. This assembly was placed under a 0.5-mm diameter metallic plugger used to dislodge the material through the aluminum stub. A 638-nm helium-neon laser beam passing through the circular opening was used to precisely align the specimens under the plugger. Push-out tests were performed at a cross-head speed of 1 mm/min with a universal testing machine (Vitrodyne V-1000 Universal Tester; John Chatillon & Sons, Greensboro, NC). The bond strength of each specimen was calculated as the quotient of the force at failure and the interface area (calculated by multiplying the thickness of the section by the circumference of the canal walls) and expressed in MPa (Fig. 1). The normally distributed data were analyzed by using one-way analysis of variance and Tukey multiple comparison test, with statistical significance set at $\alpha = 0.05$.

Results

The location of the section in the root had little effect on the bond strength of the materials to the root dentin (Fig. 2), irrespective of the material used. The variation in the strength values (n = 6) obscured any statistical differences among the means ($P > .05$, analysis of variance), and there was no correlation between bond strength and root

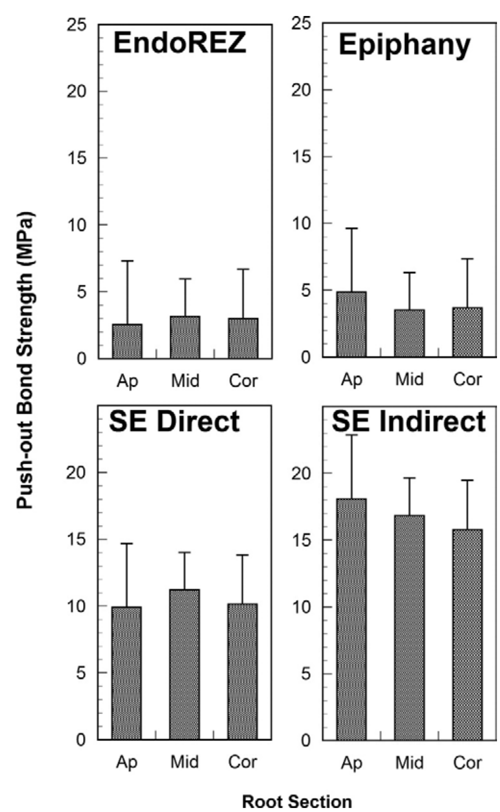

Figure 2. Mean push-out bond strength values recorded for each material at 3 levels of dentin inside the root (from coronal to apical).

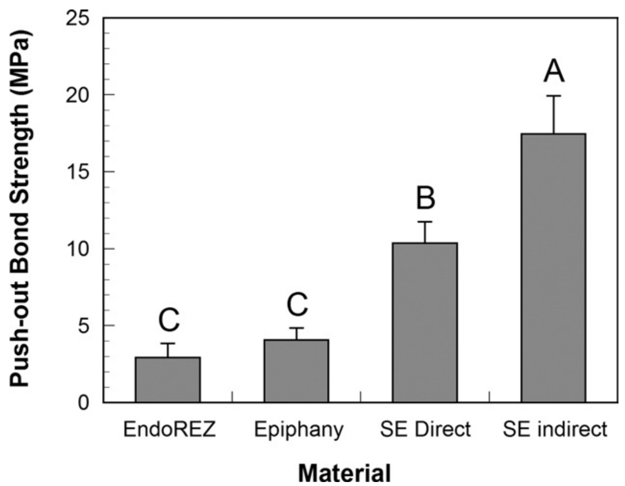

Figure 3. Mean push-out bond strength value and standard deviation for each material, averaging the 6 teeth for each group (letters indicate significant differences between materials; $P < .05$).

location. The variation among replicates was approximately the same among materials (Fig. 2).

Because differences in root location did not affect bond strength of the materials to radicular dentin, data from the 3 locations were pooled to give a single mean and standard deviation for each material, averaging the 6 teeth for each group. Statistical analysis of the pooled data indicated significant differences ($P < .05$) among the push-out strengths of the materials (Fig. 3). EndoREZ and Epiphany exhibited the lowest bond strengths to radicular dentin (2.5–5.0 MPa) that were not significantly different from each other ($P > .05$). The highest bond strength was achieved when Clearfil SE Bond was bonded by using the indirect technique (18.1 ± 1.6 MPa; $P < .05$). The use of Clearfil SE Bond with the direct technique exhibited an intermediate bond strength (10.2 ± 1.9 MPa) that was lower than the indirect technique ($P < .05$) but higher than those achieved with Epiphany or Endo REZ ($P < .05$).

Discussion

Because EndoREZ and Epiphany bonded poorly to root dentin (Figs. 2 and 3), they are unlikely to reinforce root strength in clinical situations. These results are consistent with previous reports for these materials (14–16). Conversely, bonding of acrylic master cones with Clearfil SE Bond yielded higher bond strengths (Figs. 2 and 3). Acrylic points exhibit a higher modulus of elasticity (35,000 MPa) than gutta-percha or Resilon (79–87 MPa) (8). Clearfil SE Bond is bondable to both dentin and acrylic points. With the direct technique, SE Bond strengths were approximately 10 MPa, which is much lower than strengths obtained on coronal dentin. Previous reports have shown that endodontic irrigants can significantly alter bond strengths of resins to radicular dentin, and this factor should be investigated further (17).

With the indirect technique, bond strengths of Clearfil SE Bond to radicular dentin approximated 18 MPa. This result supports our hypothesis that bond strengths to radicular dentin might be maximized by adopting procedures that compensate for polymerization stresses. In the indirect technique, the initial step allows optimal resin film formation along the root canal walls, leading to more ideal resin-dentin hybridization without stresses imposed by the core material. Concerns that the absence of an oxygen-inhibited layer on the cured initial film would limit bonding to the resin-coated core were not verified (18), but this potential problem has been recently discussed by Dall'oca et al (19).

Regardless of the material, the location of the specimen played no apparent role in the ability of the material to bond to root dentin (Fig. 2). This result differed from a previous report showing inferior bonding at the apical part of the root canal (20). However, we did not measure bond strengths at the apex of the root because the value of bonding in the last 4 mm of the root to prevent root fracture is questionable; the seal between the material and the dentin might be more important in this area.

It must be emphasized that the 2 Clearfil SE Bond techniques used in the current study were purely experimental and have no immediate clinical applications. Only one study has attempted to use a similar approach to reinforce artificially flared canals before post cementation (21). A factor that might limit the clinical application of this technique is the delivery of light into the apical portion of the canal (22). This limitation might be circumvented by using a dual-curing version of the adhesive (eg, light and chemical polymerization mechanisms) (23, 24), higher intensity curing lights, light-conducting cores materials, or pluggers. These alternatives should be examined in future studies. Nevertheless, the current study supports the concept that indirect dentin adhesive strategies and materials might be successfully adapted to endodontics to optimize bond strengths of endodontic filling materials to radicular dentin.

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