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Biodentine: Periodontal perspective

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Abstract
Biodentine is a recently introduced calcium silicate based biomaterial that has gained momentum due to its varied applications in the field of dentistry including periodontics. It has been proposed as an ideal biomaterial for periodontal repair and/or regeneration in defects that has been created by pathways of communication between the periodontium and the pulp. It has outdated the other biomaterials due to its bioactivity and biocompatibility with the periradicular tissues and owing to its superior physical and chemical properties in the multifarious oral environment. But there are only a very few review articles explaining the behavioural characteristics of Biodentine. And to the best of our knowledge there is no review article till date on Biodentine in periodontics and its interaction with the periodontal tissues. This article provides an overview of the unique features of Biodentine and its dynamic interaction with the tissues of periodontium.

Keywords: Biodentine, biodentine in periodontics, bioactivity, biocompatibility

1. Introduction
The eventual success of the periodontal surgery relies upon the regeneration of periodontal attachment apparatus which constitutes periodontal ligament, cementum and alveolar bone. To attain this, it has been endorsed to utilize a material that precludes egress of enduring microorganisms and their by-products and thereby allows the formation of a functional periodontium. A decisive material ought to be biocompatible, dimensionally stable, radiopaque, antibacterial, insoluble, have potent sealing ability and easy to deploy. Due to the fact that available materials did not fulfil these physiognomies, mineral trioxide aggregate (MTA), a calcium silicate based biomaterial was developed and recommended [1]. MTA seems to be an ideal material till date due to its acceptable physical and chemical characteristics. Yet, MTA has some hitches such as a long setting time, presence of adverse elements in its composition, and demanding usage traits. Hence, the hunt for a better biomaterial has been met with the development of Biodentine. Biodentine (Septodont Ltd., Saint Maur-des-Fosses, France), a calcium silicate based cement was introduced primarily as a dentine substitute below resin composite restorations [2]. In contrast to MTA, Biodentine exhibits short setting time and appreciable mechanical features. It may be considered as a material which can set off periodontal regeneration and/or restore. It has beneficial properties regarding biologic reaction of the cells in the periodontium. Because of its upregulating action on the activity of osteoblasts and periodontal cells, it can better be named as "bioactive cement" [3].

2. History
Although many innovative calcium silicate based products are available, Biodentine has gained the focus of attention in a variety of research. "Biodentine" became commercially available in 2009 (Septodont, http://www.septodontusa.com). It was explicitly designed as a "dentine replacement" material. It is in fact formulated using the MTA-based cement technology and the enhancement of some properties of these cements such as physical qualities and handling characteristics [2]. Soon after its launch, Biodentine has been widely applied in various fields of dentistry including restorative dentistry, endodontics, paediatric dentistry, and also in periodontics.

3. Composition [2, 5, 6]
Biodentine is commercially available as a pack which contains a capsule with powder and a pipette with the liquid [2].

Table 1: Powder

S. No	Constituents	Function
1	Tricalcium silicate $3CaOSiO_2$	Main component, regulates setting time
2	Dicalcium silicate $2CaOSiO_2$	Second main core material
3	Zirconium dioxide ZrO_2	Radiopacifier
4	Calcium carbonate $CaCO_3$	Filler
5	Iron oxide	Colouring agent

Table 2: Liquid

S. No	Constituents	Function
1	Calcium Chloride	Accelerator
2	Hydrosoluble Polymer	Water reducing agent

4. Setting Reaction

When the powder is mixed with liquid, the setting reaction initiated, leading to setting of the cement. The resultant product of this reaction is the hydrated calcium silicate gel (CSH gel) and calcium hydroxide which is achieved by dissolution of tricalcium silicate and precipitation of calcium silicate hydrate [4, 5]. Chemically it can be formulated as C-S-H (C=CaO, S=SiO_2, H=H_2O). The calcium hydroxide originates from the liquid phase. The C-S-H gel is formed by nucleation, growth and permanent hydration of the tricalcium silicate. This hydrated gel progressively occupies the spaces between the tricalcium silicate grains [6].

This hydration reaction is briefed by the subsequent formula as $2(3CaO.SiO_2) + 6H_2O \rightarrow 3CaO.2SiO_2.3H2O + 3Ca(OH)_2 C3S$ CSH

5. Properties / Unique Features [2, 4]

- High purity due to monomer free composition
- Highly biocompatible and bioactive
- Short setting time of 10-12 minutes
- Easy material handling
- Versatile to use, requires no preparation or bonding procedure and does not stain
- Superior mechanical properties-mechanical properties are comparable to sound dentine
- Excellent sealing properties with ability to form mineral tags in the dentinal tubules and outstanding micro leakage resistance, enriched by the absence of shrinkage due to resin free formula
- Excellent antibacterial properties-the calcium hydroxide ions released from the set Biodentine result in high alkaline pH which promotes an inauspicious environment for bacterial growth and leads to the disinfection of contiguous hard and soft tissues
- Cost effective in contrast to similar material

6. Mechanism of Action

Biodentine induces mineralization after its application, which occurs in the form of osteodentine. Early mineralization is empowered by expressing markers of odontoblasts & pulpal cells which increases TGF-Beta1 secretion [7].

Calcium hydroxide which is formed during setting reaction of cement causes irritation at the area of exposure due to its high pH. This alkalinity creates a zone of coagulation necrosis which induces division and migration of precursor cells to substrate surface and then addition and cytodifferentiation of these cells into odontoblast like cells. Thereby Biodentine induces apposition of reactionary dentine by odontoblast stimulation and reparative dentine by cell differentiation [8]. Due to its high alkalinity it exhibits inhibitory effect on microorganism.

The property of Biodentine to release calcium ion and enhancing the alkaline environment makes the material more favourable for osteoblastic activity [9]. Also, calcium and hydroxide ions kindle the release of pyrophosphatase, alkaline phosphatase, and BMP-2, which are well known to induce the mineralization process [10].

Also the calcium, silicon, and carbonate of Biodentine diffuse into the dentinal tubules, resulting in the formation of "mineral infiltration zone" [10, 11]. The establishment of this zone depicts that the interface between the dentine and Biodentine is highly vibrant and collaborative [12].

7. Histological Evidence

Histomorphometric analysis was done by comparing the biological interaction of different endodontic restorative material such as MTA, Biodentine, Amalgam and Composite with human osteoblast and cells of the human periodontal ligament [3]. It demonstrated that with over a time period of twenty days, PDL cells which are in contact with MTA and especially Biodentine showed an organized distribution and arrangement within them i.e., the cells matured in a second cell layer crossway to the first layer. Interestingly Biodentine displayed the greatest quantity of PDL cells ($p < 0.05$). Biodentine and MTA ensued a significantly higher concentration of osteoblast and PDL cells. The remaining materials disclosed a lower density of PDL cell and osteoblasts.

Also it has been proved that Biodentine is non-cytotoxic and non genotoxic on human gingival fibroblasts and MG63 osteoblast–like cells [13]. When studied in a three dimensional multicellular spheroid model, Biodentine did not affect the proliferation of pseudo-odontoblastic cells (MDPC-23). Furthermore, the expression of levels of collagen a1 was significantly higher in the presence of Biodentine.

8. Antibacterial activity of Biodentine

A study conducted by Valyi *et al*, 2010 [14], concluded that the antibacterial activity of Biodentine is more dependent on strain type of microorganisms.

Nikhil *et al*, 2014 [15], studied the antibacterial activity of Biodentine after addition of 2% chlorhexidine or 10% doxycycline. They concluded that the antimicrobial activity of Biodentine was clear against *E. faecalis* and *Candida albicans*. Susceptibility to Biodentine or its mixture with 2% chlorhexidine or 10% doxycycline was different for all tested bacterial strains. *C. albicans* was most susceptible while *E. faecalis* was least.

Addition of chlorhexidine to Biodentine enhanced the antibacterial activity of Biodentine alone, while addition of 10% doxycycline to Biodentine decreased the antibacterial activity of Biodentine alone.

According to V Bhavana *et al*, 2015 [16], Biodentine contains potent antibacterial and antifungal property by comparing the antibacterial efficacy of Biodentine, MTA & GIC against *E. faecalis*, *E. coli*, *S. mutans* & *Candida* and found that Biodentine created larger inhibition zones than MTA & GIC though all materials showed antibacterial activity. Thus Biodentine effectively acts in the presence of microbial infection and this effect is attributed to its property of inducing high pH.

9. Biocompatibility of Biodentine

The essential quality that a restorative material should possess is biocompatibility since these materials interact directly with the vital structures like alveolar bone, periodontal ligament and cementum for an extended time period. Fibroblasts are the chief cells of the Periodontal Ligament (PDL), which are responsible for the development, maintenance, remodelling, repair and regeneration of PDL fibres and contiguous alveolar bone and cementum [17]. Along with PDL fibroblasts, cells from the neighbouring alveolar bone also play an essential role in the repair and regeneration of periodontal tissue [18]. Moreover, osteoblasts and fibroblasts are the principal cells responsible for excisional osseous wound healing after periodontal surgeries [19]. It was shown that, Biodentine possess favourable properties towards culture of human fibroblasts [20, 21].

Patel N *et al*, 2002, showed in a study that calcium silicate cements release silicon which has a positive influence on bone metabolism and augments the rate of new bone growth. Also, calcium silicate cements play an important role in repair of bone by inducing the precipitation of calcium phosphate at the interface of periodontal tissue [22, 23]. Biodentine develops a hydroxyl apatite like surface which is biocompatible and displays good conditions for cell attachment and proliferation [3].

The null-hypotheses of an *in vitro* study by Jung *et al*, 2014 [3], were that Biodentine will show biocompatible reaction to PDL cells and osteoblasts which is comparable to ProRoot MTA, which is a reference material for root perforation repair and root end obturation. But amalgam and composite resin will have a negative impact on those cells.

10. Clinical Applications of Biodentine

10.1 In Restorative Dentistry

Biodentine has a wide range of applications including endodontic repair such as root perforations, apexification, resorptive lesions, retrograde filling material in endodontic surgery and pulp capping agent. It can be used as a dentine replacement material in restorative dentistry.

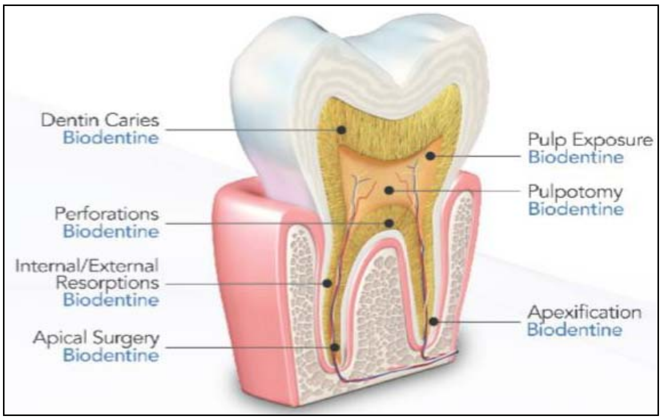

Fig 1: Applications of Biodentine

10.2 In Periodontics

In periodontics it can be used in the management of all types of dentinal defects which creates communication pathways between the root canal and the periodontal ligament [25, 26] such as palatogingival groove. In addition to that, it could also be used as bone substitute material for implant stabilization [27].

11. Biodentine in Periodontal Therapy

11.1 For Sealing of Palatogingival Groove

Biodentine has been successfully used in sealing of palatogingival groove [28]. Biodentine caused stimulation and reaction of gingival fibroblast comparable to that by MTA and thus Biodentine can be safely applied for procedures which require close contact with the functional periodontal structures [12]. Biodentine is preferred over other available biomaterials due to its unique physical characteristics and short setting time [29].

For sealing a pathologic palatogingival groove, non-surgical management of periapical lesion [30] is combined with surgical management of groove by exposing it, followed by odontoplasty and restoring the groove with Biodentine [31]. The process of healing is induced by eliminating the microbial organisms and their by-products and by sealing the probable routes of communication between the external environment and the periodontal tissues with an ideal biomaterial like Biodentine. Thus bone deposition occurs in the defect and due to the profound biostimulative effects of Biodentine reattachment of fibres of periodontal ligament ensues [28].

11.2 For Implant Stabilization

Various biomaterials are commonly used for bone augmentation in the field of dental implantology such as autogenous, allogenic, xenogenic and alloplast bone grafts. Interestingly, tricalcium silicate-based cements (TSBCs) such as Biodentine [33, 34], could be used as bone substitutes for implants because of its established bioactivity, biocompatibility and enhanced mechanical properties.

Also Biodentine comparatively requires only a low duration of 9-12 mins before clinical application and TSBCs exhibits adhesive properties with calcified tissues of teeth [32], which increase as a function of time due to their chemical composition [35]. Beside these properties, bone substitute materials must also possess fatigue behaviour [35] in order to overcome the mechanical stresses produced by dental implants.

The use of Biodentine as bone substitute material for implant stabilisation has been described in an experimental set up as shown by Vayron *et al*, 2013 [27]. An ultrasonic device was used to monitor the changes of the ultrasonic response of a dental implant inserted in Biodentine and subjected to mechanical fatigue and this was reported as effective.

11.3 For External Invasive Cervical Resorption

The property of Biodentine to induce biomimetic mineralisation process through osteoblastic activity is used in the management of external invasive cervical resorption of tooth. Biodentine induces periodontal repair and formation of new cementum formation when used in such tooth defects [24, 37].

External cervical resorption causes inflammation of the tissues of the periodontium and does not involve the pulp [36]. Biodentine remains the material of choice for complete sealing of the resorptive defect because of its biocompatibility with the periodontium. The defect is treated by open flap debridement and sealing the defect with Biodentine [38, 39].

12. Biodentine Interaction with Antiseptic Solutions

Guneser *et al*, 2013 [40], showed Biodentine as a good repair material even after being exposed to solutions such as sodium hypochlorite, chlorhexidine and saline and the push-out bond strength of Biodentine is not influenced by these irrigants [41]. This property recommended Biodentine to be used as a dentine substitute material.

13. Biodentine with Platelet Rich Fibrin (PRF) [42, 43, 44, 45]

With the 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 [22].

Biodentine has been combined with platelet rich fibrin for a novel approach for bone augmentation in infected periapical cyst [46] which is created by tissue necrosis by pulpal or extensive periodontal disease. This combination has induced the rapid rate of bone formation clinically and radiographically. However further histological studies are essential to examine the nature of newly formed tissue in the defect & long term follow up is needed over bone regeneration.

14. Future Outlook

The ultimate goal of any periodontal therapy is to achieve periodontal regeneration. Restoration of the lost tooth structure is the first step towards this goal. A wide variety of materials for periodontal regeneration have been suggested in the literature. The need for more and more new materials is never ending especially in the field of dentistry.

Biodentine have gradually become the material of choice. The future of Biodentine is very promising in the field of periodontology in achieving the periodontal health.

15. Conclusion

Biodentine, a popular and contemporary tricalcium silicate based dentine replacement and repair material, has been evaluated in quite a number of aspects since its launch in 2009. Due to its major advantages and unique properties as well as its ability to overcome the disadvantages of other materials, Biodentine has great potential to revolutionise the different fields of dentistry including periodontics.

On the other hand, further studies are needed to extend the future scope of this material regarding its clinical applications.

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