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**REVIEW ARTICLE**

# BIODENTINE: DENTINE SUBSTITUTE IN CAPSULE

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**ABSTRACT**

Biodentine is a calcium-silicate based material that has drawn attention in recent years as it overcomes the drawbacks of Calcium hydroxide and Mineral trioxide aggregate. Due to its major advantages over MTA like good handling properties, short setting time and improved mechanical properties with with excellent biocompatibility, as well as instituted bioactive behavior, biodentine has great potential to revolutionize the different aspects of managing both primary and permanent in endodontics as well as operative dentistry. This paper reviews unique properties and clinical applications of Biodentine in dentistry.

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## INTRODUCTION

Loss of dentin is perhaps one of the major losses which hamper the integrity of the tooth structure to a significant extent. Whether be in the coronal portion or the radicular one, the dentin loss must be substituted with an artificial material, which can restore the physiological integrity of the tooth structure (Wilson and Kent, 1972). Similarly, in endodontic therapy, endodontic repair materials are being used, which ideally, should adhere to tooth structure; maintain a sufficient seal; be insoluble in tissue fluids; be dimensionally stable; nonresorbable, radiopaque and exhibit biocompatibility if not bioactivity. In the era of biomaterialistic dentistry several newer materials have been formulated, and standardized to obtain maximum clinical benefits and improved performance. One such material introduced was Biodentine which had numerous clinical applications. Biodentine™ which has developed by Septodont's research group is based on Active Biosilicate Technology. The "Biodentine" calcium silicate based product which became commercially available in 2009 (Septodont, http://www.septodontusa.com/) and that was specifically designed as a "dentine replacement" material.

**Composition and setting reaction:** It is available as powder in capsule which contains Tri-calcium silicate (C3S), Di-calcium silicate (C2S), Calcium carbonate & oxides of iron and zirconium and liquid in a pipette. Liquid contains Calcium chloride and Hydrosoluble polymer. There are two types of boxes available in the market. Box is containing 15 capsules & 15 single-dose containers and another smaller box which contains only 5 capsules and 5 single-dose containers (Priyalakshmi and Ranjan, 2014). The hydration of the tricalcium silicate leads to the formation of a hydrated calcium silicate gel (CSH gel) and calcium hydroxide (Taylor, 1997). The cement located in inter-grain areas has a high level of calcite ($CaCO_3$) content. The hydration of the tricalcium silicate is achieved by dissolution of tricalcium silicate and precipitation of calcium silicate hydrate. In general, it is designated by chemists as C-S-H (C= CaO, S=$SiO_2$, H=$H_2O$). The calcium hydroxide takes origin from the liquid phase. C-S-H gel layers formation is obtained after nucleation and growth on the tricalcium silicate surface. The unreacted tricalcium silicate grains are surrounded by layers of calcium silicate hydrated gel, which are relatively impermeable to water; thereby slowing down the effects of further reactions. The C-S-H gel formation is due to the permanent hydration of the tricalcium silicate, which gradually fills in the spaces between the tricalcium silicate grains. The complete hydration reaction is as follows (Taylor, 1997; Allen *et al.,* 2007):

$$\underset{\textbf{C3S}}{2(3CaO.SiO_2)} + 6H_2O \rightarrow \underset{\textbf{CSH}}{3CaO.2SiO_2.3H_2O} + 3Ca(OH)_2$$

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**Properties**: Biodentine attracted attention in the field of dentistry due to its unique properties as follows:

**Compressive strength:** Compressive strength is considered as one of the main physical characteristics of hydraulic cements. The product sheet of Biodentine states that a specific feature of Biodentine is its capacity to continue improving in terms of compressive strength with time until reaching a similar range with natural dentin (297Mpa). Grech *et al.* (2013) studied that Biodentine showed highest compressive strength as compared to other tested materials due to its low water: powder ratio. Furthermore, ina study by Koubi *et al.* (2013), Biodentine was used as a posterior restoration and revealed favorable surface properties such as good marginal adaptation until 6 months.

**Setting Time***:* The product sheet of Biodentine indicates the setting time as 9 to 12 minutes. This short setting timewas attributed to the addition of calciumchloride to the mixing liquid (Grech *et al.* 2013). Calciumchloride has also been shown to result in accelerated setting time for mineral trioxide aggregate (Bortoluzzi *et al.,* 2009).

**Microhardness:** Camilleri in a study comparing the physical properties of Biodentine with a conventional glass ionomer (Fuji IX) and a resin modified glass ionomer (Vitrebond), showed that Biodentine exhibited higher surface microhardness compared to the other materials when unetched. On the other hand, there was no difference in the microhardness of different materials when they were etched (Camilleri, 2013).

**Flexural strength:** The 3 points bending test is used as a parameter to measure the flexural strength of a material and this test has a high clinical significance. The value of the bending obtained with Biodentine$^{TM}$ after 2 hours was 34 MPa as compared with other materials such as 5-25 MPa for Conventional Glass Ionomer Cement; 17-54 Mpa for Resin modified GIC and 61-182 MPa for Composite resin (O'Brien, 2008). Therefore, it has been inferred that the bending resistance of Biodentine TM is superior to conventional GIC, but still much lower than the composite resin.

**Push-out bond strength**: It is essential that a perforation repair material should have sufficient amount of push-out bond strength with dentinal walls for the prevention of dislodgement from the repair site. (Aggarwal *et al.,* 2013) studied the push-out bond strengths of Biodentine, ProRoot MTA, and MTA Plus in furcal perforation repairs. Push-out bond strength increased with time. Their results showed that the 24 h push-out strength of MTA was less than that of Biodentine and blood contamination affected the push-out bond strength of MTA Plus irrespective of the setting time. A favorable feature of Biodentine determined by the authors was that blood contamination had no effect on the push-outbondstrength, irrespectiveof the duration of setting time (Aggarwal *et al.,* 2013). In a study by Guneser *et al.* (2013), Biodentine showed considerable performance as a repair material even after being exposed to various endodontic irrigation solutions, such as NaOCl, chlorhexidine, and saline, whereas MTA had the lowest push-out bond strength to root dentin.

**Density and porosity**: The degree of porosity plays a very important role in the overall success of treatments performed using these materials, because it is critical factor that determines the amount of leakage. Porosity has been shown to have an impact upon numerous other factors including adsorption, permeability, strength, and density. Taylor (1997) observed that calcium hydroxide crystallizes in the form of hexagonal plate or prism. The surface of $CaCO3$ crystals is rough and irregular. Therefore, CSH gel, considered as the matrix of the cement and the crystals of $CaCO3$ are filling the spaces between grains of cement. Calcite ($CaCO3$) has two distinct functions: as an active agent it is implicated in the process of hydration and as filler it improves the mechanical properties of the cement (Garrault *et al.,* 2006). The mechanical resistance of calcium silicate based materials is also dependant on their low level of porosity. Lower the porosity, higher is the mechanical strength.

**Radiopacity:** Grech *et al.* (2013) in a study evaluating the prototype radiopacified tricalcium silicate cement, Bioaggregate, and Biodentine, concluded that all materials had radiopacityvalues greater than 3mmAl. Similar results were obtained by Camilleri *et al.* (Camilleri, 2013).

**Solubility**: Concerning the durability of water based cements in the oral cavity, one of relevant characteristics of the dental materials is the resistance to acidic environment. Grech *et al.* [6] demonstrated negative solubility values for a prototype cement, Bioaggregate, and Biodentine, in a study assessing the physical properties of the materials. Laurent *et al.* (2008). They concluded that the erosion of BiodentineTM in acidic solution is limited and lower than for other water based cements (Glass Ionomers).

**Adhesion:** The mechanical adhesion of Biodentine$^{TM}$ cement to dental surfaces may result from a physical process of crystal growth within dentine tubules leading to a micromechanical anchor.

**Microleakage:** Another significant property of Biodentine was that it did not require specificpreparation of the dentin walls. Koubi *et al.* (2012) explained the good marginal integrity of Biodentine with the ability of calcium silicate materials to form hydroxyapatite crystals at the surface. These crystals might have the potential to increase the sealing ability, especially when formed at the interface of the material with dentinalwalls. Furthermore, the interaction between the phosphate ions of saliva and the calcium silicate based cements might lead to the formation of apatite deposits, thereby increasing the sealing potential of the material.

**Discoloration:** Biodentine exhibits color stability over a period of 5 days and can serve as an alternative for use under light cure restorative materials in highly esthetic areas.

**Biocompatibility:** Laurent *et al.* (2012), revealed that 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.

**Bioactivity:** In both direct and indirect application, Biodentine does not seem to affect the target cells specific functions. About *et al.* in 2005 investigated that Biodentine material is non-cytotoxic and nongenotoxic for pulp fibroblast at any concentration and stimulates dentin regeneration by inducing odontoblasts differentiation from pulp progenitor cells and promote mineralization, generating a reactionary dentine as well as a dense dentine bridge.

***Anti bacterial properties:*** Due to high alkalinity Biodentine shows inhibitory effect on the micro organisms thus leading to the disinfection of surrounding hard and soft tissues.

**Easily material handling**: The improved physic-chemical properties, ease of manipulation, better consistency, and favorable setting kinetics make biodentine clinically easy to handle (Priyalakshmi and Ranjan, 2014; Arora *et al.,* 2013).

**Applications of Biodentine in Restorative Dentistry**

**As a dentine substitute under a composite restoration:** In comparison to the other calcium silicate based materials, biodentine possess better biological and physico-chemical properties such as material handling, faster setting time, biocompatibility, stability, increased compressive strength, increased density, decreased porosity, tight sealing properties, and early form of reparative dentin synthesis (Koubi *et al.,* 2013; Laurent *et al.,* 2008 and 2012). It is sufficiently stable so that it can be used both for pulp protection and temporary fillings. Restoration of teeth with composite has certain specific demands like bonding to the base, no interference with polymerization etc. So far a clinical study performed by the Septodont group on 116 patients has reported an excellent biocompatibility and tolerance with Biodentine applied as a base with one year follow-up. This may open future gates for biodentine to used cavity lining and base under the permanent composite restoration

**Pulp capping**

Due to its high biocompatibility, biodentine has been proposed as a potential medicament for pulp capping procedures. Biodentine TM is able to stimulate a reactionary dentine which is a natural barrier against bacterial invasions. The reactionary dentine formation stabilizes at 3 months, indicating that the stimulation process is stopped when a sufficient dentine barrier is formed (Shayegan *et al.,* 2012). A clinical evaluation over 6 to 35 months of biodentine, as a base and pulp capping, demonstrated excellent biocompatibility and longevity (Grech *et al.,* 2013) Dammaschke showed a successful result after 6 months of using biodentine as direct pulp capping of iatrogenic pulp exposure (Dammaschke, 2012). Biodentine showed good efficacy in the clinical settings and can be considered as an interesting and promising pulp capping material.

**Application in Endodontics**

**Pulpotomy:** Pulpotomy is another widely used vital pulp therapy method in which biodentine is advocated to be used (Priyalakshmi and Ranjan, 2014). Recently at the 12th Congress of European Academy of Pediatric Dentistry (EAPD) in Poland, Rubanenko *et al.* presented thei preliminary results of comparing biodentine versus formocresol as dressing agents in pulpotomized primary molars. They demonstrated a success rate of 100% for biodentine while that of formocresol was 94% (Rubanenko *et al.,* 2014). Villet *et al.* (2013) performed partial pulpotomy in an immature premolar and detected fast tissue response (radiologically evident) by the dentin bridge formation and continuation of root development in shorter time. They experienced increased speed of pulpal response and homogenous bridge formation making Biodentine good choice thancalcium hydroxide. In evaluating the current preference. endodontic material in children amongst Flemish pediatric dentists, Vandenbulcke *et al.* found that biodentine was the most preferred pulpotomy material in both primary and immature permanent teeth (Luo *et al.,* 2014).

**Apexification (Apical Plug in teeth with necrotic pulps and open apices):** As comparedto MTA, biodentine handled easily and need much less time for setting with better mechanical properties and acceptable cost (Hatibovic-Kofman *et al.,* 2008). As the setting is faster, there is a lower risk of bacterial contamination than with MTA. The mechanical resistance of biodentine is also much higher than that of MTA. Biodentine does not require a two step obturation as in the case of MTA (Priyalakshmi and Ranjan, 2014). In a series of cases, Cauwels *et al.* found that necrotic immature teeth can still achieve continued root development after proper regenerative endodontic treatment with biodentine (Cauwels *et al.,* 2014). Furthermore, the main benefits of using biodentine in this procedure is obtaining a combination of a tight bacterial seal in the apical foramen as well as inducing the formation of new cementum and periodontal ligament (PDL) (Arora *et al.,* 2013). Therefore, biodentine can be advised successfully in weakened necrotic immature teeth.

**Retrograde root end filling:** At the apical end of the root canal system, establishing an impermeable hermetic seal by adequate root end filling material is one of the most important aspects of the periradicular surgery (Andreasen *et al.,* 2012). In a case report, Pawar *et al.* (2013) assessed biodentine as a retrograde material in the management of a large periapical lesion associated with previously traumatized maxillary right central and lateral incisors After 18 months of apical surgery, they found an evident progressive periapical healing.

**Repair of resorption:** With their proven biocompatibility and ability to induce calcium phosphate precipitation at the interface to the periodontal tissue, calcium silicate cements play a major role in bone tissue repair (Reyes-Carmona *et al.,* 2010; Torabinejad and Parirokh, 2010). Biodentine has a better consistency after mixing which allows ease of placement in areas of resorptive defect or obturation of full root canal system (Priyalakshmi and Ranjan, 2014). In two case reports, Nikhil *et al.* and Ali *et al.* showed successful results of biodentine when it is used in treatment of cervical and apical external root resorption with more than 1 year of follow up (Nikhil *et al.,* 2012; Ali *et al.,* 2012). On the other hand, there is some difficulty in removal of biodentine in case of retreatment (Arora *et al.,* 2013).

**Repair of perforations**: An ideal perforation repair material should provide a tight seal between the oral environment and periradicular tissues (Hartwell and England, 1993). It also should remain inplace under dislodging forces, such as mechanical loads of occlusion or the condensation of restorative materials over it (Shokouhinejad *et al.,* 2010; Hashem and Wanees Amin, 2012). Biodentine has its own unique properties that make it preferred for perforation repair either in root canal or pulp chamber floor (Aggarwal *et al.,* 2013). Many studies demonstrated in vitro the high push out bond strength of biodentine even after being exposed to various endodontic irrigation solutions. Additionally, Aggarwal *et al.* in 2013 found that the blood contamination had no effect on the push-out bond strength of biodentine. Due to its high push out bond strength, biodentine is preferred for perforation repair either in the root canal or pulp chamber even after being exposed to various endodontic irrigants (Priyalakshmi and Ranjan, 2014; Aggarwal *et al.,* 2013).

**Treatment of combined endodontic: periodontic lesionby sealing of palato-radicular groove**: In a study by Zhou *et al*., (2013) it was concluded that Biodentine caused gingival fibroblast reaction similar to that by MTA and can be safely used in procedures requiring close approximation with the periodontal tissues. In a casre report by Naik et al in 2014,type III palatoradicular groove were sealed by using biodentine which resulted in the resolution of sinus tract and restoration of a 2-mm healthy gingival sulcus in relation to the palatal groove and radiographic evidence of bone fill at the site of the periradicular lesion (Naik *et al.,* 2014).

**Treatment of incomplete vertical root fracture (Hadrossek and Dammaschke, 2014):** Paul Henryk Hadrossek and Till Dammaschketreated the incomplete root fracture was treated by using biodentine .In this preliminary case report a maxillary incisor with a vertical root fracture retreated and stabilized with a dentine adhesive and a composite restoration. Then the tooth was extracted, the VRF gap enlarged with a small diamond bur and the existing retrograde root canal filling removed. The enlarged fracture line and the retrograde preparation were filled with a calcium-silicate-cement (Biodentine). Afterwards the tooth was replanted and a titanium trauma splint was applied for 12d. A 24 months clinical and radiological follow-up showed an asymptomatic tooth, reduction of the periodontal probing depths from 7 mm prior to treatment to 3 mm and gingival reattachment in the area of the fracture with no sign of ankylosis. They concluded that the treatment of VRF with Biodentine seems to be a possible and promising option.

**Conclusion**

Biodentine is an excellent material with innumerable qualities required of an ideal material. It can be an alternative to calcium hydroxide or MTA in pulp capping, pulpotomy, and apexification because biodentine is very successful in the formation of a dentin bridge that is faster and thicker with lesser defects. While it is stronger mechanically, less soluble and produces tighter seals than calcium hydroxide biodentine also avoids the drawbacks of MTA, i.e. extended setting time, \ difficult handling characteristics, high cost, and potential of discoloration. On the other hand, further studies are needed to extend the future scope of this material regarding clinical applications.

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