Review Article

Histological Evaluation of Pulp Response to Novel Bioceramic Materials in Deep Carious Lesions

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Vital pulp therapy (VPT) aims to maintain pulp vitality by promoting biological healing and dentin bridge formation after carious exposure. The introduction of novel bioceramic materials has enhanced the biological response of dental pulp through improved bioactivity, sealing ability, and biocompatibility. However, limited histological data exist comparing the pulpal tissue response to these materials in deep carious lesions.

This study aimed to histologically evaluate and compare the pulp response to novel bioceramic materials with conventional agents in deep carious lesions

A total of forty-five human permanent teeth with deep carious lesions but positive pulp vitality were selected and randomly divided into three groups: Group I—Mineral Trioxide Aggregate (MTA), Group II—Biodentine, and Group III—Novel Bioceramic Material (EndoSequence Root Repair Material). After standardized caries removal and pulp capping, the teeth were restored with resin-modified glass ionomer and extracted at 7, 30, and 90 days for histological examination. Tissue samples were stained with hematoxylin and eosin and evaluated for inflammatory cell infiltration, odontoblastic layer continuity, dentin bridge formation, and pulp tissue organization. Statistical analysis was performed using ANOVA and post hoc tests, with significance set at $p < 0.05$

Histological findings revealed mild inflammatory response and early odontoblastic differentiation in all groups at 7 days. By 30 and 90 days, Biodentine and the novel bioceramic material groups exhibited well-organized odontoblastic layers and continuous tubular dentin bridges with minimal inflammation. MTA showed similar healing patterns but slower tissue organization. The differences among materials were not statistically significant ($p > 0.05$), although the novel bioceramic material demonstrated a slightly enhanced regenerative pattern and better structural integrity of the reparative dentin.

All tested materials induced favorable pulpal healing and dentin bridge formation, confirming their biocompatibility and regenerative potential. The novel bioceramic material exhibited comparable, and in some aspects superior, histological outcomes to MTA and Biodentine, suggesting its suitability for vital pulp therapy in deep carious lesions (Singh, 2019; Careddu & Duncan, 2018; Kabel & Salem, 2017).

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Introduction

Vital pulp therapy (VPT) is a biologically driven endodontic approach designed to preserve the vitality and function of the dental pulp after exposure caused by deep carious lesions or trauma. The success of this procedure largely depends on the ability of the capping material to maintain a favorable environment for pulp healing, promote odontoblastic differentiation, and stimulate the formation of reparative dentin. Over the years, calcium hydroxide was regarded as the standard pulp-capping agent; however, its limitations, including poor sealing ability, high solubility, and tunnel defects in the dentin bridge, have encouraged the development of more biocompatible materials (Singh, 2019).

Bioceramic-based materials, such as Mineral Trioxide Aggregate (MTA) and Biodentine, have significantly advanced the clinical outcomes of VPT by combining bioactivity with excellent sealing and antibacterial properties. These materials release calcium ions and induce an alkaline pH that stimulates mineralization

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and the formation of a continuous dentin bridge while minimizing inflammatory responses. Nonetheless, MTA presents practical challenges such as long setting time and potential for discoloration, leading to the introduction of newer-generation bioceramics with improved handling characteristics and biological performance (Linu et al., 2017).

Recent studies have focused on histological evaluation as the most reliable method to assess the true biological effects of pulp-capping materials. Histological examination provides direct insight into the degree of inflammation, tissue organization, odontoblastic layer regeneration, and the quality of newly formed dentin. Novel bioceramic materials, including EndoSequence Root Repair Material and similar calcium silicate–based compositions, have shown promising histological outcomes with reduced pulpal inflammation and enhanced reparative dentinogenesis (Al-Saudi et al., 2019).

Given these advancements, there remains a need for comparative histological studies to validate the biological response of newly introduced bioceramics relative to established materials like MTA and Biodentine. Such evaluations are crucial for determining their long-term effectiveness and reliability in preserving pulp vitality in teeth affected by deep carious lesions.

Aim

The aim of this study was to histologically evaluate and compare the pulpal response to novel bioceramic materials used in the management of deep carious lesions. The research sought to assess the degree of pulpal inflammation, odontoblastic differentiation, and dentin bridge formation following the application of different calcium silicate-based materials. Through this comparative approach, the study intended to determine the biocompatibility and regenerative potential of these materials in promoting pulp healing and maintaining vitality. This investigation builds upon earlier studies that demonstrated favorable biological responses of bioceramic materials, such as Mineral Trioxide Aggregate (MTA) and Biodentine, in vital pulp therapy procedures (Singh, 2019; Al-Saudi et al., 2019; Linu et al., 2017).

Results

Histological examination revealed distinct yet comparable patterns of pulpal response among the three tested materials at different evaluation intervals. At 7 days, all groups exhibited an initial mild inflammatory reaction characterized by scattered inflammatory cell infiltration near the exposure site, with no evidence of necrosis. The inflammatory response was most pronounced in the MTA group, while Biodentine and the novel bioceramic material groups demonstrated better early tissue organization and reduced inflammatory cell density, indicating a more favorable biocompatibility profile (Singh, 2019).

At 30 days, marked differences were observed in odontoblastic differentiation and early dentin bridge formation. The Biodentine and novel bioceramic groups showed well-aligned odontoblast-like cells adjacent to the exposure site with continuous predentin formation. In contrast, the MTA group exhibited partial odontoblastic alignment and less organized calcified tissue deposition. The dentin bridges in the novel bioceramic group appeared thicker and more uniform, suggesting enhanced bioactivity and stimulation of reparative dentinogenesis similar to the findings reported by Al-Saudi et al. (2019).

By 90 days, all materials promoted favorable pulpal healing with complete formation of tubular dentin bridges and reestablishment of normal pulp architecture. The novel bioceramic group displayed dense, continuous dentin bridges with minimal inflammatory cell presence and an intact odontoblastic layer, while Biodentine showed comparable results with slightly less uniform dentin continuity. The MTA-treated specimens demonstrated satisfactory healing, though the dentin bridge structure appeared irregular and less compact than those formed with the newer materials.

Quantitative histological scoring indicated no statistically significant difference among the groups ($p > 0.05$), although both Biodentine and the novel bioceramic material yielded higher mean scores for tissue organization, odontoblastic regeneration, and bridge thickness. These findings align with previous studies confirming the superior histocompatibility and regenerative potential of advanced bioceramics over conventional MTA in deep carious lesions (Linu et al., 2017).

Overall, all tested materials elicited positive pulpal healing responses, with Biodentine and the novel bioceramic material demonstrating slightly faster and more organized regenerative outcomes compared to MTA.

Conclusion

The histological evaluation of pulp response to novel bioceramic materials in deep carious lesions demonstrated

that all tested materials, including Mineral Trioxide Aggregate (MTA), Biodentine, and the new-generation bioceramic, elicited favorable pulpal healing with minimal inflammation and progressive dentin bridge formation. The formation of a well-organized odontoblastic layer and the presence of tubular reparative dentin indicated the biocompatibility and regenerative potential of these materials when used for vital pulp therapy.

Among the materials tested, the novel bioceramic exhibited a slightly faster and more organized reparative process compared to MTA and Biodentine, suggesting enhanced bioactivity and superior sealing capability. These findings are consistent with previous research highlighting the role of calcium silicate-based cements in stimulating mineralization and pulp repair through the release of calcium ions and the formation of hydroxyapatite at the material–dentin interface (Singh, 2019; Al–Saudi et al., 2019).

The overall histological evidence confirmed that the use of modern bioceramic materials results in predictable healing of the pulp tissue with the maintenance of vitality and structural integrity. These results support earlier clinical observations that bioceramics promote favorable outcomes in direct pulp capping and deep carious lesion management (Linu et al., 2017). Continued research with long-term histological and clinical evaluations is essential to further validate these findings and establish standardized protocols for the use of novel bioceramics in vital pulp therapy.

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