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Recent Modifications of Glass Ionomer Cement in Pediatric Dentistry: An Update

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ABSTRACT

Glass ionomer cement (GIC) is a clinically attractive dental restorative material with wide applications in pediatric patients. GIC has numerous characteristics and the unique ones are the ability to form chemical bonds to enamel and dentin through an ion-exchange mechanism, long-term fluoride release, and the ability to reabsorb fluoride ions and act as a fluoride reservoir. Glass ionomer cement and its modifications have extensive clinical use and are widely used as filling materials, tooth repair material, cavity liner and as adhesives for artificial crowns or orthodontic brackets. Clinicians dealing with pediatric patients should be aware of newer modifications of glass ionomer cement to obtain more predictable treatment results and employ them appropriately. This comprehensive review discusses clinical applications, advantages, drawbacks, modifications, and prospects of GIC and also familiarizes practitioners with the latest recommendations regarding pediatric restorative dentistry.

1. Introduction

Pediatric restorative dentistry requires widespread knowledge and a deep understanding of the restorative materials commonly available for restoration and their techniques. [1] The success of any dental restorative treatment is dependent on the physical and mechanical properties of the restorative material used. [2]

The introduction of glass ionomer cement in dentistry led to a revolution in dental materials science. Glass ionomer cement is a versatile dental restorative material. It has been utilized for various clinical applications like restorative cement, cavity liner and base, and luting agents for the last 50 years. [3].

The glass ionomer cement or glass polyalkenoate has enormous potential in caries management in children due to its inherent and unique properties of fluoride release and uptake, chemical bonding to enamel and dentin, coefficient of thermal expansion similar to natural tooth tissue, biocompatibility, and reduced moisture sensitivity in comparison to resins. [4]

Despite many advantages, conventional glass ionomer cements have some limitations like compromised mechanical properties such as low compressive strength, fragility, slow-setting, and poor wear resistance thereby limiting their use in posterior regions of the oral cavity. [3, 5, 6]

Recently many sincere attempts have been made to improve the strength of glass-ionomer cements since they were first introduced to dentistry. Still, very few of these approaches have proven to be successful. However, improved results in the physical properties of the glass ionomer cement have been obtained with modifications in both powder and/or liquid components of various commercially available GICs.

2. Objectives of restorative treatment

It is pertinent that clinicians should be aware of the objectives of restorative treatment before they proceed with any restorative treatment. The objectives of restorative treatment are as follows: [7]

a. To repair or limit the destruction caused by dental caries.
b. To preserve the remaining tooth structure.
c. To maintain pulp vitality whenever possible.

3. Conventional Glass ionomer cements

3.1 History

Glass ionomers were invented in the United Kingdom in 1969, and the earliest formulations were first reported by Wilson and Kent in 1972 [4]. They were introduced initially as ASPA or alumino-silicate-polyacrylic acid. It was a combination of silicate and polycarboxylate cement, which released fluoride. It was considered as an alternative to existing amalgam as a dental restorative material.

Glass ionomer cement was recommended for the restoration of Class V abrasion lesions but subsequently, it was developed and used for a variety of functions in restorative dentistry, including luting, lining, and basing, and as an aesthetic translucent restoration.

However, the mechanical properties of GIC introduced earlier were not comparable to amalgam and required further modifications. Henceforth two variations were developed in the 1980s and 1990s i.e. modifications with the inclusion of metal and light-cured liquid resin components. [4]

3.2 Composition and setting reaction of cement

Conventionally GICs are mainly comprised of two main components: a powder of fluoro-aluminosilicate glass and an aqueous solution containing polyalkenoic acids which are carboxylic acids. [8] The main constituent of the aqueous component is polyacrylic acid. However, maleic and itaconic acids were added to the solution for easier manipulation. [9] Tartaric acid is added to the liquid component to further enhance the handling properties and regulate working time. [8, 10] The barium and strontium salts are added to enhance radiopacity.

Conventional glass ionomer cement are set via an acid-base reaction between the polyacrylic acid and fluoro-aluminosilicate glass particles [8.11]. Initially, a gelation reaction occurs between the components, [12] followed by the binding of the unreacted glass particles that act as fillers in the silica gel matrix. The cross-linking of the polymeric chains of the polyacid component results in a hardening process with calcium and aluminum ions present in the powder component. The setting time of GICs is 2–3 min, but the complete chemical reaction for hardening may occur during the next 48 h [8, 10]. The sodium and fluoride ions remain unreacted within the matrix. The final “maturation” of the cement takes several months while the aluminum ions may be released slowly and the binding of water by the acid and glass takes place [13].

3.3 Clinical applications

Glass ionomer cements have extensive clinical applications. The unique properties of GIC that increase its clinical applications and make it distinguishable from various other restorative materials are its chemistry that causes self-adhesion to dental hard tissues, effective fluoride-releasing and recharging, and ability to tolerate moisture.

Glass ionomers have been the mainstay of pediatric restorative dentistry since the early 1970’s. Their different formulations, diverse clinical uses, and advantages have made them essential dental materials in routine dental practice for pediatric patients. Some of the important clinical applications of GIC are as follows:

1. Glass ionomers are used as pit and fissure sealants.[4]
2. GICs are used as luting agents. [4]
3. GIC is used as a cavity liner or base.[4]
4. GIC is used for class I restorations in primary teeth, class II restorations in primary molars, small class III restorations, and class V caries lesions.[4]
5. GIC are the materials of choice for the cementation of stainless steel crowns and orthodontic bands.[4]
6. GIC can be used for orthodontic bracket adhesive.[4]
7. GIC can be used for caries control as provisional restorations.[14]
8. Glass ionomer cement is useful for small cores and buildup after pulp treatment.[14]
9. Glass inomer can be used for dentin replacement and sandwich technique.[4]

10. Glass ionomer materials are used for the repair of defective margins of previous restorations.[14]
11. Glass ionomers are used for the repair of endodontic root perforations.[14]
12. Glass ionomer cement is used for the repair of external root resorption defects.[14]
13. Glass ionomer cement is used to block out undercuts in the crown and onlay preparations.[14]
14. Traditional glass ionomer materials are used in the ART technique (atraumatic restorative treatment).[4, 14]

3.4 Advantages

Several advantages are associated with the use of glass ionomer cement in pediatric restorative dentistry. Some of them are as follows:

1. GIC forms strong chemical bonds with dental hard tissues i.e. enamel and dentine. [15]
2. GIC forms strong bonds with metals in clinical use i.e. orthodontic brackets. [15]
3. GIC adheres to prepared tooth structure in the moist environment of the oral cavity. [16, 17]
4. GIC is used to seal marginal gaps between the tooth and restoration. [16, 17]
5. GIC releases fluorides continuously and has a desirable caries inhibitory effect on adjacent tooth surfaces. [18]
6. GIC has been reported to have fewer allergic reactions and lower cytotoxic and mutagenic effects than ceramics, gold alloys, composites, and resin-modified GIC as an alternative restorative material to amalgam. [19]
7. GIC is considered an alternative sealing material and replaces mineral trioxide aggregate as it causes reduced crown discoloration.[20]
8. GIC causes enhanced fibroblast proliferation and attachment after reinforcement with hydroxyapatite. [21]
9. GIC buffers bacterial acidic byproducts enhancing the pH of the medium and inhibiting the growth of S. sanguinis and S. mutans. [22]
10. GIC bonds orthodontic brackets to the surface of a tooth resulting in lesser white spot formation on enamel in comparison with di-acrylate orthodontic cements. [23]

3.5 Drawbacks

There are some drawbacks associated with the use of glass ionomer cement. The undesirable properties of GIC are as follows:

1. Use of GIC is limited due to compromised mechanical properties. Poor mechanical properties i.e. low resistance to fracture, hardness, and resistance to wear reduce its clinical use as a restorative material in the molar regions exposed to heavy masticatory stresses. [24]
2. GIC has low flexural strength.[25, 26]
3. GIC has low compressive strength.
4. GIC is susceptible to moisture contamination during the initial setting process.
5. GIC lacks color stability. [25]
6. GIC has poor polishability.
7. GIC has reduced esthetic properties.[24]
8. GIC is susceptible to cohesive cracking in the bulk, near the interphase with tooth tissue. [26]
9. The GIC-dentine interphase varies with time possibly due to interactions between the tooth, restorative material, and water as revealed by dye penetration. [26]
10. GIC is technique-sensitive.

4. Modifications Of Glass Ionomer Cement:

4.1 Metal-reinforced glass ionomer cement- It was introduced in 1977 as an attempt to further enhance the mechanical properties of conventional GIC. The aqueous component was similar to conventional GICs and the powder comprised of a mixture of conventional powder with amalgam alloy or silver particles sintered with the glass. [14] The addition of silver amalgam alloy powder to GIC enhances its strength and radiopacity. [27] However, due to low viscosity and poor esthetics, metal-reinforced GICs have limited clinical application.[28]

4.2 High viscosity glass ionomer cements- Its high-viscosity type GICs also known as condensable or viscous GICs were introduced in an attempt to overcome the issues related to low viscosity of GICs. It has become the material of choice for atraumatic restorative treatment (ART) and interim therapeutic restorations (ITR). [29] They comprise finer glass particles and high molecular weight anhydrous polyacrylic acids and have a higher powder and liquid mixing ratio with a faster setting time. [30, 31] The high-viscosity glass ionomer is

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considered to be a viable option for restoring carious dentin lesions in single surfaces in vital primary molars.[32]

4.3 Resin-modified glass ionomer cement- Resin-modified glass ionomer cement (RMGIC) is composed of resin added to the GIC thereby improving the shortcomings of GIC. Due to the addition of the resin component, the binding strength, tensile strength, and compressive strength of the conventional GICs are maintained and their solubility in an aqueous environment is lowered. [4, 33]. Ultraviolet irradiation resulting in monomer polymerization, follows an acid-base reaction, which improves mechanical strength and increases its clinical application as a dental restorative material. [34] They release fluoride at a rate similar to glass ionomer cement. [35] RMGICs have shown to have enhanced mechanical strength but reduced biocompatibility in comparison to GIC, because 2-hydroxyethyl methacrylate (HEMA) monomer escapes from RMGIC mainly during the first 24 hours [36]. HEMA penetrates the dentinal surface [37] and is considered to be toxic to pulp cells. [38]

4.4 Compomer or polyacid-modified composite resins- They were introduced in the middle of the 1990's and showed incredible developments mainly focusing on improved mechanical properties and reduced polymerization shrinkage. They are mainly used as esthetic materials for oral rehabilitation. [39] It combined the esthetics of synthetic resins and fluoride releasing and adhesive qualities of existing glass ionomer cement. [39] They can be used as an alternative restorative material for primary dentition particularly in Class I and Class II restorations. [7]

4.5 Giomer- Giomers have been recently introduced as fluoride-releasing dental restorative materials, combining good mechanical resistance and esthetics. [40] Glass ionomer particles that have been precured and pulverized are included as an extra dispersion phase within the compomer. Giomers have incorporated the fluoride-releasing properties of glass ionomers and the mechanical and esthetic properties of composite resins. They have high flexibility and can be placed in areas with high functional stress. [40] They have a wide range of clinical applications and are preferred for restoring cervical non-carious lesions. [40] However, marginal gaps and microleakage are increased in giomers if they are associated with hemostatic agents. [41] Giomers are affected by dietary habits and some dental procedures such as acidic beverage consumption, and teeth whitening procedures. [40]

4.6 Zirconia-reinforced glass ionomer- Zirconia-reinforced restorative glass ionomer was introduced for pediatric patients `to overcome the drawbacks of tooth-colored restorative materials. It combines and retains the desirable aspects of both amalgam and conventional glass ionomer cement. [14] The powder consists of fluoroaluminosilicate glass and zirconium oxide with high levels of zirconia [14] and the liquid consists of polyacrylic acid solution and tartaric acid. The glass component is subjected to micronization to obtain optimum particle size. [42] It is indicated for use in Class I and II cavities in deciduous teeth, class I and II restoration in selected permanent teeth, and repair of amalgam-restored teeth after either tooth or restoration has fractured, in all classes of cavities where radiopacity is a prime requirement, core build-up, and repair of crown margins.

4.7 Glass carbomer cement or hydroxyapatite infiltered GIC- It's a new GIC-based material that has been developed and claims to have enhanced chemical-mechanical properties with the application of heat with an LED light curing unit. [43] The addition of hydroxyapatite has been beneficial in clinical dentistry due to its radiopacity. [44] Hydroxyapatite has extensive applications in dentistry as compared to commercial modifiers due to enhanced strength, polishability, improved biological activity, and esthetics. Glass carbomers are preferable as inlay restoration material because its structure holds the stress inside, i.e. less stress is transferred through the tooth structure. The glass carbomer inlay is especially applicable when the supportive tooth structure is weak. [43]

4.8 Glass ionomer cement containing bioactive glass- Bioactive glass (BAG) has been added to GIC to enhance its bioactivity and induce the regeneration of the tooth. [45] It was introduced by Hench in 1969 as 45S5 Bioglass and is comprised of amorphous silicate-based materials that are biocompatible with humans and can stimulate new bone growth with time. [46] BAG was initially used as a biomaterial for the replacement of osseous tissues as it binds strongly to bone via the formation of hydroxyapatite, and in periodontal diseases in bony defects [46]. It has recently been used in the treatment of dentinal hypersensitivity [47]. The addition of BAG particles to GIC reduces compressive strength and the modulus of elasticity suggesting loose attachment of the BAG particles with the GIC matrix. [48]

4.9 Nanomodified glass ionomers- Conventional GICs and resin-modified GICs can be nano-modified by the inclusion of nano-sized fillers to RMGICs, decreasing the size of the glass particles, and also by the addition of nano-sized bioceramics to the glass powder. [49] The insertion of nano-sized apatite crystals has enhanced the mechanical properties of conventional GICs along with fluoride release and bioactivity. [49] However, the bonding properties of nano-filled RMGIC are questionable and require further improvements. It has been shown that fluoride release from nano-RMGICs and conventional RMGICs are comparable with each other but still significantly reduced than conventional GICs. [50, 51] Hence, more trials are essential to establish the clinical status of nano-modified GICs.

5. Latest Recommendations for Glass Ionomer Cements

The latest recommendations by the American Academy of Pediatric Dentistry (AAPD) [7] and the International Association of Pediatric Dentistry (IAPD) [29] are of vital importance and should be considered by pediatric dentists and clinicians while devising the restorative treatment plan for pediatric patients. They are as follows:

1. GIC is mainly recommended for Class I restorations in primary teeth [7] and permanent posterior teeth. [29]
2. RMGICs may be used for Class I restorations, and in Class II restorations in primary teeth. [7]
3. High-viscosity glass ionomer cement may be used for atraumatic restorative treatment (ART) or interim therapeutic restorations (ITR) as an alternative to conventional treatment in primary dentition.[29]

6. Future Directions and Research Gaps

Further research in material science should be aimed towards improving the strength, biocompatibility, anti-cariogenic potential, operative time, and esthetics of newer modifications of glass ionomer cement, and retaining the inherent qualities such as fluoride-releasing abilities, bonding to the tooth structure, ease of use, and cost-effectiveness.

Future research studies recommended in this direction are as follows:

1. Smart bioactive restorative materials are garnering considerable interest in dentistry due to their capability for dentin remineralization. The scope of these novel materials in pediatric restorative dentistry is immense and an important perspective that needs to be explored.
2. Future research needs to focus on nanotechnology and develop newer formulations of GIC with nano-sized glass filler particles for enhanced biocompatibility.
3. Modification of resin-modified glass ionomer cement with superior biocompatibility will be desirable in the future for wider clinical applications.
4. Efforts should be made to augment the mineral-inducing potential of resin-modified GIC by the inclusion of nano-sized hydroxyapatite filler particles.
5. Researchers should focus on incorporating antibacterial agents into GIC for the prevention of secondary caries.
6. Further research investigating the effect of SDF application on the bond strength of glass ionomers to dentin is the need of the hour.
7. Materials research scientists should focus on developing restorative materials capable of inducing dentinal bridges, reducing cytotoxic effects, and achieving more durable restorations with high-bond strength in pediatric patients while maintaining esthetics.

Therefore, the search for a novel modification of glass ionomer cement is crucial for improving performance in pediatric dental practice. The material research scientist and the clinicians need to collaborate and develop dental materials with enhanced adhesion and biocompatibility. With the advent of newer technological developments and improved research facilities in material science, it will be possible to accomplish the above-mentioned research studies shortly for GIC-based dental materials.

7. Conclusion:

Glass ionomer cement is a multipurpose dental restorative material that has been shown to have extensive clinical use in children due to its inherent properties like fluoride release, good adhesion, long-term caries inhibitory effect, reduced solubility, biocompatibility, ease of use, cost-effectiveness. Fluoride release from glass ionomer restorations can be sustained by recharging through topical fluoride applications and this unique property makes them clinically significant. However, despite many advantages, their use is restricted due to compromised mechanical and esthetic properties. With time, newer formulations of glass ionomer cement were desired to overcome the shortcomings of existing restorative materials for providing better efficiency and enhanced properties. However, further long-term research studies along with clinical trials are essential to ascertain the mechanical and biological properties of these materials and validate their clinical efficacy and durability in the oral cavity of pediatric patients.

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