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Review Article

Advancements in Dental Materials for Restorative Dentistry: A Focus on Bioactive Glass Ionomer Cement

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Abstract

Objective: This review explores recent advancements in dental materials, specifically focusing on bioactive glass ionomer cement (GIC) for restorative dentistry. Traditional GICs have been widely used due to their favorable properties, including chemical adhesion to dental tissues, fluoride release, and biocompatibility. However, the introduction of bioactive modifications has significantly improved their clinical performance.

Methods: A comprehensive literature search was conducted to gather information on the latest advancements in bioactive GICs, including their composition, mechanical properties, clinical applications, and long-term performance. This review synthesizes findings from recent studies published between 2018 and 2024 to present an overview of the potential benefits and limitations of bioactive GICs.

Results: Bioactive GICs have shown enhanced mechanical properties, such as increased strength and wear resistance, compared to traditional GICs. Additionally, these materials exhibit superior bioactivity, promoting remineralization and enhancing the longevity of restorations. The incorporation of bioactive components such as calcium phosphate and fluoride has improved the material's ability to interact with the surrounding dental tissues, fostering a more stable and durable bond.

Conclusion: The advancements in bioactive GICs represent a significant step forward in restorative dentistry. These materials offer promising clinical outcomes, including enhanced durability, bioactivity, and patient satisfaction. Further research is required to optimize their properties and expand their applications in various clinical scenarios.

Key words: bioactive glass ionomer cement, dental materials, restorative dentistry, fluoride release, remineralization, mechanical properties

Introduction

Restorative dentistry plays a crucial role in maintaining dental health, aesthetics, and function. The development of innovative dental materials has been pivotal in improving the quality and longevity of restorations. Among these materials, glass ionomer cement (GIC) has been extensively used due to its favorable properties, including chemical adhesion to tooth structure, fluoride release, and biocompatibility [1]. However, traditional GICs have limitations, such as lower mechanical strength and wear resistance compared to other restorative materials like composite resins and amalgam [2]. In recent years, the introduction of bioactive glass ionomer cement has revolutionized the field of restorative dentistry. These bioactive materials not only retain the beneficial properties of conventional GICs but also exhibit enhanced mechanical strength, bioactivity, and remineralization potential [3]. This article reviews the advancements in bioactive GICs, focusing on their composition, properties, and clinical applications.

Composition and Properties of Bioactive GICs

Bioactive GICs are modified versions of traditional GICs, incorporating bioactive components such as calcium phosphate, fluoride, and bioactive glass particles [4]. These modifications enhance the material's ability to interact with the surrounding dental tissues, promoting remineralization and improving the stability of the restoration.

Mechanical Properties

One of the major advancements in bioactive GICs is the improvement in mechanical properties. Traditional GICs are known for their low compressive and tensile strength, which can limit their use in load-bearing areas [5]. Bioactive GICs, however, have shown significant improvements in these properties. The addition of bioactive glass particles has been shown to increase the material's strength and wear resistance, making it more suitable for a wider range of restorative applications [6].

Recent studies have demonstrated that bioactive GICs can achieve compressive strengths of over 200 MPa, which is comparable to some composite resins [7]. Moreover, research published in 2023 showed that the incorporation of nanofillers, such as zirconia and silica nanoparticles, further enhances the mechanical properties of bioactive GICs, providing increased fracture toughness and durability [8].

Bioactivity and Remineralization

The bioactivity of a dental material refers to its ability to interact with biological tissues and induce a beneficial response [9]. Bioactive GICs have been shown to promote remineralization of the adjacent dental tissues, which is a critical factor in preventing secondary caries and enhancing the longevity of restorations [10]. The release of fluoride and calcium ions from these materials contributes to the formation of a stable bond with the tooth structure, improving the overall success rate of the restoration [11].

A 2021 study found that bioactive GICs with added calcium-silicate particles enhanced the formation of hydroxyapatite on the material's surface, leading to better integration with the natural tooth structuree[12]. Another study in 2022 reported that bioactive GICs demonstrated superior antibacterial properties, reducing the risk of recurrent caries in high-caries-risk patients [13].

Clinical Applications of Bioactive GICs

The improved properties of bioactive GICs have expanded their clinical applications in restorative dentistry. These materials are now used in a variety of procedures, including Class I, II, and V restorations, as well as in pediatric dentistry for the restoration of primary teeth [14].

Use in Class II Restorations

Class II restorations involve the repair of carious lesions on the proximal surfaces of posterior teeth, which are subject to significant occlusal forces [15]. The enhanced mechanical properties of bioactive GICs make them a suitable option for these restorations, providing a durable and long-lasting solution [16].

A 2022 randomized clinical trial compared the performance of bioactive GICs with composite resins in Class II restorations over a two-year period. The results indicated that bioactive GICs exhibited comparable survival rates and significantly reduced secondary caries incidence compared to composite resins [17].

Pediatric Dentistry

In pediatric dentistry, bioactive GICs are particularly advantageous due to their fluoride release and ease of use [18]. These materials help in preventing secondary caries and promote the remineralization of the affected tooth structure, which is crucial in young patients [19]. The bioactive properties also reduce the need for extensive cavity preparation, preserving more of the natural tooth structure [20].

A recent study published in 2023 highlighted the effectiveness of bioactive GICs in atraumatic restorative treatment (ART) for primary molars. The study concluded that bioactive GICs provided superior outcomes in terms of caries prevention and restoration longevity compared to conventional GICs [21].

Future Directions and Challenges

While the advancements in bioactive GICs are promising, there are still challenges to be addressed. The long-term clinical performance of these materials needs further investigation, particularly in high-stress areas [^22^]. Additionally, the cost of bioactive GICs is higher compared to traditional GICs, which may limit their widespread adoption in certain settings [^23^].

Recent research has focused on developing cost-effective bioactive GIC formulations by optimizing the manufacturing process and reducing the reliance on expensive raw materials [^24^]. Additionally, future research should aim to enhance the bioactivity and mechanical properties of these materials through innovative approaches, such as the incorporation of bioactive peptides and advanced nanomaterials [^25^].

Conclusion

Bioactive glass ionomer cements represent a significant advancement in restorative dentistry, offering enhanced mechanical properties, bioactivity, and clinical outcomes. These materials have the potential to improve the longevity and success of dental restorations, particularly in cases where traditional GICs may not be suitable. As research continues to evolve, bioactive GICs may become a standard in restorative dentistry, providing patients with more durable and effective treatment options.

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