

REVIEW ARTICLE

# A review on bioactive tricalcium phosphate-based dentine substitutes (Biodentine), biochemical characteristics and vital pulp teeth clinical applications

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## ABSTRACT

There is a general agreement that vital pulp therapy in vital permanent teeth with cariously exposed pulps is a difficult process. A fast-setting calcium silicate-based cement material, Biodentine, has recently been in use in various clinical procedures as apexification, root perforations or resorptions, retrograde fillings, direct or indirect pulp capping procedures, and finally dentine replacement. Many of the recently published research articles recommended Biodentine as a vital pulp-capping material. Also, it is considered as a good dentine substitute. This review article explains different biochemical and vital pulp teeth clinical applications of this promising material.

**Keywords:** Tricalcium silicate-based material, Biodentine, bioactivity, dentin substitute, material setting, clinical applications.

## Introduction

Mineral trioxide aggregate (MTA) is widely used self-setting hydraulic, commercially available calcium silicate-based cements (CSCs) [1]. MTA is composed mainly of dicalcium silicate powder, and when mixed with water, calcium silicate hydrate and  $\text{Ca}(\text{OH})_2$  are produced and the mix forms calcium silicate hydrate gel (sticky gel) that quickly solidifies to a hard material structure [2,3]. CSCs are used commonly with non-vital teeth in endodontic procedures such as pulpotomy, apexogenesis, apexification, perforation repair, and root-end filling [4]. Also, CSC is clinically used with vital teeth in conservative clinical procedures like pulpal regeneration and hard tissue repair, such as pulp capping [5].

Many factors can direct the decision of the vital pulp capping. The primary and the chief is the pulp exposure type, which plays a major role in the efficacious for success. Either it is a carious exposure or it is a mechanical or traumatic injury to the pulp. Proper diagnosis is needed for each clinical situation, and clinical data need to be collected and evaluated when making a decision, which includes the past history of pain, evaluation of radiographs, pulp-vitality testing data, what is the planned tooth restoration, and financial considerations. A high percentage of success and tooth saving is predicated and confirmed with a lot of previous research. While still in cases of carious exposure, the success rate is different according to the vitality of the tooth and the function-related symptoms represented [6–8].

## Composition of Available Bioactive Dentine Substitutes

Tricalcium silicate cement, Biodentine, is composed of powder and liquid materials. The powder is composed of tricalcium silicates as main core component. It also contains dicalcium silicate as a second core material and filler of calcium carbonate and oxide. The powder contains zirconium oxide as a radiopacifier. The liquid includes calcium chloride as a setting accelerator and hydrosoluble polymer acts as a water-reducing agent. The presence of the setting accelerator permits the setting period of the material to 9–12 minutes, and the presence of the water-reducing agent withdraws crack formation within the material. Such cracks are usually observed after setting of cements containing a high percentage of water [9]. It has been reported that increasing particle size, adding calcium chloride to the liquid component,

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and decreasing the liquid content results in fast setting time which is considered as a unique characteristic of this material [10,11]. Tricalcium silicate-based materials are characterized by the release of calcium when in solution and considered as a source of hydroxyapatite when in contact with simulated tissue fluids [12–14].

Jang et al., reported different results of compressive strength and surface hardness of Biodentine, commercially available tricalcium phosphate-based dentine substitute material. It has been mentioned to be 61.35 MPa (after 1-day storage) and 62.6 MPa (after 3- and 7-day storage). While in another study, the compressive strength of Biodentine was 67.2 and 48.4 MPa, respectively, after 28 days of storage in an aqueous environment at 37°C. Different test parameters environments and storage periods are the main reasons of Biodentine compressive strength and surface hardness [15]. Mixed Biodentine consistency is the same as that of zinc phosphate cement [16].

No dentine pretreatment is needed before bulk Biodentine mix is placed into the prepared cavity. As Biodentine is weak and has high susceptibility to abrasion, it is to be considered as enamel substitute but it is considered as valuable dentine substitute under resin composite. Biodentine is also used as temporary restoration for up to 6 months [17]. Biodentine adequate setting needs 2 weeks to allow material maturation. So, final composite restoration over tricalcium phosphate-based dentine substitutes should be delayed until maturation of cements [18].

### Setting reactions of Tricalcium Phosphate-Based Dentine Substitutes

Biodentine can be mixed in any amalgamator, the powder and liquid are mixed together and the setting of the material starts through a hydration reaction. Calcium silicates particles are partially dissolved in the liquid resulting in a hydrogel of hydrated silicate. This formed hydrogel of hydrated silicate will precipitate on the remaining silicate particles' surface and in the spaces between the particles [19]. The set material consists of 5- $\mu$ m round particles embedded in a calcium silicate hydrate matrix. A dense microstructure is detected in set material as the porosity is almost filled by calcium silicate hydrate and calcium hydroxide. Biodentine setting time, reported by many researchers, were ranging from 6.5 to 45 minutes, which may be related to different test methods and environments used [20–22].

### Biological Properties

Calcium silicate-based cements are rich in calcium compounds, with a high rate of calcium ion release, is a good stimulant for formation of a hard tissue dentin pulp barrier [23].

In addition to the mineralized dentine barrier formation, Biodentine material induces differentiation of odontoblast-like cells from pulp cell dentine formation [24,25].

Many researchers considered Biodentine as a non-cytotoxic material and a highly-biocompatible material [26–28].

Shayegan et al., [29] mentioned that in primary porcine teeth, after 90 days of the use of Biodentine as a direct pulp capping or pulpotomy material resulted in normal radicular pulp tissue free from inflammation, with a complete dentine bridge over the pulp exposure site and thick calcified tissue at the pulpotomy site. Tran et al., [30] stated that after 14 days of Biodentine application directly to the exposed rat pulps induced odontoblastic differentiation, and the dentine bridge is formed adjacent to Biodentine. De Rossi et al., compared between Biodentine and MTA vital pulp capping of dog's teeth. They found that direct pulp capping with Biodentine has induced formation of a thicker dentine bridge than MTA at the same period of application [31].

Nowicka et al., studied clinical and histological effects of MTA and Biodentine on exposed molars to be extracted for orthodontic purposes. They found an absence of any pulp tissue inflammatory response and a formation of a complete dentinal bridge after 30 days. They concluded that there was no statistically significant difference between the responses of human pulp tissue to MTA and Biodentine used as the vital pulp-therapeutic materials [32].

### Hard Tissue Tricalcium Phosphate Interaction

Gandolfi et al., stated that Biodentine is showing superior marginal integrity when used in open-sandwich restorations. This is attributed to the ability of CSC to promote the precipitation of apatite-like crystals [33].

Khan et al., [34] assessed microleakage in open sandwich restorations and revealed that glucose diffusion at the interface between Biodentine and dentine walls is similar to that of resin-modified glass ionomer cement. Kokate and Pawar used 1% methylene blue as a tracer to compare the leakage of Biodentine and glass ionomer cement. Biodentine showed significantly less leakage than the glass ionomer cement [35].

Atmeh et al., evaluated dentin–Biodentine interface and using confocal microscopy demonstrated microstructural changes. The interfacial dentin showed an increase in the carbonate content, which suggested a hybrid zone formed of intertubular diffusion and mineral tags of Biodentine hydration products. Biodentine sets faster than other calcium silicate cements, allowing it to be used as a liner and a dentin substitute base under definitive restorative materials [36]. On the other side, Camilleri [20] mentioned that leakage was detected at the Biodentine–dentine interface either with or without etching, while no leakage was detected with Fuji IX and Vitrebond when used in a sandwich restoration overlaid with resin composite.

### Clinical Applications

Many animal *in vivo* studies demonstrate that Biodentine was applied for the vital pulp capping and pulpotomy. Subsequent formation of dentine bridge in rat teeth was detected after 4 weeks of the vital pulp therapy [37,38].

The same results were detected in miniature swine teeth. A thick dentin bridge was formed after 3 and 8 weeks, with no signs of pulp inflammation, of the vital pulp capping with Biodentine [39]. Similar results were detected when Biodentine was used for pulpectomy in primary pig teeth, and 90% of the cases showed no inflammation with a thick dentin bridge formed [29].

Biodentine shows favorable physical properties, short setting time, bioactivity, and biomineralization potential with good sealing ability. Many studies stated that Biodentine was used successfully with deep carious lesions and external root resorption [40–42]. Koubi et al., [17] confirmed that Biodentine can be used as an intermediate restoration for up to 6 months and as a permanent base material under resin composite.

Dawood et al., [43] reported that Biodentine can be used in pediatric dentistry as its short setting time especially in situations that warrant definitive treatment in a single visit.

## Conclusion

As collective data through *in vitro*, *in vivo*, clinical studies, and case reports, this review shows the biocompatibility of Biodentine with the vital pulp teeth. In cases of the deep caries-exposed vital pulps, where there is already pulp inflammation, it is difficult to get a consensus on decision-making for direct pulp capping. This innovative bioactive tricalcium silicate cement, Biodentine, is used as a material of choice. It can be used safely in the clinics for challenging conditions and questionable prognosis. Physical properties studies of Biodentine confirmed that there is no need for surface conditioning treatment before Biodentine application. As it is a good dentin substitute, it can be reshaped like natural dentin. It can replace the whole pathologic or fractured or lost dentin. Biodentine surface is similar to natural dentin when bonded with different adhesives before final resin composite restorations.

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## List of Abbreviations

CSC Calcium silicate-based cements  
MTA Mineral trioxide aggregate

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