CLINICAL USE OF GLASS IONOMER CEMENT: A LITERATURE REVIEW

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يعتبر ولسون أول من قدم الاسمنت الزجاجي الشاردي لعيادات الأسنان عام ١٩٧٢م ويخضع هذا الاسمنت لتطوير مستمر منذ صناعته وذلك للاستفادة من الخصائص الفريدة لهذه المادة . ويؤخذ في عين الاعتبار توافقه مع أنسجة الأسنان وكمية الفلورايد الخارجة منه واتحاده الكيميائي مع أنسجة الأسنان (الميناء والعاج) يفسر لنا سر الاستخدام الإكلينيكي المتعدد لهذه المادة على نطاق واسع أن تصنيف الأنواع المختلفة في الاسمنت الزجاجي يتراوح بين استخدامه كمادة لاصقة للتيجان الصناعية أو كبطانة تحت الحشوات المختلفة أو كمادة للحشوات الدائمة أو كحشوات داعمة للتيجان الصناعية .

وقد أدرك أطباء الأسنان أهمية هذه المادة في علاج أسنان الأطفال لحمايتها من النخر.

فيما يلي ملخص لأهم النقاط الخاصة بهذا الاسمنت :

- تشتمل فوائد الاسمنت الزجاجي الشاردي على خاصية الالتصاق بأنسجة الأسنان (الميناء والعاج) .
- الشيء الوحيد الذي يحد من استخدامه هو نقص قوته المضادة للكسر والتي قد يتم التغلب عليها في المستقبل ويجب أن نلاحظ أن الاسمنت الزجاجي كأي مادة حشو أخرى يحتاج إلى عناية عند استخدامه إكلينيكياً .

Class ionomer cement (GIC) was first introduced to clinical dentistry by Wilson and Kent in 1972. GIC has undergone continuous development designed to take advantage of the material's unique characteristics. GIC's tissue compatibility, fluoride release, and chemical union with underlying tooth tissue explain the wide variety for its clinical uses. Classification of the different types of GIC, ranging from luting, lining, restorative esthetics and reinforced varieties, suggests valuable potential uses in restorative dentistry. GIC has been recognized by pediatric dentists as well suited to preventive dentistry demands. The advantages of using GIC include its adhesion to underlying tooth tissue and fluoride release. However, a reservation on GIC use is its lack of fracture strength which may be surmounted in the foreseeable future. Satisfactory esthetic result can be produced with the new version of GIC but it is generally less pleasing than that with composite resin. It must be noted that GIC, like any other restorative dental materials, requires proper handling and attention to details during clinical application.

Introduction

Glass ionomer cement (GIC) was first reported in the dental literature by Wilson and Kent in 1972.[1] Since then, GIC has undergone continuous development, improvement and diversification, both in its constituents and clinical application to provide the material's unique characteristics.[2,3] Improvements on its delivery system, setting time, strength, light curing, increased molecular weight of the polyacid and adhesion have all been made since the initial introduction of the material.[4]

GICs possess certain properties that make them useful as restorative filling materials. These properties include a low coefficient of thermal expansion similar to that of tooth structure, physico-chemical bonding to both enamel and dentin[5,6] and the release of fluoride ions into adjacent tooth structures.[7] The main criticisms of the glass ionomer cements are their brittleness, poor surface polish, porosity, technique sensitivity and surface wear.[8-10]

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Composition

Glass ionomer cements (GICs) are basically formulated into powder and liquid. The powder is composed of calcium aluminum fluorosilicate glass, and the liquid iseithera polyacrylic acid or its copolymers. Tartaric acid may also be added to the liquid to prolong the working time.[11] Incorporation of metal fibers or powders into the glass ionomer powder was attempted in an effort to increase the flexural strength. Simmons[12] described the "Miracle Mixture*" in which amalgam alloy powder was incorporated in the glass ionomer cement at the mixing stage. This did not improve the abrasion resistance because of lack of strong bonding between the metal filler and the polyacrylate matrix.[12,13] This problem was solved by sintering the metal powder into the glass powder. Fine, precious metal powders such as silver or gold were mixed with glass powder resulting in the formulation of a cermet (ceramic-metal).[14-16] Two types of silver cermet ionomer cements were available, Chelon-Siiver* for hand mixing and Ketac Silver** for mechanical mixing. However, the strength of these metal reinforced cements was still found to be inadequate for use in high stress-bearing area.[17] Kerby *et al*[18] found that stainless-steel reinforced GIC has higher tensile and compressive strength than silver reinforced cement.

Recently, certain GICs contain strontium in place of calcium, barium or lanthanum to achieve radiopacity.[19] In 1984 water setting GICs were developed whereby polyacrylic acid can be obtained in solid form and blended with inorganic powder. Therefore, an aqueous solution of tartaric acid can be used to prepare the paste. This proce-dure led to prolonged working time, better stability and unlimited shelf life.[20] Ketac products add polymaleic acid to the liquid, although polyacrylic based cements appear to be less soluble and more erosion resistant.[21]

Setting Reaction of GIC

The setting reaction of GIC is represented as an acid-base reaction between polyacid liquid and glass.[22] Attack of the surface of the glass particles causes release of calcium and aluminum ions which cross-link with polyacid chains into a network.[23] This ion release is facilitated by tartaric acid which readily forms complexes with these ions and with the polyacrylate chain.[11]

When the glass powder and aqueous liquid are mixed together to form a paste, the glass reacts with the polyalkenoic acid to form a salt hydrogel which serves as the binding matrix. Water is the reacting medium, an essential part of the hydrogel, and is required to hydrate the formed metal polyal-kenoate. The glass ionomer cement sets and hardens by transfer of metal ions, calcium and aluminum, from the glass to the polyacrylic acid, which causes gelation in the aqueous phase. Dur-ing the process of transfer, the matrix-forming metal ions are in a soluble form and vulnerable to attack by aqueous fluids.[24,25] Therefore, some form of protection is essential during setting. In fast setting cements, the time span during which the cement is susceptible to water uptake is shortened to a matter of minutes at the expense of esthetics. Water loss through dehydration will cause all types of GICs to shrink, crack and produce undue stress on the newly forming ionic exchange layer at the interface with the underlying tooth structure.[26,27]

The final set structure is a complex composite of the original glass particles sheathed by a siliceous hydrogel and bonded by a matrix phase consisting of hydrated fluoridated calcium and aluminum polyacrylates.[19]

Light-Cured GIC

Two systems of light-cured GICs are commercially available, the Vitrabond* and XR-ionomer*. In Vitrabond, the powder is composed of a radiopaque fluoro-alumino-silicate glass containing a photo sensitizer. The liquid is an aqueous solution of polyacrylic acid copolymers containing methacrylate groups with 10% hydroxyethyl methacrylate (HEMA) and a photo-initiator. The structure of the light-cured polymer-reinforced cement is composed of a composite of glass particles and hydrogel matrix. This matrix is a polymer network consisting of the ionic metal polyacrylate hydrogel entangled with the polyhydroxy-ethyl-

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methacrylate hydrogel. In the XR-ionomer, the powder is composed of a calcium alumino fluosilicate glass and the liquid is a polymerizable polyacid copolymer with a photo initiator.[19]

Properties of GICs

1. Adhesion

Glass ionomer cements are capable of per-manently adheringto enamel, dentin and base metals.[5] GICs adhere so tenaciously to dentin that failure ofthe union would occur within the cement itself rather than within the dentin.[6,28] There is ionic exchange between cement and tooth structure which may result in developing an ion-enriched layer in the cement at its interface with tooth structure. This layer is composed of calcium and phosphorous from both the dentin and the cement and aluminum from the latter.[29]

2. Fluoride Release

Fluoride ions are released slowly from the glass ionomer restorations over an extended period of time. Fluoride is taken up by tooth structure not only adjacent to a restoration but also in areas up to three millimeters away from the restoration margin and may offer protection to the entire tooth.[7,30-32] Due to the fluoride released by glass ionomer restorations, fluoride level rises in saliva and also in plaque adjacent to the GIC.[33] Fluoride released from GIC restorations can exert an inhibitory effect on the development of recurrent caries due to diffusion of fluoride ions through the restoration tooth interface.[34]

3. Biocompatibility

Glass ionomer cements produce an adhesive chemical bond to tooth structure and release fluoride.[5,7] Chemical adhesion requires intimate contact with enamel and dentin. Cases of tooth sensitivity following the use of glass ionomer cement in[35,36] Post cementation hypersensitivity may occur in a deep preparation where the dentinal tubules are left without protection against the hydraulic pressure resulting from cementation.[37]

Simmons[38] believe that this post cementation hypersensitivity is limited to the anhydrous glass ionomer cements. Smith and Ruse[39] reported that glass ionomer luting cements showed low pH values for a relatively long period after mixing. The pH of Chembond*, which is an anhydrous luting cement, remained low for even a longer period which possibly explains the increased pulpal response to anhydrous luting cements. Another explanation of post cementation hypersensitivity is that it may be the result of dehydration of the tooth prior to cementation.[40] This may exacerbate the effect ofthe lower pH values for longer time periods observed with the GIC.[39] But, in a national survey, it has been found that zinc phosphate cement contributed to post operative sensitivity more than GICs when used as a luting agent.[40]

In vivo and *in vitro* studies suggest that glass ionomer cements are mild irritants[5] to the dental pulp. The extent of the inflammatory response depends upon the thickness of the residual dentin.[41]

The worst pulp reaction occurred under GICs when thickness of the remaining dentin was 0.5 mm or less.[42] Therefore, a sub-lining of fast setting calcium hydroxide is recommended if there is less than 0.5 mm of remaining dentin or there is a possi-bility of actual pulpal exposure.[43]

GICs, particularly the restorative materials, have been shown to offer good biological compatibility with the dental pulp when used as recommended and when the clinical technique followed is of a good standard.[41]

Types of Glass Ionomer Cements

A classification of four different types of GICs has evolved: I - luting cements (Chembond*, Ketac Cem‡); II - restorative esthetics (ChemFil ll†, Ketac-Fil‡); III - restorative reinforced cements (Ketac silver‡); IV - lining cements (Ketac bond‡, G-c lining cement§).[44]

Type 1 Luting Cements

GICs have been available for many years but there has been some degree of controversy over the need to change from zinc phosphate cement.

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* AD International Ltd., London, England.
* International Ltd., London, England.
‡ ESPE GmbH, SeeFeld/Oberbay, West Germany.
† De Trey Division, Dentsply, Ltd., London, U.K.
§ GC International Corporation, Tokyo, Japan.

GICs offer some advantages over zinc phosphate cement of which are better flow and lower solubility.[45] Moreover, the fluoride release helps prevent recurrent caries even though this is very minimal.[46] GICs were shown to have the highest retentive value among the luting cements.[47,48]

Type II Restorative Esthetics

This is a slow setting cement and requires con-tinuing isolation from the oral environment for up to 24 hours in order to achieve optimum physical properties and translucency. Final decision on adequacy of the color match should be delayed for *one* week.[27] Contouring and polishing should always be performed under air-water spray using a very fine diamond to begin with and finishing with aluminum oxide discs.[9,43]

Type III Restorative Reinforced

These cements have short setting times, e.g. Ketac silver. They can be finished five minutes after the start of mix. They lack translucency and esthetic appeal, therefore, they are used only in areas where esthetics is of no concern.[15]

This type has improved physical properties com-pared with conventional glass ionomers, such as higher compressive strength,[49] higher compressive fatigue limit,[50] and better wear resistance.[51] Fracture resistance is similar to the unreinforced type.[52]

Restorative reinforced GICs have a number of *clinical* uses such as for bases,[53,54] restorations (class V, minimal class II. e.g. tunnel preparation,[16] and primary teeth),[55-57] sealants, repairs of castings[16] and temporary or emergency procedures.[58]

However, the more common use of these cements is probably for core buildups where moderate strength and cariostatic effects are required. The tensile strength of these cements is not high, therefore, they still require considerable support from remaining tooth structure.[59]

Type IV Lining and Base Cements

This category includes a great variety of cements which are used for conventional lining under restorations or as a base and a dentin substitute. [53,54,60-6]2 The same cement can be used for the latter uses with alteration in the powder/liquid ratio. This type *of* GIC has a low powder/liquid ratio if used as conventional lining agent to flow easily over the pulpal floor. This lining material includes both the chemi-cally activated and light activated varieties.[63] The light activated glass ionomer cements that contain polyalkenoic acid may be superior in strength to the hand mixed cements.[64]

When this type is used as a base and dentin sub-stitute, it requires strong physical properties which is obtained through greater powder/liquid ratio. The low fracture resistance of these cements can be compensated for by the other restorative material {composite resin or amalgam) which is placed over the glass ionomer cement and will absorb the major stress.[53,54,60]

Clinical application of GICs

1. Fissure Sealing

GICs, with their caries preventing ability, might have been expected to be the ideal fis-sure sealing materials.[64] Some authors advo-cate that the fissure should be widened to ensure successful retention of the GICs.[65,66]

2. Incipient Fissure Caries

The ultra conservative fissure restoration demands early intervention.[4] The concept of "wait and see" rests on the premise that remineralization might occur, given proper dental health. Unfortunately, if remineralization does not occur, the destruction of tooth structure might be so extensive that micro-cavity preparation would no longer be usable. Therefore, if fissure caries is found, a cavity will be prepared without extending into non-carious tissue. Then the cavity is restored and the fissure is sealed with GIC. This technique is defined by the British Dental Association on fissure sealants.[67]

3. Approximal Class II Lesion

GICs are brittle materials and, although some of them have high compressive strength, they are weak and unsuitable for cavities in high stress bearing situations. Nevertheless, in early approximal carious lesions, access to the lesions could be gained from the buccal or lingual or occlusal aspect just below the crest of the marginal ridge. If access is availa-ble, approximal approach to an approximal microcavity could be used. Cement can be injected into the lesions and the marginal ridge can be preserved.[6B]

4. Class III Facial or Lingual

GICs can be used in facia! and lingual class 111 cavities. The placement of these cements require minimal operative procedure. Direct access to the carious lesion is needed with the preservation of the maximum amount of remaining sound tooth. Cements are used mainly to repair root surface carious lesions and the design applied can be either from the facial or the lingua! direction, depending upon the position of the lesion relative to the surrounding structures.[66] The material of choice for class Ill cavities is a restorative rein-forced cement, if access is difficult and esthe-tics is of no concern. Restorative esthetic cement may also be used provided that it is radiopaque. Cermet ionomers are useful for restoring areas of root caries in the posterior region. In older patients, subgingival caries is difficult to treat and the problem of moisture control makes placement of composite or amalgam difficult. In such cases, Ketac silver can be injected subgingivally despite the presence of moisture.[16] Retention of the cermet ionomer will be improved with slight mechanical retention, but bonding in a nonstress-bearing area is usually successful. Also, in older patients where the oral hygiene is poor, the fluoride released from the cermet can control the spread of root caries.[66]

5. Restoration of Primary Teeth

It was suggested that GICs are suitable to restore cavities in deciduous teeth.[69,70] Croll and Phillips[71] have made extensive use of Ketac silver for restoring primary teeth. They advocated its use in bulk to prevent fracture in a narrow isthmus. They also advised that restored marginal ridges should be left slightly out of occlusion. The basic principles of "re-tention form" must be observed for best results. Another clinical study confirmed the suitability of using glass ionomer silver cermet in restoring class II lesions in primary teeth in specific clinical situations.[72]

In young patients, Croll[57] has found that silver cermet is ideal for tunnel restorations because of its radiopacity, injectability and convenience of the precapsulated system. GICs were found to have a median survival time of around three years when used to restore class I and class II cavities in primary teeth.[73] They can be used for children as lut-ing cements, dentin replacement liners and bases, and glass ionomer dentin and enamel restorative materials.[57]

6. Cervical Root Lesions

GICs bond to enamel and dentin and require minimal cavity preparation, consequently, they are a good choice for restoring cervical lesions.[74] Clinical studies showed retention of this material in erosive root lesions to be superior to that of resin retained with dentinal bonding agents with either etched or unetched enamel.[75-77] Root surface caries can be restored successfully with G1C, keeping in mind that a minor amount of mechanical retention is desirable.[78]

These lesions can be restored with cermet in the posterior region because esthetics is not a concern. It can be injected into areas of difficult access and sets rapidly. Esthetically acceptable restoration in the anterior region can be obtained by using the unreinforced type. When color is not satisfactory the cement can be cut back and veneered with composite resin.[78-80]

7. **Tunnel Preparation**

This type of preparation was adopted by several investigators.[81,82-84] They used a small round bur to gain entry via an occlusal fossa through a tunnel under the marginal ridge towards the aproximal carious lesions. Other reports advocated this preparation in primary molars.[3,56]

In deciduous molars, tunnel preparations can be restored with cermet, while in permanent teeth the gray color and poor fracture resistance, of cermet are not acceptable. For this reason, it is better to restore the tunnel with cermet then cutting back a room for composite which means veneering on the occlusal surface. The technique of restoring a tunnel preparation with glass ionomer-silver cermet bonded to composite resin is described in detail by Croll.[85]

8. Core Build-up

Ideally, cermet ionomers are best used for core buildups in posterior teeth in which at least 2 mm of coronal dentin is still intact.[16,44,86] Some investigators[16,64,87] found that root fracture occurred when cermet ionomer was used in conjunction with endodontic posts. Therefore, they advised not to rely solely on molecular bonding to tooth structure. The strength of the bond is inadequate where high stresses occur.[88] In case of devitalized molars, at least two endodontic posts should be inserted at different angles and extended through the buildup. Yardley[89] suggested a method to use cermet ionomers for custom core construction after crown loss where the natural core had been fractured leaving a flat root surface at the gingival level. Where vital teeth are involved, accessory pin anchorage may be necessary.

9. Base/Lining Cements

GICs provide a biological seal and a useful cariostatic action in all cavities. It should not be placed directly on the exposed pulp.[90] GICs also provide thermal protection to dentin and it is as efficient an insulator as is non-carious dentin.[91] Base/lining cements' main uses are reported to be under amalgam,[54] composite resin[60] or fissure sealant.[92] The use under a fissure sealant is called "pre-ventive glass ionomer restoration".[92]

Composite resin laminated onto a glass ionomer cement base, sometimes is known as the Sandwich technique, combines translucency, aesthetics and high flexural strength of composite resin with the good adhesiveness of the glass ionomer cements. GIC with its physical properties makes an ideal dentin substitute and the composite resin with its good translucency and high flexural strength may be viewed as an enamel substitute.[78 80] Mount[91] discussed the clinical requirement for a successful "Sandwich technique".

10. Luting Cement

GICs can be used as a luting cement because of their low viscosity, finegrain andfilm thickness which is less than 20 um. Achieving the correct consistency with the use of high viscosity liquids may be difficult. It is imperative to follow the manufacturer's directions to obtain the correct consistency of the mix at the optimum powder-liquid ratio. Thrn mixes have been considered as one of the causes of the pulpal sensitivity encountered by some practitioners.[64] GICs have been suggested as luting materials for stainless steel crowns[94] and orthodontic bands.[95,96] The fluoride release to enamel adjacent to orthodontic band margins and the adhesive bonding to tooth structure are important advantages in using such cement to lute orthodontic bands.[95,96]

Luting cement can be used also for cementation of cast posts. Its higher retention value than that of zinc phosphate cements has been recorded.[48]

11. Retrograde Root Fillings

Cermet ionomers can be used for repairing perforated root canals or as retrograde root fillings. Bone healing has been shown to take place within the first year. It can be used also as sealants for molar bifurcation area exposed in periodontal disease.[16,44]

12. Miscellaneous Uses

Cermet ionomers are useful for repairing defective metal margins in crowns and inlays, provided the margins are thoroughly cleaned. Ketac silver in this regard will provide a long term marginal seal. Surface conditioning of the tooth with polyacrylic acid is advised before injecting Ketac silver.[16]

When metal crowns become loose as a result of decay at the margins, the carious dentin may be removed and the crown recemented with Ketac silver. GICs can be used as a last resort for reattachment of a loose abutment crown on one end of a fixed prosthesis, where endodontic treatment has previously been carried out using the parapost system.[16] Croll tried to repair severe crown traumatic fracture with glass ionomer and composite resin bonding to secure the fractured segment in place.[97]

Finishing of Glass Ionomer Cements

In the past, a second appointment for final finishing was required as the setting reaction was long and the material had insufficient resistance to hydration and or dehydration.[98] In 1981, a glass ionomer restorative material (KetacFil*) was introduced with faster setting so early finishing became possible.[99] Based on clinical evidence, such finishing neither disrupts the retention of the restorations nor damages the material.[16,99]

Some authors recommended that final finishing of Ketac fil restorations can be accomplished 15 minutes after placement without impairing their clinical performance.[100,101]

The behavior of the setting glass ionomer cement when the surface is exposed to air and/or moisture has been well documented.[25,26] However, clinical observations confirm that chemical maturation is not achieved in these cements for probably 24 hours or more.[102] For this reason, the cement must be allowed to mature completely under a protective coating in order to maintain its physical properties and to allow an optimum degree of translucency with improved esthetics.[103] Application of low viscosity, single component, light activated resin bonding agents were effective in inhibiting outflow of water from the cement to a significant extent for at least the first 60 minutes of the setting reaction.[104] Recently, it was found that covering the cement with glazing agent offer the same degree of protection and color stability as the bonding agent.[105] It was found that the chemically activated bonding resins are not able to control water outflow. The GIC varnishes also were ineffective in preventing the outflow of water from the glass ionomer cement. [104,106,107]

Conclusion

Glass ionomer cement, introduced 21 years ago, was the first adhesive restorative material with cariostatic property. It was mainly used for restoring root caries, erosion and abrasion problems. Since its early development by Wilson and Kent and subsequent commercial development by ASPA, great changes in properties and handling characteristics have occurred.

Recently, specifically designed materials for the various clinical applications have become available. The currently accepted classification of GICs includes: luting, restorative, reinforced and lining cements. These cements permit a wide variety of clinical applications including: cementation of castings, restoration of minimal lesions, crown buildups and cavity lining. GICs have been recognized by pediatric dentists as being well suited to preventive dentistry demands.

Great attention to details of application and manufacturer direction should be followed to have durable restorations. It is expected that improvements will occur in the coming years regarding esthetic, strength and abrasion resistance resulting in improved material for restoration of anterior and posterior teeth.

* ESPE GmbH. SeeFdd/Oberbay. West Germany.

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