Journal Homepage: - www.journalijar.com
INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)
Article DOI: 10.21474/IJAR01/14245
DOI URL: http://dx.doi.org/10.21474/IJAR01/14245

RESEARCH ARTICLE

REVIEW ON BIODENTINE - A BIODENTINE DENTINE SUBSTITUTE

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Manuscript Info

Manuscript History
Received: 15 December 2021
Final Accepted: 17 January 2022
Published: February 2022

Key words:-
Dental Caries, Biocompatibility, Regeneration, Tricalcium Silicate-Based Cement, Dentine Substitute, Vital Pulp Therapy

Abstract

Biodentine is a tricalcium silicate-based cement designed for permanent dentin replacement material and has drawn attention in recent years. Biodentine has been adviced to be used in various clinical applications such as pulp caping, apexification,root perforations, retrograde fillings and dentine replacement. There has been considerable research performed on this material since its launching; however, there is scarce number of review articles that collates information and data obtained from these studies. Therefore, this review article was prepared for providing a general picture regarding the characteristics of the material. Biodentine is a good biocompatible and bioactive material. It helps in the protection of underlying pulp by inducing tertiary dentin formation. Unlike other dentin substitutes, Biodentine application does not require any conditioning of the dentin surface. The restoration sealing of Biodentine is micromechanical retention by penetrating into the dentin tubules forming tag-like structures. After its setting, Biodentine can be reshaped like natural dentin. Published clinical trials, histology of human teeth and clinical cases show that Biodentine has a wide spectrum of clinical applications as a permanent bulk dentin substitute in pediatric dentistry and restorative dentistry as a possible replacement material.

Introduction:-

The interaction between restorative dental materials and tooth tissue encompasses multiple aspects of dental anatomy and materials science. Until relatively recently, many adhesive dental restorative materials were thought to have a passive hard tissue interaction based on simple infiltration with the enamel or dentin upon which they were placed. However, there is increasing interest in mapping the interactions between materials and tooth tissue, where the former has a more aggressive interaction with the latter, while promoting 'bioactivity'. Bioactivity can be defined as 'materials that elicit a specific biological response at the interface between tissues and the material, which

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results in the formation of a bond.[1] Since age advanced in dentistry many materials has been introduced which where biocompatible and easy to handle. This search led to the introduction of calcium hydroxide cement 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 and material resorption.[2] The recent focus on biocompatible materials such as Portland led to the development of Mineral trioxide aggregate (MTA) as a root-end filling material and direct pulp capping. When applied for pulp capping, it induces reparative dentin production leading to a regular tubular dentin bridge formation within 2 months with no signs of inflammation. However, some shortcomings have been reported with this material. These are related to its long setting time of 2 h 45 min, weak mechanical properties and difficult handling properties. Additionally, tooth discoloration has been reported when this material is used for revascularization.[3]To overcome the limitations of MTA, a novel fast setting radiopaque hydrophilic calcium silicate cement with fluoride called “protooth”was introduced. The mechanical properties of protooth is significantly superior to MTA , supports apatite formation in physiologic-like solutions, and has a setting time of less than 2 minutes. The cement’s mechanical properties increase in the wet environment and the biocompatibility of the material has been reported similar to the MTA. 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.[4] Biodentine, known as “dentine in a capsule”, a biocompatible and bioactive dentine substitute which overcomes the drawbacks of Calcium hydroxide and Mineral trioxide.This new calcium silicate-based material exhibits physical and chemical properties similar to those described for certain Portland cement derivatives. On the biological level, it is perfectly biocompatible and capable of inducing the apposition of reactionary dentin by stimulating odontoblast activity and reparative dentin, by induction of cell differentiation. It is in effect a dentine substitute that can be used as a coronal restoration material (for indirect pulp capping), but can also be placed in contact with the pulp. Its faster setting time allows either immediate crown restoration, or to make it directly intraorally “functional” without fear of the material deteriorating. Biodentine is promoted as dentin replacements, mimicking many of the physical properties of this composite biological material, they do not, as yet, have the wear resistance and mechanical properties to make them suitable as long-term enamel replacements.[1] Biodentine cement is a part of a new approach seeking to simplify clinical procedures. A modified powder composition, the addition of setting accelerators and softeners, and a new predisposed capsule formation for use in a mixing device, largely improved the physical properties of this material making it much more user friendly.An elaborate review of the history, importance, advance and clinical implication are detailed through this library dissertation.

Composition of biodentine

Powder

Tricalcium silicate -Regulate the setting reaction
Dicalcium silicate –Core material
Calcium carbonate- Filler
Zirconium dioxide - Radio pacifier

Liquid

Calcium chloride – Accelerator
Water- Superplasticiser

Manipulation

Biodentine can be manipulated by two methods namely the mechanical and the manual method. [52]In mechanical method, material is prepared by mixing with an amalgamator. However, the initial preparation involves tapping and opening the capsule containing the powder, followed by the addition of five drops of liquid from the single dose container to the capsule. Figure 3 This is then closed and placed in an amalgamator for 30 seconds. It can then be handled with an amalgam carrier, spatula or root canal Messing gun. The total handling time is 12 minutes, allowing 6 minutes for mixing and placement and a further 6 minutes for setting. [51]

In manual method, a mixing pad is taken and both liquid and powder are blend well with spatula for about 30 -45 seconds.[50]

Mechanism of action
According to Priyalakshmi.S et al Biodentine induces mineralization after its application. Mineralization occurs in the form of osteodentine by expressing markers of odontoblasts & increases TGF-Beta1 secretion from pulpal cells enabling early mineralization. [41]During the setting of the cement Calcium hydroxide is formed. Due to its high pH, Calcium hydroxide causes irritation at the area of exposure. This zone of coagulation necrosis has been suggested to cause division and migration of precursor cells to substrate surface; addition and cytodifferentiation into odontoblast like cells. Thereby Biodentine induces apposition of reactionary dentine by odontoblast stimulation and reparative dentin by cell differentiation. Because of its high alkalinity it has inhibitory effects on microorganism.[2]

Setting Time
Setting time is the duration required for biodentine to harden into its permanent stateThe net setting times of the cement were measured according to the ISO method for water-based dental cement (ISO 9917- 1:2007)The working time of Biodentine is up to 6 minutes with a final set at around 10-12 minutes.[50]

Properties
Compressive Strength
Compressive strength is Compressive stress is stress required to fracture a material. Compressive strength of biodentine is about 220 MPa is equal to average for dentine of 290 MPaDuring 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.[6]A study conducted by Grech L et al., showed that Biodentine had highest compressive strength when compared to other tested materials due to low water/cement ratio used in Biodentine[4]

Microhardness
Microhardness is Hardness of a substance (as an alloy) measured by an indenter that penetrates.

Microhardness of Biodentin is at 60 HVN is same as that of natural dentin [2]Grech et al. evaluated the microhardness of the material using a diamond shaped indenter. Their results showed that Biodentine displayed superior values compared to Bioaggregate and IRM. Camilleri[4]

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. The ISO 6876:2001 has established 3 mm Aluminium as the minimum radiopacity value for endodontic cements. Meanwhile, according to ANSI/ADA specification number 57, all endodontic sealers should be at least 2 mm Aluminium more radiopaque than dentin or bone.[4] Biodentine has a composition of aluminum-free and having tantalum oxide as a radiopacifier . Biodentine contains zirconium oxide, allowing identification on radiographs. According to the ISO standard, Biodentine displays a radiopacity equivalent to 3.5 mm of aluminum. This value is over the minimum requirement of the ISO standard (3 mm aluminum). This makes BiodentineTM particularly suitable in the endodontic indications of canal repair.[46]Grech et al. in a study evaluating the prototype radiopacified tricalcium silicate cement, Bioaggregate, and Biodentine, concluded that all materials had radiopacity values greater than 3 mm Al [6]

Bond Strength and Push Out Bond Strength
Bond strength. Amount of force required to break the connection between a bonded (dental) restoration and the tooth surface with the failure occurring in or near the adhesive/adherens interface. (bond strength) Expression of degree of adherence between tooth surface and another material.Push out bond strength determines the extent of resistance to the dislodgement of a filling material when applied to root canal dentine. In order to establish push out bond strength, a tensile load is positioned vertically to the long axis of the root till the filling is displaced

The bond strength between the restorative materials and the cavity liner is of importance factors for the quality of dental filling treatments. It has been estimated that a bond strength ranging from 17 MPa to 20 MPa is required to resist contraction forces sufficiently to constitute gap-free restoration margins.Bond strength of biodentine is 6.25±0.40 MPa.[48]Biodentine has a composition of aluminum-free and having tantalum oxide as a radiopacifier . This is claimed to be associated with improved biological property. The presence of calcium chloride, and the concordant reduced setting time and contact time, probably provided the high-bond strength in biodentine group.

The higher bond strength values of biodentine may, in part, result from its smaller particle size, which has the potential to enhance penetration of the cement into the medicament-free dentinal tubules, leading to improved bond strength. This effect might be further reinforced through the formation of dentinal bridges as a result of crystal growth within the dentinal tubules, leading to increased micromechanical retention.Considering that Biodentine is recommended for use as a dentine substitute under permanent restorations, studies were performed that assess the bond strength of the material with different bonding systems.[4] As Biodentine is recommended for use as a dentine substitute and perforation repair material, it should have sufficient amount of push-out bond strength with dentinal walls for the prevention of dislodgement from operated site.[46]Aggarwal et al evaluated push-out bond strength of Biodentine, ProRoot MTA and MTA Plus in furcation perforation repairs and found that after 24 h, MTA had less push-out strength than Biodentine. Guneser et al showed Biodentine as good repair material even after being exposed to NaOCl, chlorohexidine and saline irrigating solutions

Flexural Strength

Flexural strength of a material is defined as the maximum bending stress that can be applied to that material before it yieldsFlexural strength of biodentine is 22 MPa.**[5]** High flexural strength is a definite pre-requisite for any restorative material for its long-term efficiency in oral cavity. 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™ after 2 hours was 34 MPa .**[46]**

Density and Porosity

Porosity of biodentine is 6.8 MPaBiodentine especially indicated in cases such as perforation repair, vital pulp treatments, and retrograde fillings where a hermetic sealing is mandatory. Therefore, 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. [4] 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. The superior mechanical properties of Biodentine™ have been attributed to the low water content in the mixing stage.[46]

It is the critical factor which determines the amount of leakage and outcome of the treatment because greater pore diameter results in larger leakage which corresponds to the ingress and transmission of microorganisms and hence compromised hermetic seal.[6]

Solubility

Solubility is a property that positively or negatively influences the long-term sealing of any endodontic material. Lack of solubility has also been stated as an ideal characteristic for root-end filling materials.**[49]**The highest mean solubility percent was recorded for the Biodentine is $3.361178 \pm 0.2621\%$.**[50]**According to M. A. Alazrag et al (2020) biodentine has the high solubility when compare to TheraCal LC, MTA-angelus and biodentine .Grech et al. demonstrated negative solubility values for Biodentine, in a study assessing the physical properties of the materials. They attributed this result to the deposition of substances such as hydroxyapatite on the material surface when in contact with synthetic tissue fluids. This property is rather favorable as they indicate that the material does not lose particulate matter to result in dimensional instability.[4]

Microleakage

When specifically used as a liner or base material, leakage of Biodentine should especially be considered as leakage may result in postoperative sensitivity and secondary caries, leading to the failure of the treatment. [46]Biodentine is found to be associated with high pH (12) and releases calcium and silicon ions which stimulates mineralization and create “mineral infiltration zone” along dentin-cement interface imparting a better seal.[6]

Marginal Adaptation And Sealing Ability

Marginal adaptation has correlation with the sealing ability of dental material and, hence effect on clinical success rate. Micromechanical adhesion of Biodentine enabled excellent adaptability of Biodentine crystals to the underlying dentin.[6]A randomized clinical study was performed in the restoration of posterior teeth with Biodentine. Biodentine was applied as a bulk restorative material in deep dentin cavities in replacement of both dentin and enamel. The results of this trial reported that Biodentine was easy to handle, showed, a, excellent anatomic form, marginal adaptation and very good interproximal contact.[3]

Colour Stability and Staining Potential

Discoloration 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.[6]Josette Camilleri et al conducted a study in 2015 on Staining Potential of Neo MTA Plus, MTA Plus, and Biodentine Used for Pulpotomy Procedures and they concluded that All the materials tested are suitable to be used in the treatment of immature teeth because they all produced calcium hydroxide, which is necessary to induce dentin bridge formation and continued root formation. Neo MTA Plus and Biodentine are suitable alternatives to dentine replacment and they do not exhibit discoloration. [51]

Fracture Resistance

The mean fracture resistance of Biodentine is 458.50Parul Chauhan et al in 2021 evaluate and compare the fracture resistance of endodontically treated teeth using Biodentine, Conventional glass ionomer cement (GIC), Resin-modified glass ionomer cement (RMGIC), Nanohybrid composite and the result was Biodentine showed the highest mean fracture resistance.[52]The fracture resistance of root post-core assembly is of paramount importance for long term stability of the restoration. Stress was generated within the body opposing the external force to prevent fracture. When this force exceeds the internal stress, it results in fracture. Therefore, when stress exceeds the cohesive strength of the object; the object breaks.[38]

Bioactivity and Biocompatibility

Like any other restorative material, Biodentine Biocompatibility was investigated to ensure its safety when applied onto the cells. Evaluation of its genotoxicity on bacteria strains by the Ames test and its effects on the formation of micronuclei by human lymphocytes demonstrated the absence of any mutagenic effect of the material. Similarly, when tested on target human pulp cells, no DNA breaks or damage was observed with the Comet assay. These results demonstrated no genotoxic effects of Biodentine in vitro. The biocompatibility of the material was also investigated through its direct application to human pulp cells simulating the direct pulp condition and indirectly through a dentine slice to simulate its indirect pulp capping in vivo. Under both conditions Biodentine was not found to affect target cell viability under in vivo application conditions. Additionally, when Biodentine was applied onto human pulp cells to investigate its effects on their specific functions by studying expression of odontoblast specific functions such as expression of Nestin (a human odontoblast specific marker) and Dentin Sialoprotein, Biodentine was not found to inhibit the expression of these proteins but rather induce their expression and the cells mineralization capacity. Further investigations demonstrated the absence of toxicity of Biodentine to human MG63 human osteoblast cells with the MTT assay with properties comparable to that of MTA.[53]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.[52]

Antimicrobial Activity

Antibacterial activity of materials that can be used as both dental luting cements and pulp capping materials, during and after setting, assumes clinical relevance, as this property may help in the elimination or reduction of bacteria that have remained viable on walls of the preparation or bacteria that may gain access to the cavity through marginal gaps**.**A study conducted, by M.M. Zayed et al in 2015 and the diameter of the largest inhibition zone measured was with Biodentine, followed by that of the Resin modified glass ionomer. Light cured Calcium hydroxide showed the smallest inhibition zone [54].

Gene Expression

Biodentine exhibited the capacity to induce odontoblastic differentiation of human dental pulp stem cells (hDPSCs) obtained from impacted third molars via heme oxygenase-1 (HO-1), reactive oxygen species (ROS), nuclear factor-E2-related factor-2 (Nrf2), mitogen-activated protein kinase (MAPK) and calmodulin-dependent protein kinase (CAMKII) pathways (Chang et al. 2014; Luo et al. 2014b; Jung et al. 2015). Biodentine increased phosphorylation of extracellular signal-regulated kinase (ERK), p38, and c-Jun N-terminal kinase (Jung et al. 2015). Like ProRoot MTA, Biodentine also induced the up-regulation of osteocalcin (OCN), dentine sialophosphoprotein (DSPP), dentine matrix acidic phosphoprotein 1(DMP1), collagen type I (COL1A1), runt related transcription factor (Runx2) and bone sialoprotein (BSP) upon exposure to hDPSCs (Chang et al. 2014; Luo et al. 2014b; Widbiller et al. 2016).[34]In an in vivo analysis, it was reported that Biodentine had a higher number of inflammatory cells and interleukin-6 (IL-6) immunolabelled cells in comparison to MTA at 7 and 15 days, however this reaction revealed a gradual and significant reduction in the immunoexpression of IL-6, in the capsules adjacent to Biodentine from 7 to 60 days, reinforcing the concept that Biodentine is a biocompatible material (Da Fonseca et al. 2015).[55]

Cytotoxicity

During pulp capping, perforation repair, and retrograde filling, the cytotoxicity of the material used may influence the viability of periradicular cells and cause cell death by apoptosis or necrosis. To promote healing and restoration of the function of the tooth, dental materials should either stimulate repair or be biologically neutral. Therefore, it is important to avoid dental materials that are toxic to the pulpal and periapical tissues that might compromise the clinical outcome.[56]A study conducted by M. Collado-Gonzalez et all in 2017 on Cytotoxicity and bioactivity of various pulpotomy materials on stem cells from human exfoliated primary teeth and in this study Biodentine exhibited better cytocompatibility and bioactivity than MTA Angelus, Theracal LC and IRM.[54]

Clinical implication

Dentine Substitute

There was a strong evidence that no post-operative complications were established when biodentine was used as an alternative in class 1 and 2 composite restorations. A study by Valles Et al suggested that biodentine showed colour stability and results proved that biodentine could be a substitute for light cured restorative materials in esthetically sensitive areas. Since biodentine had all the mechanical properties similar to dentine in tooth, it can be used as an ideal dentine substitute material.[50]

Pulp Capping

Biodentine is recommended as an effective medicament for pulp capping procedure, as it has the unique feature in dentine bridge formation and tissue reaction. Moreover, it has the ability to begin early mineralization from pulpal cells by releasing TGF- BETA, thereby encouraging pulp healing. Study conducted by Nowicka et al, with biodentine used as pulp capping material found that it exhibited dentine bridge formation without any inflammatory response.[50]

Pulpotomy

In Pediatric dentistry, when the inflammation is in coronal pulp and also when direct pulp capping is not a recommended treatment option, pulpotomy is the most commonly accepted clinical procedure. One of the key advantages of using biodentine in pulpotomy is that it required less time and also acts simultaneously as a filling and a dressing material. Thereby, it was found that biodentine has the capacity of maintaining pulp vitality in patients opted for pulptomy treatment. Villat et al treated second premolar teeth in a 12 year old patient with partial pulpotomy. After a 6 months follow up, they identified a homogenous dentine bridge formation and continuation of root development was witnessed.[50]

Apexification

A study conducted by Cauwell et al found that immature necrotic teeth after proper regenerative endodontic procedure with biodentine can still produce continued root development. It was highly recommended due to its property to induce new cementum and periodontal ligament formation.[50]

Retrograde Filling Material

Pawar et al published a case report in which biodentine was used as a retrograde material for traumatized maxillary central and lateral incisors with large periapical lesion. After a follow- up for 18 months, it was identified that biodentine caused progression of periapical healing.[50]

Repair Of Resorption

In two different case reports published by Nikhil et al and Ali et al, both highlighted the unique property of biodentine in treatment of cervical and apical external root resorption cases after a time period of one year. However, they identified that on the re-treatment cases, there was equal difficulty in removal of biodentine. [50]

Repair Of Perforations

Biodentine having a high push out bond strength even after being exposed to vast number of endodontic irrigants makes it obviously a preferred choice. Due to the presence of this excellent property in biodentine, it has become a preferred material of choice in perforation repair.[50] Perforation repair using biodentin

Isolate the tooth with a rubber dam.
Rinse the cavity with a solution of sodium hypochlorite to disinfect the area.
If there is bleeding, hemostasis must be achieved before applying Biodentine®.
Dry the pulp chamber.
Prepare Biodentine® as indicated above (Biodentine® mixing instructions).
Dispense Biodentine® and condense.
Perforation repair and crown restoration are performed in a single step.
Take an X-ray and Remove excess material.
At a subsequent visit, if all clinical signs of a successful treatment are present, the possibility of a permanent restoration can be considered

Advantages
It can be placed in direct contact with pulp
It does not require photoactivation so can be placed in bulk
Easy to handle Short setting time
Good marginal integrity
Biocompatibility and bioactive

Contraindication
The limits of use include restoration of a large loss of tooth substance exposed to high stress.
Aesthetic restoration of anterior teeth and treatment of teeth with irreversible pulpitis. [47]

Disadvantages
1. Less wear resistance so placed under composite restoration and hence doesn`t withstand occlusal loading.
2. Poor flexural strength. [62]

Conclusion:-
Biodentine, The contemporary tricalcium silicate-based dentine replacement and repair material, has been evaluated in quite a number of aspects ever since it‟s launched in 2009. Biodentine in a capsule all in one biocompatible and bioactive material. Its tricalcium core allows the minerals in the biodentine to actually penetrate into the dentine tubules creating minerals to take a remarkably tight seal combined with its high dimensional stability. It exhibits outstanding micro leakage resistance which minimizes postoperative sensitivity & reduces the risk of bacterial penetration, in addition biodentine high alkaline Ph gives it bacteriostatic properties that protect the tooth from recurrent infections. These properties make biodentine highly versatile for crown and root replacement material. Procedures including permanent restorations, deep cavities, pulp capping, pulpotomy, temporary enamel restorations, root perforations, pulpal floor perforations, internal resoption, apexifications and apicosurgery. There is no other material use for all these indications. In addition to developing water tight interfaces with dentine the calcium salts in biodentine produces extremely tight seal with its heated substance making its stable material for baces for liner in Resin composite materials. Easy to handle the material produces the exceptional compressive strength reaching the same level as human dentine after only 28 days. It delivers the same flexural marginal as natural dentine after 24 hours and it has high radiopacity for clear short and long term follower. Biodentine requires no surface preparation or bonding. It cut like dentine giving a similar sensation under the bur and its ivory shade makes it easy to differentiate it from tooth structure. Taken together, through in vitro, in vivo, clinical trials/ reports, this dissertation shows that Biodentine is biocompatible, has strong mechanical properties and can safely be applied in restorative dentistry, in paediatric dentistry (as a possible alternative to formecresol) and in endodontics. It is important to know that Biodentine does not require any surface conditioning treatment. It can be cut and reshaped like natural dentin. It can be used as abulk permanent dentin substitute to replace the whole damaged/lost dentin and not only as a pulp capping material. Biodentine surface can be bonded like the natural dentin with different adhesives before final composite resins application. Thus, it proves to be a „GOLD STANDARD‟ replacing all other materials for treatment of primary and permanent teeth.

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