CLINICAL EVALUATION OF THE EFFECTIVENESS OF BIOCERAMIC MATERIALS IN MODERN ENDODONTIC TREATMENT

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Abstract. Bioceramic materials have become increasingly important in modern endodontics due to their favorable biocompatibility, bioactivity, dimensional stability and ability to interact with dental hard tissues. They are used in various clinical procedures, including root canal obturation, vital pulp therapy, perforation repair, apexification and endodontic surgery. Mineral trioxide aggregate (MTA) and Biodentine have shown promising results in vital pulp therapy. Bioceramic root canal sealers demonstrate clinical outcomes broadly comparable to conventional resin-based materials, although some studies report advantages in postoperative comfort and sealing properties. Their limitations include the risk of material extrusion, difficulties during retreatment and insufficient long-term clinical evidence for certain applications.

Keywords: bioceramic materials, endodontics, mineral trioxide aggregate, Biodentine, root canal sealers, vital pulp therapy, periapical healing, clinical effectiveness.

Introduction. Modern endodontics aims not only to eliminate infection from the root canal system but also to preserve natural tooth structure, maintain biological

function and promote periapical tissue healing. The development of bioactive materials has significantly expanded treatment options, particularly in cases involving pulp exposure, root perforations, immature apices and persistent periapical lesions. Bioceramic materials are predominantly based on calcium silicate, calcium phosphate and related bioactive compounds. Their favorable biological characteristics include biocompatibility, alkaline pH, calcium ion release and the ability to support mineralized tissue formation. These properties make them suitable for several clinical applications in endodontics [1].

Among the most widely used materials are mineral trioxide aggregate (MTA), Biodentine, calcium silicate-based root repair materials and premixed bioceramic sealers. Although their compositions and handling properties differ, many demonstrate the ability to interact with surrounding tissues and promote mineralization. MTA is widely used for pulp capping, pulpotomy, apexification, perforation repair and root-end filling. Biodentine is another calcium silicate-based material characterized by relatively rapid setting and favorable handling properties. Premixed bioceramic sealers, including calcium silicate-based formulations, are increasingly used in root canal obturation.

The biological activity of these materials is associated with calcium ion release and the formation of calcium phosphate deposits at the material–tissue interface. Their alkaline environment may also contribute to antimicrobial activity. However, these properties should not be interpreted as a substitute for adequate chemomechanical preparation, disinfection and proper coronal restoration [1].

Clinical Effectiveness in Root Canal Obturation. One of the important applications of bioceramic materials is their use as root canal sealers in combination with gutta-percha. Their hydrophilic properties, dimensional stability and potential for chemical interaction with dentin have contributed to their increasing clinical use.

Zamparini et al. Conducted a systematic review and meta-analysis comparing premixed bioceramic sealers with conventional epoxy resin-based sealers. The authors evaluated treatment success, sealer extrusion and postoperative pain. Their findings indicated that the available clinical evidence did not establish consistent superiority of bioceramic sealers in long-term treatment outcomes, although some favorable effects on postoperative discomfort and material performance were observed [2].

Similarly, Supare et al. Analyzed clinical studies comparing bioceramic-based and resin-based sealers. Their review highlighted the importance of postoperative pain assessment and demonstrated that the clinical advantages of bioceramic materials should be interpreted in relation to the individual characteristics of the materials and treatment techniques [3].

Application in Vital Pulp Therapy and Root Repair Preservation of pulp vitality is an important objective of modern minimally invasive dentistry. Bioceramic materials, particularly MTA and Biodentine, are increasingly used in direct pulp capping and pulpotomy because of their favorable biological properties and ability to support hard tissue barrier formation.

A systematic review and meta-analysis of randomized clinical trials evaluating direct pulp capping demonstrated high success rates for MTA and Biodentine. MTA showed better outcomes than calcium hydroxide in some comparisons, while no statistically significant difference was observed between MTA and Biodentine. Nevertheless, the authors emphasized that the certainty of evidence was limited by methodological heterogeneity and risk of bias in some included studies [4].

Bioceramic materials are also used in the management of root perforations, open apices and external or internal root resorption. Their ability to provide a relatively stable seal and their tissue compatibility make them valuable in these procedures.

However, clinical outcomes depend on the size and location of the defect, infection control, periodontal condition and technical accuracy.

Effectiveness in Endodontic Surgery. Bioceramic root repair materials are increasingly applied in endodontic microsurgery, particularly for root-end filling following apical resection. Their biological compatibility and sealing properties make them suitable for contact with periapical tissues.

A systematic review and meta-analysis by Ibáñez-Aravena et al. Compared newer bioceramic materials with MTA in endodontic microsurgery. The analysis included five studies, comprising three randomized clinical trials and two retrospective cohort studies. No significant difference in clinical and radiographic success was found between the newer bioceramics and MTA. The authors concluded that newer materials may offer handling advantages, but their clinical superiority has not been conclusively demonstrated [5].

Limitations and Future Perspectives.Despite their promising characteristics, bioceramic materials have several limitations. Material extrusion beyond the apical foramen may occur during obturation, and removal of certain bioceramic sealers during retreatment can be technically challenging. Differences in setting time, consistency, handling and radiopacity may also influence clinical performance. Another important limitation is the lack of sufficiently long follow-up periods in many clinical studies. Although laboratory investigations provide valuable information about biocompatibility and physicochemical properties, their results cannot fully predict clinical success. Further well-designed randomized clinical trials with standardized outcome measures are required to compare bioceramic and conventional materials across different endodontic procedures [2,5].

Conclusion. Bioceramic materials have become an important component of modern endodontic treatment due to their favorable biological properties and wide range of clinical applications. MTA and Biodentine demonstrate promising

results in vital pulp therapy and root repair, while bioceramic sealers provide a clinically acceptable alternative to conventional root canal filling materials. Current evidence, however, does not consistently demonstrate their superiority in long-term clinical outcomes. Appropriate case selection, effective infection control, precise application and adequate follow-up remain essential determinants of treatment success.

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