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Modifications Of Gic-A Review Of Literature

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ABSTRACT

Glass ionomer cements were introduced into dentistry in the late 1960s and it's used especially in the restorative dentistry. GICs are known mainly for their chemical bonding to the tooth, where in the coefficient of the thermal expansion is low and there is a lot of fluoride release and discharge. It has a wide range of applications in dentistry and said to be biocompatible with the dental pulp to a larger extent. Due to their poor mechanical properties and sensitivity to desiccation and moisture is present, modifications are definitely needed to produce a better product. Years of extensive research have yielded better products through many formulations with enhanced mechanical properties and reduced moisture sensitivity. Now, studies are mainly focused towards the nanoparticles, Bioactive glass, hydroxyapatite, fluorapatite, silica and zirconia to improve its properties. The objective of this study is to review the various modifications of GIC that could produce greater chemical affinity for GIC matrix as well as tooth structure which would increase the physicochemical properties of GIC.

Keywords: restorative dentistry, thermal expansion,desiccation,modifications, chemical affinity

INTRODUCTION

Glass ionomer cements have been developed in the late 1960s mainly as a replacement for dental silicate cements (1). The composition of GIC is by ion leachable glass powder and polyacrylic acid which is said to be its essential components. When these components are combined together, they undergo a reaction which causes neutralisation of acid groups by the powdered solid glass base (2).The uses of GIC is that it provides aesthetics properties, self adhesive capacity, is biocompatible to the pulpal tissues and even possess antibacterial properties (3) GIC lacks in few aspects by having less low mechanical properties and sensitivity to moisture which is of a major hindrance to be used as a restorative material (4). Modifications need to be carried out in order to improve its properties. Such modifications include incorporation of additives which might be metal, glass etc. as well as fillers in GIC matrix (5). Early when silicate cements were used, phosphoric acids were substituted by the organic cheating acids and adhesive property of polycarboxylic acid was exhibited which led to the rise of GICs (6).

The alumino fluoro silicate glasses component in GICmakes it possess the bioactive properties due to the presence of silicates and fluorides (7). Modifications which are made definitely have improved some of the properties of GIC. The ability of GIC to bind chemically to the tooth structure is due to chelation of the carboxyl group of acid polymeric chains and calcium ions which are present in the enamel and dentin of the tooth structure (8). GIC also has anti carious effect and moderate translucency colour due to the release of these fluoride ions (9). GIC has a wide range of applications in dentistry. It is used mainly in the deciduous restoration, anterior Class III and V restorations, cementation of crowns, bridges, various orthodontic appliances and even in non carious teeth with minimal tooth preparation (10).GIC is even being used in the atraumatic restorative treatment in order to remove infected carious tissue for therapeutic remineralisation (11). It's also being used as bone cements due to its high bio activity (12). The use of GIC as a restorative material has a chance of causing micro leakage to the tooth (13).

The conventional GIC when incorporated with the chlorhexidine dihydrochloride and chlorhexidine diacetate leads to the increase in the antimicrobial properties (14).Glass ionomer cements are generally sensitive to the water contamination and premature water contact leeches some of these components which makes it weak and opaque cement (15). Addition of amalgam alloy powder to GIC in 1977 increased the strength and provided radiopacity. Recent advances makes the manufacturer to have a combination of high strength of metallic restorative material, aesthetics and other important properties of glass ionomer cement (16). Mainly to overcome the mechanical prop ties and moisture sensitivity, certain modifications need to be definitely introduced to the conventional GICs. These modifications can be through nano sized filler particles, fibre reinforcement, bioactive glass, resin reinforced, metal reinforced GIC, cermet ionomer cements etc.Previously our team has a rich experience in working on various research projects across multiple disciplines The (17–19)(20–31). The aim of this article is to review the various kinds of modifications of GIC that have been developed in these recent times.

MATERIALS AND METHOD

A review literature was done in the preparation of the manuscript. The system and the data based searched for relevant articles from PUBMED and google scholar. The articles were primarily dated back till 2000 but few of the references were dated even earlier. About 50 articles were collected and analysed and reviewed.Databases of the journals were searching for articles based on the key words like modifications of GIC, thermal expansion, restorative dentistry etc. cross references were also included.

MODIFICATIONS OF GIC

The study includes various kinds of modification of GIC obtained from the conventional GIC. These modifications include powder modified nano glass ionomers, nano filled resin modified glass ionomer cements, bioactive glass reinforced GIC, hydroxyapatite reinforced GIC, silica reinforced GIC, zinc based modifications of GIC, nano ionomer, high viscous conventional glass ionomer cement, giomer,zirconomer,calcium aluminate GIC/ ceramir, Amalgomer. Various studies have been done on these products of the GIC and it has been said to increase the properties of the glass ionomer cements.

RESIN MODIFIED GIC

Resin reinforced GIC came into action to overcome the disadvantages for conventional GIC. They are nothing but a hybrid of glass ionomer and composite resin which contains acid base polymerizable materials. It contains fluoroaluminosilicate glasses, photo initiators, polyacrylic acid, water, water soluble methacrylate monomer (32). The composition of the liquid is methacrylate modified carboxylic acid and water miscible methacrylate monomer or glycerol dimethacrylate. These previous researches have provided information regarding the biological properties (33),((32,34). The functional groups which are present in the resin modified glass ionomer cement is polymerizable which produces curing when activated by using light or chemicals which allows the acid base reaction to take place (35).

The advantages of resin reinforced GIC over conventional GIC are it contains longer working time, finishes earlier, good aesthetics and significant increase in strengthening properties better than conventional GIC(36).Resin modified GIC bonds to the tooth structure. Acidic environments can increase the long time survival rate for this material (37). Few of the drawbacks of the resin modified GIC is that it possesses brittle and inferior strength (38). RMGICs micromechanical bond to the tooth structure which is through a collagen network exposed during 10% poly acrylic acid pretreatment when combined with chemical bonding within the partially demineralised enamel and dentin (39). Therefore, the RMGICs have been derived by the incorporation of nano sized fillers by reducing the size of the glass particles.

TABLE 1: **Studies comparing conventional glass ionomer cement vs resin modified glass ionomer cement**

STUDY	**CONVENTIONAL GIC**					**RESIN MODIFIED GIC**					**STATISTICAL SIGNIFICANCE**
	Compressive strength	**Fluoride release**	**Bond strength**	**Cytotoxicity**	**Tensile strength**	**Compressive strength**	**Fluoride release**	**Bond strength**	**Cytotoxic ty**	**Tensile strength**	
Oliveira GL et al,2019 (40)	153.3± 35.2 *MPa*	85.4 ± 8.6 μg/cm^2	-	-	-	176.9 ± 12.6 *MPa*	113.8 ± 3.9 (μg/cm^2)	-	-	-	Compressive strength- Highly significant- p<0.01 Fluoride release- very highly significant- p<0.001
Poggio C et al 2014 (41)	-	-	3.51MPa	-	-	-	-	10.24 Mpa	-	-	Bond strength- very highly significant p<0.001
Zhang et al,2013 (42)	-	-	4.75±2.22MPa	-	-	-	-	22.32± 3.65 MPa	-	-	Not mentioned

Tanaka MH et al 2013 (43)	-	-	-	0.6262MPa	-	-	-	-	0.695MPa	-	Cytotoxicity Highly significant p<0.01
Sharafeddin Fet al,2017 (44)	-	-	-	-	7.917 MPa	-	-	-	-	18.492MPa	Tensile strength- Highly significant p<0.01
Poornima P et al 2019 (45)	89.64MPa	-	-	-	-	111.93MPa	-	-	-	-	Compressive strength- Highly significant p<0.01
Williams JAet al,1991 (46)	91.88MPa	-	-	-	-	132.55MPa	-	-	-	-	Compressive strength Significant p<0.05

BIOACTIVE GLASS

Bioactive glass is a modification of GIC which is being derived from the bio activation to improve both the mechanical properties as well as biological properties (47). This type of modification was introduced by Larry L Hench in 1969 (48).First bioactive glass which was commercially available had a composition of 46.1 mol % silicon dioxide, 24.4 mol% sodium oxide, 2.6 mol% of phosphorus pentoxide and 26.9mol% of calcium oxide (49). The addition of bioactive glass improves the biocompatibility due to the apatite layer formation. BAG binds to both hard and soft tissues (50). It has an antibacterial effect which increases the pH in aqueous solutions. Bioactive glass contains good antibacterial properties (51),(52). When bioactive nanosilica with dental cements is combined, there is a lot of chance to overcome the marginal gap formation which is one of the major disadvantages that could be seen in all the cements.

TABLE 2 : **Studies comparing conventional glass ionomer cement vs Bioactive glass**

STUDY	**CONVENTIONAL GIC**	**BIOACTIVE GLASS**	**STATISTICAL SIGNIFICANCE**
	Surface microhardness	**Surface microhardness**	
Prabhakar AR et al 2010 (53)	47.7 ± 5.4 MPa	22.0 ±2.4 MPa	Surface microhardness Highly significant p<0.01

HYDROXYAPATITE REINFORCED GIC

Hydroxyapatite possesses excellent biological behaviour where in its structure is similar to that of the crystals that are seen in the human dental structures. These crystals are said to promote remineralisation of enamel (54). It also increases the mechanical properties through the ionic bond formation between polyacrylic acid and apatite crystals (55). This modification is done through the synthesis using ethanol based sol gel technique and synthesised nanoparticles are introduced into the conventional GIC (56). The cement exhibited higher compressive strength, higher diametral tensile strength, higher biaxial flexural strength. Decreasing the size of the particle size of the apatite from micrometer to nanometer scale increases their surface area and infiltration of the crystals into demineralised dentin as well enamel increase bonding at the tooth surface.

TABLE 3: **Studies comparing conventional glass ionomer cement vs hydroxyapatite reinforced glass ionomer cement**

STUDY	**CONVENTIONAL GIC**				**HYDROXYAPATITE REINFORCED GIC**				**STATISTICAL SIGNIFICANCE**
	Fluoride release	**Tensile strength**	**Shear bond strength**	**Compressive strength**	**Fluoride release**	**Tensile strength**	**Shear bond strength**	**Compressive strength**	
Tiwari S,et al 2016(57)	3.2104±0.2728MPa	-	-		3.2660±0.3305MPa	-	-	-	Fluoride release- Very highly significant p<0.001
Jowkar et al 2019(58)	-	8.69MPa	-		-	8.79MPa	-	-	Tensile strength Very highly significant p<0.001
Kannupriya Choudary et al 2015(59)	-	-	5.25 ± 0.88 MPa,		-	-	3.28 ± 0.89 MPa	-	Shear bond strength- Very highly significant p<0.001
Khangani M et al 2013(60)	-	-	-	46.10±3.39 MPa	-	-		74.76±6.50MPa	Not mentioned
Kenji Arita et al 2011(61)	-	-	3MPa	-	-	-	7MPa	-	Shear bond strength Very highly significant p<0.001

SILICA MODIFIED GIC

This type of modification was mainly done to increase the number of poly salt bridges in the glass matrix and mainly to improve the transparency of the cement. This was done using the sol-gel technique (62). It has shown an improvement in the compressive, flexural and shear bond strength of the material (63). Another study has used sodium silicate formulation to synthesise silica. There was another method wherein silica particles were added to RMGICs which showed a significant increase in the mechanical properties, water sorption rates and even decrease in the micro leakage and water solubility (64). Hence, this new modification is very useful as a dental restorative material.

TABLE 4: **Studies comparing conventional glass ionomer cement vs silica reinforced glass ionomer cements**

STUDY	CONVENTIONAL GIC	SILICA REINFORCED GIC	STATISTICAL SIGNIFICANCE
	Cytotoxicity	**cytotoxicity**	
Noorani TY et al 2017(65)	57.83MPa	9.86MPa	Cytotoxicity Significant p value $p<0.05$
Hii SC et al 2019(66)	89.6MPa	96.57MPa	Cytotoxicity Very high significant value $p<0.001$

GIOMER

Giomer is one of the modifications of GIC which is fluoride releasing, resin based dental adhesive material which consists mainly of PRG fillers. These fillers are mainly fabricated by an acid base reaction that takes place between fluoro alumino silicate glass and poly alkanoic acid in the presence of water thereby forming wet siliceous hydrogen. Few of the giomer properties are similar to that of resin modified GIC and bioactive glass but except for some enhanced properties (67),(68),(69). Desiccatedxerogel was milled once the freeze drying got over and the silanized which produces PRG fillers with specific size range (70). There are 2 types of fillers namely, S-PRG and F-PRG which are included in the giomer formulations ike,. Giomer exhibits biological properties like the antiteridonike effect which is through the fluoride release and ion release and hence produces modulation effect. Hence it is a specialised product which contains both the properties of glass ionomer cements and composites.

TABLE 5: **Studies comparing conventional glass ionomer cement vs giomer**

STUDY	CONVENTIONAL GIC						GIOMER						STATISTICAL SIGNIFICANCE
	Setting shrinkage	**Fluoride release**	**microhardness**	**Toughness**	**flexural strength**	**Compressive strength**	**Setting shrinkage**	**Fluoride release**	**microhardness**	**Toughness**	**Flexural strength**	**Compressive strength**	
Spajić J et al 2018(71)	1.22MPa	-	-	-	-	-	0.23MPa	-	-	-	-	-	Not mentioned
M Gururaj et al 2013(72)	-	0.99MPa	-	-	-	-		0.65MPa	-	-	-	-	Not mentioned
Mukundan Vijayan et al 2018(73)	-	-	53.833 MPa	-	-	-	-	-	50.700MPa	-	-	-	Microhardness Very highly significant p<0.001
Dr. Abhishek Bhattacharya et 2017(74)	-	0.53MPa	-	0.599 MPa	53.4 MPa	252.3 MPa	-	0.98MPa	-	0.566 MPa	81.7 MPa	324.4 MPa	Not mentioned

ZIRCONOMER

Zirconomer is the new class of modification of GIC which is called as the white amalgam since it possesses the properties of amalgam and even the durability of the restorative material is increased. The previous studies provide information regarding its properties and effects (75),(76). The maintenance of the structural integrity of zirconomer is due to the presence of zirconia fillers as a glass component and hence imparts high mechanical properties for posterior teeth restoration (77). It helps in aesthetic quality when it is used (78). The increased amount of strength of zirconomer is exhibited by the polyalkenoic acid and other specialised products which are present. The major advantage of zirconomer is that it provides high class restoration for high carious condition, easy manipulation, adequate working time and it is ideal for posterior teeth restoration.

TABLE 6: **Studies comparing conventional glass ionomer cement vs zirconomer**

STUDY	CONVENTIONAL GIC	ZIRCONOMER	STATISTICAL SIGNIFICANCE

	Colour stability	**Surface texture**	**Microleakage**	**Compressive strength**	**Diametral tensile strength**	**Colour stability**	**Surface texture**	**microleakage**	**Compressive strength**	**Diametral tensile strength**	
AR Prabhakar ,et al 2015(79)	63.75MPa	20(frequency)	-	-	-	79.75MPa	20(frequency)	-	-	-	Not mentioned
Albeshti R, et al 2018(80)	-	-	3.71 ± 0.48MPa	-	-	-	-	2.86 ± 0.69MPa	-	-	Not significant p>0.05
Ahmad ZH et al 2016 (78)	-	-	-	107±10 MPa	17.6 ± 2.8 MPa	-	-	-	197 ± 27 MPa	44.7 ± 4.7 MPa	Compressive strength and Diametral tensile strength Very highly significant p<0.001

AMALGOMER

Amalgomer is named so because it resembles few properties of amalgam which turned out to be one of the modifications of GIC. It is a ceramic reinforced glass ionomer cement which is similar to that of strength and durability of amalgam (81),(82). It possesses many good properties like minimal cavity preparation is only required, and provides a lot of fluoride content. It bonds to the tooth structure very well and exhibits bio compatibility to many tissues that are present (83). It even exhibits high compressive and diametral tensile strength. This type of ceramic reinforced glass ionomer cement is one of the best modifications of GIC that possess properties similar and superior to amalgam.

TABLE 7: **Studies comparing conventional glass ionomer cement vs amalgomer**

STUDY	**CONVENTIONAL GIC**	**AMALGOMER**	**STATISTICAL SIGNIFICANCE**
	Antibacterial effect (S.mutants)	**Antibacterial effect (S.mutans)**	
Rajesh Hemant Bariker,et al 2016(84)	Zero MPa	31.30±2.51MPa	Not mentioned

Hugar SM et al 2016 (85)	0.1068MPa	0.0811MPa	Not mentioned

CALCIUM ALUMINATE GIC or CERAMIR

Ceramir was originally known as xera cem which was used as a luting cement. It is bio active chemically bonded to the tooth structure. Ceramir consists of the setting reaction which is of hybrid type wherein acid base reaction and glass ionomer reaction takes place (86). It contains 2 components - glass ionomer component and calcium illuminate component where both of these components contribute to the properties exhibited by ceramir. These studies have shown few properties and usage by dentists (87),(88),(89). Low initial PH, improved flow and setting characteristics, early strength properties are contributed by the glass ionomer component. Calcium illuminate components play an important role in increased strength, no solubility or degeneration, property of bio activity due to apatite formation (90). The luting cement is actually a hybrid composition containing both calcium illuminate and glass ionomer chemistry and an acid base reaction.

ZINC BASED GIC

Zinc based glass ionomer cement is one of the modifications of GIC which does not involve the presence of aluminium in the glass phase. Zinc oxide acts as modifying oxide which in turn acts as a network modifying oxide and that is similar to alumina (91). Another study included GeO2, ZrO2 and Na2O in the zinc based GIC to evaluate the mechanical properties of GIC. There was a significant improvement in the properties of the strength of GIC.

NIOBIUM PENTOXIDE MODIFIED GIC

Niobium pentoxide is a metal oxide generally presenting a form which contributes to enhancing the mechanical properties when incorporated to metal alloy. The addition of resin based dental materials has already shown improved the radiopacity and microhardness of adhesive systems and root canal sealers. The glass ionomer cements were incorporated with niobium pentoxide to enhance the mechanical properties, biocompatibility and bioactivity of GIC (92). When the modifications were done the setting time of the cement increase but that decreased the mechanical strength of the material . A new formulation of Niobium pentoxide was made by adding 5 weight percentage Nb2O2 which surprisingly did not affect the physical and chemical properties but improved the radio opacity of the material. Hence this material is suitable for further testing for its remineralisation potential.

FUTURE SCOPE

For the dental clinicians to do better restorations using GIC. they must be able to find a better product that can provide good results in their treatment. The more number modifications that arise, it creates more advancement in the field of dentistry.

CONCLUSION

Within the limitations of the study, it can be concluded that there are a lot of modifications made to the conventional glass ionomer cement to improve the physical, mechanical and biological properties but there are very few comparative studies between conventional and modified glass ionomer cements. A greater number of studies should be done to prove that these novel modifications are as good as the conventional glass ionomer cement.

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