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An insight into biodentine

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Abstract

Calcium silicate based materials have gained popularity in recent years due to their resemblance to mineral trioxide aggregate (MTA) and their applicability in cases where MTA is indicated. "Biodentine" is a calcium silicate based product which became commercially available (Septodont) and that was specifically designed as a "dentine replacement" material. The material is actually formulated using the MTA-based cement technology, with the improvement of some material properties. Biodentine™ is a second generation hydraulic calcium silicate material that is composed mainly of tricalcium silicate and it also contains zirconium oxide radiopacifier and some additives. It is scientifically engineered for a specific purpose to be used as a dentine replacement material. The enhanced physical and biologic properties of Biodentine™ could be attributed to the presence of finer particle size, use of zirconium oxide as radiopacifier, purity of tricalcium silicate, absence of dicalcium silicate, and the addition of calcium chloride and hydrosoluble polymer. This article is aimed to review the properties of Biodentine by exploring the research work done in this field so far.

Keywords: Biodentine, composition, setting reaction, physical and mechanical properties, clinical applications

1. Introduction

For many decades since 1928 calcium hydroxide has been standard material for maintaining the vitality of pulp since it is capable of stimulating tertiary dentin formation. However it has some drawbacks like poor bonding to dentin, material resorption. However it has some drawbacks like poor bonding to dentin, material resorption. Later Mineral Trioxide Aggregate introduced by Torabinejad M, in 1990 is used as a material of choice for all dentinal defects due to their biocompatibility & ability to induce calcium phosphate precipitate at interface to periodontium & bone tissue repair. However there exist some drawbacks of this material such as slow setting kinetics and complicated handling properties^[1].

Calcium silicate based materials have gained popularity in recent years due to their resemblance to mineral trioxide aggregate (MTA) and their applicability in cases where MTA is indicated. Although various calcium silicate based products have been launched to the market recently, one of these has especially been the focus of attention and the topic of a variety of investigations. This material is the "Biodentine" calcium silicate based product which became commercially available in 2009 and that was specifically designed as a "dentine replacement" material^[2].

2. Composition

Biodentine™ is presented as powder and liquid. The powder is placed in a capsule while the liquid is in an ampoule. The powder is composed of tricalcium silicate, zirconium oxide, calcium carbonate and some minor additives of iron oxide added to give the colour. The liquid is made up of water with some additions of calcium chloride and a water soluble polymer. Biodentine™ powder and its hydrated materials have been characterised well. The design of Biodentine™ ensures optimal properties and thus enhances clinical performance.

2.1 Powder^[3]

Tri-calcium silicate- This is the main core material.

Di-calcium silicate- this is the second core material Calcium carbonate & oxide- it acts as a filler. Iron oxide-it acts as a colouring agent. Zirconium oxide- it acts as a radioopacifier.

2.2 Liquid

Calcium chloride- it acts as an accelerator. Hydrosoluble polymer- it is a water reducing agent

3. Setting reaction

The powder is mixed with the liquid in a capsule in the triturator for 30 seconds. The initial setting time of Biodentine as indicated by its manufacturer is about 12 min. However, some studies have reported the initial setting time of Biodentine to be 6.5 ± 1.7 min^[4]. According to the International Organisation for Standardisation guidelines, ISO 9917-1:2007, the setting time of Biodentine was assessed as 15 ± 1 min. Both saliva and blood contamination, increased the setting time of Biodentine by 1 ± 6.51 min and 16 ± 8.21 min respectively. While, the blood-contaminated group showed a significantly longer setting time compared to the non-contaminated Biodentine group (p 0.05)^[5].

The reaction of the powder with the liquid leads to the setting and hardening of the cement. The hydration of the tricalcium silicate leads to the formation of a hydrated calcium silicate gel (CSH gel) and calcium hydroxide^[6]. 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 ($\text{C}=\text{CaO}$, $\text{S}=\text{SiO}_2$, $\text{H}=\text{H}_2\text{O}$). 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^[7].

4. Characteristics of Biodentine

The electrochemical properties of this cement are due to the solid phase and ion mobility of free ions inside the pores filled with the electrolyte. The electrical resistance increases when the porosity of the system is reduced. The setting reaction of Biodentine leads to the formation of initial porosities that are gradually filled after several days by new crystal compounds. During this final step, the solid phase increases and finally reaches a maximum^[8].

Biodentine induces early mineralization by increasing the secretion of TGF- β 1 from pulpal cells after its application. It also acts by odontoblasts stimulation and cell differentiation, there by facilitating reactionary and tertiary dentin formation. Recent study results suggested that biodentine is bioactive because it increased OD21 cell proliferation and it can be considered as a suitable material for clinical indications of dentine-pulp complex regeneration^[9]. It has antibacterial properties due to high alkaline pH Biodentine has inhibitory effect on the micro organisms. In addition, the alkaline change leads to the disinfection of surrounding hard and soft tissues^[10].

Biodentine preserves pulp vitality and promotes its healing process. Laurent et al tested a new Ca_3SiO_5 - based material to evaluate its genotoxicity, cytotoxicity and effects on the target cells specific function. The study concluded that the

Biodentine material is biocompatible. The material was not found to affect the specific functions of the target cells and thus could safely be used. About et al investigated biodentine activity by studying the effects on pulp progenitor cells activation, differentiation and dentine regeneration in the human tooth cultures. The study concluded that bio dentine is stimulating dentine regeneration by inducing odontoblast differentiation from pulp progenitor cells. Laurent et al. did further study to investigate the capacity of biodentine to affect TGF- β 1 secretion from pulp cells and to induce reparative dentine synthesis. Biodentine was applied directly onto the dental pulp in a human tooth culture model, resulting in a significant increase of TGF- β 1 secretion from pulp cells and thus inducing an early form of dental pulp mineralization shortly after its application. It does not affect human pulp fibroblast functions, expression of collagen1, dentine sialoprotein & Nestin^[11-13].

5. Physical and mechanical properties of Biodentine

Biodentine has significantly higher push-out bond strength than MTA. The push out bond strength of Dyract AP, amalgam, IRM and biodentine was not significantly different when immersed in sodium chloride, chlorhexidine and saline solution whereas MTA has lost its strength when exposed to chlorhexidine. Hence biodentine shows considerable performance as a perforation repair material even after being exposed to various endodontic irrigants^[14].

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. It is known that glass ionomers have a tendency to erode under such conditions. The acid erosion and the effects of aging in artificial saliva on the Biodentine TM structure and composition were investigated by Laurent *et al.* They concluded that the erosion of Biodentine TM in acidic solution is limited and lower than for other water based cements (Glass Ionomers). In reconstituted saliva (containing phosphates), no erosion has been observed. Instead, a crystal deposition on the surface of BiodentineTM occurs, with an apatite-like structure. This deposition process due to a phosphate rich environment is very encouraging in terms of improvement of the interface between BiodentineTM and natural dentine. The deposition of apatitic structures might increase the marginal sealing of the material^[15].

The mechanical adhesion of BiodentineTM cement to dental surfaces may result from a physical process of crystal growth within dentine tubules leading to a micromechanical anchor. The possible ion exchanges between the cement and dental tissues constitute an alternative hypothesis, or the two processes may well combine, eventually contributing to the adhesion of the cement, as it appears at the interface of BiodentineTM - adhesive systems^[12, 17].

The interfacial water tightness is an important parameter of the functionality and longevity of a restoration. The interface with dentine and enamel was examined using dye penetration methodology (silver nitrate), which is one of the most commonly used assays to assess, *in vitro*, the interfacial seal, by measuring the percolation of a dye along the different interfaces studied. They concluded that BiodentineTM has a similar behavior in terms of leakage resistance as Fuji II LC at the interface with enamel, with dentine and with dentine bonding agents. BiodentineTM is then indicated in open sandwich class II restoration without any preliminary treatment. Biodentine exhibits low penetration at enamel/dentin interface. 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 [18-20].

The compressive strength of Biodentine™ amounts to 10.6 ± 2 , 57.1 ± 12 and 72.6 ± 8 MPa after 35 min, 24 h and 28 days, respectively. The greater strength of Biodentine™ in comparison to other tricalcium silicate cements is attributed to the low water/cement ratio made possible by the water soluble polymer in the liquid. The physical properties of Biodentine™ such as flexural strength (34 MPa), elastic modulus (22,000 MPa) and Vickers hardness (60 HV) are higher than those of MTA but similar to dentine. Biodentine™ is reported to be more dense and less porous when compared to MTA (Camilleri et al. 2013b). Mean porosity percentage for Biodentine™ is 7.09 ± 1.87 while that of MTA is 6.65 ± 1.93 . Moreover, the Microleakage assessed in open sandwich restorations showed that glucose diffusion at the interface between Biodentine™ and dentine walls is similar to that of resinmodified glass ionomer cement [21-24].

6. Clinical applications of Biodentine

Although Biodentine is a recently developed material as it has been released by the end of the year 2010 in Europe, different clinical applications have been so far published with this material. These include applications in restorative dentistry, pediatric dentistry and endodontics. Although it can be used as a temporary enamel substitute for up to 6 months, Biodentine is mainly used as a permanent dentin substitute. It can be used to replace the missing/damaged bulk dentin volume. It can also be used as an alternative to Formecresol in pulpotomy [25].

It can be used as a dentin substitute under a permanent restoration, and can be categorized as Indirect pulp capping material. Direct pulp capping and partial pulpotomy can also be performed using Biodentine. It has been advocated for use in performing Pulpotomy in primary molars and apexification. It finds a significant application for repair of perforated root canals and/or pulp chamber floor. Its use has also been advocated as a root end filling material [26-30].

While many studies reported its biocompatibility and Bioactivity *in vitro* and *in vivo*, preclinical investigations shed the light on the mechanisms of its interaction with the dental hard tissue. Indeed, many investigations performed both *in vitro* and *in vivo* demonstrated that the interactions of Biodentine with both hard and soft tissues provide a hermetic seal protecting the dental pulp by preventing bacterial infiltration. These studies demonstrated that, through its interactions with the hard tissues, Biodentine provides a micro-mechanical retention by infiltrating the dentin tubules [31, 32].

7. Conclusion

The clinical uses of bioceramics have increased exponentially over the years because of their wide range of applicability in dentistry. 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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