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GLASS IONOMER CEMENTS IN DENTISTRY

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Учебно-методическое пособие

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На английском языке

Introduction

During the period of use of glass ionomer cements (GIC), significant progress has been made in improving their characteristics. In modern dentistry, glass ionomer cements occupy a worthy place due to their unique properties — high biocompatibility with tooth tissues, chemical adhesion, have a remineralizing effect on dentin and enamel, providing a degree of protection against caries.

Glass ionomer cements have wide indications for use — in the case of unsatisfactory oral hygiene and when it is necessary to provide the proper technology for applying the composite material, but it is technologically impossible to perform the restoration with the composite.

When working with children, as a rule, it is difficult to exclude the ingress of saliva into the prepared cavity, in this case it is preferable to use GIC.

The use of GIC for fixing orthopedic and orthodontic constructions ensures their long retention on natural teeth.

Glass ionomer cements are ideal for minimally invasive and atraumatic (A.R.T) techniques. Materials for permanent fillings mainly have an irritating effect on the hard tissues of the tooth and pulp, therefore, when filling carious cavities, it is necessary to use cushioning materials. The risk is especially high in people with reduced resistance to the carious process, and here GIC provides excellent treatment results.

With the progressive development of dental materials science, new filling materials are being developed and introduced; in recent years, the number of GIC has increased significantly. Depending on the clinical situation, materials with different physical and mechanical properties and clinical characteristics are required.

Any filling material, along with positive properties, has a number of disadvantages, therefore, the correct choice of GIC, depending on its properties, will allow the practitioner to choose the most suitable material and get the best result in dental treatment.

The material of the educational — methodical manual corresponds to the curriculum and can be used to train students of the Faculty of Dentistry, clinical residents. This topic is reflected in lectures for students of the Faculty of Dentistry and the Medical Faculty of foreign students, it is studied in practical classes by students of the 2nd year of educational institution "Belarusian State Medical University" (Minsk) and includes: classification and composition of glass ionomer cements, hardening stages, their main properties and, separately by groups, indications for use and the disadvantages of glass ionomer cements, curing mechanisms and clinical use of GIC.

Glass ionomer cements

In the early 70s of the twentieth century, an intensive search for new cements for dental fillings began. The existing phosphate and polycarboxylate cements did not meet all the requirements for modern materials in terms of physical and mechanical properties, and had low biological compatibility and adhesion to dentin and enamel. Radiopacity and transparency were also inadequate. To fulfill these requirements, the idea arose of creating powder components from ground glass and a liquid in the form of polycarboxylic acids. The bonding reaction for these materials was the same as for all cements, and took place with the formation of salts when metals and acid groups were combined.

The first glass ionomer cements (GIC) were developed in 1969. British scientists Wilson and Kent, the first industrial design of the GIC "ASPA-IV" was released in 1971. by De Trey. Today glass ionomer cements are the only biologically active group of filling materials, and this is their uniqueness and special significance.

Definition: GIC is a cement consisting of glass and an acidic component that hardens through an acid-base reaction between these components.

Composition of the GIC

Glass ionomer cement consists of two components — glass powder and copolymer acid. To achieve certain properties of the material, it is possible to use various glass compositions, as well as a significant number of combinations of polyacids for copolymerization.

The powder of the first glass ionomer cements consisted of silicon dioxide with aluminum in a 2: 1 ratio and contained about 23 % fluorine.

Currently, glass ionomer cement powder is a finely ground (calcium) fluoroaluminosilicate glass with a large amount of calcium and fluorine and a small amount of sodium and phosphates. Its main components are silicon dioxide (SiO_2), aluminum oxide (Al_2O_3) and calcium fluoride (CaF_2). Glass also contains small amounts of sodium and aluminum fluorides, calcium or aluminum phosphates (Na_3AlF_6, $AlPO_4$, etc.). The X-ray opacity of many cements is provided by the addition of radiopaque barium glass or metal compounds (in particular zinc oxide).

The high (> 40 %) content of quartz (silicon dioxide) provides a high degree of transparency of the glass, however, it slows down the process of cement setting, lengthens its hardening time and working time, and slightly reduces the strength of the hardened material (with a decrease in the ratio of aluminum and silicon).

A large amount of aluminum oxide makes the material opaque, but increases its strength, acid resistance, reduces working time and curing time.

The Al_2O_3 / SiO_2 ratio is responsible for the cement setting reaction: the reaction with acid with the release of ions begins if the aluminum / silicon ratio is greater than 2 : 1.

The ratio of aluminum and silicon ions in glass ionomer cements is higher than that of previously used silicate cements, since polyacrylic acid and its analogs are weaker than phosphoric acid. One of the effects of this increase is a reduction in working hours. Therefore, an important problem that arose in the development of glass ionomer cements was insufficient working time with a long curing time. To ensure optimal working time with constant hardening time, additives of a certain concentration of tartaric acid have been developed to the powder or liquid.

An increase in the content of calcium fluoride in the powder reduces the transparency of the material, but ensures its cariesstatic properties by increasing the amount of fluorine. The content of fluorides (including sodium and aluminum fluorides) is also important for the melting point of glass, the final strength of the material and its solubility. It has been found that processing and mechanical strength are also positively influenced by a high fluoride content.

The average content of fluoride ions in traditional glass ionomer cements is 20–25 %.

Aluminum phosphate, like its oxide, reduces the transparency of the material and increases its strength and mechanical stability.

The level of ion release and the aesthetic properties of the material (presence of pigments, reflection and refractive indices) also depend on glass.

Glass ionomer cement powder is prepared by mixing quartz and aluminum in aluminum cryolite phosphate fluoride. The mixture is melted at a temperature of 1000–1300 °C and upon cooling forms an opalescent glass, which is crushed to obtain a powder. The size of the powder particles depends on the purpose of the material: it is the largest (40–50 microns) for restorative materials, for lining and fixing cements, the size of the powder particles is less than 20–25 microns. The smaller the particles, the faster the cement sets and the higher its strength.

As a polymer, combinations of different polycarboxylic acids with different molecular weights, formulas and configurations are used. Three unsaturated carboxylic acids are commonly used for polymerization: acrylic, itaconic and maleic. It is these acids that are used in glass ionomer cements because their polymers have the largest number of carboxyl groups, due to which crosslinking of polymer chains and adhesion to hard tooth tissues occurs. Polymaleic and polyitaconic acids contain 2 times more carboxyl groups than polyacrylic acid, in addition, itaconic acid reduces the viscosity of the liquid and inhibits thickening due to the formation of intermolecular hydrogen bonds.

Copolymers of acrylic and itaconic or acrylic and maleic acids are used. Copolymer is the product of polymerization (copolymerization) of a mixture of two different monomers.

If only one type of monomer is used for chain formation, a so-called homopolymer is obtained.

By increasing the concentration of the polyacid, the powder to liquid ratio can be reduced, which leads to an increase in working time. With an increase in the concentration of polyacrylic acid, the solubility of the cement decreases and the compressive and tensile strength increases linearly. However, the concentration limiting factor is the consistency of the cement paste, since the concentration of the acid and its molecular weight (ranging from 10,000 to 30,000) affect the viscosity of the fluid. The liquid of glass ionomer cement is usually a 47.5 % (40–50 %) aqueous solution of a copolymer of acrylic and itaconic or acrylic and maleic acids. But more often than others (40–50 %) an aqueous solution of polyacrylic acid is used. Acidic ingredients can be freeze dried and added directly to the powder. In this case, the mixing liquid is distilled water, and GIC is called water-soluble. Water is not just a solvent, but a necessary component of glass ionomer cement, which plays an important role in the process of its hardening, it is a medium in which ion exchange takes place.

Curing mechanism. The hardening of glass ionomer cement is due to the formation of a complex combined matrix, consisting of silicate and polyacrylate matrices. Since the release of various ions from glass and, thus, the formation of the salt matrix occurs unevenly over time, the process of cement hardening is carried out in stages. Calcium ions are released most quickly, then aluminum ions, which are involved in the formation of the salt matrix. Sodium and fluorine ions do not take part in the solidification reaction, but are combined in the process of sodium fluoride release.

The curing process of glass ionomer cement (GIC) was studied by determining the compressive strength at specified intervals and the structural changes of the corresponding fractured samples according to spectroscopy and differential scanning calorimetry. Cement based on zinc polycarboxylate was used as a reference. The compressive strength of GIC increased with aging. In the destroyed GIC samples, the studies at specified intervals revealed changes in the structure of the matrix and the layer at the interface, including silica gel, but no significant changes were found in zinc polycarboxylate. Consequently, the increase in strength during aging is due to changes in the structure of the matrix and / or layer at the interface. Structural changes include cross-link density, complex-to-ion ratio, glass element ratio, formation and maturation of an inter-surface layer including silica gel.

Hardening reaction of traditional GIC

1. Dissolution (or hydration, release of ions, leaching of ions).
2. **Thickening** (or primary gelation, initial, unstable hardening).
3. Curing (or dehydration, ripening, final curing).

During the **dissolution stage**, the acid that has passed into the solution reacts with the surface layer of glass particles with the extraction of aluminum, calcium, sodium and fluorine ions from it, after which only silica gel remains on the surface of the particles (formed from silicon oxide when exposed to acid, as in the hardening of silicate cement). The protons (hydrogen ions) of the dissociated polycarboxylic acid diffuse into the glass and provide the release of metal cations, which tend, according to the laws of electrostatic interaction, to the anionic molecules of the polymeric acid. The final process of ion extraction is completed 24 hours after the beginning (although the material basically solidifies after 3–6 minutes, depending on the composition, without reaching its final physical and mechanical properties). The dissociation process occurs only in the presence of water (present as a solvent for the polyacid or the one on which the cement is mixed). Under the influence of acid, about 20–30 % of glass particles are decomposed.

The thickening stage lasts about 7 minutes. Initial hardening is provided by rapid crosslinking of polyacid molecules with calcium ions. Crosslinking is predominantly donor-acceptor in nature. In this case, polycarboxylic acid acts as a donor, and metals act as an acceptor of protons. Calcium ions are divalent, more numerous and therefore more ready to react with carboxylic acid groups than trivalent aluminum ions. However, the efficiency of binding of polyacid molecules by calcium ions is not high enough, since divalent ions can chelate carboxyl groups of the same polymer chain, rather than two different ones. In addition, in the early stages of curing, the calcium-polyacrylic chains are readily soluble in water. Excess moisture at this stage leads to the loss (washing out) of aluminum ions, which reduces the possibility of further cross-spatial crosslinking of acid molecules. The loss of water complicates the process of ion extraction, which makes it impossible to complete the reaction to the end. In both cases (with excess and lack of moisture), the material becomes weaker, not reaching optimal strength due to the impossibility of forming the maximum number of transverse and spatial bonds.

The high crosslinking ability of calcium, if there is a sufficient amount of its ions in an aqueous solution of polyacrylic acid, can cause solidification within 15 s, and only a gradual slow leaching of the ion from the calcium compounds fused with glass provides an increase in the working time of the cement.

Thus, the transformation of polyacid molecules into a gel begins. At this stage, the pH value of the cement begins to increase markedly.

The hardening stage can last up to 7 days (it is believed that the binding of polyacid chains by calcium ions lasts on average about 3 hours, with aluminum ions — 48 hours). It is provided mainly by cross-linking of polyacid chains with aluminum ions (Fig. 1). It takes about 30 minutes to release a sufficient amount of aluminum ions for the reaction, and they form the final strength of the material, forming cross-links of acid molecules. The trivalent nature of aluminum ions allows for a higher degree of cross-linking and spatial structure formation.
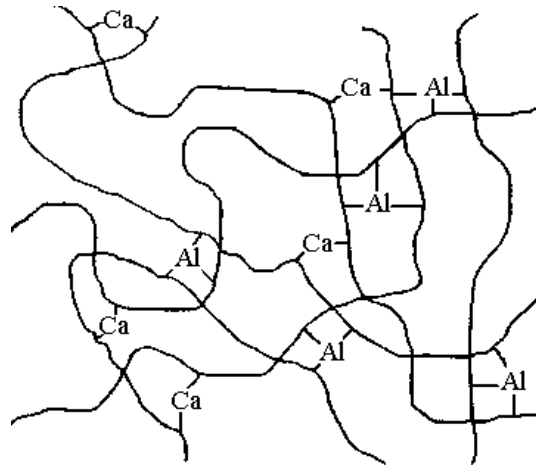
Fig. 1. Stage of hardening of glass ionomer cement: cross-linking of polyacid molecules with threevalent aluminum ions with the formation of the spatial structure of the polymer

However, there is evidence that calcium and aluminum chains can be broken and rearranged throughout the life of the restoration.

At the same stage, the process of the formation of silica gel on the surface of glass particles is completed. When silica gel is formed surrounding the unreacted glass particles, water is released. The material then becomes insensitive to moisture.

The final structure of the hardened cement is glass particles, each of which is surrounded by silica gel and located in a matrix of cross-linked polyacid molecules (metal polyacrylate) (Fig. 2). The interfacial layer of silica gel plays the role of a binder, forming a bond with the surface of the unreacted particle and with the matrix, thereby increasing the strength of the material. Approximately 11–24 % of the hardened cement is water, which can be classified as "loosely bound", which is easily lost during dehydration, and "tightly bound" or stable, which is an integral part of the curing reaction and structure of the hardened cement.

Fluorine and phosphate ions form insoluble salts and complexes that play an important role in the transfer of ions and their interaction with polyacrylic acid.

The term "glass ionomer cement" comes from the name of the component of the hardened cement: particles of fluoroaluminosilicate glass and the so-called ionomer — a polymer bound by metal ions.
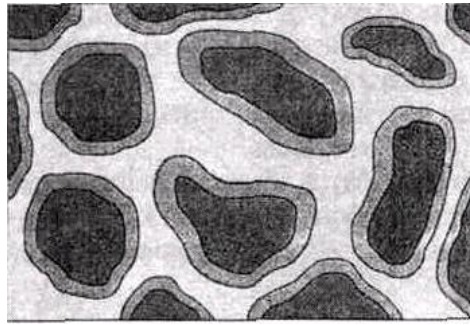
Fig. 2. Structure of hardened glass ionomer cement

▮ – aluminosilicate glass
▨ – silica gel
▢ – cross-linked polyacid chains

Basic properties of glass ionomer cements

Chemical adhesion to dentin, enamel and cement without acid etching is achieved by two mechanisms. The first of them is based on the fact that the carboxylate groups of a polyacrylic acid macromolecule are capable of chelating with calcium, in particular with calcium hydroxyapatite of dentin and enamel. Adhesion to the mineral part of the hard tissues of the tooth begins at the moment of its contact with the mixed glass ionomer cement. Phosphate ions are displaced from apatites by carboxyl groups, which bind calcium ions to maintain electrical neutrality. These compounds are formed by diffusion. Thus, polyacrylate ions react with the apatite structure, moving calcium and phosphate ions and creating an intermediate layer of myacrylate, phosphate and calcium ions or by binding directly to the calcium of apatite.

The second hypothesized linkage mechanism is based on the affinity of polycarboxylic acids for nitrogen of protein molecules, in particular collagen, which is manifested by the absorption of polyacrylic acid on dentin collagen. Collagen binding consists in creating bridges with hydrogen ions or metal ions between polyacid groups and collagen molecules. The strength of this adhesion has not yet been precisely determined, the connection mechanism itself has not been conclusively proven. Thus, the bond with dentin may consist of an ionic bond with apatite of the dentin structure and, possibly, a hydrogen-type bond with collagen.

However, the bond strength of glass ionomer cement with hard tissues of the tooth is not large enough. According to various sources, it can reach 2–7 MPa, which is much less than the stress forces developing due to the shrinkage of the composite material, the bond forces with the tooth tissues of the 4th–5th generation adhesive systems, and even less the bond forces inside the dentin itself. The relatively high viscosity of traditional cements practically excludes the possibility

of their fixation to enamel and dentin due to microretention. Thus, the presence of a chemical bond between the material and the tooth tissue is important not so much for the strength of the bond, but for its density, ensuring the impermeability of the cement-tooth tissue contact for moisture. Glass ionomer cement forms a chemical bond with tooth tissues even in the presence of a lubricated layer. But, the strongest bond of glass ionomer cement with tooth tissues is formed after special preparation of the latter, which consists in removing impurities. Initially, low concentration citric acid or hydrogen peroxide was used for this purpose, which partially removed the smeared layer from carious cavities. The optimal conditioning (preparation) turned out to be treatment with a 10 % solution of polyacrylic acid for 10–15 s. This treatment, in addition to cleaning, contributes to the reactivation of calcium ions prevailing in the lubricated layer, which then, upon contact with glass ionomer cement, react more quickly and easily. Longer (more than 20 s) exposure to polyacrylic acid on hard tooth tissues can cause opening of dentinal tubules and demineralization of deeper layers of dentin. Demineralization can lead to a significant decrease in the chemical adhesion of the cement by reducing the calcium content that provides this bond. Open dentinal tubules can cause post-filling hypersensitivity. Therefore, the conditioning time should not exceed 15–20 sec.

Since polyacrylic acid is part of glass ionomer cement, insufficient rinsing after conditioning does not adversely affect the curing process of the material.

The bond of the glass ionomer with enamel is higher than with dentin (the bond strength with dentin is usually in the range of 1–3 MPa), which can probably be explained by the higher content of calcium ions in the enamel.

Chemical adhesion to most materials used for restoration work (composites, amalgams, materials containing eugenol, adhesion to nitrogen, platinum, oxidized foil, stainless steel, tin, gold alloy) is explained by the ability of glass ionomer cements to form chelate and hydrogen bonds with various substrates.

The fluorine-dependent caries-static effect is based on two phenomena that occur during and after the hardening of glass ionomer cement — the release of fluoride and the formation of a layer of fluorine-containing apatites at the border between the filling material and the tooth tissues. An important property of GIC is their ability to anticariogenic action. This ability of silicate cements was reported as early as the middle of the last century, and it was associated with fluorides that release silicate cements.

The ability to release fluorine ions in GIC is manifested during the entire period of its existence, slightly decreases after 2–3 months, but there are data in the literature on the duration of the release of fluorine ions from GIC up to 8 years. Studies of the boundary "glass ionomer cement — dentin" showed that there are large amounts of carbonaceous apatites saturated with fluorine, which are the result of the reaction between dentin and glass ionomer cement containing fluorine salts, at the boundary. This layer forms within 2–4 hours after the appli-

cation of glass ionomer cement to the dentin surface. Apatites saturated with fluorine dissolve less than other dentin apatites, and their presence at the "GIC — dentin" interface can serve as a barrier in the development of secondary caries.

The maximum amount of fluorine from glass ionomer cements is released after 24–48 hours. A later release of fluorine occurs when the fluoride salts present in the hardened material dissolve. Most often, fluorine is released from the sodium salt, which is not a matrix-forming element. Consequently, the strength of the cement does not decrease. Aluminum, also released from the GIC and adsorbed on the enamel surface, contributes to an increase in the acid resistance of the tooth enamel in the area of contact with the GIC.

Traditional GIC contains on average 20–25 % fluorine ions. The release of fluoride is directly proportional to the size of the filling, so interlining glass ionomer cements release a small amount of fluorine.

Researchers distinguish the initial (24–48 hours) stage — with a high degree of fluorine release, and the subsequent prolonged phase — an insignificant release of fluorine from the GIC. The anti-carious effect of fluoride includes the mechanisms of increasing the resistance of the tooth tissues due to the replacement of the hydroxyl ion with the fluorine ion and the antibacterial effect. According to literature data, fluorine has a bacteriostatic effect at a concentration of about 0.16–0.31 mmol / L, while fluorine concentrations of about 1 mmol / L are capable of blocking the formation of acid by bacteria. Such concentrations do not have a bactericidal effect, but they disrupt metabolic processes in the cells of microorganisms. The result of this intervention of fluoride is that the pH of dental plaque does not drop to a critical level, the number of acid-resistant microbes increases, counteracting the growth of the number of cariogenic microbes. In addition, fluorine in the form of ions or complexones with metals can inhibit enzymes produced by bacteria. Thus, the main mechanism of action of fluorine is inhibition of acid production by the bacterial cell. Protonated fluorine (HF) is able to increase the permeability of the cell membrane, having a 107 times higher penetrating ability than F^-, it is a transmembrane proton carrier. Once HF enters the relatively alkaline cytoplasm, it breaks down into F^- and H^+. These ions, being oxidized, inhibit glycolytic enzymes. Thus, under the influence of fluorine, the pH decreases, the number of protons penetrating the cell membrane increases, the energy status of the cell changes, and the consumption of ATP increases to maintain the acid-base balance.

Thus, fluoride ions are capable of disrupting the metabolism in dental plaque by changing the permeability of the cell membrane. Under the action of fluorine ions, there is a decrease in the synthesis of polysaccharides in the cell, including glycogen, which occurs due to an increase in acidity in the cell and a violation of the production of bacterial enzymes.

The influence of fluorine around the edge of the filling is carried out in the zone of 3 mm and is due to the following aspects:

– fluorine, replacing the hydroxyl group in the enamel hydroxyapatite, forms fluorapatite, which is more resistant to the action of acids than hydroxyapatite;

– slowly dissociating low-soluble calcium fluoride forms on the enamel surface, supplying fluorine ions for the previous aspect;

– fluorine blocks microbial glycolysis, thereby helping to reduce the production of lactic acid by microorganisms;

– there is a decrease or blocking of the production of extracellular polysaccharides dextran and levan by microorganisms, which ensure the attachment of dental plaque to the surface of the tooth;

– negative charge of the fluorine ion prevents the settling of microorganisms on the enamel surface.

The role of fluoride when applied topically is undeniable. In addition, the literature contains information on the ability of glass ionomer cements to adsorb fluorine ions. Such adsorption is possible from materials rich in fluorine, for example, from toothpastes, gels, etc. This phenomenon is called the "battery" effect of glass ionomer cements. Fluoride ions first bind to the GIC and then are slowly released into the oral fluid and into the hard tissues of the tooth in contact with the GIC.

By their pronounced ability to release fluoride ions and strengthen the tooth tissues, glass ionomer cements can be attributed not only to restoration, but also to therapeutic materials. These cements are indispensable in the treatment of diseases such as acute dental caries and enamel necrosis of various etiologies.

Literature data indicate the termination and regression of the carious process after sealing the cavity with a biologically active material, which is glass ionomer cement. In addition to the role of fluorides in remineralization, there is evidence for the transfer of calcium, phosphate and strontium ions from GIC deep into demineralized dentin and surrounding enamel.

Glass ionomer cements have a fairly high biocompatibility. Repeated tests with tissue culture indicated a weaker response of cells to glass ionomer cements than to zinc oxide eugenol material or zinc polycarboxylate cement. However, there are studies that indicate significant cell destruction during tests with cell culture, as well as pulp necrosis, a delay in the formation of irregular secondary (tertiary) dentin when cement is applied to the bottom of deep carious cavities. This may be due to the irritation of the pulp with hydrogen ions due to the low (0.9–1.6) initial pH value immediately after mixing the cement. That is why freshly mixed cement is highly cytotoxic, but this effect decreases in parallel with the hardening of the material. By itself, polyacrylic acid cannot diffuse into dentin due to its high molecular weight.

Another aspect of the effect of glass ionomer cement on the pulp is its hydrophilicity. Immediately after the introduction of the material into the cavity, a high concentration of acid and free ions can lead to increased movement of fluid from the slurry to the cement. This can lead to the development of pulp hypersensitivity, and with overdrying of dentin and a violation of the powder / liquid ratio towards the powder — to its strong dehydration. However, the fulfillment of all the necessary requirements when working with glass ionomer cements practically eliminates the risk of the described complications.

The biocompatibility of glass ionomer cements allows them to be used without a lining or as a lining material, but the possibility of irritation of the pulp due to the initial high acidity dictates the need to use calcium-containing linings in deep cavities in combination with the acute course of the carious process.

The closeness of the coefficient of thermal expansion to that of enamel and dentin. The coefficient of thermal expansion of glass ionomer cements is the closest to the tooth tissues in comparison with other dental filling materials. This prevents cracking of the filled teeth or disruption of the marginal fit of the fillings with changes in the temperature in the oral cavity.

The thermal conductivity of glass ionomer cements is also the closest to that of dentin compared to other filling materials.

The release of heat during the hardening of glass ionomer cement is insignificant, which excludes the possibility of an unfavorable thermal effect on the pulp.

High compressive strength. The compressive strength of glass ionomer cements is the highest among all restoration cements and is close to that of composite materials. This property of glass ionomers allows them to be used as a base for a composite material when using "sandwich" — a technique that puts forward high strength requirements for the base material. The compressive strength of glass ionomer restorative cement increases over a period of time from 24 h to 1 year from an average of 160 MPa to 280 MPa (in contrast to zinc polycarboxylate cements) due to the incorporation of ions into the matrix and the formation of cross-links in it. Strength builds up faster if the cement is insulated from moisture in the early period.

Shrinkage. The volumetric shrinkage of glass ionomer cements is 1.0–3.6 % (according to other data — 3–4 %) after 30 seconds after their application and 2.8–7.1 % — after 24 hours. The force of this shrinkage is 40 % the shrinkage force that occurs during the polymerization of composite materials, which makes it possible to compensate for this force to a certain degree while being used with composite materials in the "sandwich" technique.

Water absorption, as well as ion exchange between the filling and the tooth tissues, partially or completely compensate for the shrinkage inherent in glass ionomers during hardening; water sorption is responsible for the dimensional stability of the fillings. Water is absorbed by cement under conditions of

high relative humidity (85 % or more) or in the presence of water itself, which forces the cement to expand. Shrinkage occurs if the cement is overdried, which occurs in an environment with a relative humidity of less than 80 %.

Solubility. High solubility in water is a disadvantage of many cements, including silicate ones. Glass ionomer cements are no exception. The solubility of the material depends on the cementitious composition, the clinical technique used and the oral environment. Dissolution of unripe cement can continue until the material has completely hardened within 24 hours. This explains the need to temporarily protect the cement surface with a waterproof layer. This protection should last for at least 1 hour until the ion extraction level is reached that allows the cement to achieve optimum cure.

To protect against excessive moisture and dryness, varnishes are used. It is more effective to use low-viscose light-curing varnishes. As varnishes, you can use adhesives from composite materials that do not contain alcohol and acetone.

The solubility of the material is also reduced by increasing the powder-to-liquid ratio. Cement erosion can be minimized by strict adherence to clinical material handling techniques.

The loss of material due to dissolution in the oral fluid stops a few days after the final hardening of the cement, and the further loss of material depends on the environment of the oral cavity — from acid attacks and abrasion. Acid attacks are carried out mainly in places where dental plaque accumulates, the microflora of which produces acids. The advantage of glass ionomer cements over other cements is the lowest solubility in acids.

However, a very low pH level can lead to dissolution of the glass ionomer cement matrix, destruction of the filling, starting from the surface. The use of acidified solutions with a pH level approaching 3 for fluoride prophylaxis promotes the formation of cavities in the material matrix, especially with regular use. Therefore, for fluoride prophylaxis in persons with glass ionomer cements fillings, it is advisable to use compounds with a pH level approaching 7.

Low abrasion resistance. The resistance to mechanical abrasion of glass ionomer cements is low, especially in the first days, which limits their use in areas with high loads. For the same reason, in addition to its high fragility, this material generally cannot be used as a long-term permanent filling material (with the exception of Black Class III and V cavities).

Aesthetic properties. The color of glass ionomer cement is provided by the type of glass and additives of color pigments (such as iron oxide or coal). The color qualities of these materials are quite satisfactory and can be close to those of dental tissues, as in composite materials, slightly differing from them in brightness and saturation.

For glass ionomer cements, the main aesthetic problem is not color, but unsatisfactory transparency, which is significantly inferior to the transparency of composite materials. Often these cements look dull and lifeless, which limits their

use as restorative materials for the treatment of cervical defects and small cavities of the III class. The clarity of glass ionomer cements is closer to that of dentin than of enamel. It changes over time, reaching an appropriate degree in a few days.

Fast hardening glass ionomers achieve appropriate clarity almost immediately. It may change slightly after a few days, but these changes will not be very pronounced.

The opacity (property opposite to transparency) of the early versions of glass ionomer cements was 0.39–0.85, modern — it reaches 0.4 (the opacity of the enamel — 0.35, dentin — 0.70). In some cases, the high opacity of cements is useful for masking stains or other formations of high staining intensity. However, it is this property that usually makes it much more difficult to eliminate the optical boundary between the material and the tooth tissues.

Thus, the possibility of creating an aesthetically acceptable glass ionomer cement is still problematic; materials with relatively satisfactory optical characteristics have inferior curing characteristics.

However, a positive property of glass ionomer cements is their lower susceptibility to staining than that of silicate cements and composites, which is explained by the better bonding between the matrix and glass compared to that between the filler and resin in the composite.

The problem with glass ionomer cements is the lack of polishability, which does not allow to provide a surface quality of the filling close to the surface of a natural tooth.

Curing mechanisms of glass ionomer cements

Chemical GIC — hardening due to acid-base reaction.
Self-curing PM GIC (two mechanisms):
– acid-base reaction;
– reaction of chemical activation by catalysts (benzoyl peroxide and amine accelerator).
Light-curing PM GIC (two mechanisms):
– photoinitiated reaction of polymerization of methacrylate groups of the polymer and HEMA;
– acid-base reaction between polyacrylic acid and fluoroaluminosilicate glass.

A feature of the Vitremer hybrid glass ionomer system (3M ESPE) is three curing mechanisms: acid-base reaction, polymerization under the influence of photoinitiator light and "dark polymerization" of reaction activation by catalysts located in microcapsules (glass ionomer, photopolymerizing, chemical). Thanks to three polymerization mechanisms, the material can be introduced into the tooth cavity in a single portion.

The latest developed by the GIC group are photoactivated self-curing GICs — these are traditional GICs where the acid-base reaction is accelerated by the addition of a light-initiated red pigment. This principle is realized only in one material "Fuji VII" (GC).

Used for: sealing fissures, protecting the exposed root surface (pink imitates the gum) and as a temporary filling material.

Indications for the use of glass ionomer cements

1. Carious cavities of classes III and V in permanent teeth, including cavities extending to the dentin of the root. The low modulus of elasticity of glass ionomer cements compensates for tension in the cervical region. And the absence of heavy loads makes it possible to use these materials in permanent teeth.

2. Carious cavities of all classes in milk teeth.

3. Non-carious lesions of the teeth of the cervical localization (erosion, wedge-shaped defects).

4. Tooth root caries.

5. Delayed treatment of permanent teeth. Most often, such procedures are combined with endodontic treatment.

6. Treatment of dental caries using the ART method proposed by Taco Pilot.

7. Tunnel caries treatment technique. This technique is not widely used, described as early as 1963 (Jinks).

8. Fixation of inlays, onlays, crowns, bridges, orthodontic appliances.

9. Intrachannel fixation of pin structures.

10. As a lining material for permanent fillings.

11. Use in the method of open and closed "sandwich"

12. Reconstruction of the tooth stump with a badly damaged crown before prosthetics, making crown-root inlays.

13. Filling of root canals with gutta-percha pins.

The use of GIC is preferable under conditions:

– poor oral hygiene;
– with multiple or secondary dental caries, rapidly flowing caries;
– in case of damage to hard tissues of teeth below the level of the gums;
– in the presence of root caries;
– when treating children;
– in geriatric practice
– with non-carious lesions
– in case of restoration of teeth previously treated with the resorcinol-formalin method.
– if it is technically impossible to perform restoration with composites (high salivation, hard-to-reach cavities of the third molars, bleeding with marginal periodontitis).

Classification of glass ionomer cements

Glass ionomer cements by **chemical composition** and curing method are divided into:

1. Traditional (chemical).
2. Polymer-modified (light-cured) hybrid.
3. Polymer-modified (self-hardening) hybrid.

I. Glass ionomer cements are divided into 3 types **according to their purpose:**

Type 1 — fixing (luting) — for temporary fillings and cementation of fixed orthopedic structures.

Type 2 — restoration materials:

A. Aesthetic.

B. Packaged.

B. Reinforced (cermets).

Type 3 — fast-hardening gasket materials and sealants.

II. Glass ionomer cements for root canal filling

Glass ionomer cements type 1

The main features of these GICs are as follows:

– low ratio of powder to liquid (1 : 1);

– long working hours;

– the minimum film thickness of the material is up to 14 microns;

– fast on curing, pH to neutral.

These include:

"Ketac-Cem" (3M ESPE);

Fuji I (GC);

Agua-Cem (Dentsply);

Agua Meron (VOCO);

Meron (VOCO);

Ionoscell (Septodont);

Ionofix (VOCO).

Glass ionomer cements of type 2 restoration A. Aesthetic.

These include the following chemically cured materials:

Ketac-Fil Plus (3M ESPE);

Chelon (3M ESPE);

Fuji II (GC);

ChemFil Superior (Dentsply);

Ionofil (VOCO);

Agua Ionofil (VOCO);

Glass-ionomer (Heraeus Kulzer).

GICs of this type are **characterized by:**

– a higher ratio of powder to liquid (3 : 1);

– satisfactory strength;
– low solubility;
– satisfactory aesthetics (lightfastness).
Glass ionomer cements type 2 B. Packed.
These include the following materials:
Fuji IX GP (GC);
Ketac-Molar (3M ESPE);
ChemFlex (Dentsply);
Ionofil Molar (VOCO).

This group has appeared recently. In its composition, the type of glass has been changed, which made it possible to increase the strength characteristics.

Packaged GIC is characterized by:
– high ratio of powder to liquid (3 : 1);
– convenience in work, packing;
– increased strength;
– durability;
– the speed of hardening;
– resistance to moisture;
– the possibility of final grinding and polishing on the first visit.

This type of GIC is used for stressed restorations; can be used to replace dentine in the sandwich technique for creating bases for restorations.

Type 2. B. Reinforced GIC (Cermets)
Metal components (silver — about 17.5 % by volume) are added to the composition of the powder of this group of materials.

There are three types of cermets:

Type 1 — a mixture of glass and silver (disadvantages: lack of connection between silver and the cement matrix, staining of hard tooth tissues and possible staining of the gingival papilla);

Type 2 — silver is incorporated into glass;

Type 3 — palladium is added to silver, which forms chelates with PAA.

This group has the following properties:
– shorter curing time;
– increased strength;
– increased resistance to abrasion;
– increased coefficient of thermal expansion.
These include:
Chelon-Silve (3M ESPE);
Ketac-Silver (3M ESPE);
Miracle Mix (GC);
Argion (VOCO);
Argion Molar (VOCO);

High-Dense (Shofu);

Alpha Silve r (DMG).

Type 3. Fast-hardening GIC (gaskets and sealants)

This group includes the following chemically cured materials:

Ketak-Bond (3M ESPE);

Fuji III (GC);

GC Lining Cemen t (GC);

Ionobond (VOCO);

Agua Ionobond (VOCO).

The characteristics of fast-hardening GIC depends on varying the ratio of powder to liquid depending on the type of lining: from 1.5 : 1 to 4 : 1.

They are characterized by the following properties:

– shorter working time and curing time;

– radiopacity;

– the identity of dentine aesthetics.

GIC is used as insulating liners for all types of cavities as: liner and base liners.

Disadvantages of chemical GIC

With all its positive qualities, traditional GICs have a number of disadvantages, namely:

– difficult to work with;

– are very viscous, have low plasticity;

– have early sensitivity to premature moisture ingress and overdrying;

– have a short working time, fast setting;

– not strong enough (cannot be used in areas with a high chewing load);

– have low resistance to abrasion and porosity, which leads to poor surface polishing;

– long final hardening reaction within 24–48 hours;

– high initial acidity of the material;

– insufficient strength;

– insufficient chemical resistance.

Polymer-modified (PM) GIC

The advent of polymer-modified, light-curing, hybrid GICs marked a fundamental change in glass ionomer technology. The first Vitrebond light-curing GIC appeared in 1993.

Classification PM GIC

By appointment:

– lining;

– restoration;

– fixing.

By curing method:

– ligh-cured;

– self-affirming.

Lining PM GIC includes:

Vitrebond (3M ESPE);

Ionoseal (VOCO);

Agua Cenit (VOCO);

Vivaglass Liner (Vivadent);

Fuji Lining LC (GC);

Photac-Bond (3M ESPE)

The restorative PM JRC includes:

Vitremer (3M ESPE);

Photac-Fil Quick (3M ESPE);

Fuji II LC (GC);

Fuji IX LC (GC).

Hyophilus (RB)

The fixing PM GIC includes:

RelyX Luting (3M ESPE);

Vitremer SC (3M ESPE);

Fuji Plus (GC);

Edvans (Dentsply).

The acid-base reaction in polymer-modified GIC proceeds according to the classical scheme, and the composite component protects the cement immediately after curing both from the loss of unbound water and from excessive water absorption.

In connection with the introduction of an organic matrix into the PM, the properties of the material change. PM GIC is characterized by:

– lower initial acidity of the material;

– regulated working hours;

– high adhesion to tooth tissues due to the double bonding mechanism;

– increased strength due to the double curing mechanism, acquired immediately after polymerization;

– less shrinkage (up to 4 %), post-polymerization stress is 2 times less than that of composites, due to the low modulus of elasticity;

– high resistance to compression and diametrical stretching;

– less sensitivity to dryness and excess moisture;

– prolonged release of fluoride;

– the possibility of immediate processing after polymerization;

– improved aesthetics.

However, it should be noted that, in a certain sense, PM GIC contradict the philosophy of glass ionomers, since they contain a monomer, which, firstly, has a certain toxicity, and secondly, can lead to the development of allergic reactions.

Light-curing PM GIC is widely recognized today, but they also have a number of disadvantages. All light-cured JRCs allow light to penetrate only to a certain depth. Therefore, a layering technique is required, the layer thickness should be no more than 2 mm. It is impossible to fix intracanal pin structures on these materials, since all GICs contain elements with methacrylate groups, and in the absence of light, methacrylates will remain largely uncured.

GIC for filling root canals

For obturation of root canals in Europe since 1975, in the USA since 1977, glass ionomer cements (GIC) have been widely used, which have not lost their relevance at the present time. GIC combine the properties of silicate and polymer fixing materials. GIC have good adhesion (chemical bond) to the dentin of the root of the tooth and to gutta-percha pins, long-term bacteriostatic action, no irritating effect on periodontal tissues, insignificant solubility, as well as long-term fluoride release after hardening. The GIC root filling is characterized by stability and durability, which ensures reliable obturation of the root canal. A number of researchers have noted good results in the treatment of chronic periodontitis, root perforations, post-resection conditions. The representatives of this group are "Ketak Endo" [3M / ESPE], "Endion" [Voco], "Endo Jen" [Jendental], "Stiodent" [VladMiVa]. One of the disadvantages of the GIC group is the short working hours.

At the Belarusian State Technological University, at the Department of Chemical Technology of Binding Materials, together with the Department of General Dentistry of the Belarusian State Medical University, a new glass ionomer cement for filling root canals has been developed – Endosil. The material consists of polyacrylic acid, which acts as a binding agent, and several powdered fillers. These include bioactive ceramics "Kafam" (heat-treated hydroxyapatite), as well as finely dispersed silicophosphate glass. Introduced calcium — phosphate ceramics "Kafam" increases the biocompatibility of the material to root dentin and periodontal tissues, reduces shrinkage, and improves the plastic properties of aluminum hydroxide. Polyacrylic and tartaric acids

regulate working hours and pH of the environment. Fluorine has a long-term bactericidal and fungicidal effect on fungi of the genus "Candida". In addition, a number of special additives are introduced into the composition of the powder of the Endosil GIC, which provide the necessary physicochemical and mechanical properties of cement. To obtain cement paste, distilled water is used, mixed with powder in a ratio of 1 : 2.2.

GIC "Endosil" has a high radiopacity and adhesive bond with root dentin, ensures a tight fit of gutta-percha pins to the canal walls and reliable sealing of

the filling, ties together gutta-percha pins, fills additional canals, is stable (does not dissolve), biocompatible with tissues healing of periapical tissues, easy to handle. Unlike its counterparts, JRC has a longer working time of 7–10 minutes. and the time of complete hardening is 30–40 minutes.

Clinical application of glass ionomer cements

The main reason for failures in working with glass ionomer cements is a violation of the technology of their use, which undoubtedly affects the quality of the restorations performed. The use of glass ionomer cements should be carried out strictly according to the instructions for the material. If there is an air conditioner, the first stage of work will be air conditioning. Such treatment allows you to remove the lubricated layer, while leaving partially sealed tubules. The use of strong acids will lead to demineralization of hard tooth tissues, a decrease in the efficiency of ion exchange and a decrease in the adhesion of the material to the underlying tissues.

The powder-to-liquid ratio has a great influence on the physical properties of the material. The material should be dosed using special devices — capsules, measuring tanks, optimal mixing is carried out only in a mixer. A properly prepared cementitious mixture for fixing has a flowing consistency and flows down from the spatula in a thick drop. For gaskets, a more viscous consistency is used (touching the material with a probe and lifting it pulls the material by 1–2 mm.) To obtain full adhesion, it is very important to apply the mixed material to the bottom of the cavity, while preventing the appearance of pores and cavities. To do this, it is necessary to thoroughly condense in the GIC cavity, for this purpose, various methods are used: sealing with a corkscrew moistened with water or powdered with powder, or moistened (squeezed out in a roller) with a microbrush applicator (sponge) or a cotton ball. In the case of using capsules, the situation is simpler, since the capsule itself acts as a cannula. For filling carious cavities — pasty consistency with a glossy surface. When preparing teeth for cementing or filling with GIC, it is necessary to remember that the dentin must be moist. Failure to comply with this condition will lead to dentin hypersensitivity. Remember about the rapid dehydration of glass ionomer cements, therefore, immediately after the introduction of GIC into the cavity, coating with varnish or adhesives without light curing is shown.

Pre-treatment of fillings is carried out on the first visit to the patient without jet-water cooling, removing excess material in the direction from the filling to the tooth and then again varnishing. Final wet polishing is done after 24 hours. The surface of the PM GIC fillings is treated during the first visit to the patient. When working with GIC, it is preferable to use matrices (lavsan, soft metal), which will allow you to get the optimal cleanliness of the filling surface and minimize its processing.

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Contents

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