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Glass Ionomer Cement: From Past to Present

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Abstract

The ideal requisite of a dental material is its ability to bond to enamel and dentine, and in this context, glass ionomer cement is one of the ideal choice of the dentists. The positive characteristics of the GICs include chemical adhesion to enamel and dentin in the presence of moisture, resistance to microleakage, good marginal integrity, dimensional stability at high humidity, coefficient of thermal expansion similar to tooth structure, biocompatibility, fluoride release, recharge ability with fluoride, and less shrinkage than resins upon setting with no free monomer being released. The latter material has improved esthetics, resistance to moisture and greater toughness. The aim of present review of literature is to discuss glass ionomer cement from past to present in brief.

Keywords: Glass Ionomer Cement, GIC, RMGIC

Introduction

"Necessity is the mother of invention". It was the late 1960's. History had already witnessed a host of restorative materials including amalgam, composite, cast alloys etc. but all had fallen short of that certain perfection that the dental researches and clinician yearned for that of a material that would be esthetic, adhesive, biocompatible, anticariogenic and relatively economical. It was during this time that cement came into the picture and created quite a sensation by not only possessing a majority of the desirable properties but also providing much scope for modification and improvement. This was the Glass Ionomer Cement.[1]

Glass ionomer cement a versatile material in dentistry, used ever since 1971.But its use resurged recently as a smart material. A material with two basic types ,the older, self-hardening cement which sets by an acid base neutralization reaction to give a relatively fragile material, and the latest modified material which sets partly by polymerisation and partly by neutralization. The latter material has improved esthetics, resistance to moisture and greater toughness. Recent studies have evaluated various combinations in glass ionomer structure, which will enhance the bio compatibility, strength; regeneration capacity of Glass Ionomer Cement. [2] The aim of present review of literature is to discuss glass ionomer cement from past to present in brief.

Evolution of GIC: In 1873, Thomas Fletcher of United Kingdom developed silicate cements, as an anterior restorative material, which was translucent and released fluoride, but was weak, not adhesive. This was followed by a combination of similar glasses and poly acids to produce GIC in 1972 by Wilson &Kent (also known as Glass Polyalkenoate Cement).[3,4] Jurecic in 1973 found that gelation of concentrated polyacrylic acid solution on standing due to intra change hydrogen bonding, could be avoided by the use of acrylic acid, it aconic acid copolymers. The use of this principle allowed GIC to be used as a restorative material. Many years passed by before a clinically acceptable GIC was commercially produced, although GIC was first patented in 1969, it was in 1974 that the first commercial brand ASPA was available. Since then commercial companies have made significant improvements to basic GIC formulations.[2,5]

Conventional glass-ionomer cements have a large number of applications in dentistry. They are biocompatible with the dental pulp to some extent. GI is predominantly used as cements in dentistry; however, they have some disadvantages, the most important of which is lack of adequate strength and toughness. In an attempt to improve the mechanical properties of the conventional GI various modifications has been done.

Clinical classification of GIC[6]

1. Type I GICs are the luting cements, characterized by low film thickness and rapid set. Type I ionomers are indicated for the cementation of inlays, crowns, fixed partial dentures, orthodontic appliances, and endodontic filling.
2. Type II GICs are ionomers indicated for restorations, presenting particles larger than those of type I, with subtypes 1 and 2.

- Type II–1 GICs are esthetic cements (available in both conventional and resin-modified presentations)
- Type II–2 GICs are “reinforced” (however, despite their description, are not necessarily stronger than type II–1 products). However, they are more wear-resistant.

3. Type III GICs are the lining cements and fissure sealants, characterized by low viscosity and rapid set also known as bond and lining or F.

Composition of GIC

There are three essential ingredients to glass-ionomer cement, namely polymeric water-soluble acid, basic (ion-leachable) glass, and water.[7]

Glass: It is vital that glasses for ionomer cements should be basic, i.e., capable of reacting with an acid to form a salt. In principle, several different glass compositions can be prepared that fulfill this requirement but in practice, only alumino-silicate glasses, with fluoride and phosphate additions, are fully satisfactory. Commercial glasses for glass-ionomer cements are typically based on calcium compounds, with some extra sodium.[8]

Polymeric acid: The polymers used in glass-ionomer cements are polyalkenoic acids, either homo polymer poly (acrylic acid) or the 2:1 copolymer of acrylic acid and maleic acid.[8]

Water: Water is the third essential component of the glass-ionomer cement. Several roles have been identified for water. It is the solvent for the polymeric acid, it allows the polymer to act as an acid by promoting proton release, it is the medium in which the setting reaction takes place, and lastly, it is a component of the set cement. Incorporation of water with glass ionomers is associated with increases in the translucency of the glass-ionomer cement.[9]

Conventional GIC: Glass ionomers are derived from organic acids and a glass component, and are referred to as acid-base reaction cements. Basically an acid soluble calcium alumino silicate glass containing fluoride, it is formed by fusing silica, alumina, calcium fluoride, metal oxides and phosphates at 1100-1500° C & then pouring the melt into water. In anhydrous cements, the liquid acid component was freeze-dried (dehydrated) and incorporated into the powder. It is mixed with distilled water or in an aqueous solution of tartaric acid, which accelerate the setting reaction. It is also available as powder and liquid. The glass components and the fluoride are inside the powder and the acid components inside the liquid.[10,11]

Recent Modification of GIC

This basic composition has been modified for the new development of GIC. Glass can be modified by several ways to enhance the physical properties of the cement:[2]

- Ca can be replaced by Sr, Ba or La to give a radio-opaque glass.
- Corundum, Rutile disperse phases can be added to increase flexural strength.
- Metals, resins, fibers are added to increase the strength.

Resin modified glass ionomer cement: Resin modified glass ionomer cement was designed to overcome the problem of moisture sensitivity and lack of command cure of conventional glass ionomers. It produces favourable physical properties similar to those of resin composites while maintaining the basic features of the conventional glass ionomer cement.

RMGIC contain the same essential components as conventional glass-ionomers (basic glass powder, water, polyacid), but also include a monomer component and associated initiator system. The monomer is typically 2-hydroxyethyl methacrylate, HEMA, and the initiator is camphorquinone. Resin-modified glass-ionomers set by the twin processes of neutralization (acid-base reaction) and addition polymerization, and the resulting material has a complicated structure based on the combined products of these two reactions. [12, 13]

Compomers: Shortly after the introduction of RMGICs, “compomers” were introduced to the market. They were marketed as a new class of dental materials that would provide the combined benefits of composites (the “comp” in their name) and glass ionomers (“omer”).

These materials have a superior esthetic value along with the fluoride-release capabilities of GI. Compomers are in fact light-polymerized composite resin restoratives, modified to contain ion-leachable glass particles and anhydrous (freeze-dried) polyalkenoic acid. The compomers have relatively lower rates of fluoride release due to the presence of the resin bonding agents required for compomer tooth adhesion. Mechanical properties of compomers are inferior to those of conventional composite resins, thus limiting their use for restoration of noncarious cervical lesions.[15-17]

Zirconomer: Zirconia reinforced GIC (Zirconomer) is a recent modification of GIC introduced by SHOFU in which zirconia is incorporated. They are also known as white amalgam. Zirconia is a high-strength ceramic.[18,19]

The inclusion of zirconia fillers in the glass component of Zirconomer increases the structural integrity of the restoration. It imparts superior mechanical properties for the restoration of posterior load bearing areas where the conventional restorative of choice is amalgam. Properties like outstanding strength, durability and sustained fluoride protection deems it ideal for permanent posterior restoration in patients with high caries incidence as well as cases where strong structural cores and bases are required.[20]

Zirconomer is used in restoring Class I & II cavities. It can be used as a structural base in sandwich restorations, all classes of cavities where radiopacity is a prime requirement, as a core build-up under indirect restorations, on root surfaces where overdentures rest, in pediatric and geriatric restorations, as a long-term temporary replacement for fractured cusps, fractured amalgam restoration, also suitable for ART techniques.[18]

Condensable/self-hardening GIC: These are basically, purely chemically activated resin-modified glass ionomer cements (RMGICs) with no light activation at all. It is used mainly in pediatric dentistry for cementation of stainless steel crowns, space maintainers, bands, and brackets. Advantages over conventional GIC"s are packable + condensable, easy placement, non sticky, rapid finishing can be carried out, improved wear resistance and solubility in oral fluids is very low.[21]

Low viscosity/flowable GIC: It is mainly used as lining, pit and fissure sealing, endodontic sealers, sealing of hypersensitive cervical areas, and it has increased flow.[21]

Giomer: Giomer is a unique class of restorative material. It has been introduced as the true hybridization of glass ionomer and composite resin and has the distinguishing feature of a stable surface prereacted glass ionomer (S-PRG), which is coated with an ionomer lining incorporated in a resin matrix. This arrangement aids in the protection of the glass core from moisture, adding to long-standing aesthetics, durability, physical and handling properties of composite resins with fluoride release, and recharge property like the GI cement.[22]

Amalgomer: This (ceramic reinforced glass ionomer cement) is introduced into restorative dentistry to match the strength and durability of dental amalgam. It contains a high level of fluoride with good aesthetics and it requires only minimal cavity preparation. It bonds to tooth structure and has excellent biocompatibility.[23]

Hainomers: These are newer bioactive materials developed by adding hydroxyapatite within glass ionomer powder. They are mainly being used as bone cements in oral maxillofacial surgery and can be used as retrograde filling material. They bond directly to bone and affect its growth and development.[21]

Bioactive glass impregnated GIC: Developed by Hench and colleagues in 1973, this material considers the fact that on acid dissolution of glass, there is formation of a layer rich in calcium and phosphate around the glass, such a glass can form intimate bioactive bonds with bone cells and get fully integrated with the bone. It is used in retrograde filling material, for perforation repair, augmentation of alveolar ridges in edentulous ridges, implant cementation, and infra-bony pocket correction.[24]

Zinc impregnated GIC: The presence of aluminum in the glass phase of all commercially available GICs has restricted their widespread use in orthopedics, as aluminum is believed to cause defective bone mineralization, inhibiting the formation of a stable bond between GIC and bone. However, the aluminum ion plays an integral role in the setting process of a GIC, and its absence can hinder cement formation. Fortunately, zinc oxide (ZnO) can act as both a network modifying oxide and an intermediate oxide in a similar fashion to alumina.[25]

Fiber reinforced GIC: To improve the depth of cure, reduced polymerization shrinkage, improved wear resistance, and increase in flexural strength of GIC, alumina fibers are mixed with glass powder. This technology is called the polymeric rigid inorganic matrix material, which involves incorporation of a continuous network/scaffold of alumina and silicon dioxide ceramic fibers.[21]

Calcium aluminate GIC: A hybrid product with a composition between that of calcium aluminate and GIC, it is designed for luting fixed prosthesis. The calcium aluminate contributes to a basic pH during curing, reduction in microleakage, excellent biocompatibility, and long-term stability and strength.[21]

CPP – ACP Containing GIC: The goal of addition of CPP-ACP into GIC is to produce a material with improved biological properties while retaining acceptable physical and working properties. Mazzaoui et al. incorporated 1.56% w/w CPP-ACP into GIC and investigated cements physical and chemical properties and found that Incorporation of CPP-ACP into the GIC significantly increased microtensile bond strength (33%) and compressive strength (23%) and significantly enhanced the release of calcium, phosphate, and fluoride ions at neutral and acidic pH.[26]

Glass Carbomer: This is a novel commercial material of the glass-ionomer type, which has enhanced bioactivity compared with conventional glass-ionomer cement. It is manufactured by GCP Dental of the Netherlands. The glass used in glass carbomer contains strontium, and also high amounts of silicon, as well as a small amount of calcium. It is relatively high in silicon compared with the glasses used in the well-established brands of conventional glass ionomer Fuji IX and Ketac Molar, but it contains comparable amounts of Aluminium, phosphorus and fluoride.[27, 28]

Chlorhexidine impregnated GIC: Duque C et al. (2017) evaluated the effect of inclusion of CHX in GIC and found that the CHX improves in vitro antimicrobial/antibiofilm action, without causing detrimental effects on cytotoxicity, mechanical and fluoride release properties of the material. Clinical follow-up demonstrated that ART restoration with GIC+CHX had a similar survival rate and better antimicrobial performance at the 7th day when compared to conventional GIC. GIC containing chlorhexidine could be an alternative to traditional GIC indicated to ART, for it provides an additional antimicrobial effect that is interesting for children with high mutans streptococci counts during the initial adaptive phase of treatment.

Chitosan modified GIC: It was reported in 2007 that the flexural strength of a commercial GIC was significantly improved by the addition of chitosan. Moreover, in the presence of chitosan, it was found that release of fluoride ions from GIC was catalyzed. Chitosan is a partially or completely deacetylated derivative of chitin. Researchers have demonstrated its great potential for a wide range of uses due to its versatile chemical and physical properties like biodegradability, biocompatibility, antimicrobial activity, nontoxicity.[30]

Discussion

Glass-ionomer cements are mainstream restorative materials that are bioactive and have a wide range of uses, such as lining, bonding, sealing, luting or restoring a tooth.

The salient features of the GIC, include adhesive properties, marginal adaptation, biocompatibility, moisture sensitivity, fluoride release and strength. Since its introduction in dentistry, several modifications have been introduced with the purpose of enhancing their mechanical properties.[10] The newer generation of GI retained the most desirable qualities of conventional versions, namely fluoride release, ion exchange adhesion to conditioned enamel and dentin, and low interfacial shrinkage stress. With the introduction of the new generation of GICs, there have been significant improvements to GICs that allow them to be used for routine restorations and provisional restorations..[31, 32]

Conclusion

Since the development of glass ionomer cements nearly three decades ago, these materials have found increasing applications in clinical dentistry. With the introduction of newer generations, the GICs are getting wider applications. There is further scope for improving the properties of these materials, making them even more efficient to compete with the other restorative materials in terms of strength and esthetics.

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