In vitro bond strength of bioceramic root canal sealer in comparison to resin-based and eugenol-based root canal sealers

Key words  bioceramic, resin-based, zinc oxide-eugenol-based root canal sealer

Aim: Evaluation of the push-out bond strength of bioceramic root canal sealer (EndoSequence BC) in comparison to a resin-based (AH Plus) sealer and a zinc oxide-eugenol-based (Kerr EWT) sealer.

Materials and methods: Sixty-three roots were randomly divided into three groups (n = 21) according to the root canal sealer: group 1, EndoSequence BC; group 2, AH Plus; and group 3, Kerr EWT. Two millimetre-thick horizontal sections from the coronal, middle, and apical thirds of each root were sliced for the push-out bond strength measurement using a universal testing machine after 7, 14 and 30 days. Modes of failure were evaluated using a scanning electron microscope. Statistical analysis was performed using Kruskal-Wallis test and Mann-Whitney U test (P ≤ 0.05).

Results: The EndoSequence BC samples showed the highest mean push-out bond strength values after 1 and 4 weeks, followed by AH Plus and Kerr EWT. After 2 weeks, the AH Plus samples showed the highest mean push-out bond strength values followed by EndoSequence BC. Statistically, there was a greater significant difference between the push-out bond strength mean values of the three sealers at each time interval (P < 0.001).

Conclusion: The time after obturation and the basic composition of the sealer are important factors in determining the bond strength of the sealer to the root canal wall.

Introduction

Root canal sealers have been continuously developed and the difference in the properties of the sealers is mainly based on the composition of each sealer. Some sealers consist of zinc oxide, calcium hydroxide and glass ionomer, while others are made up of epoxy resin, silicone, and methacrylate. EndoSequence BC Sealer (Brasseler USA, Georgia, USA) has been introduced to the market as a bioceramic-based sealer (Table 1). It is a premixed and injectable root canal sealer that is characterised by a high flow into the canal irregularities and dentinal tubules due to its nanoparticle size. In addition, it is hydrophilic and uses moisture in the dentinal tubules to initiate and complete the setting reaction. Hess et al. reported that it has no shrinkage on setting, resulting in a gap-free interface between the sealer and dentin. The manufacturer also states that the sealer is highly biocompatible and is antibacterial during the setting reaction because of its highly alkaline pH.

Epoxy resin-based sealers were introduced to endodontics by Schroeder. One of these sealers is AH Plus (Dentsply DeTrey, Konstanz, Germany) (Table 1), which has been extensively evaluated within the last few years. This is because of its physical properties, reduced solubility, apical seal ability, microretention to root dentin and adequate biological performance.
The purpose of this study was to evaluate the bond strength of EndoSequence BC root canal sealer in comparison to AH Plus and Kerr EWT (Kerr Corp, Michigan, USA) (Table 1) root canal sealers. The null hypothesis for this investigation is that there is no difference among these three sealers with respect to push-out bond strength.

### Materials and methods

#### Sample preparation

A total of 63 recently extracted human maxillary central incisors were selected for the study. Before canal instrumentation, the crown of each tooth was cut using a diamond rotary cutting instrument (Intensiv 314, O ISO 014, L.8.0 mm [Intensiv, Grancia, Switzerland]) and water spray to obtain 16 mm-long roots. The root canal was prepared using a crown-down technique using the ProTaper Universal NiTi rotary system (Dentsply Tulsa Dental, Oklahoma, USA) until the F4 file (size 40; taper 0.06). NaOCl (5.25%) was used for irrigation during the shaping procedure for a total of 5 ml. The canals were then irrigated with 5 ml of 17% ethylenediaminetetraacetic acid, 5 ml 5.25% NaOCl and a final irrigation with 5 ml sterile saline. A standardised method of irrigation was performed on all teeth by using a 28-gauge Monoject endodontic needle (Sherwood Medical, Missouri, USA). All samples were classified into three groups (n = 20) according to the type of the sealer used: group 1, EndoSequence BC; group 2, AH Plus; and group 3, Kerr EWT (Table 1).

#### Sample obturation

The canals were dried using paper points size 40 with taper 0.06 (Vericom, Gyeonggi-Do, South Korea). Root canals were filled by the lateral compaction technique; all sealers were mixed according to the manufacturer’s instructions. A pre-fitted size 40 gutta-percha cone with taper 0.06 (Dentsply DeTrey, Konstanz, Germany) was coated with the sealer. The gutta-percha cone was inserted to full working length; and lateral compaction was achieved by using five accessory gutta-percha cones (Dentsply DeTrey) and endodontic finger spreader size B (Dentsply-Maillefer, Ballaigues, Switzerland). A heated instrument was used to cut the excess gutta-percha. Radiographs (Eastman Kodak, Health Group Division, Georgia, USA) were taken of each sample to ensure appropriate quality of the root canal filling. Samples in all groups were stored at 37°C with 100% humidity. Each group was further subdivided into three subgroups according to the time interval until the push-out test: subgroup A, after 7 days; subgroup B, after 14 days; and subgroup C, after 30 days.

#### Push-out test

Each root was inserted in resin in a split-ring copper mould. After setting of the resin, three horizontal sections of 2 mm thickness each were cut from the coronal, middle and apical thirds of each root by using a water-cooled precision saw (Ernst-Leitz, Wetzlar, Germany) to obtain 2 mm-thick discs. The plungers used were 0.4, 0.6 and 0.8 mm diameter stainless steel cylindrical plungers for the apical, middle and

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**Table 1** Materials tested and their composition.

<table>
<thead>
<tr>
<th>Material</th>
<th>Composition</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>EndoSequence BC Sealer</td>
<td>Zirconium oxide, calcium silicates, calcium phosphate monobasic, calcium hydroxide, filler and thickening agents.</td>
<td>Brasseler USA (Georgia, USA)</td>
</tr>
<tr>
<td>Kerr EWT Sealer</td>
<td>Powder: zinc oxide. Liquid: 4-Allyl-2-Methoxyphenol, balsam resin and water.</td>
<td>Kerr Corp (Michigan, USA)</td>
</tr>
</tbody>
</table>
coronal sections, respectively. The plungers were connected to the load cell of a universal testing machine (Lloyd LRXplus, Lloyd Instruments Ltd, Fareham, UK). A vertical load was applied in an apical to coronal direction at a rate of 1.0 mm/min on the root canal filling. Failure was determined when the graph showed a reduction in load (20%). Samples of subgroup A (n = 7) were subjected to the push-out test after 7 days of obturation; while samples of subgroup B (n = 7) were subjected after 14 days; and subgroup C (n = 7) after 30 days.

The force was recorded by using Nexygen data analysis software (Lloyd Instruments Ltd). The bond strength at failure was then calculated and expressed in MPa by dividing the load (recorded in N) by the area of the bonded interface. The area of the bonded interface was calculated using the formula Area = 2Pr × h, where \( P = 3.14 \) and \( r \) and \( h \) were the measured radius and height, respectively, in millimetres of the filling material pushed-out. After the push-out test, samples of each group were examined by a scanning electron microscope (SEM) to determine the mode of failure (JSM-6400, JEOL, Tokyo, Japan). Each sample was evaluated and placed into 1 of 3 failure modes: type 1, adhesive failure at material/dentin interface; type 2, cohesive failure within the material; or type 3, mixed cohesive and adhesive failure.

### Statistical analysis

Data were subjected to a nonparametric Kruskal-Wallis test followed by the pair-wise Mann-Whitney U multiple comparison tests with the level of significance set at \( P \leq 0.05 \). Statistical analysis was performed with IBM SPSS statistics version 20.

### Results

The EndoSequence BC samples showed the highest mean push-out bond strength after 1 week (3.52 ± 0.78 MPa) and after 4 weeks (9.87 ± 1.82 MPa) followed by AH Plus after 1 week (1.68 ± 0.77 MPa) and after 4 weeks (7.51 ± 1.15 MPa). After 2 weeks, the AH Plus samples showed the highest mean push-out bond strength (6.14 ± 1.29 MPa) followed by Endo-Sequence BC (5.08 ± 0.75 MPa). Kerr EWT showed the lowest push-out bond strength mean values at all time intervals. Statistically, there were greater significant differences between the push-out bond strength values of all three sealers at every time interval (\( P < 0.001 \)) (Table 2).

Microscopic examination revealed cohesive failure as the most common mode in all groups of EndoSequence BC samples and after 2 and 4 weeks in samples of AH Plus sealer (Fig 1). However adhesive failure was the most common mode of failure in Kerr EWT samples (Fig 1).

### Discussion

Over the past few years, many sealers have been introduced in an attempt to provide a barrier against the leakage of bacteria in the cleaned and shaped root canal system. The aim of the current study was based on the idea that one of the major causes for failure in root canal treatment is the migration of microorganisms leaking root canal obturation. In 1976, Grossman demonstrated that adhesion of sealers is a highly desirable property. In 1988, Caicedo et al and in 2006, Schwartz, both agreed with this notion and showed that the ideal sealer should adhere to both the gutta-percha cone and the canal walls.

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**Table 2** Total bond strength (Mean ± SD) for all groups at three different time intervals.

<table>
<thead>
<tr>
<th>Sealer</th>
<th>EndoSequence BC</th>
<th>AH Plus</th>
<th>Kerr EWT</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 week</td>
<td>3.52 ± 0.78</td>
<td>1.68 ± 0.77</td>
<td>1.03 ± 0.44</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td>2 weeks</td>
<td>5.08 ± 0.75</td>
<td>6.14 ± 1.29</td>
<td>1.88 ± 1.27</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td>4 weeks</td>
<td>9.87 ± 1.82</td>
<td>7.51 ± 1.13</td>
<td>3.85 ± 0.61</td>
<td>&lt; 0.001*</td>
</tr>
</tbody>
</table>

*Significant at \( P \leq 0.05 \) Different small letters in the same row indicate significant differences between materials. Different capital letters in the same column indicate significant differences between different time periods.
The purpose of this study was to evaluate the bond strength of three different types of sealers to root canal dentine. AH Plus sealer is resin-based, EndoSequence BC is calcium silicate-based while Kerr EWT is a zinc oxide-eugenol-based sealer.

The null hypothesis stating that there is no difference among the materials under investigation with respect to push-out bond strength was rejected as EndoSequence BC showed the highest mean push-out bond strengths after 1 and 4 weeks. This may be due to the chemical nature of the EndoSequence BC sealer, which is hydrophilic, in addition to its low surface tension which provides better adaptation. In 2012, Candeiro et al. conducted a study evaluating the radiopacity, pH, release of calcium ions and flow of EndoSequence BC sealer. They found that EndoSequence BC sealer demonstrated flow greater than 20 mm, which is in agreement with ISO 6786/2001 recommendations. AH Plus presented a flow significantly lower than that of EndoSequence BC Sealer. This superior flow of EndoSequence BC together with smaller particle size results in deep penetration into the dentinal tubules for mechanical interlocking and therefore superior adhesion. Another possible reason is the ability of the EndoSequence BC sealer to form a hydroxyapatite hybrid layer. This apatite layer is formed based on the release of calcium and hydroxyl ions from the calcium silicate–containing material when it comes in contact with phosphate-containing fluids. Therefore the formation of this interfacial layer develops a chemical bond between calcium silicate-based materials and dentinal walls. Hence, it is expected that EndoSequence BC Sealer, which consists of a calcium silicate composition, has the potential to adhere chemically to dentin.

The superior bond strength of EndoSequence BC Sealer may be the reason for its superior performance in increasing the fracture resistance of root canal treated teeth, which was demonstrated by Uoglu et al. However, a sealing ability study conducted by Hirschberg et al. showed that the samples of EndoSequence BC sealer leaked significantly more than samples in the Mineral Trioxide Aggregate (MTA) group.

A study conducted by Mamootil and Messer showed that the epoxy resin-based sealers had higher adhesion to root canal dentin. The epoxy resin–based sealers penetrate better into micro-irregularities because of their creep capacity and long polymerisation period. Therefore the bond strength was improved by mechanical locking between the canal dentine wall and the sealer. Kerr EWT samples showed the lowest bond strength among groups however the mean push-out bond strength of the zinc oxide-based sealer in the current study was higher than that of the study conducted by Fisher and Bahcall. They explained the bond strength of the zinc oxide-based sealer by a chelating...
reaction that occurs during setting. The zinc ion may react with the mineral component of the dentin as well as with the zinc oxide in gutta-percha cones. In addition, the softening effect of eugenol on gutta-percha, creates an interlocking meshwork that will increase adhesion between the two materials. The mode of bond failure was mainly cohesive for EndoSequence BC and AH Plus groups in the current study. This result was augmented by other studies conducted by Shokouhinejad et al19,25,26. The effect of different time periods on the push-out bond strength of the three materials was the same with a significant increase reported in the bond strength over time. This may be attributed to increased setting and hardening of the material over time.

## Conclusion

Under the conditions of the present study it was concluded that after 4 weeks, EndoSequence BC sealer provided superior bonding to root canal dentine when compared with the zinc oxide-eugenol and the AH Plus sealers. In addition there was an increase in the bond strength of the three tested sealers over time.

## References