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A Journey through the World of Glass Ionomer Cements in Orthodontics

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Abstract

The development of the first glass ionomer cement by A. D. Wilson and B. E. Kent in 1971 resulted in cements that have adhesive properties of polycarboxylate cements and hardness, insolubility of silicate cements. Glass ionomer cements contain a powder similar to that of silicate cements and a polyacrylic liquid similar to that of polycarboxylate cements.

Glass ionomer cements possess unique combination of properties that make them potentially useful in clinical orthodontics. Firstly, they adhere to tooth enamel and metal. Secondly, they release fluoride and thereby may prevent enamel decalcification. Also, they can be removed more easily than composite resins at the time of debonding. This article gives a brief review of the role played by glass ionomer cements in orthodontic practice.

Introduction

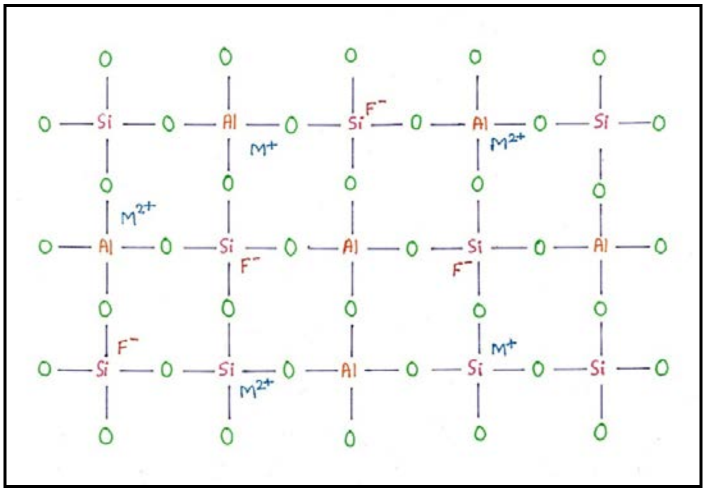
The first glass ionomer cement developed by A. D. Wilson and B. E. Kent was a product of an acid-base reaction between basic fluoroaluminosilicate glass powder and polycarboxylic acid in the presence of water. The nature of the set cement comprised an organic-inorganic complex with high molecular weight.[1]

Therefore, glass ionomer cement can be defined as a water based material that hardens following an acid-base reaction between fluoroaluminosilicate glass powder and an aqueous solution of polyacid.[2]

Structure of Fluoroaluminosilicate Glass

The following diagram illustrates the skeletal structure of fluoroaluminosilicate glass (a tetrahedron). Si is in the center and O is at the vertex. Al can replace the Si site, is attacked by the H^+ ion, and can react with anion.

The modified ion M^{2+} (Ca^{2+}, Sr^{2+}, Na^{+}, K^{+}) also is reactive. F^{-} is not in the tetrahedron so it can diffuse through the glass structure.



Acids That May Form the Polyacid Component of Glass Ionomer Cements

The following acids may form the polyacid component of glass ionomer cements:

- Acrylic acid
- Maleic acid.
- Itaconic acid.
- Butene dicarboxylic acid.
- Vinyl phosphonic acid.

Setting Reaction Of Conventional Glass Ionomer Cements

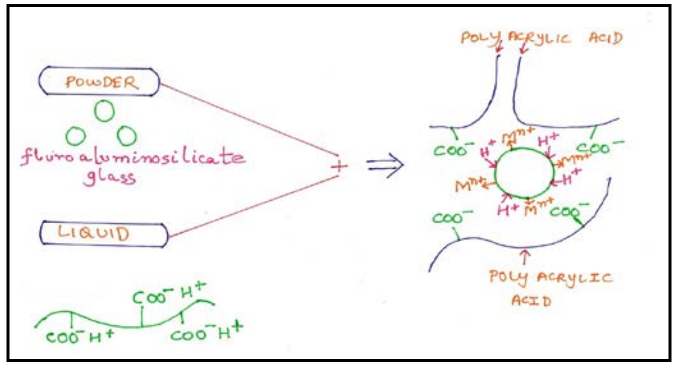
The setting reaction of conventional glass ionomer cements starts when the fluoroaluminosilicate glass powder and the aqueous solution of polyacrylic acid are combined, producing an acid-base reaction with the powdered fluoroaluminosilicate glass.

Fluoroaluminosilicate Glass (Base) + Polyacid (Acid) = Polyacid Matrix (Salts).

The hydrogen ions of the acid attack the glass particles in the presence of water, releasing calcium, strontium, and aluminium salts. The metal ions combine with the carboxylic acid groups of the polyacid to form the polyacid salt matrix, and the glass surface is changed to a silica hydrogel.

The surface layer of the glass powder reacts with acid, whereas the glass core remains intact. The glass core exists as filler in the cement matrix glass. A silica gel layer is formed at the interface between the cement matrix and the glass particles.

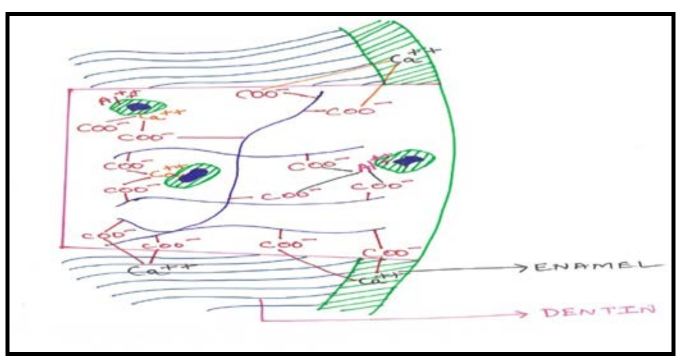
The following diagram illustrates the setting reaction of conventional glass ionomer cements:



Mechanism Of Adhesion

The mechanism of adhesion of glass ionomer cements to the dental hard tissues primarily involves chelation of carboxyl groups of the polyacids with the calcium in the apatite of the enamel and dentin. The bond strength to enamel is always higher than that to dentin because of the greater inorganic content (Calcium) of enamel and its greater homogeneity.[3]

The following diagram illustrates the mechanism of adhesion of glass ionomer cements to the enamel and dentin:



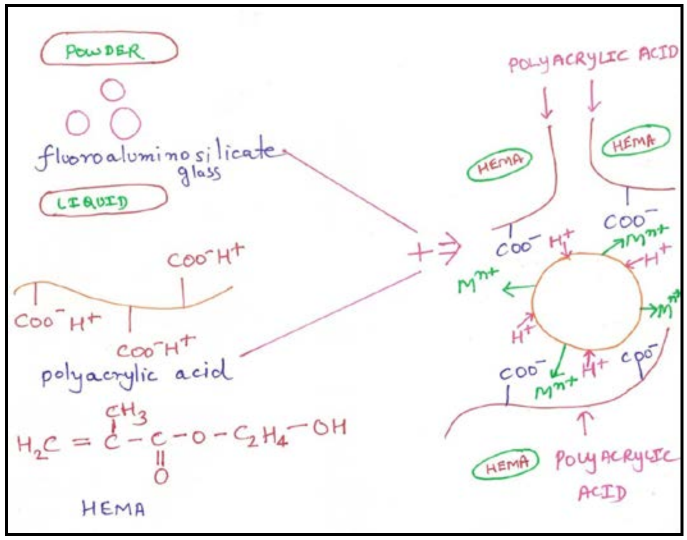
Resin Modified Glass Ionomer Cements

Resin modification of glass ionomer cement is designed to produce favourable physical properties similar to those of composites and resin cements while retaining the basic features of the conventional glass ionomer cement. This goal is achieved by incorporating water soluble present monomers into an aqueous solution of polyacrylic acid. In this way the system undergoes polymerization of the resin monomer while the acid-base reaction continues simultaneously. The resulting resin modified glass ionomer cements exhibit many advantages of both resin cements and glass ionomer cements. Resin modified glass ionomer cements contain 2-hydroxyethylmethacrylate (HEMA).

Setting Reaction Of Resin Modified Glass Ionomer Cements

The essential acid-base reaction between the fluoroaluminosilicate glass and the polycarboxylic acid is initiated by mixing the powder and liquid. At the same time, the polymerization of HEMA and cross-linking material is started by an oxidation-reduction or a photopolymerizing catalyst. This forms a hardened mixture in which HEMA polymer and polycarboxylic acid are linked by hydrogen bonding. The acid with polymerizable double bonds that is included in some products is formed with a monomer. The double bonds of the polymerizable monomer included in the liquid disappear after hardening, and the number of carboxyl groups in the polycarboxylic acid decreases as the acid-base reaction advances.

The following diagram illustrates the setting reaction of resin modified glass ionomer cements:



Fluoride Release And Fluoride Uptake

Glass ionomer cements have a beneficial effect on the human dental hard tissues because of their continuous release of fluoride which reduces the rate of caries. Another great advantage of glass ionomer cement is the continuous uptake of fluoride, which may greatly extend the beneficial effects of these cements.[2]

Studies Conducted On Glass Ionomer Cements With Regards To Their Application In The Orthodontic Arena

In 1983 Einar Kvam et al showed that zinc phosphate cement was more soluble than glass ionomer cement. The disadvantage of glass ionomer cement was lack of good manipulative characteristics. The short setting time permitted cementation of only one band for each mix. They concluded that appliances that were under any sort of mechanical strain should be cemented with glass ionomer cement. They also reported that glass ionomer cement could serve as an excellent luting agent in cases of abnormal crown morphology.[4] In 1986 D. Stephen Norris et al conducted a study on three cements (zinc phosphate, zinc polycarboxylate and glass ionomer), they reported that glass ionomer cement could offer excellent clinical protection against decalcification in cases of loose orthodontic bands.[5]

Dr. Larry W. White in 1986, reported that glass ionomer cement had a tendency to wash out before gelation which could become a matter of concern during its clinical usage. However, he concluded that this disadvantage could be solved by using thicker cement mixtures. He also advocated the use of glass ionomer cement for both bracket bonding and band cementation. Based on his clinical experience with glass ionomer cements, he observed 75% lesser amount of band failures as compared with zinc phosphate cement.[6]

R. Maijer and D. C. Smith in 1988 conducted a study to compare the clinical efficiency between zinc phosphate and glass ionomer cements. Their study showed that glass ionomer cement dissolved to a lesser extent than zinc phosphate cement and in addition the glass ionomer cement released fluoride. They also observed absence of decalcifications on the molars that were cemented with glass ionomer cement. Thus, according to them glass ionomer cement could serve as an excellent luting agent for orthodontic band cementation.[7]

Eliakim Mizrahi in 1988 conducted a study to determine the failure rate of bands cemented with a glass ionomer cement (Ketac – Cem) to premolar and molar teeth. Stainless steel bands were cemented to premolar and molar teeth with a glass ionomer cement (Ketac – Cem). The failure rate of the bands was found to be a mere 1.9%.[8]

In 1988 Hans W. Seeholzer and Walter Dasch compared two groups of orthodontic patients, banded with Ames Red Copper cement and glass ionomer cement (Ketac). Adhesion of the cement to the bands and teeth was observed every four to six weeks by visual inspection or with an explorer. The Copper cement was observed on 1000 bands over an average time period of nineteen months. The glass ionomer cement was observed on 2034 bands over an average time period of fifteen months. The results of their study showed that the incidence of band loosening was 19.7% lower with glass ionomer cement than with the copper cement. Loosening of bands occurred due to failure of the bond between the cement and band, rather than between the cement and enamel. Teeth banded with glass ionomer cement (Ketac) were also analyzed according to the duration of attachment. The average time of good adhesion was about seventeen months. It appeared that the percentage of loose bands decreased as the duration of attachment increased.[9]

In 1991 D. R. Stirrups performed a comparative clinical trial between a glass ionomer cement and a zinc phosphate cement for luting orthodontic bands. D. R. Stirrups reported that the performance of the glass ionomer cement as a luting agent was far better in comparison to the phosphate cement. The failure rate of the phosphate cement was approximately three times more as compared to the glass ionomer cement.[10]

In 1993 Axel Voss, Reinhard Hickel and Stefan Mölkner conducted an in vivo study wherein the adhesion of orthodontic bracket bases was examined twenty four to thirty two hours after bonding with a glass ionomer cement. In contrast to bonding with composite resin, the glass ionomer cement did not require etching of the enamel surfaces. Based on their study they concluded that the glass ionomer cement was suitable for use as a bonding material for orthodontic attachments provided that the bracket bases were modified in order to improve the bond strength with the enamel surfaces.[11]

In 1993 P. G. Jost-Brinkmann, R. R. Miethke and A. H. Appenzeller conducted an in vitro investigation on factors influencing the adhesive strength of a glass ionomer cement. They reported that in order to reduce the rate of loosening of orthodontic bands, the cement should be mixed at a refrigerated temperature.[12]

In 1995 Nels Ewoldsen et al studied the effects of enamel conditioning on bond strength with a restorative light cured glass ionomer cement. Their results indicated that the bond strength of resin modified glass ionomer cements to enamel was not dependent on phosphoric acid etching and was only marginally enhanced by polyacid conditioning. They further reported that the application of brackets to clean, conditioned, moist enamel produced the highest bond strengths. They also observed that even salivary contamination did not hinder successful bonding with the resin modified glass ionomer cement.[13]

In 1995 Elliott Silverman et al tested a light cured resin modified glass ionomer cement (Fuji Ortho LC) for bonding teeth.[14] The study showed that Fuji Ortho LC had the following advantages for bonding orthodontic brackets:

- Saved significant amount of chair time.
- Eliminated the need for working in a dry field.
- Eliminated the need for etching and priming enamel surfaces.
- Fluoride release protects teeth against decalcification.
- Repairs were quick and easy.
- Increased patient and operator comfort.

In 1997 Akira Komori and Haruo Ishikawa conducted a study to evaluate the tensile and shear bond strengths of Fuji Ortho (resin modified glass ionomer cement). They concluded that Fuji Ortho could be used in place of composite resins for the bonding of orthodontic brackets.[15]

In 1997 John P. Fricker performed a clinical trial of three different orthodontic band adhesives. The adhesives consisted of a light activated dual cure resin modified glass ionomer cement (Fuji II LC, GC International), light activated dual cure resin with added glass (Bandlok, Reliance Orthodontic Products) and a chemically cured second generation glass ionomer cement (Ketac Cem, Espe).

The results of the failure rates of the three different orthodontic band adhesives were as follows:

- Fuji II LC (2.9%).
- Bandlok (8.1%).
- Ketac Cem (3.5%).

Cement failures with Fuji II LC and Ketac Cem were at the adhesive/metal interface, leaving the majority of adhesive on the enamel surface. Cement failures with Bandlok were at the enamel/adhesive interface, leaving the majority of adhesive on the surface of the band. Thus, John P. Fricker reported that Fuji II LC and Ketac Cem could serve as orthodontic band adhesives rather than Bandlok for cementation of orthodontic molar bands because of their greater adhesion to enamel.[16]

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