A Review of Glass Ionomer Restorations in the Primary Dentition

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Abstract

Glass ionomer cements are tooth-coloured materials that bond chemically to dental hard tissues and release fluoride for a relatively long period. They have therefore been suggested as the materials of choice for the restoration of carious primary teeth. However, the clinical performance of conventional and metal-reinforced glass ionomer restorations in primary molars is disappointing. And although the handling and physical properties of the resin-modified materials are better than their predecessors, more clinical studies are required to confirm their efficacy in the restoration of primary molars.

MeSH Key Words: *dental restoration, permanent/methods; dentition, primary; glass ionomer cements.*

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Restoring carious teeth is one of the major treatment needs of young children. A restoration in the primary dentition is different from a restoration in the permanent dentition due to the limited lifespan of the teeth and the lower biting forces of children.[1,2] As early as 1977, it was suggested that glass ionomer cements could offer particular advantages as restorative materials in the primary dentition because of their ability to release fluoride and to adhere to dental hard tissues.[3] And because they require a short time to fill the cavity, glass ionomer cements present an additional advantage when treating young children.[2]

Basic Chemistry

In general, glass ionomer cements are classified into three main categories: conventional, metal-reinforced and resin-modified.[4-7] Conventional glass ionomer cements were first introduced in 1972 by Wilson and Kent.[8] They are derived from aqueous polyalkenoic acid such as polyacrylic acid and a glass component that is usually a fluoroaluminosilicate. When the powder and liquid are mixed together, an acid-base reaction occurs. As the metallic polyalkenoate salt begins to precipitate, gelation begins and proceeds until the cement sets hard.[4,5]

Recently, several faster setting, high-viscosity conventional glass ionomer cements have become available. Called viscous or condensable glass ionomer cements by some authors,[9] these restorative materials were originally developed in the early 1990s for use with the atraumatic restorative treatment in some developing countries.[10] These materials set faster and are of higher viscosity because of finer glass particles, anhydrous polyacrylic acids of high molecular weight and a high powder-to-liquid mixing ratio.[9,10] The setting reaction is the same as the acid-base reaction typical of conventional glass ionomer cements.

Metal-reinforced glass ionomer cements were first introduced in 1977. The addition of silver-amalgam alloy powder to conventional materials increased the physical strength of the cement and provided radiopacity.[11] Subsequently, silver particles were sintered onto the glass, and a number of products then appeared where the amalgam alloy content had been fixed at a level claimed to produce optimum mechanical properties for a glass cermet cement.[11,12]

In 1992, resin-modified glass ionomer cements were developed that could be light cured. In these materials, the fundamental acid-base reaction is supplemented by a second resin polymerization usually initiated by a light-curing process.[6,7] In their simplest form, they are glass ionomer cements that contain a small quantity of a water-soluble, polymerizable resin component. More complex materials have been developed by modifying the polyalkenoic acid with side chains that could polymerize by light-curing mechanisms in the presence of photo initiators, but they remain glass ionomer cements by their ability to set by means of the acid-base reaction.[6]

Advantages

Glass ionomer cements exhibit a number of advantages over other restorative materials.

Adhesion

By bonding a restorative material to tooth structure, the cavity is theoretically sealed, protecting the pulp, eliminating secondary caries and preventing leakage at the margins. This also allows cavity forms to be more conservative and, to some extent, reinforces the remaining tooth by integrating restorative material with the tooth structures.[13] Bonding between the cement and dental hard tissues is achieved through an ionic exchange at the interface.[4,14] Polyalkenoate chains enter the molecular surface of dental apatite, replacing phosphate ions. Calcium ions are displaced equally with the phosphate ions so as to maintain electrical equilibrium.[5] This leads to the development of an ion-enriched layer of cement that is firmly attached to the tooth.[14]

The shear bond strength of conventional glass ionomer cements to conditioned enamel and dentin is relatively low, varying from 3 to 7 MPa.[7,13] However, this bond strength is more a measure of the tensile strength of the cement itself, since fractures are usually cohesive within the cement, leaving the enriched residue attached to the tooth.[5] Comparisons between resin-modified glass ionomer cements and conventional materials reveal that the shear bond strength of the former is generally greater,[15] but that they show very low bond strength to unconditioned dentin compared to conventional materials.[13] Conditioning therefore plays a greater role in achieving effective bonding with the resin-modified glass ionomer cements. In addition, when the enamel surface is etched with phosphoric acid, the bond strength of the resin-modified materials is close to that of composite-resin bonded to etched enamel.[16] This suggests, along with the effects of light-curing, that the bonding mechanism of resin-modified glass ionomer cements may be different from that of conventional materials.

Margin Adaptation and Leakage

The coefficient of thermal expansion of conventional glass ionomer cements is close to that of dental hard tissues and has been cited as a significant reason for the good margin adaptation of glass ionomer restorations.[4,7] Even though the shear bond strength of glass ionomer cements does not approach that of the latest dentin bonding agent, glass ionomer restorations placed in cervical cavities are very durable.[7] Nevertheless, microleakage still occurs at margins. An in vitro study has shown that conventional glass ionomer cements were less reliable in sealing enamel margins than composite-resin.[17] They also failed to eliminate dye penetration at the gingival margins.[17-19] Although resin-modified glass ionomer cements show higher bond strength to dental hard tissues than conventional materials, they exhibit variable results in microleakage tests.[20-22] Not all of them display significantly less leakage against enamel and dentin than their conventional counterparts.[20,22] This may be partly because their coefficient of thermal expansion is higher than conventional materials, though still much less than composite-resins.[6,7] Controversy also exists as to whether the slight polymerization shrinkage is significant enough to disrupt the margin seal.[6]

Fluoride Release

Fluoride is released from the glass powder at the time of mixing and lies free within the matrix. It can therefore be released without affecting the physical properties of the cement.[23] Since it can also be taken up into the cement during topical fluoride treatment and released again, the cement may act as a fluoride reservoir over a relatively long period.[24] As a result, it has been suggested that glass ionomer cements will be clinically cariostatic.[25] This assumption is supported by some in vitro studies using an artificial caries model in which less decalcification has been found in cavities restored with glass ionomer cements.[26,27] The amount of constant fluoride release did not differ much between brands of conventional glass ionomer cements.[28] The fluoride release of some resin-modified materials is at least the same as conventional materials but varies amongst different commercial products.[28,29] Nevertheless, the critical amount of fluoride released from a restoration that is required to be effective in inhibiting caries has not yet been established.

Despite the constant fluoride release of glass ionomer restorations, results from clinical studies are not so promising. Kaurich and others[30] compared glass ionomer and composite-resin restorations over one year and concluded that there was little clinical advantage in using glass ionomer cement. Tyas[31] examined cervical composite-resin and glass ionomer restorations five years after placement and found no significant difference in recurrent caries rates. More clinical studies would therefore be needed to confirm the cariostatic effect of glass ionomer cements.

Esthetics

Conventional glass ionomer cements are tooth-coloured and available in different shades. Although the addition of resin in the modified materials has further improved their translucency, they are still rather opaque and not as esthetic as composite-resins. In addition, surface finish is usually not as good. The colour of resin-modified materials has been reported to vary with the finishing and polishing techniques used.[32] Potential also exists for increased body discolouration and surface staining because of their hydrophilic monomers and incomplete polymerization.[33] Nevertheless, the demand for esthetics in the primary dentition is usually lower than in the permanent dentition.

Biocompatibility

The biocompatibility of glass ionomer cements is very important because they need to be in direct contact with enamel and dentin if any chemical adhesion is to occur. In an in vitro study, freshly mixed conventional glass ionomer cement was found to be cytotoxic, but the set cement had no effect on cell cultures.[34] In another study, the pulpal response to glass ionomer cements in caries-free human premolars planned for extraction was examined.[35] The result showed that although glass ionomer cement caused a greater inflammatory response than zinc-oxide eugenol cement, the inflammation resolved spontaneously with no increase in reparative dentin formation. More recently, Snugs and others[36] have even demonstrated dentin bridging in monkey teeth where mechanical exposures in otherwise healthy pulps were capped with a glass ionomer liner. Therefore, lining is normally not necessary under conventional glass ionomer restorations when there is no pulpal exposure.[5]

Concern has been raised regarding the biocompatibility of resin-modified materials since they contain unsaturated groups. A cell culture study revealed poor biocompatibility of a resin-modified liner.[37] In contrast, Cox and others[38] showed that a resin-modified glass ionomer cement did not impair pulp healing when placed on exposed pulps. As a result of this uncertainty, use of resin-modified materials in deep unlined cavities is probably not advisable.[6]

Disadvantages

The use of glass ionomer cements can have limitations in very specific circumstances.

Physical Strengths

The main limitation of the glass ionomer cements is their relative lack of strength and low resistance to abrasion and wear. Conventional glass ionomer cements have low flexural strength but high modulus of elasticity, and are therefore very brittle and prone to bulk fracture.[39] Some glass cermet cements are arguably stronger than conventional materials but their fracture resistance remains low.[9,11] The resin-modified materials have been shown to have significantly higher flexural and tensile strengths and lower modulus of elasticity than the conventional materials.[39,40] They are therefore more fracture-resistant but their wear resistance has not been much improved.[33,39] In addition, their strength properties are still much inferior to those of composite-resins, and so should not be subject to undue occlusal load unless they are well supported by surrounding tooth structure.[6,33,39]

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Water Sensitivity

Conventional glass ionomer restorations are difficult to manipulate as they are sensitive to moisture imbibition during the early setting reaction and to desiccation as the materials begin to harden. Although it was believed that the occurrence of the resin polymerization in the modified materials reduces the early sensitivity to moisture,[23] studies have shown that the properties of the materials changed markedly with exposure to moisture.[41] Whether it is necessary to place protective covering on resin-modified glass ionomer restorations remains controversial.[6,21,41]

Clinical Success in Primary Molars

Clinical trials investigating the longevity of glass ionomer restorations in primary molars are mostly short-term studies of less than three years. The longest survival rates for glass ionomer restorations are in low stress areas such as Class III and Class V restorations.[23] In an early study, Vlietstra and others[42] reported that 75% of conventional glass ionomer restorations in primary molars were intact after one year, and that margin adaptation, contour and surface finish were all satisfactory. The longest clinical study has been conducted by Walls and others[43] who compared conventional glass ionomer restorations with amalgam restorations in primary molars. Although they reported no significant difference in overall failure rates after two years, follow-up of the restorations up to five years showed that glass ionomer restorations had significantly inferior survival time to amalgam.[44] The importance of long-term clinical studies should therefore not be overlooked.

Other short-term trials also show poor success rates of conventional glass ionomer restorations in primary molars. Ostlund and others[45] compared Class II restorations of amalgam, composite-resin and glass ionomer cement in primary molars and reported a high failure rate for glass ionomer cement of 60% after one year. In contrast, the failure rates for amalgam and composite-resin restorations were eight and 16% respectively. Fuks and others[46] compared the clinical performance of a glass ionomer cement with amalgam in Class II restorations in primary molars. Only nine of 101 glass ionomer restorations met all quality criteria after one year, whereas 90% of the amalgam restorations met all the evaluation criteria after three years. Papathanasiou and others[47] investigated the mean survival time of different types of restorations in primary molars and found that the mean survival time for glass ionomer restorations was only 12 months compared to more than five years for stainless steel crowns and amalgam restorations. In a recent study, the median survival time for Class II glass ionomer restorations in primary molars was also reported to be significantly shorter than for amalgam restorations.[48] The results of these studies indicate that conventional glass ionomer cement is not an appropriate alternative to amalgam in the restoration of primary molars unless the teeth are expected to exfoliate in one or two years.

Short-term clinical studies have shown that the performance of Class II glass cermet restorations in primary molars is significantly worse than conventional materials.[1,49] Although Hickel and Voss[2] found no significant difference in the cumulative failure rates between glass cermet and amalgam restorations in primary molars, they did find that the loss of anatomical form was more severe with glass cermet cement, concluding that amalgam should be preferred in restorations with occlusal stress.

Only limited data are available for resin-modified glass ionomer restorations in primary molars and they are mostly in the form of clinical experience[50] or abstracts.[51,52] The initial results show that these restorations perform better than conventional materials in short-term comparisons.[51,52] Long-term trials would be required to confirm their efficacy. Until then, the choice of resin-modified glass ionomer restorations in primary molars remains a relatively empirical one and should therefore be restricted to cavities well supported by surrounding tooth structures, such as small Class I and Class II restorations. In cases where high occlusal load is expected, other alternatives such as amalgam or stainless steel crowns should be considered.

Conclusion

The desirable properties of glass ionomer cements make them useful materials in the restoration of carious lesions in low stress areas such as smooth surface and small anterior proximal cavities in primary teeth. Results from clinical studies, however, do not support the use of conventional or metal-reinforced glass ionomer restorations in primary molars. More clinical studies are required to confirm the efficacy of resin-modified glass ionomer restorations in primary molars.

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