

MTA versus Biodentine: Review of Literature with a Comparative Analysis

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ABSTRACT

An ideal dental repair material should possess certain exclusive properties such as adequate adhesive ability, insolubility, dimensional stability, biocompatibility, bioactivity etc. New materials claiming better performance are continuously being introduced in the market to optimize the care of dental patients. Biodentine has been recently introduced as the “the first all-in-one, bioactive and biocompatible material for damaged dentin replacement”. Manufacturers claim that Biodentine has noticeably shorter setting time in contrast to other silicate cements such as Mineral Trioxide Aggregate (MTA) and also has better mechanical and handling properties. This article is aimed to compare the properties of MTA and Biodentine analyzing the research work done in this field so far by various researchers all across the globe.

Keywords: Adhesive ability, Biological properties, Mechanical properties

INTRODUCTION

During the last 200 years, there have been many changes in the way of performing endodontic treatment. The standard protocol has undergone several modifications, more so because of increased demand from the patients for saving their teeth and advances in material science and innovative equipments. Bioceramics materials in endodontics can be considered as a magnanimous entity which has changed the prognosis of many cases which were once considered as next to impossible.

A remarkable biocompatible material, MTA with exciting clinical applications was pioneered by Dr. Mahmoud Torabinejad and co-workers in Loma Linda University [1]. MTA can be used in surgical and non-surgical applications, including direct pulp capping [2], temporary filling material, Perforation repairs in roots or furcations [3], apexification and root end fillings [4,5]. Despite the high clinical efficacy of this wonder cement, there were always some issues which prevented the clinicians to use it for many cases. The major ones being very long setting time and difficult manipulation.

Biodentin new bioactive calcium silicate-based cement has been recently launched in the dental market as a ‘dentin substitute’. This new biologically active material aids its penetration through opened dentinal tubules to crystallize interlocking with dentin and provide mechanical properties. Biodentin has been formulated using MTA-based cement technology and hence; claims improvements of some of the properties such as physical qualities and handling, including its other wide range of applications like endodontic repair and pulp capping in restorative dentistry [6].

This review article attempts to compile and compare the properties of MTA and Biodentin for better clinical understanding.

Chemical Composition

Chemical composition of Biodentine: Biodentine is available in the form of a capsule containing the ideal ratio of its powder and liquid. The composition of powder is given in [Table/fig-1] while the liquid contains calcium chloride which act as an accelerator, hydrosoluble polymer function as water reducing agent and water. However, the exact concentration of its components has not been provided by the manufacturer, various researchers have studied the same and provided the data. One such study performed by Camilleri J et al., has revealed the concentration of components of Biodentine [Table/fig-1] [7].

Chemical composition of MTA: MTA is basically a mechanical mixture of three powder ingredients: portland cement (75%), bismuth oxide (20%) and gypsum (5%) [8]. According to MTA patent, it consist of calcium oxide (50-75 wt %) and silicon oxide (15-20 wt %), which together constitute 70-95% of the cement. Upon blending of these raw materials; tricalcium silicate, dicalcium silicate, tricalcium aluminate, tetracalcium aluminoferrite are produced [9]. There are two commercial types of MTA: grey and white and the difference lies due to the presence of iron in the former which further forms the tetracalciumaluminoferrite phase. On the contrary, there is absence of oxide of iron in white MTA and hence the phase [Table/fig-2] [10].

Setting Reaction

Setting reaction of Biodentine: The reaction of the powder with the liquid leads to the setting and hardening of the cement. Just after mixing, the calcium silicate particles of Biodentine react with water to form a high pH solution containing Ca^{2+} , OH^- and silicate ions. The hydration of the tricalcium silicate leads to the formation of a hydrated calcium silicate gel on the cement particles and calcium hydroxide nucleates. With the passage of time, calcium silicate hydrated gel polymerizes to form a solid network and the alkalinity of the surrounding medium increases due to the release of calcium hydroxide ions. Further the hydrated calcium silicate gel surrounds the unreacted tricalcium silicate particles and due to its relatively impermeable nature to water, it helps in slow down the effects of further reactions [11,12]. The complete reaction can be summarized as [6]:



C_3S

CSH

Setting reaction of MTA: The hydration reaction during setting occurs between tricalcium silicate and dicalcium silicate to form a calcium hydroxide and calcium silicate hydrate gel, producing an alkaline pH. A further reaction between tricalcium aluminate and calcium phosphate forms a high-sulphate calcium sulphoaluminate. The calcium ions leach through the dentinal tubules, and the concentration increases with time as the material cures [8,13,14].

Setting Time

The working time of Biodentine and MTA is given in [Table/fig-3] [6]. The presence of setting accelerator in Biodentine results in faster

Powder	Percentage
Tricalcium silicate (3CaO.SiO ₂) (main core material)	80.1
Dicalcium silicate (2CaO.SiO ₂) (second core material)	-
Calcium carbonate (CaCO ₃) (filler)	14.9
Zirconium Oxide (ZrO ₂) (radiopacifier)	5
Iron oxide (colouring agent)	-

[Table/Fig-1]: Composition of Biodentine.

Composition	Percentage
Powder	
Tricalcium silicate	66.1
Dicalcium silicate	8.4
Tricalcium aluminate	2.0
Tetracalciumaluminoferrite	-
Calcium sulphate	-
Bismuth oxide	14
Calcium oxide	8
Silicon oxide	0.5
Aluminium oxide	1.0

[Table/Fig-2]: Composition of MTA.

Material	Initial setting time (minutes)	Final setting time (minutes)	Porosity characteristics {density (g/cm ³)}
MTA (ProRoot)	70	175	1.882 (0.002)
Biodentine	6	10.1	2.260 (0.002)

[Table/Fig-3]: Setting time and porosity characteristics of MTA and Biodentine.

setting thereby improving its handling properties and strength. This is an advantage over MTA, since a delayed setting time studied by Torabinejad M et al, leads to an increased risk of partial material loss and alteration of the interface during the finishing phase of the procedure [5, 13, 14]. Therefore, Biodentine has a great improvement compared to MTA in terms of setting time.

Density and Porosity

It is the critical factor which determines the amount of leakage and outcome of the treatment because greater pore diameter results in larger leakage which corresponds to the ingress and transmission of microorganisms and hence compromised hermetic seal. A study performed by Torabinejad M et al., [5] did not reveal any significant solubility of MTA whereas; Fridland M and Rosado R have reported the significant increase in solubility and porosity of ProRoot MTA with the increase in water to powder ratio [15]. De Souza ET et al., conducted a study on porosity and compared Biodentine with IRoot BP, Ceramicrete and ProRoot MTA using micro-CT characterization. They observed that no significant differences were found in porosity between the new calcium silicate containing repair cements and MTA [16].

Due to low water content in the mixing stage Biodentine exhibits lower porosity than MTA [Table/Fig-3].

Compressive Strength

During the setting of Biodentine, the compressive strength increases 100 MPa in the first hour and 200 MPa at 24th hour and it continues to improve with time over several days until reaching 300 MPa after one month [8] which is comparable to the compressive strength of natural dentine i.e 297 MPa [17]. A study conducted by Grech L et al., showed that Biodentine had highest compressive strength when compared to other tested materials due to low water/cement ratio used in Biodentine [14].

Flexural Strength

Flexural strength of any dental material is an important factor as it decreases the risk of fracture in clinical use. Walker MP et al., found that the flexural strength of MTA was 14.27 MPa when specimens were exposed to two-sided moisture after 24th hour of setting time [18]. However, the flexural strength of Biodentine recorded after two hours, has been found to be 34 MPa [6].

Microhardness

Microhardness of MTA has been affected by several factors like

the pH value of the environment, the thickness of the material, the condensation pressure, the amount of entrapped air in the mixture, humidity, acid etching of the material, and temperature [19-22]. Matt GD et al., investigated the microhardness of grey MTA and white MTA with 2 mm and 5 mm thickness of material and found that 5 mm thickness has significantly more hardness regardless of the material used [19]. Grech L et al studied that Biodentine showed superior value of microhardness when compared to Bioaggregate and IRM [14]. The hardness of biodentine by Goldberg et al., was found to be 51 Vickers Hardness Number (VHN) at 2 hour and 69 VHN after one month [23]. The crystallization of calcium silicate hydrate gel continues which reduces porosity and increase hardness with time [6].

Radiopacity

The mean radiopacity for MTA has been found to be 7.17 mm of equivalent thickness of aluminium [5] and Biodentine reported a radiopacity to 3.5 mm of aluminium [6]. Grech L et al., evaluated the radiopacity of Biodentine, bioaggregate and tricalcium silicate cement and found that all materials had radiopacity value greater than 3 mm of aluminium [14]. However Caron G et al., observed lower radiopacity of biodentine when compared to MTA Angelus [24].

Solubility

From the literature available, there is no definite conclusion regarding the degree of MTA solubility and it was concluded that with increase in water-to-powder ratio, release of calcium from MTA increases which accelerates its solubility [5,20,15]. Grech L et al., investigated lowest degree of solubility for Biodentine, bioaggregate and prototype cement while assessing the physical properties of these materials. They confirmed the deposition of hydroxyapatite crystals on material surface in presence of synthetic tissue fluid [14].

Microleakage

Biodentine is found to be associated with high pH (12) and releases calcium and silicon ions which stimulates mineralization and create "mineral infiltration zone" along dentin-cement interface imparting a better seal. Caron G et al., have found that Biodentine exhibits superior sealing properties than MTA [24]. While Torabinejad M reviewed a comprehensive literature to investigate studies regarding the leakage of MTA and concluded that MTA has good sealing ability and it seals well [25]. Ravichandra PV et al., evaluated that Biodentine provide better adaptation and seal than commonly used root-end filling material [26]. However, Ozbay G et al., observed less microleakage with MTA than Biodentine when analysed by fluid filtration method [11].

Marginal Adaptation and Sealing Ability

Marginal adaptation has correlation with the sealing ability of dental material and, hence effect on clinical success rate. Micromechanical adhesion of Biodentine enabled excellent adaptability of Biodentine crystals to the underlying dentin [27].

Soundappan S et al., conducted invitro study to compare the marginal adaptation of Biodentine with MTA and Intermediate Restorative Material (IRM) using scanning electron microscope and concluded that both MTA and IRM were significantly superior to Biodentine in terms of marginal adaptation when used as a root end filling material [28].

Bond Strength and Push Out Bond Strength

Tunc ES et al., reported that the application of total-etch 1-bond adhesive system with a composite and compomer over MTA results significantly higher bond strength than with a 1-step self-etch adhesive system [29]. Whereas, Hashem DF et al., investigated that Biodentine has low strength during initial stages of setting, hence the application of final overlying resin composite restoration

(laminated or layered) should be delayed for more than two weeks in order to achieve adequate bond strength of matured biodentine to withstand contraction forces of composite [30].

Another important use of MTA and Biodentine is perforation repair and to deliver higher success rate, the material should possess high push out bond strength which aids to prevent the dislodgement of material during tooth function from the repair site. El-Maaita AM et al., examined the effect of smear layer on push out bond strength of biodentine, ProRoot MTA and Harvard MTA and reported that push out bond strength decreases with removal of smear layer in all tested materials [31]. Gunesser MB et al., assessed the effect of different endodontic irrigating agents (sodium hypochlorite, chlorhexidine and saline) on push out bond strength of MTA and Biodentine when used as a root perforation repair material and concluded that MTA possess low push out bond strength than Biodentine [32].

Discoloration

Literature reveals that presence of transitional elements namely iron, manganese, copper and chromium impart strong color to the material in its oxide forms. In the same way, bismuth, heavier element causes discoloration owing to its yellow oxide.

Valles M et al., conducted an in vitro study to evaluate color stability of five calcium silicate based material under the influence of light and oxygen and found that combination of light and anaerobic conditions results in significant differences in color of Angelus white MTA, ProMTA, white portland cement with bismuth oxide whereas Biodentine and PC exhibited color stability for five days [33].

Antibacterial and Antifungal Activity

The antibacterial and antifungal properties of MTA and Biodentine can be best attributed to the high pH of these materials. This high alkalinity has inhibitory effect on the growth of microorganism and causes disinfection of dentin. Hiremath GS et al., evaluated the antimicrobial efficacy of Biodentine, MTA, and MTA Plus and found that MTA and Biodentine showed significant antimicrobial effect against *E. faecalis* whereas MTA Plus was proved to be a good anti fungal agent against *Candida albicans* [34]. Another study reported the antibacterial and anti fungal characteristics of Biodentine, MTA and Glass Ionomer cement (GIC) and concluded that Biodentine shows superior antimicrobial action than MTA and GIC [35].

Biocompatibility and Cytotoxicity

Biocompatibility and cytotoxicity of a dental material have to be taken care of when material is used as a perforation or furcal repair, retrograde filling or pulp capping agent to avoid its toxic effect on surrounding tissue (pulpal and periradicular cells). Zhou H et al., compared the cytotoxicity of biodentine with white MTA and GIC using human gingival fibroblast and observed that biodentine caused similar reaction as compared to white MTA, and both materials were less cytotoxic than GIC [36]. Similarly, Nunez CMC et al., have found similar pattern of cytokine expression between Biodentine and MTA while using fibroblast cell [37]. Perard M et al., compared biocompatibility and gene expression of Biodentine and MTA using three-dimensional multicellular spheroid cultures and observed similar response between these two materials indicating its use for direct pulp-capping [38].

Bioactivity and Regenerative Potential

Laurent P et al., assessed the ability of Biodentine, MTA, calcium hydroxide and Xeno III adhesive resin to induce reparative dentin synthesis and transforming growth factor beta 1 (TGF- β 1) secretions. They showed that both Biodentine and MTA involved in early odontoblastic differentiation and initiation of mineralisation and thus form reparative dentin synthesis then other two materials. TGF- β 1 secretion was significantly increased with Biodentine, MTA and calcium hydroxide than Xeno III [39].

In another study, Biodentine showed greater ability to produce apatite crystals and release of dental elements than MTA and BC sealer [40]. Luo Z et al., studied the effect of Biodentine on the human dental pulp stem cells (hDPSCs) and found that biodentine significantly increased the proliferative, migratory and adhesion of stem cells when placed directly in contact with the pulp, which further reflects bioactivity and biocompatibility properties of the material. Biodentine is able to promote mineralisation, generating a reactionary dentine as well as a dense dentine bridge when placed in contact with pulp [41].

Bonson S et al., observed differentiation of fibroblasts and bone formation when MTA was placed on cell cultures of gingival and periodontal ligament fibroblasts. Thus, MTA is considered as a bioactive material with osteoinductive properties [42].

Clinical applications	Related studies
Pulp capping	Primary teeth: Tuna D and Olmez A 2008 [43] Permanent teeth: Witherspoon DE [44] concluded that MTA is a good substitute of Ca(OH) ₂ for vital pulp therapies because it stimulates a higher and greater quality and quantity of reparative dentin and also aids superior long term sealing ability
Pulpotomy	Primary teeth: Torabinajad M and Chivin N [4], Ni Chaollai A et al., 2009 [45] Permanent teeth: Belobrov I et al., 2008 [46], Eghbal MJ et al., [47] revealed that MTA pulpotomy forms a dentine bridge completely and maintains the vitality of the radicular pulp by limiting the inflammation.
Perforation repair (Furcal or root)	Primary teeth: Oliveria TM et al., 2008 [48] Permanent teeth: Arens DE and Torabinajad M [3], Wang P et al., 2009 [49] (MTA promotes bone healing and eliminates the signs of inflammation. hence, MTA can be considered as an alternative option for repair of furcal perforations both in primary and permanent teeth).
Root end filling	Permanent teeth: Christiansen R et al., 2009 [50] found that healing of teeth treated with MTA as root end filling material had significantly better healing (96%) than those treated with orthograde GP filling (52%).
Root canal filling	Primary teeth (absence of permanent successor): O'Sullivan SM and Hartwell GR 2001 [51] Permanent teeth: Bogen G and Kuttler S 2009 [52] (obturation with MTA seemed to provide a biocompatible seal of root canal system).
Resorption	Primary teeth: Sari S and Sonmez D 2009 [53] Permanent teeth: Silveria FF et al., [54] treated a double "Pink tooth" with MTA as root canal filling material and found favourable results after 18 months. Hence, MTA may be suitable material for treatment of internal resorption.

[Table/Fig-4]: Clinical uses of MTA.

Clinical applications	Related studies
Pulp capping	Laurent P et al., (39), Nowicka A et al., [55] (When Biodentine was applied directly onto pulp, it induces a reparative dentine formation due to modulation of pulp cell TGF- β secretion).
Pulpotomy	Villat C et al., [56] demonstrated that Biodentine should be considered as a conservative intervention in treatment of symptomatic immature teeth.
Root end filling	Pawar AM et al., 2013 [57] showed that routine endodontic therapy followed by surgical intervention with placement of biocompatible material like Biodentine for management of chronic peripapal lesions would positively affect the treatment outcome.
Dentin substitute	Koubi G et al., [58] conducted a randomized 3 years prospective study and concluded that Biodentine can be used as a dentine substitute under composite for posterior restorations.
Perforation repair (Furcal or root)	Hassan FN et al., [59] found that both ProRoot MTA and Biodentine performed equally well when used as furcation repair materials.
Root canal filling and apex closure	Han L and Okiji T 2013 [40], Elumalai D et al., 2015 [60] described that that initial healing was better in case of Biodentine when using in open apices cases however MTA showed better long term effects.

[Table/Fig-5]: Clinical uses of Biodentine.

Drawbacks	Related Studies
MTA Long setting time	Torabinejad M et al., 1995 [5], Chng HK et al., 2005 [61] (MTA showed longest setting time when compared to that amalgam).
Difficult handling	Mooney GC and North S 2008 [62] observed that the manipulation of MTA was messy when the moisture was excessive in the preparation which further results in soupy material and hence difficult to use
Discoloration	Accorinte ML et al., 2008 [63] (iron and manganese were the possible elements responsible for discoloration).
Toxic elements in composition	Asgary S et al., 2006 [64] (MTA contains elements like arsenic which diffused into the tissue fluids and could potentially cause toxicity).
High cost	
BIODENTINE Poor radio-opacity	Caron G et al., 2014 [24] (despite the presence of zirconium dioxide, Biodentine has unfavourable radiopacity as compare to MTA).
Lower wash out resistance	Grech L et al., 2013 [14], Elumalai D et al., 2015 [60] demonstrated that Biodentine has a high washout, low fluid uptake and sorption values, low setting time and superior mechanical properties.

[Table/Fig-6]: Limitations of MTA and Biodentine.

Clinical Implications and Limitations of MTA and Biodentine

The clinical applications and limitations/drawbacks of MTA and Biodentine are summarized in a tabular form [Table/Fig-4-6].

CONCLUSION

The clinical uses of bioceramics have increased exponentially over the years because of their wide range of applicability in restorative dentistry and endodontics. The introduction of MTA was considered as a major break-through in the history of material science and since then the properties of this material have been improvised in order to achieve its maximum benefits. However, there have been a few limitations of this material which have always compelled the researchers worldwide to look for its alternatives. Difficult manipulation, slow setting time and high cost are the ones to name a few. In order to overcome these limitations, a new bioceramic material named Biodentine was introduced in the year of 2010 which has proved to be a second major break-through. Relatively easier manipulation, low cost and faster setting is the major advantages of this material when compared to MTA. Studies have also proved that its compressive and flexural strength are superior to that of MTA. High biocompatibility and excellent bioactivity further go in favour of this dental replacement material. Due to lack of long term observational studies, it is difficult to infer concretely that which material out of MTA and Biodentine is superior, however, manoeuvrability and economical factors fall in favour of Biodentine.

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