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GIOMER- The Intelligent Particle (New Generation Glass Ionomer Cement)

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Abstract

This paper reviews a revolutionary PRG (pre-reacted glass ionomer) filler technology-which was developed as a new category as "Giomer". This review is the first article that covers comprehensive information about the evolution, fabrication of PRG fillers, types of PRG particles, biological properties, physical properties, optical properties and applications of giomer based on numerous studies available.

Keywords: Fluoride release giomer; Glass ionomer; Prereacted glass ionomer

Introduction

The search for a material that has the fluoride releasing capability of conventional glass ionomer and the durability of composites led to the introduction of polyacid modified composite or compomers by Denstply in 1993.

Compomer is mainly composed of resin matrix with glass fillers and dehydrated polyalkenoic acid. Their advantage being that they undergo initial light activated polymerization which provides early strength development followed by a slow acid base reaction because of hydration of the dehydrated polyalkenoic acid by absorption of water after placement into the cavity. But the fluoride release even though was higher than conventional composites was lesser then the conventional glass ionomer and has no fluoride recharge capacity.

To overcome these disadvantages recently a new category of hybrid aesthetic restorative material which differs from both resin modified glass ionomer and composites has been introduced by Shofu Inc. (Kyoto, Japan 2000 known as GIOMERS, in which they created a Stable Glass-ionomer phase on a glass core in which they induced an acid-base reaction between fluoride containing glass and polycarboxylic acid in the presence of water-developed as Pre-Reacted Glass-ionomer (PRG) filler.

Robert et al. first remarked the fact that the fluoride releasing mechanism of glass ionomer cement was derived from its acid-base reaction phase between ion leachable fluoroaliminosilicate glass and polyalkenoic acid in permeable polyalkenoate matrices, and newly developed a revolutionary Prereacted glass ionomer (PRG) filler technology [1]. So the fluoride ion release was because of the formation of the acid base reaction phase on the surface of the glass core. This PRG technology was applied to the filler component of resin composite materials to provide a bioactive result that released and was recharged with fluoride-like a traditional glass ionomer cement-all the while maintaining the original physical properties of the resin composite system [2,3].

Giomer

Giomer is a fluoride-releasing, resin-based dental adhesive material that comprises PRG fillers.

Fabrication of PRG fillers

PRG fillers are fabricated by the acid-base reaction between fluoroalumino –silicate glass (FASG) and polyalkenoic acid (PAA) in the presence of water to form a wet siliceous hydrogel. After freeze-drying, the desiccated xerogel was further milled and silanized to form PRG fillers of a specific size range [4].

Types of PRG fillers

The PRG-fillers depending on the degree of reaction of the glass ionomer with the acid are divided into two types, and are included into the formulation of giomer products [5].

S-PRG: The reaction is detected in surface-loans and are called surface reaction (surface reaction type, S-PRG fillers)

F-PRG: The reactions proceeded throughout and called are complete reactions (full reaction type, F-PRG fillers), to make the production of F-PRG- the presence of large quantities of water. The use of both types of PRG fillers promote rapid fluoride release through a ligand exchange within the prereacted hydrogel[6] So the F-PRG, fillers would release a huge amount of fluoride as the core of the particle is completely reacted unlike in the S-PRG fillers, the F-PRG would degrade faster than S-PRG fillers. The further advantage of S-PRG is that it releases five ions other than fluoride which have beneficial properties. The ions are Al, B, Na, Si, Sr ions [7,8].

Modified S-PRG: Recently, improvement on the PRG technology has been developed that resulting in the development of Modified "S-PRG filler" which consists of a Three-layered structure with an original glass core of multifunctional fluoro-boro-alminosilicate glass and Two-surface layers that form a pre-reacted glass-ionomer phase on the surface of a glass core and a reinforced modified layer that covers the surface of pre-reacted glass-ionomer phase. This trilaminar structure forms a type of stable glass ionomer which allows ion release and recharge to take place, while protecting the glass core from the damaging effects of moisture, greatly improving long-term durability. Fujimoto demonstrated that the new fluoride releasing restorative system with modified S-PRG filler also releases the F-ion as well as other ions such as Al, B, Na, Si, and Sr [8].

The benefits of S-PRG filler

As the S-PRG fillers release ions other than fluoride, the serve a range of benefits, (i) Fluoride release and fluoride recharge, (ii) formation of acid resistant layer [9] (iii) reinforcement of tooth structure [10] (iv) antiplaque effect [11] (v) remineralization of dentin [12] (vi) acid buffering capacity and reduce acid production by acidogenic bacteria [8].

Properties of GIOMER: The properties of giomer need to be understood under (i) Biological, (ii) Physical / Mechanical properties, (iii) Optical properties

Biological properties: Antiteridonike effect – Fluroide release and recharge, Ion release & modulation effect, Buffering of lactic acid, Antibacterial properties, Adherence of streptococcus mutans, PRG and biofilm, Mineral induction, Cytotxicity

Fluoride release

Study by Itota et al. has shown that the amount of total and free fluoride release from Giomer was higher than Compomer and resin composite and concluded, the extent of glass ionomer matrix of glass filler play an important role for fluoride releasing and recharging abilities of the resin based materials [13]. Also it has been shown that giomers and compomers do have the initial fluoride burst effect of the glass ionomer cements [14]. Gururaj 2011, Values of 1 ppm for fluoride release in artificial saliva were attained only with conventional GIC, resin modified GIC and giomer [15].

Fluoride recharge

Preston and Han reported that the ability of a material to exhibit fluoride recharge depends on its ability to retain fluoride [16]. The recharge ability is governed by the number of sites available within a material able to retain absorbed fluoride. So more the fluoride release, more sites are available and more is the fluoride recharge [17].

A study conducted by Naoum 2011, compared the fluoride release and recharge between different fluoride releasing materials and reported that the fluoride release and recharge was maximum for giomer products [18]. But Fuji IX Extra (glass ionomer) demonstrated greater fluoride release and recharge compared to the other three composite and giomer as well. This could be explained on the basis on resin matrix that is permeability, hydrophilic nature of matrix which encompasses the filler particles [18].

Difference in Fluoride Release before and after Recharge

Pre recharge release

Itota 2005 reported that, Beautiful showed the maximum release both in deionozed water and lactic acid and Greater fluoride release in lactic acid when compared to water is stated as "smart behaviour" [19]. Giomer have more release when compared to other fluoride releasing composites as the hydogel of S-PRG particles exhibited a higher permeability and porosity than resin matrices. This hydrogel provides Beautiful II with areas within the structure capable of greater fluoride uptake relative to a composite not containing a glass ionomer phase.

After recharge

Beautifil II, showed greater rerelease in water compared to acids. This may be due to the dissolving action of acid facilitating additional cation release from the filler. These cations have the capability to form fluoride complexes with fluoride ions introduced through recharge into the resin [20,21]. Such complexes are of greater molecular size than free fluoride ions and are may experience resistance to movement as well as increased retention time within resin matrix. A delayed release of such complex point to possible sustained release and enhance potential of recurrent caries [18].

Dijkman reported that, placement of unfilled resin over glass ionomer reduce the level of fluoride release by a factor of 1.5 to 4 times [22], It follows that the post recharge fluoride release from Beautifil II would be comparable and would potentially exceed the Plateau Release of glass ionomer that demonstrate caries inhibition. While the greater permeability and porosity of glass ionomer contributed to the significantly higher fluoride release, these characteristics also contributed to reduction in elastic moduli and hardness with aging [18].

Ion release and modulation effect

As stated earlier, the S-PRG fillers release six different ions, those being the Na^{+}, BO^{3-}, Al^{3+}, F^{-}, Sr^{2+}, SiO^{2-}.

Their functions being as follows in table 1.

Silicate ions – mineral induction

It was reported that Si seemed to promote hydroxyapatite formation as silica gel induced apatite nucleation on its surface. The surface silanol groups of hydrated silica gel interacted with the calcium and phosphorous ions from the surrounding environment, thereby generating biologically active apatite on the silica gel surface [23].

Alternatively, it was reported that Si ions released from bioactive glass particles were adsorbed on the substrate surface, thereby providing sites for heterogeneous apatite nucleation. Once nucleated, it will spontaneously grow to form a bone-like apatite layer [24].

For bonelike apatite coating on materials with complex shapes, it was reported that an apatite layer was formed when sodium silicate was used as a catalyst for apatite nucleation —whereby particular silicate oligomers with structures such as dimer, linear trimer, and cyclic tetramer contributed most to apatite nucleation [25]. On its contribution to dentin mineralization, it was reported that Si promoted dentin mineralization by a mechanism based on the condensation of silicic acid to oligomers. When a sufficient quantity of Si was adsorbed on dentin with anionic groups (SiO–), it acted as a nucleation centre for subsequent, increased Cap formation [26].

Modulation by ion release/ Buffering of acidic medium

The release rate of fluoride and other ions is controlled by a diffusion mechanism of the ions through the matrix and is influenced by myriad factors such as the duration of fluoride release, pH of the extraction medium, and the surface area and degree of erosive wear of the glass ionomer cement. On the effect of medium pH ion release behavior, acidic conditions are known to enhance the release of all ions [27]. Nonetheless, it must be pointed out that this enhanced release in acids is not uniform, but occurs to different extents for each ion [28].

Interestingly, despite these differences, ion release tends to lead to fairly uniform shifts in the pH of the extraction medium towards neutral [29]. In a study conducted by, Fujimoto in 2010 showed that, in lactic acid, the highest amount of ions released was observed for Sr, followed by F and Si. Similarly, B and Na showed a gradual increase in the amount of ions released as the ratio of solution increased [8].

The same study reported that S-PRG filler altered the pH values of both distilled water and lactic acid solution closer to neutral, regardless of their different pH levels before mixing. These results thus showed that S-PRG filler, like the conventional glass ionomer cements, had a modulation effect on acidic solutions.

The acidic attack on glass ionomer cements has been shown to occur mainly on the gel phase rather than the unreacted glass cores, indicating a release of ions from the matrix phase of set cement. Nonetheless, acidity of the surrounding solution has been shown to degrade the glass cores of glass ionomer cements, thereby increasing the number of ions released.

Ions Released by S-PRG Filler		Bioactive Properties
Na^{+}	Sodium ion	Water soluble/Induces the function of 5 other ions
BO^{3-}	Borate ions	Bactericidal activity/ Promotion of bone formation, prevention of bacterial adhesion, antiplaque properties
Al^{3+}	Aluminium ions	Control of hypersensitivity
SiO^{2-}	Silicate ion	Calcification of bone
Sr^{2+}	Strontium ion	Effect of neutralization and acid buffer, promotes formation of bone tissue and calcification/ Improves of acid resistance
F^{-}	Fluoride ions	Creation of fluoroapatite (formation of acid insoluble crystals- caries prevention, antibacterial effect, Remineralization in decalcifies lesions

Table 1: Ion release and modulation effect

In contrast, S-PRG filler-unlike glass ionomer cements-was relatively stable in acidic conditions; On the clinical implications of S-PRG fillers, results of this study suggested that they could wield a two-fold impact: 1) Able to release ions that contribute to tooth mineralization. 2) And have a modulation effect on the acidic conditions produced by oral cariogenic microorganisms.

Giomer on Biofilm

Adherence of streptococcus mutans/Anti-plaque effect

The colonization of dental plaque by *S. mutans* plays a causative role in dental caries. Nishio and Yamamoto 2002, Found that fluoride released from S-PRG fillers was connected with the prevention of plaque accumulation on the surface of experimental resin composite containing S-PRG fillers [30]. Other commercial composite resins showed matured plaque on their surfaces after 24 hours compared to giomer. On the surface of a tooth restored using Beautifil II a "material film" layer is formed by saliva that is reported to minimize plaque adhesion and inhibit bacterial colonization. Although this "material film" layer may be removed by brushing, subsequent layers are reproduced by saliva. Therefore S-PRG filler has a function of inhibiting plaque accumulation.

Recently, an in vivo experiment showed that less dental plaque was formed on S-PRG-containing resin materials than on two alternative materials. In addition, the adherence of S. Mutans to the saliva-treated resin surface was significantly lower on the S-PRG-containing resin than that on the other two materials, despite none of the materials possessing significant bactericidal activity .From these results, we can conclude that S-PRG can inhibit S. Mutans in both solid resin and soluble forms [11].

Periodontal biofilm

Periodontitis is caused by periodontopathic bacteria such as Porphyromonasgingivalis, a black-pigmented, Gramnegative, asaccharolytic anaerobic bacterium [31]. *P. Gingivalis* has several biologic activities such as protease secretion and coaggregation [32]. The protease gingipain is reported to have suppressive activity on human neutrophils [33]. Gingipain is related to the growth promotion of *P. gingivali*. Gingipain is also associated with gelatinase activity which may cause periodontal tissue degradation [34]. *P. gingivalis* coaggregates with other oral bacteria such as *Fusobacterium nucleatum*, and the formation of these multistrain complex communities is an initial and critical step in the pathogenesis of periodontitis [35].

Effect of S-PRG on the coaggregation between *P. gingivalis* and *F. nucleatum*

F. nucleatum exhibits coaggregation with *P. gingivalis*. Coaggregation of periodontopathic bacteria is associated with bacterial attachment in the gingival crevice [36]. Recently, some metal ions were found to suppress the coaggregating ability of P.gingivalis and they are expected to inhibit the settlement of *P. gingivalis* in the gingival sulcus [37] S-PRG may also disturb the formation of advanced multistrain bacterial communities in the periodontal environment. The mechanism of these inhibitory effects is unclear and needs to be clarified. S-PRG is known to release various ions, including F^{-}, Al^{3+},Sr^{2+}, SiO^{3-}, BO_3^{3-}, and Na^{+} [38].

Boron is known to have an antibacterial activity in cutaneous diseases and periodontitis and inhibits bacterial and fungal quorum sensing. [39-41]. Quorum sensing is a key factor in biofilm formation, so inhibition of this function in Streptococci may be a good candidate mechanism underlying the actions of S-PRG. In *P. gingivalis*, the mechanism responsible for S-PRG actions may involve the control of metal salts and ions that regulate bacterial enzyme activity. Gingipains are known to require metal ions to achieve maximum enzyme activity whereas gelatinases are inhibited by metal salts. Thus, S-PRG may affect enzyme activity by modulating the concentrations of these metal salts and ions [42,43]. S-PRG eluate was found to have a suppressive effect on the BAPNA-hydrolyzing and gelatinase activities of *P. gingivalis*.

Giomer and Dentine Hyper Sensitivity

Tsubota et al. reported that S-PRG fillers have a superior, occluding effect on open dentinal tubules, thereby providing acid resistance to the underlying dentin. Fluoride and other minerals in concentrated release from S-PRG fillers may contribute to remineralization in the tubules and subsequently, occlusion over a long period [44].

Cytotoxicity

It has been revealed that the low initial pH of dental materials may lead to cytotoxic reactions [45,46] Since giomer employs prereacted glass ionomer technology, the fluoroaluminosilicate glass reacts with polyalkenoic acid in water prior to the inclusion into silica-filled urethane resin , it seems that the initial pH in giomer does not decrease as much as that of resin ionomer and conventional GIC [47]. A study demonstrated that the resin modified glass ionomers maintained a low surface pH for at least the first 60 min of setting [48]. Huang et al. had demonstrated that resin-modified glass ionomer cement was cytotoxic to cultured human gingival fibroblasts by inhibiting cell growth, attachment and proliferation [49]. In vitro study reported that Giomer composite is a non-toxic material for Human gingival fibroblasts [50].

Ii) Physical properties/mechanical properties

Flexural Strength: 130 Mpa

Shear bond strength =12.39 Mpa

Vickers Hardness: 62 Hv

Wear Resistance: 0.52 wt% [51].

Study conducted by Quader, reported the Comparative Compressive strength of Giomer, Compomer and Composite [52] (246 Mpa, 151.943 Mpa and 146.265 Mpa respectively)

Water absorption/ dimensional change

Dental restorative materials which are designed to release fluoride do so by diffusion of fluoride ions within an absorbed aqueous medium. Central to the ability to release fluoride, is an ability of a material to

support diffusion of water whilst not having an excessively large value of water absorption.

McCabe [53] reported that the nature of the resin matrix is a fundamental parameter which may control not only the rate of diffusion of water but also the extent of water sorption into that part of the material structure. In the giomer, the pre-reacted zone may affect only the surface of the glass or may consume almost the whole of the glass particles and this difference creates a further sub-division of products within this group. The reacted zones on the surfaces of filler particles may not only act as reservoirs for fluoride re-charging but may also contribute to an increased water absorption and diffusion. Such absorption can be tolerated provided that it does not lead to any deterioration in mechanical properties or produce excessive swelling or result in internal or radial pressure being generated when the material is confined, either within a cavity, or when being used as a luting agent.

McCabe also reported between giomer and compomer, only the giomer gave a substantial degree of swelling which suggests that the mechanism of water absorption for this material was able to overcome the restraining influence of the cavity [53]. The main difference in microstructure between the giomer and compomer materials is the presence of pre-reacted glass polyacid zones which become part of the filler in the giomer structure. It seems likely that these zones are responsible for generating the osmotic effect which leads to swelling and pressure. Whether or not the pressure is great enough to cause tooth fractures is uncertain as this will depend upon the cavity dimensions, residual tooth structure thickness [53].

Fatma, interestingly reported that, there is a direct relation between the degree of water sorption of different restorative materials and either color stability and marginal integrity [54].

Optical properties

The patented filler technology integrates the light transmission and diffusion properties of natural teeth. This enables naturally appearing restorations with even one layer. The filler structure has been developed to simulate the internal structure of natural teeth with ideal light transmission and optical characteristics. The moderate translucency and light transmission of enamel combined with the light-diffusion of dentin offers predictable aesthetics with a close shade match to natural teeth.

Excellent natural shade reproduction can be achieved with a chameleon effect, using a single shade that blends well with surrounding teeth making the restoration undetectable. In aesthetically demanding cases additional shades can be used to achieve exceptional results. Fluorescence close to natural teeth and Radiopacity of 3.4 Al : mm, exceptional radiopacity, 70% greater than enamel and 200% greater than dentin and 1.7 times of Enamel and 3 times higher than Dentin. It has a depth of cure: 5.9 mm.

Applications/Indications

1. Restorations of Class III, IV and V cavities
2. Restorations of Class I cavities and selectively Class II cavities
3. Restorations in deciduous teeth
4. Base / liner under restorations
5. Fissure sealant
6. Undercut blockout
7. Restorations of fractured porcelain and composites
8. Restoration of cervical erosion and root caries
9. Repair of fractured incisal edges
10. Veneers and posts
11. Direct cosmetic repairs
12. Pulp capping agent

Conclusion

Giomer is a specialized restorative material which the properties of both glass ionomer cement and composites. The S-PRG technology not only provides the benefits of mechanical strength of a composite material but also provides release of multiple ions i.e Sodium ions, Silicate ions, Aluminium ions, Fluoride ions, Borate ions and Strontium ions which in turn provide multiple biological functions like Fluoride release and recharge, Anti-plaque effect, Anti Biofilm effect, Modulation of pH. Also, the aesthetics, light transmission, diffusion and fluorescence properties similar to natural teeth. It has unequalled radiopacity, color stability and excellent handling and material properties.

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