Comparison of Efficiency and Responses of Biodentine with Other Agents on Direct and Indirect Pulp Capping in Primary and Permanent Teeth - A Review

Dr Pushpalatha C¹, Dr Prem Kumar R²

¹Professor and Head of the Department, Department of Paediatric and Preventive Dentistry, Bengaluru, India
²Postgraduate, Department of Paediatric and Preventive Dentistry, Bengaluru, India

ABSTRACT

The retention of teeth over the long term is significantly impacted by pulp necrosis in immature teeth following caries. By removing bacteria from the dentin-pulp complex and creating a setting conducive to apexogenesis, vital pulp treatment aims to preserve pulp viability. Phillip carried out the first pulp capping process in 1756. Vital pulp therapy has gained attention and has advanced since then. The challenge of estimating the extent of pulpal damage complicates the treatment of developing teeth. During the process, it is crucial that the clinician be able to maintain the pulpal tissue's health. In recent years, when compared to interventions like root canal therapy and extraction of the teeth, saving the tooth by indirect pulp capping, direct pulp capping has become the most preferred treatment option.

Various biocompatible materials have been used in the past like calcium hydroxide and others. Recent advances in the materials have improved the biological properties and the materials commonly used are Biodentine, mineral trioxide aggregate (MTA), Theracal which are calcium-based silicate cements. This review will give an insight about the recent advances in Biodentine, its properties, modifications, application in various clinical scenarios and the pulpal responses to Biodentine when used in direct and indirect pulp capping compared with other agents.

Keywords: Biodentine, Pulp Capping agents, Direct pulp capping, Indirect pulp capping

1. Introduction

The goal of modern dentistry is to prevent dental disease from developing and to promote health. Following the principle of minimal intervention, less intrusive procedures are selected when intervention is required to protect the sound dental structure. One of the most important factors for the longevity of dental treatments on teeth that have been compromised by caries, trauma, or are undergoing any restorative or rehabilitative procedure is the maintenance of pulp vitality. However, in some cases, the tooth structure is so compromised that it is necessary to use techniques for direct or indirect pulp capping (Barreto et al., 2021).

Dentin protects the sensitive vascular tissue that makes up dental pulp, and the two combined, form a complex that is both functional and formative. Depending on the intensity, a tissue reacts to various physiological pressures, pathologic stimuli, or developmental defects. The tooth pulp has the potential to consistently produce reparative dentin throughout life. This preserves pulp vitality and assists in making up for lost enamel or dentin (Anwar et al., 2022).

The defensive mechanism of the pulp is conserved and dentin production is made possible by maintaining the health of the teeth. Devitalized and root-filled teeth also have a higher risk of developing root fractures because they need more force to elicit a proprioceptive response than healthy teeth. Vital pulp therapy (VPT) methods may not just be used to cure irreversible pulpitis, as has been assumed. This is due to the fact that clinical indications and symptoms, such as the intensity or features of pain, cannot be used to conclusively assess the reversible or irreversible condition of pulp. The case for VPT in teeth is currently becoming stronger, independent of the patient's clinical symptoms and indicators that point to reversible or irreversible pulpitis (Awawdeh et al., 2018).

When the pulp is clearly exposed (vital pulp exposure), either owing to pathogenic exposure (cavities) or unintentional exposure, direct pulp capping is performed (trauma, during tooth preparation or caries removal). The use of indirect pulp capping is often restricted to deep cavity preparations that are in close proximity to the pulp but do not expose it in any way (Elwaseef et al., 2022).

Indirect pulp capping success rate is determined by factors such as an accurate assessment of the pulp state, removing the diseased carious tissue, the permanent restorative material of choice provides a good marginal barrier that prevents microleakage, which in turn limits nourishment to the remaining cariogenic bacteria (Sahin et al., 2021).
In the coronal region, profound carious lesions and dentin loss have been treated often using glass-ionomer cement (GIC). However, because to its intrinsic drawback of not encouraging any reparative dentin development, several alternative materials have developed in its place (Kadali et al., 2021). Clinical uses for calcium silicate cements, such as Mineral Trioxide Aggregate (MTA) and Biodentine, are widespread and effective. Silicate cements are known as dental biomaterials owing to their biocompatibility and physicochemical properties. They have the capacity to induce odontogenic differentiation and proliferation in human dental pulp cells in vitro (AKKOÇ, 2021).

Biodentine contains bioactive qualities, promotes the regeneration of hard tissues, and doesn’t cause an inflammatory pulp reaction. Additionally, it has remarkable antimicrobial and sealing qualities. There is no likelihood of microleakage, which might make the pulp diseased or necrotic. Calcium hydroxide causes the pulp to develop hard tissue more as a defence mechanism against the material's irritant properties, whereas Biodentine is compatible with cell recruitment. For vital pulp therapy to be effective, the pulp must be in good health and have an unhindered blood flow at the time of protection. Indirect pulp capping, direct pulp capping, partial (superficial) pulpotomy, and total (cervical) pulpotomy are critical pulp treatments. When utilised in vital pulp treatments, Biodentine delivers high compatibility. It is advised to use Biodentine to induce a hard tissue barrier in developing permanent teeth which is curiously exposed and Biodentine is a non-cytotoxic substance that is very biocompatible. Even in challenging circumstances, retaining the patient’s own teeth is now preferred to surgical intervention, which encourages the development of appropriate dental restoration materials. In both the dental crown and root, Biodentine, mineral trioxide aggregate replacement, has been utilized to replace dentin in a bioactive and biocompatible way. In addition to encouraging the development of mineralized tissue and reparative dentin, Biodentine stimulates the differentiation of pulp cells into odontoblast-like cells. It has the capacity to engage in interactions with dentin, resulting in the formation of a mineralized interfacial zone with label-like structures extending into the dentinal tubules (Barreto et al., 2021).

### 1.1 Ideal properties of pulp capping material

Phillip Pfaff historically carried out the first pulp capping technique in 1756, sealing a little piece of gold over an exposed critical pulp to aid in healing. However, the conditions under which the pulp capping technique is carried out have a significant impact on its performance, and the prognosis is affected by the age, kind, site, and size of pulp exposure. The optimum characteristics for pulp capping materials include things like promote the production of tertiary dentin, keep the pulp healthy, fluoride should be released to minimize secondary caries, bactericidal or bacteriostatic, adhere to dentin and restorative material, ensure an adequate bacterial seal (Myrna elwaseef et al., 2022).

#### Table 1 - Composition of Biodentine (Kadali et al., 2021)

<table>
<thead>
<tr>
<th>Powder</th>
<th>Liquid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tricalcium silicate (3CaO.SiO2)</td>
<td>Calcium chloride (CaCl2.2H2O)</td>
</tr>
<tr>
<td>Di-calcium silicate (2CaO.SiO2)</td>
<td>Water reducing agent (Superplasticizer)</td>
</tr>
<tr>
<td>Calcium carbonate (CaCO3)</td>
<td>Filler – Improve mechanical property</td>
</tr>
<tr>
<td>Zirconium dioxide</td>
<td>Radiopacifier</td>
</tr>
</tbody>
</table>

### 1.2 Shear Bond Strength of Biodentine

Bond strength is an interfacial adhesion between substrate and material, which is intermediated by an adhesive layer. The bond strength of Biodentine at the end of 48 hrs is 7.97 Mpa 9.69 after 1 week, 11.21 after 1 month and 11.61 after 6 months (Pradeep et al., 2018).

### 1.3 Responses of pulp to Biodentine

Through the development of odontoblast-like cells, dental pulp stem cells (DPSCs) are essential in the process of tissue repair. DPSCs have the ability to self-renew and differentiate in a variety of ways. In order to replace lost odontoblasts, DPSCs respond to tooth damage by developing, proliferating, differentiating, and adhering to odontoblast-like cells. This results in the development and secretion of tertiary dentin, which in turn causes the production of dentin bridge (AKKOÇ, 2021).

DPSCs multiply, move to the site of damage, and develop into odontoblastoid cells in pulp exposure cavities or extremely deep cavities with a residual dentin thickness of 0.25 to 0.01 mm (Tomás-Catalá et al., 2018).

### 1.4 Cell attachment, Morphology and Viability

When SHED were enclosed inside the amorphous Biodentine specimens, which were made up of a number of cuboidal irregular crystals of varied sizes, some of which were affixed to the cell surfaces directly. A characteristic elongated well-spread phenotype with many linked filopodia is seen when SHED is seeded in direct contact with the substance, indicating that the cells are successfully attached. Cell proliferation is concentration dependent when subjected to Biodentine eluates.
1.5 Odontogenic differentiation potential of SHED exposed to Biodentine at different concentrations

Numerous osteo/odontogenic differentiation-related genes' mRNA expression under non-inductive (CCM) and inductive (osteogenic medium) conditions shows upregulation of Alkaline phosphatase at higher concentration in non-inductive environment and is concentration independent in conductive environment.

Upregulation of Bone Morphogenetic Protein 2 is seen in inductive environment and not in non-inductive environment and is concentration dependent.

Upregulation of Bone Gamma-Carboxyglutamate Protein is seen in both the inductive and non-inductive environment.

Dentin sialophosphoprotein shows upregulation only at higher concentration irrespective of conductive or non – conductive environment.

Upregulation of MSX2 – Msh Homeobox 2 is seen in non-inductive environment and decrease in MSX2 expression is seen in case of inductive environment.

Down regulation of RUNX2 – Runt-related transcription factor 2 is seen in non-inductive environment and upregulation in case of conductive environment.

1.6 In vitro biomineralization potential of SHED

One of the main traits of Biodentine is its capacity to create an apatite or hydroxyapatite-like layer and this process is known as biomineralization. The in vitro biomineralization capability of SHED treated to serially diluted Biodentine eluates increased in a concentration-dependent manner and did not make any difference in the medium either inductive or non-inductive. The high cell viability rates on the surface of Biodentine are confirmed by live/dead fluorescence labelling and confocal imaging.

At lower concentrations DSPP, MSX2 and RUNX2 expression is seen and at higher concentration BGLAP and BMP-2 expression is seen. At increasing concentration Biodentine, ALP behaved in a certain “pulse-like” manner. ALP, BMP-2, and BGLAP are not particular indicators for odontogenic differentiation. However, because of their significant contribution to the mineralization of the dentin matrix, it is feasible to employ them as markers of odontogenic differentiation.

Bone morphogenic proteins (BMPs) are a subset of the superfamily of transforming growth factors (TGF). BMP-2 is a crucial gene that regulates odontogenic differentiation and DSPP transcriptional activation through Smad 1/5 signalling. It also plays a role in the regulation of dentin matrix mineralization processes.

The expression patterns of the DSPP gene point to this marker as being the most accurate for predicting the biomineralization capacity in SHED cultures. DSPP, which is a member of the SIBLINGs (Small Integrin-Binding Ligand N-linked Glycoproteins) family and is described in the literature as a particular marker for the early phases of odontogenic differentiation and plays a significant role in controlling crystal growth and dentin matrix mineralization.

It has been suggested that MSX2 controls formation of mineralized tissues by inhibiting the Wnt/b-catenin pathway, it is possible that MSX2 acts indirectly on dentinogenesis by modulating both osteoclast activity and the signalling network connected to eruption (Athanasiadou et al., 2018).

1.7 Distribution of oedema, inflammation, calcification, fibrous capsule, and necrosis (Karabulut et al., 2020)

Day 7 - A little oedema is noticed. There's been evidence of inflammatory cell infiltration. There seemed to be obvious fibrous capsule development. There was calcification that was dystrophic.

Day30 - Inflammation will become less severe. However, there is a little infiltration of inflammatory cells and development of a fibrous capsule has been seen.

Day 60 - Establishment of thick fibrous capsules and dystrophic calcification.

Table 2- Distribution of oedema, inflammation, calcification, fibrous capsule, and necrosis

<table>
<thead>
<tr>
<th>No. of Days</th>
<th>Responses after placement of Biodentine</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>little oedema, inflammatory cell infiltration</td>
</tr>
<tr>
<td>30</td>
<td>little infiltration of inflammatory cells, development of a fibrous capsule</td>
</tr>
<tr>
<td>60</td>
<td>Establishment of thick fibrous capsules, dystrophic calcification</td>
</tr>
</tbody>
</table>
2. Discussion

Modern dentistry has adopted cutting-edge technology and materials that allow patients to receive suggested treatments. Correct diagnosis and appropriate clinical practise can help with this. The goal of restorative care is to maintain the pulp's functioning and vitality. According to Pradelle-Plasse et al, Biodentine is mechanically stronger, less soluble, and generates tighter seals than calcium hydroxide. It overcomes the three main problems of calcium hydroxide, namely material resorption, mechanical instability, and microleakage (Tomer et al., 2019).

According to Garrocho et al, in vivo evaluation of the effectiveness of Biodentine and a light-activated Ca(OH)2-based liner as an indirect pulp-capping material is 95% and 98.3% respectively. Ca(OH)2 and Biodentine treatments were successful clinically and radiographically over a 12-month follow-up period. Reduced setting time (12 min), improved mechanical qualities, and excellent sealing ability are the key advantages of Biodentine over competing solutions (Chauhan et al., 2018).

Nur Sahin et al declared the clinical and radiographic success rates to be 100% in the Dycal and Biodentine groups, 93.3% in the TheraCal LC group, and there was no statistically significant difference between the three groups after 24-month follow-up period. Sahin, N et al showed that Dycal has a decreased odontoblastic layer, fibrosis and mild chronic inflammation that is restricted to the coronal pulp. They are distinguished by the appearance of reversible pulpitis rather than a healthy pulp. Tertiary dentin development and the integrity of the odontoblastic layer, both of which are demonstrated by Biodentine, point to the conservation of a sound pulp structure. It has been demonstrated that the growth factor TGF-beta 1 (TGF-1) induces the differentiation of dental pulp cells into odontoblastic cells, hence promoting the production of tertiary dentin. Additionally, compared to TheraCal LC, Biodentine has been demonstrated to cause fibroblasts to secrete more TGF-1 and fibroblast growth factor-2 (FGF-2) in the presence of pulpal perforation (Trowbridge H (2002)) (Gandolfi et al., 2012).

Another element influencing the creation and quality of the dentin deposited is the setting response of the selected restorative material. Decalcium silicate (CS2) and tricalcium silicate (C3S), which are both calcium silicate-based compounds, react with water to produce byproducts such OH-, Ca++, and Si++. Of them, OH raises the pH of the essential tissue, causing a thin necrotic layer to grow on top of it. The resulting layer shields important pulp cells from the capping material’s alkaline pH. Contrarily, Ca++ promotes mineralization by activating the pulp cells. The fundamental structural component of all silicate-based materials is Si++ (Camilleri et al., 2014).

Only as compared to Ca(OH)2-based materials can calcium silicate-based materials have a higher contribution to the development of hard tissue. Camilleri et al reported that when compared to TheraCal LC, Biodentine released more calcium ions. The authors also mentioned that because TheraCal LC includes both calcium silicate and resin, its hydration was incomplete during setting. Instead, it was completed in the surrounding tissues over time following exposure to light curing, which is why calcium ion release was higher in the Biodentine group than in the TheraCal LC group (Sahin et al., 2021). Proinflammatory cytokines are produced more often by calcium silicate-based materials, and TheraCal LC causes pulpal fibroblasts to generate more VEGF and IL-6 than Biodentine does (Giraud et al., 2018).

Investigations into the interactions of TheraCal LC and Biodentine with dental pulp revealed that TheraCal LC had higher inflammatory activity and lower bioactive capacity than Biodentine. TheraCal LC demonstrated better outcomes in the second week regarding continuity and the thickness of the dentin bridge when comparing two intervals of the identical materials. This improvement is explained by the decrease in hydroxyl ion release after 7 days. When fresh or reparative tertiary dentin is formed, this achieves a physiological pH that may produce an environment that is favourable for pulp cell survival and metabolic activity (Gandolfi et al., 2012).

DPSC expressed Dentin Sialophosphoprotein (DSPP) in close proximity to Biodentine(BD), plays a regulatory function in the mineralization of reparative dentin. However, in order for BR to express DSPP, mineralizing conditions, or phosphate ions as seen in a dentin environment, were required (S. Chen, J., 2009). A chemical bond or micromechanical anchoring via cement tags in the dentinal tubules may be the precise mechanisms by which calcium silicate cements adhere to dentin. The tiny gap between the MTA and the dentin surface is filled with hydroxyapatite crystals when the MTA is applied to the dentin surface. This seal is mechanical at first. The process causes chemical bonding between hydroxyapatite and dentin over time. While Biodentine causes the organic collagen component of the interfacial dentin to become denatured and more permeable (Atmeh et al., 2012; Sarkar et al., 2005), for Biodentine, the ion migration into dentin was not demonstrated. Biodentine’s adhesion is therefore less ion exchange-based and more micromechanical. However, Biodentine has demonstrated good adaptation to dentin. The differing particle sizes of Biodentine and MTA are primarily responsible for the shear bond strength, which in turn impacts the material penetration into dentinal tubules. Small Biodentine particles could help the dentin and dentin better interlock, which might encourage cohesive failure in the filling materials as opposed to failures in the interface. (Gjorgievsk et al., 2013; Gunesar et al., 2013).

According to Levin, Biodentine has a 92.68% effectiveness rate as a direct pulp capping agent when it comes to not developing radiolucency. 50 Biodentine-capped teeth were used in this investigation. Levin claims that Biodentine is a material with promise that is simple to use and manipulate (Levin, 2010). The success rate of BD and MTA at the 6-month follow-up was 93.3%, which is comparable to the results of another research that reported combined success rates for capping with MTA and calcium hydroxide ranging from 72.9% to 99.4%. Because the majority of failures happened right after treatment, the failure rate was lower at the 1-year follow-up. The success rate was great (98%) and comparable to other trials that used MTA and BD as a capping agent, with no appreciable differences (Aguilar and Linsuwanont, 2011; Katge and Patil, 2017; Parinyaprom et al., 2018) (Awawdeh et al., 2018).
A study conducted by Shanmugapriya Baskaran et al, where short-term clinical outcomes of pulp capping using MTA Angelus was done and the results showed higher success rate was in the Biodentine group relative to the MTA group after 6 months, which was not statistically significant (Baskaran et al., 2018).

When it comes to pulp therapy, calcium hydroxide has long been regarded as the "gold standard." Direct pulp capping with CH had a wide range of success rates, ranging from 31.8% after one year to 72.7% after ten years. However, this material's drawbacks include inadequate dentin bonding, material resorptions, tunnel flaws, and mechanical instability, which make calcium hydroxide ineffective at stopping microleakage over time. Additionally, the calcium hydroxide suspensions' high pH (12.5) results in liquefaction necrosis at the pulp tissue's surface (Malkondu et al., 2014) (Hørsted, P et al., 1985).

Nowicka et al concluded the use of Biodentine as a pulp-capping material resulted in full dentinal bridge development without an inflammatory pulp reaction. Under the osteodentin, layers of cells that resemble odontoblasts were discovered to generate tubular dentin (Nowicka et al., 2013). IPT is explained by the finding that postmitotic odontoblasts may be made to upregulate their secretory and synthesis activities in response to a decreased pathogenic challenge. This causes the deposition of a tertiary dentin matrix, which increases the distance between the caries and the pulp and reduces the permeability of the dentin. Dycal has been shown to release bone morphogenetic protein and transforming growth factor beta 1 from dentin, supporting their role as important mediators in pulp regeneration after pulp capping. Studies, however, have shown that pulp survival rates following calcium hydroxide pulp capping have been dropping over time. The cement's lack of adhesion and gradual degradation might cause microleakage and allow microbes to enter the dentin-pulp complex (Foreman and Barnes, 1990; Graham et al., 2006; Sangwan et al., 2013).

According to Arora et al, Biodentine has a sealing ability that is comparable to apatite crystals under a scanning electron microscope, making it a suitable agent for VPT (Arora, 2013). According to Peng et al, the silicon ions in Biodentine may boost the stimulation of cell proliferation and differentiation (Peng et al., 2011).

A study conducted by Ananya Chauhan, compared the indirect pulp treatment in primary posterior teeth with Dycal, MTA and Biodentine, and found that among all the groups, Biodentine saw the greatest increase in dentin bridge formation. Additionally, it was noted that in all groups, the rate of dentin bridge development was higher in the first three months compared to the final three. This might be explained by the idea that dentin is laid down most quickly in the first month after IPT and then gradually slows down over time (Chauhan et al., 2018).

According to research by Tran et al, after 14 and 30 days, Biodentine's % porosity of the dentin bridge was considerably equivalent and superior to Dycal (Tran et al., 2012). According to Nowicka et al, Biodentine may be viewed as an intriguing substitute for MTA during pulp capping due to its comparable clinical effectiveness (Nowicka et al., 2013). The ultimate restorative substance is another element that affects IPT's effectiveness. It is thought that bacterial leaking through the final repair is quite harmful (George et al., 2015). According to Nandini et al, placing Glass Ionomer Cement (GIC) over MTA after 45 min did not impact its setting reaction, and calcium salts may develop at the materials' interface (Nandini et al., 2007). Due to GICs strong shear bond strength, Ashou et al showed that it can be successfully used over Biodentine as the ultimate restorative material (17–20 MPa) (Al-Ashou et al., 2014).

References


