Glass Ionomer cements- A narrative review

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Abstract

Glass ionomers have been used in dentistry since 1960s. At present, there has been a variation in the properties of glass ionomers and introduction of newer modifications of the reinforced glass ionomer cement. The present article is a narrative review which analysesthe earliest forms of glass ionomer cements to the most recent bioactive forms of glass ionomers. It explains the mechanical properties of the glass ionomers. In addition, a clinical insight to the use of various forms of glass ionomers have been mentioned along with an evidence-based approach to their uses.

Keywords: glass ionomer, dental cements, dental bases, dental fillings

Introduction

Dentistry involves the use of materials which should act as a replacement of the damaged tooth structure. The ideal requirements of a material to be used as a restorative material is that it should be passive, stable, should not have undue interaction with the surrounding environment of the oral cavity, should have good compressive and tensile strength to resist the occlusal masticatory forces and should mimic the properties of dentinal structures as close as possible(Rekow et al. 2013). However, more favourable properties like bonding to the tooth structure, releasing bioactive components have shown benefits as compared to passive restorative materials(Darvell & Smith 2022; Chandra 2018). Glass ionomer cements are one such material used in dentistry which shows properties of a smart material.

The smart properties of glass ionomer restorative cements were first studied by Davidson (McCABE et al. 2009). These materials are known to show bonding to the dentin creating a chemical bond to the tooth structure rather than mechanical bond like composite and silver amalgam restoration (Almubarak 2016). However, this material lacks the compressive and tensile strength of other restorative materials (Almubarak 2016). Currently , various modifications of this material have been done to improve the mechanical properties of glass ionomer materials (Yli-Urpo et al. 2005; Sidhu & Watson 1995; Geurtsen et al. 1999).

The present study is a narrative review of the composition and setting reaction of glass ionomer cement material and also highlights various modifications and its application in clinical dentistry.

Composition of Glass Ionomer cement

The earliest form of glass ionomer cement was introduced in late 1960 by Wilson and his colleagues as aluminosilicate polyacrylic cements. These cements have high aluminium to silica ratio in their powder composition as compared to the traditional silicate cements. These cements also used polyacrylic acid which is known to be weaker acid as compared to the phosphoric acid used in silicate cements (Cattani-Lorente et al. 1993). Later on, with further modifications Wilson and Kent introduced a calcium aluminosilicate glass system which consists of calcium oxide in addition to the alumina, silica and fluoride ions. At present glass ionomer cements contain silicon dioxide, aluminium oxide, aluminium fluoride, calcium fluoride, sodium fluoride and calcium phosphate. Later on, calcium was replaced by strontium to improve the radio-opacity of the glass ionomer cements (Kantrong et al. 2021)

The earliest form of liquid used for glass ionomer cement was a homopolymer which was 50% polyacrylic acid alone. However, this underwent a gelation reaction due to the hydrogen bond present (Matsuya et al. 1996). With the aim to eliminate the gelation reaction, introduction of copolymer was done. Hence, the composition of the liquid used for glass ionomer cement involves a copolymer of maleic acid and acrylic acid. After the introduction of the copolymer, a positive isomer of tartaric acid was introduced to improve the manipulation properties of cement and its setting time (Smith 1990).

Various generations of glass ionomer cements have been introduced. The first generation of glass ionomer cement involves a low reactivity between the aluminosilicate glass and polyacrylic acid (Nagaraja Upadhya & Kishore 2005). These cements had a very low reactivity and showed long setting time and decreased translucency. Hence, tartaric acid was introduced to fasten the setting reaction. The second-generation glass ionomer cement is the water hardening glass ionomer cement. These glass ionomers have polyacid incorporated into the powder. The setting reaction of these glass ionomers occurs by the aqueous solution of tartaric acid or water. By this technique, there is an increase in the shelf life by preventing gelation. In addition, there is a decrease in the viscosity during mixing and an increased strength. Further improvement in the composition of glass ionomer cement was done by introducing reinforced glass ionomer cements. The main aim to reinforce glass ionomer cement was to increase the strength (Hernandez 2004). Listed below are the reinforced glass ionomer cements:

1. Use of dispersed phases of alumina, titanium oxide and zirconium oxide.
2. Fiber-reinforced glasses: This involves incorporation of alumina fibers or glass fibers, silica fibers, carbon fibers. This increases flexural strength (Oznurhan & Ozturk 2020).
3. Glasses in the powder reinforced with metals: Mixing with amalgam powder, referred to as Miracle Mix. The amalgam can be either milled together or introduced at the time of manipulation. Another form includes sintering the metal with the glasses which is known as Cerment. Cement increases the bond between the metal and the glass powder (Gu et al. 2005).
4. High viscosity glass ionomer cement: These materials can be used in atraumatic restorative treatment (ART) technique. These are known to have a higher flexural strength and translucency. Additionally, it involves additional calcium and phosphate ions which leach into the tooth surface (Poornima et al. 2019).
5. Resin-modified glass-ionomers : These involve introduction of methacrylate of the polyacid molecule. These have a command sent using light cure in addition to the traditional acid base reaction. Bisphenol A-Glycidyl Di methacrylate or urethane Di methacrylate was introduced along with the acidic monomers. These materials are known to show increased translucency and wear resistance (Sidhu & Watson 1995).
6. Amino acid-modified glass-ionomers (Karkera et al. 2016)

Setting Reaction of Glass ionomer cement

The glass ionomer cement is set by an acid base reaction. It takes 2-3 minutes for the completion of the initial setting reaction (Zainuddin et al. 2009)

The setting reaction is completed in 4 stages:
Stage 1: Decomposition of the powder: The surfaces of glass particles in the powder react with the acid. This leads to the release of metallic cations into the solution and the formation of a silicate gel layer on the surface of the particles.
Stage 2: Gelation: There is an increase in the concentration of positively charged ions which causes a rise in the pH value of the aqueous phase. This results in a greater ionization potential of carboxylic acid. The gel structure is formed through cross-linkage and formation of hydrogen bonds. This process initiates with an increase in ionization that leads to the carboxylate groups of polymer chains to become charged which repel each other, uncoils and gets converted into a more linear configuration. This progression of the reaction of positively charged metals with carboxylate groups results in an increase in viscosity. The diffusion of the cationic ions exerts the main effect on the gelation reaction of the cement.
Stage 3: Hardening: This occurs due to cross-links in the polymer chains as a result of release of metallic cations. The final resultant material obtained consists of un-reacted glass particles surrounded by the polysalt matrix containing cross-links.
Stage 4: Maturation: The acid base reaction continues after setting. Hence, there is an increase in the bond strength (inter-molecular forces). The full compressive strength is achieved after 24 h, however there is an increase in bond strength and increase in Young's modulus for a few months as a result of continuous ion exchange reaction (Walls et al. 1988). Water is known to play a significant role which increases the translucency of glass ionomer cements. There is an increase in the proportion of the tightly bound water over a period of 1 month. This leads to strong hydration of the polyanion molecule. In case of the loss of unbound water leads to chalky appearance of the glass ionomer and decrease in the strength. The preservation of the strength can be achieved by placement of a coating over the restoration to prevent water loss (Cattani-Lorente et al. 1994).

Physical and Mechanical properties of Glass ionomer cement

The glass ionomer cement has its mechanical properties largely influenced by the powder liquid ratio, the particle size of the glass in the powder and the concentration of polyacid(Hill 1991). Under ISO standards the glass ionomer cement prepared should have a compressive strength of 100 MPa for restorative material and 70MPa for luting materials(Centre & International Trade Centre 2010). In Addition to the compressive strength which is lower than that of the composites and amalgam restoration, the glass ionomer cement has a biaxial flexural strength which mimics dentin-like characteristics(Mount et al. 1996). The glass ionomer shows a variable tensile strength in the enamel and dentin. It is known to have a tensile strength of 2.6-9.6MPa in the enamel and 1.1 to 4.1 MPa in the dentin(Forsten et al. 1994).

Glass ionomer cements are bioactive cements which release fluoride. They show an initial rapid release of fluoride ions followed by a sustained release(Forsten 1977). Glass ionomer can also be recharged with fluoride ions by topical application of fluoride and acts as fluoride reservoir(El-Safty et al. 2021).

Glass ionomer also shows adhesion to the tooth surface. The glass ionomers are hydrophilic in nature like the tooth surface. The adhesion takes place by the formation of hydrogen bonds between the carboxylate ions and the bound water from the tooth surface(Cook et al. 2015). After the maturation of the restoration, these initial hydrogen bonds formed are replaced by ionic bonds between the cations in the tooth structure and anionic elements in the glass ionomer cement. In addition to the chemical bonding the use of polyacrylic acid also provides micromechanical bonding by the self-etching action on the tooth surface(Kantrong et al. 2021).

Newer advances of glass ionomer cements are developed with addition of bioactive elements like hydroxyapatite crystals and calcium and phosphate ions. Studies have shown a remineralization action of the bioactive material in the dentin (Yli-Urpo et al. 2005; Nanavati et al. 2021). A decrease in the pH leads to the release of the calcium and phosphate into the saliva therapy increasing the pH and initiating a remineralization action.(Yli-Urpo et al. 2005)

Clinical application of Glass ionomer cement

Clinically glass ionomer cements are used as leuting agents, restorative material, lining or base materials, pit and fissure sealants, core build up material and bonding of orthodontic brackets(Knibbs 1988). It is the material of choice for Atraumatic Restorative Treatment since its bonds to the tooth and shows remineralization potential of early enamel lesion. Atraumatic Restorative Treatment requires use of hand instruments and placement of a material which promotes remineralization(Rahmatulla & Frencken 2000; Anon 2000). A systematic review by Maia et al shows greater survival of glass ionomer in atraumatic restorative treatment in elderly patients (Maia et al. 2021)

For leuting agents, the manipulation of glass ionomers requires low power liquid content like 1.5:1 to 3.8:1. For increased strength, the powder liquid content used for restoration can be from 3:1 to 6.8:1(Klockowski 1988). Some glass ionomer cements are used specially for geriatric and paediatric use, hence exhibit fast setting properties. The powder liquid composition for these glass ionomers varies from 3:1 to 4:1(Panpisut et al. 2020; Aratani et al. 2005). Glass ionomers can also be used along with composite resin in sandwich technique. Here the glass ionomers are used as a liner or a base to mimic the dentinal structure of the tooth and composite resin above the base for better aesthetics and compressive strength(Taha et al. 2012). For liners the powder liquid ratio of 1.5:1 is used and for base a ratio of 3:1 to 6.8:1 can give good manipulation and strength to the resultant use(Sidhu 1992). Glass ionomers are used as fissure sealants since they show bonding to the enamel and dentin surface. The High viscosity glass ionomer cement when used as a sealant leach out calcium and phosphate minerals into the enamel surface. Even when the sealants show an initial wear, since they bond to the tooth, they will always be present in the deepest layers(Anon 2015). This is shown in studies which show its higher clinical performance and mechanical properties as compared to glass ionomer cement (Ali et al. 2019; Poornima et al. 2019; Shagale et al. 2020).

Recent modification of glass ionomers with resin, have increased the physical properties of the restoration and promoted command set. Study by Butterfloss has shown that Resin Modified glass ionomers show decreased decalcification when used in orthodontic attachment as compared to composite resin (Butterfoss n.d.; Kumar et al. 2020; Moosa 2012).

Conclusion

Glass ionomers have shown mimicking properties to the dentin and have shown a wide variety of application in dentistry. Future studies with various modification of glass ionomer cement would be beneficial for its improved mechanical and aesthetic properties and further expand the spectrum of its use in dentistry

References

Ali, A., EL-Malt, M. & Mohamed, E., 2019. A Comparative Evaluation of EQUIA Forte Microleakage Versus Resin-Modified Glass Ionomer. *Al-Azhar Dental Journal for Girls*, 6(3), pp.249–254. Available at: http://dx.doi.org/10.21608/adjg.2019.6774.1065.

Almubarak, N., 2016. *Marginal Integrity of Composite Resin and Glass Ionomer as A Restoration for Non-Carious Cervical Lesions: A Mixed Systematic Review and Cumulative Meta-Analysis in Pursuance of the Best Evidence Base*, University of California, Los Angeles.

Anon, 2015. GC EQUIA Forte : New Restorative System with Glass Hybrid Technology. *Smile Dental Journal*, 10(2), pp.34–34. Available at: http://dx.doi.org/10.12816/0023224.

Anon, 2000. Management of Dental Caries Through the Atraumatic Restorative Treatment (ART) Approach. Available at: http://dx.doi.org/10.5005/jp/books/11036.

Aratani, M. et al., 2005. Compressive strength of resin-modified glass ionomer restorative material: effect of P/L ratio and storage time. *Journal of Applied Oral Science*, 13(4), pp.356–359. Available at: http://dx.doi.org/10.1590/s1678-77572005000400008.

Butterfoss, J., A clinical comparison of decalcification following orthodontic treatment using composite resin and reinforced modified glass ionomer cements. Available at: http://dx.doi.org/10.18297/etd/191.

Cattani-Lorente, M.A., Godin, C. & Meyer, J.M., 1993. Early strength of glass ionomer cements. *Dental materials: official publication of the Academy of Dental Materials*, 9(1), pp.57–62.

Cattani-Lorente, M.A., Godin, C. & Meyer, J.M., 1994. Mechanical behavior of glass ionomer cements affected by long-term storage in water. *Dental materials: official publication of the Academy of Dental Materials*, 10(1), pp.37–44.

Centre, I.T. & International Trade Centre, 2010. ISO – International Organization for Standardization. Available at: http://dx.doi.org/10.18356/e9b37b76-en.

Chandra, A., 2018. Bioactive Materials: Unfolding of a New Era. *Austin Journal of Dentistry*, 5(3). Available at: http://dx.doi.org/10.26420/austinjdent.2018.1108.

Cook, N.B. et al., 2015. Bonding Ability of Paste-Paste Glass Ionomer Systems to Tooth Structure: In Vitro Studies. *Operative Dentistry*, 40(3), pp.304–312. Available at: http://dx.doi.org/10.2341/14-030-l.

Darvell, B.W. & Smith, A.J., 2022. Inert to bioactive – A multidimensional spectrum. *Dental Materials*, 38(1), pp.2–6. Available at: http://dx.doi.org/10.1016/j.dental.2021.11.002.

El-Safty, S.M. et al., 2021. Microhardness and Fluoride Release of Glass Ionomer Cement Modified with a Novel Al Complex to Enhance Its Antimicrobial Activity. *International journal of biomaterials*, 2021, p.1925388.

Forsten, L., 1977. Fluoride release from a glass ionomer cement. *European Journal of Oral Sciences*, 85(6), pp.503–504. Available at: http://dx.doi.org/10.1111/j.1600-0722.1977.tb00586.x.

Forsten, L., Mount, G.J. & Knight, G., 1994. Observations in Australia of the use of glass ionomer cement restorative material. *Australian Dental Journal*, 39(6), pp.339–343. Available at: http://dx.doi.org/10.1111/j.1834-7819.1994.tb03102.x.

Geurtsen, W., Leyhausen, G. & Garcia-Godoy, F., 1999. Effect of storage media on the fluoride release and surface microhardness of four polyacid-modified composite resins ("compomers"). *Dental materials: official publication of the Academy of Dental Materials*, 15(3), pp.196–201.

Gu, Y.W. et al., 2005. Zirconia–glass ionomer cement—a potential substitute for Miracle Mix. *Scripta materialia*, 52(2), pp.113–116.

Hernandez, G., 2004. *Reinforcement of Conventional Glass Ionomer Cement*, Indiana University School of Dentistry.

Hill, F.J., 1991. An atlas of glass-ionomer cements. A clinician's guideG. J. Mount. Pp. 136. 1989. London, Martin Dunitz. Hardback, £29.95. *Journal of Dentistry*, 19(3), pp.152–152. Available at: http://dx.doi.org/10.1016/0300-5712(91)90004-i.

Kantrong, N. et al., 2021. Differential induction of surface chemical compositional change on tooth structure by glass ionomer restorative materials. *Odontology*, 109(1), pp.124–138. Available at: http://dx.doi.org/10.1007/s10266-020-00528-6.

Karkera, R. et al., 2016. Comparison of the Solubility of Conventional Luting Cements with that of the Polyacid Modified Composite Luting Cement and Resin-modified Glass lonomer Cement. *The journal of contemporary dental practice*, 17(12), pp.1016–1021.

Klockowski, R.J., 1988. *Evaluation of Glass Ionomer Cements as Luting Agents in the Placement of Orthodontic Brackets*,

Knibbs, P.J., 1988. Glass ionomer cement: 10 years of clinical use. *Journal of Oral Rehabilitation*, 15(1), pp.103–115. Available at: http://dx.doi.org/10.1111/j.1365-2842.1988.tb00150.x.

Kumar, G.V., Vinaya Kumar, G. & Anto, N., 2020. Comparison of Retentive Strength of Glass Ionomer Cement, Resin-modified Glass Ionomer Cement, and Adhesive Resin Cement with Nickel–Chromium Cast Crown: An In Vitro Study. *CODS Journal of Dentistry*, 11(1), pp.11–14. Available at: http://dx.doi.org/10.5005/jp-journals-10063-0046.

Maia, T.S. et al., 2021. Survival of atraumatic restorative treatment restorations in the elderly patients: a systematic review. *Brazilian oral research*, 35, p.e130.

Matsuya, S., Maeda, T. & Ohta, M., 1996. IR and NMR analyses of hardening and maturation of glass-ionomer cement. *Journal of dental research*, 75(12), pp.1920–1927.

McCABE, J.F. et al., 2009. Smart materials in dentistry-future prospects. *Dental Materials Journal*, 28(1), pp.37–43. Available at: http://dx.doi.org/10.4012/dmj.28.37.

Moosa, S.I., 2012. *Resin Modified Glass Ionomer Cements*, LAP Lambert Academic Publishing.

Mount, G.J., Makinson, O.F. & Peters, M.C.R., 1996. The strength of auto-cured and light-cured materials. The shear punch test. *Australian Dental Journal*, 41(2), pp.118–123. Available at: http://dx.doi.org/10.1111/j.1834-7819.1996.tb05924.x.

Nagaraja Upadhya, P. & Kishore, G., 2005. Glass ionomer cement: The different generations. *Trends in biomaterials & artificial organs*, 18(2), pp.158–165.

Nanavati, K. et al., 2021. Comparative Evaluation of Shear Bond Strength of Bioactive Restorative Material, Zirconia Reinforced Glass Ionomer Cement and Conventional Glass Ionomer Cement to the Dentinal Surface of Primary Molars: an Study. *Journal of dentistry*, 22(4), pp.260–266.

Oznurhan, F. & Ozturk, C., 2020. Evaluation of Polypropylene Fiber Reinforced Glass Ionomer Cement: A Comparative In-Vitro Study. *Journal of Advanced Oral Research*, 11(2), pp.196–201. Available at: http://dx.doi.org/10.1177/2320206820930490.

Panpisut, P. et al., 2020. The effect of powder to liquid ratio on physical properties and fluoride release of glass ionomer cements containing pre-reacted spherical glass fillers. *Dental Materials Journal*, 39(4), pp.563–570. Available at: http://dx.doi.org/10.4012/dmj.2019-097.

Poornima, P. et al., 2019. Comparative evaluation of compressive strength and surface microhardness of EQUIA Forte, resin-modified glass-ionomer cement with conventional glass-ionomer cement. *Journal of Indian Society of Pedodontics and Preventive Dentistry*, 37(3), p.265. Available at: http://dx.doi.org/10.4103/jisppd.jisppd_342_18.

Rahmatulla, M. & Frencken, J.E., 2000. Atraumatic Restorative Treatment (ART) Approach to Control Dental Caries: Challenges for the Year 2000 and Beyond. *Management of Dental Caries Through the Atraumatic Restorative Treatment (ART) Approach*, pp.5–5. Available at: http://dx.doi.org/10.5005/jp/books/11036_2.

Rekow, E.D. et al., 2013. What constitutes an ideal dental restorative material? *Advances in dental research*, 25(1), pp.18–23.

Shagale, A.M. et al., 2020. Clinical performance of Equia Forte: A glass hybrid GIC versus Tetric N Ceram; a bulk fill composite in class II carious primary molars: A 12 month split mouth clinical trial. *International Journal of Applied Dental Sciences*, 6(4), pp.435–440. Available at: http://dx.doi.org/10.22271/oral.2020.v6.i4g.1098.

Sidhu, S.K., 1992. Sealing effectiveness of light-cured glass ionomer cement liners. *The Journal of Prosthetic Dentistry*, 68(6), pp.891–894. Available at: http://dx.doi.org/10.1016/0022-3913(92)90545-l.

Sidhu, S.K. & Watson, T.F., 1995. Resin-modified glass ionomer materials. A status report for the American Journal of Dentistry. *American journal of dentistry*, 8(1), pp.59–67.

Smith, D.C., 1990. Composition and characteristics of glass ionomer cements. *Journal of the American Dental Association* , 120(1), pp.20–22.

Taha, N.A., Palamara, J.E. & Messer, H.H., 2012. Assessment of laminate technique using glass ionomer and resin composite for restoration of root filled teeth. *Journal of Dentistry*, 40(8), pp.617–623. Available at: http://dx.doi.org/10.1016/j.jdent.2012.04.006.

Walls, A.W., McCabe, J.F. & Murray, J.J., 1988. Factors influencing the setting reaction of glass polyalkenoate (ionomer) cements. *Journal of dentistry*, 16(1), pp.32–35.

Yli-Urpo, H. et al., 2005. Compressive strength and surface characterization of glass ionomer cements modified by particles of bioactive glass. *Dental materials: official publication of the Academy of Dental Materials*, 21(3), pp.201–209.

Zainuddin, N. et al., 2009. A long-term study on the setting reaction of glass ionomer cements by 27Al MAS-NMR spectroscopy. *Dental materials: official publication of the Academy of Dental Materials*, 25(3), pp.290–295.