Comparative Evaluation of Push-out Bond Strength of Three Different Root Canal Sealers: An In Vitro Study

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ABSTRACT

Aim: The aim of this present study was to compare the dislodgement resistance of calcium silicate-based sealer, zinc oxide sealer, and a new sealer combining both zinc oxide and calcium silicate-based sealer in vitro.

Materials and methods: 60 single-rooted human teeth were instrumented with F3 Protaper Gold. All endodontic canals were filled using gutta percha cones using the cold lateral condensation technique in combination using one of the mentioned sealers (n = 20 per group). The teeth were divided into three groups: group A consisted of Sealite® Ultra, group B consisted of K-Sealer®, and group C consisted of BioRoot® RC. After 2 months of incubation (37°C, 100% humidity) and after cutting out 2 mm from the most apical portion of the root apex, six slices of 1 mm thickness were generated. Mechanical dislodgement resistance was examined using a universal pressure-testing machine and the push-out bond strength (POBS) was calculated. Specimens were examined under 20× magnification to define the bond failure mode. Statistical analysis was executed using ANOVA, post hoc Turkey test for pairwise comparisons and Kruskal–Wallis tests.

Results: The POBS of BioRoot® was significantly higher than the POBS of the two other sealers with a mean of 10.54 MPa ± 2.10 and 5.73 MPa ± 2.34, respectively (p < 0.001). Sealite® and K-Sealer® showed similar results in the median and coronal part. K-Sealer® revealed highest POBS compared with Sealite® in the apical part (p < 0.05).

Conclusion: The POBS of the zinc oxide and calcium silicate-based sealer was significantly lower compared with calcium silicate. Sealite® and K-Sealer® exhibited almost same results. BioRoot showed the highest POBS of all sealers.

Clinical significance: The current study was needed to evaluate the bond strength of three different cements to dentinal walls, by evaluating their respective POBS in vitro. The findings of this study may provide guidance for the clinician in the selection of an adequate endodontic sealer that guarantees an enhanced adhesive seal between the Gutta-percha and the dentinal canal walls.

Keywords: BioRoot RCS, Calcium silicate-based sealer, K-Sealer, Push-out bond strength, Sealite Ultra, Zinc oxide-based sealer.

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INTRODUCTION

The main objective of root canal obturation is to create a strong bond between filling materials and dental walls.¹ This is achieved by combining a solid obturation substance with an endodontic cement that binds to dentin and maintains dimensional stability for a hermetic seal.²–⁴

In the present study, three different cements have been selected.

On the one hand, BioRoot®, RCS, a calcium silicate-based root canal sealer, is constituted of a powder and a liquid.⁵,⁶ The powder consists of tricalcium silicate whereas the liquid is an aqueous solution of calcium chloride (curing accelerator) and exipients.⁷,⁸

On the other hand, zinc eugenol oxide-based obturating pastes is another common cement that has been widely used as common well-known materials for endodontic obturations.⁸–¹⁰ Many clinicians may prefer its use, because retreatment of a canal is easier when dissolving by chloroform.

Lastly, K-Sealer® is a new cement that is distinguished by its combination of calcium silicate and zinc oxide material. Due to the combination of the constituents of both, it is believed that this mixed cement presents the advantages of both materials.

Root canal obturation material needs to adhere well to dentinal walls in both static and dynamic conditions. It should seal any gaps and resist disruption from mechanical stresses.¹¹,¹² Tensile shear bond strength and push-out bond strength (POBS) experiments were used to ascertain a material’s adhesion to the surrounding dentin. However, the push-out test has been deemed a more practical and reliable method.¹³–¹⁵

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Consequently, the aim of this study, is to compare the POBS of BioRoot® and Sealite® ultra with K-Sealer® in vitro.

The null hypothesis is that there is no statistically significant difference between the POBS of BioRoot®, Sealite® ultra and K-Sealer® at the dentinal canal walls.

**Materials and Methods**

The in vitro comparative study was conducted at the laboratory of Cranio-Facial Research, Oral Biology unit, at Saint Joseph University, Beirut between January and July 2023.

**Sample Preparation**

The minimum required sample size was 16 teeth per group, as determined by power analysis using the software G*Power for analysis of variance (ANOVA), with a power of 80%, an alpha error of 5%, and an effect size of 0.47 (48 dry teeth in total).

The current study was approved by the Ethics committee (2022–219). From a pool of 100 extracted incisors for periodontal reasons, sixty central incisors were included.

The inclusion criteria included fully developed maxillary central incisors, with non-calciﬁed and intact pulp chamber and without any prior radicular canal preparation or obturation. Radiographs were taken to deﬁne only single-rooted teeth with Vertucci type I conﬁguration with straight root canal (curvature <5°). The dentitrus and hard deposits on the exterior surfaces of the teeth were removed using an ultrasonic debris extractor. Samples were then stored in distilled water with 0.5% thymol until required.16

All treatment procedures were performed by a single practitioner experienced in endodontics. Teeth were sectioned at the level of the CEJ (cemento-enamel junction) using a diamond-coated disk to yield 12 mm radial lengths. Apical patency was determined using a k-ﬁle of size 15 (VDW, Munich, Germany) and working length (WL) was obtained by gradually retracting the instrument until it reached the major apical foramen minus 1 mm. All teeth were instrumented with rotating ProTaper Gold instruments (Dentsply-Maillefer in Ballaigues, Switzerland) connected to an endomotor X-Smart at a ﬂow rate of 300 tr/min of apical ﬁle F3. For instrument irrigation, 5.25% sodium hypochlorite (Chemident) was used, followed by 17% EDTA (Glyde, Dentsply, N.A.), and a ﬁnal rinse with saline solution. After that the channels were dried with paper points.17,18

The samples were divided at random into three groups (n = 20). The following groups were created: group A consists of Sealite® Ultra (Pierre Rolland, Merignac, France), group B consists of K-Sealer® (Issam Khalil, Rekita, Lebanon), and group C consists of BioRoot® RCS (Septodont, Saint-Maur-des-Fossés, France).

Gutta percha cones were brought to WL. All sealers were mixed according to the manufacturer’s instructions. The lateral compaction method was the chosen obturation technique for all three sealers.

At the end of the obturation, orthogonal and deviated radiographs of the teeth were taken to validate a successful canal hermiticity.19 The orifices of the canal were later ﬁlled with Cavit G. (3 M ESPE, Seefeld, Germany) and the teeth were preserved in an incubator at 37°C and 100% for 8 weeks, with the knowledge that the calcium silicate precipitation reaction may persist for at least 21 days or longer. The teeth were then sectioned using a microtome (EXAKT 300, EXAKT Technologies, Norderstedt, Germany), resulting in six slices per tooth with a thickness of 1 mm ± 0.1 mm distributed as follows: 2 coronal slices, 2 middle slices, and 2 apical slices. The apical 2 mm of each tooth was abandoned to avoid apical ramiﬁcations.20,21

**Push-out Bond Strength Application**

The specimens were then placed on a perforated acrylic resin slab. The perforation allowed the canal ﬁlling material to push-out from the canal after dislodgement due to the applied tension.

To allow an even distribution of the charge between 60 and 85% of the diameter of the Gutta-percha cone without affecting the sealing phase of canal obturation, the diameter of the plunger was proportional to the diameter of the Gutta-percha with a tip of 0.3 for the apical third and 0.5 for the middle and coronal thirds. The vertical charge was generated by a universal test machine (DL-1000, Emic, Pinhais, SP, Brazil) and administered in the direction of apical to coronal. The software connected to the machine generated a charge application graph, and a connection break was determined automatically when the graph reveals a signiﬁcant decrease in the applied charge. This sudden reduction of load was recorded in Newtons (N).

Using the POBS formula:

\[
R (\text{MPa}) = \frac{F(N)}{\text{Area (mm}^2\text{)}} \]

\[
= 2r \times h,\]  

The resistance is then calculated and expressed in N/mm² (equivalent to MPa) (8).

After dislodgement of the root canal ﬁlling, all samples were examined under a 20× magniﬁcation stereomicroscope (Olympus, BX60M, Japan). Two experienced operators independently evaluated the images and recorded the failure mode. Consequently, three possible categories of failure could be reported: adhesive failure (no material remains on the canal wall), cohesive failure (material completely covers the canal wall), and mixed failure (material in the form of plaques).15–23

The statistical software IBM SPSS (version 25.0) was used to statistically analyze the data obtained.

Data were analyzed using (ANOVA) test followed by post hoc Tukey test for pairwise comparisons and Kruskal–Wallis tests were used to assess potential signiﬁcant differences between the different types of sealers in terms of fracture resistance.

The Chi-square test was performed to assess associations between sealers’ types and different types of rupture (adhesive rupture, cohesive rupture, and mixed rupture).

A p-value of less than 0.05 was considered statistically significant.

**Results**

Three hundred and sixty specimens were included in the study (n = 360), equally divided between the different regions and types of sealers.

The results for the resistance to fracture by type of sealer for the different regions are presented in Table 1. Statistically signiﬁcant differences, in resistance to fracture were found at different levels and between diﬀerent groups.

At the apical region, BioRoot® demonstrated the highest resistance to fracture (19.93 ± 2.45 MPa) (p < 0.001), followed by K-Sealer® (15.41 ± 2.88 MPa), and Sealite® (9.49 ± 2.79 MPa), respectively.

At the median and coronary region, BioRoot® also provided a greater resistance to dislodging (p < 0.001) with a mean of 10.54 MPa ± 2.10 and 5.73 MPa ± 2.34, respectively. No signiﬁcant diﬀerences were found between the K-Sealer® and the Sealite® at the median and the coronary regions (4.55 ± 0.96 at the median

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Table 1: Fracture resistance (in MPa) by region and type of sealer (n = 360)

<table>
<thead>
<tr>
<th>Region</th>
<th>Sealite* Mean ± SD</th>
<th>K-Sealer* Mean ± SD</th>
<th>BioRoot* Mean ± SD</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apical</td>
<td>15.41 ± 2.88&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.93 ± 2.45&lt;sup&gt;c&lt;/sup&gt;</td>
<td>15.41 ± 2.88&lt;sup&gt;a&lt;/sup&gt;</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Median</td>
<td>4.55 ± 0.96&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10.54 ± 2.10&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>4.55 ± 0.96&lt;sup&gt;b&lt;/sup&gt;</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Coronary</td>
<td>2.83 ± 0.63&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.73 ± 2.34&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>2.83 ± 0.63&lt;sup&gt;b&lt;/sup&gt;</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*Same lowercase letters show statistically significant differences between the groups; ANOVA followed by Tukey test; Kruskal-Wallis test.

Table 2: Type of rupture by region and type of sealer (n = 360)

<table>
<thead>
<tr>
<th>Region</th>
<th>Type of rupture</th>
<th>Sealite* N (%)</th>
<th>K-Sealer* N (%)</th>
<th>BioRoot* N (%)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apical</td>
<td>Adhesive rupture</td>
<td>13 (32.5)</td>
<td>2 (5.0)</td>
<td>2 (5.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Cohesive rupture</td>
<td>23 (63.5)</td>
<td>29 (72.5)</td>
<td>7 (17.5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mixed rupture</td>
<td>4 (10.0)</td>
<td>9 (22.5)</td>
<td>31 (77.5)</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>Adhesive rupture</td>
<td>13 (32.5)</td>
<td>10 (25.0)</td>
<td>11 (27.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Cohesive rupture</td>
<td>17 (42.5)</td>
<td>15 (37.5)</td>
<td>2 (5.0)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mixed rupture</td>
<td>10 (25.0)</td>
<td>15 (37.5)</td>
<td>27 (67.5)</td>
<td></td>
</tr>
<tr>
<td>Coronary</td>
<td>Adhesive rupture</td>
<td>9 (24.25)</td>
<td>17 (42.5)</td>
<td>14 (35.0)</td>
<td>0.014</td>
</tr>
<tr>
<td></td>
<td>Cohesive rupture</td>
<td>17 (42.5)</td>
<td>16 (40.0)</td>
<td>7 (17.5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mixed rupture</td>
<td>15 (40.0)</td>
<td>7 (17.5)</td>
<td>19 (47.5)</td>
<td></td>
</tr>
</tbody>
</table>

In this present study, the null hypothesis was rejected. Based on these results, BioRoot* showed the best results when compared with both Sealite* and K-Sealer*, in all root portions: apical, middle and coronal. On the other hand, there was a statistically significant difference between Sealite* and K-Sealer* in the apical part, while on the other hand, they both reflected same outcome in the middle and coronal root levels (p < 0.001).

Previous research has demonstrated that the single-cone technique may have inherent limitations regardless of the sealant used. Furthermore, the properties of sealers are affected by heat application during warm vertical compaction for BioRoot*, which showed reduced flow and setting time. Therefore, for optimal testing conditions, with all of the three sealers, the cold lateral condensation technique was selected in this current study without any constraints as per manufacturer recommendations.

For appropriate standardization of the POBS method, it is recommended that the ratio between the plunger’s diameter and the specimen’s diameter be set between 0.6 and 0.85, which was adopted in the present study.

BioRoot* is a bioceramic sealer that contains calcium silicate, calcium phosphate, and zirconium oxide. It is known for its excellent biocompatibility, bioactivity, and ability to stimulate tissue regeneration. In a study performed by Milanovic et al. about immediate and long-term porosity of calcium silicate-based sealers, he evaluated the POBS of BioRoot* and zinc oxide and resin-based cements using human extracted teeth. The results showed that BioRoot* cement had significantly higher bond strength values compared with Sealite* cement in all regions of the root canal.

When evaluating the effect of calcium hydroxide on the efficacy of the root canal obturation, Uzunoglu-Ozyurek et al. also found that BioRoot* cement had significantly higher bond strength values.

Similarly, Ballal et al. confirmed a strong bond between dentin and BioRoot* when comparing the presence or removal of smear layer using chelating agents.

BioRoot*’s enhanced physical and chemical properties contribute to its superior performance compared with other sealants. The presence of zirconium oxide in BioRoot* increases its radiopacity and promotes a strong bond with dentin. The bioceramic-based sealer undergoes a setting reaction that results in excellent bond strength with root dentin, surpassing the performance of Sealite*. BioRoot* absorbs water from dental tubules and forms hydroxyapatite and calcium silicate hydrogel. The hydroxy group facilitates a chemical bond between the hydrogel and hydroxyapatite, promoting continuous crystal growth and attachment to the dentin. Unlike resin-based sealants, BioRoot* lacks shrinkage and can penetrate dental tubules. Its high flowability and hydrophilic behavior enable effective sealing of auxiliary canals even in the presence of moisture. Interaction with tissue fluids leads to the formation of mineral marks.

Despite the favoring features of BioRoot*, Sealite* and K-Sealer* have been found to have similar POBS, nonetheless they are lower than the former.

Sealite* and K-Sealer* are both commonly used endodontic obturation materials for filling root canals. While both materials have been shown to have similar POBS in the middle and coronal parts of the root canal, this present study has demonstrated that K-Sealer* has superior POBS in the apical part of the root canal compared with Sealite*. This higher POBS of K-Sealer* in the apical part of the root canal may be advantageous in cases where the root canal is particularly narrow or curved in the apical region. Additionally, K-Sealer* is a calcium silicate and zinc oxide-based sealant that is often used in clinical endodontics.

**Discussion**

The POBS of root canal sealers is an important factor to consider in an endodontic treatment. The adhering ability of a sealer to the root canal walls can influence the success of the root canal treatment by preventing microleakage and bacterial penetration.

The purpose of this study is to compare the POBS of three different root canal sealers: BioRoot*, Sealite* and K-Sealer*.
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material, which may offer better sealing properties and reduced microleakage. However, it is important to note that POBS is just one of many factors that should be considered when choosing an obturation material for a root canal procedure. Other factors, such as biocompatibility, setting time, ease of placement, and cost, may also be important considerations.

With respect to the failure mode, the current obtained results for BioRoot® sealer are shown similar with previously reported findings. Comparisons between Sealite® and K-Sealer® with other studies are not possible due to the differences in failure reporting or experimental setups. Sealite® and K-Sealer® mostly showed cohesive failure modes, while BioRoot® had mixed failure modes. Higher dislodgment resistance correlated with mixed failures, while lower resistance was associated with cohesive failures. The connection between zinc oxide sealer and Gutta-percha appears weaker than its connection to dentin, as seen in the higher proportion of cohesive failures in the Sealite® group. The same conclusion applies to K-Sealer®. BioRoot® showed comparable connections to both dentin and Gutta-percha, indicated by the higher proportion of mixed failures. Overall, the cement demonstrated better adhesion to root canal walls compared with Gutta-percha, as seen by the lower proportion of adhesive failures in all groups.

Despite the present limitations of this study, in vitro study on extracted teeth, the POBS of the examined calcium silicate and zinc oxide-based sealers was lower than the POBS of BioRoot®. BioRoot® showed the highest POBS while K-Sealer® and Sealite® demonstrated very comparable results in the middle and coronal parts.

Following up on the findings of the present study, a second stage evaluation of the investigated cements permits to analyze the hindering factors in K-Sealer® that despite its composition of calcium silicate, the former did not significantly enhance the outcome of the POBS compared with cements solely made of zinc oxide.

Furthermore, a greater clinical significance of the study can be followed up by a cohort in vivo application and comparison over time, taking into consideration the biological effects in the outcome of the endodontic success.

CONCLUSION

It is of interest to document data on the POBS of three different root canal treatment sealers, such as BioRoot® (calcium silicate-based material), Sealite® (zinc oxide-based), and K-Sealer® (zinc oxide and calcium silicate-based). Across all segments, BioRoot® demonstrated a significantly greater push-out bond resistance before failure as compared with Sealite® and K-Sealer®. In the apical portion, K-Sealer® demonstrated a significant greater resistance to dislodgement compared with Sealite®.

Microscopic analysis displayed that the majority of the failure types were of cohesive category for K-Sealer® and Sealite® and of mixed category failures for BioRoot®.

REFERENCES

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