

## Determination of the Apical Sealing Abilities of Mineral Trioxide Aggregate, Portland Cement, and Bioaggregate After Irrigation with Different Solutions

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### Abstract:

**Objectives:** The purpose of this study was to investigate the sealing ability of root-end filling materials such as mineral trioxide aggregate (MTA), Portland cement, and bioaggregate (BA) after irrigation with different solutions.

**Materials and Methods:** We examined 130 human maxillary central teeth. After cutting the teeth at the cemento-enamel junction, the root canals were expanded using nickel-titanium rotary instruments. Root canals were filled with AH-plus and gutta-percha. Then, the roots were cut apically, and 3 mm deep retrograde cavities were prepared. The roots were divided into 12 experimental groups, consisting of 10 teeth each; the positive and negative control groups contained five teeth each. The retrograde cavities were rinsed using ethylenediaminetetraacetic acid (EDTA), chlorhexidine (CHX), BioPure™ mixture of a tetracycline isomer, an acid, and a detergent (MTAD), or distilled water. Next, groups 1, 2, 3, and 4 were sealed with MTA; groups 5, 6, 7, and 8 were sealed with Portland cement; and groups 9, 10, 11, and 12 were sealed with BA. Then, apical microleakage was evaluated by using a computerized fluid filtration method. The results of the leakage test were statistically evaluated by the *post-hoc* Tukey's test.

**Results:** MTA, Portland cement, and BA root-end filling materials showed the least leakage in the CHX and distilled water groups. The highest leakage was observed in the EDTA and MTAD groups.

**Conclusions:** The sealing ability of BA was as good as that of MTA. EDTA and MTAD increased the apical leakage and CHX and distilled water decreased the leakage of the root-end filling materials examined in this study.

**Key Words:** Bioaggregate, leakage, mineral trioxide aggregate, Portland cement, root canal irrigants

### Introduction

Apical surgery may be necessary when nonsurgical endodontic therapy is not indicated or when it fails.<sup>1</sup> Apical surgery involves debridement of pathologic tissue, exposure of the root apex, resection of the apex, preparation of the root apex for the root-end filling materials, and placement of the root-end filling materials.<sup>2</sup> Numerous materials have been recommended for use as root-end filling materials, including amalgam, gutta-percha, zinc oxide-eugenol cements, composite resin with and without dentin-bonding adhesives, polycarboxylate cement, glass ionomer cement, compomers, resin-modified glass ionomers, resin cements, and mineral trioxide aggregate (MTA).<sup>3</sup>

MTA has been used for apexification, perforation repair, root resorption, and as root-end filling material.<sup>4</sup> The main components of MTA are tricalcium silicate, tricalcium aluminate, tricalcium oxide, and silicate oxide.<sup>5</sup> The properties of Portland cement have been analyzed, and it has been found to be composed of the same components as MTA, except for bismuth oxide.<sup>6</sup> MTA and Portland cement were similar macroscopically, microscopically, and according to X-ray diffraction analysis.<sup>6</sup> Holland *et al.* reported that MTA and Portland cement exhibited similar tissue reactions.<sup>7</sup> Thus, the use of Portland cement as an alternative to MTA produces favorable physical and biological results.<sup>6,8,9</sup>

Bioaggregate (BA) is a new bioceramic-based material produced for perforation repair, retrograde root filling,<sup>10</sup> and vital pulp therapy.<sup>11</sup> BA consists of tricalcium silicate, dicalcium silicate, calcium phosphate monobasic, amorphous silicon dioxide, and tantalum pentoxide.<sup>12</sup> The biocompatibility of BA with regard to mesenchymal human cells is similar to that of white MTA.<sup>13</sup> Furthermore, Tay *et al.* reported that the root-end sealing quality of ceramicrete was better than that of MTA.<sup>1</sup>

Following the preparation of the root-end cavity, various irrigation solutions may be used to clean the canal. Some of the irrigation solution may remain in the root canal space, which may affect the properties of the root-end filling material.<sup>14</sup> Thus, endodontic irrigants come in contact with root-end filling materials; however, there is little information regarding

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the influence of endodontic irrigants on the sealing properties of root-end filling materials.

Therefore, the purpose of this study was to investigate the sealing ability of root-end filling materials such as MTA, Portland cement, and BA after different irrigation solutions had been used.

## Materials and Methods

### Preparation and obturation of teeth

130 extracted single-canal teeth were used in this study. The reason for extraction, age and sex of the patients were unknown. All teeth were examined for fractures or defects, and teeth with fractures were excluded. Next, the crowns of the teeth were removed using a water-cooled diamond disc at a distance of 15 mm from the apex of the root. Standard occlusal access cavities were prepared, and working lengths were determined visually by subtracting 1 mm from the point at which a size 10 K-file just exited the apical foramen. The canals were instrumented by ProTaper rotary nickel-titanium instruments using a crown-down technique to attain a master apical file size of finishing file 3 (F3). During preparation, the canals were irrigated with 5.25% NaOCl (Sultan Healthcare Inc., Englewood, USA). The canals were subsequently dried by using paper points. All the teeth were obturated with gutta-percha (Dentsply De Trey, Konstanz, Germany) and AH-Plus (Dentsply De Trey) using the cold lateral compaction technique.

The apices of all the teeth were resected using a diamond bur under a continuous water spray at an angle of 90°, 3 mm from the apex. Root-end cavities that were 3-mm deep and 1.5-mm diameter were prepared using a calibrated fissure steel bur in pumping motion. Each of the three experimental groups was subdivided into four irrigation subgroups of 10 teeth each; each subgroup was further divided into two control groups. The roots were filled as follows:

Group 1: Root-end cavity Irrigation with 4 ml of 17% ethylenediaminetetraacetic acid (EDTA) followed by MTA (Angelus, Londrina, Brazil) for root-end filling, Group 2: irrigation with 4 ml of 2% chlorhexidine (CHX) gluconate solution (Drogsan, Ankara, Turkey) followed by obturation with MTA, Group 3: Irrigation with 4 ml of mixture of a tetracycline isomer, an acid, and a detergent (MTAD) (Dentsply, Tulsa Dental, Johnson City, Tulsa, OK, USA) and obturation with MTA, Group 4: Irrigation with 4 ml of distilled water and obturation with MTA, Group 5: Irrigation with 4 ml of 17% EDTA and obturation with Portland cement, Group 6: Irrigation with 4 ml of 2% CHX and obturation with Portland cement, Group 7: Irrigation with 4 ml of MTAD and obturation with Portland cement, Group 8: Irrigation with 4 ml of distilled water and obturation with Portland cement, Group 9: Irrigation with 4 ml of 17% EDTA and obturation

with BA (Diadent Group International, Vancouver, Canada), Group 10: Irrigation with 4 ml of 2% CHX and obturation with BA, Group 11: Irrigation with 4 ml of MTAD and obturation with BA, and Group 12: Irrigation with 4 ml of distilled water and obturation with BA. Furthermore, in the positive control group, no root-end filling material was used, and in the negative control group, the cavities were sealed with red wax.

MTA and BA were mixed according to the manufacturer's recommendations, and Portland cement water/powder ratios were similar to that of MTA. The cement mixtures were placed in the cavities by using a carrier and were condensed with MTA pluggers.

Radiography was performed for all the teeth after placement of the restorative materials to verify their uniformity and density, and the root-end filling materials were allowed to set for 4 days at 37°C and 100% humidity. In the experimental and positive control groups, the surface of the teeth, with the exception of the apical 3-mm portion, was coated with two layers of nail polish. In the negative control group, the entire surface of the teeth was coated with two layers of nail varnish.

### Determination of microleakage

In this *in vitro* study, the apical leakage was calculated using the computerized fluid filtration method. For each sample, fluid movement was automatically measured at 2-min intervals for 8 min by means of PC-compatible software (Fluid Filtration'03, Konya, Turkey). The fluid flow rates (i.e., microleakage) were expressed as  $\mu\text{l} \cdot \text{cm H}_2\text{O}^{-1} \cdot \text{min}^{-1}$ .

### Statistical analyses

The results of the leakage test were statistically evaluated using the post-hoc Tukey's test. The results were expressed as means  $\pm$  standard deviation, and  $P < 0.05$  was considered statistically significant.

### Results

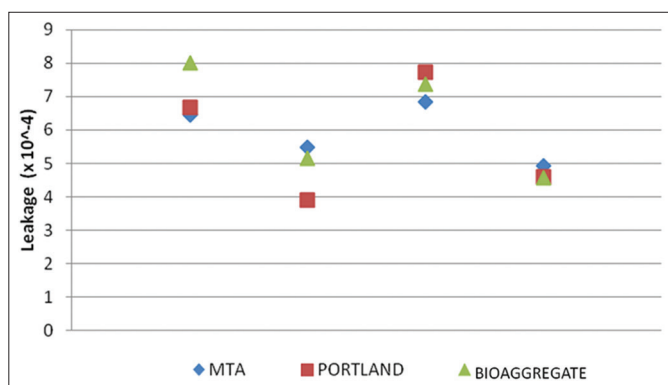
The apical leakage calculated for each group is presented in Table 1. No leakage was detected in the negative control group, and the leakage in the positive control group was considerably high. According to the results of this study, the amount of leakage was independent of the root-end filling materials - MTA, Portland cement, and BA - but was dependent on the irrigation agent. MTA, Portland cement, and BA showed the least leakage in the groups with CHX and distilled water solution as irrigants. No statistical difference between CHX and distilled water was observed among all the material groups. The highest leakage was found in the EDTA and MTAD solution groups. However, no significant difference was found between EDTA and MTAD solution groups.

Furthermore, this study showed that Portland cement prevented leakage as well as MTA and the newly developed

**Table 1: Apical leakage of the root-end filling materials after irrigation.**

Filling material	Irrigation solution	Mean±SD ([ $\mu\text{l} \cdot \text{cmH}_2\text{O}^{-1}$ ]* $\text{min}^{-1}$ )
MTA	EDTA	0.000644±0.000175
	CHX	0.000548±0.000199
	MTAD	0.000685±0.000132
	Distilled water	0.000494±0.000162
Portland cement	EDTA	0.000667±0.000173
	CHX	0.00039±0.000135
	MTAD	0.000774±0.000255
	Distilled water	0.00046±0.000164
BA	EDTA	0.000801±0.000190
	CHX	0.000514±0.000210
	MTAD	0.000737±0.000179
	Distilled water	0.000455±0.000139

MTA: Mineral trioxide aggregate, EDTA: Ethylenediaminetetraacetic acid, CHX: Chlorhexidine, MTAD: Mixture of a tetracycline isomer, an acid, and a detergent, SD: Standard deviation

**Graph 1:** The mean values of apical leakage

BA. Graph 1 shows the sealing ability of the newly developed bioceramic-containing canal repair material BA was similar to that of MTA.

## Discussion

In the present study, we investigated the effect of different endodontic irrigation solutions on the apical sealing ability and the potential of using MTA, Portland cement, and BA as root canal filling materials. In general, apical microleakage can be evaluated by several methods, including bacterial leakage, fluid filtration, and glucose leakage model.<sup>15,16</sup> In this study, the computerized fluid filtration technique was chosen for the evaluation of leakage because this method provides a quantitative assessment of microleakage without destroying the specimens.<sup>16</sup> Thus, with this method, the quality of the seal can be evaluated as a function of time.<sup>17</sup>

According to our study results, MTA, Portland cement, and BA showed similar sealing ability properties in all irrigation groups. BA and MTA have similar biomineralizing characteristics and concentration of calcium relapsed; in addition, the precipitates from both these materials were similar as they contained calcium, phosphorous, and hydroxyapatite.<sup>18</sup> MTA and different bioceramic-based root-end filling materials

showed similar sealing properties when different leakage methods were used.<sup>1,2,19</sup> Our results also showed that MTA and a bioceramic-based root-end filling material (BA) had the same sealing ability. This finding is also consistent with that of Leal *et al.*,<sup>20</sup> who showed that bioceramic repair cements displayed similar leakage results to MTA when used as root-end filling materials.

Endodontic treatment involves the use of an array of irrigation solutions having different pH and chemical properties.<sup>14</sup> The ideal pH for the setting reaction is 7.00 for MTA and for materials that have the same structure as MTA.<sup>21</sup> Acidic pH may negatively affect the bond strength to dentin, thus inhibiting the setting reaction and increasing the solubility of these repair materials.<sup>21-25</sup> Lee *et al.*<sup>24</sup> showed that calcium-depleting agents adversely affected setting in the case of MTA, since it inhibits the formation of calcium-silicate-hydrate gel. Uyanik *et al.*<sup>26</sup> reported that EDTA and MTAD decreased the sealing efficacy of MTA and super-ethoxy benzoic acid. In the present study, the different irrigation procedures showed varying apical leakage. EDTA and Biopure MTAD decreased the sealing ability of all root-end filling materials.

Considering that Portland cement contains the same chemical elements as MTA, and that both of them have a similar mechanism of action, the similarities in their results can be easily understood.<sup>27</sup>

Based on our results and those of other studies,<sup>21-25</sup> leakage of MTA and Portland cement increased when EDTA or MTAD was used for irrigation. We believe that the EDTA and MTAD irrigation solutions destroyed the structures of MTA and Portland cement and adversely affected the setting reaction of these materials.

Yıldırım *et al.*<sup>28</sup> showed that removal of the smear layer increased the amount of apical leakage of MTA when used as a root-end filling material. The decrease in leakage in smeared canals, compared to smear-free MTA-obtured canals, may be attributed to the hydrophilic properties of MTA. MTA is hydrophilic cement that sets in the presence of water. The smear layer is a more or less moist layer. The smear layer may be treated as a connective agent, enhancing the bond between the MTA and root canal dentin.<sup>28,29</sup>

Tyrkel *et al.*<sup>30</sup> proposed that MTA created a mechanical seal and dissolved, leading to the formation of hydroxyapatite that reacted with root canal dentin to form a chemical adhesion. Therefore, EDTA and MTAD irrigation solutions, which remove the smear layer, may prevent chemical adhesion of BA and other root-end filling materials to the root canal wall. Therefore, the presence of hydroxyapatite in BA may explain the similarity in the leakage results of BA, MTA, and Portland cement in the present study.



Previous investigations regarding the effect of acids on Portland cement showed that various types of acids produce either retarding or accelerating effects on setting of the cement, and samples irrigated with CHX and distilled water had the lowest leakage values.<sup>30,31</sup> According to our study, the sealing ability of BA, MTA, and Portland cement was not negatively affected by CHX and distilled water irrigation solutions. Thus, we believe that CHX and distilled water do not affect the setting reactions of the root-end filling materials used in this study.

### Conclusion

The results of this study show that Portland cement prevents leakage as efficiently as MTA and the newly developed BA. To establish the clinical use of Portland cement instead of MTA, more studies should be performed in the future. The sealing ability of BA was also as good as that of MTA. The use of BA instead of MTA should also be evaluated in further clinical studies. Within the limitations of this study, it can be concluded that EDTA and MTAD increased the apical leakage and that CHX and distilled water decreased the leakage of the root-end filling materials examined in this study. In clinical situations such as apical surgery and the perforation repair placement with MTA, BA, and Portland cement, we recommend that the canal should be irrigated with CHX or distilled water.

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