Methods to enhance physical and mechanical properties of conventional and resin modified glass ionomer cements. A narrative review.

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Abstract

Glass ionomer (GI) cement, although is widely used as luting agent for indirect restorations, presents inferior mechanical properties compared to resin cement due to its low elastic modulus. In dental literature, many attempts to enhance the mechanical qualities of GIs by adding reinforcing fillers to the GI powder or altering the GI liquid have been done.

To increase the mechanical characteristics of GICs while maintaining their adhesive and fluoride release qualities, reactive glass fibers, metal powders, and other nonreactive fillers have all been considered as suitable reinforcement leading to development of multiple formulations.

Objectives

The aim of this review was to highlight how the glass powder and polyacid liquid components of GIs had changed and evolved since they were first developed in the late 1960s.

Materials and Method

Review of the dental literaturefrom 1970 to 2022 covering the development of GIs from the earliest experimental to current commercially available was conducted. Additionally, English-language papers with full texts and abstracts reporting different GI reinforcement tactics were included.

Conclusion

Despite numerous reinforcements, considerable improvements in GI formulations via a further reinforcing approach still needs to be established to allow the practical application of GIs for the restoration of posterior teeth.

Keywords- mechanical, glass ionomer, resin, modifications

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Introduction

Clinical dentists frequently employ glass-ionomer cements (GICs) for full restorations, liners and bases, luting agents, fissure sealants, and adhesives for braces. The development of dental silicate cements and zinc polycarboxylate cements led to the creation of glass ionomer cements (GICs) in the late 1970s. [1]

Glass-ionomer cements belong to the class of materials known as acid-base cements.They are based on the result of the reaction between weak polymeric acids and basic glass powders [1].Setting occurs in concentrated solutions in water and the final structure contains a substantial amount of unreacted glass which acts as filler to reinforce the set cement.

Glass ionomer cement, although is widely used as luting agent for indirect restorations, presents inferior mechanical properties compared to resin cement due to its low elastic modulus. In dental literature, many attempts to enhance the mechanical qualities of GIs by adding reinforcing fillers to the GI powder or altering the GI liquid have been done. Despite the claimed improvements in the modified GIs' mechanical characteristics, a wide range in mixing and testing, it is essential to standardize the mixing and testing circumstances when researching GI reinforcement strategies in order to make meaningful comparisons between experiments. [1]

Numerous changes in the GICs' composition, particularly in the glass powder, have been made to address their flaws and limits. To increase the mechanical characteristics of GICs while maintaining their adhesive and fluoride release qualities, reactive glass fibers, metal powders, and other nonreactive fillers have all been considered as suitable reinforcement. [2-5]

Materials and Method

This review was done following the criteria of Cochrane Handbook for Systematic Reviews of Interventions. Analyses were based on the population, intervention, comparison, and outcome (PICO) index.An electronic search of papers from 1970 to 2022 was done using the databases Scopus, ISI Web of Science, PubMed, and EBSCO host. The search was conducted using five keyword combinations: (1) GICs; (2) glass powder; (3) mechanical properties; (4) modifications; and (5) nanoceramics.

Articles were first screened based on articles title and abstract, then afterward full texts were reviewed to confirm its eligibility. Studies were excluded during the title screening stage according to the following criteria: Titles not in English language and irrelevant titles. Studies that were included at the abstract level were according to the following criteria: English language; Full text available; Randomized clinical trials studies; retrospective and prospective clinical studies; cross-sectional studies and cohort studies. Studies that were excluded during abstract screening stage were based on the following criteria: Irrelevant topics that are not related to this review and studies that are not in English language.

Discussion

To study the evolution of glass ionomer over the years, it is appropriate to assess the mechanical qualities of both varieties of glass-ionomer cements. This is important because it sets the starting point from which reinforcement must be achieved and because some authors refer to the latter group of glass-ionomers as "resin-reinforced." In the middle of the 1990s, the appropriate term ‘resin-modified’ was first put out [6] and is often used in the literature [7]. This is not the term of preference. It is difficult to compare these material classes due to the various strengths indicated by the relevant international standards [8]. Conventional glass-ionomer cements must have a minimum compressive strength of 100 MPa in order to be used for restorative procedures on patients. However, resin-modified glass ionomers need to pass flexural strength testing and have a minimum strength of 20 MPa in order to be used in clinical settings.[9]

In an effort to compare the materials, a few published research have provided compressive strength values for resin-modified glass-ionomers and flexural strength values for traditional glass-ionomers. Despite what the various studies suggest, it is unfortunately impossible to draw any trustworthy generalizations due to the large variations in reported data. For instance, one studies by Illie et al and Busanello et alrevealed that the typical glass-ionomer Fuji IX (GC, Tokyo, Japan) in its hand-mixed form had a compressive strength of 83.6 MPa at 24 h. [10,11] An earlier study came to the conclusion that resin-modified glass-ionomers are stronger in all test modes, but the data cannot be accepted when the traditional cement's claimed compressive strength is so low. Not that the researchers' competence or talent is in doubt.When preparing specimens for testing, there are numerous variables that must be under control because these components are challenging to mix and attain consistency [12].

For typical glass-ionomers, other low compressive strength values have been recorded. In contrast to the resin-modified materials Vitremer, which had a compressive strength of 169.50 MPa, the material Ionofil Molar was found to have a compressive strength of 78.78 MPa [13]. The utility of a typical glass-ionomer must be questioned, despite how intriguing it is to see how high a resin-modified glass-compressive ionomer's strength can be. It is lower than what the relevant international standard recommends, which is an unlikely result for a material from a respectable producer. [13] Despite these differences in reported values across separate articles, there does appear to be general agreement that RMGICs have higher diametral tensile strength and flexural strength than traditional materials [14,15]. The superiority of toughness and flexural qualities was demonstrated to be constant across a variety of brands in a recent study [16]. A variety of commercial conventional glass ionomers' fracture toughness at 24 hours ranged from 0.18 to 0.30 MPa m1/2, while that of a comparable group of commercial RMGICs was 0.49–0.67 MPa m1/2. Flexural strength at 24 hours for the same materials varied between 18 and 34 MPa for standard glass-ionomers versus 49-76 MPa for RMGICs [16]. The polymerized resin component, which toughens the cement and increases its capacity to withstand stress in flexure, is responsible for these variances. Saran et al concluded in their study that the addition of 10%concentration of the two all-ceramic powders successfullyincreasedthestrengthofbothglassionomercementsusedinthestudy.However,thefilmthicknessofthesecementswasmuch higher than the specifications given by ISO. (17)

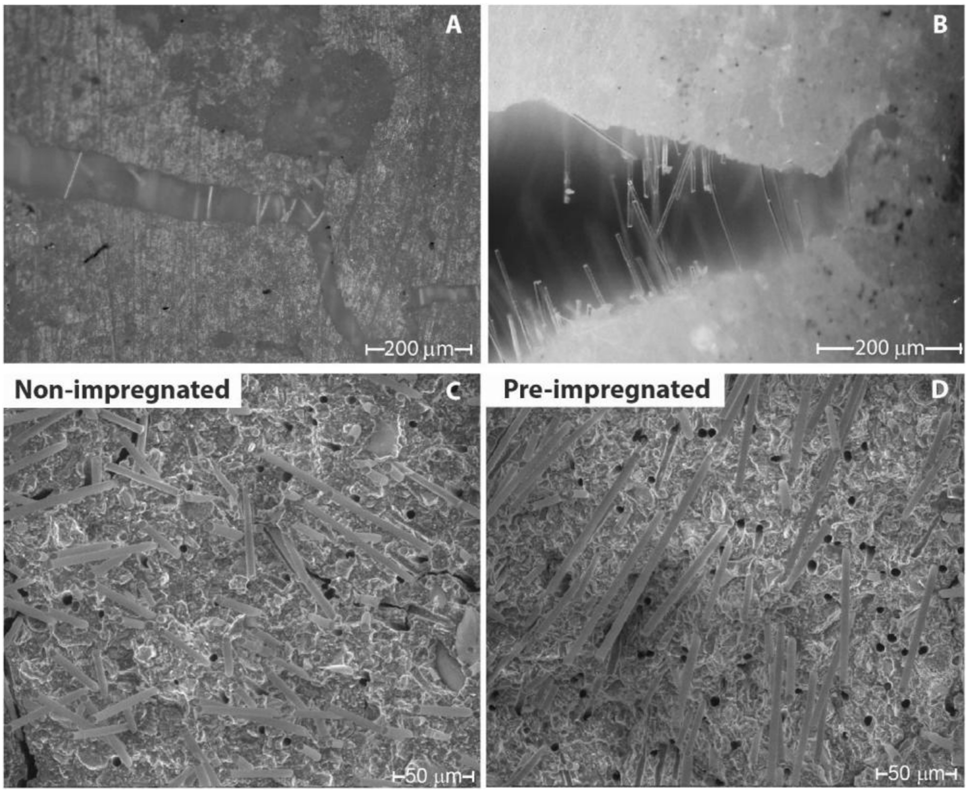

Fig.3–(A)and(B)arein-situopticalmicrographsofthefractureprocessforfracturetoughnessspecimens.(A)Duringtheearlystagesofcrackpropagation,fiberbridgingoccurs.(B)Laterinthefractureprocessthefiberspull-outfromtheGICmatrix.In(A)and(B)thecrackpropagationdirectionwaslefttoright.(C)and(D)areSEMimagesofflexuralstrengthsamplefracturesurfacesshowingsimilarfracturesurfacefeaturesforboththenon-impregnated(C)andresinpre-impregnated(D)fibers.In(C)and(D)thecrackpropagationdirectionwasbottomtotop.
(Picture Courtesy Tanaka CB, Ershad F, Ellakwa A, Kruzic JJ. Fiber reinforcement of a resin modified glass ionomer cement. Dental Materials. 2020 Dec 1;36(12):1516-23.)

In early 1990s when materials were first made available to dentists, they featured a monomer component and related initiator system in addition to the same fundamental components as traditional glass-ionomers (basic glass powder, water, and polyacid). Typically, 2-hydroxyethyl methacrylate, or HEMA, serves as the monomer while camphorquinone serves as the initiator [18]. The twin processes of neutralization (acid-base reaction) and addition polymerization are used to create resin-modified glass-ionomers, and the final material has a complex structure based on the combined byproducts of these two reactions [19]. Additionally, as these two network-forming reactions compete with one another, there is a delicate equilibrium between them [20]. In order to generate material with the best qualities, strict attention to the manufacturer's instructions on the length of the irradiation step is crucial [20]. This mixture of setting processes may threaten the dependability of the set material.

The same glasses that are used in traditional glass-ionomers are also utilized in resin-modified glass-ionomers.

Although in some materials it is changed with side chains that end in unsaturated vinyl groups, the acidic polymer may be the same as well. These may participate in the addition polymerization reaction and create covalent crosslinks between the chains of the polymer.

Glass-ionomers modified with resin have equivalent physical characteristics to glass-ionomers made without resin [19]. Additionally, they release fluoride in a two-step process that is the same as that of traditional glass ionomers in that there is an initial wash-out phase followed by a prolonged diffusion-based phase [21]. This process' kinetic equation is same as the kinetic equation for traditional glass-ionomers [21,22].

Under neutral conditions, resin-modified glass-ionomers emit trace amounts of sodium, aluminum, phosphate, and silicate, like typical glass-ionomer cements [23]. Greater amounts are released in an acidic environment, and calcium (or strontium) is also released [23]. The buffering effect that occurs when ions are released under acidic conditions causes the pH of the storage medium to progressively rise over time [24].

In comparison to ordinary glass ionomers, the biocompatibility of resin-modified glass ionomers is significantly reduced. This is as a result of HEMA monomer being released from leachedresin-modified glass-ionomers, primarily in the first 24 hours in different proportions. The amount released is determined by how much light-curing the cements have undergone [24]. Human dentine can distribute HEMA, which is also damaging to pulp cells [25, 26].

Dental professionals may also experience issues since HEMA from resin-modified glass-ionomers is a contact allergen and is volatile, making it possible to inhale [27]. Clinicians are advised to use well-ventilated workspaces and to avoid inhaling any vapours to guarantee the safe use of these materials [28]. Additionally, they are instructed to light-cure any unwanted materials before discarding them. Although there is some anecdotal evidence of allergies arising in the latter group, it appears that there are no case studies or reports in the literature of negative reactions by patients or dental professionals to resin-modified glass-ionomers.

Although resin-modified glass-ionomers need the use of electrically driven cure lights, they still have the same therapeutic applications as traditional glass-ionomers [29]. As a result, they are utilized in Class V restorations as well as liners and bases, Class I, Class II, and Class III restorations, all of which are primarily for the primary dentition [30]. Other applications include bonding agents for orthodontic brackets [31] and as fissure sealants [30].

Glass Carbomer

This is a newer commercial glass-ionomer material that is more bioactive than traditional glass-ionomer cement. The Netherlands-based GCP Dental produces it. It is regrettable that the name "glass carbomer" has been accepted in the scientific literature as the substance is truly a form of glass-ionomer[32,33]. Although it also comprises ingredients that are not typically seen in glass-ionomer formulations, the glass-ionomer sets by an acid-base reaction between an aqueous polymeric acid and an ion-leachable basic glass [34].

These elements are listed as follows:

• Glass powder that has undergone a severe acid wash, leaving the calcium content of the surface layers of the particles significantly diminished [35]. As a result, most calcium ions are found well inside the particles, toward the core.

• A silicone oil made of a polydimethylsiloxane with hydroxyl groups and a typically linear structure. In order for the silicone oil to stay incorporated into the cement after setting, this enables it to form hydrogen bonds with other cement constituents.

• A bioactive substance that functions as a secondary filler. This filler, which has been identified as hydroxyapatite by solid state NMR spectroscopy is used to encourage the development of enamel-like material at the interface with the tooth, as was previously shown with traditional glass-ionomer fissure sealants [33].

Glass used to make glass carbomer contains strontium, as well as significant amounts of silicon and calcium [33]. Compared to the glasses used in the well-known brands of conventional glass-ionomer Fuji IX and Ketac Molar, it has a considerably higher silicon content, but it also has comparable levels of aluminum, phosphorus, and fluoride.

The glass is comparatively unreactive to poly (acrylic acid) or acrylic/maleic acid copolymer because of the acid-washing process. Additionally, the silicone oil added to the glass powder is absorbed onto the surface of the glass, which also hinders the polyacid reaction. Because of this, the glass carbomer is simple to combine at high powder-liquid ratios, and little reaction takes place as these two components are combined.

After the material is prepared, a dental cure lamp is applied for at least 20 seconds to hasten its slow setting response [34]. This is due to the heat that dental cure lights produce. The cement's temperature rises as a result, setting in a fair amount of time.

Compared to ordinary glass-ionomers, glass carbomers have higher quantities of glass and hydroxyapatite filler, making the set glass carbomer particularly brittle.Silicone oil is then added to this. This makes the material stronger and maintains its hydrogen-bonding-based internal bond.

According to studies on the setting reaction, there are two parallel reactions involved in setting glass carbomer. One involves glass and polyacid, and the other involves hydroxyapatite and polyacid. Both processes produce an ionically crosslinked polyacid matrix with embedded filler and are acid-base reactions. However, in this instance, the filler also includes partially reacted hydroxyapatite in addition to ion-depleted glass. Despite the addition of polydimethylsiloxane oil, the resultant matrix is different from that found in a traditional glass-ionomer cement [35].

Long-term studies have not yet been published, and there have only been preliminary reports on the usage of glass carbomer in therapeutic settings. As a result, it is unknown how long the substance sustains in oral environment.

Conclusion

Glass-ionomer cements are adaptable acid-base materials with a variety of uses in contemporary dentistry, as demonstrated by this review's analysis of the published literature. The high endurance of their adhesion to the tooth surface is due to the bioactivity they exhibit when set, which causes them to form an interfacial ion-exchange layer with the tooth. Although the evidence for this is somewhat ambiguous, they emit fluoride over long periods of time, which is generally thought to be advantageous. Glass ionomer cements have periodically undergone changes and there could be additions to reinforce them in future too.

Clinical Significance

Improvements in the physical and mechanical qualities of glass ionomers would be desirable because they are mechanically weak by nature yet attach to sound tooth structure without the requirement for preconditioning or removal of sound tooth structure. Although improvements have been made over the past 40 years through various GI glass powder and polyacid liquid formulations, more advancements in the mechanical qualities of the present GIs are needed. There are multiple studies on GI reinforcement in the literature. Nevertheless, for a valid assessment of the reinforcement techniques, enhanced reporting and control of mixing and testing settings are needed.

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