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Evaluating Biodentine: A Review of Current Research and Clinical Findings

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ABSTRACT

Biodentine is a bioactive dentin substitute increasingly utilized in restorative and endodontic dentistry. This review evaluates its properties, including mechanical strength, biocompatibility, and dentin regeneration capabilities. While Biodentine presents numerous advantages, such as effective pulp capping, challenges related to handling and long-term performance remain. Current research findings are synthesized to provide a comprehensive overview of Biodentine's clinical efficacy and its potential future applications in dental practice.

INTRODUCTION

Biodentine is a bioactive dentin substitute that has garnered significant attention in the field of dentistry since its introduction. Developed as an innovative material for restorative and endodontic applications, Biodentine is known for its excellent mechanical properties, biocompatibility, and ability to promote dentin regeneration. As a calcium silicate-based material, it mimics the natural structure of dentin, making it an ideal choice for a variety of clinical scenarios, including pulp capping, repair of root perforations, and as a base or liner under restorations.[1]

Over the years, extensive research has been conducted to evaluate the physical, chemical, and biological properties of Biodentine. Studies have highlighted its favorable characteristics, including high compressive strength, low solubility, and effective bonding to dental substrates. Additionally, Biodentine's ability to stimulate the formation of a mineralized barrier has made it a preferred option in vital pulp therapy.[2]

Despite its many advantages, some challenges and limitations have been noted in the literature, particularly concerning setting time, handling properties, and long-term performance in clinical settings. This review aims to critically analyze the current research on Biodentine, emphasizing its applications, benefits, and potential drawbacks. By synthesizing the latest findings and clinical experiences, we aim to provide a comprehensive understanding of Biodentine's role in contemporary dental practices and its future prospects in restorative dentistry.[3]

Composition of Biodentine: Biodentine is a novel two-component material widely used in restorative and endodontic dentistry. Its unique formulation comprises a powder and a liquid, each carefully designed to optimize its properties and functionality.

Powder Composition: The powder component of Biodentine is primarily composed of

Tricalcium Silicate (Ca_3SiO_5), which forms the backbone of this bioactive material. Tricalcium silicate is renowned for its excellent ability to react with water, facilitating hydration and leading to the formation of calcium silicate hydrates, which significantly contribute to the material's mechanical strength and biocompatibility.

In addition to Tricalcium Silicate, the powder contains Dicalcium Silicate (Ca_2SiO_4) as a second core material. Dicalcium silicate plays a crucial role in enhancing the hydration process and contributes to the overall strength and longevity of the material.

Further enhancing its performance, Biodentine incorporates Calcium Carbonate ($CaCO_3$) and Calcium Oxide (CaO) as fillers. These fillers not only improve the material's physical properties but also augment its bioactivity, promoting mineralization when in contact with dental tissues. The fillers facilitate the release of calcium ions, which can stimulate the formation of reparative dentin and support pulp healing.

To ensure adequate visibility during radiographic examinations, Zirconium Oxide (ZrO_2) is included in the powder as a radio-opacifier. This addition allows clinicians to easily identify the material on X-rays, providing a clear view of its placement and any potential complications during follow-up assessments.[4-6]

Liquid Composition: The liquid component of Biodentine consists primarily of a solution that includes Calcium Chloride ($CaCl_2$), which serves as a crucial setting accelerator. Calcium chloride enhances the rate of setting and hardening of the material, ensuring that it reaches adequate strength quickly. This rapid setting time is particularly beneficial in clinical situations that demand prompt restoration or pulp capping.

Additionally, the liquid may contain a water-reducing agent, which optimizes the workability of the material. This agent modifies the viscosity and flow properties of the liquid, facilitating easier mixing with the powder and ensuring a smooth, homogenous consistency. The proper rheological properties are essential for achieving effective bonding to dental tissues and adequate manipulation during application.[4-6]

Setting Reaction of Biodentine: When the powder and liquid components of Biodentine are combined using an amalgamator, a crucial hydration reaction takes place. This process is fundamental to the development of the material's properties, and involves several key steps and chemical interactions that ultimately lead to the formation of a bioactive dental material with enhanced strength and stability.[7-8]

Mixing Process: When Biodentine's powder, primarily composed of calcium silicates (Tricalcium Silicate and Dicalcium Silicate), is mixed with the liquid (containing Calcium Chloride and water), it undergoes a series of rapid physical and chemical interactions:

Mechanical Activation: The amalgamator helps to mix the components thoroughly and consistently, ensuring that the powder particles are effectively wet by the liquid. This mechanical mixing is vital for promoting good contact between the powder and the liquid, which facilitates the hydration reaction.

Hydration Reaction: Upon mixing, the hydration reaction is initiated:

Dissolution of Calcium Silicates: The liquid contains water and calcium chloride, which interact with the solid powder. As the powder is added, the calcium silicates partly dissolve, releasing calcium ions (Ca^{2+}) and silicate ions (SiO_4^{4-}) into the liquid phase.

Hydrogel Formation: As calcium silicates dissolve, they generate a hydrogel of hydrated silicate. This hydrogel is primarily composed of calcium silicate hydrates (C-S-H) and other hydrogel components, which form a semi-solid, jelly-like structure.

Precipitation and Particle Interaction

Precipitation on Silicate Particles: The hydrogel begins to precipitate on the surfaces of remaining silicate particles and fills the interstitial spaces between them. This precipitation is a critical step that significantly influences the properties of the final material.

Reduction of Porosity: This accumulated hydrogel leads to a marked reduction in the inherent porosity of the initial mixture. The filling of spaces between particles and on their surfaces minimizes voids, which are undesirable in structural materials because they can weaken overall material integrity.

Strength Development: As the hydration process continues:

Crystallization: Over time, the hydrogel undergoes further changes, leading to the crystallization of more stable phases. The formation of crystalline structures contributes to the material's compressive strength and durability.

Increase in Compressive Strength: With the hydrogel solidifying and binding the silicate particles together, the overall compressive strength of Biodentine increases. This strength growth occurs over time, as the material continues to evolve and mature chemically. The material's strength is vital for its application in load-bearing dental restorations and procedures, ensuring that it can withstand biting forces without failing.

Long-term Behavior

Bioactivity: Biodentine remains bioactive even after setting. The calcium ions released during the hydration process continue to support mineralization processes within surrounding dental tissues. This ongoing activity enhances the healing potential of the material and its ability to promote reparative dentin formation.

Sustained Strength: The initial increase in compressive strength observed during the early setting phase continues to improve as the material ages under physiological conditions. Over time, Biodentine exhibits a robust structural integrity, making it suitable for various dental applications such as pulp capping, root repair, and as a base for restorations.

Properties of Biodentine: Biodentine is a bioceramic material widely used in dental applications, particularly for endodontics and restorative dentistry. Below are its properties in detail:[9]

Fast Setting: Biodentine has a rapid setting time, allowing for quick application during dental procedures. This property makes it advantageous in clinical settings where time efficiency is critical.

Microleakage Comparison: When compared to resin-modified glass ionomer cement, Biodentine exhibits similar levels of microleakage. Microleakage is the phenomenon where bacteria and fluids can penetrate the margins between the tooth structure and the restorative material, potentially leading to secondary caries and pulp inflammation. Biodentine's performance indicates it provides a secure seal similar to other tested materials in maintaining the integrity of the dental restoration.

Marginal Integrity: Biodentine demonstrates excellent marginal integrity, meaning that it effectively seals at the interface between the tooth structure and the restoration. This property is crucial for preventing microleakage and promoting long-term success of dental restorations.

Bond Strength: In comparisons involving mineral trioxide aggregate (MTA), Biodentine shows superior bond strength when used in furcation perforation repairs. This is significant in endodontic treatments where the reinforcement of tooth structure is necessary after accidental perforations.

Low Porosity: Biodentine has low porosity, which contributes to its durability and longevity as a restorative material. Reduced porosity minimizes the likelihood of fluid infiltration and enhances the overall mechanical properties of the material.

Radiopacity: One noted limitation of Biodentine is its insufficient radiopacity. Radiopacity is important for dental materials as it allows for clear visualization on radiographs, helping clinicians evaluate the success of the treatment and detect any possible complications over time. The low radiopacity of Biodentine may complicate post-treatment assessments.

Biocompatibility: Biodentine is biocompatible, meaning it poses minimal risk of adverse reactions when used in dental applications. It promotes biological responses conducive to tissue healing and repair, making it a desirable choice for procedures involving pulp tissues and dentin.

Clinical Applications of Biodentine

Biodentine as Pulpotomy agent: Pulpotomy treatment is the preferred clinical procedure for preserving deciduous molars when there is coronal pulp exposure due to caries, cavity preparation, or trauma. However, it requires careful case selection to ensure successful outcomes. Biodentine, which closely resembles natural dentin, possesses bioactive properties and does not induce moderate to severe inflammatory responses that could lead to irreversible pulp changes. It promotes the release of growth factors that aid in the differentiation of odontoblasts and dentin formation. Research by Guagnano R et al. indicates that Biodentine is an effective material for pulpotomy in primary molars, regardless of the root resorption stage, achieving a success rate of 95.5% after 12 months.[10]

Biodentine as Pulp Capping Agent: With the introduction of calcium silicate materials, the use of calcium hydroxide in pulp vitality therapies has declined due to its limited adhesion to tooth walls, instability over time, risk of tunnel defects in the dentin bridge, and inconsistent success rates. A systematic review and meta-analysis by Cushley et al. in 2020 found that the success rate for pulp capping with calcium hydroxide was 74% at six months, 65% at one year, 59% at two to three years, and 56% at four to five years.[11] In contrast, direct capping using MTA showed success rates of 91%, 86%, 84%, and 81% over the same time periods, while Biodentine achieved rates of 96%, 86%, and 86%. Notably, no significant differences were found between the success rates of MTA and Biodentine.

Biodentine offers several advantages over calcium hydroxide, including a shorter processing time, greater mechanical strength, reduced solubility, and a tighter seal. These characteristics enable it to overcome three major limitations associated with calcium hydroxide: material resorption, mechanical instability, and the failure to prevent micro-percolation. Furthermore, Biodentine is bioactive, stimulating progenitor or pulp stem cells to form a reparative dentin-like matrix secreted by odontoblast-like differentiated cells. These pulp cells are responsible for synthesizing osteodentin and represent the initial wave of cells engaged in forming the dentinal bridge during instances of pulpal exposure.[12]

Biodentine as Apexification Material: Biodentine serves as an effective apexification material due to its bioactive properties, promoting the regeneration of dental tissues. It enhances root development and formation of a stable apical barrier in immature teeth following pulp necrosis. Its advantages include quick setting time, mechanical strength, and superior sealing capabilities, making it a preferred alternative to traditional materials for apexification procedures. Additionally, Biodentine stimulates stem cells and encourages the formation of a dentin-like matrix, supporting overall healing and recovery. Tolibah YA et al. found that Biodentine produced comparable outcomes in apical lesion healing and clinical recovery to MTA. Therefore, it can serve as an effective apical plug for treating immature permanent molars with apical lesions in a single visit. This is particularly beneficial for uncooperative children and allows for treatment under general anesthesia or deep sedation due to the reduced treatment duration.[13]

Biodentine as Perforation Repair Material: A perforation is an unfortunate complication that can occur during treatment, affecting anyone. Whether the procedure is surgical or non-surgical, various factors can significantly influence the success of the repair. To prevent perforations, clinicians must possess a deep understanding of tooth morphology, strong clinical judgment, and proficient operative skills. By choosing Biodentine as the material for perforation repair, clinicians can effectively manage this challenging issue, aiming for predictable and successful outcomes. One of the major advantages of Biodentine is its ability to create an effective seal even in the presence of moisture and blood, making it ideal for furcation repairs. Additionally, with an alkaline pH of 12.5, Biodentine supports periodontal ligament repair and cementogenesis, while also offering a shorter setting time and enhanced push-out bond strength.[14]

Overview of Biodentine: Overview of Biodentine is discussed in table 1

Table 1: Overview of Biodentine

Property	Interpretation
Setting Time	9-12 Min (Malkondu Ö et al, 2014)[2]
Compressive strength	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 (Sarkar NK et al. 2005)[15]
Microhardness	The hardness of biodentine by Goldberg et al., was found to be 51 Vickers Hardness Number (VHN) at 2 hour and 69 VHN after one month.[16]
Radiopacity	Biodentine reported a radiopacity to 3.5 mm of aluminium. Grech L et al., evaluated the radiopacity of Biodentine, bioaggreagte and tricalcium silicate cement and found that all materials had radiopacity value greater than 3 mm of aluminium.[7]
Solubility	Grech L et al., investigated lowest degree of solubility for Biodentine.[7]
Antibacterial Property	Biodentine shows superior antimicrobial action than MTA and GIC. (Bhavna V et al. 2015)[17]
Cytotoxicity	Biodentine cytotoxicity is similar to MTA and less than GIC. (Zhou H et al. 2013)[18]
Bioactivity and Regenerative Potential	Biodentine showed greater ability to produce apatite crystals and release of dental elements than MTA and BC sealer. (Han L et al. 2013)[19]

CONCLUSION

In conclusion, Biodentine demonstrates promising properties as a versatile dental material, showcasing excellent biocompatibility, mechanical strength, and dentin-like characteristics. Current research and clinical findings indicate its effectiveness in pulp capping, root repair, and various endodontic procedures. However, further studies are required to optimize its application and enhance understanding of its long-term performance. Overall, Biodentine represents a significant advancement in restorative dentistry, offering reliable outcomes and improved patient care.

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