

GLASS IONOMER CEMENTS: A COMPREHENSIVE REVIEW OF THEIR USES, ADVANCEMENTS, AND CLINICAL APPLICATIONS IN DENTISTRY

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Abstract

Glass ionomer cements (GICs) are versatile and widely used dental materials that have revolutionized restorative, preventive, and adhesive procedures in dentistry. Since their introduction in the early 1970s, GICs have undergone significant advancements, evolving from conventional formulations to resin-modified and bioactive glass ionomers. This review explores the unique properties of GICs, including fluoride release, chemical adhesion to tooth structures, biocompatibility, and thermal expansion, which make them suitable for a variety of clinical applications. These include their use in restorative dentistry for non-carious cervical lesions, pediatric dentistry, fissure sealants, atraumatic restorative treatment (ART), orthodontics, and as luting agents for cementation. Additionally, the article discusses the limitations of GICs, such as low tensile strength, moisture sensitivity during setting, and aesthetic shortcomings, and highlights the advancements made to address these challenges. Emerging innovations, including resin-modified GICs, bioactive GICs, and nano-modified GICs, have enhanced their mechanical properties, antibacterial activity, and aesthetics, expanding their clinical utility. This review underscores the importance of GICs in modern dentistry and their potential for future development to meet evolving clinical demands and improve patient outcomes.

Glass Ionomer Uses in Dentistry

Glass ionomer cements (GICs) are one of the most versatile and widely used materials in dentistry due to their unique properties, including adhesion to tooth structures, fluoride release, biocompatibility, and ease of use. Since their introduction in the 1970s, GICs have undergone significant advancements, expanding their applications in restorative, preventive, and adhesive procedures. This article provides a detailed

overview of GICs, including their history, clinical applications, properties, advancements, and limitations, supported by comprehensive research and literature.

Historical Development of Glass Ionomer Cements

The development of glass ionomer cements marked a significant milestone in restorative dentistry. Introduced by Wilson and Kent in 1972, GICs were designed to address the limitations of existing materials, particularly their lack of adhesion and cariostatic properties (Wilson, 1991). The combination of silicate cement and polycarboxylate cement resulted in the first generation of GICs, which exhibited fluoride release and chemical bonding to enamel and dentin. Over the years, advancements in formulation, such as the development of resin-modified glass ionomer cements (RMGICs), bioactive GICs, and high-viscosity GICs, have greatly expanded their clinical utility (Khoroushi & Keshani, 2013; Sidhu & Nicholson, 2016).

Composition and Setting Reaction

Composition

The basic components of glass ionomer cements are:

1. **Fluoroaluminosilicate Glass Powder:** This forms the backbone of the material and is responsible for fluoride release, which aids in preventing caries and remineralizing adjacent tooth structures (Baig & Fleming, 2015; Mousavinasab & Meyers, 2009).
2. **Polyacid Liquid:** Typically polyacrylic acid or its derivatives, this reacts with the glass powder to form a rigid matrix that bonds chemically to enamel and dentin (Nicholson, 2018).
3. **Water:** Essential for initiating the acid-base reaction and maintaining the material's hydration during the setting and maturation process (Tay & Lynch, 1989).

Setting Reaction

The setting of GICs is a two-stage process:

- **Initial Set:** An acid-base reaction occurs between the polyacid liquid and the glass powder, resulting in the release of calcium and aluminum ions, which form a cross-linked matrix (Nicholson, 2018). This phase is critical for the material's initial strength and adhesion.
- **Maturation Phase:** Over time, the material undergoes further cross-linking and hydration, improving its mechanical properties and reducing solubility. This process can take weeks to months (Nicholson, 2018; Sidhu & Nicholson, 2016).

Properties of Glass Ionomer Cements

GICs are renowned for their unique combination of properties that make them suitable for a variety of clinical applications. These properties include:

1. Fluoride Release and Recharge

One of the most significant advantages of GICs is their ability to release fluoride ions, which contribute to caries prevention and remineralization of adjacent enamel and dentin (Wiegand et al., 2007). This fluoride release is sustained over time, and the material can recharge fluoride from external sources, such as fluoride toothpaste or mouthwash, enhancing its long-term cariostatic effect (Mousavinasab & Meyers, 2009).

2. Adhesion to Tooth Structure

GICs chemically bond to enamel and dentin through ionic interactions, eliminating the need for an additional adhesive system. This adhesion is durable and resistant to microleakage, making GICs an excellent choice for restorations in high caries-risk patients (Wilson, 1991).

3. Biocompatibility

GICs are highly biocompatible and exhibit minimal irritation to the pulp and surrounding tissues. Their neutral pH during the setting reaction and fluoride release contribute to their excellent compatibility with oral tissues (Sidhu & Nicholson, 2016).

4. Thermal Expansion

The coefficient of thermal expansion of GICs closely matches that of natural tooth structure, reducing the risk of marginal gaps and secondary caries (Wilson, 1991).

5. Mechanical Properties

While GICs have moderate compressive strength, their tensile strength and wear resistance are limited compared to composite resins. However, advancements in formulation, such as RMGICs and high-viscosity GICs, have addressed these shortcomings (Prosser et al., 1986; Nicholson et al., 2020).

6. Aesthetic Properties

Conventional GICs are opaque and lack the translucency of composite resins. However, newer formulations, including resin-modified GICs and nano-filled GICs, have improved their aesthetic appeal, making them suitable for anterior restorations (Mount, 1990).

7. Antibacterial Properties

The fluoride release from GICs contributes to their antibacterial activity, reducing plaque formation and bacterial colonization around the restoration (Ching et al., 2018).

Clinical Applications of Glass Ionomer Cements

Glass ionomer cements are used in a variety of clinical situations due to their unique properties. Key applications include:

1. Restorative Dentistry

GICs are commonly used for restoring non-carious cervical lesions (NCCLs), root caries, and class V cavities. Their adhesion to dentin, fluoride release, and biocompatibility make them particularly effective for these indications (Francisconi et al., 2009). Additionally, GICs are used as a base or liner beneath composite restorations in the "sandwich technique," where they reduce polymerization shrinkage and enhance the restoration's longevity (Manihani et al., 2021).

2. Preventive Applications

- **Fissure Sealants:** GIC-based fissure sealants are widely used to prevent pit and fissure caries in children and high-risk populations. Their fluoride release offers additional protection against demineralization (Yengopal et al., 2009).
- **Atraumatic Restorative Treatment (ART):** GICs are the material of choice for ART procedures due to their ease of handling, fluoride release, and ability to bond to moist tooth surfaces. This minimally invasive technique is particularly useful in low-resource settings (Saber et al., 2019).

3. Pediatric Dentistry

In pediatric dentistry, GICs are used for restoring primary teeth, as liners under restorations, and as luting agents for stainless steel crowns. Their fluoride release and biocompatibility make them ideal for managing caries in children (Vaikuntam, 1997).

4. Orthodontics

GICs are used for bonding orthodontic brackets and bands due to their fluoride release, which helps prevent white spot lesions during orthodontic treatment. They are also used as luting agents for cementing orthodontic bands (Nicholson & Sidhu, 2016).

5. Luting and Cementation

GICs are used as luting agents for cementing crowns, bridges, and orthodontic bands. Resin-modified GICs are particularly effective for this purpose due to their improved strength and resistance to moisture (Hill & Lott, 2011).

6. Management of Root Caries

GICs are ideal for restoring root caries lesions in geriatric patients due to their adhesion to dentin, fluoride release, and ease of placement. They are particularly beneficial in patients with xerostomia or reduced salivary flow (Francisconi et al., 2009).

Advancements in Glass Ionomer Cements

1. Resin-Modified Glass Ionomer Cements (RMGICs)

RMGICs incorporate resin components, such as hydroxyethyl methacrylate (HEMA), to enhance their mechanical properties, aesthetics, and resistance to moisture. These materials set through both an acid-base reaction and light polymerization, offering improved handling and faster setting times (Sidhu, 2010).

2. High-Viscosity GICs

High-viscosity GICs have been developed for use in ART and other minimally invasive procedures. These materials offer improved strength, wear resistance, and fluoride release compared to conventional GICs (Nicholson et al., 2020).

3. Bioactive GICs

Bioactive GICs are designed to interact with the surrounding tissues, promoting remineralization and tissue regeneration. They release higher levels of fluoride, calcium, and phosphate ions, enhancing their cariostatic and regenerative potential (Khoroushi & Keshani, 2013).

4. Nano-Modified GICs

The incorporation of nanoparticles, such as nano-hydroxyapatite and nano-silver, has improved the mechanical, antimicrobial, and aesthetic properties of GICs. These advancements have expanded their applications in restorative and preventive dentistry (Ching et al., 2018).

Limitations of Glass Ionomer Cements

Despite their numerous advantages, GICs have certain limitations:

1. **Low Tensile Strength:** GICs are prone to fracture under high tensile forces, limiting their use in stress-bearing areas (Prosser et al., 1986).
2. **Moisture Sensitivity:** Conventional GICs are sensitive to moisture during the initial setting phase, which can compromise their properties (Wilson, 1991).
3. **Aesthetic Limitations:** Although advancements have improved the aesthetics of GICs, they still lack the translucency and color stability of composite resins (Mount, 1990).
4. **Wear Resistance:** GICs have lower wear resistance compared to composite materials, limiting their durability in high-stress areas (Nicholson et al., 2020).

Future Directions

The future of GICs lies in the development of materials with enhanced properties and broader clinical applications. Current research is focused on:

- **Improving Mechanical Properties:** Strategies such as nano-modification and fiber reinforcement aim to enhance the strength and wear resistance of GICs (Ching et al., 2018).
- **Bioactive Materials:** The development of bioactive GICs that promote tissue regeneration and remineralization is a promising area of research (Khoroushi & Keshani, 2013).
- **Antibacterial Properties:** Incorporating antimicrobial agents to reduce bacterial colonization and enhance caries prevention remains a key focus (Ching et al., 2018).

Conclusion

Glass ionomer cements are an essential material in modern dentistry, offering a unique combination of properties that make them suitable for a wide range of clinical applications. Their ability to bond chemically to tooth structure, release fluoride, and promote biocompatibility has solidified their role in restorative, preventive, and adhesive procedures. While GICs have certain limitations, advancements in material science continue to expand their capabilities and applications. As research progresses, GICs are poised to play an even greater role in improving oral health outcomes worldwide.

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