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ORIGINAL RESEARCH

Newer Glass Ionomer Cements having Strontium Ions and the Effect of their Release on Acidic Medium

Umair Hassan, Imran Farooq, Sarosh Mahdi, Rizwan Ullah, Hajra Rana

ABSTRACT

Glass ionomer cements (GICs) are mostly used in restorative dentistry. Their efficacy is enhanced as compared to other direct restorative materials because they release various ions like fluoride (F^-), strontium (Sr^{+2}) and calcium (Ca^{+2}) when they are exposed to an acidic environment. Newer GICs often have Sr^{+2} in place of Ca^{+2} ions as part of their powder component. Both ions (F^- and Sr^{+2}) have a synergistic effect on the remineralization process. These elements are not dependent on each other. Either one has an effect on remineralization. A combination of Sr^{+2} and F^- might provide more benefits than either of these elements individually. An attempt has been made in this article to discuss the composition, setting reaction and bonding mechanism of GIC with the tooth surface and to cover the effects of release of Sr^{+2} and F^- ions from GIC on the tooth structure.

Keywords: Glass ionomer cement, Strontium, Fluoride.

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INTRODUCTION

Glass ionomer cements (GICs) were first introduced by Wilson and Kent to the clinical dentistry** in late 1960's.[1] GICs are nowadays widely used in dentistry because of their direct adhesion to the tooth tissue, low setting shrinkage and a coefficient of thermal expansion which is close to that of a tooth. In addition, they also release therapeutic ions. Like dental silicate cements in the past, GICs also releases cariostatic F^- ions. Studies on more modern formulations indicate that release of Sr^{+2} and Ca^{+2} can aid in the remineralization of tooth structure. Sr^{+2} and F^- are added in the composition of GICs because of their anticariogenic properties.

Because of GICs clinical importance, it is still undergoing continuous development, upgrading and modification, mainly in its composition in order to improve its clinical handling and chemical and physical properties of the cement.[2,3]

GICs are presently used in the clinical setting because of their better esthetic properties as compared to metal restorations and are therefore used as an alternative to amalgam fillings. GICs make a chemical bond with the dental hard tissues. GICs are biocompatible and are also used as lining and luting cements.

The release of fluoride and strontium ions from GICs has an antibacterial effect.[4] Release of fluoride ions from the GICs is effective in the inhibition of recurrent caries. Strontium was included in GICs composition to enhance the radiopacity of the GICs[5,6] but it was found that the strontium was also related to low caries prevalence in many areas.[7,8] Strontium and calcium are present in the group II of the periodic table and this may clarify the role of Sr^{+2} in the remineralization.[9,10]

Composition of GICs

GICs contain two components, powder and liquid. The powder contains strontium or calcium alumina-silicate glass. Liquid consists of poly (acrylic) acid aqueous solution. GIC are made by the reaction between glass powder and polyacid or other poly-(alkenyl) acids.[9]

Powder Component

The powder component of GIC consists of alumina-silicate glass having Sr^{+2} or Ca^{+2} with high amount of F^-.[12] Alumina silicate glass can be formed by melting alumina and other metal oxides, silicates, fluorides and phosphates at temperature ranges between 1,100 and 1,500°C. Then it is cooled in water producing 'frit'. Other elements like silver, potassium and barium are also included to enhance the glass properties.[11]

Wilson listed the formulation of some original alumina silicate glasses as follows:

$SiO_2\ Al_2O_3\ CaF_2$
$SiO_2\ Al_2O_3\ CaF_2\ Al_3PO_4$
$SiO_2\ Al_2O_3\ CaF_2\ Al_3PO_4\ Na_3AlF_6$.[12]

Liquid Component

Polyacrylic acid was used initially as a liquid when GIC was first developed.[13] But this liquid converts into gel form upon storage.[14] To avoid this problem, malic acid and tartaric acid were included but these additions made the setting reaction slow. One solution of this problem was to mix dry polyacrylic acid with the glass powder. This enabled the molecular weight to be increased, enhancing the strength

** GICs were discovered in 1969 but were not usable in the mouth till about 1972 and not sold until 1975.

and the powder could then be mixed with water or tartaric acid solution. Tartaric acid enhances manipulation of GICs and also enhances the setting time without reducing the working or manipulation time available to the dentist.[15,16]

Light activated GIC's contain hydroxyethyl methacrylate (HEMA), a small molecule in their liquid composition that provides more working time and also protects the GIC from moisture by polymerization.[17,18]

Setting Reaction of GIC

GICs components (powder and liquid) are mixed; this initiates a setting reaction having acid components neutralized by the glass part of the cement.[19]Initially this creates Sr^{+2} and Ca^{+2} polyacrylate and after that aluminium polyacrylate is formed. This is a slow chemical reaction which includes the ion depletion of inorganic components from the glass due to reaction with acid. This reaction appears to account for the multiple changes which occur during maturation, e.g. enhancement of translucency, increase in compressive strength and also decrease in the water sensitivity.[20]

Bonding between GIC and the Tooth Surface

The GICs make an adhesive bond with the enamel and dentine.[21] They demonstrate direct chemical adhesion to the tooth structure without the need of extensive retentive preparation of the cavity, acid etching or the need to apply dentine adhesives. Almost 80% of bonding to the tooth surface by GIC is completed within 15 minutes after the insertion of filling material in the cavity.[22] Hydrogen bonding in the GICs provides free carboxyl group, which helps in adhesion to the tooth structure. As the GIC ages, the hydrogen ions are replaced by metal ions like calcium and aluminum. Hydrogen bonds convert into ionic bonds and these ionic bonds are also much stronger.[23] Therefore this action leads to the formation of a chemical bond between the tooth and the material.[24]

Due to GICs adhesive property, it is thought to be an ideal material for the restoration of noncarious cervical cavities.[25] Matis et al (1996) performed 10 years extended research on the retention of GIC in cervical noncarious lesions which resulted in 90% of success rate.[26] A very important property of GICs is their value of coefficient of thermal expansion which is very close to the value of dentine and also the hydrophilic natures of GICs helps it to bond well to the dentine.[27]

Ion Release from GICs

GIC releases different types of ions, both free and complex. GICs contains 8 to 20% proportion of water, which permits diffusion from the surrounding liquid. Monovalent ions like sodium and fluoride (Na^{+1}, F^-), divalent ions like calcium and strontium (Ca^{+2}, Sr^{+2}) and also trivalent ions like aluminum and phosphate (Al^{+3}, PO_4^{-3}) or their complexes, all these ions must be present in the glass components for ion release. To prevent accumulation of ions in the surrounding liquid, the proportion of cement to water should be small. Release of ions from GICs is long-term process which cannot be predicted.[9]

Fluoride Release from GICs

Fluoride release from GICs is not entirely understood; nevertheless it is widely acknowledged that its initial fast release occurs because of the loosely bounded ions of fluoride in matrix of GICs. Slow release of fluoride also occurs because of its slow diffusion through the bulk of the cement.[28] In acidic environment F^- ions takes a proton, i.e. hydrogen ion (H^+) and form an undissociated form of hydrogen fluoride (HF). This is more cariostatic as the membrane of bacteria is more penetrable to HF than fluoride ion alone. $H^+ + F^-$!HF, according to this equilibrated equation, the value of pKa (acid dissociation constant) is 3.15.[29,30] HF breaks into H^+ and F^- ions once it is inside the bacterial cells. Fluoride inside the cell stops an enzyme enolase and due to this action, the production of acid by the process of glycolysis is reduced.[31-33]

Strontium in GICs

Strontium (Sr^{+2}) was included in the glass content of GICs to give radiopacity to the material. However, some studies have also documented antibacterial potential of Strontium.[34] Ca^{+2} and Sr^{+2} ions have same size to charge ratio and therefore replacement of Sr^{+2} for Ca^{+2} has a very small effect on the release of fluoride from GICs.[35] Sr^{+2} is a natural element present inside the body and diet and it has the ability to influence the structural property of apatite.[36,37]

Synergistic effect of fluoride and strontium on the acidic medium. For the maximum decline in dental caries, combination effect of F^- and Sr^{+2} are used.[38] At the time of apatite development, addition of Sr^{+2} and F^- can create a few structural changes in the crystallites of enamel.[36] Combined effect of Sr^{+2} and F^- provides more protection to the dental enamel against *Streptococcus mutans* as compared to their individual effect.[39] Handelman and Losee (1971) concluded in their study that decrease in the dissolution of synthetic hydroxyapatite (HAP) due to the acid production of *Streptococcus mutans* occurs because of synergistic effect of Sr^{+2} and F^- in low levels.[40] Strontium and few other trace elements like molybdenum, boron and lithium had no or little effect if used alone, but the synergistic action of F^-

and Sr^{+2} were shown to decrease demineralization of synthetic HAP in an *in vitro* study.[41] Another study by Spets-Happonen et al (1991) on the effect of chlorhexidine-strontium-fluoride rinses against caries prevalence, concluded that DMFT scores was reduced in a group using strontium and fluoride simultaneously as compared to the group using fluoride alone.[42] A study on strontium and fluoride's synergistic effects was conducted by Thu Thuy et al (2008) and different concentrations of fluoride and strontium were included in the remineralizing sample solutions. It was concluded that strontium when used in combination with fluoride, leads to their synergistic effect.[43]

GICs having fluoride and strontium ions can enhance remineralization process and make HAP crystals more resistant to dissolution in acid, preventing demineralization and discontinuing caries progression. GICs are widely used in dentistry for their unique properties. The Sr^{+2} and F^- ions possess anti cariogenic property, synergistic effect of F^- and Sr^{+2} ions can enhance remineralization process as compared to fluoride alone.

Recent Trends

Current data provides confirmation about resin-modified GICs durability and reliability compared to conventional GICs with in limits.[44-46] Ketac[TM] and GC Fuji IX have better esthetic, improve physical properties, better shade and lower moisture sensitivity, having better results in non stress bearing areas, atraumatic restorative technique (ART), intervening fillings in permanent teeth.[47,48] Most common drawbacks of GICs are poor resistance to fracture and wear, poor esthetic and handling of material are been modified by ongoing research to improve the properties of GICs.[49]

CONCLUSION

The presence of fluorine as a component of the glass in GIC glass has been established as a source of F^- ion release. This provides the cement with cariostatic properties both by reducing the susceptibility to acid erosion of the adjacent tooth tissue and by the action on acid producing bacteria. Modern glass ionomers often contain strontium in place of calcium in the glass component. This provides clinically useful levels of radiopacity as compared to calcium. However, recent studies have shown that cements releasing fluoride and strontium ions have a synergistic effect in terms of cariostatic action. Remineralization of enamel is also an important potential effect reported. The beneficial properties of GIC with respect to its adhesion, biocompatibility and matching of thermal properties to tooth are now joined by its beneficial effects on the surrounding tissues both in terms of protection and repair.

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ABOUT THE AUTHORS

Umair Hassan (Corresponding Author)

Assistant Professor, Department of Oral Biology, Jinnah Medical and Dental College, Karachi, Pakistan, e-mail: drumairhassan@gmail.com

Imran Farooq

Lecturer, Department of Biomedical Dental Sciences, University of Dammam, Saudi Arabia

Sarosh Mahdi

Assistant Professor, Department of Community Dentistry, Jinnah Medical and Dental College, Karachi, Pakistan

Rizwan Ullah

Demonstrator, Department of Dental Prosthetics, Jinnah Medical and Dental College, Karachi, Pakistan

Hajra Rana

Postgraduate Trainee, Department of Oral and Maxillofacial Surgery Abbasi Shaheed Hospital, Karachi, Pakistan