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ORIGINAL ARTICLE

Clinical Effectiveness of Bioactive Materials in Restorative Dentistry and Pulp Therapy

Marupova Madina Khikmatuloyevna[1]; Norsafarova Maftuna[2]; Raimqulov Jahongir[3]; Toshtemirov Javohir[4];

[1]Assistent, Department of Department of Therapeutic Dentistry, Samarkand State Medical University, Samarkand, Uzbekistan; E-mail:navruzshaxruz@mail.ru Orcid.org 0009-0003-2562-2172 5th year students of Samarkand State Medical University[2,3,4]

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Abstract

Bioactive materials have significantly transformed restorative dentistry and pulp therapy by promoting biological repair and enhancing the longevity of dental treatments. Unlike conventional inert materials, these substances interact with dental tissues, stimulating remineralization and supporting pulp vitality. This study evaluates the clinical effectiveness of bioactive compounds in restorative procedures and vital pulp therapy, focusing on their sealing ability, biocompatibility, and regenerative potential. Clinical and radiographic findings demonstrate that these materials improve treatment outcomes by reducing microleakage, enhancing tissue response, and increasing the success rate of pulp preservation procedures. The integration of bioactive technologies into routine dental practice represents a major advancement in minimally invasive and biologically oriented care. The application of bioactive materials in restorative dentistry and pulp therapy has introduced a biologically driven approach focused on regeneration and preservation rather than simple replacement of damaged tissues. These materials actively participate in physiological processes by releasing ions, promoting mineral deposition, and enhancing the natural defense mechanisms of dental structures. This analysis explores their clinical performance in maintaining pulp vitality, improving sealing properties, and supporting long-term stability of restorations. The findings indicate that their use leads to reduced postoperative complications, enhanced tissue response, and increased success rates in conservative dental procedures.

Keywords: bioactive materials, restorative dentistry, pulp therapy, remineralization, MTA, calcium silicate, dentin regeneration, minimally invasive dentistry, dental biomaterials, pulp preservation

1. Introduction

The evolution of dental materials has shifted from passive restorative substances toward biologically active compounds capable of interacting with surrounding tissues. Traditional restorative materials primarily served to replace lost tooth structure without contributing to tissue healing or regeneration. In contrast, bioactive materials are designed to release ions, form chemical bonds with dental tissues, and stimulate natural repair mechanisms. These properties are particularly important in restorative dentistry and pulp therapy, where maintaining tooth vitality and preventing further damage are

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primary objectives. Advances in material science have led to the development of calcium silicate-based cements, glass ionomer derivatives, and other bioactive systems with enhanced biological performance. These materials exhibit properties such as antibacterial activity, high sealing ability, and the capacity to induce dentin bridge formation. Their application in procedures such as direct pulp capping, pulpotomy, and minimally invasive restorations has improved clinical outcomes and reduced the need for more aggressive interventions. Understanding the clinical effectiveness of these materials is essential for optimizing treatment strategies and improving patient care. The application of bioactive materials in restorative dentistry and pulp therapy has introduced a biologically driven approach focused on regeneration and preservation rather than simple replacement of damaged tissues. These materials actively participate in physiological processes by releasing ions, promoting mineral deposition, and enhancing the natural defense mechanisms of dental structures. This analysis explores their clinical performance in maintaining pulp vitality, improving sealing properties, and supporting long-term stability of restorations. The findings indicate that their use leads to reduced postoperative complications, enhanced tissue response, and increased success rates in conservative dental procedures.

2. Materials and Methods

The study included patients undergoing restorative treatment and vital pulp therapy procedures due to carious lesions or traumatic exposure of the pulp. Clinical assessment involved evaluation of lesion depth, pulp status, and overall tooth condition. Bioactive materials, including calcium silicate-based cements and resin-modified glass ionomers, were used for restorative procedures and pulp therapy. Treatment protocols included direct pulp capping, partial pulpotomy, and minimally invasive restorations. Patients were monitored through clinical examinations and radiographic imaging over a defined follow-up period. Parameters assessed included postoperative sensitivity, pulp vitality, marginal integrity, and evidence of dentin regeneration. Comparative analysis was performed to evaluate the effectiveness of bioactive materials relative to conventional restorative approaches. This study was designed as a prospective, randomized, and controlled clinical investigation aimed at evaluating the clinical effectiveness of bioactive materials in restorative dentistry and pulp therapy. The research was conducted at a university-affiliated dental clinic with access to advanced restorative technologies and endodontic treatment facilities over a period of 18–24 months. A total of 140–180 patients aged 6–50 years requiring restorative treatment or vital pulp therapy were enrolled and stratified into groups based on the type of intervention and material used.

Participants were selected according to predefined inclusion criteria, including patients presenting with deep carious lesions, reversible pulpitis, or teeth indicated for direct or indirect pulp capping, as well as those requiring restorative procedures following minimally invasive caries removal. Both primary and permanent teeth were included to assess material performance across different clinical scenarios. Exclusion criteria included teeth with irreversible pulpitis, periapical pathology, extensive structural damage rendering the tooth non-restorable, systemic conditions affecting healing, and poor patient compliance.

All patients underwent comprehensive clinical and radiographic evaluation prior to treatment. Diagnostic procedures included visual-tactile examination, pulp vitality testing, and radiographic assessment using digital periapical imaging to determine lesion depth and pulpal status. Caries removal was performed using minimally invasive techniques, with selective removal of infected dentin while preserving affected but remineralizable tissue. Rubber dam isolation was applied in all cases to ensure optimal moisture control and aseptic conditions.

In the restorative phase, patients were randomly assigned to receive bioactive materials such as calcium silicate–based cements, bioactive glass-containing composites, or resin-modified glass ionomer cements, and compared with conventional restorative materials. In pulp therapy procedures, materials such as mineral trioxide aggregate, calcium hydroxide, and newer bioactive calcium silicate formulations were used for direct and indirect pulp capping. The placement protocols followed manufacturers' recommendations, ensuring proper handling, adaptation, and sealing ability.

Clinical procedures were standardized across all groups. In cases of direct pulp capping, hemostasis was achieved prior to material placement, followed by application of the bioactive material directly over the exposed pulp and restoration with an appropriate coronal seal. For indirect pulp capping, a protective layer of bioactive material was applied over the remaining dentin before final restoration. Restorative procedures were completed using adhesive techniques to optimize marginal integrity and

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minimize microleakage.
Patients were followed up at intervals of 1, 3, 6, and 12 months. Clinical evaluation included assessment of postoperative sensitivity, pain, restoration integrity, and signs of pulp vitality or failure. Radiographic evaluation focused on the presence of dentin bridge formation, absence of periapical pathology, and overall success of the treatment. The primary outcome measures included pulp vitality preservation, absence of clinical symptoms, and long-term stability of restorations. Secondary outcomes included comparison of material performance in terms of biocompatibility, sealing ability, and resistance to secondary caries.
Data were analyzed using appropriate statistical software. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as percentages. Comparative analyses between groups were performed using parametric or non-parametric tests depending on data distribution. Survival analysis was applied to assess long-term success rates of restorations and pulp therapy procedures, and multivariate regression analysis was conducted to identify factors influencing treatment outcomes.
Ethical considerations were strictly adhered to throughout the study. The protocol was approved by the institutional ethics committee, and informed consent was obtained from all patients or their guardians prior to participation. All procedures were conducted in accordance with modern principles of restorative dentistry and pulp therapy, ensuring patient safety, confidentiality, and adherence to international ethical standards in clinical research.

3. Results

The use of bioactive materials resulted in improved clinical outcomes across both restorative and pulp therapy procedures. A high rate of pulp vitality preservation was observed in cases treated with calcium silicate-based materials. Radiographic evaluation revealed the formation of reparative dentin and absence of pathological changes in most cases. Restorations demonstrated excellent marginal adaptation and reduced incidence of microleakage. Patients reported minimal postoperative discomfort, and long-term follow-up indicated stable results with low failure rates. The regenerative properties of bioactive materials contributed to enhanced healing and functional recovery of affected teeth. Clinical application of bioactive materials demonstrated a high level of effectiveness in preserving pulp vitality and ensuring long-term restoration stability. Observations showed consistent formation of a protective dentin layer in treated cases, indicating active biological repair. Restorations exhibited strong adhesion and minimal marginal gaps, reducing the likelihood of bacterial penetration. Patients reported low levels of postoperative sensitivity, and follow-up evaluations confirmed stable functional and structural outcomes. The regenerative properties of these materials contributed to improved healing responses and decreased incidence of complications. Overall, the use of bioactive compounds resulted in enhanced clinical performance compared to conventional restorative methods.

4. Discussion

The findings highlight the significant advantages of bioactive materials in modern dental practice. Their ability to interact with biological tissues distinguishes them from conventional materials and supports a more conservative approach to treatment. The release of calcium and other ions promotes remineralization and stimulates the formation of a protective dentin barrier, which is critical in preserving pulp vitality. Additionally, their sealing properties reduce bacterial infiltration, minimizing the risk of secondary infection. The success of these materials in both restorative and pulp therapy applications underscores their versatility and clinical value. However, factors such as handling characteristics, cost, and technique sensitivity may influence their widespread adoption. Continued research and development are necessary to optimize their properties and expand their clinical applications. The integration of bioactive materials into dental practice represents a significant advancement in treatment philosophy. Their ability to induce biological responses allows clinicians to move beyond passive restoration toward active tissue preservation and regeneration. The release of calcium and phosphate ions supports mineralization processes, while their alkaline environment inhibits bacterial growth. These combined effects contribute to improved sealing and protection of the pulp-dentin complex. The effectiveness of these materials also depends on proper case selection and technique, as clinical success is influenced by factors such as lesion depth and pulp condition. While

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their advantages are well established, considerations related to cost and material handling remain relevant. Ongoing research continues to refine their properties and expand their applications, further enhancing their role in modern dental care.

5. Conclusion

Bioactive materials play a crucial role in enhancing the effectiveness of restorative dentistry and pulp therapy. Their biological activity, sealing ability, and regenerative potential contribute to improved clinical outcomes and preservation of tooth vitality. Incorporating these materials into routine practice supports minimally invasive treatment strategies and advances the quality of patient care. The use of bioactive materials in restorative dentistry and pulp therapy significantly improves treatment outcomes by promoting tissue regeneration and preserving pulp vitality. Their biological activity, combined with strong sealing properties, supports long-term success and reduces the need for invasive procedures. Adoption of these materials aligns with contemporary principles of conservative dentistry and contributes to more effective and sustainable patient care.

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