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The Impact of Different Surface Coatings on Roughness, Fluoride Release and micromorphology analysis from Resin-Modified and Glass Ionomer Restorations: (Review of literature)

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ABSTRACT: This article presents a current summary of the existing literature on glass-ionomer cements, including their composition, properties, and practical uses in dentistry, with a particular focus on new discoveries.

Through an acid-base interaction, glass ionomers have been shown to form hard, relatively durable, and esthetically appealing substances in as little as two to three minutes. In addition to the progressive formation of a long-lasting interfacial ion-exchange layer at the tooth interface, bioactivity and the release of fluoride are responsible for their adhesion.

The text also covers the characteristics and applications of resin-modified glass ionomers. Despite the slight decrease in biocompatibility caused by the resin component, 2-hydroxyethyl methacrylate, the physical qualities of the resin-modified glass-ionomers are excellent and similar to those of regular glass ionomers.

Key words:glass ionomer cement, resin modified glass ionomer cement, surface roughness, fluoride release, scanning electron microscope.

I.INTRODUCTION:

The development of glass-ionomer cement was precipitated by a shift in expectations regarding dental materials. In the 1920s, when dental materials research was first initiated, a preoccupation with mechanical properties tended to impede advancements in the field. During this time period, conventional materials created before the end of the nineteenth century were still widely employed. In the 1950s and 1960s, the realization of the importance of biocompatibility and adhesion caused a paradigm shift in the field of dental materials science. During this time period, materials scientists and medical professionals collaborated more closely. Glass-ionomer cement is just one illustration of a new material with distinctive properties that has been utilized in medical innovation. Glass-ionomer cement's ability to adhere to untreated dentine and enamel has prompted the development of clinical procedures that reduce tooth loss by minimizing the need for cavity preparation.[1]

II.CONVENTIONAL GLASS IONOMER CEMENT:

Dental cements were developed as a more appealing alternative to amalgams and other traditional dental restoration materials. New and improved materials are always required to address issues such as color constancy, thermal expansion, tooth adhesion, mechanical resistance, bacterial penetration, material stability, toxicity, setting, and operation times. After many years of research, scientists have concluded that glass ionomers are the key to solving these problems. Wilson and Kent were the first to use glass ionomer cements in dentistry in the 1970s.[2]

In 1977, McLean and Wilson described the open-sandwich technique for the first time. They proposed it as a method for increasing resin composite adhesion in the cervical region by placing GIC in the cervical region and composite in enamel-deficient regions. Therefore, GIC served as a protective barrier, decreasing gingival recession. Consider GIC to be a simple restoration. They are fundamental because they have existed for a considerable amount of time, are inexpensive, and are simple to implement. They do not require specialized dental instruments for application, can self-cure, and are typically applied in large quantities without adhesive.[3]

Wilson decided to adopt Smith's use of a polyalkenoic acid as the liquid after modern thought and technology revealed the true nature of the chemical setting reaction. Unanticipated and indicative of future success, the outcome was unexpected. To withstand hydrolysis and compete with water for the tooth's surface, it was determined that dental adhesives must be hydrophilic.[4]

Glass ionomer cements is a specific type of cement (acid-base cements). They are the result of a reaction between basic powdered glass and weak polymeric acids. In the final structure, the unreacted glass acts as a filler and reinforces the

hardened cement during the process of setting, which occurs in water-concentrated solutions. Their original publication incorrectly referred to them as "glass-ionomers." Although "glass polyalkenoate cement" is the official name given by the International Organization for Standardization (ISO), "glass-ionomer" (including the hyphen) is accepted as a trivial name and is commonly used in the dental industry.[1]

The primary components of GICs are a powdered form of fluoro-aluminosilicate glass and an aqueous solution of polyalkenoic acids, which are carboxylic acids. The majority of the aqueous fraction is polyacrylic acid. However, the solution may also contain less viscous polyacids, such as maleic and itaconic acids, to facilitate handling. Other ingredients, such as Ba- and Sr-salts, can be added to the powder to improve its radiopacity. Individuals can try adding tartaric acid to the liquid component to achieve improved handling properties and a longer working time.[5]

Materials' physical and mechanical properties were impacted by polyacrylic acid's composition. In the case of cement, the degree of polymer cross-linking and the movement of water across the cement are both affected by the conformation and flexibility of polyelectrolyte chains in the polyacrylate salt matrix. In addition, it is well-known that water is necessary for the acid-base neutralization reaction that allows fluoride and other ions to be released from fluoro- alumino-silicate glass. The amount of unreacted glass particles that act as reinforcing fillers to increase the mechanical strength of GIC was also influenced by the intensity of the acid-base reaction.[6]

Cement composed of glass ionomers, which are produced by combining a glass powder with a solution of a polymeric water-soluble acid, typically polyacrylic acid. The initial neutralization reaction that causes cement to harden is followed by several maturation reactions. These maturation reactions are responsible for the following modifications: enhanced strength, decreased plasticity, rising opacity, and a higher percentage of tightly bound water. In addition, an ion-exchange interfacial layer forms slowly at the compound's interface with the tooth. This material is durable and chemically resistant. The slow diffusion of water and various ions through the hardened cement causes these changes. Water can bind to co-ordination sites on metal cations, form a hydration sheath around polymer molecules, and react with the surfaces of glass particles to form silanol groups, all of which contribute to the material's setting.[1]

Modern iterations of these materials typically consist of powders containing dried polymeric acid, allowing high levels of acid to be present in freshly mixed cement without making the acid solution too viscous, resulting in rapid setting and high strength. This formulation is distinguished by high viscosity glass ionomers and powder:liquid ratios of at least 3.6 to 1. Polymers derived from homopolymers of polyacrylic acid or copolymers of acrylic and maleic acid are used in glass ionomer cements (monomer ratio 2:1). Although other monomers have been proposed for use in polymers for cements, none are currently used in commercial products. Polyvinyl phosphonic acid is used in practical glass ionomer cements, but only as a rate modifier in a blend with polyacrylic acid.[1]

While the initial hardening reaction in glass ionomer cements occurs quickly, the cement continues to change for some time after the initial reaction has completed. All of these subsequent steps are defined by maturation.[1] In the early phase of the setting procedure, the polymeric acid solution in water neutralizes the glass powder. Aluminium polyacrylate is produced slightly later in the reaction, whereas calcium (or strontium) polyacrylate is produced immediately. The polymeric matrix is primarily strengthened by unreacted glass particles, which constitute a significant portion of the cement. Typically, setting durations range from 2 to 6 minutes.[1]

It is anticipated that the clinical performance of glass ionomers will improve as a result of these modifications. Enhancements in durability, opacity, and esthetics are all highly desirable characteristics. Ultimately, the binding of water is not particularly valuable, but the resulting reduction in sensitivity to water loss is undeniably advantageous, as it eliminates the need to protect cement with varnish or petroleum jelly. Once water-binding has occurred, cements will no longer lose water, thereby preventing the formation of microcracks and the resulting chalky appearance.[1]

It may take several months for the cement to fully "mature," during which time the aluminium ions are released slowly and the water is bound by the acid and glass. Nevertheless, according to a study by Zainuddin et al.[5]aluminium can remain in the cement structure for up to a year. [1]

Fluoride release is an important property of glass ionomers. Low concentrations of fluoride promote remineralization of the hydroxyapatite component of the tooth, thereby mitigating the effects of dental caries.[1] Fluoride must be replenished from an exogenous source, such as

topical fluoride, fluoride toothpaste, and mouthwash, in order to maintain adequate levels as a fluoride reservoir,[7] moreover biocompatibility, minimal shrinkage, minimal marginal leakage, protection against caries at the restoration's periphery, and enhanced remineralization of adjacent proximal caries are all desirable qualities.[8]

The disadvantages of conventional GIC include poor fracture and abrasion resistance, inadequate color stability, moisture sensitivity, and unattractive esthetic properties. Due to these drawbacks, the material cannot be used in areas that are subject to significant chewing forces.[8] In addition, the reported 10 year survival rate for GICs restorations was 37%, which was lower than the reported 10 year survival rates for resin composites (43%) and dental amalgam (50%).[6]

III.RESIN-MODIFIED GLASS IONOMER:

Resin-modified glass ionomer is a hybrid material that solidifies partially through photochemical polymerization and partially through an acid-base reaction as a result of the incorporation of the resin into the glass ionomer. The resin component improves the material's physical properties; the modified type is less sensitive to water and has a longer working time than standard GI.[12] The 1990s saw the introduction of resin-modified glass ionomers.[3]

Because it adheres so strongly to dental hard tissues, RMGIC requires no special adhesion techniques. RMGIC's adhesion to dental hard tissues is facilitated by both chemical bonding between poly alkenoic acid chains and calcium ions in hydroxyapatite and micro-mechanical retention obtained by infiltration of organic components into a partially demineralized dentin surface due to its self-etching property[2] by conditioning the dentin with polyacrylic acid , washing and drying. Dentin conditioning removes the smear layer structure, with the exception of smear plugs, and partially demineralizes the dentin surface[9]. Pretreatment with a polyacrylic-acid conditioner is advised to improve GIC bonding.[2]

In addition to basic glass powder, water, and polyacid, resin-modified glass ionomers also contain a monomer component and associated initiator system.2-hydroxyethyl methacrylate (HEMA) is the preferred monomer, and camphor quinone is the initiator. Resin-modified glass ionomers cured by neutralization (acid-base reaction) and addition polymerization simultaneously; complex structure based on the combined products of these reactions. Due to the competitive nature of these two network-forming reactions, a delicate equilibrium exists between them. Due to the possibility of multiple simultaneous setting reactions, it is essential to strictly adhere to the manufacturer's recommendations for the duration of the irradiation step in order to achieve the best possible material properties.[1]

The biocompatibility of resin-modified glass ionomers is significantly lower than that of standard glass ionomers. This is due to the fact that resin-modified glass ionomers emit HEMA monomer, predominantly within the first 24 hours.[1]

Resin-modified glass ionomer was produced by adding hydrophilic resin monomers to an aqueous solution of polyacrylic acid in order to increase the material's resistance (RMGI). RMGIs retain the beneficial characteristics of conventional GICs while exhibiting superior mechanical properties. GICs and RMGIs, as polymer-based composites, may exhibit viscoelastic behavior in terms of their elastic properties. Typically, evaluations of creep are used to determine the viscoelastic properties of these materials. The elasticity of these materials varies significantly between different manufacturers.[10]

The superior mechanical properties of RMGI materials have been demonstrated by extensive clinical studies. In 36 month clinical evaluations of RMGI class II restorations in primary teeth, Donly et al.[11] discovered that the material performed comparably to amalgam and better than silver cermet. During a six-month study period, Dulgergilet al.[7] discovered that the clinical performance of the RMGI for ART was superior to that of GIC materials. Ge et al.[10] utilized RMGI restorations to treat noncancerous cervical lesions; after seven years, they observed a cumulative survival rate of retention of 95.8%.

Typically, RMGICs contain 20% light-cured methacrylates and 80% GIC (fluoroaluminosilicate glass and polyacrylic acid). Within twenty four hours, RMGICs will be fully cured without the use of a curing light (dark cure). This characteristic distinguishes RMGIC from polyacid-modified resin composite materials (e.g. compomer and giomer).[9],[13]

IV.HYDROLYTIC STABILITY IN GLASS IONOMER CEMENT:

The sophisticated function of water in glass ionomer materials has also been studied. Water is required for the polyalkenoate reaction to occur; it serves as the medium for the setting reaction and is a component of the hardened

cement. This water content maintenance not only determines the ultimate mechanical properties, but also mediates the setting processes and contributes to the material's esthetics. As the cement solidifies, nearly all of the water initially incorporated into the cement becomes a component of the cementitious materials; there is no active expulsion of water as the cement hardens. Due to the current climate, avoiding water damage and loss is a necessity that is widely acknowledged.[1]

It is believed that glass ionomer materials contain two types of water molecules: a "loosely bound" variety that can be easily removed from the material, and a "tightly bound" variety that is much more difficult to remove. In addition, it has been proposed that there is a third, superficial water species whose small size negates the need for diffusion through the glass ionomer material. It is believed that 24 hours of exposure to a desiccant or 105 °C heat will remove loosely bound water, while tightly bound water is more resistant to removal.[1]

Despite their subjectivity, these conditions establish that water is present in distinct regions within the GIC and exhibit some degree of diffusion mobility, with the possibility that the location of the internal distribution may shift over time. Wilson and Crisp estimated that 18-28% of the total water content of glass ionomer was loosely bound, whereas 5% of the water was believed to be tightly bound. Estimates of tightly bound water are consistent with more recent research to some extent. Various mechanisms have been proposed to explain why, as suggested by early studies, the ratio of tightly bound to loosely bound water increases with age. Others point to the formation of strong hydrated ions from the Na+, Ca+2, Sr+2, and Al+3 cations released from the glass as the cause of the formation of silanol groups with strong bonds.[1]

While more recent study [1]has shed light on certain aspects of glass ionomer materials, the majority of what is known about the water balance within GIC materials stems from the earliest studies. Water dynamics and properties are not known to exist in contemporary glass ionomer materials, as expected.

Within twenty-four hours of mixing, GIC undergoes a setting reaction that renders it susceptible to moisture and temperature fluctuations. If exposed to moisture, premature GIC may experience component loss, surface wear, and diminished translucency. However, when the reaction occurs in dry conditions, the GIC is more likely to lose water, which compromises adhesion, alters the material's dimensions, and causes internal cracks, thereby decreasing its strength. To combat this early susceptibility to moisture, the surface of GIC is coated with protective materials such as varnishes, adhesive systems, petroleum jelly, and nanofilled self-adhesive light-cured coating.[14]

Surface coating resins applied to GIC surfaces increase the material's brightness, prevent the material's translucency from degrading over time, smooth out any surface irregularities or gaps left by the material and finishing processes, and reduce the material's susceptibility to moisture during the hardening process. With the incorporation of nano-fillers, low molecular weight monomers, photo initiators, and other factors, there are now new agents for repairing surface coatings.[8]

V.MEASUREMENT OF SURFACE ROUGHNESS :

At present, there exist various techniques for the measurement of surface roughness, encompassing contact stylus tracing, non-contact laser stylus metrology, scanning electron microscopy (SEM), atomic force microscopy (AFM), and 3-D Optical Profilometry (white light interferometry).[15] The contact stylus tracing is the most prevalent form.This particular method of tracing enables the collecting of a quantitative assessment of surface roughness. While the contact profilometer is capable of measuring a significant surface area, it has the potential to cause damage to a specimen due to the creation of surface scratches. Moreover, it is imperative that the radius of the stylus is lower than the concavities present on the rough surface. In the event that the profilometer fails to capture the concavities, it will result in diminished precision and accuracy of the recorded measurements.[15]

Quantitative and qualitative descriptions of surface topography can be obtained using a 3-D optical interferometer. It has been shown through investigation[16] that the contact profilometer is superior to other methods for measuring changes in surface height, such as the evaluation of restoration margin discrepancies. When it comes to measuring surface texture. However, the laser profilometer provides more reliable results. Optical depth measurement device white light interferometer, or 3-D optical profilometer, is an optical imaging method used to quantify surface roughness.[16] Using low-wavelength light, the technique relies on low-coherence interferometry to obtain a reflection from the specimen surface rather than a transmission. It is made to evaluate the three-dimensional contour of a large surface area.[16]

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Atomic force microscopy is a flexible cantilever with a pyramidal or spherical probe (tip) is used to produce nanometer-sized indentations on the surface of a cell or substrate for standard AFM cell mechanics measurements. As force is applied from the tip to the cell surface, the cantilever deforms similarly to the substrate. A photodiode detector measures the deformation of a cantilever by reading the light reflected from a small laser focused on its back. As the cantilever is deformed, light is refracted away from its initial axis of arrival. As the tip deforms reactively at the surface during indentation and retraction, an indentation force-indentation curve is generated by plotting the indentation force against the depth of the indentation (where depth of indentation is equivalent to deflection against an infinitely rigid substrate, such as glass). Elastic/modulus, Young's i.e. elastic/rigidity qualities, can be determined by fitting force-indentation curves to a number of proposed models, the Hertz model being one of the most prominent.[17]

AFM has expanded its applications beyond materials science and electrochemistry to include the life sciences. In recent years, as AFM technology has advanced, observation resolution has increased, and the spectrum of possible applications has expanded, quantitative analysis of observed images has become more prevalent. The majority of experimental investigations in the field of biomedicine are now centered on the structure and related functions of biological macromolecules, particularly nucleic acids and proteins. Using AFM, scientists in the field of materials science can determine not only the three-dimensional morphology and surface irregularities of a material, but also the distribution variations in physical parameters such as impedance and dielectric constant. [17],[18]

Depending on the variation in micro-surface height, the gravitational or repulsive force between the tip and the sample surface will change during the scanning process. Measuring the form variable of the microcantilever yields the force, which is highly correlated with the separating direction. The feedback loop is utilized throughout the scanning procedure to maintain a constant force and tip shape relative to the sample. Tracing the up-and-down motion of the tip will provide information about the sample's surface topography. The most prevalent AFM scanning mode for detection is the constant force mode. In 1986, Binning and Quate established AFM.[18]

VI.MEASUREMENT OF FLUORIDE RELEASE:

Since the days of colorimetric analysis, which produced imprecise results and was susceptible to interference from other ions in the samples, more advanced techniques for identifying the presence of fluoride (F) have been developed, including mass spectrometry, gas chromatography, ion chromatography, electroanalysis, catalytic-enzymatic, and radioanalytical techniques. In the past forty years, F analysis has progressed significantly.[19] Despite the development of new methods, determining F has neither become simpler nor less expensive.[26] Several of the most recent techniques are expensive and challenging to implement, in addition to having limited applicability.[20]

The F ion-selective electrode consists of both an epoxy body and a sensing element. The F ion-selective electrode generates a voltage across a lanthanum fluoride based solid ion exchange phase (LaF3). The Nernst equation (Nernst and Schonflies, 1895) characterizes the observed potential associated with fluoride ion activity in solution. There is no universally accepted method for determining F, and the current methodologies for measuring F are not standardized.[19]

VII.MICROMORPHOLOGICAL ANALYSIS OF RESTORATION/TOOTH INTERFACE UNDER SCANNING ELECTRON MICROSCOPE:

The development of scanning electron microscopy (SEM) was made possible by the invention of the first transmission electron microscope. Because these techniques share a common ancestry, their histories are typically discussed together. Max Knoll and Ernst Ruska of Berlin's Technical University invented electron microscopy in 1931 by using an electron beam scanner to take a succession of photographs.[21] The technologies developed in the twenty-first century include digital image processing utilizing computers and attempts to observe in less artificial settings without a vacuum or by situating the object.[22]

Since dental tissues are nonconductive specimens, it is difficult to prepare them for SEM observation without electrostatic charge. Among the common causes of image artifacts is exposing the specimen to an electron beam. To prevent this, the specimen must be coated with an electroconductive material. Gold is commonly used for this purpose, but other materials, such as noble metals (palladium, platinum, iridium, or osmium), wolfram, or graphite, are also utilized in research. By using

sputter deposition, the coating is applied to the surface.[23]

The specimen must also be dehydrated, which is essential. The presence of water can result in surface tension, which can alter the surface morphology of conventional SEM images captured in a vacuum environment. Due to their high water content, soft-tissue specimens require a chemical fixative (typically glutaraldehyde) and subsequent dehydration prior to examination under the microscope.[24] The fixation of dental specimens has been brought into question. Due to its extremely low water content, mineralized hard tissue, such as enamel, is comparatively dry and does not necessitate specialized methods of fixation. Despite the fact that dentin has a higher organic content than enamel and that its collagen network appears to be more susceptible to collapse during dehydration, study[24] indicate that both structures can withstand air-drying without being obliterated. After drying and coating the tooth specimen, electrically conductive carbon tape is then used to adhere it to the stub. Rapidly, scanning electron microscopy (SEM) has become the primary imaging technique for biological research. Studies[24],[25] evaluating the biofilm on enamel and the condition of hard tissues following abrasion, polishing, etching, or bonding utilized imaging due to its ability to precisely map the morphological characteristics of surfaces.[24]

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