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Biodentine-A Novel Dentin Substitute: A Review

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Abstract: ***Dentin substitutes are cements, which have dentin like mechanical properties and can be used as dentin replacements in the tooth crown and root region. There are a wide variety of materials that have been used as dentin substitutes. 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". This review briefly describes about properties, advantages and clinical application of biodentine and is also aimed to compare the properties of biodentine with MTA.***

Keywords: Biodentine, dentin substitute, physical properties, indications, advantages over MTA

1. Introduction

The main objective of pulpal healing process is to form a barrier of mineralized tissue to protect the underlying pulp from bacterial or toxin leakage. Clinically, the objectives of treatments such as direct pulp capping, Cvek pulpotomy, or the stepwise technique are to seal the pulp wound, induce odontoblast-like cell differentiation, and stimulate dentin secretion and mineralization in order to build a dentin bridge[1].

An ideal biomaterial should stimulate and modulate the healing process to properly seal the pulp wound to prevent bacterial leakage. So far, several materials have been investigated for their potential to stimulate tertiary dentinogenesis. Calcium hydroxide has been the gold standard as a pulp-capping material for a long time. Histologically, newly secreted dentin is generally porous and the gap between this barrier and the dentinal wall is considered responsible for bacterial leakage, leading to pulp inflammation and/or necrosis.[2]

Biodentine™ is a new bioactive cement with dentine like mechanical properties, which was developed by ***Septodont, St.Maur-des-Fosses, France***, which can be used as a dentine substitute on crown and roots, has positive effect on vital pulp cells and stimulates tertiary dentin formation.[3]

2. Composition

Biodentine is principally composed of a highly purified tri-calcium silicate powder. It comes in the form of a capsule containing the powder (0.7 g) and an ampule with the liquid(0.18 ml). For mixing purposes, a premeasured dose of liquid is dropped into the capsule and then mixed with an amalgamator.

Powder	*Function*
Tri-calcium Silicate	Main core material
Di-calcium Silicate	Second core material
Calcium Carbonate and Oxide	Filler material
Iron Oxide	Shade
Zirconium Oxide	Radio opacifier

Liquid	Function
Calcium chloride	Accelerator
Hydrosoluble polymer	Water reducing agent, keep a good flowability with a low water/solid ratio

3. Properties of Biodentine

1) Setting time

The setting time of Biodentine was determined as 6-12 minutes. This short setting time was attributed to the addition of calcium chloride to the mixing liquid. Another method used to assess the setting time is the impedance spectroscopy that assesses the changes in electrical resistivity. Impedance values were stabilized after 5 days for the glass ionomer cement while at least 14 days were necessary for the calcium silicate based cement. This is due to the higher porosity for Biodentine cement, characterizing higher capacity of ion exchanges between the material and its environment [5].

2) Compressive strength

Compressive strength is considered as one of the main physical characteristics of hydraulic cements. It is essential that the cement has the capacity to withstand masticatory forces, in other words, sufficient compressive strength to resist external impacts [6]. A specific feature of Biodentine™ is its capacity to continue improving with time in terms of strength over several days until reaching 300 MPa after one month. 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 which is comparable to the compressive strength of natural dentine i.e 297 MPa[7]. Biodentine showed highest compressive strength

as compared to other tested materials due to its low water: powder ratio.

3) Radiopacity

Radiopacity is an important property expected from a retrograde or repair material as these materials are generally applied in low thicknesses and they need to be easily discerned from surrounding tissues. Zirconium oxide is used as a radio opacifier in Biodentine contrary to other materials where bismuth oxide is preferred as a radiopacifier. [8]The reason might be due to some study results which show that zirconium oxide possesses biocompatible characteristics and is indicated as a bio inert material with favorable mechanical properties and resistance to corrosion.

Radio opacity values of biodentine and bioaggregate were found to be greater than 3mm Al.Contrary to this a clinical observation stated that the radiopacity of Biodentine is in the region of dentin and the cement is not adequately visible in the radiograph. This posed difficulty in terms of practical applications [9]. This was further supported in a study by Tanalp et al.[10]where the radiopacity of Biodentine was found to be lower compared to other repair materials tested.

4) Solubility

The erosion of Biodentine™ in acidic solution is limited and lower than for other water based cements (Glass Ionomers).[11] In reconstituted saliva (containing phosphates), no erosion has been observed. Instead, a crystal deposition on the surface of Biodentine™ 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 Biodentine™ and natural dentine. The deposition of apatitic structures might increase the marginal sealing of the material.[12]

5) Marginal adaptation and microleakage

The quality and durability of the interface is a key factor for the survival of a restorative material in clinical conditions. The marginal adaptation and the intimate contact with the surrounding materials (dentine, enamel, composites and other dental materials) are determinative features of its success. This was investigated by erosion in acid solutions, electron microscopy and microleakage tests[13]. In the case of Biodentine™, the dissolution/precipitation process, which is inherent to the setting principle of calcium silicate cements, differentiates its interfacial behavior from the already known dental materials (composites, adhesives, glass ionomers).

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 [14]. They concluded that Biodentine™ 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. Biodentine™ is then indicated in open sandwich class II restoration without any preliminary treatment. Biodentine exhibits low penetration at enamel/dentin interface.

6) Adhesion

Biodentine causes alkaline corrosion (caustic etching) on the hard tissue, which leads to a "mineral interaction zone"[15]. A diffusion of Biodentine up to 10-20 µm into the dentine tubule is observed. Thus a micromechanical anchoring with mineral Biodentine tags in the dentine tubule can form, which contributes to the increased adhesive properties of Biodentine. [16]

Due to remodelling processes, the sealing of the dentine by Biodentine™ improves in the course of time. Biodentine can deposit impermeably onto the cavity walls and prevent micro leakage.

Biodentine™ to be keyed to the dentine by means of innumerable microscopic cones, creating a stable anchorage with a sealing, bacteria tight effect, without the need for prior treatment with irritants that compromise the pulp.[17]

7) Antibacterial properties

The antibacterial properties are due to the release of calcium hydroxide (Ca(OH)2) on surface hydrolysis of the calcium silicate components This high pH also exerts a clear inhibitory effect on microorganisms. In addition, the alkaline change leads to the disinfection of adjacent hard and soft tissue structures.[18] Biodentine has a very pronounced and a demonstrable impact on treating not only the dentine damage but also the conditions with varying areas of exposed pulp with non carious causes, such as accidental pulp opening or direct abrasive trauma and extensive carious defects caused by bacteria . Biodentine increases TGF-B1 (growth factor) secretion from pulp cells resulting in angiogenesis and progenitor cell recruitment, cell differentiation and mineralization.[19]

8) Biocompatibilty

Biodentine is non-toxic and has no adverse effects on cell differentation and specific cell function.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.[20]

9) Bioactivity

In both direct and indirect application, Biodentine does not seem to affect the target cells specific functions. About et al.[21] 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.

	Properties	MTA	Biodentine
1	Setting time (minutes)	Initial-70 Final-175	Initial-6 Final-10-12
2	Density(g/cm^3)	1.88	2.26
3	Porosity(%)	22.6	6.8
4	Compressive strength(MPa)	- (1hr) 7.5(24hr)	131.5(1hr) 241.1(24hr)

		164.5(7days)	253.2(7days)
5	Flexural strength(MPa)	14.27	34
6	Microhardness (KHN)	37.54-53.56	60
7	Ph	Initial 10.2,rises to 12.5 after 3 hours	12
8	Mechanical resistance	Lower	Higher
9	Cytotoxicity (cell death)	0+9	0+8
10	Radiopacity	7.17mm of equivalent thickness of aluminium	3-5 mm of equivalent thickness of aluminium

10) Mineralisation

The ability to release calcium by biodentine is a key factor for successful endodontic and pulp capping therapies because of the action of calcium on mineralizing cells (osteoblasts, cementoblasts, pulp cells and odontoblasts), differentiation and hard tissue mineralisation. Calcium ions are necessary for the differentiation and mineralization of pulp cells and calcium ions specifically modulate osteopontin and bone morphogenic protein-2 during pulp calcification.[22] In addition the eluted calcium ions increase the proliferation of human dental pulp cells in a dose dependent manner and

COMPARISON BETWEEN BIODENTINE AND MTA

Calcium release enhance the activity of pyrophosphatase, which helps to maintain and the formation of a dentine bridge.[23]

Hydroxide ions stimulate the release of alkaline phosphatase and BMP-2, which participate in the mineralization process. Calcium silicate materials share their properties to induce the proliferation and genes activation of periodontal fibroblasts, dental pulp cells, cementoblasts, osteoblasts, mesenchymal stem cells and to stimuate reparative hard tissues.

Indication[24]

Clinical applications of biodentine includes:

- Temporary enamel replacement
- Apexification procedure
- Permanent dentine replacement
- Pulp protection in deep carious lesions (sandwich technique)
- Restoration of cervical and/or radicular lesions
- Direct and indirect pulp capping
- Pulpotomy
- Repair of furcation and root perforation
- Retrograde root end filling
- Repair of internal and external resorption.

Certain advantages of Biodentine over MTA includes

- Reduced setting time
- Better handling & manipulation
- Improved mechanical properties
- Bioactivity of material

4. Conclusion

Biodentine, a popular and contemporary tri calcium silicate based dentine replacement and repair material, has been evaluated in quite a number of aspects ever since its launch in 2009. The studies are generally in favor of this product in terms of physical and clinical aspects despite a few contradictory reports. Though accumulation of further data is necessary, Biodentine holds promise for clinical dental procedures as a biocompatible and easily handled product with short setting time. As more research is performed regarding this interesting alternative to MTA, we will be provided with more reliable data and more confidently implement Biodentine into routine clinical applications.

Biodentine is a viable and predictable alternative to RCT in teeth with carious exposures and that lack pulpitis symptom. Biodentine can be used as bulk fill, simplifying a pulp capping procedure. There is no need to carefully place the Biodentine on the pulp exposure. The clinician need only fill the entire preparation with Biodentine™ thereby sealing the tooth from additional exposure. Hopefully Biodentine's lower cost and ease of use will encourage the general dentist as well as the Endodontist to make use of Biodentine in various non-invasive procedures.

In regard to biocompatibility, long-term impermeability, antibacterial properties, induction of hard tissue regeneration, stability, low solubility, non-absorbability and ease of handling, Biodentine™ fulfils the requirements found in the literature for a material suitable for these purposes. On the basis of the good material properties of Biodentine, this cement will be an interesting alternative to the conventional materials.

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