Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.47750/jptcp.2023.30.16.021

Review of literature on the properties and studies done on Biodentine as a pulp rehabilitating agent

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Submitted: 27 April 2023; Accepted: 18 May 2023; Published: 21 June 2023

ABSTRACT

Calcium silicate based materials have gained significant popularity in recent years due to their similarities to mineral trioxide aggregate (MTA) and their wide range of applications in dentistry (Prati and Gandolfi, 2015). One commercially available calcium silicate material is "Biodentine," which was introduced in 2009 as a dentin replacement material (Rajasekharan et al., 2014). Biodentine exhibits excellent properties for various dental procedures, including endodontic repair (such as root perforations, apexification, resorptive lesions, and retrograde filling in endodontic surgery), pulp capping, and as a dentin replacement material in restorative dentistry (Rajasekharan et al., 2014). Moreover, it can be used as a pulpotomy agent for both primary and permanent teeth. Biodentine is formulated using the MTA-based cement technology, which has led to improvements in its physical qualities and handling properties (Kaur et al., 2017).

Keywords: *primary , literature, studies, perforations, apexification*

INTRODUCTION

Calcium silicate based materials have gained significant popularity in recent years due to their similarities to mineral trioxide aggregate (MTA) and their wide range of applications in dentistry (Prati and Gandolfi, 2015). One commercially available calcium silicate material is "Biodentine," which was introduced in 2009 as a dentin replacement material (Rajasekharan et al., 2014). Biodentine exhibits excellent properties for various dental procedures, including endodontic repair (such as root perforations, apexification, resorptive lesions, and retrograde filling in endodontic surgery), pulp capping, and as a dentin replacement material in restorative dentistry (Rajasekharan et al., 2014). Moreover, it can be used as a pulpotomy agent for both primary and permanent teeth. Biodentine is formulated using the MTA-based cement technology, which has led to improvements in its physical qualities and handling properties (Kaur et al., 2017).

Chemical And Physical Properties Of Biodentine

Compressive Strength

Compressive strength is considered as one of the main physical characteristics of calcium silicate cements(Septodont 2010). As Biodentine is often used in vital pulp therapies, it is essential that the cement has to have the capacity to withstand masticatory forces, in other words, sufficient compressive strength to resist any external force((Lakshmanan & Jeevanandan, 2021; Shenoy et al., 2019)Kayahan et al. 2013).

A specific feature unique to that of Biodentine is its capacity to continue improving in terms of compressive strength with time until it reaches a similar range as that of natural dentine, hence the name “Dentin substitute”(Septodont 2010). Biodentine shows the highest compressive strength compared to the other tested materials(Grech, Mallia, and Camilleri 2013b(Akshayaa et al., 2021; Asif et al., 2019; Teja et al., 2021; Teja & Ramesh, 2021)). This results in enhanced strength as the water/cement ratio used in Biodentine is less. This is due to the presence of a water soluble polymer added to the mixing liquid. Acid etching is usually done for increased mechanical retention when composite is placed. It was found that acid etching procedures after 7 days did not reduce the compressive strength of ProRoot MTA and Biodentine(Kayahan et al. 2013(Lakshmanan et al., 2021)). Biodentine can be found to be a suitable material for use in procedures, such as vital pulp therapies, where there is direct exposure to external masticatory forces and compressive strength capacity is of primary significance. In another study, Biodentine was used as a posterior restoration and revealed favorable surface properties such as good marginal adaptation until 6 months(G. Koubi et al. 2013).

Compressive strength is a crucial physical characteristic of calcium silicate cements (Septodont, 2010). When considering the use of Biodentine in vital pulp therapies, it is essential for the cement to possess sufficient compressive strength to withstand masticatory forces (Kayahan et al., 2013).

Biodentine has a unique feature that sets it apart - its compressive strength continues to improve over time until it reaches a range similar to that of natural dentin, earning it the name "Dentin substitute" (Septodont, 2010). In comparison to other tested materials, Biodentine demonstrates the highest compressive strength (Grech, Mallia, and Camilleri, 2013b). This enhanced strength can be attributed to the lower water/cement ratio used in Biodentine, achieved by incorporating a water-soluble polymer in the mixing liquid. Acid etching is commonly performed to enhance mechanical retention when placing composites. However, studies have shown that acid etching procedures conducted after 7 days do not reduce the compressive strength of ProRoot MTA and Biodentine (Kayahan et al., 2013).

Biodentine proves to be a suitable material for procedures like vital pulp therapies, where exposure to external masticatory forces and high compressive strength are crucial factors. Another study utilized Biodentine as a posterior restoration and observed favorable surface properties, including good marginal adaptation up to 6 months (G. Koubi et al., 2013).

Microhardness

The microhardness of a material is determined by analyzing it using a diamond-shaped indenter. In comparison to Bioaggregate (Biodentin) and IRM, Biodentine demonstrated superior microhardness values. In a study that compared the physical properties of Biodentine with a conventional glass ionomer (Fuji IX) and a resin-modified glass ionomer (Vitrebond), it was found that Biodentine exhibited higher surface microhardness than the other materials when unetched (Josette Camilleri, 2013). However, when the materials were etched, there was no significant difference in the microhardness among them.

Bond Strength

Biodentine is recommended as a dentin substitute for permanent restorations, and several studies have been conducted to assess its bond strength with different bonding systems. A study evaluated the shear bond strength of Biodentine with an etch-and-rinse adhesive, a two-step self-etch adhesive, and a one-step self-etch adhesive system at different time intervals (Odabaş, Bani, and Tirali, 2013). Significant differences were found between all the adhesive groups at the same time intervals (12 minutes and 24 hours).

In endodontics, Biodentine is commonly used for perforation repair, which is a frequent occurrence in clinical practice. Adequate push-out bond strength between the repair material and dentinal walls is crucial to prevent dislodgement. A study compared the push-out bond strengths of Biodentine, ProRoot MTA, and MTA Plus in furcal perforation repairs (Aggarwal et al., 2013).

The push-out bond strength increased over time, and at 24 hours, Biodentine exhibited higher push-out strength compared to ProRoot MTA, regardless of blood contamination. Blood contamination did not affect the push-out bond strength, which is a favorable characteristic of Biodentine (Alhodiry, Lyons, and Chadwick, 2014).

Another study aimed to assess the effect of the smear layer on the push-out bond strength of calcium silicate cements, including Biodentine, ProRoot MTA, and MTA (El-Ma'aita, Qualtrough, and Watts, 2013b). The results demonstrated that the removal of the smear layer significantly reduced the push-out bond strengths of calcium silicate cements. The smear layer was identified as a critical factor affecting the bond strength between dentin and calcium silicate cements like Biodentine. The inability of calcium silicate cement particles to penetrate the dentinal tubules due to their particle size contributed to this outcome. It is worth noting that it is not common to use calcium silicate-based materials for complete root canal obturation, especially in narrow and curved root canals. However, the mentioned study (El-Ma'aita, Qualtrough, and Watts, 2013a) provided valuable insights into the bonding characteristics of these popular materials, which have unique applications in contemporary dentistry.

During the early setting phase, Biodentine is considered a weak restorative material. Therefore, in cases of laminate or layered definitive restorations, it is recommended to delay the placement of the overlying resin composite for more than two weeks to allow adequate maturation of Biodentine to withstand contraction forces from the resin composite (Hashem et al., 2014). Additionally, Biodentine has shown significant performance as a repair material even when exposed to various endodontic irrigation solutions, such as NaOCl, chlorhexidine, and saline. In comparison, MTA exhibited the lowest push-out bond strength to root dentin (Gurgel-Filho et al., 2014).

Porosity And Material-Dentin Interface Analysis

Tricalcium silicate-based materials are commonly used in procedures such as perforation repair, vital pulp treatments, and retrograde fillings, where a hermetic sealing is essential. The level of porosity in these materials plays a crucial role in the success of these treatments as it affects factors like adsorption, permeability, strength, and density. The maximum pore diameter is indicative of the leakage that occurs along the root-end filling materials, including tricalcium silicate cements like Biodentine (De Bruyne, De Bruyne, and De Moor, 2006).

A study evaluated the root dentine to material interface of Bioaggregate, Biodentine, a prototype radiopacified tricalcium silicate cement (TCS-20-Zr), and intermediate restorative material (IRM) when used as root-end filling materials (Viapiana et al., 2014). Biodentine and IRM exhibited the lowest degree of porosity. However, dry storage of Biodentine led to changes in the material's microstructure and the formation of cracks at the root dentine to Biodentine interface, allowing the passage of fluorescent microspheres. These gaps were considered significant as they had the potential to allow the ingress and transmission of microorganisms (Grech, Mallia, and Camilleri, 2013a).

The type of treatment performed is a critical factor in determining the porosity and subsequent leakage. In retrograde fillings with a continuously moist environment, lower porosity provided by Biodentine is advantageous. However, in procedures such as liners, bases, or dentine replacement, where the material is kept dry, porosity and the formation of gaps at the interface can pose problems and allow bacterial passage. Caution should be exercised when selecting Biodentine in certain clinical conditions where moisture is not present (Uzunoglu et al., 2016).

Another study compared the porosity of Biodentine with other silicate-based cements, including IRoot BP Plus, Ceramicrete, and ProRoot MTA, using micro-CT characterization (De Souza et al., 2013). The study found no significant difference in porosity between Biodentine, IRoot BP Plus, and Ceramicrete. Additionally, no significant differences were observed compared to the gold-standard MTA. The study concluded that tricalcium-based materials behaved similarly to conventional MTA in terms of microleakage, solubility, and microfractures in the clinical setting.

In a study comparing the interfacial properties of different dental substitutes, including Biodentine, with dentine, it was observed that Biodentine crystals were firmly attached to the underlying dentine surface. The interfacial layer formed between Biodentine and dentine resembled the hard tissue layer formed by ProRoot MTA, and the micromechanical adhesion was emphasized (Gjorgievska et al., 2013).

Another study examined the interfacial properties of Biodentine and glass ionomer cement using microscopy and spectroscopy methods (Atmeh et al., 2012). The study observed interfacial tag-like structures along the dentine, and the alkaline caustic effect of hydration products degraded the collagenous component of dentine adjacent to Biodentine.

Solubility

Biodentine has been found to be insoluble in fluids(Grech et al., 2013). This is due to the deposition of insoluble substrate hydroxyapetite on the material surface when in contact with synthetic tissue fluids. This is considered a favourable property as this indicates that the material is dimensionally stable(Kadali et al., 2021).

Flexural Property

The prolonged contact of root dentine with calcium hydroxide and calcium silicate cement has been found to weaken the resistance of the dentine (Soares et al., 2007; Doyon, Dumsha, and von Fraunhofer, 2005). Biodentine has been observed to alter the strength and stiffness of dentine tissue after aging in 100% humidity. While the ability of dentine to withstand external impacts and resist external forces may not be significantly affected when Biodentine is used in very thin layers, such as in pulp capping or as an apical plug, caution is advised when using these materials for the entire root canal obturation or as dentine replacements (Sawyer et al., 2012).

Discoloration

A study was conducted to assess the color stability of Biodentine under various oxygen and light conditions. Spectrophotometric analysis was performed at different time intervals up to 5 days. The results showed that Biodentine exhibited favorable color stability over the 5-day period. This indicates that Biodentine can be a suitable alternative for use in esthetically sensitive areas, particularly when combined with light-cured restorative materials (Vallés et al., 2013).

Washout Resistance

Washout refers to the disintegration of freshly prepared cement paste when it comes into contact with fluids like blood or other liquids. Biodentine exhibited a high washout rate, which can be attributed to the addition of a water-soluble polymer that reduces the water/cement ratio. This surfactant effect in Biodentine led to unfavorable results in terms of washout (Grech, Mallia, and Camilleri, 2013b).

Radiopacity

Radiopacity is an essential property for restorative materials, particularly when they are applied in thin layers and need to be distinguishable from surrounding tissues in radiographs. The International Organization for Standardization (ISO 6876:2001) specifies a minimum radiopacity value of 3 mm Al for endodontic cements (Tanalp et al., 2013).

Unlike other calcium silicate cements that utilize bismuth oxide as a radiopacifier, Biodentine incorporates zirconium oxide. This choice is based on the biocompatible nature of zirconium oxide, which possesses favorable mechanical properties and corrosion resistance (Piconi and Maccauro, 1999).

Although Biodentine meets the ISO requirement of 3 mm Al radiopacity, clinical observations have indicated that it appears similar to dentin on radiographs and may not be adequately visible. This lack of radiopacity has posed challenges in practical applications. A study by Tanalp et al. (2013) supports these findings, reporting that Biodentine exhibited lower radiopacity compared to other tested repair materials (MM-MTA and MTA Angelus), falling slightly below the 3 mm Al baseline value specified by ISO.

Microleakage

When Biodentine is used as a liner or base material, the potential for leakage should be carefully considered, as it can lead to postoperative sensitivity and secondary caries, ultimately resulting in treatment failure. In a study conducted by S. Koubi et al. in 2012, the marginal integrity of open-sandwich restorations using aged calcium silicate cement and resin-modified glass ionomer cement was assessed. Glucose filtration analysis after one-year aging revealed similar leakage patterns for both materials, with Biodentine performing as well as the resin-modified glass ionomer cement. An important advantage of Biodentine is that it does not require specific preparation of the dentin walls. The good marginal integrity of Biodentine can be attributed to the ability of calcium silicate materials to form hydroxyapatite crystals on the surface, which enhances sealing ability, especially at the interface with dentinal walls. Additionally, the interaction between phosphate ions in saliva and the calcium silicate-based cements may lead to the formation of apatite deposits, further increasing the sealing potential. The nanostructure and small size of the forming gel of the calcium silicate cement were also identified as factors influencing sealability, as they enable better spreading onto the dentin surface. The slight expansion of these materials also contributes to their improved adaptation (S. Koubi et al., 2012).

In another study by Raskin et al. in 2012, the leakage of Biodentine was compared with a resin-modified glass ionomer (Fuji II LC) in cervical lining restorations. The results were consistent with those of Koubi et al., indicating that Biodentine performed well as a dentin substitute in cervical lining restorations or as a restorative material in approximal cavities, without the need for conditioning. However, the only drawback was a longer operating time compared to the resin-modified glass ionomer.

A contradictory report by Josette Camilleri in 2013 compared the physical properties of Biodentine with a conventional glass ionomer cement (Fuji IX) and a resin-modified glass ionomer (Vitrebond). When used as a dentin replacement material in the sandwich technique overlaid with composite, significant leakage was observed at the dentin-to-material interface. In contrast, the glass ionomer cement-based materials showed no chemical or physical changes or microleakage when used as bases under composite restorations. It is important to note that the contradictory findings may be attributed to differences in the methodologies used to detect leakage, and further studies are needed to clarify the extent of leakage associated with calcium silicate-based materials

Composition And Setting Time

The composition of Biodentine, as stated in its product description, includes tricalcium silicate, dicalcium silicate, calcium carbonate, oxide filler, iron oxide shade, and zirconium oxide (Septodont, 2010). Tricalcium silicate and dicalcium silicate serve as the main core materials, while zirconium oxide acts as the radiopacifier. Unlike MTA, the liquid component of Biodentine contains calcium chloride as an accelerator and a hydrosoluble polymer as a water reducing agent. The unique characteristic of Biodentine is its fast setting time, which is achieved by increasing particle size, adding calcium chloride to the liquid component, and reducing the liquid content. The material sets in a short period of 9-12 minutes, which is an improvement compared to other calcium silicate materials (About, 2021). Biodentine releases calcium when in solution, as observed in studies by J. Camilleri in 2008 and J. Camilleri, Kralj, and Veber in 2012. Tricalcium silicate-based materials are also known to generate hydroxyapatite when in contact with synthetic tissue fluid (Grech, Mallia, and Camilleri, 2013a).

When hydrated, Biodentine forms a cementitious phase rich in calcium and silicone, along with a radiopacifying material. The powder component of Biodentine contains calcium carbonate inclusions, which are relatively larger compared to cement particles. Hydration products form around the calcium carbonate particles, acting as nucleation sites and enhancing the microstructure (Grech, Mallia, and Camilleri, 2013a).

A study comparing the composition of Biodentine, MTA Angelus, and laboratory-produced cement consisting of tricalcium silicate and zirconium oxide reported similar findings. Tricalcium silicate was identified as the main constituent of Biodentine, with no dicalcium silicate or calcium oxide detected. Additional additives were present in Biodentine to enhance its properties. The powder component contained 15% calcium carbonate, which acted as a nucleation site for C-S-H, reducing the induction period and resulting in a faster setting time. The tricalcium silicate grains in Biodentine were also reported to be finer, and the liquid portion included calcium chloride and a water-soluble polymer (Josette Camilleri, Sorrentino, and Damidot, 2013).

Biocompatibility

Biocompatibility is a crucial factor in dental procedures where the material comes in direct contact with the surrounding tissue. Biodentine has been found to be biologically neutral and non-toxic, making it an ideal material for procedures such as pulp capping, perforation repair, or retrograde filling. A study comparing Biodentine and white ProRoot MTA observed that both materials formed tag-like structures and dentine element uptake was more prominent for Biodentine than MTA(Han and Okiji 2011). Another study compared Biodentine, white MTA (ProRoot), and glass ionomer cement (FujiIX) and found that Biodentine and MTA were less toxic compared to glass ionomer during the 1- and 7-day observation period, with cell adhesion and growth being more favorable on their uneven and crystalline surface topography(Zhou et al. 2013). A study by Pérard et al. showed that Biodentine could be used as an ideal material for pulp capping, as it was found to modify the proliferation of pulp cell lines, and it was more similar to dentin in terms of microhardness and solubility rate(Pérard et al. 2013a, Pérard et al. 2013b).

Invitro Studies Done Using Biodentine

A comparative study conducted in 2015 examined the solubility, microhardness, radiopacity, and setting time of MTA and Biodentine. The results showed that MTA had superior radiopacity, while Biodentine had a significantly shorter setting time (Kaup, Schäfer, and Dammaschke 2015).

In another study comparing the color stability of teeth restored with white MTA and Biodentine, spectrophotometry was used, and it was found that Biodentine exhibited better color stability over a 6-month period. MTA showed discoloration within 1 week, which increased over time (Vallés et al. 2015).

An in vitro evaluation was conducted to assess the fracture resistance of Biodentine compared to other restorative materials such as composite and amalgam. The study found that Biodentine combined with composite yielded the best results (Ghahramani, Ghaffaripour, and Mohammadi 2019).

In a study from 2018, the shear bond strength of Biodentine and MTA was compared, and it was found that Biodentine exhibited a stronger bond.

Another study focused on comparing the physical and mechanical properties of MTA and Biodentine, including setting time, handling properties, and compressive strength. Significant differences in microleakage were observed between the two groups at 4 hours and 24 hours, but no difference was found at 1, 2, 4, 8, and 12 weeks. The setting time of MTA-Angelus and Biodentine did not show a significant difference, although Biodentine demonstrated better handling consistency. Furthermore, Biodentine exhibited significantly higher compressive strength compared to MTA-Angelus. These findings suggest that Biodentine offers improved sealing ability and clinical manageability as a dental filling material (Butt et al. 2014).

Animal Studies Done Using Biodentine

Several animal studies have been conducted to evaluate the effectiveness of Biodentine. In a study from 2012, the pulpal response after pulpotomy using Biodentine, White MTA, formocresol, and calcium hydroxide was assessed and compared in pig teeth. The study concluded that both Biodentine and White MTA were suitable and biocompatible materials (Shayegan et al. 2012).

A similar study in 2014 evaluated pulp repair after the placement of Biodentine in a rat model of pulpitis. The results indicated that Biodentine effectively controlled pulpal inflammation and enhanced repair in cases of controlled pulpitis (Minic et al. 2021).

In a study conducted on dog teeth in 2014, the pulpal and periapical response following pulpotomy and pulp capping using Biodentine and MTA were evaluated through radiographic, histopathologic, and histomicrobiological analysis. The findings revealed that Biodentine exhibited a higher incidence of mineralized tissue bridge formation compared to MTA, as observed radiographically and histopathologically ((De Rossi et al., 2014)).

Another study conducted in 2021 by Santos examined the influence of preoperative pulpal inflammation on the histologic outcome using four bioactive cements in dog teeth. The study demonstrated that both MTA and Biodentine were capable of forming calcified barriers(Santos et al., 2021)).

Invivo Studies Done Using As Biodentine Pulpotomy Agents In Primary Teeth

A randomized split-mouth trial was conducted to compare Biodentine and Formocresol as pulpotomy agents in primary molars. The study measured the radiographic and clinical success rates as the outcome. It was found that both groups showed favorable outcomes, and there was no significant difference between the two groups (El Sadek El Meligy et al., 2016)).

In a study from 2017, the clinical and radiographic success of Biodentine and MTA as pulpotomy agents in primary molars were compared, with a follow-up period of 24 months. The study reported no significant difference between the two materials (Bani et al. 2(Bani et al., 2017)017).

Another study assessed the success rates of Biodentine and MTA as pulpotomy agents, and similar results were obtained, suggesting comparable performance of the two materials ((Kamboj et al., 2019)).

A similar study compared Biodentine, Formocresol, and MTA as pulpotomy agents. The clinical and radiographic success rates were calculated, and it was found that Biodentine had the highest success rate at 12 months, indicating its suitability as a pulpotomy agent in primary teeth ((Musale et al., 2018)).

CONCLUSION

Evidence shows that various invitro and invivo studies have been conducted and show that Biodentine can be used in endodontic procedures an vital pulp therapy. More randomized control trials are needed for stronger evidence with a longer follow up period.

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