



## Review Article

## Biodentine VS MTA: A comparative analysis

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## ABSTRACT

An ideal dental repair material should possess certain exclusive properties such as adequate adhesive ability, dimensional stability, biocompatibility, bioactivity etc. Calcium silicate based materials seem to have intrinsic properties suitable for their clinical use, such as good sealing correlated to expansion, and the ability to set in the presence of fluids, bioactivity, the release of ions acting as epigenetic signals, and good biological properties. The introduction of MTA was considered as a major break-through in the history of material science. Biodentine has been recently introduced as the “the first all-in-one, bioactive and biocompatible material for damaged dentin replacement”. This article attempts to compare the properties and clinical applications of MTA and Biodentine.

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## 1. Introduction

The use of materials in dentistry dates long back in history. With the increase in patients awareness and demand for saving teeth there developed a need for the advancement in material science and techniques.<sup>1</sup> Thus the calcium based materials in dentistry has led to the change the prognosis of many cases. These materials have gained popularity because of their biocompatibility, tissue repairing abilities, bioactivity, adequate adhesive ability etc.<sup>2</sup>

Wide range of materials are available under this category. The ability to release calcium is a key factor for successful endodontic and pulp capping therapies because of the action of calcium on mineralizing cell differentiation and hard tissue mineralization. This property has led to the incorporation of calcium hydroxide in several materials and antimicrobial formulations used in number of treatment modalities in endodontics and restorative dentistry.<sup>3</sup>

These materials can be used in various endodontic procedures such as root end filling materials, root

perforation repair, pulp capping, pulpotomy, internal resorption, apexification etc.<sup>4</sup>

Mineral Trioxide Aggregate (MTA), a calcium silicate cement was introduced as tooth filling material in 1995 by Torabinejad and White as Grey ProRoot MTA and subsequently in 1998 white MTA was introduced.<sup>5</sup> Despite of the wide variety of advantages of MTA, there are certain limitations like difficult handling characteristics, long setting time, high cost, discoloration potential etc.<sup>6</sup> Thus to overcome the limitations of previous materials, a new calcium silicate based material called Biodentine was introduced in 2010 by Gilles and Olivier.<sup>7</sup>

So this review article would focus on the various physio chemical and biological properties of MTA and Biodentine along with their clinical and comparative evaluation.

## 2. Biodentine

Biodentine was developed as a new class of dental material, introduced in 2010 by Gilles and Olivier which could conciliate high mechanical properties with excellent biocompatibility, as well as a bioactive behavior.<sup>7</sup>

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Biodentine is a new tricalcium silicate ( $\text{Ca}_3\text{SiO}_5$ ) based inorganic restorative commercial cement and advertised as 'bioactive dentine substitute'.<sup>8</sup> The material is claimed to possess better physical and biological properties compared to other tricalcium silicate cements such as mineral trioxide aggregate (MTA) and Bioaggregate(Bioaggregate).<sup>9</sup> It is used for crown and root dentin repair treatment, repair of perforations or resorptions, apexification, root-end fillings and as permanent dentine substitute in large carious lesions.<sup>7</sup>

### 3. Chemical Composition of Biodentine

Biodentine is a powder and liquid system where the powder is composed of tricalcium silicate (main component), calcium carbonate (filler material), zirconium oxide (radiopacifier), dicalcium silicate traces), calcium oxide (traces), iron oxide (traces) and the liquid is an aqueous solution of a hydrosoluble polymer (water reducing agent) with calcium chloride (decreases the setting time).<sup>9</sup>

### 4. Physio-Chemical Properties of Biodentine

#### 4.1. Setting time

The working time of Biodentine is up to 6 minutes with a final set at around 10-12 minutes.<sup>10</sup> The final setting time of Biodentine is assessed to be 45 min.<sup>11</sup>

#### 4.2. Density and porosity

Biodentine is reported to be more dense and less porous when compared to MTA.<sup>12</sup> Mean porosity percentage for Biodentine is  $7.09 \pm 1.87$ .<sup>13</sup>

#### 4.3. Modulus of elasticity

The elastic modulus of 22.0 Gpa is very similar to that of dentine at 18.5.<sup>9</sup>

#### 4.4. Compressive strength

The setting of Biodentine is illustrated by a sharp increase in the compressive strength.<sup>14</sup> The compressive strength of Biodentine amounts to  $10.6 \pm 2$ ,  $57.1 \pm 12$  and  $72.6 \pm 8$  MPa after 35 min, 24 h and 28 days, respectively.<sup>9</sup>

#### 4.5. Flexural strength

The value obtained with Biodentine after 2 hours is 34 MPa.<sup>9</sup>

#### 4.6. Microhardness

The microhardness of this dentine substitute, at about 60 VHN (Vickers hardness) is virtually the same as that of natural dentine, which is 68 KHN (Knoop hardness).<sup>9</sup>

#### 4.7. Radiopacity

According to the ISO standard 6876, Biodentine displays a radiopacity equivalent to 3.5 mm of aluminum.<sup>15,16</sup>

#### 4.8. PH

Khan et al. evaluated the pH of set Biodentine which was  $9.14 \pm 0.16$ ,  $8.88 \pm 0.27$  and  $8.02 \pm 0.19$  at 3 h, 1 day and 1 week, respectively confirming the alkalinity of the cement.<sup>17</sup>

#### 4.9. Push-out bond strength

Guneser et al evaluated the push-out bond strength recorded after immersion of samples in 3.5 % sodium hypochlorite, 2 % Chlorhexidine or saline solution for 30 min and recorded as  $7.23 \pm 4.22$ ,  $7.13 \pm 2.17$  and  $7.22 \pm 3.14$  MPa, respectively.<sup>18</sup>

#### 4.10. Microleakage

Kokate et al demonstrated that Biodentine shows less microleakage ( $0.13 \pm 0.006$  mm) compared to MTA ( $0.73 \pm 0.13$  mm) and Glass Ionomer Cement ( $1.49 \pm 0.23$  mm) when used as root- end filling materials.<sup>19</sup>

### 5. Biocompatibility and Cytotoxicity

Biodentine exhibits outstanding biocompatibility.<sup>20</sup> Laurent et al. established that Biodentine was non-cytotoxic and non-genotoxic for pulp fibroblasts at any concentration and the specific functions of these cells were not modified when the material was used as either direct pulp-capping agent or as a lining material.<sup>21</sup>

### 6. Bioactivity

Pulp capping and pulpotomy studies showed that Biodentine was very well tolerated.<sup>22</sup> Moreover Biodentine promotes mineralisation, generates a reactionary dentine as well as a dense dentine bridge. The pulp capped with biodentine showed complete dentinal bridge formation and an absence of inflammatory pulp response.<sup>16</sup> About et al. concluded that Biodentine stimulates dentine regeneration by inducing odontoblast differentiation from pulp progenitor cells.<sup>23</sup>

### 7. Clinical Applications of Biodentine

The consistency of Biodentine is found to be similar to that of phosphate cement.<sup>24</sup> Biodentine has better material handling properties compared to MTA, which is more time consuming and technically difficult.<sup>25</sup> The various clinical applications are:

### 7.1. As a direct pulp capping material

Formation of the dentinal bridge is interpreted as a positive reaction to stimulation and a sign of healing. Biodentine induces the formation of a dentinal bridge at its interface with the pulp tissue columnar cells.<sup>25</sup>

### 7.2. As a root- end filling material

Biodentine exhibits better marginal adaptation to dentin in comparison to MTA and GIC cements.<sup>26</sup> The better handling properties of this material combined with superior biological, mechanical and physical properties suggest the superiority of Biodentine over other root end filling materials.<sup>27</sup>

### 7.3. As a dentine substitute

Biodentine could be both a temporary enamel restoration and a definitive dentine substitute. Its good sealing properties, high compression strengths and short setting time are suggestive of its potential as a restorative material.<sup>28</sup>

### 7.4. As a perforation repair material

Due to its various physio-chemical and biological properties, Biodentine can serve as an excellent perforation repair material.<sup>29</sup>

### 7.5. For external root resorption and obturation of root canal system

When used in cases of root resorption, Biodentine has the capacity to develop watertight interfaces both with dental structures and with adhesive systems. Biodentine has a better consistency after mixing which allows ease of placement in areas of resorptive defect or obturation of full root canal system.<sup>30</sup>

## 8. Mineral Trioxide Aggregate (MTA)

Mineral trioxide aggregate (MTA) was developed for use as a dental root repair material by Dr. Mahmoud Torabinejad and White in 1995 as grey ProRoot MTA formulated from commercial Portland cement combined with bismuth oxide powder for radiopacity. MTA has since been recognized as a bioactive material that is hard tissue conductive, hard tissue inductive and biocompatible.<sup>31</sup>

MTA is currently marketed in two forms: grey (GMTA) and white (WMTA). To overcome the limitation of long setting time of MTA, an alternative was introduced in 2001 and was named MTA- Angelus which lacked calcium sulphate dihydrate as one of its main compounds.<sup>3</sup>

## 9. Composition

MTA is composed of calcium silicate powder (white Portland cement) radiopacified with bismuth oxide and water. The major component, Portland cement (PC), is a mixture of dicalcium silicate, tricalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite. Calcium oxide, Silica and bismuth oxide are the main oxides present.<sup>2</sup>

## 10. Physio- Chemical Properties of MTA

### 10.1. Setting reaction and time

The mean setting time of MTA is  $165 \pm 5$  minutes.<sup>31</sup>

### 10.2. Discoloration potential

The initial formulation of mineral trioxide aggregate (MTA) was a gray powder and was associated with coronal tooth discoloration.<sup>33</sup>

### 10.3. Solubility

Lack of solubility has been stated as an ideal characteristic for root end filling material and MTA shows low or no solubility in water.<sup>34</sup>

### 10.4. Compressive strength

The compressive strength of MTA is significantly less than that of amalgam, IRM, and Super EBA after 24 hours.<sup>31</sup>

### 10.5. Push-out Strength

MTA has lower push-out strength in comparison with IRM or Super EBA after immersion in walking bleach materials.<sup>35</sup>

### 10.6. PH

The pH value of MTA is 10.2 after mixing. This value rises to 12.5 at 3 hours.<sup>31</sup>

### 10.7. Radiopacity

The mean radiopacity for MTA has been reported at 7.17mm of an equivalent thickness of aluminum.<sup>36</sup>

### 10.8. Microhardness

The greatest mean surface hardness values (Vickers hardness) of WMTA ( $53.19 \pm 4.124$ ) were observed following exposure to pH 7.4 with the values decreasing to  $14.34 \pm 6.477$  following exposure to pH 4.4.<sup>31</sup>

### 10.9. Density and porosity

MTA has a density of  $1.882 \text{ g/cm}^3$  and porosity of 22.6%.<sup>16</sup>

**Table 1:** Chemical composition of GMTA and WMTA.<sup>32</sup>

Chemical	WMTA(%)	GMTA(%)
CaO	44.2	40.45
SiO <sub>2</sub>	21.20	17.00
BiO <sub>2</sub>	16.13	15.90
Al <sub>2</sub> O <sub>3</sub>	1.92	4.26
MgO	1.35	3.10
SO <sub>3</sub>	0.53	0.51
Cl	0.43	0.43
FeO	0.40	4.39
P <sub>2</sub> O <sub>5</sub>	0.21	0.18
TiO <sub>2</sub>	0.11	0.06
H <sub>2</sub> O+CO <sub>2</sub>	14.49	13.72

### 10.10. Effect on pulp tissues

MTA is an effective pulp capping material due to its ability to stimulate hard tissue bridge formation in about two months period.<sup>6</sup>

### 10.11. Sealing ability

MTA has enhanced sealing ability which could be due to the setting expansion when it is used in moist oral environment.<sup>37</sup>

### 10.12. Marginal adaptation

MTA exhibits significantly less marginal leakage than the other materials.<sup>8</sup>

## 11. Biocompatibility and Cytotoxicity

### 11.1. Biocompatibility

Application of MTA as a root end filling material promotes regeneration of dental and osseous tissues, and may induce cementoblasts to produce matrix for cementum formation over MTA.<sup>38</sup>

### 11.2. Cytotoxicity

In the presence of water, calcium oxide, one of the major components of MTA, is converted into calcium hydroxide, which in turn elevates the surrounding pH. Alkaline pH has a destructive effect on protein structures and may promote enzyme denaturation and also cell membrane damage.<sup>39</sup>

### 11.3. Bioactivity

Mineral Trioxide Aggregate is considered as a bioactive material with possible osteoinductive properties since it has been shown that MTA up-regulates bone morphogenetic protein-2 (BMP-2) expression.<sup>2</sup>

## 12. Clinical Applications of MTA

The various clinical applications of Mineral Trioxide Aggregate are:-

### 12.1. Pulp capping

MTA stimulates dentin bridge formation adjacent to the dental pulp; the dentinogenesis may be due to sealing ability, biocompatibility, and alkalinity of MTA.<sup>40,41</sup>

### 12.2. Pulpotomy

MTA induces pulp healing with dentin bridge formation and prevents necrosis at long-term periods in most of the pulpotomy cases.<sup>42</sup>

### 12.3. Root canal filling

MTA has a profound advantage when used as canal obturation material because of its superior physiochemical and bioactive properties.<sup>43</sup>

### 12.4. Perforation repair

Being primarily hydrophilic, MTA can today be considered the ideal material to seal perforations.<sup>44</sup>

### 12.5. Root end filling

Due to its sealing properties, biocompatibility, and hydrophilic nature, MTA is considered the best choice as a retrofilling material.<sup>45</sup>

### 12.6. MTA as an intracoronal barrier

Mineral trioxide aggregate due to its excellent biological and physical properties and superior apical sealing ability, provides good coronal seal compared to other intracoronal barriers.<sup>46</sup>

**Table 2:** Comparative properties of biodentine and MTA

Material characteristics	Time period	Biodentine	MTA	
Final setting time(min)		45		Grech et al. <sup>47</sup>
Compressive strength(MPa)	28 days	67.18		Grech et al. <sup>47</sup>
Vickers hardness(VHN)	28 days	48.4		Grech et al. <sup>47</sup>
Specific surface area(m <sup>2</sup> /g)		2.8116	1.0335	Camilleri et al. <sup>48</sup>
	1 day	0.006		
Fluid uptake (%) (stored in HBSS)	7 days	0.011		
	21 days	0.010		Grech et al. <sup>47</sup>
	28 days	0.010		
Push-out bond strength after immersion in NaOCl (MPa)		7.23± 4.22	3.49± 3.02	Guneser et al. <sup>18</sup>
Push-out bond strength after immersion in CHX(MPa)		7.13± 2.17	2.45± 1.99	Guneser et al. <sup>18</sup>
Push-out bond strength after immersion in saline (MPa)		7.22± 3.14	6.18± 3.80	Guneser et al. <sup>18</sup>
Microleakage (mm)		0.13	0.73	Kokate and Powar <sup>19</sup>
Radiopacity (/mmAl)	1 day	4.1		
	28 days	3.3		Grech et al. <sup>49</sup>
	3h	9.14	9.52	
pH of leachate(deionized water)	24 h	8.88	9.32	Khan et al. <sup>47</sup>
	168 h	8.02	8.45	
	1 day	11.7		
pH of leachate (HBSS)	7 days	12.1		
	14 days	12.3		Grech et al. <sup>47</sup>
	21 days	12.4		
Calcium ion release(mg/l) (when immersed in distilled water)	5 h	24	17.7	
	5- 24 h	34	24	Han and Okiji <sup>49</sup>
	24-28h	27.6	20.2	
	1 day	39	23	
Incorporation of calcium into human root canal dentine(μm)	7 days	74	50	Han and Okiji <sup>49</sup>
	30 days	118	75	
Cytotoxicity after indirect contact (undiluted) (%)		0±8	0±9	Laurent et al. <sup>21</sup>
Cytotoxicity after indirect contact (diluted) (%)		0±8	0±9	Laurent et al. <sup>21</sup>
	24 h	14.9	15.7	
Flexural modulus of dentine after being in contact with material (MPa)	1 month	14.6	14.2	
	2 months	13.1	13.8	Grech et al. <sup>47</sup>
	3 months	13.8	13.9	
	24 h	3.58	3.48	
Modulus of toughness of dentine after being in direct contact with material (MPa)	1 month	2.22	3.69	
	2 months	2.52	3.27	Grech et al. <sup>47</sup>
	3 months	2.15	2.66	
Mean thickness of the hard tissue dentin bridge after direct pulp capping	6 weeks	221.56	230.1	Nowicka et al. <sup>25</sup>

### 12.7. Apical barrier for tooth with necrotic pulps & open apex

MTA can also be used as an apical barrier (in a thickness of 3–4 mm) in cases of open apices. Mineral trioxide aggregate appears to be a promising alternative to calcium hydroxide apexification because of its high biocompatibility, superior sealing ability and reduced treatment time.<sup>50</sup>

### 12.8. Use of MTA in resorption

MTA is currently the material of choice for non-surgical and surgical repair of resorption.<sup>51</sup>

### 12.9. MTA as a root canal sealer

MTA as a sealer induces closure of main canal foramen by new cementum formation with absence of inflammatory cells after 6 months.<sup>52</sup>

## 13. Comparative Evaluation of Mineral Trioxide Aggregate (MTA) and Biodentine

Though MTA and Biodentine are both calcium silicate based materials and are used in similar clinical applications but a thorough comparison of both the materials is necessary for the selection of the appropriate materials for various clinical applications.

### 13.1. Solubility

Tricalcium silicate (the Biodentine component) is very reactive and hydrates rapidly (heat peak of the hydration reaction at approx. 10 h) whereas dicalcium silicate (the main ProRoot MTA component together with tricalcium silicate) hydrates slowly.<sup>2</sup>

### 13.2. Push out bond strength

Guneser et al. showed that irrespective of the irrigation solution, the force needed for displacement of Biodentine from root dentine is significantly higher than the force required for MTA.<sup>53</sup>

### 13.3. Modulus of toughness (MOT) and flexural strength

MOT of dentine in contact with Biodentine is significantly different from that in contact with MTA after 1 and 2 months but not after 3 months.<sup>9</sup>

### 13.4. Radiopacity

Biodentine yielded a lower radiopacity value compared to the other materials.<sup>15</sup>

### 13.5. Calcium ion release

Biodentine showed a markedly higher release of free calcium ions compared with ProRoot MTA.<sup>9</sup>

### 13.6. Effect on pulp

Nowicka et al. histologically analyzed the dentin bridge and the mean thickness of hard tissue was lesser with Biodentine (211.56 mm) compared to that obtained with MTA (230.31 mm).<sup>25,54</sup>

## 14. Conclusion

MTA is a biocompatible material with numerous exciting clinical applications. It serves as an ideal root repair material which has qualities like resistance to marginal leakage, allows normal healing response, ease of clinical manipulation and being non-resorbable and is non-toxic.

Biodentine is a fast-setting tricalcium silicate-based material having extended alkalinizing properties principally able to release ions involved in mineralization processes. The material's large porosity and water sorption are correlated with a pronounced ion release allowing the formation of calcium phosphate deposits.

Considering the physical (increased compressive strength, push-out bond strength, density and porosity), biological (immediate formation of calcium hydroxide, higher release and depth of incorporation of calcium ions) and handling properties (faster setting time), Biodentine could be an efficient alternative to mineral trioxide aggregate to be used in a variety of indications in the field of endodontics, dental traumatology, restorative dentistry and pediatric dentistry. However, more prospective clinical studies and high quality randomised control trials with adequate sample size and long term follow up are necessary to draw definitive conclusions.

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None.

## 16. Conflict of Interest

None.

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