ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4

Journal of Coastal Life Medicine

Glass-Ceramic and Zirconia-Based Dental Restorations; A Narrative Review on Introduction and Applications

Received: 16 February 2023, **Revised:** 18 March 2023, **Accepted:** 19 April 2023

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Keywords:
Ceramics, Adhesives, Glass Ceramics, Zirconia

Abstract
Background: The clinical success of indirect restorations is influenced by a variety of factors, including the choice of appropriate cement. With the introduction of adhesive resin systems, the use of all-ceramic bonded coatings has increased. The purpose of this study was to review the adhesive agents and their clinical characteristics and requirements that help the dentist in selecting the appropriate adhesive cement in specific clinical conditions. Methods: The study was conducted using the keywords Clinical, Zirconia, Glass Ceramic, and Dental restoration (Toughening Transformation, Machining, Performance) and review of articles in library resources, books, PubMed, and ISI databases. The scope of the article search was mainly from 2000 onwards. Results: Since new materials are constantly marketed, it becomes more difficult to select the appropriate cement and teach the method of application. Proper selection and knowledge of the nature of the material are of great importance because only then the dentist can apply the appropriate surface preparation to be cemented. Conventional cement is superior when the desired compressive strength, minimum layer thickness, and low solubility in water are desired. Of course, these types of cement require the ideal preparation of the desired tooth. Ordinary cement is used to bond non-etching porcelain. On the other hand, resin cement is a better choice for metal-free restorations due to its superior physical properties and more beauty than conventional cement. Conclusion: Despite the appropriate clinical results in short-term research, long-term clinical and laboratory studies on zirconia and glass and ceramic restorations are still needed.

1. Introduction

Dental cement has different clinical applications and is widely used in dentistry. They are used as temporary fillers, base materials, and adhesives. They are also used in orthodontic and endodontic treatments[1]. Cement used as a base material protects the pulp from thermal, chemical, and electrical stimuli. Temporary fillers play the role of filling cavities and protecting teeth until the next visit and adhesive cement also creates a close match between teeth and indirect restorations that Depending on the physical properties and durability of the restoration, the adhesives can be temporary or permanent[2].

Dental cement is used to trap restorations, appliances, posts, and cores, and provides long-term stability of restorations in the oral cavity. The trapping mechanism can be chemical, mechanical, or micromechanical, that is often depending on the type of cement, substrate, a combination of two or three methods. among cements, resin and non-resin cement are available that must have special properties for clinical approval (Meyer, Cattani-Lorente, & Dupuis, 1998; Rosenstiel, Land, & Crispin, 1998).

It must be compatible with living tooth tissue, its components must not damage the pulp, have anti-decay properties, have a low dissolution rate in oral fluids, have resistant to chewing and tensile forces of food, Pass enough light, must be suitable thermal insulation

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to protect living teeth from thermal damage (Rosenstiel et al., 1998), have a long half-life, good color stability, and good radiopacity (Simon & Darnell, 2012), In order to achieve maximum alignment between the tooth and the restoration, the cement must have a very low thickness (Film thickness) and viscosity.

2. Cement Classification

Cement is usually provided in powder and liquid form and the setting mechanism is acid-base. Acid is in liquid form and base is in powder form. Except for resin cement, which is formed by the polymerization of macromolecules, the rest of the types of cement have an acid-base reaction and are classified as cement -AB (AB-cement) (Meyer et al., 1998).

Articles on cement classifications are very diverse. Some of the old classifications were based on their major components (e.g., zinc phosphate, silicon zinc phosphate, eugenol zinc oxide, zinc polyacrylate, glass ionomer, and resin) (Powers & Sakaguchi, 2006), new classifications of case function The expectation of the compound in the oral environment is supported, which is divided into two types, temporary and permanent, as well as in another classification of acid-base set mechanism (glass ionomer, glass ionomer modifier resin, eugenol zinc oxide, zinc phosphate, and poly Zinc carboxylate) or various types of polymerization (resin cement, compomer, self-adhesive resin cement) are used. It should be noted that this classification refers to the dominant mechanism so that the resin cement modified with glass ionomer has polymerization groups and self-adhesive compomers and self-adhesive resin cement can have an acid-base reaction (Powers & Sakaguchi, 2006). O'Brien (O'Brien, 2002), also developed another classification that supported matrix bonding (phosphate, phenolate, polycarboxylate, resin, and glass ionomer resin modification).

3. Resin-Modified Glass Ionomer

Despite the favorable properties of glass ionomer cement, which has led to their use in dentistry since the 1970s, in the late 1980s, to increase the properties of glass ionomer cement and reduce its disadvantages (such as low initial strength and high solubility), resin Glass ionomer was added to cement and resin-modified glass ionomer (RMGIC) was produced (E. E. Hill, 2007; Simon & Darnell, 2012).

Cement originally contains 80% glass ionomer and 20% resin, and other modifications could be made depending on the manufacturer. In the liquid, (2-hydroxyethyl methacrylate; HEMA) (Yiu et al., 2004), there are groups of methacrylate, hydroxy acid, tartaric acid, polyacrylic acid, and water. This powder contains glass fluorine aluminosilicate glass particles. RMGICs are hybrid materials and their properties are between ordinary glass ionomer cement and composite resins (E. E. Hill, 2007). Therefore, polymerization of methacrylate groups in cement can be initiated with light or chemically (Diaz-Arnold, Vargas, & Haselton, 1999). In dual curing materials, HEMA polymerization begins with light and then continues at a slower acid-base reaction to increasing the stability of the material.

In Tricure materials, although the polymerization of HEMA begins chemically, the strength of the matrix increases with the progressive reaction of acid and base. The advantage of cement with Tricure sting compared to dual-cure is additional polymerization and more resin in places where light does not reach. In set cement, two matrices are placed inside each other, one of them is an ionic matrix which is composed of acid and base reaction and the other is resin matrix (Bakshi & Ahuja, 2016; SÜMER & DEĞER, 2011).

The adhesion of these cements to dentin and enamel and their fluoride release pattern is similar to that of ordinary glass ionomer cement (Diaz-Arnold et al., 1999; Ferracane, Stansbury, & Burke, 2011). Due to the presence of carboxyl groups in polyalkenoic acid in RMGI, these materials have adhesive (SÜMER & DEĞER, 2011)

Clinically, mixing and working with RMGI is very similar to regular glass ionomer, and teeth cleaning is the same (E. E. Hill & Rubel, 2009; Mirmohammadi, Aboushelib, Salameh, Kleverlaan, & Feilzer, 2010). The cement should be mixed according to the manufacturer's instructions on a glass slab or pad (if not in the form of a capsule) and while the material has a shiny appearance, the restoration should be done quickly and with finger pressure (E. Hill & Lott, 2011; Zhang & Lawn, 2018).

Applying polyacrylic acid conditioner on dentin before using RMGIC not only improves the wettability of the tooth surface but can also strengthen the cement and create ion exchange by creating hydrogen bonds (Kheur et al., 2020). Abrasion and fracture resistance

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
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of these cements is higher than ordinary glass ionomer cements [19] and also these cements are more beautiful than ordinary glass ionomer cement (Mehta et al., 2020). They are also more resistant to water contamination during the hardening reaction and have less solubility (de Mendonca, Souza, Hebling, & de Souza Costa, 2007). Another advantage of RMGICs is that they are easy to mix and apply, as they do not require multiple bonding steps. Also, the thickness of the cement layer in them is small and desirable (Kannan, Venugopalan, Ganapathy, & Jain, 2018). In RMGI cements, the removal of cement additives after cementing is a major problem. For this reason, as soon as the initial hardening reaction is performed, the excess material below the restoration margin must be cleaned (Chander & Biswas, 2018).

The most important disadvantage of RMGI is the increase in hygroscopic and plastic moisture due to the hydrophilicity of poly-HEMA and the consequent high-water absorption. Water uptake initially reduces shrinkage stress during polymerization, but continued water uptake has destructive effects (Robaian et al., 2021). Due to the large dimensional changes and the possibility of hygroscopic expansion, these cements are not recommended for use in all-ceramic feldspar (etched) restorations as well as cement cores (Mount, 2001; Rezaie, Rizi, Khamseh, & Öchsner, 2020).

Modified glass ionomer resin is used for cementing metal and metal-porcelain crowns and bridges, as well as a base material under composite restorations (Manar, 2018; O'Brien, 2002). When aluminum or zirconium cores are used to cement all-ceramic crowns, safe and beautiful work is created that provides a high grip (Ernst, Cohnen, Stender, & Willershausen, 2005; E. E. Hill, 2007; Snyder, Lang, & Razzoog, 2003). Different types of this cement are used in orthodontics (Diaz-Arnold et al., 1999; Praveen et al., 2020) and RMGICs in the market are in the form of powder-liquid and capsules (O'Brien, 2002).

4. Glass-Ceramics

Leucite-reinforced feldspar glass and feldspar glass are still widely used in top coatings, veneers, and inlays, and their extraordinary beauty is achieved through their translucency, fluorescence, and application. However, these ceramics have disadvantages such as low strength and toughness. Available glass-ceramic systems include:

1. Leucite-containing glass-ceramics (made by Hot sintered, Pressed, or computer-aided design-Computer-aided construction using CAD-CAM) with a flexural strength of 120 MPa are suitable for veneers, anterior coatings, and rear inlays (Barber, 2008; Samani, Samimi, & Mazaheri, 2013), such as Finesse Authentic PM9 OPC, Paradigm C, IPS Empress

2- CAD-CAM (Flourmica) glass-ceramics with a flexural strength of 150-120 MPa, which has adhesion to the teeth and can be suitable for posterior veneers (Cornish, 2020) such as Dicor.

3- Advances in the mechanical properties of glass-ceramics were achieved with the development of lithium disilicate ceramic glass CAD-CAM or Hot pressed (flexural strength of about 450-350 MPa). Since the introduction of lithium disilicate ceramics, the use of Lucite glass-ceramics has decreased. In addition, in addition to better mechanical properties and superior aesthetic results, high bond strength is also achieved in tooth bonding. Examples of this category are E.max Press E.max CAD OPC 3G and IPS Empress2 (El-Etreby, Metwally, & Gihan, 2021; Leenakul & Kraipok, 2021).

5. High Strength Polycrystalline Ceramic

Although high-strength polycrystalline ceramics (alumina and zirconia) are widely used for posterior crowns and bridges, their long-term clinical results are discussed in (Mohammadi, Movahedzadeh, Zahra, Hoseini, & Iraj, 2017; Raigrodski & Chiche, 2002a, 2002b; Raigrodski et al., 2006; Sailer, Fehér, et al., 2007; Sailer et al., 2009; Sailer, Pjetursson, Zwahlen, & Hämmerle, 2007; Tinschert et al., 2008). Zirconia is the first choice for cores or all-ceramic restoration frames due to its higher mechanical properties than alumina. It should be noted that the mechanism of connection to high-strength ceramics is problematic due to the lack of glass particles in their composition.

Among all-ceramic materials, zirconium and lithium disilicate have become the most popular materials in dentistry due to their desirable mechanical properties (Conrad, Seong, & Pesun, 2007). For example, of the 600,000 all-ceramic restorations performed by Glidewell Laboratories in 2011, 75 percent were zirconia ceramics, 23 percent lithium disilicate, and only less than 2 percent leucite-reinforced ceramics and other ceramic (Chen & Suh, 2012).

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6. Structural Properties of Zirconia

Today, all-ceramic crowns with zirconia bases have entered the field of dentistry widely due to their extraordinary beauty, biocompatibility, chemical durability, and high strength. These special functional properties and especially the abundant capabilities of zirconia in shaving in dry and wet shaving environments have put this material in the list of the best category of materials for use in the clinic. Since its introduction to dentistry, numerous studies have been performed to improve mechanical properties, improve aesthetics, simplify preparation methods, and improve bonding with adhesive resins or coating ceramics (Madfa, Al-Sanabani, Al-Qudami, Al-Sanabani, & Amran, 2014).

Zirconium is a glassless phase- polycrystalline ceramic that is found in three electropic forms (Azzaldeen, Georges, Nikos, & Muhamad, 2017; Ispas, Iosif, Murariu-Măgureanu, Craciun, & Constantiniuc, 2021; Kumar, Sakthivel, & Vanmathi, 2021; Lambert, Durand, Jacquot, & Fages, 2017; Pilathadka, Vahalová, & Vosáhlo, 2007): (T) tetragonal, cubic (C), and monoclinic (M). Adding oxide stabilizers (such as Y_2O_3, C_eO_2, MgO, C_aO) to pure zirconia produces a multi-phase material called partially stabilized zirconia (PSZ). The tetragonal phase in PSZ is semi-constant at room temperature. Due to external factors such as stress or temperature change, deformation of T to (tetragonal phase to monoclinic phase) M occurs. Any change or conversion between these three phases creates a force on the surface of the zirconia that changes the volume of the crystals at the pressure site. The increase in volume due to this phase change from T to M floods the cracks created at the stress point and prevents it from progressing. This property of zirconia, which improves its physical and mechanical properties, is called transformation toughening (Garvie & Nicholson, 1972; Surlari et al., 2018).

7. Connection Methods for Ceramic Systems

The ability to combine resin/adhesive cement with dental ceramics depends on the microstructure of the restoration and the surface preparation used. A reliable and durable bond for bonded ceramic resins is often achieved by two main mechanisms: the chemical bond between the cement and the ceramic (through the use of silane) and the micromechanical bond through the application of surface roughness. Solutions for surface roughness include: grinding, abrasion by rotating diamond tools (or other materials), aeration with alumina particles (or other particles), micromechanical entrapment within the pores obtained by etching with hydrofluoric acid (Alsarani, Souza, Rizkalla, & El-Mowafy, 2018; Thompson, Stoner, Piascik, & Smith, 2011). Roughening the surface with airborne abrasion or grinding particles is a way to improve the adhesion to most cosmetic materials, while the use of silane seems to be effective only for silica-based ceramics (Blatz, Sadan, & Kern, 2003; Zarone, Di Mauro, Ausiello, Ruggiero, & Sorrentino, 2019). Evaluation of bond strength between ceramic and resin composite has announced different results regarding the effect of surface treatments. Differences in studies (Barghi, Chung, Farshchian, & Berry, 1999; Hooshmand, van Noort, & Keshvad, 2002) may be due to the inefficiency of the silane coupling agent and operator error in the work process.

8. Conclusion

Zirconia-based restorations promise a great alternative to metal-ceramic restorations. Zirconia products that are fully sintered and semi-sintered appear to be clinically acceptable. Adaptation of zirconia frameworks made with CAM / CAD technique is clinically acceptable. In terms of resistance fracture, permanent restorations of zirconia particles can withstand occlusal physiological forces in the posterior region. Clinical evaluations have shown that the clinical success of single restorations and zirconia bridges is excellent. However, some articles have reported porcelain veneer chipping. It is similar to metal-ceramic restorations in terms of tooth preparation and cementing. Restoration with full coverage and sufficient adhesion does not require resin cement. However, it may be necessary for some clinical conditions. Recently, surface preparation using air-borne particle abrasion and MDP-10 composite resin for bonding zirconia seems appropriate. Despite excellent clinical results in short-term research, we still need more clinical and laboratory studies to have long-term information on zirconia restorations. Due to the high prevalence of porcelain veneer chipping, it is recommended that more research be done to solve this problem. Due to the lack of long-term clinical information on the success of these restorations, further systematic studies or meta-analyses are recommended.

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