Dislocation Resistance of iRoot SP, a Calcium Silicate–based Sealer, from Radicular Dentine

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Abstract

Introduction: The aim of this study was to evaluate the push-out bond strength of iRoot SP (Innovative Bioceramix, Vancouver, Canada) and compare it with that of other widely used root canal sealers. **Methods:** Sixty extracted human maxillary canines were sectioned transversally below the cement-enamel junction to obtain 120 4-mm-thick dentin disks that were randomly divided into four groups (n = 30) for treatment with one of four different root-canal sealers (iRoot SP, AH Plus [Dentsply DeTrey GmbH, Konstanz, Germany], Sealapex [SybronEndo Corporation, Orange, CA], EndoREZ [Ultradent Inc, South Jordan, UT]). Standardized cavities were prepared to simulate root canals, cavities were filled with sealer material, and push-out bond-strength testing was performed using a universal testing machine. Failure modes were assessed quantitatively under a stereomicroscope and morphologically under a scanning electron microscope. Statistical analysis was performed using one-way analysis of variance and the post hoc Tukey test, with the significance level set at 0.05. **Results:** Bond strengths of iRoot SP and AH Plus were significantly higher than those of Sealapex and EndoREZ. There was no significant difference between the bond strength of iRoot SP and AH Plus (p = 0.274). **Conclusions:** iRoot SP and AH Plus performed similarly and better than EndoREZ and Sealapex in terms of bond strength. *(J Endod 2010;36:2000–2002)*

Key Words

Calcium silicate-based root canal sealer, iRoot Sp, push-out bond strength

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The use of a root canal sealer in conjunction with a core material remains the most widely accepted obturation technique in endodontics (1). An adequate seal cannot be obtained without the use of a sealer because gutta-percha does not spontaneously bond to dentin walls. Therefore, ideal endodontic cement should show good sealing ability (2, 3). In addition, it should have adhesive strength and also have cohesive strength to hold the obturation together (4).

A variety of different sealers are available for endodontic use. Epoxy resin-based sealer cements such as AH Plus (Dentsply DeTrey GmbH, Konstanz, Germany) have been widely used for many years and have shown higher bond strengths to dentin than zinc oxide eugenol, calcium hydroxide, and glass-ionomer sealers (2, 3, 5). EndoREZ (Ultradent Inc, South Jordan, UT), a hydrophilic, urethane dimethacrylate resin-based sealer developed specifically for filling root canals, has also shown extensive resin penetration into dentinal tubules in a manner similar to that of epoxy resin (6). Recently, a new sealant product has been introduced for the obturation of endodontically treated teeth. iRoot SP (Innovative Bioceramix, Vancouver, Canada) is described by its manufacturer as an insoluble, radiopaque, aluminum-free material composed of calcium, calcium phosphate, calcium hydroxide, and zirconium oxide that requires the presence of water to set and harden. The extremely small particle size of iRoot SP suggests that it may easily flow into dentinal tubules, lateral canals, and webs. However, no information is available regarding the ability of iRoot SP to adhere to root canal dentin. Therefore, this study aimed to evaluate the push-out bond strength of iRoot SP and compare it with other widely used root canal sealers.

Materials and Methods

Specimen Preparation

Sixty extracted human maxillary canines were sectioned transversally below the cemento-enamel junction using a water-cooled precision saw (Isomet 2000 Precision Saw; Buehler, Lake Bluff, IL) to obtain 120 4-mm-thick dentin disks. Standardized, simulated root canals were prepared (2.60-mm large diameter, 1.90-mm small diameter, 4-mm height) and irrigated with 5 mL of 5.25% NaOCl followed by 5 mL of 17% EDTA to remove the smear layer and then 10 mL of distilled water. Specimens were randomly divided into four groups (n = 30), and the cavities were bulk filled without a core material using one of the following sealers: iRoot SP, Sealapex (SybronEndo Corporation, Orange, CA), AH Plus, and EndoREZ. Samples were stored at 37°C and 95% relative humidity for 1 week to allow the sealer cements to set completely.

Push-out Bond Strength Testing

The push-out bond strength was performed using a universal-testing machine (Shimadzu AG-1; Shimadzu Corp, Tokyo, Japan). For this test, a Teflon ring support was used to hold the specimens. A 1.70-mm diameter cylindrical stainless-steel plunger applying a constant compressive load at a crosshead speed of 0.5 mm/min was positioned in such a way that it only contacted the filling material and avoided contact with the dentin. Also, the disk samples were positioned to allow the plunger to move in an apical to coronal direction, which resulted in the displacement of the filling material toward the larger diameter coronal aspect of the disk. This method ensured the alignment of the specimen in an accurate and reproducible manner and also maintained the plunger centralized and avoided its contact with the dentin wall when the material was pushed and dislodged from the dentin wall. The bond strength was recorded in MPa according to Skidmore et al (7) by dividing the load in newtons by the area of the bonded interface using the following formula: $(MPa) = \frac{Maximum\ \ load}{Adhesion\ area\ of\ root\ canal\ filling(mm^2)}$, with the adhesion surface area of each section calculated as $\mu \cdot (r1 + r2) \cdot L$, where $L = \sqrt{(r1 - r2)^2 + h^2}$.

Failure Analysis

Failure modes were analyzed by examining each debonded specimen under a stereomicroscope (Olympus SZ61; Olympus Optical Co, Tokyo, Japan) at ×40 magnification. Failures were classified according to Skidmore et al (7) as type I (adhesive failure at the sealer-dentin interface), type II (cohesive failure within the sealer or dentin), or type III (mixed failure; ie, failure in both the sealer and dentin). For each group, one specimen representative of each failure mode was evaluated under a scanning electron microscope (Jeol JSM 6360 LV; Jeol Technic Co, Tokyo, Japan).

Statistical Evaluation

G*Power (G*Power Ver. 3.1.2; Franz Faul, Universität Kile, Germany, http://www.psycho.uni-duesseldorf.de/aap/projects/gpower/) analysis was used to determine the minimum sample size required and accept the outcome of the statistical test with a 95% confidence level. Thus, the power of the analysis with a = 0.05 (b = 0.10, f = 0.40) was 0.90. The power analysis revealed that our sample size is sufficient for the statistical evaluation. After $\log_{10}$ transformation of raw data, the Shapiro-Wilk normality test was used to determine whether a random sample of values follows a normal distribution. Because the normality (Shapiro-Wilk) assumptions of the transformed data appeared to be valid, they were analyzed with one-way analysis of variance and the post hoc Tukey tests to determine the presence of a significant difference among the groups. The significance level was set at $p \leq 0.05$.

TABLE 1. Minimum, Maximum, and Mean Bond Strength Values and Standard Deviations (Mpa)

Groups	Min	Max	Mean	Standard Deviation
iRoot	0.62	4.15	1.32	0.83
Sealapex	0.15	2.04	0.87	0.56
AH Plus	0.40	5.31	1.99	1.33
EndoREZ	0.13	2.65	0.71	0.59

Results

Mean push-out test values for each group were as follows: iRoot SP, 1.32 ± 0.83 MPa; Sealapex, 0.87 ± 0.56 MPa; AH Plus, 1.99 ± 1.33 MPa; and EndoREZ, 0.71± 0.59 MPa (Table 1). One-way analysis of variance showed significant differences among groups ($p < 0.001$). Multiple paired comparisons (Tukey test) showed iRoot SP and AH Plus to have significantly higher bond strengths than Sealapex and EndoREZ. No significant differences were found between Sealapex and EndoREZ ($p = 0.482$) or between iRoot SP and AH Plus ($p = 0.274$).

Failure analysis showed the predominant failure modes to be cohesive failure for Sealapex and iRoot SP, adhesive failure for EndoREZ, and mixed failure (both cohesive failure within the sealer and adhesive failure to dentin) for AH Plus. Scanning electron microscopic examination of debonded specimens showed AH Plus penetrated deeply into the dentin tubules to form resin tags, with the dentin surface partly covered by sealer remnants and partly showing exposed dentinal tubules (Fig. 1*A*), whereas the debonded dentin surfaces of specimens sealed with iRoot SP and Sealapex were completely covered by sealer (Fig. 1*C*).

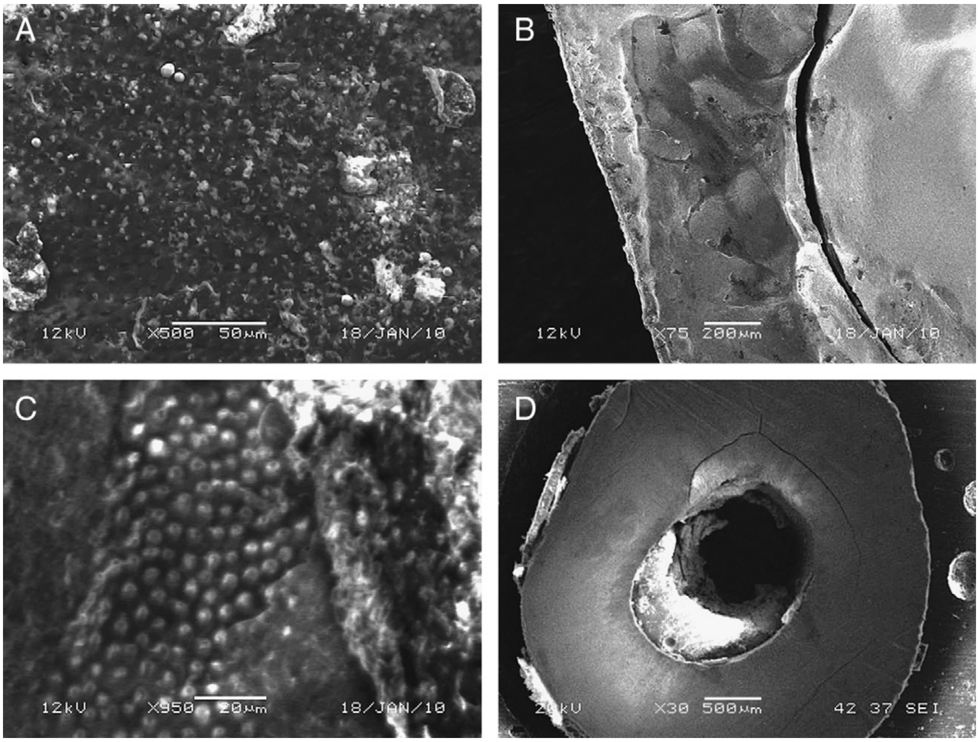

Figure 1. Scanning electron microscopic micrographs of dentin disks. (*A*) Remnants of AH Plus sealer are observable on the debonded dentin surfaces. (*B*) A representative adhesive failure of EndoREZ sealer. (*C* and *D*) Debonded dentin surfaces are completely covered by iRoot SP and Sealapex sealers.

Discussion

The recently introduced calcium silicate-based sealer iRoot SP is claimed by its manufacturer to perform successfully as a root canal filler with or without the use of gutta-percha points. Moreover, a recent study (8) has shown the apical sealing ability of iRoot SP to be equivalent to that of AH Plus. However, there is limited information available regarding the bond strength of iRoot SP. Therefore, this study aimed to measure the push-out bond strength of iRoot SP at the dentin-sealer interface and compare it with those of other widely used root canal sealers.

The adhesive strength of root canal sealers has been examined by various methods that include shear bond strength, microtensile bond strength, and push-out bond strength testing (9). The push-out test is easy to reproduce and interpret and provides a realistic assessment of bond strength to dentin even at low levels (9); however, the nonuniform stress distribution and the tendency of the thermoplastic core material to deform when a compressive load is applied during testing are two major drawbacks of the push-out test (10). In order to overcome these limitations, the present study adopted the method proposed by Sousa-Neto et al (11) whereby the tested sealer is in contact with root canal dentin, allowing the material to adapt to the shape of the canal and penetrate into the dentin tubules.

Among the four materials tested, AH Plus and iRoot SP showed similar and higher bond strengths when compared with Sealapex and EndoREZ. Zhang et al (8) also found iRoot SP and AH Plus to have similar apical sealing ability. The high bond strength of iRoot SP may be explained by its calcium silicate composition, which uses the moisture naturally present in dentinal tubules to initiate and complete the setting reaction so that no shrinkage occurs during setting.

Numerous studies have shown AH Plus to have higher bond strength than most other sealers (3, 5). In the present study, AH Plus sealer was found superior to Sealapex and EndoREZ in terms of bond strength. Similarly, many studies have reported that AH Plus provides better sealing properties than both Sealapex and EndoREZ (9, 12). The higher bond strength obtained with AH Plus may be associated with its ability to react with any exposed amino groups in collagen to form covalent bonds between the resin and collagen upon opening of the epoxide ring (3). AH's very low shrinkage while setting and its long-term dimensional stability may also contribute to its observed bond strength. Our finding that Sealapex had low bond strength to dentin (0.87 MPa) is in line with that of Wennberg and Ørstavik (2) and may be caused by the low tensile cohesive strength of self-cured calcium hydroxide-based sealers (Fig. 1*D*).

The bond strength values of EndoREZ were lower than expected. Although it is possible that the cohesive strength of EndoREZ is lower than its adhesive strength, it is also possible that the immediate coronal sealing provided by this light-activated material prevents full curing within the canal, thereby increasing the stress on the material (13). Current results are also confirmed by the recently published data of Beriat et al (14) in which setting characteristics of a methacrylate-based sealer were affected by light curing. They reported that inadequate conversion may result in lower bond strength to dentin. The configuration of the root canal cavity represents the greatest obstacle to root canal adhesives (15–17). As the unbonded surface area becomes small in long narrow root canals, there is insufficient stress relief by flow and a high risk of pull-off or debond at the interfaces (15, 16). A recent study conducted by Stiegemier et al (18) comparing push-out bond strength of different methacrylate-based resin sealer/core material combinations showed that the most common failure mode in all groups was adhesive, which correlates well with the failure mode of EndoREZ group. In this study, scanning electron microscopic examination revealed gaps along the sealer-dentin interface in the EndoREZ group that may have occurred as a result of polymerization shrinkage (Fig. 1*B*).

The findings of failure analysis correlate well with the results of the push-out test in that increased resistance to dislocation decreases the likelihood of disruption of the sealer-dentin interface and increases the likelihood that failure will occur within the sealer itself. This would explain why iRoot SP, which showed higher push-out strength than both Sealapex and EndoREZ, also had a higher prevalence of cohesive failure than Sealapex and EndoREZ. In view of the higher resistance to dislocation exhibited by both iRoot SP and AH Plus when compared with Sealapex and EndoREZ, one can assume that iRoot SP and AH Plus are also more impermeable to leakage than Sealapex and EndoREZ. In conclusion, this study showed iRoot SP and AH Plus to perform similarly and to be preferable to both EndoREZ and Sealapex in terms of bond strength.

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