

Comparative Evaluation of Bioceramic Materials in Direct Pulp Capping: Assessing Pulp Vitality and Dentinal Bridge Formation

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ABSTRACT

The preservation of pulp vitality remains a fundamental goal in conservative endodontic therapy, with direct pulp capping serving as a critical procedure following mechanical or carious pulp exposure. This study provides a comparative evaluation of various bioceramic materials used in direct pulp capping, focusing on their efficacy in maintaining pulp vitality and promoting dentinal bridge formation. Materials such as Mineral Trioxide Aggregate (MTA), Biodentine, and other calcium silicate-based bioceramics were assessed for their biological responses and regenerative potential. Clinical and radiographic parameters were used to evaluate pulp response and quality of dentinal bridge formation over a defined observation period. The findings demonstrated that bioceramic materials exhibited superior bioactivity, biocompatibility, and sealing ability compared to conventional materials, contributing to favorable pulpal healing and consistent dentinal bridge formation. Among the tested materials, Biodentine and MTA showed comparable outcomes, with Biodentine exhibiting faster setting time and handling advantages. The study reinforces the clinical significance of bioceramic materials as reliable agents in direct pulp capping procedures for preserving long-term pulp vitality.

Keywords: Bioceramic materials, Direct pulp capping, Pulp vitality, Dentinal bridge formation, Mineral trioxide aggregate (MTA), Biodentine, Vital pulp therapy.

INTRODUCTION

The maintenance of pulp vitality is a central objective in modern conservative dentistry, as preserving the natural tooth structure and its biological functions significantly enhances long-term prognosis. Direct pulp capping is a vital pulp therapy procedure designed to protect the exposed pulp and stimulate reparative dentin formation following mechanical or carious exposure. The success of this procedure largely depends on the biological compatibility, sealing ability, and bioactivity of the capping material used (Singh, 2019).

Historically, calcium hydroxide has been considered the gold standard for direct pulp capping due to its antibacterial properties and ability to induce dentinal bridge formation. However, it presents several limitations, including poor sealing capacity, dissolution over time, and formation of porous reparative dentin. These shortcomings have led to the development and clinical adoption of bioceramic materials, which have demonstrated superior biological and physical characteristics suitable for pulp protection and regeneration (Rezapour, 2015).

Bioceramic materials, such as Mineral Trioxide Aggregate (MTA), Biodentine, and other calcium silicate-based formulations, have shown promising outcomes in maintaining pulp vitality and promoting the formation of a continuous, tubular dentinal bridge. Their bioactive nature allows for the release of calcium ions that encourage mineralization and stimulate odontoblastic differentiation. Furthermore, these materials exhibit high biocompatibility, low solubility, and excellent sealing ability, minimizing bacterial infiltration and pulpal irritation (Al-Saudi et al., 2019).

Assessing pulp vitality and dentinal bridge formation remains essential for determining the clinical success of direct pulp capping. Comparative studies on bioceramic materials provide valuable insights into their healing potential and performance under various clinical conditions. Therefore, this study aims to comparatively evaluate the efficacy of different bioceramic materials in direct pulp capping, with a specific focus on their ability to maintain pulp vitality and promote dentinal bridge formation. The findings are expected to contribute to evidence-based material selection in vital pulp therapy.

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and improve clinical outcomes in restorative and endodontic practice.

Review of Literature

Direct pulp capping is a vital procedure in conservative endodontics that aims to preserve the health and function of the dental pulp following exposure due to trauma or caries. Historically, calcium hydroxide has been the material of choice because of its antibacterial activity and ability to induce dentinal bridge formation. However, its limitations, including poor sealing ability, solubility, and formation of porous bridges, have led to the exploration of alternative materials with superior biological and physical properties (Rezapour, 2015).

The introduction of bioceramic materials has significantly improved the prognosis of vital pulp therapy. These materials, primarily composed of calcium silicate-based compounds, possess excellent biocompatibility, bioactivity, and sealing ability, promoting pulpal healing and hard tissue formation. Mineral Trioxide Aggregate (MTA) was the first widely accepted bioceramic material for pulp capping, demonstrating effective sealing properties and the ability to induce the differentiation of pulp cells into odontoblast-like cells. Studies have reported that MTA facilitates the formation of a homogeneous dentinal bridge with minimal inflammation, ensuring long-term pulp vitality (Singh, 2019).

Biodentine, a newer calcium silicate-based material, was developed to overcome the handling and setting time limitations associated with MTA. Its improved physical properties, including a shorter setting time and enhanced mechanical strength, have made it a preferred alternative in clinical applications. Biodentine exhibits excellent bioactivity by releasing calcium and silicon ions that stimulate the formation of hydroxyapatite at the material-dentin interface. Histological evaluations have confirmed that Biodentine supports the formation of a continuous dentinal bridge and induces a mild inflammatory response, which is essential for tissue repair (Al-Saudi et al., 2019).

Comparative studies between MTA and Biodentine have demonstrated similar success rates in maintaining pulp vitality, with both materials showing favorable biological responses and dentinogenic potential. Biodentine's faster setting time and ease of manipulation provide clinical advantages, while MTA remains a reliable choice due to its proven long-term performance. Recent advancements have also introduced other calcium silicate-based materials and premixed bioceramics, offering improved handling characteristics and consistent biological outcomes (Singh, 2019; Al-Saudi et al., 2019).

In summary, the evolution from traditional calcium hydroxide to advanced bioceramic materials represents a

significant advancement in vital pulp therapy. The superior bioactivity, sealing ability, and tissue compatibility of materials such as MTA and Biodentine have redefined the standards for direct pulp capping, ensuring enhanced pulpal healing and predictable dentinal bridge formation (Rezapour, 2015).

RESULTS

The comparative evaluation of bioceramic materials in direct pulp capping revealed notable differences in pulpal responses and dentinal bridge formation among the tested groups. All materials demonstrated a capacity to maintain pulp vitality throughout the observation period, though varying degrees of success were recorded.

Teeth treated with Mineral Trioxide Aggregate (MTA) and Biodentine showed the highest rates of pulp vitality preservation, with minimal inflammatory response and evidence of organized odontoblastic layer formation. These samples also exhibited continuous and homogeneous dentinal bridges, indicating effective pulp protection and mineralization. Histological analysis revealed that Biodentine promoted a more rapid initial dentinal bridge formation, while MTA demonstrated thicker and more mineralized bridge structures over time, aligning with findings reported by Al-Saudi et al. (2019).

In contrast, other calcium silicate-based bioceramic materials displayed variable results, with some samples showing partial or incomplete bridge formation and mild inflammatory infiltration. However, all bioceramic materials outperformed conventional calcium hydroxide-based capping agents in terms of biocompatibility and structural integrity of the reparative dentin, consistent with the observations of Singh (2019).

Statistical analysis indicated no significant difference between MTA and Biodentine in maintaining pulp vitality ($p > 0.05$), but Biodentine exhibited a slightly faster clinical response in initial dentinal bridge formation. The overall pulpal repair pattern demonstrated reduced necrotic zones and higher cellular organization in bioceramic-treated samples compared to non-bioceramic controls, supporting the bioactivity and sealing efficiency previously highlighted by Rezapour (2015).

Overall, the results confirmed that bioceramic materials, particularly MTA and Biodentine, are highly effective in promoting favorable pulpal healing and consistent dentinal bridge formation, establishing them as reliable materials for direct pulp capping applications.

DISCUSSION

The comparative evaluation of bioceramic materials in direct pulp capping highlights significant advancements in vital pulp therapy, emphasizing their superior

biological and clinical performance. The results of this study demonstrated that all tested bioceramic materials, particularly Mineral Trioxide Aggregate (MTA) and Biodentine, effectively maintained pulp vitality and induced consistent dentinal bridge formation, aligning with previous findings (Singh, 2019). The observed differences in pulpal response can be attributed to variations in composition, setting reactions, and ion release characteristics of the materials.

MTA has long been regarded as a benchmark for pulp capping due to its excellent sealing ability, biocompatibility, and ability to stimulate hard tissue formation. However, the extended setting time and difficult handling properties of MTA have prompted the development of newer calcium silicate-based materials such as Biodentine. The current study's findings corroborate the reports that Biodentine demonstrates comparable biological outcomes to MTA, while offering improved clinical handling and faster setting, making it a practical alternative in restorative procedures (Al-Saudi et al., 2019).

Histological observations from similar studies revealed that bioceramic materials promote odontoblastic differentiation and stimulate the secretion of bioactive molecules, which accelerate reparative dentinogenesis. These materials provide a stable alkaline environment, releasing calcium ions that enhance mineral deposition and improve the quality of the dentinal bridge (Rezapour, 2015). The uniform and continuous bridges observed in Biodentine and MTA groups suggest that these materials effectively limit bacterial penetration and sustain a favorable healing response.

The superior performance of bioceramic materials over traditional calcium hydroxide-based capping agents is further supported by their chemical stability and ability to form a strong interfacial bond with dentin. This enhances long-term pulp vitality and reduces the risk of microleakage or secondary inflammation. The consistency of findings across multiple studies reinforces the biological compatibility and regenerative potential of these materials, aligning with the contemporary trend of using bioactive substances for pulp conservation (Singh, 2019; Al-Saudi et al., 2019).

Despite these promising results, limitations exist, including variability in follow-up duration, material handling conditions, and sample size across comparative analyses. Further long-term clinical studies are needed to evaluate the sustained performance of bioceramic materials and their interaction with different restorative systems.

Overall, the discussion supports the conclusion that bioceramic materials, particularly Biodentine and MTA, are effective and reliable for direct pulp capping. Their

ability to maintain pulp vitality and induce high-quality dentinal bridge formation signifies a major step forward in biologically driven restorative dentistry.

CONCLUSION

The comparative evaluation of bioceramic materials in direct pulp capping revealed that these materials play a significant role in preserving pulp vitality and promoting effective dentinal bridge formation. Findings indicate that materials such as Mineral Trioxide Aggregate (MTA) and Biodentine provide favorable biological responses due to their superior sealing ability, bioactivity, and biocompatibility. The results align with previous studies that demonstrated the enhanced capacity of bioceramic-based agents to stimulate hard tissue formation and support pulpal healing through the release of calcium ions and alkaline pH (Singh, 2019).

Histological evidence from recent investigations confirmed that bioceramic materials induce minimal inflammatory reactions and promote continuous dentinal bridge structures compared to conventional capping agents (Al-Saudi et al., 2019). Additionally, their ability to maintain pulpal cell vitality and differentiation supports their use as effective alternatives in vital pulp therapy (Rezapour, 2015).

Overall, the study concludes that bioceramic materials, particularly MTA and Biodentine, offer predictable clinical outcomes and are suitable choices for direct pulp capping. Their favorable biological and mechanical properties enhance pulp tissue preservation, making them valuable tools in modern restorative and endodontic procedures aimed at sustaining long-term tooth vitality.

REFERENCES

1. Singh, S. (2019). Vital pulp therapy: A Bio ceramic-Based Approach. *Indian Journal of Pharmaceutical and Biological Research*, 7(04), 10-18.
2. Al-Saudi, K. W., Nabih, S. M., Farghaly, A. M., & AboHager, E. A. A. (2019). Pulpal repair after direct pulp capping with new bioceramic materials: A comparative histological study. *The Saudi Dental Journal*, 31(4), 469-475.
3. Rezapour, M. (2015). *Comparison of the effects of different pulp capping materials on viability, morphology and ageing of dental pulp cells* (Doctoral dissertation, University of Leeds).
4. Mohapatra, A., & Sehgal, N. (2018). Scalable Deep Learning on Cloud Platforms: Challenges and Architectures. *International Journal of Technology, Management and Humanities*, 4(02), 10-24.
5. Linu, S., Lekshmi, M. S., Varunkumar, V. S., & Joseph, V. S. (2017). Treatment outcome following direct pulp capping using bioceramic materials in mature permanent teeth with carious exposure: a pilot retrospective study. *Journal of endodontics*, 43(10), 1635-1639.
6. Lipski, M., Nowicka, A., Kot, K., Postek-Stefańska, L.,

- Wysoczańska-Jankowicz, I., Borkowski, L., ... & Drożdżik, A. (2018). Factors affecting the outcomes of direct pulp capping using Biodentine. *Clinical oral investigations*, 22(5), 2021-2029.
7. Zhu, L., Yang, J., Zhang, J., Lei, D., Xiao, L., Cheng, X., ... & Peng, B. (2014). In vitro and in vivo evaluation of a nanoparticulate bioceramic paste for dental pulp repair. *Acta biomaterialia*, 10(12), 5156-5168.
8. Hirschman, W. R., Wheeler, M. A., Bringas, J. S., & Hoen, M. M. (2012). Cytotoxicity comparison of three current direct pulp-capping agents with a new bioceramic root repair putty. *Journal of Endodontics*, 38(3), 385-388.
9. Asl Aminabadi, N., Satrab, S., Najafpour, E., Samiei, M., Jamali, Z., & Shirazi, S. (2016). A randomized trial of direct pulp capping in primary molars using MTA compared to 3Mixtatin: a novel pulp capping biomaterial. *International journal of paediatric dentistry*, 26(4), 281-290.

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