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NEWER ADVANCES IN GLASS IONOMER CEMENT: A REVIEW

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ABSTRACT Glass Ionomer Cement has its origin in the mid twentieth century, as a biocompatible, cost effective, tooth coloured restorative material and is in constant evolution. Considering its unique ability to bond to the tooth structure without the use of any bonding agent coupled with fluoride releasing potential, GIC has gradually emerged as material of choice for various applications in the field of dentistry. This article elaborates on the composition of GIC and its recent advances which have markedly improved their properties for optimal incorporation of these materials into various restorative treatment procedures.

KEYWORDS: Glass Ionomer Cements (GIC), Advances in GIC, Fluoride release.

INTRODUCTION

"Necessity is the mother of all inventions". It was in the late 1960's, history had already witnessed a host of restorative materials including dental amalgam, composites, but all had fallen short of that certain perfection that the dental researchers and clinicians yearned for, that of a material which is tooth coloured,esthetic, adhesive, biocompatible, anticariogenic and relatively economical.[1]

Glass ionomer cements (GIC) have a large number of applications in dentistry. One of the advantages of GIC compared to other tooth coloured restorative materials is that they can be placed in prepared cavities without any need for bonding agents.[2]

Glass Ionomer Cement came as a breakthrough and created quite a sensation, by not only possessing majority of desirable properties, but also with its various advances.[3]This article is an attempt to review various newer advances of Glass Ionomer Cement like, Bioactive GIC, Fibre Reinforced GIC, Giomers, Amalgomers, Chlorhexidine impregnated GIC, CPP-ACP containing GIC, Zirconomer, Nano Bioceramic Modified GIC, Calcium aluminate GIC.[4]

Definition

GIC consists of a basic glass and an acidic polymer which sets by an acid-base reaction between these components.[1]

GIC was originally invented by Wilson and Kent in 1972.[5] Other Names of GIC[5]: Glass Polyalkenoate Cement, Alimino Silicate PolyAcrylate (ASPA), Dentin Substitute, Man-Made Dentine, Artificial Dentin. ANSI/ADA Sp. No: 96.[6]

First commercial glass ionomer cement was manufactured by De Trey Company & Caulk in the United States, known as ASPA (AluminoSilicate PolyAcrylate). It consists of ion leachable aluminosilicate glass and an aqueous solution of a copolymer of acrylic acid.

Composition

Glass ionomer cement is a combination of Glass powder and Ionomer acid as liquid.[3,7]

GIC Powder

The powder is a acid-soluble calcium fluoroalumino-silicate glass similar to that of silicate but with a higher alumina-silicate ratio. Fluoride portion acts as a "ceramic flux". Lanthanum, Strontium barium or zinc oxide additives provide radiopacity, these components are combined and fused (at temperatures 1100 to 1500^{0}C) with a fluoride flux which serves to reduce their fusion temperature. The molten glass is then poured onto a steel tray. To fragment it, the mass is plunged into water and the resulting fragments are then crushed, milled and powdered. The particles are then sieved to separate them according to size. Particle size ranges from 20 microns for luting forms to 50 microns for restorative products. For cementation purposes, a glass particle size of 13 to 19 microns is optimal. The powder contains fluoride in a 10% to 23% concentration resulting from the calcium fluoride, sodium fluoride and aluminium fluoride. The fluoride flux also contributes to the final fluoride concentration.

I.Powder: Silica - 41.9% Alumina - 28.6% Aluminum fluoride - 1.6% Calcium fluoride - 15.7% Sodium fluoride - 9.3% Aluminum phosphate - 3.8
II.Liquid Polyacrylic acid (Itaconic acid,maleic acid) - 40- 55% Tartaric acid - 6-15% Water - 30%

Original liquid for GIC was aqueous solution of 40 to 50% polyacrylic acid . It was quite viscous with a tendency to gel over time. To overcome this, liquid was modified by adding itaconic and tri-carboxylic acids. Addition of these acids causes:

- Decrease in viscosity
- Increase in reactivity between powder and liquid
- Reduced gelation of liquid.

Newer advances of Glass Ionomer Cement

Conventional GIC lacks in sufficient strength and toughness, which has attracted focused research in order to improve the mechanical properties of conventional GIC, Resin-modified glass-ionomers(RMGI) were introduced, which contains hydrophilic monomers and polymers like HEMA and they have higher flexural strength compared to conventional GIC.[8] Recently, a new restorative concept is marketed, a system application consisting of a posterior restorative GIC combined with a novel nanofilled coating material, the compounded nanofillers protect against the abrasive wear and the coating acts as a glaze, enhancing its esthetic properties.[9,10] Hybridization of GIC and Composites using pre-reacted glass ionomer technology, 'Giomer' was developed by Shofu.[9] Newer bioreactive material 'HAINOMER' was developed using hydroxyappatite with glass powder and have shown a promising future during initial clinical trials as retrograde filling material. More recently, Zirconia containing GIC, Proline containing GIC, CPP-ACP GIC are synthetically manufactured to enhance the remineralization potential and aimed at improving the strength.[5]

(a) Bioactive glass (BAG)

Larry Hench etal[10] invented the first Bioglass at the University of Florida. It takes into account the fact that on acid dissolution of glass, their is formation of a layer rich in Ca^+ and PO_4^+ ions around the glass, such a glass can form intimate bioactive bonds with bone cells and gets fully integrated with the bone.[2]

Because of its good bioavailability, osteo-conductivity and biodegradability, BAG has been used as a restorative material for more than a decade and its degradation products stimulate for the production of growth factors, cell proliferation and activate the gene expression of osteoblasts, also helps in treating dentine hypersensitivity and promoting enamel remineralisation.[11]

BAG bonds to both hard and soft tissues.[11] Hydrated silica formed on the surface of BAG includes nucleation of the apatite. Hence, it was confirmed that pure silica gel prepared by hydrolysis and poly-condensation of tetraethoxysilane in aqueous solution containing polyethylene glycol induces the formation of the apatite layer on its surface, when the gel is leaked in stimulated body fluid. A material is said to be bioactive, if it gives an appropriate biological response and results in the formation of a bond between material and tissue in addition to remineralisation.[10]

BAG has antibacterial effect as it raises the pH of aqueous solutions. Combination of bioactive nano silica with dental cement improves its biocompatibility, which is helpful to overcome marginal gap formation which is a major disadvantage of many dental cements.[11]

(b) Casein Phosphopeptide Amorphous Calcium Phosphate Complex (CPP – ACP):

ACP is the initial solid phase that precipitates from a highly supersaturated calcium phosphate solution and converts readily into stable crystalline phase such as osteocalcium phosphate. Morphologically, Structurally and X -ray- diffraction patterns are typical for non crystalline substances with short range periodic regularity. ACP has shown to have better in-vivo osteo-conductivity than hydroxyapatite, better biodegradability than tricalcium phosphate. These properties make ACP widely used in restorative dentistry. It was first developed by Aaron S Posener in mid 1960's. In conjunction with CPP it is creating wonders with GIC as restorative material.[3]

CPP is a milk product which helps in remineralisation and helps in the prevention of dental caries. CPP kills streptococcus mutans bacteria and it binds to calcium and phosphate ions of tooth structure and also to CPP. CPP forms nanoclusters with ACP and makes a pool of Calcium and phosphate ions which maintains the super saturation of saliva. Mazzoui etal[12] in 2003, used CPP-ACP with fluoride and demonstrated a synergistic remineralisation potential. It can be delivered using tooth mousse, chewing gums, mouth rinses, toothpastes and GIC. It has the ability to counteract acid action.[13]

Incorporation of 1.56% CPP-ACP into the GIC significantly increases its tensile strength, compressive strength and significantly enhances the release of calcium, phosphate, and fluoride ions at neutral and acidic pH.[13]

(c) Reinforced GIC

Incorporation of alumina fibres into the glass powder of GIC helps in improving the flexural strength of GIC. This technology is called as Polymeric Rigid Inorganic Matrix Material. It is a light-cured GIC. It involves the incorporation of continuous network / scaffold of alumina and SiO2 ceramic fibres into the powder. This increases the depth of cure, reduces the polymerization shrinkage, improves wear resistance and increases the flexural strength of the set cement.[2]

Recently, nano particles such as TiO_2, nano tubes, nano fluroapatites are incorporated into GIC matrix to enhance their mechanical strength. This allows a highly packed density of particles within the GIC matrix. An acid-base reaction takes place during the setting procedure, which forms a salt hydrogel, acting as a bonding element in matrix within which glass acts as a reinforcing component. Thus, Al_2O_3 and TiO_2 nano powders can be used to manufacture reinforced GIC.[3]

(d) Zirconomer

A new class of restorative GIC with increased strength and durability is developed, it shows strength of amalgam, so it is also called white amalgam. The inclusion of zirconia fillers in the glass component of zirconomer reinforces the structural integrity of the restorative material & imparts higher mechanical properties for the restoration of posterior teeth and the protective and esthetics of GIC, completely eliminating mercury hazards.[14] The polyalkenoic acid and other components have been specially processed to impart superior strength. Easy mixing and adequate working time enhances its utilization as a restorative material. Combination of outstanding strength, durability and sustained fluoride release, deems it as the ideal restorative material for posterior teeth especially in patients with high caries incidence. Easy mixing and adequate working time enchances its utilization as a future restorative material of choice.[3]

(e) Chlorhexidine impregnated GIC

High viscosity GIC is the material of choice for atraumatic restorative treatment, since GIC adheres chemically to the tooth structure and releases fluoride, which contributes to the reduction in amount of residual bacteria in restored teeth but also favors in remineralisation of tooth.[15]GIC releases approximately 10 ppm of fluoride during the 1st 48 hrs following its placement in the prepared cavity.[16] In order to improve the antibacterial characteristics Chlorhexidine digluconate can be added to it.[3]

(f) Nano bioceramic impregnated GIC

It is well-documented that incorporation of nano-sized particles in powder-modified nano glass ionomers improves its mechanical properties.[17] De Caluwé etal[18] showed that doping conventional GICs with nano-sized glass particles can decrease the setting time and enhance the compression strength and elastic-modulus.[17] The main advantages of decreasing setting time of direct restorative materials are: enhanced ease of handling, manipulation and it decreases treatment time and is helpful to both the clinician as well as to the patient. Enhancing the mechanical properties adds to the serviceability and shelf-life of GIC, as they are able to withstand the masticatory and occlusal forces more efficiently. Addition of apatite to GIC powder, increases the crystallinity of the set GIC, hence improving the chemical stability and water insolubility.

Due to the similarity to that of mineralized bone and dental tissues, hydroxypatite and fluoro-hydroxyapatite have been used in many fields of dentistry such as implant dentistry and caries prevention.[19] Addition of nano-fluoroapatite (nFAp) to the powder component of conventional GIC has a positive impact on its compressive, tensile and flexural strengths of the set cement. Nano-apatite containing glass ionomers are expected to have superior bonding to the tooth surface due to the formation of the strong ionic linkages between the apatite crystals/particles in the cement and Calcium ions in the tooth structure.[20] Calcium fluoride (CaF2) nanoparticles can be incorporated into RMGIC to improve its mechanical properties. However, it slightly reduces its fluoride releasing ability, as CaF2-doped GIC becomes highly insoluable. Likewise, addition of TiO2 (3–5 wt. %) nano particles to GIC powder has shown to improve mechanical properties and anti-bacterial effect of the set glass ionomer cement.[20]

Nano-Filled Resin-Modified Glass Ionomer Cement[18]consists of glass powder and a polyacid solution, resin modified GIC also have a polymer resin component which usually set by a self-activated (chemically cured) or light-activated polymerization reaction. These “hybrid” materials have been developed to combine the mechanical properties of a resin composite with the anti-carious potential of GIC. Indeed, it has been observed that RMGIC not only release fluoride but also have high flexural strength compared to conventional GIC and it also shows lower solubility.[21]

(g) Calcium Aluminate GIC/Ceramir

The most recent modification in bioactive chemically bonded dental cements with a predominant use in restorative dentistry is calcium aluminate–glass ionomer luting cement (CM Crown & Bridge, originally named Xera Cem). The luting cement is actually a hybrid composition combining both calcium aluminate and glass ionomer chemistry. The setting mechanism of Ceramir is a combination of a glass ionomer reaction and an acid base reaction of the type occurring in hydraulic cements.[4] Glass ionomer component contributes to: Low initial pH, improved flow and setting characteristics, early adhesive properties to tooth structure, early strength properties.
Calcium aluminate component in the cement contribute to: increased strength and retention over time, biocompatibility, better sealing of tooth-material interface, bioactive because of apatite formation, stable, shows sustained long-term properties, lack of solubility/degradation.[19]

(h)Giomer

Giomers are the latest category of hybrid dental restorative materials. This fluoride-releasing ,light-cured restorative material is touted as true hybridization of glass ionomer and composite restorative materials, as they exhibit both fluoride release and recharge of glass ionomer cement. The added advantages of giomers are its good esthetics, ease of handling and improved physical properties of the set material. The "giomer" concept is based on the fluro-aluminosilicate glass reacted with polyalkenoic acid to yield a stable phase of GIC, this pre-reacted glass is then mixed with the resin depending on the amount of glass which is reacted. Depending on the unique pre-reacted glass ionomer technology (PRG) fillers produced using either the surface pre-reacted type of glass ionomer (S-PRG) or the fully pre-reacted type of glass ionomer(F-PRG) technology.[23]

(i)Amalgomer

Amalgomer technology (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 minimal cavity preparation required. It bonds to tooth structure and has excellent biocompatibility and shows all the advantages of GIC. Amalgomer shows the conventional acid-base reaction of GIC. The product includes a particulate ceramic component with the intention of increasing its strength, supposedly without sacrificing the appearance or the general characteristics of GIC.[24] It shows higher compressive and diametral tensile strength values. It is evident that ceramic-reinforced glass ionomer restorative material has physico-mechanical properties that are so close and even superior to dental amalgam.[25]

CONCLUSION

There exists a plethora of direct tooth coloured restorative materials in today's era of clinical dental practice. The exclusive inherent features of the Glass Ionomer family discussed above, place them in their own ubiquitous league. In contrast to resin bonding, the adhesion of glass-ionomer to tooth structure is not technique sensitive and its quality increases with time. Their is a continuous urge for innovations in dentistry originating from changing professional perceptions and changing demands from the patient with raising consciousness that, treatment of dental caries is not merely a technique, but also requires a bio-medical approach that is less-invasive. This new family of GIC restorative materials in their course of inception, have held many nifty facets and are still holding the baton in never ending quest of clinical dental research excellence. GIC will make it all to happen.

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