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Review article

GLASS-IONOMER CEMENT- A MAGICAL GENIE FOR ALL RESTORATIVE NEEDS

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ABSTRACT

For centuries, the quest for an ideal 'biomimetic' material has been the holy grail of dental restorative materials. ***'Change is inevitable, progress is a choice.'*** With the advent of innovative novel technologies, contemporary dentistry now has access to many outstanding restorative materials. A paradigm shift has occurred from conventional dentistry to futuristic concept of bio-esthetic restorations. The concept of developing 'smart' materials in dentistry has gathered pace since their properties simulate natural tooth substance such as enamel or dentin. Smart behavior was reported for the first time in Glass-Ionomer Cement. They possess phenomenal properties of true chemical adhesion, therapeutic anti-cariogenic effect due to fluoride release, good biocompatibility, wondrous remineralization, attractive esthetics and low toxicity. These appealing attributes, not enjoyed by its contemporary counter-parts, empower GIC for its versatile applications and entitle it for being an indispensable part of a dentist's restorative armamentarium. Since their release into market in the mid 1970s, GICs have enjoyed somewhat of a rollercoaster ride, moving in and out of popularity. But current level of intensive research on them introduced new horizon of ever-improving range of materials of this type. The aim of this article is to revise the unique properties of GIC and various clinical applications of this magical genie that have propelled restorative dentistry to new heights.

INTRODUCTION

Dental profession continues its voyage in pursuit of a 'biomimetic' ideal restorative dental material, the 'holy grail' of dentistry that may synergistically emulate enamel and dentin. For centuries, main challenges have been development and selection of biocompatible and long-lasting direct-filling tooth restorative materials that can withstand the adverse conditions of the oral environment. With the advent of innovative novel technologies, the concept of developing 'smart' materials in dentistry has gathered pace. But the broad array of choices currently available, poses clinicians into dilemma-whether to proceed towards the surge of revolutionary cosmetic dentistry or revert to fundamental postulates of amalgam.

'***Dental caries is as old as mankind***.' Historically cavities in teeth have been replaced or restored since ancient times to 18th century with wide variety of materials including stone chips, ivory, human teeth, turpentine resin, cork, gums and metal foils - tin and lead. More recently, gutta-percha, metals (gold leaf, amalgam, cast metals, alloys), cements, metal-modified cements, unfilled resins, composites, ceramics and metal ceramics have been used for tooth restoration. [1] Notably, an ideal restorative

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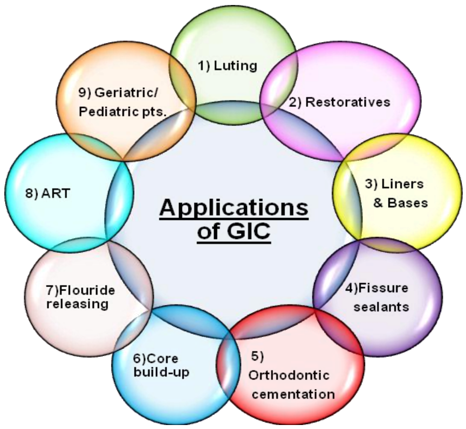

Figure-1: Various clinical applications of GIC

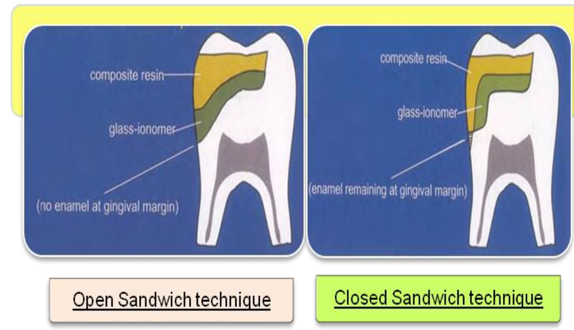

Figure 2- Sandwich technique

material should i) be biocompatible, ii) bond permanently to tooth structure or bone, iii) match the natural appearance of tooth structure and other visible tissues, iv) exhibit properties similar to those of tooth enamel, dentin and other tissues, vi) be capable of initiating tissue repair or regeneration of missing or damaged tissues. [1]

The hallmark of dental profession has been the goal of prevention, [2] in harmony with Hippocratian principle of '***Primum Nil Nocere'*-First Do No harm**! The principle objective of Operative Dentistry is to maintain oral health defined as the absence of disease of teeth, periodontium and oral mucosa. [3] Henceforth it is of paramount importance that focus of a dental professional should be solely to promote oral health and healing and to preserve and conserve what nature has given. In light of this, the restorative material that is serving this dual purpose of 'restoring function' and 'maintaining aesthetics' altogether in contemporary dentistry is ***GLASS IONOMER CEMENT***.

HISTORICAL PERSPECTIVE

It was some 40 years ago that Wilson and Kent introduced GIC to dentistry. During 1950's a small group of dental practitioners and researchers in United Kingdom began research studies to produce a new restorative material with mechanical, thermal and optical properties comparable to those of tooth. They initially made attempts to improve properties of dental silicate cement. [4] [5] In 1960, Smith produced the first Zinc polyalkeonate cement and used polyalkeonic acid instead of eugenol as liquid. He concluded that resultant cement can bond to tooth structure. During same period, Wilson and his group decided to use polyalkeonic acid as liquid for silicate cements which was a surprising event and foundation for success. [4]

Furthermore investigations carried out on variants of silicate glasses showed that their reactivity depended on ratio of alumina-to-silica in fusion mixture. This ratio determines the basicity of glass. Since the reaction between glass and liquid is an acid-base reaction hence an increase in basicity of glass will increase the rate of setting reaction. This was a key observation in development of a new cement system. As a result, the first GIC was produced in late 1960's by Alan Wilson and his group in a chemistry laboratory in London, [5] that was originally called ASPA, an acronym of Aluminium Silicate Polyacrylic Acid. In this powder, alumina-to-silica ratio had increased which resulted in increase in reactivity of glass and hence it reacted

Material Type	Conventional glass ionomers	Resin-modified glass ionomers
1. Luting agent	Fuji I[1] Glass-ionomer CV-Plus[2] Ketac –Cem[3]	Fuji Plus[1] Fuji Cem[1] Rely-X Luting Cement[3]
2. Restorative/Core buildup	FujiII[1] Glass-ionomer Cement Type II[2] Ketac Aplicap II[3]	Fuji II LC[1] Fuji II LC Core[1] Vitremer Core buildup/Restorative[3]
3. Liner/base	Glass-ionomer Lining cement [2] Glass-ionomer Base Cement[2] Lining Cement[1] Ketac-Bond[3]	Fuji Lining LC[1] Vitrebond[3]
4. Silver/glass-ionomer cement restorative	Ketac-Silver[3]	
5. Silver/glass-ionomer admixture restorative	Miracle Mix[1]	
6. High viscosity restorative	Fuji IX GP[1]/Fuji IX GP Fast[1] Ketac-Molar Aplicap[3]	
7. Pit/fissure sealant	Fuji Triage[1]	
8. Root canal sealer	Ketac Endo Aplicap[3]	
9. Composite bonding agent		Fuji Bond LC[1]
[1]GC America [2]Shofu [3]3M ESPE		

Table- 1: Various Glass-Ionomer Products faster with polyacrylic acid. However ASPA I set sluggishly; was susceptible to moisture while setting and was having very low translucency. Its solution was discovered by Wilson and Crisp in 1972 by incorporating positive isomer of tartaric acid to liquid that improve manipulation properties of cement and its setting time. [5] [6] This refinement of ASPA I was termed as ASPA II and constituted the first practical glass-ionomer cement. [7]

However in initial glass-ionomers, the liquid was an aqueous solution of 50% polyacrylic acid, which converted to gel form only after a few months because of presence of inter-molecular hydrogen bonds. One approach adopted by Wilson and Crisp in 1974 was to add methyl alcohol to polyacrylic acid solutions. This GIC was termed as ASPA III. Later, Crisp and Wilson in 1977 reasoned that copolymers of acrylic acids would be less regular so less liable to form intermolecular hydrogen bonds and hence decrease gelation process. They synthesized a copolymer of acrylic and tartaric acid termed as ASPA IV. This was the first commercial marketable cement.[8] Since then, considerable improvisations of the existing material and explicit introduction of next generation glass-ionomers giving way to variety of outstanding acid/base reaction and resin-modified or auto-cure and light-cured versions of GICs have revolutionized the science of restorative dentistry. **(Table-1)**

GIC- A MULTIFARIOUS RESTORATIVE MATERIAL

GIC possess several appealing attributes that render it an excellent choice for wide variety of clinical situations in rather demanding constraints of oral environment. Various properties desirable in a restorative material are entwined together in GIC which have serendipitously benefited the art and science of Operative dentistry.

Adhesion-

An ideal restorative material should adhere tenaciously to surrounding enamel and dentin. Over centuries, microleakage between restoration and cavity wall is probably recognized as dentistry's greatest hazard. GIC came as a major breakthrough and created quite a sensation by possessing property of adhesion. It offers remarkable advantage of being the only restorative material with a true chemical bond to tooth structure. Unlike adhesive resins (eg-Composites) that bond micromechanically to partially demineralized enamel and dentin, GIC bond chemically to mineralized tooth structure through Ion-Exchange mechanism. [9]

As the name suggests, Glass-Ionomer cement is a combination of "Glass" powder and "Ionomer" acid. Basically, GICs are made up of calcium or strontium alumino-flouro-silicate glass powder (base) combined with water soluble polymer (liquid). The setting reaction involves 4 stages- i) Decomposition of powder ii) Gelation iii) Hardening iv)Maturation. In essence, an acid-base reaction takes place between polyacrylic acid as a proton donor and alumino-silicate glass as proton recipient. The acid destroys glass network and releases cations such as Al^{3+}, Ca^{2+}, Na^{+}, etc. These cations are trapped by carboxylate powder and chelated, finally producing cross-links in polymer network and forming a hard polysalt matrix [6], therefore producing an ion-enriched interfacial layer attached to both- the tooth and the restoration. This ion-exchange continues throughout the lifetime of restoration, henceforth resulting in a dynamic bioactive interaction between the two interfaces.

Studies have revealed that glass-ionomer materials like Fuji IXGP allows for an improved biological seal and bond compared to resin-bonding.[10] Furthermore, restorations relying totally on bond strengths of micromechanical retentions associated with composites are known to decrease overtime and may become dislodged.[11]

<u>Anti-cariogenic effect-</u>

One of the most valuable attribute of GIC is its inherent anti-cariogenic property.

Fluoride ions remain free from matrix formation of glass-ionomer. The phenomenon of diffusion of leached fluoride ions occur through the porous cement matrix. Thus, fluoride gets incorporated within adjacent tooth structure forming flouroapatite or hydroxyapatite.[12] Additionally, whenever restoration gets exposed to unusually high external levels of fluoride ions from other sources such as topical fluoride, fluoride rinse or fluoride containing dentrifices, concentration gradient is temporarily reversed and fluoride diffuses into the glass-ionomer restorations. This process is called *recharging*. [13] In a nut-shell, glass-ionomer restorations act as 'flouride reservoir'.

Studies demonstrated that conventional GIC release cumulatively over 5 times more fluoride than compomer and over 21 times more than fluoride containing composites after 12 months. [14]

<u>Remineralization-</u>

In the tsunami of cosmetic dentistry, it seems we have virtually slammed concept of conservation and repair of damaged tooth structure with similar replacements. In words of William John Murray, "***Aesthetic is itself nothing more than a beautiful symbol of spiritual, without which, aesthetic is a shadow without substance***". One of the incredible qualities of GIC is its ability to repair demineralized and damaged enamel & dentin.

During 1988 Purton and Rodda showed that the cement not only releases fluoride ions but also it can release calcium and phosphate ions. [15]A recent study demonstrated that for both enamel and dentin adjacent to GIC restorations; silica, strontium and alumina ions diffuse from the restoration into the tooth substance.[16] Calcium-exchange into the restorative material was also observed that aid in transforming the material into more robust enamel-like material. [17] This remineralization capacity renders GIC the potential to heal damaged tooth structure. It can aptly be summed as- '*a seal that heals'*.

<u>Biocompatibility-</u>

By definition, smart materials can change their behavior in response to various stimuli- stress, heat, moisture, pH, electricity and magnetic field. Smart behavior was reported for the first time in GIC; it does not undergo great dimensional changes in a moist environment in response to heat or cold. It exhibits noticeable shrinkage in dry environment at temperatures higher than 50^0C, which is similar to the behavior of dentin. [18] GlCs have shown to offer good biologic compatibility with dental pulp if standard clinical protocols are followed properly. The slow progression of setting reaction of glass-ionomer combined with water uptake from oral environment counteracts volumetric changes and minimizes shrinkage induced stresses at restoration-tooth interface. Also, low coefficient of thermal expansion (similar to tooth) has been cited as significant reason for good margin adaptation of GIC.

Physical Properties-

Ever since the advent of GIC, it has been highly criticized for its limitation of possessing relative lack of strength and low resistance to abrasion and wear comparative to amalgam and composite. Since '***Necessity is the mother of invention***', through an explicit research ultimately a variety of outstanding version of GIs have been manufactured. Various incarnations of glass-ionomers in form of Mircale Mix, Cermet, and RMGIC are the improvisation in this direction. Fuji IXGP is the most appreciable in this context. Studies performed ex-vivo demonstrated that Fuji IXGP has comparable wear resistance to composite. [19] Also, the micro-tensile bond strength of Fuji IXGP fast set averages ~ 12MPa to coronal dentin. The resultant bond is therefore not weak and matches well the micro-tensile bond strength of composites. [20] Recently, material scientists have projected Reinforced GIC with concept of introducing nano particles such as TiO_2, nano tubes, nano flouroapatites into GIC matrix to enhance their mechanical strength. A yet new material- Zirconomer reinforces structural integrity of restoration and imparts higher mechanical properties befitted for utilization in posterior teeth.

Aesthetics-

Conventional glass-ionomer cements are tooth colored and available in different shades. The addition of resin in the modified materials has further improved their translucency. Among its restorative counterparts, GIC is the only versatile restorative material that is proposing all the desirable attributes of biocompatibility, adhesion, anti-cariogenicity, remineralization and improved esthetics- all wrapped in one. This is the fundamental difference between a restorative material that only fills a cavity like an obturator and one that rehabilitates the principles of biomechanics of tooth. After all, aesthetics is the cherry on cake for only those who follow sound biomemmetic concepts imperatively!

GIC- AN ALL-ROUNDER: OUTLOOK ON CLINICAL APPLICATION

GICs can be virtually termed as 'universal restorative material'. They are clinically attractive dental material applicable to versatile dental situations **(Fig. 1)** both as stand-alone restoratives as well as in conjunction with other contemporary restorative materials. They are comparatively inexpensive and less demanding with respect to clinical application supporting the cliché – '***The best and the economical dentistry is when the right thing is done extremely well the first time and it lasts for a long time'.***

Use in cervical root caries -:

The increased prevalence of patients taking multiple medications irrationally has created challengeable restorative situations. In a published study of 131 different prescribed medications, the most common side-effect is Xerostomia.[21] Alterations to salivary flow and composition have significantly increased incidence of cervical root caries. Undoubtedly GIC is clearly the material of choice for root surface caries restorations due to its eminent assets of ion-exchange adhesion to dentin, caries-inhibition and simplified placement protocols. Clinical studies have shown retention of GIC in erosive root lesions to be superior to that of resin retained with dentinal bonding agents with etched/unetched enamel. [22]

Luting agent –:

GIC luting cement is extensively used for permanent cementation of crowns, bridges, veneers and other facings. It bonds chemically to enamel & dentin, porcelain restorations and precious metals while mechanically to the composite restorative materials. Properties that popularize glass-ionomers as luting cements are their low viscocity and low film thickness. GICs have shown to have highest retentive value amongst the luting cements. [23]

Core build up -:

The removal of decayed or old restorative material before preparing tooth for a crown, often results in further exposure tooth structure. While composite core build-ups require bonding technique that resulted in increased post-operative sensitivity; amalgam core build ups require undesirable additional working time. The most satisfactory results can be retrieved from GIC. It exceptionally eliminated the negative effects of polymerization shrinkage, recurrent decay and post operative sensitivity of other core build up materials. A significant decrease in post-operative sensitivity following placement in deep restorations has been reported compared to traditional composites. [24]

Fissure sealants -:

Long term clinical studies indicate that pit and fissure sealants provide a safe and effective method of preventing caries. [25] After all, '***an ounce of prevention is better than a pound of cure***'. High success rate with fissure sealing has been demonstrated using GICs. [26]

Liners and Bases –:

GIC is comprehensively used as cavity lining. Since they not only bond chemically to enamel and dentin but also release fluoride, this helps to prevent decay and minimizes chances of secondary caries. It facilitates remineralization as well; hence promote formation of secondary dentin. It is widely used beneath composite and amalgam to provide biological seal and insulation to pulp.

Sandwich technique for Class II lesions-:

Enamel is the hardest mineralized tissue in human body perfectly fabricated by the nature to endure mechanical, chemical and thermal insults in oral environment. Dentin is a unique biologic tissue that cushions enamel. GIC offer this explicit opportunity in conjunction with good enamel substitutes like composites or porcelain, to leave remaining sound structure and repair only damaged areas and serves as an excellent dentinal substitute and hence to achieve the goal of '***heal to health to beauty***'.

The term sandwich technique **(Fig. 2)** refers to a laminated restoration using GIC to replace dentin and composite to replace enamel. This technique combines the most favorable attributes of two restorative materials i.e. translucency, aesthetics, durability and higher flexural strength of composite resin with good adhesiveness and anti-cariogenic properties of GIC. The sandwich technique is applicable in Class II lesions using either the open/closed approach.

ART -:

In locations such as rural areas of underdeveloped countries where routine dental treatment is not available due to lack of skilled dental men power and facilities, ART (Atraumatic Restorative Treatment) is the used method of caries management. It is a recognized procedure by the World Health Organization (WHO) and aim to halt or lessen the progression of frank carious lesions until the patient has the access to dental facilities.

ART glass-ionomers have increased strength under functional loads. A review concluded that no difference exists in survival of single and multiple surface amalgam and ART restorations using high-viscosity glass-ionomer in both primary and permanent teeth upto 6 years. [28]

For Pediatric & Geriatric patients-:

The broad span of valuable properties of high fluoride release, chemical adhesion and ease of use in various clinical scenarios undoubtedly make glass-ionomer highly beneficial for geriatric, pediatric, high-caries risk and impaired patients with compromised hygiene skills. Their aforementioned attributes and versatile formulations preferentially make them overall utility restorative material that has been a mainstay material of pediatric dentistry.

CONCLUSION

Glass-ionomers are therefore an essential part of dental restorative armamentarium for everyday clinical practice. They have insidiously become a "standard of care" in a variety of clinical indications and have always carried the torch with excellent outcomes.

With advent of technological boom, dentistry has advanced by leaps and bounds. There is ever-increasing interest in application of bioactive materials in restorative dentistry to validate the claims that such combinations will enhance tooth bioactivity, regeneration capacity and restoration; supporting the axiom "*mimicking nature*". In this league, GIC has been the mainstay material offering a wide-scope of enhancements and improvisations. Bioactive glass (BAG), CPP-ACP incorporated GIC, Chlorhexidine impregnated GIC, Reinforced GIC and Zirconomer have re-established a whole new horizon for GIC in coming future making it that phoenix which rises from its own ashes and swears high for a new flight.

Dental professionals should be proactive and flexible enough to incorporate novel approaches and implement research strategies into their routine clinical practice yet at the same time adhering to the tenets of state-of-art of conservative dentistry. **Esthetics should be valued but not at the cost of functionality**. The quandary is to have acumen to focus on future directions on the creation of more ideal restorative materials that can be available world-wide. We should learn to think differently, think biomimmetically. Until then, certainly we can safely rely on GIC. Hopefully, golden day dawns when the biomimetic restorations become a pleasant reality.

"Miles to go before I sleep…………!"

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