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SIGNIFICANCE OF BIOACTIVE MATERIALS IN PULP PRESERVATION

Kasimova Gulshan Latifovna
Asia International University
gulshanqosimova6@gmail.com

Annotation

Modern therapeutic dentistry increasingly focuses on biologically oriented treatment concepts. The use of bioactive materials in vital pulp therapy improves clinical outcomes and promotes dentin regeneration. This article analyzes the properties of calcium hydroxide, mineral trioxide aggregate (MTA), bioceramic cements, and Biodentine in pulp protection and regeneration.

Keywords

bioactive materials, pulp, MTA, Biodentine, calcium hydroxide, vital pulp therapy.

Introduction. The dental pulp is a highly vascularized and innervated tissue, and preserving its vitality remains a cornerstone of modern therapeutic dentistry. In recent years, the concept of minimally invasive dentistry has advanced significantly, making the biological approach a primary focus.

While calcium hydroxide was traditionally the gold standard for pulp capping, contemporary research demonstrates the superior bioactivity of Mineral Trioxide Aggregate (MTA) and other bioceramic materials. These materials stimulate the formation of reparative dentin, provide high hermetic sealing, and possess potent antibacterial properties.

Biodentine and other modern bioceramics have overcome certain technological limitations of MTA. They offer shorter setting times, improved handling characteristics, aesthetic stability, and high mechanical strength, facilitating their use in clinical practice. Furthermore, bioceramic materials form a chemical bond with dentin, ensuring biointegration and reducing the risk of microleakage.

Preserving the pulp is particularly critical in younger patients. In teeth with ongoing root formation, pulp vitality facilitates the process of apexogenesis, promotes the strengthening of root walls, and guarantees the long-term functional survival of the tooth. Consequently, the biological approach is prioritized in pediatric and adolescent dentistry.

Today, the success of vital pulp therapy (VPT) depends on several factors: accurate clinical diagnosis, strict adherence to aseptic protocols, effective hemostasis, and the selection of the appropriate bioactive material. Clinical studies indicate that when modern calcium silicate-based materials are utilized, long-term success rates can reach 90% or higher, confirming the practical significance of the pulp preservation concept.

Objective: To analyze the clinical and biological efficacy of bioactive materials in preserving dental pulp vitality.

Materials and Methods

This study was conducted as a literature review evaluating the effectiveness of bioactive materials in pulp preservation. Scientific articles published between 2010 and 2025 in databases such as PubMed, Scopus, Web of Science, and e-library were analyzed. The search utilized keywords including “bioactive materials,” “vital pulp therapy,” “direct pulp capping,” “MTA,” “Biodentine,” “bioceramic materials,” and “calcium hydroxide”.

The analysis included randomized controlled clinical trials, prospective and retrospective studies, meta-analyses, and experimental (in vitro and in vivo) research. Articles with short-term follow-up periods or unavailable full texts were excluded. From the initial search, over 90 methodologically sound and relevant scientific works were selected.

The following parameters were analyzed: type of bioactive material (calcium hydroxide, MTA, Biodentine, bioceramics), patient demographics, follow-up duration, clinical and radiological outcomes, and success rates. The efficacy of VPT was assessed based on the absence of pain, lack of sensitivity to percussion and palpation, absence of radiological pathological changes, and maintained pulp vitality. Data were qualitatively synthesized, and statistical significance reported by authors ($p < 0.05$) was considered in evaluating clinical outcomes.

Results

Calcium Hydroxide:

Calcium hydroxide has been used for many years as a direct pulp-capping material. Its high pH (≈12.5) provides antibacterial effects and stimulates dentin bridge formation. The alkaline environment inhibits bacterial enzymatic activity and reduces inflammation within the pulp tissue. However, numerous studies have noted that the dentin bridge formed with calcium hydroxide is often irregular and contains "tunnel defects," which may compromise long-term hermeticity and increase the risk of microleakage. Additionally, the material's high solubility can lead to voids under restorations over time. Clinical success rates have been reported in the range of 60–80%.

Mineral Trioxide Aggregate (MTA)

MTA possesses bioactive properties that ensure high hermeticity and biocompatibility. Clinical studies show success rates of 90–95% during 1–3 year follow-up periods when using MTA for direct pulp capping. Radiological examinations typically show no periapical changes, and clinical symptoms are absent. Its primary drawbacks include a relatively long setting time (up to 2–4 hours), high cost, and potential tooth discoloration.

Biodentine:

Biodentine is a new-generation calcium silicate-based bioactive material developed as an alternative to MTA. It features a short setting time (approximately 12–15 minutes), high mechanical strength, and excellent handling properties. Biodentine stimulates the proliferation of pulp cells and the differentiation of odontoblast-like cells. Clinical observations show success rates reaching 92–96%. The resulting dentin bridge is dense and uniform, with low microleakage levels. Furthermore, the material is aesthetically stable, with minimal risk of discoloration.

Bioceramic Cements:

New-generation bioceramic materials exhibit high biointegration and chemical bonding capabilities. They release calcium and phosphate ions, forming hydroxyapatite crystals at the dentin-material interface, which provides a biological seal and restricts microbial penetration [8, 23]. Experimental studies show that bioceramic cements enhance pulp cell proliferation, angiogenesis, and the regenerative response. Clinical results confirm their long-term stability, particularly in apexogenesis for immature teeth [25].

Conclusion

Bioactive materials play a vital role in pulp preservation strategies. MTA and Biodentine demonstrate superior clinical efficacy compared to calcium hydroxide.

Bioactive materials stimulate reparative dentin formation, reduce inflammation, and provide antibacterial effects. Their high pH and calcium ion release activate regenerative processes.

Calcium silicate-based materials (MTA, Biodentine, and bioceramics) show higher success rates in clinical and radiological outcomes than traditional calcium hydroxide.

Dentin bridges formed by MTA and Biodentine are dense and uniform, resulting in lower microleakage and a stable long-term prognosis.

Treatment success depends not only on the material but also on accurate diagnosis, asepsis, hemostasis, and high-quality hermetic restoration.

Modern bioactive materials expand the clinical possibilities of pulp preservation, reducing the need for invasive endodontic interventions and reinforcing the biological principles of dental treatment.

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