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GLASS-IONOMER CEMENTS IN DENTISTRY: THE CURRENT POSITION

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Summary:

Glass-ionomer cements have become important dental restorative and luting materials, finding particular application in paediatric dentistry. They form chemical bonds to enamel and dentine, which prove highly durable over time. They are biocompatible, and release fluoride ions which can be taken up by adjacent tooth structure. Modern glass-ionomers are much easier to use than the earlier versions, and high-viscosity materials have been developed for use with the Atraumatic Restorative Treatment (ART) technique. Resin-modified glass-ionomers have improved toughness compared with conventional glass-ionomers, and have established niche applications, also in paediatric dentistry. As well as in resin-modifed glass-ionomers, the fundamental chemistry of glass-ionomers has been employed in composte resin systems, both compomers and giomers. Both are essentially composite resins, and their properties and clinical indications are those of composites. In both cases, it is doubtful if the glass-ionomer chemistry adds anything significant to their performance.

Introduction:

Glass-ionomers have been used in various areas of restorative dentistry for approaching 30 years. Invented and originally described by Wilson and Kent [1], they consist of a basic glass powder and a water-soluble acidic polymer, such as poly(acrylic acid). The glass powder is a calcium (or strontium) aluminofluorosilicate [2]. Setting occurs by neutralization, and involves initial formation of calcium or strontium polyacrylate and later formation of aluminium polyacrylate. There is also evidence for a later, slow reaction involving the ion-depleted inorganic species from the acid-attacked glass [3].

Glass-ionomers are classified into three categories, namely conventional, metal-reinforced and resin modified [4-6]. All involve the acid-base setting chemistry of the original glass-ionomer, but in the case of resin-modified glass-ionomers this is augmented by a polymerization reaction of an additional monomer, typically 2-hydoxyethyl methacrylate, HEMA. Metal-reinforced glass-ionomers set only by the acid-base process, and are strengthened by the inclusion of finely divided metal powers, typically the silver-tin alloy of dental amalgams [7].

Recently fast-setting, high-viscosity conventional glass-ionomers have been developed [8]. These were developed during the early 1990s for use with the atraumatic restorative treatment (ART) technique in developing countries. These are considered later in this article, and the clinical success of the ART approach has relied on the improved properties of these newer glass-ionomer materials.

Properties of Glass-ionomers:

Adhesion

Glass-ionomers form a natural adhesive bond to tooth structure (enamel or dentine) [9]. This seals the cavity, preventing leakage at the margins, protecting the pulp and eliminating secondary caries [11] The adhesive bond arises due to an ion-exchange process at the interface [4,10], and in strontium-based glass-ionomers, this has been shown to result in strontium migrating from the cement to well inside the tooth surface, and calcium migrating from the tooth to well inside the cement [12]. The result is a very durable bond to the tooth [10].

When determined relatively soon after placement, reported shear bond strengths of glass-ionomers are of the order of 3-7 MPa [6, 13]. However, because the material fails cohesively, this is actually a measure of the tensile strength. As the cement matures, the tensile strength increases, and failure rates in clinical service are very low [14].

Despite the good adhesion, conventional glass-ionomers show some microleakage at the margins of restorations. One in vitro study showed that conventional glass-ionomers were less reliable in sealing enamel margins than composite resin [15], and that there was significant dye penetration at the gingival margins.

Appearance

Conventional glass-ionomers are tooth coloured, and have a degree of translucency, which gives them reasoable aesthetics. However, they are less aesthetic than composite resins, mainly because they remain relatively opaque compared with the tooth itself [11].

Fluoride release

The glasses from which these cements are made contain fluoride, and some of this is transferred to the matrix during setting. From there it can be released, essentially without altering the physical properties of the cement [16]. Release has been shown to occur by two mechanisms, an early "wash-out" process, and a longer-term diffusion process [17]. The long-term nature of the release can continue over a long period of time, with one in vitro study showing release over a period of five years [18].

Fluoride release has been suggested to make glass-ionomers cariostatic when used clinically [19]. This is supported by in vitro studies using an artificial caries gel, when teeth restored with glass-ionomer and stored in this gel showed less decalcification than unrestored teeth stored similarly [20, 21]. However, clinical studies are more equivocal. For example, studies of the reasons given by dentists for replacement of restorations have shown that glass-ionomers are as likely to be associated with secondary caries as composite resins [22, 23], which suggests that they may not be proving as cariostatic in clinical use as has been anticipated.

As well as releasing fluoride, glass-ionomers are capable of taking up fluoride under appropriate conditions, eg from dentifrices, mouthwashes and topical fluoride solutions [24, 25]. This makes glass-ionomers permanent suppliers of fluoride, a feature that is advantageous for patients with high susceptibility to dental caries.

Mechanical properties

Glass-ionomers have good comporessive strengths, with modern restorative materials having values in excess of 200 MPa [26]. However, toughness is poor, and this leads to them being brittle and having low resistance to wear and abrasion [11]. This limits their use, and they cannot be used, for example, in repairing incisal edges of teeth, where composite resins again have the advantage. The longest recorded survival times for conventional glass-ionomers are consequently in areas of low stress, such as Class III and Class V restorations [16].

Clinical aplications of conventional glass ionomers:

Glass-ionomers have found considerable use in paediatric dentistry for many years. The occurrence of caries in children is widespread, though declining, and restoration of carious teeth remains an important clinical procedure. Restoration of the primary dentition is less demanding than for the permanent dentition, because the restoration will be in use for much less time, and also experience lower biting forces than in adults [27, 28]. Glass-ionomers are well suited to these uses, and they have the additional advantages of fluoride release and adhesion [29]. The possibility of relatively quick placement is also advantageous when treating young children [28].

In adults, glass-ionomers are widely used to repair Class V cavities, a technique which exploits the inherent adhesion of these materials. Clinical results for this procedure are good, though in vitro studies suggest that resin-modified glass-ionomers, with their enhanced fracture toughness, and improved bond strength, are likely to give superior results [30].

Early glass-ionomer luting cements were particularly success. They were strong enough to cement stainless steel crowns, space maintainers and individual orthodontic brackets. Fluoride release was considered an added advantage in these applications [31]. They continue to be supplied for this purpose, and recent studies have suggested that capsulated versions of these materials, which benefit from controlled high-energy mixing by machine, give superior luting properties, at least in vitro [32].

Metal-containing glass-ionomers were developed in the 1980s in an attempt to create stronger and more durable cements. One approach was to add silver-tin alloy, and another was to preform a glass-silver metal hybrid material called a cermet. The latter was less successful, and resulting cements did not show any improvement in mechanical properties [7]. The main advantage of these materials was that the presence of silver made them radiopaque, but the fact that the fracture resistance and fracture toughness were no higher than for conventional glass-ionomers meant that these materials still could not be used in stress-bearing regions of the teeth [33]. However, there were some reports on the use of the cermet-containing cement as an amalgam substitute in children [34, 35]. However, this use declined with the introduction of resin-modified glass ionomers in the early 1990s [33].

One important application for conventional glass-ionomers is in the ART technique. This is based on two main principles, namely the removal of caries with hand instruments only and the restoration of the cavity with an adhesive materials, ie a conventional high-viscosity glass-ionomer [36]. The technique is available to all population groups, and employs minimal cavity preparation that conserves sound tooth material and reduces the trauma of repair.

Clinical results with ART have been found to be good. For example, in one report, which involved a long-term oral health programme in schools in Zimbabwe, survival rates for one-surface ART restorations averaged 85.3% [37]. The most common cause of failure was unacceptable marginal defects (8.1%), with 6.1% falling out and 2.5% experiencing excessive wear. The mean treatment time for one-surface ART restorations without chairside assistance was 22.1 min. ART is therefore considered appropraite for population groups not receiving preventive and restorative care [37].

Resin Modified Glass-ionomers:

Resin modified glass-ionomers are a subset of the main glass-ionomer class. They consist of the same components as conventional glass-ionomers, ie water, basic glass powder and polyacrylic acid, but with the addition of 2-hydroxyethyl methacrylate (HEMA) as the resin component [38]. They also usually contain photosensitive initiators designed to bring about free radical polymerization on irradiation with blue light from a conventional dental curing lamp. Certain brands also have HEMA side-chains grafted onto the polyacrylic acid backbone [39].

The overall effect of this highly varied chemistry is that resin modified glass-ionomers are complex materials [40]. There is some tendency for them to undergo phase separation. In their unset state, this is driven by the thermodynamic effects of the relatively non-polar HEMA in the aqueous solution of polyacrylic, and on setting, is exacerbated by the insolubility of polyHEMA in water. Thus, the set material may consist of domains of differing composition. Regardless of this, their clinical performance is good, and they are now widely used and popular materials [41].

The presence of polyHEMA gives resin modified glass-ionomers some hydrogel character. This means that they will take up water [42-46], with the extent of uptake being determined by inter alia the chemical potential of water in the surrounding medium [45]. Experimental studies have shown that water uptake is greater from pure water, where the chemical potential is greatest, than from 0.9% NaCl solution [45].

A postive effect that resin modified glass-ionomers share with conventional glass-ionomers is the ability to release fluoride [47]. This has been shown to be greater in acid solution than in neutral [48]. Other ions have also been shown to be released by these materials by these materials, again with greater release under acidic conditions [48].

Resin-modified glass-ionomers have significantly higher flexural and tensile strengths than conventional glass-ionomers [11]. This means that they are more resistant to fracture. However, this has not resulted in improvements to their wear-resistance, and as a result they tend to be used in non-load bearing applications.

Like conventional glass-ionomers, resin-modified glass-ionomers have found particular use in children's dentistry. Uses include restoration of the primary dentition [49, 50], luting and bonding of orthodontic bands. For restorative work, light-curable versions of these cments are used, with cure being brought about about with a dental curing lamp for up to 40 seconds per layer. For luting, resin-modified glass-ionomers that initiate polymerization simply by mixing two-component initiator systems can be employed, and these do not require the application of light On the other hand, some materials of this type exploit the translucency of the tooth, and these do employ light to bring about cure [51].

Compomers:

Polyacid modified composite resins, informally known as “compomers” are complex materials that make some use of glass-ionomer chemistry [52]. They mainly consist of the same components as conventional dental composite resins, materilas that have been successfully used in clinical dentistry for many years [53]. However, they also contain minor amounts of an acid-functional monomer, and some reactive glass of the type used in glass-ionomer cements [54]. They therefore cure by polymerization but also have a later acid-base neutralization reaction due to the gradual uptake of water in situ. This gives them the desirable feature of fluoride ion release [55] and, in addition, some have been claimed to be able to adhere to tooth structure directly [56].

Since their introduction in the early 1990s, there have been a number of reports on the properties of compomers under different storage. An in vitro comparative study on the mechanical and physical properties of four compomers stored for 24 hour showed that these materials have acceptable properties for clinical use [57]. Water up-take is essential to promote the later acid-base reaction [58] but there is evidence that it has deleterious effects on the strength of these materials [59] and on their surface texture [60].

Mechanical properties such as compressive, diametral and biaxial flexural strengths of commercial compomers have been determined in different storage media at different times [61]. Environmental conditions were found to affect the strength of the materials with time with the most striking finding being that specimens stored in dry conditions underwent slight increases in strength, whereas all specimens stored in wet conditions became significantly weaker. Hence the water uptake, though essential to promote the secondary acid-base reaction, actually weakens the compomer. This would be expected to occur in the moist conditions of the mouth, and in this way the performance of these materials may be compromised.

Giomers

A giomer is a new type of restorative material that is based on composite resin, but filled with ground pre-reacted glass-ionomer cement particles. Giomers behave essentially as composite resins, and are light-curable. They need to be bonded using the typical resin bonding systems, which involve surface treatment and the application of bespoke bonding agents. However, they have the important property of fluoride release, which gives them some similarity to glass-ionomers. Unlike glass-ionomers, they do not have the initial burst of release, and their diffusion-based fluoride release is at a lower level than conventional glass-ionomers [62]. Because of their fundamental composite resin nature, giomers are easier to polish than glass-ionomers [63].

To date there have been few reports of the clinical performance of giomers. However, one three-year clinical study has appeared comparing the performance of a giomer and a composite resin in Class V cavities. Eight performance characteristics were measured, after which it was concluded that there were no significant differences between the two materials [64].

Not surprisingly, given their composition, giomers show very similar behaviour to composite resins. It is doubtful whether the inclusion of pre-prepared glass-ionomers makes any significant difference to these materials, and they are not fundamentally new materials, but a very slightly modified version of well-established materials. The modest fluoride release is unlikely to prove important.

Conclusions:

This review has shown tha glass-ionomer cements are important materials for use by dental clinicians, with particular benefits when used in paediatric dentistry. They bond to enamel and dentine, are biocompatible, and release fluoride. Among the modern glass-ionomer cements now being used clinically are the high-viscosity materials have been developed for use in the Atraumatic Restorative Treatment (ART) technique. Resin-modified glassionomers have better toughness compared with conventional glass-ionomers, and have established specific clinical applications, including in paediatric dentistry. The fundamental chemistry of glass-ionomers has also been employed in composite resin-based systems known respectively as compomers and giomers. Both have properties that are dominated by their essential composite resin nature and their clinical uses reflect this. However, both exhibit the property of fluoride release, and this may confer advantages under certain clinical conditions.

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