International Journal Dental and Medical Sciences Research
Volume 4, Issue 3, May-June 2022 pp 58-66 www.ijdmsrjournal.com ISSN: 2582-6018

Metalnanop Article Incorporated Bioactive Glass Ionomer Cements

Tisha Prakash

Submitted: 01-05-2022 Accepted: 08-05-2022

ABSTRACT
Glass ionomer cements (GICs) are silicon and fluorine based composite biomaterials with diverse applications in restorative dentistry that have strong adhesive properties which makes it a suitable for cementing, sealing, luting, and bonding in dental restorative procedures. GICs have been used as materials of choice for treating tooth caries and in orthodontic procedures because of their many beneficial and suitable properties. But their performance in treating and restoring high stress areas is not very satisfactory because of their poor physical and mechanical stress bearing properties and less resistance to wear and abrasion. GIC are mixed with other materials to improve their performance and properties. GICs are often mixed with metals as reinforcing agents that may be in the form of different types of metal nanoparticles leading to the formation new nanoparticle-based GICs. This review is based focuses on the use of different types of metal nano-blends of GIC. Literature available on metal nanoparticle blends of GIC was reviewed and critically analyzed. The review reveals that different nanoparticles have diverse and distinct influence on the properties of GICs resulting in overall improvement in the durability, performance and functionality of nanoparticle incrorporated GICs.
Keywords: Glass ionomer cement; Nanoparticles; Metal nanoparticles; nanocomposites; restorative dentistry; bioactive material; biocompatibility.

I. INTRODUCTION

There are different types of restorative materials used in dentistry. Amalgams, resins, ceramic or cements are some of the commonly used restorative materials. Glass ionomer cement (GIC) is a type of cement/ceramic dental restorative material which has superior binding and cementing properties that make it suitable for restoration of carious teeth. GICs are grouped into three main categories, namely conventional, metal-reinforced and resin-modified (1-4). GICs were first developed and introduced by Wilson and Kent in 1972 (5). GIC was prepared by mixing aqueous polyalkenoic acid like polyacrylic acid and a glass component which is generally a fluoroaluminosilicate. When the two components i.e. powder and liquid are mixed an acid-base reaction is initiated to give the product, GIC. Its solidification to maturation occurs slowly in a stepwise manner over an extended duration. Once the metallic polyalkenoate salt startsprecipitating, gelation starts and proceeds to attain complete hardness after 24 hours duration (1, 2)

GIC is glass polyalkenoate obtained by mixing of the two components mentioned above, the basic glass and an acidic polymer. One is a glass component which is calcium alumino-silicate in powdered form and second component is an acidic component which is a polycarboxylic acid like polyacrylic acid (PAA). Use of water in place of an acid changes the properties of GIC (6, 7). Fluoride ions released from glass ionomers GIC are anticariogenic and antimicrobial which also promote remineralization and inhibit dental degeneration caused by plaque formation. (5).

Several properties of GIC makes them ideal for their use in restorative dentistry, like their stability in aqueous environment, biocompatibility, high retention factor, similar thermal expansion coefficient to dental material, good sealing properties (5).

GICs have good adhesive, cementing, sealing, luting, and handling properties but it lacks strength and hardness to resist the mechanical stress in molar and premolar regions. It has poor wear and abrasion resistance, Young's modulus is high which makes it brittle and more prone to loss by stress, wear and fracture during the process of mastication.

To improve the properties of GIC it is mixed with different metals to reinforce strength. Many ofthose metals which are combined with GIC are in the form of nanomaterials. When GICs combine with the nanomaterials they modulate the properties of GIC to enhance and improve their clinical performance. (6). GICs are comparatively new when compared to other restorative materials like amalgams (10, 11).

The blending of GIC with the nanoparticles like silver, zinc, magnesium, copper,

International Journal Dental and Medical Sciences Research
Volume 4, Issue 3, May-June 2022 pp 58-66 www.ijdmsrjournal.com ISSN: 2582-6018

zirconium and titanium improves the performance of GIC (12). The metal oxide nanoparticles when combined with GIC not only increase the surface area of the material which results in its improved adhesive and bonding properties, but metal oxides exhibit very strong antimicrobial properties too. This bioactive property helps nanoparticle composites to perform clinically better, besides improvement in other properties like modulus of elasticity, shrinkage and resistance to wear. The metal nanoparticles due to their high density make GIC nanocomposites tougher and more versatile from clinical dentistry point of view. (13). Increased density also makes GIC composites better to handle by thickening the resin and reducing the viscosity also enhances the handling property of the nanocomposites (14, 15 &16). Nanoscale size of the nanoparticles allows them to occupy and fill empty nano spaces granting smoothness to the texture of the material and hence better biocompatability (14, 15). Together, antimicrobial properties, improved mechanical and physical properties, enhanced biocompatibility, material texture makes the GIC nanocomposites ideal for use in restorative dentistry (11, 14, 16).

Types of GICs

- Conventional glass ionomers (CGIs)

Conventional GIs are opaque have inferior surface finish besides they show low flexural strength and high modulus of elasticity which makes them brittle susceptible to wear and fracture. Therefore CGIs are not suitable for restoration of high stress areas and class V restorations. CGIs require the use of a cavity conditioner before performing an implantation procedure, which generally is PAA and used to prepare the surface for receiving an implant.

- Resin modified glass ionomers (RMGIs)

RMGIs were developed to improve the properties of glass ionomers and are considered a hybrid between glass ionomers and composite resin. Contain the same components as CGIs viz., glass powder, PAA and water, besides an additional monomer component and an associated reaction initiator. The monomer is 2-hydroxyethyl methacrylate, HEMA, and the reaction initiator is camphorquinone. RMGI reacton takes place in two steps. First is an acid-base reaction or a neutralization reaction. Second reaction is a addition polymerization reaction resulting in a complex structure.

Properties of RMGIs are similar to CGIs. Like CGIs, RMGIs too release small amounts of sodium, aluminium, phosphate and silicate under neutral conditions and under acidic conditions, larger amounts of calcium ans strontium are released which is associated with the buffering capacity o RMGI. Biocompatibility of RMGIs is comparatively compromised as it causes the release of HEMA in initial stages of setting which diffuses from the dentine into dental pulp causing inflammation. HEMA is a contact allergen and may cause problems for the dental personnel.

Applications

GIC has number of applications in restorative dentistry and they are used as luting or lining material, cement base, dentine substitute, restoration of deciduous teeth and caries. GICs are also used for repairing crowns and margins of damaged teeth. They may be used for common applitions as marix; cermets; cementing agents in orthodontic brackets; sealants of fissures; fluoride vanishes to prevent dental caries; and for surface treatments.

1. As restorative and repair material

   High opacity and natural colouration of glass ionomer materials makes them suitable for repairing defective crowns and teeth margins. GICs have also been useful in treating abrasion and erosion cavities, restoration of deciduous teeth, repairing and refilling of carious lesions besides tunnel restorations.
2. GICs are useful in applications where they are employed as matrix
3. Because of their good adhesive properties they are used as cementing agents in orthodontic brackets; sealants of fissures.
4. Their ability to form fine durable film-like coatings makes them suitable for various surface treatments as fluoride varnishes to prevent dental caries.
5. GIC can be combined with other restorative materials for lamination or ‘sandwich technique.’

Fissure sealants

Tooth repair using atraumatic restorative treatment (ART) technique. This technique has been mainly employed for children besides ART has been effective in treating and providing dental

care to the people where dental care is non-existent because of which treatment would requiretraumatic extraction of several teeth.

Properties

Various properties of GICs determine their suitability in their diverse types of applications andthese properties are modifiable depending upon the composition of their components.

(i) Fluoride ion release

Fluoride is a halide element which is known to possess antimicrobial properties just like its other sister halides like chlorine and iodine. Fluoride is used to impart antimicrobial activityto a GIC material. Bioactive fluoride within the reconstituted GIC upon implantation of the dental restorative material causes initial fluoride burst that last upto 4 weeks. This is followed by a reduced but sustained release of fluoride ions over extended long periods. Fluoride ion release from GICs is reported to increase in acidic conditions (Sidhu and Nicholson 2016). Fluoride ions are inhibitory and microbicidal for broad range of microbes that grow in dental environment and are corrosive and cariogenic due to acid producing activity that leads to the degradation of teeth. GICs because of their buffering capacity are able to resist the change in pH by increasing it to alkaline conditions. Thus, the fluoride in GIC serves as germicidal bioactive component that prevents tooth decay (7, 8). Fluoride release happens during complexation under acidic conditions. Low leve ls of fluoride release at parts pe million level of concentrations are sufficient to inhibit demineralization of dentine tissue. Fluoride is asoknown to reduce sensitivitytowards cold foods.

(ii) Antimicrobial activity

Bioactivity of GIC is related to its antimicrobial nature. Fluorine present in GIC is gradually release fluoride ions which have established antimicrobial property like other halides. This antimicrobial property prevents microbial growth in and around the dentine thus prevents dental caries and blocks cariogenic microbes (6).

(iii) Adhesion

Adhesion of GICs to the tooth is an important clinical value addition.

Tensile bond strengths of glass-ionomers to untreated enamel and dentine are good. The bond strength values of GICs on enamel vary between 2.6 to 9.6 MPa and those of dentine vary from 1.1 to 4.1 MPa.

Bond strengths are tighter to enamel than to dentine indicating that the binding occurs with the mineral phase. Adhesive binding strength develops quickly, with about 80% of the final bond strength achieved in first 15 minutes, and the rest of the strength is achieved after several days.

The process of adhesion occurs in a step wise manner. In the first, application of the freshcement paste allows wetting of the tooth surface . Hydrophilic nature of both the cement and the tooth surface drives adhesion which then progresses rapidly resulting in the formation of hydrogen bonds between the free carboxyl groups of the cement and the bound water on the surface of the tooth. Ionic bond formation occurs between cations on the tooth surface with that of anions in the cement by replacing H-bonds, which is followed by gradual formation of an ion-exchange layer between the tooth and the cement. Strong bond formation between carboxylate groups of the PAA and the surface Also occurs which is confirmed by infrared spectroscopy.

(iv) Setting Time

It is the intrinsic property and activity of a dental restorative material which is initiated when the material, cement in this case, is mixed with water. The restorative material loses its plasticity and gradually becomes hard. Thus, the time taken by a restorative material to become hard is known as its setting time. Setting time is determined various factors and may vary depending upon the composition of the material. It may be divided into initial setting time and final setting time to distinguish the two events based on their hardness. Initial setting time is the time taken for a material from the moment the reaction is initiated till the time when the material starts to lose its plasticity. While the final setting time is the total time taken for a material to lose its complete plasticity or to attain complete hardness or firmness and resist a definite amount of pressure. Another sub-division of or sub-component of setting time is mixing time.

Factors determining the setting time are intrinsic or extrinsic. Intrinsic factors are elemental composition of the material, molecular arrangement and lattice structure, dispersity and polydispersity index, hydration etc. (1, 9)

(v) Compressive strength

Compressive strength of a dental material is the ability or property of a material to resist or withstand a certain amount of pressure or stress without undergoing any deformity. It is measured in miliPascals (MPa) it is an important property that helps to determine whether a material is suitable for particular type of restorative procedure e.g. core material or a luting agentor as a cementing material. Compressive strength is generally determined after twenty four hours of performing a wet procedure that involves use of water. The addition of various NPs has already been evaluated. Their addition to GIC lends structural support and strength leading to overall improvement in their mechanical properties and performance (10).

International Journal Dental and Medical Sciences Research
Volume 4, Issue 3, May-June 2022 pp 58-66 www.ijdmsrjournal.com ISSN: 2582-6018

(vi) Microhardness

Microhardness is the property of a material which is used to evaluate the hardness by applying small volumes of load to the testing material. The volume of the material being evaluated is in microquantities. It is used for the indirect assessment of important properties of a composite material using or by adopting certain standard procedures. Microhardness of a composite material is tested using disc shaped samples following ISO4049 standards employing different tests like Vicker's hardness test, Knoop's hardness test etc. It is used for determining the hardness of small amount of specimens, complex shapes, coatings and platings used in surface applications (9).

Bioactivity

GICs are known to be naturally bioactive. Primarily because they release biologically active fluoride, sodium, silicate and phosphate ions in their surrounding aqueous environment at biologically beneficial levels. As mentioned in case of release of fluoride ions these ions are release in larger quantities when conditions are acidic.

Biocompatibility. There is significant enhancement in the biocompatibility of nanocomposites compared to nomal GIC. Which is notable in terms of dental tissue bonding, release of bioactive metal ions that bring about smoothness in the texture of GIC.

Pros and cons of GICs

Certain properties of GICs make them popular as dental restorative materials which is reflected in the following clinical advantages:

Pros

- Natural colouration and aesthetic value : Their similar tooth-colouration and their modifiability to get suitable colour.
- Adhesion: their ability to bond chemically with the tooth material and metals used in dentistry without requiring additional adhesive ingredients.
- Bioactivity: The ability of GICs to cause sustained and extended fluoride release makes them superior to other materials. Fluoride release has multi-pronged tooth preventive activities. They are cariostatic and prevent decalcification/demineralization.
- Thermal expansion coefficient: their coefficient of thermal expansion is matches to that of enamel and dentine which makes more compatible than other materials resulting in better margin adaptation and leakage prevention. Resin modified glass ionomers are better suited than conventional GIs.
- Biocompatibility: This is an important property of a material as the materials used in dentistry are in direct contact with both the hard and soft tissues. Freshly mixed conventional GIC is found to be toxic compared to the hardened one. Similarly conventional GIC is more inflammatory compared to zinc oxide eugenol cement.

Cons

GICs have been found to have certain limitations owing to their chemical and physicalproperties that influence its mechanical nature, too. The following disadvantages are suffiecient to illustrate the point:

- Physical strength: inadequate fracture toughness and limited wear resistance are the results of poor physical strength of the material, thus preventing their application in high load- bearing areas like molars and premolars.
- Vulnerability to acid erosion: low physical strength and ability to react with acids and water makes them more vulnerable to erosion by acids.
- Water sensitivity:
- Clinical success: GICs clinical success rate has been determined in number of studies. Although, most studies conducted only short term effects while some log term studies have demonstrated low success rate of conventional GIs compared to resin modified GIs and amalgam in two to five year duration.
- Multiple patient visits: some types cannot be finished and polished at the same visit or because of poor physical strength procedure are repeated in case of loss or damage to the restorative material.

Nanoparticle/nanostructure based GICs

Nanotechnology has impacted progress and development of science and technology. It has numerous applications in all the branches of medical sciences and so in dentistry. Nanotechnology or nanoscience is the science or technique which involves manipulation of matter to synthesize or create structures and materials of nano-dimensions (0.1 to 100 nm) using various chemical, physical and biological methods [1]. Nanomaterials and nanoparticles have immense potential in therapeutics, diagnostics, and regenerative medicine especially regenerative and restorative dentistry, where nanomaterials and nanoparticles are used as structural support materials, either singly or in combination as nanocompoites [2 and references therein]. It is this area of dentistry that wide range of nanoparticles has immense applicability. Nanoparticles not only bring about value addition but have the ability to modify the properties of other materials with which they are blended. This property of nanomaterials is helpful manipulating the properties of the matter to the desired needs. Restorative materials used routinely in dentistry have different and dissimilar properties compared to dentine material, its size and structure namely, hydroxyapatite, dentile tubules and enamel rods. This makes the restorative material less biocompatible with the dental tissue [3]. It is the biocompatibility, strength and hardness of the restorative material that often requires enhancement and improvement. This is achieved by blending of restorative materials like GIC with the nanoparticles. The blending of GIC with the nanoparticles like silver, zinc, copper and titanium results in improvement of the performance of GIC due to its resultant modified properties. The nanopartiles when combined with GIC increase the contact surface area of the material which enhances its adhesive and bonding strength of the GIC and also makes the restorative material more resistant to wear and shrinkage. The use of metal nanoparticles because of their highly dense nature helps to enhance the mechanical properties of the polymer material to make them hard. Their thickening effect and low viscosity also bring about enhancement in the handling property of the material. Nanoparticles because of their nano size have the ability to fill nano spaces and thus act as nano-fillers which improve the texture of the material and provide smoothness to surface of GIC material. The following content would explore the potential of the metal nanoparticles in imparting value additions and benefits to the GICs in restorative dentistry.

Metalnanoparticle (MNPs) based GIC

Various metal and their oxides in their nanoparticle (NP) form are known to be antimicrobial, and when they are mixed with or incorporated into GICs they impart their antimicrobial property to the composite GICs. Incorporation of MNPs in GICs also bring about a change in the physical, mechanical and optical properties.

Properties of Metalnanoparticle based GICs

Nanoparticles (NPs), especially the metal nanoparticles along with the oxides of metal (MNPs) are known to possess antimicrobial activity. Antimicrobial nature of MNPs as well as metal oxide NPs (MONPs) has been observed against broad range of microbes, both Gram positive and Gram negative bacteria, fungi, protozoa, besides viruses. MNPs and MONPs act against microbes by diverse types of actions. Different modes of actions have been suggested. One of the mechanisms responsible for antimicrobial activity is the inherent nature and size of NPs that makes them ideal for antimicrobial use. Increased surface area and their nanoscale size prevents the viruses and microbes from binding and entering into the host cells and allow MNPs and MONPs exert their microbicidal effects. The alternatively proposed mechanism is their ability to ionize biomolecules like nucleic acids, proteins and membrane lipids and proteins. MONPs generate superoxide radicals on binding with microbes and cause their destruction, besides MNPs are known to disrupt cell membrane integrity of microbes by different mechanisms. Additional proposed mechanism for MONPs is their enzyme mimicking action, i.e. they act as nanozymes exhibiting peroxidase and catalase activities (11).

Several metals like Ag, Al, As, Cd, Co, Cr, Cu, Fe, Ga, Hg, Mo, Mn, Ni, Sb, Te, Zn possess the demonstrated antimicrobial activity (Gudkov et al 2021).

MNPs when blended with GICs change the properties of the resulting composite cement by enhancing their strength and toughness, and overall improved clinical performance. Silver, copper, zinc oxide, titanium oxide are among the most commonly used MNPs in diverse types of applications. Silver NPs (AgNPs) are easy to synthesize and blend with other materials retaining their antimicrobial and nanoparticle like behaviour and the properties associated with AgNPs. Similarly copper NPs also retain their nanoparticle-like behaviour but due to coppers reactivity with oxygen it is difficult to maintain the atomic state of copper. Whereas zinc oxide and titanium oxide when blended with other materials like GICs they contribute to antimicrobial activity and to improved mechanical strength of the GIC composites and bring about significant value addition as an improvement over other materials used as dental restoratives. Numerous reports have shown that MNPs incorporated in GICs refashioned with superior compressive strength and microhardness, improved bioactivity and biocompatibility, decreased setting time, increased wear resistance besides resistance to dissolution and disintegration.

Silver nanoparticles (AgNPs)

AgNP-GIC nanocomposites are prepared by different methods. One method is photoreduction of $AgNO_3$ solution to AgNPs by continuous exposure to UV in the presence of polyacrylate solution of GIC. The resulting AgNPs are complexed with GIC to form silver

International Journal Dental and Medical Sciences Research
Volume 4, Issue 3, May-June 2022 pp 58-66 www.ijdmsrjournal.com ISSN: 2582-6018

nanocomposites of GIC (AgNP-GIC) (Paiva et al 2018; Enan et al 2021). AgNP-GIC are reported to be twenty five times more antimicrobial compared to chlorohexdine (Amin 2021) and their reinforcement in GIC material may improve their overall performance in restorative dentistry compared to normalGICs. Silver and silver ions are known to possess antifungal and antibacterial activity and have been combined with resin based GICs, as well as with the modified tissue conditioner , light cured flowable composite resin materials to prevent tooth decay, colloidal AgNPs are added to polymeric adhesive to improve electrical conduction. AgNP filled epoxy composites show improved electrical and flexural properties. and incorporation of silver nitrate and AgNPs considerably reduced the adhesion of C. albicans to the resin surface, suggesting that AgNPs- combined materials may prevent denture stomatitis. There are a number of factors that need to beconsidered in silver nanoparticles-filled epoxy composites such as filler concentration, filler shape and size, and filler composition to modify the properties of metal filled polymer composites.

Analysis of AgNP distribution by TEM and atomic adsorption spectroscopy in acrylic resin revealed their compatibility with the resin formulation and the NPs are well dispersed in the resin matrix and further demonstrated that AgNPs have no detrimental effect on resin photopolymerization.

Copper nanoparticles (CuNPs)

Because of their antimicrobial properties, CuNps have received the sigificant attention. Both CuO and CuNps have either been coated onto or incorporated into various materials. There is aninverse relationship between the NP size and antimicrobial activity. It has been demonstrated that nanoparticles of 1-10 nm size have the maximum antibacterial activity. CuONPs have advantages for being cheaper than silver, easily miscible with polymers, and Nano-scaled CuO synthesized by thermal plasma technology spossess a particle size of 20 to 95 nm, with a mean surface area of 15.7 m2 /g. CuO NPs in suspension show the activity against a range of bacterial pathogens. Comparison of CuO with AgNPs silver demonstrated superior bactericidal activity. Studies of CuONPs incorporated into polymers suggest that the release of Cu ions may be essential for optimum killing.

Copper NPs are (CuNPs) are synthesised by chemical or green synthesis approaches using copper sulphate solution. In general, There are five methods for synthesizing Copper NPs are (CuNPs) chemical treatment, electrochemical synthesis, photochemical technique, sonochemical method, and thermal treatment method. Since CuNPs get oxidised in presence of oxygen hydrazine is added during the synthesis of CuNPs which removes oxygen from the environment and promotes maintenance unoxidised NPs.

Zinc nanoparticles (ZnNPs)

Research efforts are currently directed towards eliminating or reducing infection of medical devices. Strategies to prevent biofilm formation include physiochemical modification of the biomaterial surface to create anti-adhesive surfaces, incorporation of antimicrobial agents into medical device polymers, mechanical design alternatives, and release of antibiotics. In this context, zinc oxide nanoparticles have undergone in vitro testing in biofilm culture test systems. Zinc oxide nanoparticles blended into a variety of composites were shown to significantly inhibit the growth of S. sobrinus biofilm over a three-day test period. Kishen et al. demonstrated a reduction in the number of E. faecalis adhered to the dentine on the surface of the root canal treated with cationic antibacterial nanoparticulates such as zinc oxide alone or the combinationof zinc oxide and chitosan nano-particulates. In theory, such surface treatment could prevent bacterial recolonization and biofilm formation in vivo.

Zinc oxide nanoparticles (ZnONPs) are NPs of zinc having the size smaller than 100 nm. Their properties depend upon their size and shape. Their synthesis is performed by chemical or by other methods like sol-gel method, chemical vapour deposition, thermal decomposition, combustion, microwave assisted combustion, ultrasound etc. ZnO is among the most commonly synthesised NPs. Their ability to inhibit or inactivate enzymes renders them with antimicrobial property by utilizing their potential to generate reactive oxygen species (ROS) and cause initiation of Fenton reactions that damage proteins, nucleic acids, and destroys cell membrane integrity of microbes. A large number of MNPs are known to produce ROS. It is also used in sunscreens to absorb harmful ultraviolet radiation like TiO_2 (TiONPs) besides its antimicrobial property.

Titaniumdioxide (TiO2) nanpparticles (TiNPs)

TiO_2 is also known as titanim dioxide, and rutile. TiO_2NPs (TiONPs) can be sythesised by different methods which are as follows: sol-gel process, chloride process, and the sulphate process.

Sulphate process Ilmenite ($FeTiO_3$) is on mixing with sulphuric acid leads to the formation of TiO_2 (anatase). TiO_2NPs are separated by centrifugation to remove impurities. TiONPs make use of light to add an electron to the oxgen atom that tends to destroy microbes. This photocatalytic function of TiO_2 is attributable to its enzyme-like function.

Glass ionomer-containing (3% and 5%, W/W) TiO2 nanoparticles showed improved fracture toughness, flexural strength and compressive strength compared to the unmodified glass ionomer. However, a decrease in mechanical properties was found for glass ionomer containing (7%, W/W) TiO2 nanoparticles. Glass ionmer-containing (5% and 7%, W/W) TiO2 nanoparticles compromised the surface micro-hardness. Setting time of glass ionomer-containing TiO2 nanoparticles is accepted and meets the requirement of water-based cements. The addition of TiO2 nanoparticles to the conventional glass ionomer did not compromise its bond strength with dentine or fluoride release of the glass ionomer. Glass ionomer-containing TiO2 nanoparticles possessed the most potent antibacterial activity against S. mutans compared to the unmodified glass ionomer.

Zirconia

Zirconia is ZrO2 and and it is a biocompatible dental restorative material which has white colour appearance. Zirconia exhibits high resistance towards corrosion, fracture and cracking and chemically very stable possessing high tensile strength in addition to low thermal and high ionic conductivity low thermal and high ionic conductivity and excellent toughness. Due to its high strength, The processing of zirconium particles is a challenging task owing to its high strength. Because of its excellent properties zirconium NPs (ZrNPs) have found use in dental restorative materials as nanopowder fillers, nano-coatings and as a sintering raw materials. The nanopowder of the ZrNPs is incorporated into various dental materials can be usedas a scaffoldin regenerative dentistry and tissue engineering to increae their mechanical strength. Similarly, addition of ZrNPs into dental materials will also enhance the flexural strength, microhardness, fracture toughness etc of the the restorative material.

It has also been used as dental abutment, implant, and for making crowns and bridges in posterior restorations. And also to match colors of human teeth, zirconia has been established with enhanced translucency that has high flexural strength (900–1400 MPa) and fracture toughness (6 MPa) [GICs are also modifiable with composites of hydroxyapatite (HA) and ZrNPs. (Gu et al.). Variable Percentages of HA (4, 12, 28 and 40 vol%) were incorporated in a conventional GIC.

HA/ZrO2-GIC composite was immersed in distilled water for time periods of 1 day and 1 week and then tested for their mechanical strength. They found that within the GIC matrix, the HA/ZrO2 and glass particles were uniformly dispersed on SEM examination.

Authors found that diametral tensile strength, compressive strength and surface microhardness of HA/ZrO2-GIC were improved when compared with the conventional GIC.

The study demonstrated that mechanical properties of the composite also improve as the soaking time is increased and enhanced final strength of the cements which might be because of the continuous formation of aluminum salt bridges. Moreover, by increasing the soaking time, ZrO2 did not dissolve. To evaluate the genotoxic effect of zirconium particles on human gingival fibroblasts (HGFs), Laiteerapong et al. formulated a novel GIC containing zirconia macroparticles (MPs) and NPs. The authors used H2AX fluorescent assay to evaluate genotoxic effect of zirconium particles on HGFs. Both conventional and modified GIC had no genotoxic effect on HGFs.

A study conducted by Gjorgievska et al. who conducted the study on GIC demonstrated that addition of ZrO and TiO enhanced the compressive strength of the GIC while Al2O3 weakened its strength. Sajjad et al. utilized one-pot technique for the synthesis of nanozirconia–silica–hydroxyapatite (nano ZrO2-SiO2-HA). Compressive strength, flexural strength and surface roughness were evaluated. Significant increase in the flexural and compressive strengths was observed after addition of 5 wt% nano ZrO2-SiO2-HA in conventional GICs. Moreover, surface roughness profile of modified GIC was similar to conventional GICs. Hence, the GICs modified with nanoZrO2-SiO2-HA has favorable properties, and these materials can be used for permanent restorations in the high stress bearing areas. the effect of ZrO2 on the performance of GICs has been investigated in combination with other ingredients—namely, Al2O3, TiO2, SiO2 and HA. The combinations appears to be impove and enhance overall strength and mechanical properties. Spectrometric analysis revealed that the GIC composites of NPs did not release any noticeable amount of Al, Zr or Ti ions, thus, making them suitable for clinical use.

II. CONCLUSION AND FUTURE PERSPECTIVES IN GICS

The objective of the current review is to assess and understand the impact of various nanoparticles on different properties of nano-modified GICs, in terms of their setting time, compressive strength, microhardness, biocompatibility, antimicrobial activity, toxicity of corrosiveness/corrosion. Use of various nanocomposites to reinforce GIC's strength has demonstrated positive outcomes. It remains to be seen in the long-term studies if the nano- modified GICs perform better than resin modified GIs and other restorative materials that have proven long-term durability. Their superiority in terms of biocompatibility, bioactivity, toxicity and over all clinical success also remains to be established by long-term comparative studies. Thus, any further comparisons must be made in the light of long-term studies conducted to compare and analyze nanocomposite based GICs with other restorative materials in terms of clinical data.

REFERENCES

[1]. Wilson AD, McLean JW. Glass ionomer cement, Chicago: Quintessence; 1988.
[2]. Mount G. Making the most of glass ionomer cements. Dent Update 1991; 18:276-9.
[3]. Sidhu SK, Watson TF. Resin-modified glass ionomer materials. A status report for theAmerican Journal of Dentistry. Am J Dent 1995; 8:59-67.
[4]. Burgess J, Norling B, Summit J. Resin ionomer restorative materials: the new generation.J Esthet Dent 1994; 6:207-15.
[5]. Mitra SB, Wu D, Holmes BN. An application of nanotechnology in advanced dental materials. The Journal of the American Dental Association. 2003 Oct 1;134(10):1382-90.
[6]. Khan AS, Khan M, Rehman IU. Nanoparticles, properties, and applications in glass ionomer cements.
[7]. Terry DA. Direct applications of a nanocomposite resin system: Part 1--The evolution of contemporary composite materials. Practical procedures & aesthetic dentistry: PPAD. 2004 Jul 1;16(6):417-22.
[8]. Van Noort, Richard; Barbour, Michele (2013). Introduction to Dental Materials (4 ed.). Edinburgh: Elsevier Health Sciences. pp. 95–106.
[9]. Millett DT, Glenny AM, Mattick RC, Hickman J, Mandall NA. Adhesives for fixed orthodontic bands. Cochrane Database Syst Rev. 2016;10(10):CD004485. Published 2016 Oct 25. doi:10.1002/14651858.CD004485.pub4
[10]. Amin F, Rahman S, Khurshid Z, Zafar MS, Sefat F, Kumar N. Effect of Nanostructures on the Properties of Glass Ionomer Dental Restoratives/Cements: A Comprehensive Narrative Review. Materials. 2021 Jan;14(21):6260. doi.org/10.3390/ma14216260
[11]. Aguilar-Perez D, Vargas-Coronado R, Cervantes-Uc JM, Rodriguez-Fuentes N, Aparicio C, Covarrubias C, Alvarez-Perez M, Garcia-Perez V, Martinez-Hernandez M, Cauich- Rodriguez JV. Antibacterial activity of a glass ionomer cement doped with copper nanoparticles. Dental materials journal. 2020:2019-046. doi:10.4012/dmj.2019-046
[12]. Bakhadher W. Modification of glass ionomer restorative material: A review of literature. EC Dental Science. 2019;18:1001-6.
[13]. Paiva L, Fidalgo TK, da Costa LP, Maia LC, Balan L, Anselme K, Ploux L, Thiré RM. Antibacterial properties and compressive strength of new one-step preparation silver nanoparticles in glass ionomer cements (NanoAg-GIC). Journal of dentistry. 2018 Feb 1;69:102-9. https://doi.org/10.1016/j.jdent.2017.12.003
[14]. Nicholson JW, Sidhu SK, Czarnecka B. Enhancing the mechanical properties of glass- ionomer dental cements: a review. Materials. 2020 Jan;13(11):2510. doi:10.3390/ma13112510
[15]. Kavitha R, Sarassri N, Silambarasan RV, Kumar V, Rajakumar P. Nanotechnology-A Review on Application of Nanotechnology in Orthodontics. International Journal of Recent Advances in Multidisciplinary Topics. 2022 Jan 9;3(1):37-40.
[16]. Najeeb S, Khurshid Z, Zafar MS, Khan AS, Zohaib S, Martí JM, Sauro S, Matinlinna JP, Rehman IU. Modifications in glass ionomer cements: nano-sized fillers and bioactive nanoceramics. International journal of molecular sciences. 2016 Jul;17(7):1134. doi:10.3390/ijms17071134
[17]. Murugan R, Yazid F, Nasruddin NS, Anuar NN. Effects of Nanohydroxyapatite Incorporation into Glass Ionomer Cement (GIC). Minerals. 2022 Jan;12(1):9. doi.org/10.3390/min12010009
[18]. Melo MA, Guedes SF, Xu HH, Rodrigues LK. Nanotechnology-based restorative materials for dental caries management.

Trends in biotechnology. 2013 Aug 1;31(8):459- 67. http://dx.doi.org/10.1016/j.tibtech.2013.05.010

[19]. Hajipour, M.J. et al. (2012) Antibacterial properties of nanoparticles. Trends Biotechnol. 30, 499–510

[20]. Hajipour, M.J., Fromm, K.M., Ashkarran, A.A., de Aberasturi, D.J., de Larramendi, I.R., Rojo, T., Serpooshan, V., Parak, W.J. and Mahmoudi, M., 2012. Antibacterial properties of nanoparticles. Trends in biotechnology, 30(10), pp.499-511.

[21]. Hamouda, I.M., 2012. Current perspectives of nanoparticles in medical and dental biomaterials. Journal of biomedical research, 26(3), pp.143-151.

[22]. Lee WF, Tsao KT. Preparation and properties of nanocomposite hydrogels containing silver nanoparticles by ex situ polymerization. J Appl Polym Sci 2006; 100: 3653-61.

[23]. [69] Xie D, Weng Y, Guo X, Zhao J, Gregory RL, Zheng C. Preparation and evaluation of a novel glass-ionomer cement with antibacterial functions. Dent Mater 2011; 27: 487- 96.

[24]. [70] Sui L, Liu Q, Li C. Dispersibility of SZP Antimicrobial Agents in Silicone Denture Soft Lining Materials and Their Effect on Operational Performance. Biomed Eng (iCBBE) 2010; 4: 1-4.

[25]. Balan L, Schneider R, Lougnot DJ. A new and convenient route to polyacrylate/silver nanocomposites by lightinduced cross-linking polymerization. Prog Org Coat 2008; 62: 351-7

[26]. Pieniak, D., Walczak, A., Walczak, M., Przystupa, K. and Niewczas, A.M., 2020. Hardness and wear resistance of dental biomedical nanomaterials in a humid environment with non-stationary temperatures. Materials, 13(5), p.1255.