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Push-out bond strength of a new bioceramic-based root canal sealer

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Abstract

Objective: The present study aimed to evaluate the bond strength of Sure-Seal Root as a new bioceramic-based sealer, and compare it with other sealers, including an epoxy resin-based sealer (AH-Plus), zinc oxide eugenol (ZOE) and a mineral trioxide aggregate-based sealer (MTA Fillapex).

Methods: In this in vitro study, 40 extracted mandibular premolars were randomly assigned into 4 groups (n=10) according to the type of sealer applied as follows: Group 1: AH-Plus, Group 2: MTA-Fillapex, Group 3: Sure-Seal Root, and Group 4: ZOE. The canals were prepared and obturated with gutta-percha and the corresponding sealer. The samples were sectioned into horizontal segments, and the push-out bond strength was determined using a universal testing machine at the coronal, middle, and apical root thirds. The data were analyzed by repeated measures ANOVA, and the significance level was set at $P<0.05$.

Results: There were no significant differences in the push-out bond strength between groups in the coronal third ($P>0.05$). In the middle third, AH-Plus exhibited significantly greater bond strength compared to Sure-Seal Root and ZOE sealers ($P<0.05$), whereas MTA-Fillapex was not significantly different from the other groups ($P>0.05$). In the apical third, both AH-Plus and MTA-Fillapex showed significantly greater push-out bond strength than Sure-Seal Root and ZOE sealers ($P<0.05$).

Conclusions: AH-Plus sealer exhibited the highest and ZOE showed the lowest bond strength. Sure-Seal Root indicated promising bond strength results when compared to ZOE and MTA-Fillapex. The push-out bond strength of all sealers to dentin increased from the coronal to the apical third.

Keywords: Bioceramic, Bond strength, Gutta-percha, Mineral trioxide aggregate, Root canal obturation, Root canal sealer

Introduction

In recent decades, various root canal obturation materials have been introduced to dentistry (1). Research has shown that the apical migration of microorganisms and their products leads to root canal treatment failures. This phenomenon is primarily caused by improper obturation of the root canals (2, 3). Gutta-percha is the most commonly used material for root canal obturation; however, it cannot seal the root canal by itself, and thus it is usually used in conjunction with another material, called a sealer (4). Grossman (5) studied the physical properties of obturation materials and concluded that bond strength is one of the most important properties of root canal sealers to prevent leakage and subsequent problems. Therefore, assessing the capacity of bonding to dentin can provide a suitable measure for evaluating the performance of root canal sealers.

Studies have used different techniques to evaluate the adhesion of sealers to dentin, including the tensile bond strength, push-out bond strength and shear bond strength (6-8). It has been shown that the evaluation of the push-out bond strength is a proper and reliable criterion for the evaluation of bond strength (7).

The composition of a sealer significantly influences its performance and application in endodontic procedures.

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ZOE sealers have long been used successfully in endodontic treatments. If these sealers penetrate the periradicular tissues, they will be absorbed over time. ZOE sealers have a slow setting time, exhibit shrinkage during setting, are soluble and can cause tooth structure discoloration. One advantage of these sealers is their antimicrobial activity (9, 10).

Resin sealers have an adhesive potential and do not contain eugenol. AH-Plus is a sealer with an epoxy resin base, with some favorable properties, including antimicrobial activity, adhesion potential, long working time, easy mixing, and very good sealing ability. Its disadvantages include discoloration, relative toxicity until its setting is complete and some degree of solubility in the oral fluids (11, 12).

MTA-Fillapex is a MTA-based sealer that contains resin salicylate components, calcium silicate and bismuth trioxide. This sealer has the same structure as MTA after mixing, with high radiopacity and long-term setting ability. MTA-based sealer increases the resistance of the tooth against fracture, which might be attributed to its resin component or the delayed strength of MTA (24 hours) after the setting reaction (13-15)

Bioceramic-based sealers are considered a useful advancement in endodontics (16). These sealers have exhibited favorable bond strength values in previous studies (17, 18). Recently, a new type of bioceramic-based sealer has been introduced, which is referred to as Sure-Seal Root. This sealer has favorable properties, including radiopacity (due to the presence of barium sulfate in its structure), and an ideal seal with minor expansion during setting (19). In addition, it has a biocompatible, osteogenic, antibacterial, and hydrophilic structure, and it can induce the hydroxyapatite formation process. Furthermore, it offers a suitable shelf time and ideal hardening characteristics (20).

According to our literature review, no study has yet evaluated the push-out bond strength of this new bioceramic-based sealer. The present study was designed to evaluate the push-out bond strength of Sure-Seal Root sealer in comparison to three other types of sealers with different bases, including AH-Plus, MTA-Fillapex, and ZOE.

Materials and methods

Sample preparation

The protocol of this in vitro study was approved by the research and ethics committee of Urmia University of Medical Sciences (IR.UMSU.REC.1397.287).

Forty human-extracted single-rooted mandibular premolars were obtained and underwent radiographic examination from buccolingual and mesiodistal aspects. All the teeth were extracted due to periodontal disease or impaction and had fully developed roots, without any caries, internal or external resorption or calcification in the root structure. Teeth with previous root canal treatments and those exhibiting procedural errors during preparation (such as broken files, etc.) were excluded (21).

The root surfaces were cleaned with ultrasonic tips to remove any residual periodontal soft tissues. To ensure better disinfection, the extracted teeth were stored in a 3% chloramine-T solution at 4 °C for 1 month.

Grouping

The samples were randomly assigned to 4 groups (n=10) according to the root canal sealer applied as follows:

Group 1: AH-Plus (Dentsply, Dentery, Germany)

Group 2: MTA-Fillapex (Angelus, Londrina, Brazil)

Group 3: Sure-Seal Root (Sure Dent, Gyeonggi-do, South Korea)

Group 4: ZOE (Golchai, Alborz, Iran)

Root canal treatment

Each tooth was decoronated to achieve identical samples with a similar root length of 15 mm. Then the working length was determined with a #15 K-Flexofile (Dentsply Maillefer, Ballaigues, Switzerland), 1 mm coronal to the apical foramen. Instrumentation was carried out with K-files up to #35, followed by preparation of the coronal two-thirds of the root canals with #3 and #4 Gates-Glidden drills (Dentsply, Maillefer, Ballaigues, Switzerland).

Subsequently, the canals were shaped by RaCe rotary instruments with apical tip sizes of 40/0.10, 35/0.08, 25/0.04, 25/0.06, 30/0.06, and 35/0.06 (RKG, La Chaux,-De-Fonds, Switzerland), employing the crown-down technique. A master apical file of #35 was considered for all root canals.

Irrigation of the root canals in all the stages of preparation was carried out with 5 mL of a 2.5% NaOCl solution (Taj Corp., Tehran, Iran). The apical patency of the root canal was maintained by a #10 file. The smear layer was removed using 1 mL of 17% ethylenediaminetetraacetic acid (Pulpdent Corp., Watertown, MA, USA) for 3 minutes, followed by rinsing with 1 mL of 5.25% NaOCl. The final irrigation was carried out with a phosphate-buffered saline (PBS) solution. Finally, the root canals were dried with paper points (Meta Biomed, Seoul, South Korea). The root canals were obturated using the cold lateral compaction technique with 2% tapered gutta-percha (Ariadent, Tehran, Iran). The corresponding sealer was applied in the study groups according to the manufacturer's instructions. The samples were incubated at 37°C and 100% humidity for 24 hours after completing the obturation (22).

Push-out test

The coronal, middle and apical portions of each root were sectioned perpendicular to the long axis into 2.00 ± 0.05 mm thick serial slices by using a water-cooled diamond blade on a precision cut-off machine (Mecatome, Presi, France). Three sections were selected from each specimen, corresponding to the coronal, middle, and apical thirds of the root.

The push-out bond strength of sealers to dentin was determined in a universal testing machine (Hounsfield Testing Equipment, UK) using coronal, middle and apical root sections. The cylindrical plunger of the machine, measuring 1 mm in diameter, applied a force on the surface of dentin at a crosshead speed of 1 mm/minute, and the maximum force necessary to dislodge the sealer from the root canal was recorded in Newton (N). To express the bond strength in megapascals (MPa), the load at failure (N) was divided by the interfacial area (mm^2).

Finally, the slices were examined under a stereomicroscope at ×40 magnification to determine the failure mode. Modes of failure were categorized as: (1) adhesive: at the filling material/dentin interface, (2) cohesive: within the filling material, and (3) mixed failure: a combination of adhesive and cohesive failure (23).

Statistical analysis

The Kolmogorov-Smirnov test was used to assess if the data followed a normal distribution or not. Due to the normal distribution of the data (P>0.05), a repeated measures analysis of variance (ANOVA) was applied to determine any significant difference in bond strength between different groups and cross sections. SPSS 16.0 (SPSS, Chicago, IL, USA) was used for all the analyses, and the statistical significance was set at P<0.05.

Results

Table 1 presents the mean push-out bond strength of the four groups of sealers in the coronal, middle and

Table 1. The mean and standard deviation (SD) of push-out bond strengths of the sealers in different sections

Group	Sealer	Coronal Mean ± SD	Middle Mean ± SD	Apical Mean ± SD	P-value
1	AH-Plus	63.88 ± 29.27	125.87 ± 28.25[a]	175.17 ± 49.32[a]	<0.001
2	MTA-Fillapex	49.58 ± 31.31	102.14 ± 37.60[a, b]	151.27 ± 49.04[a]	<0.001
3	Sure-Seal Root	62.93 ± 36.55	82.85 ± 26.81[b]	104.87 ± 31.31[b]	0.022
4	ZOE	47.70 ± 28.89	68.64 ± 35.62[b]	92.86 ± 30.19[b]	0.003
P-value		0.264	0.011	0.017	

P-value<0.05 was considered significant.
MTA: Mineral trioxide aggregate, ZOE: Zinc oxide eugenol

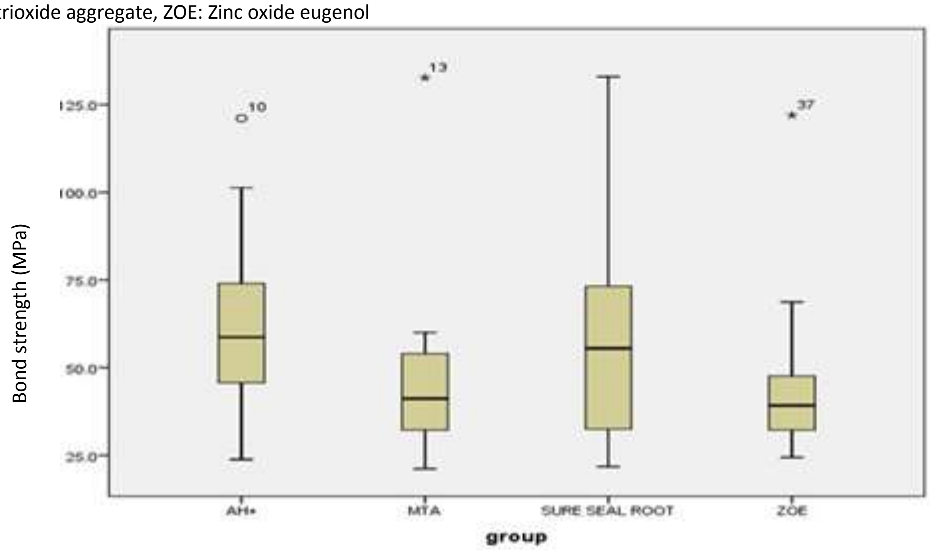

Figure 1. Comparison of the push-out bond strengths of the study groups in the coronal root section

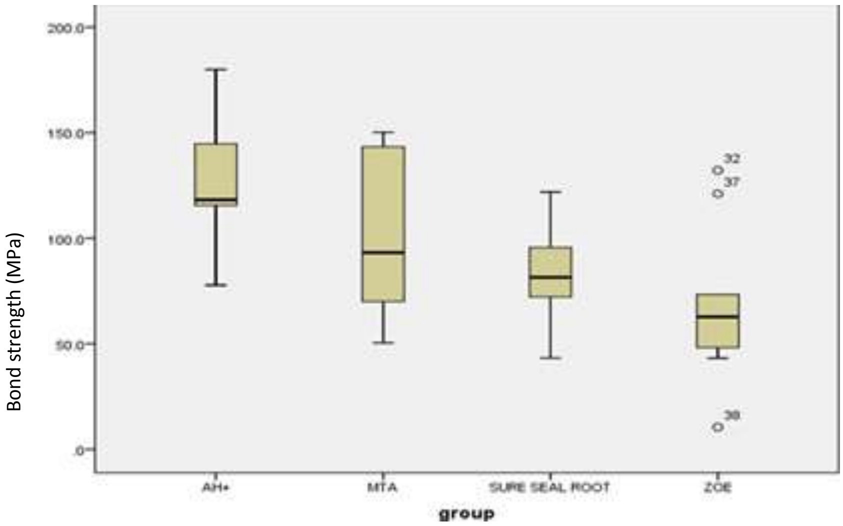

Figure 2. Comparison of the push-out bond strength of the study groups in the middle root sections

apical cross sections. A comparison of the push-out bond strength between different sealers has also been illustrated in Figures 1 to 3 for the coronal, middle, and apical root sections, respectively.

The greatest mean push-out bond strength was related to the apical section of teeth obturated with AH-Plus sealer (175.17 ± 49.32 MPa), whereas the ZOE group exhibited the lowest mean bond strength value in the coronal third (47.70 ± 28.89 MPa). The mean bond strength increased from the coronal to the apical third in all groups (P<0.05; Table 1).

There was no significant difference in the mean bond strength values between different sealers in the coronal third (P=0.264; Table 1). In the middle third, the AH-Plus group exhibited significantly greater bond strength compared to the Sure-Seal Root and ZOE groups (P<0.05; Table 1), whereas MTA-Fillapex was not significantly different from any of the study groups (P>0.05; Table 1). In the apical third both AH-Plus and MTA-Fillapex groups showed significantly greater push-out bond strength values in comparison to Sure-Seal Root and ZOE sealers (P<0.05; Table 1).

Discussions

The present study assessed the push-out bond strength of a recently introduced bioceramic-based sealer, i.e., Sure-Seal Root, and compared it with other commonly used sealers, including ZOE, AH-Plus and MTA-Fillapex. The results of this study can be useful for recognizing the properties of such new bioceramic-based sealers, providing information about the possibility of more extensive application of these materials in root canal treatment. The ability to adhere to dentin is a key factor for root canal-filling materials. The push-out bond strength technique was selected for the present study because it has been considered a

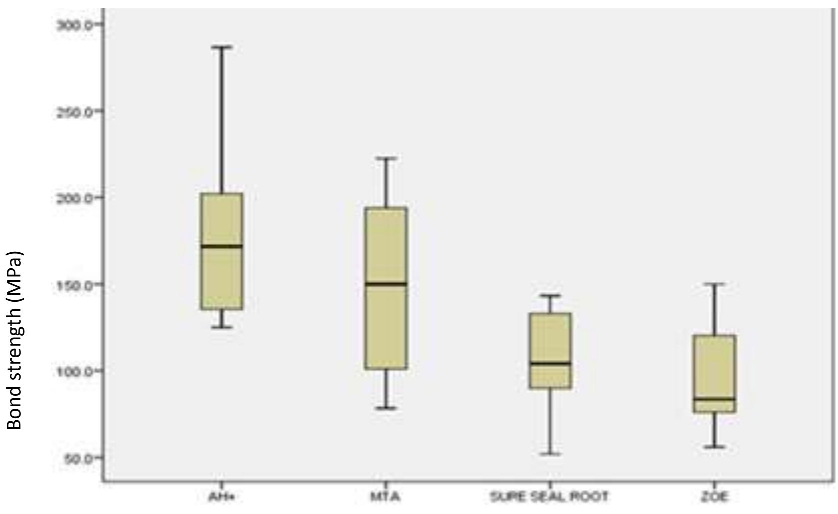

Figure 3. Comparison of the push-out bond strengths of the study groups in the apical root sections

valid, reliable and interpretable technique for assessing the materials adhering to the root dentin (10, 15, 19, 23, 24).

In the present study, several sealers were selected for comparison with Sure Seal Root. AH-Plus has been used as the gold standard in different studies (25-27). ZOE sealers have long been employed as the sealer of choice for many clinicians (9) and MTA-Fillapex was selected due to its high bond strength and favorable properties (11, 25, 28).

Based on the obtained results, AH-Plus and ZOE exhibited the highest and lowest push-out bond strength values, respectively. In addition, the push-out bond strength to dentine increased from the coronal third toward the apical third in all groups. This may be due to the higher number of dentinal tubules in the cervical third than in the apical third. There was no significant difference in bond strength between the groups in the coronal third, but in the middle and apical root thirds, significant between-group differences were found.

In this study, AH-Plus indicated the highest bond strength at all cross-sections. The favorable results with the sealing ability of AH-Plus sealer might be attributed to its ability to react with dentin's exposed amino groups, forming strong covalent bonds. In addition, AH-Plus exhibits very low polymerization shrinkage, contrary to the majority of other sealers. Furthermore, it shows favorable dimensional stability in the long term (23, 29). The outcomes of this study are consistent with those of Gade et al. (1), who observed the maximum push-out bond strength in the AH plus group when using the lateral compaction technique. However, the push-out bond strength of Endosequence BC sealer was higher than AH plus when the thermoplasticized technique was applied (1). Carvalho *et al.* (30) compared the push-out bond strength and biocompatibility of a bioceramic-based sealer and reported lower bond strength of this sealer compared to AH-Plus. Ferreira *et al.* (31) also demonstrated a higher bond strength of AH plus in comparison to a bioceramic-based sealer (GuttaFlow Bioseal). In contrast to the present findings, a recent study by Sarrafan *et al.* (22) concluded that irrespective of the drying technique, Sure-Seal Root yielded the highest push-out bond strength to root dentin. This contrast could be attributed to different methods of root canal obturation. The cited authors used the single cone technique, whereas, in the present study, cold lateral compaction was applied for obturation.

MTA-Fillapex ranked second concerning bond strength in the middle and apical root thirds. There was no statistically significant difference between MTA-Fillapex with other sealers in the middle root third. In the apical third, MTA-Fillapex showed comparable bond strength to AH-Plus, and significantly greater bond strength than Sure-Seal Root and ZOE groups. A study conducted by Forghani *et al.* (32) showed no significant difference between the microleakage of MTA-Fillapex and AH-Plus sealers. In contrast, Sonmez *et al*. (29) compared the apical microleakage of MTA-Fillapex sealer with that of AH Plus and ProRoot MTA sealers and reported that AH Plus and ProRoot MTA exhibited similar sealing ability, whereas MTA-Fillapex exhibited greater microleakage compared to the other sealers. Kurup *et al.* (33) reported higher push-out bond strength values of AH plus compared to the MTA-Fillapex and Apexit plus sealers. Gurgel-Filho *et al*. (34) compared the push-out bond strengths of MTA-based sealers and reported that the push-out bond strength of the AH Plus sealer was significantly higher than that of the MTA-Fillapex sealer. MTA-Fillapex is a sealer with a structure very close to that of MTA. Sarkar et al. (35) showed that the release of calcium and hydroxyl ions by MTA after its setting results in the formation of apatite. Reyes-Carmona *et al.* (36) reported that the formed apatite precipitates among collagen fibrils to form tag-like structures. Assmann *et al*. (37) evaluated the bond strength of AH-Plus, iRoot SP and MTA-Fillapex sealers and attributed the poor results achieved in the MTA-Fillapex group to the weak adhesion of these tag-like structures, which is assumed to compromise the root canal seal. In addition, the resin components in this sealer might negatively affect its bond strength and sealing ability.

Based on the results of this study, the ZOE group exhibited the lowest mean bond strength in the coronal, middle, and apical thirds. The possible reason is that the adhesion of Grossman sealers (sealers with ZOE base) to dentin is mediated through electrostatic bonds rather than penetration into the dentinal tubules (10). The zinc ion in zinc oxide might react with the mineral content of dentin and with the zinc oxide component of gutta-percha (9). In addition, eugenol might exert a softening effect on gutta-percha. Therefore, a crisscross pattern is created that increases the adhesion between the materials (9).

The limitation of the present study was the fact that it was not carried out clinically. It is recommended that future studies evaluate the physico-chemical properties of new bioceramic-based sealers and compare them with other commonly used sealers. In addition, studies should be carried out with larger sample sizes for more valid results.

Conclusions

According to the results of the present study, Sure-Seal Root showed promising results when compared to ZOE and MTA-based sealer (MTA-Fillapex). The push-out bond strength of all sealers to dentin increased from the coronal to the apical third.

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Conflict of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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