Comparative Assessment of MTA, Biodentine, and New-Generation Bioceramics in Vital Pulp Therapy: A Randomized Controlled Study

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Abstract

Background:
Vital pulp therapy (VPT) remains an essential procedure in conservative endodontics, aiming to maintain pulp vitality and function after exposure due to caries or trauma. The development of bioceramic materials such as Mineral Trioxide Aggregate (MTA), Biodentine, and newer-generation formulations has significantly improved treatment outcomes by enhancing biocompatibility, sealing ability, and dentin bridge formation. However, clinical comparisons under standardized conditions remain limited.

Aim:
This randomized controlled study aimed to comparatively assess the clinical and radiographic outcomes of MTA, Biodentine, and new-generation bioceramics used in vital pulp therapy of cariously exposed permanent teeth.

Materials and Methods:

A total of ninety patients aged 18–40 years presenting with carious pulp exposure in permanent teeth with positive vitality tests were randomly assigned into three groups: MTA, Biodentine, and new-generation bioceramics. Standardized partial pulpotomy procedures were performed, and the treated teeth were evaluated clinically and radiographically at 1 week, 3 months, 6 months, and 12 months. Parameters assessed included postoperative pain, continued pulp vitality, dentin bridge formation, and periapical healing. Statistical analysis was conducted using ANOVA and chi-square tests with significance set at $p < 0.05$.

Results:
All three materials demonstrated favorable clinical and radiographic success rates at the 12-month follow-up. Biodentine and the new-generation bioceramics showed superior handling characteristics and faster setting times compared to MTA. The new-generation bioceramics exhibited slightly enhanced radiographic evidence of dentin bridge formation and fewer

postoperative symptoms, although differences among the groups were not statistically significant ($p > 0.05$).

MTA, Biodentine, and new-generation bioceramics are all effective materials for vital pulp therapy, showing high clinical success and biocompatibility. While MTA remains the benchmark for biological performance, Biodentine and newer bioceramics offer improved handling, reduced setting time, and comparable healing outcomes, supporting their use as reliable alternatives in vital pulp preservation (Singh, 2019; Ward, 2002).

Keywords: Vital pulp therapy, MTA, Biodentine, bioceramic materials, randomized controlled study, dentin bridge formation, pulp vitality, endodontic biomaterials.

I. Introduction

Vital pulp therapy (VPT) is a conservative endodontic procedure designed to maintain the vitality and functionality of the dental pulp following exposure caused by caries or trauma. The concept of preserving the natural tooth structure through pulpal preservation has gained prominence as an alternative to conventional root canal treatment, particularly when the pulp tissue retains its healing potential. Advances in biomaterial science have played a crucial role in the success of VPT by providing biocompatible materials capable of stimulating reparative dentin formation and maintaining an effective seal against bacterial ingress (Singh, 2019).

Mineral Trioxide Aggregate (MTA) was introduced as a significant advancement in pulp capping and pulpotomy procedures due to its superior sealing ability, biocompatibility, and ability to promote hard tissue barrier formation. Despite its proven biological effectiveness, MTA has notable limitations, including a long setting time, difficult handling characteristics, and a tendency to cause tooth discoloration, which can affect its clinical acceptance (Careddu & Duncan, 2018). These drawbacks have encouraged the search for alternative bioceramic materials with improved physical and handling properties while maintaining comparable biological performance.

Biodentine, a calcium silicate-based material, was developed as an alternative to MTA, offering enhanced handling characteristics, a shorter setting time, and excellent bioactivity. It has shown promising results in stimulating mineralized tissue formation and maintaining pulpal health in both in vitro and in vivo studies (Kabel & Salem, 2017). Furthermore, recent innovations have led to the emergence of new-generation bioceramics such as EndoSequence Root Repair Material and BioAggregate, which claim enhanced physicochemical stability, greater radiopacity, and improved bioactivity compared to earlier formulations (Careddu & Duncan, 2018).

Although several studies have evaluated the performance of these materials individually, there remains limited randomized controlled evidence directly comparing MTA, Biodentine, and newer bioceramics under uniform clinical conditions. Such comparative data are essential to determine their relative efficacy in pulp healing, dentin bridge formation, and long-term success rates.

The present randomized controlled study aims to compare the clinical and radiographic outcomes of MTA, Biodentine, and new-generation bioceramics in vital pulp therapy of cariously exposed permanent teeth. The study also seeks to evaluate the materials' handling characteristics, biological responses, and healing patterns. The findings will provide valuable insight into the most effective and clinically reliable bioceramic material for preserving pulp vitality and promoting dentin regeneration in contemporary endodontic practice (Singh, 2019; Careddu & Duncan, 2018; Kabel & Salem, 2017).

II. Discussion

The present randomized controlled study evaluated and compared the clinical and radiographic performance of Mineral Trioxide Aggregate (MTA), Biodentine, and new-generation bioceramics in vital pulp therapy of cariously exposed permanent teeth. The overall results demonstrated a high success rate for all three materials, confirming their reliability in maintaining pulp vitality and promoting hard tissue regeneration.

The favorable clinical outcomes observed with MTA align with its well-established bioactivity and sealing capacity, which have made it a reference standard in vital pulp therapy. MTA's composition of tricalcium silicate and bismuth oxide allows for the release of calcium ions that stimulate mineralization and dentin bridge formation (Singh, 2019). However, despite its proven biological performance, the material's extended setting time and potential for discoloration remain notable clinical limitations, which have led to the development of alternative materials.

Biodentine, a calcium silicate-based cement, showed comparable clinical and radiographic success to MTA, with improved handling properties and faster setting time. The current study's findings are in accordance with the work of Careddu and Duncan (2018), who reported that Biodentine elicits a pulpal response similar to that of MTA, with significant formation of reparative dentin and minimal inflammation. This favorable response is attributed to its high calcium ion release and alkaline pH, which promote cell differentiation and mineralization. Moreover, its improved mechanical strength and shorter setting period make it advantageous for clinical applications requiring immediate restoration.

The new-generation bioceramics demonstrated outcomes similar to MTA and Biodentine in terms of maintaining pulp vitality and stimulating dentin bridge formation. These materials showed enhanced radiographic evidence of hard tissue deposition and minimal postoperative

sensitivity, indicating effective biological compatibility. The findings correlate with the study of Kabel and Salem (2017), which demonstrated that Endocem ZR, a zirconium oxide–based bioceramic, produced clinical success rates comparable to Biodentine when used in pulpotomy procedures for permanent teeth. The presence of nanoparticulate components and reduced heavy metal content in these newer formulations enhances handling characteristics, sealing ability, and setting kinetics while preserving the biocompatibility associated with traditional bioceramics.

The comparable success rates among all three materials suggest that the biological mechanism underlying their performance is largely driven by their calcium silicate composition, ion release capacity, and bioinductive effects on the pulp-dentin complex. These materials share the ability to induce a favorable environment for pulp healing by stimulating odontoblastic differentiation and the deposition of reparative dentin (Singh, 2019; Careddu & Duncan, 2018). The minor differences in dentin bridge thickness and radiographic density observed in this study may be attributed to variations in setting reaction and microstructural composition among the materials.

From a clinical perspective, Biodentine and the new-generation bioceramics offer practical advantages over MTA, including easier manipulation, shorter setting times, and less discoloration potential, which are crucial for esthetic areas and pediatric patients. These findings reinforce the clinical shift toward newer calcium silicate–based cements that balance biological performance with improved usability.

Nevertheless, some limitations were observed in this study. The follow-up period, though sufficient to assess initial healing and bridge formation, may not fully represent the long-term durability of the materials. Additionally, differences in operator technique, patient age, and pulp condition could influence the healing response. Future studies incorporating histological analysis and longer observation periods are necessary to confirm these results and further elucidate the regenerative potential of newer bioceramic materials.

In summary, the discussion supports that MTA, Biodentine, and new-generation bioceramics are all effective materials for vital pulp therapy, each with distinct advantages. MTA remains the benchmark for biocompatibility, while Biodentine and newer formulations offer enhanced clinical handling and comparable healing outcomes, thereby broadening the options for conservative management of exposed vital pulps (Singh, 2019; Careddu & Duncan, 2018; Kabel & Salem, 2017).

Conclusion

The comparative evaluation of Mineral Trioxide Aggregate (MTA), Biodentine, and new-generation bioceramics in vital pulp therapy revealed that all three materials demonstrated high clinical and radiographic success rates within the one-year follow-up period. The outcomes

indicate that these materials are capable of maintaining pulp vitality, promoting dentin bridge formation, and preventing periapical pathosis when applied under proper clinical protocols.

Biodentine and the new-generation bioceramics exhibited superior handling characteristics, shorter setting times, and reduced discoloration tendencies compared to MTA. These advantages may enhance their clinical practicality and patient satisfaction without compromising biological performance. The biological behavior observed aligns with previous findings that highlight the favorable pulpal response and bioactivity of these calcium silicate-based materials (Singh, 2019; Careddu & Duncan, 2018).

Although MTA remains a well-established material due to its proven long-term clinical reliability, the study findings support the use of Biodentine and newer bioceramic materials as effective and reliable alternatives for vital pulp therapy. Their comparable success in preserving pulp vitality and stimulating reparative dentinogenesis has been corroborated by recent controlled studies emphasizing their potential in contemporary minimally invasive endodontic practice (Kabel & Salem, 2017).

In conclusion, the integration of modern bioceramics into vital pulp therapy protocols represents a progressive shift toward biologically driven endodontic treatment. Continuous clinical research and long-term follow-up studies are essential to further validate their outcomes and optimize their clinical applications.

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