Comparison of Push-Out Bond Strength of Three Calcium Silicate Cements to Dentin

Üç Kalsiyum Silikat Esaslı Simanın Dentine Bağlanma Dayanımının Karşılaştırılması

ABSTRACT Objective: To compare the push-out bond strength of ProRoot MTA (PRM), Biodentine (BD) and BioAggregate (BA) to root dentin. Material and Methods: Twenty extracted mandibular premolar teeth were used. Serial slices of 1.00 ± 0.05 mm thickness were obtained from the middle third of the roots by sectioning vertically to the long axis using a water-cooled diamond blade on a cutting machine. The specimens were prepared with Gates Glidden burs (sizes 4, 5 and 6) to obtain a standard diameter of 1.3 mm. A total of 60 slices were randomly divided into three groups (n = 20). The root slices were filled with PRM, BD and BA cements. The push-out bond strengths were measured by using a universal testing machine. Force was applied to the fillings with a 1-mm diameter cylindrical stainless steel plunger, at a speed of 1 mm/min. Stereomicroscopic images were obtained at 25× magnification to determine the type of bond failure. Data were analysed using one-way analysis of variance and post hoc Tukey tests. A chi-square test was used to determine if there were any significant association between the type of material and type of failure. Results: PRM and BD each had higher bond strength values than BA (p<0.001). Conclusion: Since the push-out bond strength of ProRoot MTA and Biodentine are higher than BioAggregate, their usage in clinical applications can be advised if seen necessary.

Key Words: Calcium silicate; mineral trioxide aggregate


Anıhtar Kelimeler: Kalsiyum silikat; mineral trioksit agregat

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pulp capping and the closure of the apex in immature teeth; it is also used as a coronal barrier and canal paste in the treatment of root resorptions.6-8

Like any material, calcium silicate cements (CSCs) have several disadvantages, such as long setting times, difficulties in manipulation, and the risk of tooth discolouration.8 Because of these disadvantages, the original formulation was modified to improve the material’s physicochemical and mechanical properties.9 The main components of MTA are tricalcium silicate, bismuth oxide, dicalcium silicate, tricalcium aluminate, tetracalcium aluminoferrite, and calcium sulphate dehydrate; in the dental market, PRM is its commercial form. According to the manufacturer, the recommended setting time for MTA is 4 h. BA is a material similar to MTA, modified so as to contain no aluminium; this modification precludes cytotoxic effects.10 It contains tricalcium silicate, dicalcium silicate, calcium phosphate, and monobasic and amorphous silicon dioxide. Additionally, tantalum pentoxide is replaced with bismuth oxide in conventional MTA to provide radiopacity.11 BD consists of tricalcium silicate, calcium carbonate, zirconium oxide, a setting accelerator that contains calcium chloride, and a water-reducing agent. BD can be called a dentin replacement material; it can be used as a base material under composite restorations, with the advantages of good sealing ability, resistance to high compressive strengths, a short setting time, and good biocompatibility, bioactivity and biominalisation properties.12-15

The ability to prectule microleakage through the pulp and periradicular tissues and be resistant to various forces are some of the principal properties that a repair material should ideally possess; the ability of such a material to adapt to dentin walls, as well as its bond strength, are also very important.9,16 Adhesion of any dental material to dentin can be evaluated through the use of tensile, shear, and push out strength tests.17 Push out tests area a frequently used in endodontics, as they provide more reliable results than the conventional shear test; by using this method, more realistic specimens are obtained with parallel fractures.18-21 The aim of this study was to compare the push-out bond strength of PRM, BD, and BA to root dentin. The null hypothesis states that there are no significant differences among the three in terms of push out bond strength.

**MATERIAL AND METHODS**

**SAMPLE PREPARATION**

Twenty single rooted permanent mandibular pre-molar teeth that had been extracted for orthodontic reasons were used in the present study. Each teeth had fully formed apex and lacked both root resorption and previous endodontic treatment. Teeth were stored in tap water containing 0.1% thymol until they were used in the study. A standard length of 11 mm was obtained by sectioning the tooth at the cementoenamel junction with a diamond saw. Serial slices of 1.00 ± 0.05 mm thickness were obtained from the middle third of the roots by sectioning vertically to the long axis, using a water cooled diamond blade on a cutting machine (Isomet 1000; Buehler, Lake Bluff, NY, USA). A total of 60 root dentin slices were drilled with Gates Glidden burs (Dentsply Maillefer, Ballaigues, Switzerland) sizes 4, 5, and 6 to obtain standardised cavites with 1.3 mm diameters. All slices were irrigated 5 ml of distilled water and dried on paper points. The specimens were then randomly divided into three groups (n = 20).

Different CSCs (ProRoot MTA, Biodentine, and DiaRoot BioAggregate cements) were prepared according to manufacturer’s instructions, placed inside the root canal space of the slices, and compacted with an endodontic plunger. A scalpel was used to remove any excess material. The specimens were then covered with serum soaked gauze and incubated for 7 days at 37 °C and 100% humidity, in order to achieve complete setting. The specimens in each group were stored separately in plastic containers. The humid environment was maintained inside the container by replacing wet gauze every day.

**PUSH-OUT TEST**

A universal testing machine (Instron, Norwood, MA, USA) was used to measure push-out bond
strength. Force was applied on the fillings with a 1-mm diameter cylindrical stainless steel plunger at a 1 mm/min speed. The maximum load needed to achieve filling failure was recorded in newtons. The data obtained were converted to megapascals (MPa) by using the following formula: newtons / (2πrh), where π indicate the constant, and r and h the canal radius and the thickness of the root slice, both in millimetres.

**STEREOMICROSCOOPY ANALYSIS**

Stereomicroscopic images were obtained at 25× magnification to determine the type of bond failure. Categorisation of the type of failure was than performed, in terms of one of three types namely, adhesive failure between MTA and dentin, cohesive failure within MTA, or mixed failure.

**STATISTICAL ANALYSIS**

IBM SPSS statistics software 20.0 was used in this study to undertake statistical analyses. Push out strength data were analysed using one-way analysis of variance (ANOVA) and post hoc Tukey tests (p < 0.05). A chi-square test was used to determine if there were any significant association between material type and failure type.

### RESULTS

Table 1 showed the mean and standard deviations of the groups. Statistically significant differences were found among the groups, according to the results of the ANOVA test (p < 0.001). The PRM and BD groups exhibited higher mean values of push-out bond strength than the BA group (p<0.001). No statistically significant difference could be found between PRM and BD (p=0.181) in terms of mean bond strength. Differences among the bond failure modes of the groups were not statistically significant according to the results of the chi-square test (p=0.780) (Table 2). While a majority of the samples exhibited an adhesive type failure, some exhibited cohesive and mixed failure types (Figure 1).

### DISCUSSION

Many studies have evaluated the clinical usage and, biological and physical characteristics of CSC materials. These materials gained importance in endodontics, since they have used in hard-to-cope areas such as external root surface resorptions and apical plug-in resected teeth. Therefore, they should have properties such as biocompatibility, stability after setting, adherence to dentin, resist-

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**TABLE 1:** The mean push out bond strength in MPA of three different materials.

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>Mean(Mpa)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>ProRoot MTA</td>
<td>20</td>
<td>10.7a</td>
<td>±2.1</td>
</tr>
<tr>
<td>Biodentine</td>
<td>20</td>
<td>9.2a</td>
<td>±2.7</td>
</tr>
<tr>
<td>Bioaggregate</td>
<td>20</td>
<td>2.6b</td>
<td>±1.2</td>
</tr>
</tbody>
</table>

Different superscript letters indicate significant differences between the groups (P<0.05). Same superscript letters indicate no significant differences (p>0.05); SD: Standart deviation.

**TABLE 2:** Bond failure was of the adhesive type in the majority of samples; however, some samples exhibited cohesive and mixed failure patterns.

<table>
<thead>
<tr>
<th></th>
<th>Adhesive</th>
<th>Cohesive</th>
<th>Mix</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>ProRoot MTA</td>
<td>10</td>
<td>6</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>Biodentine</td>
<td>11</td>
<td>4</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>BioAggregate</td>
<td>8</td>
<td>5</td>
<td>7</td>
<td>20</td>
</tr>
</tbody>
</table>

Different superscript letters indicate significant differences between the groups (P<0.05). Same superscript letters indicate no significant differences (p>0.05).

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**FIGURE 1:** Stereomicroscopic images of the failure modes from representative samples. Adhesive type (a), cohesive type (b) and mix type (c) failure patterns.
ance to dislodging forces and the rendering of a good seal to prevent bacterial leakage and the passage of tissue fluids. Some formulation modifications have been performed to improve their properties, as in the examples of BA and BD. This study was designed to assess the push-out bond strength of the adherence of three CSC to canal dentin.

Gancedo-Caravia and Garcia-Barbero have reported that the push-out strength of CSC increased in the presence of moisture. In the present study, the specimens were incubated for 7 days at 37 °C at 100% humidity, to allow the materials to set completely; this was done on the understanding that CSCs have a long setting time. In previous studies, after the root canal slices were prepared with the Gates Glidden, or post-drilling, they were obturated with CSC. In the present study we used similar methods with previous studies.

The selection of mixing and compaction techniques relates to the chemical, physical, and biological characteristics of the CSCs used. When CSCs are mixed, a slurry paste forms that is difficult to handle and compact inside the root canal spaces, without voids. The use of a lentulo, manual files, pluggers, and ultrasonic activation are some of the techniques used to apply CSCs to root canals. When hand condensation is combined with indirect ultrasonic activation, improvements can be made to the compaction of CSCs and their adaptation to dentin by applying compressive forces; these improvements derive from the reorganisation of particles and the escape of entrapped air. On the other hand, El-Ma’aita et al. have reported on manual compaction results in denser root canal fillings, compared to those rendered through ultrasonic activation. Yet another study compared ultrasonic and hand condensation methods in terms of their effects on the adaptation of CSCs in simulated root canals and found that ultrasonic activation causes more voids and poorer adaptation. Namazikhah et al. and Nekooifar et al. each state that voids may actually not pose a problem for the optimal setting, since they act as water passages through CSCs. In the current study, standardised root slices were filled with PRM, BD and BA cements, using a plugger.

It remains controversial whether or not leaving the smear layer intact is advantageous in endodontics. It has been suggested that the smear layer may block the dentinal tubules and therefore preclude bacterial or toxin penetration; it has also been suggested, however, that the smear layer leads to the possibility of infection and microleakage, and so it must be removed. On the other hand, this smear layer prevents medicaments from penetrating the dentinal tubules and killing bacteria within. Additionally, the smear layer also reduces the adaptability of filling materials and their penetration into the canal walls, thus reducing sealing ability. Still, other studies report that smear layer removal prior to CSC application has a negative effect on the CSC’s sealing ability. Uyanik et al. evaluated the effect of different irrigation methods on the sealing capacity of CSC; they concluded that the use of MTAD and EDTA causes an increase in the leakage of CSC. In yet another study, CSC exhibited higher leakage when the smear layer was removed prior to CSC application. Having considered all these matters, we decided that in the current study, the smear layer would be left intact.

Guneser et al. showed that the bond strength of White PRM was weaker than that of BD. In addition, Ma’atta et al. have reported that the bond strength of Biodentine was stronger than that of PRM; they attribute this to the fact that the particle size of BD was small and has better capacity for penetration into dentinal tubules. Shokouhinejad et al. showed that the bond strength of BA was weaker than that of PRM or Endosequence, in a study evaluating the bond strength of those materials as root repair materials. Ertas et al. evaluated the push-out bond strength of PRM, Angelus MTA, and calcium-enriched mixture (CEM) cement; they found PRM to have the greatest strength. They explained that this comparatively greater strength could be attributed to its different formulation.

The results of the current study indicated that the push-out bond strength of BA was lower than PRM and BD. This difference might stem from the presence of different chemical components in each CSC; some are present in PRM and BD, for example, but not in BA. These results align with those of pre-
vious studies. Han and Okiji stated that the higher retention in White MTA and BD groups might be explained by the tag-like structure forms in the adjacent root canal dentin; Liu et al. indicated that the addition of tricalcium aluminate improves the strength of CSC. In the absence of Ca$_3$Al$_2$O$_6$, the strength of a CSC may be attenuated.

Shokouhinejad et al. have showed that following push-out testing, the mode of failure is mainly of an adhesive nature. Ertas et al. have stated that the mode of failure does not significantly differ among PRM, Angelus MTA, and CEM.