

An overview of composition, properties, and applications of Biodentine

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INFORMATION ABSTRACT

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A series of events leads to loss of tooth structure by dental caries, tooth wear and trauma, which is often replaced by inert dental materials that replace the bulk of the tooth. If pulp health is affected, a series of interventions need to be undertaken. Initially, the pulp vitality needs to be maintained. Later, elimination of infection and filling of the pulp space is necessary. When pulpal involvement occurs the choice of material has to change, and materials that interact with the pulp are indicated. Interactive materials used for dental procedures include calcium hydroxide in its various presentations and hydraulic calcium silicate cement. Biodentine is a promising dentine substitute that has been recently introduced in dentistry. Although many other materials like Glass Ionomer Cement (GIC), composite and Mineral Trioxide Aggregate (MTA) are available for repair of dentin loss in tooth structure, none of them possesses ideal properties. Despite many advantages, MTA has been replaced by Biodentine, which is a new calcium silicate-based material, due to its limitations. It has good handling properties, short setting time, and improved mechanical properties. Biodentine was designed explicitly as a "dentine replacement," with applications ranging from endodontic repair to pulp capping.

1. Introduction

Glass-Ionomer cement has been used extensively in deep carious lesions and dentine loss in the coronal part. However, its inherent limitation of not stimulating any reparative dentin formation led to the evolution of many other materials [1-3]. When pulpal involvement occurs, the material choice must change, and materials that interact with the pulp or the dentine are indicated. Calcium hydroxide, in various forms, and, more recently, hydraulic calcium silicate cement, are interactive materials used in dental procedures. They can even be used on moistened tooth surfaces. In endodontic therapy, the practitioner employs endodontic repair materials that are insoluble in oral fluids, maintain an adequate seal, are dimensionally stable, non-resorbable, radiopaque, and biocompatible. Amalgam, zinc-oxide eugenol cement, composite resin, and glass-ionomer cement have all been utilised in the past for retrograde filling and perforation repair. Unfortunately, none of these materials has been able to meet all of the ideal material's requirements.

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In the early 1990s, mineral trioxide aggregate (MTA), a biomaterial, was investigated for its potential in restorative dentistry. Its multiple applications include direct & indirect pulp clapping, the formation of the apical plug, root-end filling, perforation repair, furcation repair, repair of resorptive defects, and the management of immature apices (Apexogenesis/Apexification) etc. [4-9]. However, this material has a few inherent limitations, including difficulty in manipulation, a prolonged setting time, and is expensive [10].

Septodont's research group recently developed Biodentine™, a novel dental material class that combines high mechanical qualities with exceptional biocompatibility and bioactive behavior. Biodentine is the first -in-one biocompatible dentine substitute, based on Active Biosilicate Technology™, that is used to restore and endodontically treat damaged dentine [2]. In 2009, it was made commercially available.

2. Composition of Biodentine

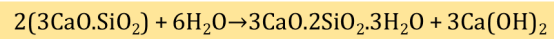
Biodentine is available in powder and liquid forms. The powder primarily consists of Tricalcium silicate ($3\text{CaO}\cdot\text{SiO}_2$) and Di-calcium silicate ($2\text{CaO}\cdot\text{SiO}_2$). They regulate the setting reaction and act as core materials. Calcium carbonate (CaCO_3) acts as a filler and is responsible for improving mechanical properties. A radiopacifier may also be present such as Zirconium dioxide (ZrO_2).

The liquid contains Calcium chloride ($\text{CaCl}_2\cdot 2\text{H}_2\text{O}$), which acts as an accelerator and regulates the setting reaction. Water reducing agent (Super-plasticizer) such as a hydro-soluble polymer is added to reduce the amount of water required for the mix (water/cement), decreases viscosity and improve cement handling characteristics [11].

3. Setting reaction

Initially, the reaction starts with the hydration of the tricalcium silicate, leading to hydrated calcium silicate gel (CSH gel) and calcium-hydroxide [12]. The cement located in inter-grain areas contains a high level of calcite (CaCO_3) content. The tricalcium silicate is hydrated by the dissolution and precipitation of calcium silicate hydrate. In general, it is represented by chemists as C-S-H; where 'C' is CaO , 'S' is SiO_2 , and 'H' is H_2O . The calcium hydroxide takes origin from the liquid phase. C-S-H gel layer formation occurs after the

nucleation and growth on the tricalcium silicate surface. The remaining unreacted tricalcium silicate grains are surrounded by layers of calcium silicate hydrated gel, which are relatively impervious to water, thereby slowing the further reactions. The C-S-H gel formation is due to tricalcium silicate's permanent hydration, which gradually fills in the spaces between the tricalcium silicate grains. The following chemical equation summarises the complete hydration reaction [12].



C-S-H gel

3.1 Structure of cement

The set cement consists of calcite rich (CaCO_3) structures of variable sizes. The crystals of CaCO_3 are diamond-shaped (or rhombohedra form) and observed at the surface. Taylor (1997) observed that calcium-hydroxide crystallizes in the form of a hexagonal plate [13]. The surface of the CaCO_3 crystals is rough and irregular. Therefore, CSH gel is considered the cement matrix, and the crystals of CaCO_3 fill the spaces between grains of cement. Calcite (CaCO_3) has two distinct functions including Calcite acts as an active agent, is implicated in the process of hydration, and as a filler that improves the mechanical properties of the cement [14]. The hardening process results from the formation of crystals that are deposited in a super-saturated solution. Setting reaction of $3\text{CaO}\cdot\text{SiO}_2$ includes four elements such as the unreacted particles, surface products (CSH gel), the content of the pores ($\text{Ca}(\text{OH})_2$) and porous capillary space [15].

4. Properties of Biodentine

4.1 Setting time

Compared to MTA, Biodentine has a shorter setting time and is in the range of 9-12 minutes. The main reason for the shorter setting time is the presence of Calcium chloride, which acts as an accelerator. Further, this material also contains a Hydro-soluble polymer, which acts as a water-reducing agent [16]. The initial and final setting times of Biodentine and MTA are given in table 1.

Table 1: Setting time of MTA and Biodentine

Materials	Initial setting time (Minutes)	Final setting time (Minutes)
Biodentine	6	10.1
MTA	70	175

4.2 Adhesion

The Biodentine adheres to the dental surfaces with the help of physical bonding by ion exchange. The Physical process of crystal growth within dentine tubules leads to a micromechanical tag that gives a long-lasting seal. Compared to the MTA and Dycal, Biodentine exhibits a greater bond strength with the dental surfaces [14].

4.3 Density and porosity

The use of hydro-soluble polymer in Biodentine composition reduce the amount of water that exhibits a positive influence on the density and porosity of Biodentine. The lower porosity of Biodentine leads to higher mechanical strength. Also, it exhibits a lower porosity compared to Dycal and MTA [16].

4.4 Radiopacity

Biodentine is a radiopaque material as it contains zirconium oxide, which allows easy identification on the radiographs. According to the ISO standard 6876, Biodentine shows a radiopacity equivalent to 3.5 mm of aluminium. This value obtained is over the minimum requirement of ISO standard (3mm aluminium) and makes Biodentine™ particularly suitable in the endodontic indications of canal repair [16,17].

4.5 Compressive strength

The cement must have the capacity to withstand masticatory forces; in other words, sufficient compressive strength to resist external forces [18]. Biodentine has the unique property of demonstrating its ability to improve compressive strength over time until it reaches a level comparable to natural dentine [19]. In a study, Grech *et al.* (2013) [20] reported that the highest compressive strength with the Biodentine compared to Bioaggregate, Tricalcium-Silicate cement and Intermediate Restorative Materials (IRM). This increase in compressive strength can be attributed to the requirement of lower water: powder ratio of the Biodentine as it contains a water-soluble polymer in the liquid. Kayahan *et al.* (2013) [18] evaluated the compressive strength from another perspective and attained conclusions specifically on clinical usage. Acid etching was done for mechanical adhesion of Biodentine to the tooth structure. Numerous studies aimed to assess whether there will be any alteration in the compressive strength due to the etching process. They concluded that the acid etching process after

seven days did not reduce the compressive strength of ProRoot MTA and Biodentine [18]. In a study by Koubi *et al.* [19], Biodentine was used as a posterior restoration and revealed favourable surface properties such as good marginal adaptation until six months. The compressive strength of Biodentine will be 100 MPa in the first hour, which will be increased to a value of 300 MPa after one month. This value becomes relatively stable and is in the compressive strength of natural dentine (297MPa).

4.6 Flexural strength

High flexural strength is a compulsory prerequisite for any restorative material for its long-term efficiency in the oral cavity. The three-point bending test was used to measure the flexural strength and is of high clinical significance. The bending value obtained after 2 hours was 34 MPa compared with other materials such as 5-25 MPa for the Conventional Glass Ionomer Cement; 17-54 MPa for Resin modified GIC; and 61-182 MPa for Composite resin [21]. Therefore, it has been inferred from the test that the bending resistance of Biodentine™ is superior to conventional GIC but much lower than the composite resin.

4.7 Microhardness

There is an increase in microhardness of Biodentine with time. After one month, the hardness of Biodentine reaches the same range as natural dentine [14].

4.8 Biodentine interfaces

Biodentine's interface with adjacent phosphate-rich hard tissue substances is improved by the deposition of calcium phosphate crystals on the surface. As a result, Biodentine is more resistant to acid erosion and microleakage. Biodentine appeared to have more resistance to decay and microleakage than MTA, Dycal and GIC [22].

4.9 Discoloration

Biodentine exhibits colour stability over five days and can serve as an alternative for use under light cure restorative materials in highly esthetic areas [23].

4.10 Antibacterial activity

Biodentine exhibits a significant amount of antibacterial activity as well. Calcium hydroxide ions released

from cement during the setting phase of Biodentine increases pH to 12.5, which inhibits the growth of microorganisms and can disinfect the dentin.

4.11 Biocompatibility

According to Laurent *et al.* [24], Biodentine is non-toxic and has no adverse effects on cell differentiation and specific cell function. They reported that Biodentine increases TGF-B1 (growth factor) secretion from pulp cells which causes angiogenesis, recruitment of progenitor cells, cell differentiation and mineralization. The material is inorganic and non-metallic and can be used in direct and indirect pulp capping procedures as a single application dentin substitute without any cavity conditioning treatment [2].

4.12 Stability in the oral environment

Biodentine is not that stable as a composite material so that it is not suitable as permanent enamel replacement material. When compared to other Portland cement-based materials, Biodentine is stable enough to use as a temporary filling in the load-bearing areas [22].

4.13 Washout resistance

Washout of a material can be defined as the tendency of freshly prepared cement paste to disintegrate upon early contact with the fluids such as blood or other liquids. The available study results on these characteristics of Biodentine does not reveal favourable results as it demonstrated a high washout with every sample used in the methodology [11].

The advantages of Biodentine include reduced setting time, better handling and ease of manipulation, improved mechanical properties, biocompatibility, preserves pulp vitality, which promotes pulp healing and helps in remineralisation of dentine [1,2]. However, this material possesses a few disadvantages, such as poor radio-opacity and lower washout resistance [13,25].

5. Clinical applications of Biodentine

In restorative dentistry, Biodentine is used as a direct pulp capping material, which helps for reactionary dentine stimulation in indirect pulp capping. In endo-

dentics, it is used for pulpotomy, endodontic repairs, and root-end filling material.

5.1 Pulp capping agent

Biodentine is used as an indirect pulp capping agent. Biodentine™ can stimulate reactionary dentine, which is a natural barrier against bacterial invasions. The reactionary dentine formation stabilizes at three months, indicating that the stimulation process is stopped when a sufficient dentine barrier is formed [26]. It causes early mineralization by releasing TGF-β1 from pulpal cells to encourage pulp healing and by odontoblast stimulation for dentine bridge formation to protect the pulp. In contrast to Dycal, which is associated with tissue necrosis and inflammation during the initial time of installation, Biodentine has a well-localized pattern (full dentinal bridge development) and no inflammatory reaction histologically. A clinical trial conducted by Septodont suggested that the Biodentine™ could be used in direct pulp capping indications with a reasonable success rate. Perard *et al.* [27] assessed the biological effects of Biodentine for use in pulp-capping treatment on pseudo-odontoblastic and pulp cells. They found that MTA and Biodentine modify the proliferation of pulp cell lines. Nowicka *et al.* [28] concluded that Biodentine had similar efficacy to MTA in the clinical setting and can be considered an alternative to MTA in pulp capping treatment because it preserves pulp vitality and promotes its healing.

5.2. Dentine substitute

Due to its dentine like mechanical properties, Biodentine is used as a permanent dentine substitute under a composite, especially in deep carious teeth. The absence of aluminates results in less brittleness and is thus used as an ideal base under restorations. A study conducted by Septodont to compare the Biodentine with Filtek™ Z100 as posterior restorative material showed that Biodentine™ has easy handling, excellent anatomic form, perfect marginal adaption, and establishes a very good interproximal contact [1].

5.3 In vital pulpotomy

Biodentine is also utilised in a pulpotomy, which is a vital pulp therapy. It is commonly employed in pediatric dentistry and involves amputation of the pulp chamber and material placement to preserve the radicular pulp tissue vitality. It is preferred when the coro-

nal pulp tissue is inflamed, and direct pulp capping is not suitable. The success rate of vital pulpotomy with Biodentine is higher than that of MTA and Pulpotec [29-31].

5.4 Endodontic repair material for perforations

The endodontic indications of Biodentine™ are similar to the normal calcium silicate-based materials, like the Portland cements and MTA. Biodentine is recommended for perforation repair, the formation of apical plug and furcation repair.

5.5 Root-end filling material

To evaluate this application, Soundappan *et al.* [32] compared MTA, IRM and Biodentine as a retrograde filling material and found that at 1mm level, there was no difference among tested materials. Still, at 2mm level MTA was superior to both IRM and Biodentine. The results reveal that further research is required before Biodentine can be advocated as root-end filling material. Biodentine as root-end filling material has also been advised because of its better consistency, better handling, safety and faster setting time.

6. Advantages of Biodentine Over MTA [5,33-35]

- Biodentine™ consistency is better suited to clinical use than MTA.
- Biodentine™ presentation ensures better handling and safety than MTA.
- Biodentine™ exhibits better mechanical properties than MTA.
- Biodentine™ does not require a two-step restoration procedure as in the case of MTA.
- As the setting is faster, there is a lower risk of bacterial contamination than with MTA.

Despite a few contradicting reports, numerous studies support this substance in terms of physical and therapeutic characteristics [19, 36, 37].

7. Conclusion

Biodentine, a popular tricalcium silicate-based dentine replacement and repair material, has been evaluated in several aspects since its launching in 2009. Despite a few inconsistent results, various investigations have demonstrated that the Biodentine is superior in terms of physical and clinical features. Biodentine holds

promise for clinical dental procedures as a biocompatible and easily handled product with a short setting time. As more research is performed regarding this exciting alternative to MTA, we will be provided with more reliable data and confidently implement Biodentine into routine clinical applications.

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