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A Comprehensive Analysis of Luting Cements for Zirconia Crown Adhesion – A Narrative Review

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Abstract

Restorative dentistry is a blend of science and art. Its success hinges on achieving both functional and aesthetic results in any given intervention. Recent advancements in materials and technologies have significantly impacted clinical dentistry, revolutionizing traditional restorative treatment concepts. Achieving reliable bonding between luting cement and high-strength ceramics is challenging due to their chemical inertness and lack of silica, which prevents etching. Zirconia, however, has become increasingly important, fundamentally changing clinical applications and expanding the range of indications for all-ceramic restorations. These restorations now span from single-tooth restoration to full-mouth implant-supported rehabilitations, thanks to zirconia's excellent mechanical properties and biocompatibility. The purpose of this review is to Analyze the adhesion of Luting Cements for Zirconia Crown prosthesis, to improve the adhesion of zirconia to the dental substrate by using glass ionomer cement, and composite resin cement in order to use in routine dental practice with predictable results. To review the literature, Studies were selected from PubMed, Scopus, Web of Science, and Google Scholar without restrictions on publication year, to provide a comprehensive overview of current knowledge on zirconia adhesive materials relevant to routine dental practice. The review including case reports, laboratory studies, clinical studies, and systematic reviews. It is necessary to evaluate the behavior of different luting cements and techniques before their clinical application. So, it was concluded that RMGIC and MDP are superior out of all cement. A clinical protocol for adhesive cementation to zirconia should have been performed.

Keywords: Zirconia, Crown Prosthesis, Adhesion, luting Cements, Routine Dental Practice

Introduction

The introduction of zirconia in dentistry opened up new possibilities for indirect restorations. However, with the onset of the new millennium, a new question arises, how to effectively bond zirconia prosthesis to the tooth. Over the past two decades, countless studies have sought to find a reliable method for achieving consistent bonding between teeth and zirconia. However, a universally accepted "gold standard" approach remains elusive.[1] Damage or loss of teeth significantly affects phonetics, appearance, and chewing. Repairing or replacing damaged or lost dental tissues involves using artificial materials that can endure the harsh mechanical, chemical, and thermal conditions in the mouth. Currently, a range of materials and techniques are available to researchers for restoring dental tissue function. Addressing these issues with dental interventions, such as prosthetics, implants, or orthodontics, is crucial for maintaining not just oral health but also general well-being and quality of life. In recent years, the demand for dental aesthetics has significantly increased, resulting in the use of non-metallic prostheses over metal-ceramic ones for indirect restorations. Metal-ceramic restorations have gradually declined in popularity, ushering in a new era of metal-free dental solutions.[2]

The cementation of indirect restorations is a crucial step in prosthetic and restorative dentistry. Cementation aims to bond the prosthetic restoration to the prepared enamel or a combination of enamel and dentin. Effective cementation protocols help prevent biofilm formation at the margin between the tooth and the restoration, minimizing mechanical and biological complications. With advancements in dental cements, they have been modified to be versatile in terms of handling, curing, and bond strengths.

Successful ceramic-resin bonding depends on roughening the ceramic substrate's surface to enhance surface area and enable micromechanical interlocking. Surface activation also facilitates the formation of chemical bonds. Acid-etching and silane application are ideal techniques for achieving strong and durable resin bonds to silica-based ceramics. [3] The application of silane promotes chemical coupling between the ceramic and resin monomers.

Chemical interactions are key for reliable resin-ceramic bonds. [4,5] However, densely sintered, polycrystalline zirconia can't be etched with hydrofluoric acid using the typical temperatures, times, and concentrations available to dental practitioners. [6-8] Physical methods like surface grinding or abrading can be used to roughen the surface instead. It's important to establish safe and standardized adhesive cementation protocols for zirconia to effectively complete conservative/prosthetic treatment plans, especially when the preparation lacks retention due to abutment or prosthesis design characteristics, or when enhancing the mechanical properties of the tooth-prosthesis complex is necessary.[3]

The aim of the review is, to compare and evaluate different luting cements on the adhesion of Zirconia Crown to enhance results in routine clinical practice.

Material and Methodology

To review the literature, Studies were selected from PubMed, Scopus, Web of Science, and Google Scholar without restrictions on publication year, to provide a comprehensive overview of current knowledge on zirconia adhesive materials relevant to routine dental practice. The review focused on evaluating the bond between zirconia and composite resins. The search terms included: “Zirconia,” “Adhesive materials,” “Adhesive cementation,” “Bonding,” “glass ionomer cement,” “Resin,” “Composite resin,” “Composite material,” "Dentin," and "Enamel." The research encompassed, Case reports, laboratory studies, clinical studies, and systematic reviews.

Importance of Zirconia

Zirconia was first discovered as a mineral in 1892,[9] Zirconia (ZrO_2), A crystalline oxide of zirconium, boasts excellent mechanical, optical, and biological properties.[10] This biomaterial exists in three basic crystalline forms: monoclinic, tetragonal, and cubic. [11] It possesses unique properties that are valuable from mechanical, biocompatibility, color stability, and suitable mechanical and tribological behavior standpoints. Zirconia has increasingly played a crucial role and offers a wide array of clinical applications, such as root posts, implant abutments, or as the material of choice for indirect ceramic restorations. It boasts the most favorable mechanical properties compared to other high-strength ceramics, with flexural strengths ranging from 700 to 1200 MPa, fracture resistance of over 2000 N, and fracture toughness of 7 to 10 MPa. [12, 13]

However, it's not only strength that matters; cementation and the adhesion of cement to both dental tissues and restorative material are critical for the long-term success of these restorations.[14].

Recently, significant advancements in restorative biomaterials, including dental zirconia, have enabled the production of various types of zirconia for prosthetic dental restorations.[15] Pure zirconia is monoclinic at room temperature but transforms to the tetragonal form at elevated temperatures (1,170 °C) or under low-temperature degradation (LTD). With further temperature increases (2,370 °C), aging, or hydrothermal aging, it progressively reverts to the monoclinic phase. Kern and Blatz et al. reviewed the success of bonding high-strength ceramics, specifically alumina and zirconia ceramics, with adhesive resin. Zirconia ceramics are chemically stable and possess excellent mechanical properties, making them suitable as restorative materials in areas subjected to high occlusal loads [3] (Çakırbay et al., 2020). However, conventional zirconia has the drawback of limited translucency. Recent generations of zirconia have been developed with improved optical characteristics by introducing larger amounts of the cubic phase. Despite the enhanced translucency of these new zirconia materials, the high cubic content significantly reduces their strength [16]. Ensuring proper bonding between the zirconia restoration and the tooth is crucial for the longevity of the prosthetic restoration. To achieve effective adhesion with luting cement, zirconia requires surface treatments such as acid etching for surface abrasion [17]

Adhesion between zirconia and resin cement

Adhesion between the restoration and the tooth is crucial for the successful clinical performance of indirect restorations and prosthesis [18, 19]. Unlike glass ceramics, zirconia is resistant to acids due to its glass-free polycrystalline microstructure [20, 21]. Both mechanical and chemical pre-treatments are recommended for zirconia bonding [22]. Studies have shown that combining air-borne particle abrasion with the application of an MPD-containing primer enhances the bond between zirconia and resin cement [23].

Self-adhesive resin cements are designed to bond to tooth structure using a one-step protocol that eliminates the need for etching, rinsing, and priming. These cements are clinically appealing due to their single-step application and ease of use, despite the fact that the luting procedure can be technique-sensitive [24]. Self-adhesive resin cements primarily consist of predominant functional acidic monomers and conventional di-methacrylate monomers, such as Bisphenol A glycidyl methacrylate, Urethane dimethacrylate, and triethyleneglycol dimethacrylate [25]. The functional acidic monomers commonly used in these cements include bis 2-methacryloxyethyl acid phosphate (BMP), 10-methacryloyloxydecyl dihydrogen phosphate (MDP), 4-methacryloxyethyl trimellitic anhydride (4-META), pyromellitic glycerol dimethacrylate (PMGDM), 2-methacryloxyethyl phenyl hydrogen phosphate (Phenyl-P), and dipentaerythritol penta-acrylate monophosphate (Penta-P) [24]. The initial low pH and high hydrophilicity of self-adhesive resin cements promote surface demineralization, similar to the effect of self-etching adhesives [26]. The primary acidic monomers can chemically interact with zirconia and hydroxyapatite in tooth structure [27,28].

Studies have demonstrated that the type of cement used significantly impacts the distribution of stresses within the tooth-restoration complex, aiding in the dissipation of occlusal forces away from the tooth-restoration interface. Weak bonding between the ceramic restoration and the resin cement leads to uneven stress distribution and increased susceptibility to failure [28]. Fractures in ceramic restorations can originate either at the intaglio surface or at the cementation interface, where tensile stresses are concentrated. When selecting a self-adhesive resin cement, some studies have found that adding an MDP-containing primer can enhance the performance of zirconia crowns [16].

Yttrium-stabilized tetragonal zirconia polycrystal (Y-TZP) has been used in both monolithic and bilayered restorations. Various bonding protocols have been proposed to enhance the adhesion between Y-TZP and resin cements. These protocols include air abrasion, silanization, the use of phosphate acid monomers, vitrification, silica infiltration, and the deposition of glass nanoparticles on the surface, among others [16]

Layered zirconia cementation for crown prosthesis

Layered zirconia crown cementation for prosthesis provide significant advantages, notably a substructure flexural strength of 1200 MPa, exceeding that of most PFM prosthesis. Additionally, their fracture toughness and flexural strength are markedly higher compared to alumina or other all-ceramic materials [29] Unlike metal prosthesis, layered zirconia does not present esthetic issues such as metal showing through or black lines at the gingival margins. Furthermore, clinicians can conventionally cement layered zirconia using glass ionomer and resin-modified glass ionomer cement, both known for their excellent biocompatibility.[29] If the primary resistance and retention form of the preparation is insufficient, bonding agents with resin cement may be recommended for long-term prosthesis success.[30] Studies explores that the use of layered zirconia prosthesis with glass ionomer cement to efficiently and effectively restore a patient's dental form and function.[31] In a case report on zirconia crown cementation with glass ionomer cement, Ara Nazarian concluded that layered zirconia crown prosthesis meet the criteria sought by dental providers for anterior all-ceramic crown prosthesis. This cementation of crown prosthesis provides clinicians with a simple, cosmetic, cost-effective option that offers optimal strength, high-quality esthetics, color stability, and biocompatibility.[32]

Adhesion between zirconia and GIC

Successful anterior cases typically require excellent aesthetics, strength, and flexibility. Glass ionomer cements (GICs) are primarily used to bond cast-metal and metal-ceramic restorations, ensuring sufficient retention and resistance.[33] Microleakage poses a significant risk in restorative dentistry, but it can be prevented by the ion-exchange adhesion of glass ionomers. Glass ionomer (GI) cements consist of finely balanced powder and liquid components.[34] While their chemical bonding to the tooth surface makes GICs appealing for clinical use, traditional GICs may not be ideal for high-strength ceramic restorations like zirconia due to their lower strength and solubility in moist environments compared to resin-modified GICs. Zirconia-based bridges, featuring zirconia margins and conventionally luted with resin-modified GIC, have shown success in terms of marginal adaptation, with no reported loss of retention or secondary caries.[33]

Resin-modified glass ionomer cement

Resin-modified glass ionomer (RMGI) cements differ from photocured resin composites and traditional glass ionomer (GI) cements due to their dual-setting process, which involves both photocuring and an acid-base reaction.[34-36] The final set material features glass particles encapsulated in a matrix made up of two networks: one originating from the resin and the other from the GI reaction.[35] This dual-setting system results in higher bond strength to dental tissues and improved mechanical strength. However, a drawback of RMGI cement is its hydrophilicity, stemming from the formation of polyhydroxyethyl methacrylate during the setting reaction, which leads to increased water absorption and hygroscopic expansion. Resin cements that release fluoride and contain the adhesive phosphate monomer MDP are referred to as MDP cements. [38,39]

Authors view

The first step to successful adhesion between zirconia and material is to adhere to a strict protocol. Avoid any contact between phosphoric acid and the zirconia restoration during cementation, as the phosphate ions in the acid significantly reduce the bonding potential to the zirconia. Avoid cleaning tooth preparations with prophy paste, as the emollients and fluoride in some pastes can negatively impact crown retention. Instead, use a mixture of pumice and water. Preppies from Whip Mix is a recommended product for this purpose.

For zirconia restorations, use resin-modified glass ionomer (RMGI) cement when the tooth preparations exhibit near-optimal characteristics. Most clinicians and researchers concur that the tooth preparation should have a minimum height of 4 mm from the gingival margin to the occlusal table, and the walls of the preparation should have a divergence of no more than 20 degrees from the tooth's long axis. For tooth preparations lacking 4 mm of axial walls and exhibiting a taper greater than 20 degrees from the long axis, many dentists opt to use self-adhesive resin cement (where bonding materials are integrated into the cement) or adhesive cement (where bonding material is applied to the tooth preparation before cementation).

Studies have investigated various ceramic surface treatments to optimize bond strength at the ceramic-cement interface. High alumina- or zirconia-reinforced ceramics cannot be roughened by hydrofluoric acid etching because these ceramics do not contain a silicon dioxide (silica) phase. A strong and reliable resin bond to alumina and zirconia ceramics has been achieved by using air particle abrasion followed by a resin composite luting cement containing the monomer 10-methacryloyloxydecyl dihydrogen phosphate (MDP). Sebnem Begum Turker et al conducted a study to evaluate and compare the shear bond strength (SBS) of 3 different luting agents hence they concluded that artificial aging affected the bond strength of both the RMGI and MDP cements to the airborne particle-abraded zirconia ceramic specimens. The bond strength of the MDP was superior to the GI and RMGI luting cements with and without aging. In addition, aging affected the type of failures. Mohamed Saber Abd

Elghaffour Elsawy et al conducted a study to evaluate zirconia-infused glass ionomer cement versus resin-modified glass ionomer in class II restorations of primary molars. It was found that RMGI is better in shear strength than zirconia-infused glass ionomer, while the two materials have the same resistance to wear.

In various clinical scenarios, such as when insufficient retention is provided by a short or tapered tooth structure, it becomes necessary to use adhesive bonding with either conventional adhesive or self-adhesive resin cement. Firstly, it has been proven that the fracture resistance and longevity of ceramic restorations are improved by sealing the internal surface flaws. Secondly, it provides the benefit of enhancing marginal fit and preventing microleakage at the margin of the restoration.

Some studies currently researching whether or not we need to place a bonding agent on the tooth surface to potentially enhance the bond of the resin component of the RMGI cement (20% resin) to the tooth. Based on the results of the in vivo study, it can be concluded that a bonding agent is unnecessary. However, the ongoing research currently underway in CR soon will answer that question more thoroughly. In the same study mentioned earlier, it was observed that zirconia primer wasn't applied to the internal surface of the zirconia restorations when using RMGI cement. They have studied that aspect of the cementation process to see if the zirconia primer will enhance the bond of RMGI to the zirconia surface. The findings of this study suggest that using a zirconia primer may not be necessary with RMGI cement. However, it seems that a zirconia primer is still recommended when using resin cement.

Conclusion

In the present review, the studies were conducted in vitro, in vivo, case reports, and systematic reviews, and a great heterogeneity was observed among the studies. Despite the limitations of this type of study, it's crucial to assess how various materials and techniques behave before using them in clinical practice. So, it was concluded that RMGIC and MDP are superior out of all cement. A clinical protocol for adhesive cementation to zirconia should have been performed.

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