

# Evaluation of Marginal Adaptation of MTA, Biodentine, and MTA Plus as Root-End Filling Materials—An SEM Study

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## Abstract

**Objective** This study aimed to evaluate adaptation of mineral trioxide aggregate (MTA), Biodentine, and MTA Plus when used as root-end restorative materials using scanning electron microscope.

**Materials and Methods** Forty-five extracted teeth with one root canal were cleaned and sectioned at cemento-enamel junction, maintaining a standardized length of 15 mm. Chemomechanical preparation and obturation was done in all the samples, and access was restored with glass ionomer cement (GIC). Root-end cavities were prepared in all the samples after 3-mm apical root end was resected. Forty-five samples were divided into three groups with 15 samples each. Root apices were filled with ProRoot MTA in group I, Biodentine in group II, and MTA Plus in group III. The sample teeth were sectioned for examination of gaps at the margins using scanning electron microscope. The data collected were put to statistical analysis by one-way ANOVA (analysis of variance) and post hoc tests.

**Results** The minimum margin gap score of 2.44  $\mu\text{m}$  was observed in group II (Biodentine), whereas maximum gap score of 5.63  $\mu\text{m}$  was observed in group I (ProRoot MTA); 4.92  $\mu\text{m}$  mean margin gap score was observed in group III (MTA Plus).

**Conclusion** Biodentine showed least margin gap at the interface, so it can be considered as the best root-end filling material, whereas, MTA Plus can be considered as a substitute to ProRoot MTA as a root-end filling material.

## Keywords

- ▶ Biodentine
- ▶ MTA
- ▶ MTA plus
- ▶ root-end filling
- ▶ scanning electron microscope

## Introduction

The goal of endodontic treatment is to hermetically seal all the links between root canal space and periradicular tissues forming a fluid tight seal.<sup>1</sup>

Endodontic treatment is a conservative and nonsurgical treatment. In cases such as calcified root canals, severely dilacerated roots, and separated instruments in root canals, surgical endodontic therapy is often required for saving the tooth.<sup>2</sup>

An endodontic surgery includes root apex exposure after hard and soft tissue removal, periradicular curettage if required, root-end resection, and preparation of root end, followed by sealing of root end with a restoration.<sup>3</sup>

Root-end filling material does not allow bacteria and bacterial products from root canal to pass into periapical

tissues and vice versa.<sup>4</sup> Materials such as amalgam, intermediate restorative material (IRM), glass ionomer cement, composite resin, and carboxylate cement have been used for the same.<sup>5</sup>

In 1993, mineral trioxide aggregate (MTA) was developed as endodontic material by Dr. Torabinejad at Loma Linda University, California, United States. It was approved for use in endodontics by the U.S. Food and Drug Administration (FDA) in 1998 (ProRoot MTA, Dentsply Tulsa dental, Tulsa, Oklahoma, United States). MTA consists of tricalcium silicate, tricalcium aluminate, dicalcium silicate, calcium sulfate (present in hemi-hydrate and anhydrate form), and bismuth oxide.<sup>6</sup> It is used in clinical endodontics for procedures such as pulp capping, root-end filling, repair of furcation perforations, apexification, and for obturation.<sup>7</sup>

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Some clinical problems with MTA include discoloration, handling difficulty, longer setting time, presence of toxic elements in the composition, and high material cost, and there is no known solvent making its removal from the root canal after setting very difficult.<sup>8</sup>

In 2010, a bioactive cement, Biodentine (Septodont, Saint-Maur-Des-Fosses, France) also known as *smart dentin replacement* was introduced by Gilles and Olivier.<sup>9</sup> Manufacturer claimed several advantages of Biodentine such as ease of manipulation, shorter setting time, tissue regeneration, early mineralization, better consistency, greater bond strength, acid resistance, elastic modulus being similar to dentine, and more biocompatibility.<sup>10</sup> Hence, it can be used for dentin replacement in crown besides endodontic repair material such as MTA. It has indications for root-end filling, repair of perforations, apexification, and direct and indirect pulp capping. Certain drawbacks of Biodentine were less wear resistance, less radio-opacity when compared with MTA, and poor flexural strength.<sup>11</sup>

In 2012, MTA Plus came to dental market (Avalon Biomed, Houston, Texas, United States). MTA Plus has composition similar to MTA but has finer particle size and has a greater surface area, which results in shorter setting time than MTA.<sup>7</sup>

Microleakage occurring at the interface between dentin and root-end restoration is the key determinant for successful periapical surgery. Methods for detecting the microleakage include dye penetration, fluid filtration, dye extraction or dissolution method, bacteria or toxin infiltration method, electrochemical method, reverse diffusion method, use of radioisotopes and metal solution tracers, and microscopic methods such as scanning electron microscope (SEM), confocal microscope, and transmission electron microscope.<sup>12</sup>

SEM visualizes the adaptation of restoration to cavity margins because of its good depth of focus and higher magnification.<sup>13</sup> It also allows better visualization of irregular root-dentin structures, with different heights, without altering the focus, and generates data in digital form.<sup>14</sup>

Henceforth, this study was planned for evaluating the gaps at the margins MTA, Biodentine, and MTA Plus when used as root-end filling materials using SEM.

## Materials and Methods

Forty-five teeth with closed apices without any visible evidence of root fracture, cracks, and external resorption were selected for this study. All the tooth surfaces were cleaned with No. 15 bard parker blade. They were then immersed in 5% sodium hypochlorite solution for disinfection overnight and then stored in 0.2% thymol (NICE, Coimbatore, Tamil Nadu, India).

The crowns of all the selected teeth were sectioned from the roots to standardize the root length to 15 mm. Size 10k file (Mani inc, Takenzawa, North of Tokyo, Japan) was put into the root canal until it was seen at the apex, and then 0.5 mm was subtracted from that point to establish final working length. Root canal preparation was completed with step-back technique up to ISO 40 apical size using manual K-files (Mani, Inc., Japan) in all the samples.

The canals were thoroughly irrigated with alternate use of 5% sodium hypochlorite (5% Hyposol, Pervest Denpro Ltd.,

Jammu, India) and 17% ethylene diamine-tetraacetic acid solution (Pervest Denpro, Jammu, India). A final irrigation with normal saline was done to eliminate or neutralize the effects of sodium hypochlorite. Absorbent paper points were used to dry canals, and obturation was done with matching gutta-percha points (Dentsply) and Sealapex sealer (SybronEndo, Orange, California, United States) using cold lateral compaction technique. Glass ionomer cement (GC Fuji IX GC Asia, Singapore) was used to restore access cavity. Samples were then stored in 100% humidity until use.

The 3 mm of all roots was resected using straight fissure diamond bur from apex, making sure the resection is perpendicular to long axis of the tooth. This was followed by preparation of retrograde cavities in root canal exit on resected root surface using round diamond bur in slow speed handpiece. All prepared roots were divided in three groups having 15 teeth each depending on the material used for root-end filling:

Group I: ProRoot MTA (Dentsply Maillefer, Switzerland)

Group II: Biodentine

Group III: MTA Plus (Pervest Denpro Ltd., Jammu, India)

Group I: ProRoot MTA was used in this group. It is packaged in powder liquid form. The powder was dispensed on one side of pad and liquid was squeezed next to the powder, maintaining powder-liquid ratio 3:1 ratio and mixed according to the manufacturer's instructions.

The material was mixed until all the powder particles were hydrated and material turned into a thick, creamy, and putty-like consistency. Then it was filled into the prepared root-end cavity using MTA carrier (GDC, Hoshiarpur, Punjab, India) and thoroughly condensed with the help of hand plugger 5/7 (API, Delhi, India). Root end was left in contact with moist cotton for 4 hours to ensure complete setting of ProRoot MTA.

Group II: In each sample of this group, Biodentine was used as a retrograde filling material. It is available as powder liquid system.

Biodentine capsule-containing powder was opened and placed in a capsule holder of mechanical triturator (Dentsply Maillefer). Then five drops of liquid was poured into the capsule, and mixing was performed for approximately 30 seconds until the material turned into thick putty-like consistency as recommended by the manufacturer. It was then carried in the prepared cavity, thoroughly condensed with the help of hand plugger 5/7, and allowed to set for 12 minutes to ensure complete setting.

Group III: In each sample of this group, MTA Plus was used as a retrograde filling material. It is available as powder and gel system.

MTA Plus powder and a small drop of gel were put onto the slab. The mixing of powder and gel was performed for about 1 minute using mixing spatula until the material turned into thick, creamy putty-like consistency, which was filled into the prepared root-end cavity with MTA carrier. The material was then thoroughly condensed in the prepared cavities with the help of hand plugger 5/7. Root end was then covered with moist cotton for 1 hour to allow complete setting of MTA

Plus. Radiographs confirmed the quality of root-end filling of all the samples from the three groups.

All the prepared samples were then incubated at 37°C and 100% humidity for 24 hours. Each sample was then sectioned longitudinally along the long axis of the tooth using diamond disc in micromotor contra-angled handpiece (NSK, Confident Dental Equipment, New Delhi, India). The gap at interface of dentin and root-end filling materials was measured in micrometers using SEM in all the three groups, and 30 readings were recorded for each sample. The average of these 30 readings was taken as a mean marginal gap of that particular sample. The data thus obtained were recorded and put under statistical analysis.

## Results

The mean marginal gap obtained at the interface of dentine root-end filling materials was recorded to be minimum in group II (Biodentine), that is, 2.44 µm, whereas the mean marginal gap obtained for group I (ProRoot MTA) was found to be maximum, that is, 5.63 µm. The mean marginal gap obtained for group III (MTA Plus) was found to be 4.92 µm (► Fig. 1). When compared statistically using one-way ANOVA (analysis of variance) test, the difference in mean marginal gap between three groups was found to be highly significant ( $p < 0.001$ ) (► Table 1).

Group I in which root-end preparation was restored with ProRoot MTA had mean marginal gap of 5.63 µm whereas

**Fig. 1** Bar graph showing comparison of mean marginal gap in three groups. MTA, mineral trioxide aggregate.

in group II in which root-end preparation was restored with Biodentine had mean marginal gap of 2.44 µm. When compared statistically, this difference in mean marginal gap between the two groups was highly significant ( $p < 0.001$ ). Group II in which root-end preparation was restored with Biodentine had mean marginal gap of 2.44 µm whereas in group III in which root-end preparation was restored with MTA Plus had mean marginal gap of 4.92 µm. When compared statistically, this difference in mean marginal gap between the two groups was highly significant ( $p < 0.001$ ). Group I in which root-end preparation was restored with ProRoot MTA had mean marginal gap of 5.63 µm whereas in group III in which root-end preparation was restored with MTA Plus had mean marginal gap of 4.92 µm. When compared statistically, this difference in mean marginal gap between the two groups was statistically insignificant ( $p > 0.05$ ) (► Table 2).

**Table 1** One-way statistical analysis

Descriptive gap								
	N	Mean	SD	Standard error	95% CI for mean		Minimum	Maximum
					Lower bound	Upper bound		
Group I (ProRoot MTA)	15	5.6330420	2.17240401	0.56091230	4.4300048	6.8360792	2.94400	12.05230
Group II (Biodentine)	15	2.4444880	0.94871556	0.24495730	1.9191068	2.9698692	0.94017	3.90463
Group III (MTA Plus)	15	4.9216947	1.41883646	0.36634200	4.1359692	5.7074201	1.57940	7.36443
Total	45	4.3330749	2.08295127	0.31050804	3.7072870	4.9588627	0.94017	12.05230

Abbreviations: CI, confidence interval; MTA, mineral trioxide aggregate; SD, standard deviation.

**Table 2** Post hoc tests

Multiple comparisons dependent variable: gap Tukey HSD						
(I) group	(J) group	Mean difference (I-J)	Standard error	Sig. (p-value)	95% CI	
					Lower bound	Upper bound
ProRoot MTA	Biodentine	3.18855400 <sup>a</sup>	0.58242776	< 0.001 <sup>b</sup>	1.7735494	4.6035586
	MTA Plus	0.71134733	0.58242776	0.447	-0.7036573	2.1263520
Biodentine	ProRoot MTA	-3.18855400 <sup>a</sup>	0.58242776	< 0.001 <sup>b</sup>	-4.6035586	-1.7735494
	MTA Plus	-2.47720667 <sup>a</sup>	0.58242776	< 0.001 <sup>b</sup>	-3.8922113	-1.0622020
MTA Plus	Biodentine	2.47720667 <sup>a</sup>	0.58242776	< 0.001 <sup>b</sup>	1.0622020	3.8922113
	ProRoot MTA	-0.71134733	0.58242776	0.447	-2.1263520	0.7036573

Abbreviations: CI, confidence interval; HSD, honestly significant difference; MTA, mineral trioxide aggregate.

<sup>a</sup>The mean difference is significant at the 0.05 level

<sup>b</sup>p-value is significant at 0.05 level.

## Discussion

Nonsurgical root canal therapy includes removal of infected contents of the canal along with irritants, followed by complete sealing of root canal system in three dimensions.<sup>15</sup> Endodontic therapy failure is caused by apical microleakage. However, cases in which fluid tight seal is not possible by an orthograde approach, for example resorptive root defects, ledges, perforation defects, root canal obstructions, anatomical variations, and separated instruments in the apical region of the tooth, surgical endodontics becomes the only option to save the tooth.<sup>16</sup>

Surgical endodontic therapy includes root-end cavity preparation with appropriate instruments and restoration with a biocompatible root-end filling material.<sup>17</sup> This procedure seals the root end against microleakage and also stimulates the regeneration of periodontium.<sup>17</sup>

Studies on root-end resection showed that minimum 3 mm of root-end resection can eliminate 98% apical ramifications and 93% of the lateral canals, which are responsible for endodontic therapy failure.<sup>18</sup>

Root-end resection at 30 and 45 degrees to the long axis of the tooth removes more root structure and exposes more dentinal tubules to the periradicular tissues, whereas resection at 90 degrees conserves root structure and exposes less dentinal tubules, also maintaining a better crown/root ratio.<sup>19</sup> A fluid tight apical seal is very important for achieving success in surgical endodontics.<sup>20</sup> Therefore, it becomes important to seal the root ends with a suitable root-end filling material.

According to Torabinejad et al, an ideal root-end filling material should have ability to adhere to the dentine walls for complete seal of the root canal system. It should be nontoxic, should not irritate periradicular tissues, and promote healing. Also, it must not corrode and should not be electrochemically active. It should have easy manipulation and should be radio-opaque. Additionally, it should be dimensionally stable, non-resorbable, and impervious to moisture.<sup>21</sup>

Several restorative materials were used for retrograde filling in the past such as silver amalgam, cavite, zinc oxide eugenol-based cements line IRM and super EBA, glass ionomer cements, modified glass ionomer cements, and composites. The requirements of an ideal root-end filling material are not fulfilled by any of the restorative material.<sup>22</sup> Amalgam has potential for corrosion and mercury release; also, being moisture sensitive precludes its use as retrograde filling material.<sup>23</sup> Cavite disintegrates very fast in tissue fluids as it is soluble. Super EBA and IRM are cytotoxic, sensitive to moisture, and difficult to handle.<sup>24</sup> Glass ionomer cement and composite resin are technique and moisture sensitive, hence difficult to use in endodontic surgical situations.<sup>23</sup>

MTA was developed by Torabinejad et al at Loma Linda University.<sup>22</sup> It was approved in 1998 for endodontic use by the U.S. FDA (ProRoot MTA, Dentsply Tulsa).<sup>25</sup> Favorable properties of MTA include excellent sealing ability, biocompatibility, acceptable compressive strength, insolubility in fluids, excellent radio-opacity, and antibacterial effect.<sup>26</sup> Additionally, it induces hard tissue formation, which includes deposition

of cementum and periodontal fiber regeneration.<sup>27</sup> However, it has several disadvantages such as discoloration potential, difficult handling, long setting time, presence of toxic elements in the material composition, high material cost, absence of known solvent, and difficulty in removal after setting.<sup>28</sup>

Biodentine was introduced in 2010 by Gilles and Olivier.<sup>9,29</sup> It is available in powder and liquid form. It has less setting time of 12 minutes, easier manipulation, good compressive strength, no effect of blood contamination on the physical properties, and cost-effectiveness.<sup>30</sup> However, it has many disadvantages such as less wear resistance, less radio-opacity as compared with MTA, and poor flexural strength.<sup>11</sup>

MTA Plus was introduced to dental market in 2012. Manufacturers claim that it has composition similar to MTA but has finer particle size and has a greater surface area, which results in shorter setting time than that of MTA.<sup>7</sup>

Dye penetration is the most commonly used method for detecting apical leakage, but the disadvantages of this technique are dye dissolving, random sectioning not showing deep dye penetration, dentinal tissue loss with dye, demineralization, and dehydration.<sup>31</sup> Dye extraction method has the main disadvantage of difficulty of dye to reach the porosity of interface between filling material and root.<sup>31</sup> Fluid filtration is not a standardized method as there is wide range in time (1–3 hours) and pressure values (1–2 psi). Radioisotope penetration and electrochemical penetration techniques are complex procedures and are difficult to perform.<sup>31</sup>

SEM visualizes adaptation of restorative materials to cavity margins because of its high magnification and depth of focus.<sup>13</sup>

It allows better visualization of root dentin structures, with different heights, without alternation of the focus, and generates data in digital form.<sup>14</sup> SEM was used in the present in vitro study to evaluate the margin adaptation of MTA, Biodentine, and MTA Plus when used as root-end filling materials.

In this study, the mean margin gap obtained at the interface of dentine root-end filling materials was recorded to be minimum in group II (Biodentine), that is, 2.44  $\mu\text{m}$ , whereas the mean margin gap obtained for group I (ProRoot MTA) was determined to be maximum, that is, 5.63  $\mu\text{m}$ . The mean marginal gap obtained for group III (MTA Plus) was found to be 4.92  $\mu\text{m}$ . When compared statistically using one-way ANOVA test, the difference in mean marginal gap between the three groups was found to be highly significant ( $p < 0.001$ ) (► **Table 1**).

Group I in which root-end preparation was restored with ProRoot MTA had mean marginal gap of 5.63  $\mu\text{m}$  whereas in group II in which root-end preparation was restored with Biodentine had mean marginal gap of 2.44  $\mu\text{m}$ . When compared statistically, this difference in mean marginal gap between the two groups was highly significant ( $p < 0.001$ ) (► **Table 1**).

It was found that Biodentine showed least amount of microleakage as compared with MTA and glass ionomer cement when dye leakage study was performed.<sup>32</sup> Biodentine also exhibited less microleakage than ProRoot MTA, when compared using dye penetration technique.<sup>33</sup> When root-end filling materials for margin adaptation were compared using confocal laser scanning microscope, it was found that Biodentine had better marginal adaptation than MTA and glass ionomer cement.<sup>34</sup>

When Biodentine comes in contact with dentine, it leads to the formation of “mineral tag” like structures along the interface, called the “mineral infiltration zone.” The collagen component of the interfacial dentin is degraded by the alkalinity of the hydration products, resulting in prominent biomineralization leading to better seal.<sup>35</sup>

Physical properties of a material such as adsorption, permeability, strength, density, and sealing ability of a material are severely affected by the porosity. Biodentine exhibits less porosity and pore volume on complete setting when compared with MTA, resulting in better marginal seal and less microleakage.<sup>36</sup>

Group II in which root-end preparation was restored with Biodentine had mean marginal gap of 2.44  $\mu\text{m}$ , whereas in group III in which root-end preparation was restored with MTA Plus had mean marginal gap of 4.92  $\mu\text{m}$ . When compared statistically, this difference in mean marginal gap between two groups was highly significant ( $p < 0.001$ ) (►Table 2). When comparing sealing ability of MTA Plus and Biodentine for furcal perforations using spectrophotometry, less dye absorbance with Biodentine was seen than MTA Plus.<sup>29</sup>

Group I in which the root-end preparation was restored with ProRoot MTA had mean marginal gap of 5.63  $\mu\text{m}$ , whereas in group III in which the root-end preparation was restored with MTA Plus had mean marginal gap of 4.92  $\mu\text{m}$ . When compared statistically, this difference in mean marginal gap between the two groups was statistically insignificant ( $p > 0.05$ ; ►Table 2). Lesser microleakage was seen with MTA Plus than ProRoot MTA when dye leakage study was performed, confirming better seal with MTA Plus.<sup>7</sup> The chemical composition of ProRoot MTA and MTA Plus was found to be almost similar, but MTA Plus had a finer particle size.<sup>37</sup> Additionally, MTA Plus had an advantage of the presence of an anti-washout gel that increases its the washout resistance. It was also found that ProRoot MTA, when mixed with water, formed a sandy consistency due to leaching of bismuth in solution, whereas MTA Plus mixed with anti-washout gel had a more viscous and rubbery consistency. This consistency of MTA Plus in cement phase results in high strength. Moreover, anti-washout gel does not affect the radio-opacity of the material and increases its sealing ability by forming a branched polymer network at the interface.<sup>37</sup>

Thus, it can be concluded that Biodentine has least gap at the interface, and it can be considered as the promising root-end filling material. However, MTA Plus and ProRoot MTA showed almost similar gap at the interface. Therefore, MTA Plus can become a possible substitute to ProRoot MTA as a root-end filling material. As our study was performed in in vitro conditions, results obtained cannot be directly extrapolated clinically, but they permit comparison of the similar materials. However, owing to the limitations of the in vitro conditions, further in vivo research is required to evaluate Biodentine as a root-end filling material.

## Conclusion

All the root-end filling materials used in this study, that is, ProRoot MTA, Biodentine, and MTA Plus showed gap at the interface of dentin and root-end filling material. However,

Biodentine showed minimum gap at the interface. Also, MTA Plus and ProRoot MTA had similar interfacial gap on investigation. Hence, MTA Plus can be a substitute to ProRoot MTA as a root-end filling material.

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## Conflict of Interest

None declared.

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