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Exploring Innovations in Resin Cement Technology for Prosthodontic Applications

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Abstract:- In recent years, resin cement technology has undergone transformational advancements, revolutionizing prosthodontics. This review explores resin cement's evolution, emphasizing its types, historical development, and impact in modern dentistry. It highlights innovations in material science, bonding techniques, and clinical applications. The journey begins with an examination of its historical roots, tracing the path from traditional cements to today's versatile resin-based alternatives. Different resin cement types, including conventional, aesthetic variations and self-adhesive are discussed. Material science has enhanced resin cement's durability, strength and aesthetic appeal. The article explores contemporary bonding protocols and their application in prosthodontic procedures. While celebrating these innovations, the review also candidly addresses challenges like adhesive failures, post-operative sensitivity and allergic reactions offering a balanced perspective. It looks ahead, discussing ongoing research and potential technological advancements. Supported by informative case studies, this review underscores the real-world impact of resin cements in prosthodontics. In conclusion, resin cement technology continues to reshape prosthodontic practice, providing clinicians with a versatile toolkit for superior patient outcomes.

Keywords:- *Resin Cement, Polymerization, Prosthodontics, Advancements, Bonding.*

I. INTRODUCTION

The fundamental objective of oral rehabilitation is to achieve durable and reliable indirect repairs, hinging significantly on the effectiveness of resin-matrix cements [1]. These cements are instrumental in determining the mechanical properties of the restorative interface, particularly in the context of ceramic or resin-matrix composite restorations [2,3]. The process of polymerization within these resin-matrix cements plays a vital role in dictating the longevity and integrity of such restorations.

Insufficient polymerization of these cements can have detrimental consequences, as it accelerates the degradation of the resin-matrix and markedly elevates the risk of fracture at the restorative interface. Ultimately, this can result in debonding, posing challenges to the longevity of the restoration [4]. The intricate balance between the resilience of these cements and their adhesion to tooth structures is thus of paramount importance in ensuring the success of oral rehabilitation procedures.

Dental luting agents, specifically cements, are a critical component of this process. They are employed to securely bond fixed prosthetic elements, such as crowns, onlays, and bridges, to the underlying tooth structures [5]. Consequently, the selection and effective use of these cements are vital considerations in the field of restorative dentistry, as they directly impact the structural integrity and durability of dental restorations, and by extension, the overall oral health and well-being of patients. This paper delves into the diverse aspects of resin-matrix cements, their polymerization mechanisms, and their implications in ensuring the long-lasting success of dental luting procedures.

II. HISTORICAL PERSPECTIVE

Over the last half-century, there has been significant progress in developing various materials known as luting cements in dentistry. Prior to this period, zinc phosphate had been the primary choice for permanent cement for nearly a century since the late 1800s and was considered the standard [6]. However, in the late 1960s, zinc polycarboxylate emerged as an alternative, providing clinicians with more options [7]. During the 1970s and 1980s, glass ionomer cement (GIC) and resin-modified glass ionomer cement (RMGIC) were introduced. Resin cement, invented in the 1950s, has evolved over the years and gained popularity in modern dentistry, especially with the demand for aesthetic all ceramic restorations [6]. In the 2000s, self-adhesive resin cement simplified the clinical process [8].

III. CLASSIFICATION

The classification of dental resin cements is instrumental in guiding the selection of the most appropriate cement for specific clinical situations, taking into account factors like material compatibility, bonding requirements, and working conditions. This classification is based on two key criteria:

➢ *Classification According to Polymerization Mechanisms:*

Dental resin cements are categorized based on their polymerization mechanisms, which primarily include light-cured, dual-cured, and chemical-cured resin cements. These mechanisms determine the activation method and influence various characteristics, ultimately affecting their clinical indications.

- **Light-cured resin cements** rely on photo-initiation activated by light. They offer advantages such as extended working time, reduced finishing time, and superior color stability. These cements are ideally suited for aesthetic restorations, metal-free restorations, and the cementation of thin, translucent ceramics. Notable examples include Duo-Link Universal.
- **Dual-cured resin cements** utilize a combination of chemical and light activation. They excel in bond strength, aesthetics, and ease of use. One notable example is Clearfil Esthetic Cement.
- **Chemical-cured resin cements** undergo polymerization through a chemical reaction when two materials are mixed (self-curing). They are particularly useful in areas where light curing is challenging. Indications for these cements include metal restorations, endodontic posts, and ceramic restorations that inhibit luting cement from light polymerizing resin cement. An illustrative example is Glass Ionomer Cement.

➢ *Classification According to Adhesive Schemes:*

The second classification criterion categorizes resin cements based on adhesive schemes, differentiating them into total-etch, self-etch and self-adhesive cements. This categorization is dependent on the bonding approach with the tooth structure.

- **Total-etch resin cements** involve a 30-40% phosphoric acid etch to remove the smear layer, followed by the application of adhesive. They exhibit excellent cement-to-tooth bond strength, reduced microleakage, and long-term predictability. However, they necessitate a multi-step application technique. A representative example is One-Step Plus with Duo-Link.
- **Self-etch resin cements** utilize a self-etching primer before applying the mixed cement. They are characterized by ease of use, reduced technique sensitivity, and good bond strength (although somewhat weaker than total-etch systems).
- **Self-adhesive resin** cements incorporate acidic monomers, such as phosphoric acid, into their resin formulation. These monomers enhance the adhesive properties of the cement by promoting a chemical bond with the tooth structure. This allows bonding to untreated tooth surfaces, and selective etching can be incorporated to improve bond strength. Examples include RelyX™ Unicem (3M ESPE) and BisCem® (BISCO, Inc.). It's worth noting that while self-adhesive cements offer convenience, they may exhibit disadvantages, such as reduced stress resistance, decreased color stability, and wear resistance.

This comprehensive classification system serves as an invaluable guide for dental practitioners, enabling them to make informed decisions regarding the choice of resin cements in diverse clinical scenarios, thus contributing to the long-term success of dental restorations and enhancing overall patient outcomes.

IV. IDEAL PROPERTIES

Resin cements serve as indispensable components in modern restorative dentistry, and achieving specific ideal properties is paramount to ensuring their success in a diverse range of clinical applications [5]. These properties encompass a comprehensive set of attributes that contribute to the overall effectiveness, longevity, and aesthetics of dental restorations. The following are the key ideal properties of resin cements:

➢ *Radiopacity:*

Radiopacity is crucial for the radiographic assessment of the cement's integrity and the surrounding tooth and bone structures. An ideal resin cement should provide clear radiographic visibility, aiding in the identification of potential issues, such as voids, gaps, or secondary caries, and ensuring accurate clinical evaluation.

➢ *Dissolution Resistance:*

An effective resin cement should exhibit resistance to dissolution and degradation over time. This property ensures the long-term stability of the cement, preventing its breakdown in the oral environment, which can lead to restoration failure and microleakage.

➢ *Adequate Marginal Seal:*

An optimal marginal seal is essential for preventing microleakage and bacterial ingress at the restoration-tooth interface. A well-sealed margin contributes to the restoration's longevity and minimizes the risk of secondary caries and post-operative sensitivity.

➢ *Promotion of Tissue Health:*

Resin cements should be formulated with a focus on promoting overall tissue health. This includes reducing the risk of pulp irritation and inflammation by being non-toxic and maintaining the vitality of the underlying dental tissues.

➢ *Adequate Mechanical Properties:*

The mechanical properties of a resin cement are pivotal in ensuring the restoration's longevity and stability. Ideal resin cements should offer adequate compressive strength, flexural strength, and wear resistance to withstand the forces of mastication and protect the restoration from mechanical failures.

➢ *Biocompatibility with Oral Tissues:*

Biocompatibility is a fundamental requirement. Resin cements must be well-tolerated by oral tissues, minimizing the risk of allergic reactions or tissue irritation. This aspect is essential for the patient's comfort and long-term oral health.

- *Excellent Aesthetics:*

In an era where aesthetic considerations are of utmost importance, resin cements should seamlessly integrate with the surrounding tooth structure and exhibit superior color stability. This ensures that the restoration blends harmoniously with the natural dentition, preserving the patient's smile.

- *Cost-Effectiveness:*

While meeting all of the above criteria is essential, cost-effectiveness remains a significant consideration. Resin cements should provide a balance between optimal clinical performance and affordability to make them accessible to a wide range of patients and clinical scenarios.

The ideal properties of resin cements represent a multifaceted set of criteria that are essential for the success of dental restorations. Meeting these benchmarks ensures that resin cements contribute to long-lasting, aesthetically pleasing, and biocompatible solutions that benefit both the clinician and the patient, ultimately enhancing oral health and well-being.

V. ADVANCEMENTS IN ENHANCING RESIN CEMENT

- *Recent Advances in Resin Cement: Enhancing Caries Prevention and Mechanical Properties*

In contemporary restorative dentistry, enhancing the properties of resin cement has become a focal point, particularly with regards to its capacity to prevent caries formation [9]. Resin cement is a commonly employed luting agent in dentistry, renowned for its reliable adhesive properties, yet it lacks inherent antibacterial characteristics, which makes it susceptible to the recurrence of tooth decay [10,12]. This limitation is a critical factor contributing to the failure of dental restorations, necessitating innovative modifications in resin cement formulations.

In an endeavor to overcome this challenge, researchers have introduced antimicrobial elements into resin cement formulations. These include quaternary ammonium polyethyleneimine nanoparticles, silver nanoparticles, montmorillonite modified with cetylpyridinium chloride, as well as the integration of ursolic acid and chlorhexidine diacetate [11]. A key focus in this research is to determine the optimal concentrations of these antimicrobial agents that do not compromise the mechanical properties of the resin while effectively endowing it with antibacterial properties [12].

Moreover, recent advancements have introduced a "self-healing" capability into resin cements to mitigate fractures and cracks [13,14]. This is achieved by incorporating microcapsules into the cement mixture through a shell and liquid treatment. When the polymer experiences damage, these microcapsules rupture, releasing healing water into the cracks. Subsequently, this water comes into contact with the catalyst within the polymer matrix, facilitating a polymerization reaction that effectively fills the cracks [14]. Notably, discoveries in composites using Triethylene glycol dimethacrylate-N and N-dihydroxyethyl p-toluidine curing fluids in poly(urea-formaldehyde) shells have exhibited remarkable self-healing abilities, particularly in terms of initial fracture toughness [15].

Another avenue of enhancement involves optimizing the polymerization of resin monomers, as the bond strength and mechanical properties of the resin cement are profoundly influenced by this process [16]. Researchers have tackled the challenge of acidic functional monomers, which hinder free radical formation when using benzoyl peroxide/tertiary amine. They've devised innovative methods to effectively combine these monomers, providing an efficient solution [16,17].

Additionally, there is a technique referred to as "contact curing" [18], where specific promoters not including tertiary amines are incorporated into the primer. These accelerators expedite the curing process upon contact with the cement, offering yet another promising avenue for enhancing polymerization and performance [19].

Innovations have not been limited to the chemical composition alone. Advanced processing and curing techniques have enabled the production of nanocomposites and nanofiller particles, introducing nanoclusters and nanoparticles into the equation. These nanocomposites, prominently used in dentistry, are characterized by excellent translucency, high polishability, and the ability to retain a microfilm-like polish. Importantly, they retain good physical properties, making them comparable to many hybrid composites. Thus, nanocomposites have become preferred materials in both internal and external dentistry, marrying durability with aesthetic appeal [22].

These recent advancements in resin cement, spanning both compositional and technological domains, hold promise for improving the clinical performance of dental restorations, extending their longevity, and ultimately enhancing the oral health and satisfaction of patients.

VI. CLINICAL APPLICATIONS

Resin-based cements find a wide array of clinical applications in modern dentistry. They are extensively utilized for the placement of all-ceramic crowns, veneers, bridges, inlays, onlays, cast alloy crowns, high-strength ceramics, implant-supported crowns and bridges, fiber posts, and cast-iron posts. These versatile materials play a pivotal role in the secure adhesion of various dental restorations, ensuring their functional and aesthetic integration.

However, it is imperative to pay special attention to the surface preparation when using cement products. The interior of the restoration should be adequately treated with hydrofluoric acid, sandblasting, and salinization, while the tooth surface should undergo phosphoric acid etching to facilitate optimal adhesion.

Self-etched and fully-etched resin cements have demonstrated superior edge compatibility when compared to glass ionomer cements (GIC), resin-modified glass ionomer cements (RMGIC), and zinc phosphate cements [23].

Nonetheless, self-adhesive cements, despite being double-cured, exhibit limitations in terms of adhesion strength, wear resistance, and color stability. To address these shortcomings, light activation equipment is often employed to enhance the integrity of the cement edges, bolster wear resistance, and prevent discoloration. The presence of water at the interface between the binder and the cement can be detrimental, as water droplets can act as stress points that weaken the bond. This issue can be mitigated by introducing a hydrophobic, non-acidic, low-viscosity resin interlayer between the acidic binder and the composite resin, although this may introduce thickness concerns in aesthetic treatments [24].

➢ *Disadvantages of Resin-Based Cements:*

Resin-based cements, while versatile, are not without their limitations:

- The multi-step application process of total-etch cements increases the risk of contamination and necessitates meticulous control [25,26].
- Self-adhesive resin cements perform less effectively in bonding to enamel and dentin compared to traditional multi-step resin cements [27,28].
- Restorations with poor retention and resistance, such as resin-bonded bridges and low-crown height restorations, are not suitable for self-adhesive resin cement [29].
- Traditional resin cements can be expensive, method-sensitive, time-consuming, and challenging to remove excess cement after setting, making them less suitable for prefabricated crowns [30].
- Light-cured resin cements may have controlled polymerization times compared to self-cured resin cements [31,32].
- Self-curing resin cements are not recommended for bonding with translucent or thin ceramic restorations due to lower color stability caused by chemical components [33].
- In comparison to resin-modified glass ionomer cements (RMGIC), resin cements have fewer caries-inhibitory actions and are less effective in preventing secondary caries [34,35].
- Some resin cements may exhibit limited working duration, lack anti-corrosion properties, and lead to hypersensitivity during polymerization shrinkage [36,37,38].

➢ *Advantages of Resin-Based Cements:*

In contrast, resin-based cements offer numerous advantages in clinical applications:

- Conventional resin cements find use in various scenarios, including post-cementation in teeth that underwent root treatment and cementation of metal and metal-ceramic restorations with low retention and resistance forms, such as resin-bonded bridges and short crowns [7].
- Self-adhesive resin cements tend to produce less postoperative sensitivity when compared to glass ionomer cements [39,40].
- Resin cements provide robust adhesion with low microfluidity, enhancing resistance to low permeability.
- They exhibit superior hardness, high flexural strength, minimal thermal expansion coefficients, and excellent resistance to compressive forces, setting them apart from alternative luting materials.
- Resin cements offer low marginal permeability, wear resistance at margins, high retention, color stability, high fatigue strength, and adhesion to a wide range of materials [44, 45, 46].
- They establish an ideal bond with all-ceramic restorations and uniformly transmit compression stress across contact surfaces [47].
- The incorporation of dentin adhesives in resin cements is believed to reduce pulp response and marginal micropermeability.
- Adhesive resin cements provide better marginal sealing compared to zinc phosphate cement [48,49].

In summary, resin-based cements have evolved to address various clinical needs in restorative dentistry, offering a spectrum of advantages while requiring careful consideration of specific application requirements and potential limitations. Understanding these facets is crucial for optimizing clinical outcomes and patient satisfaction.

VII. CASE DISCUSSION

This review paper provides information on the properties of resin cements, based on the results of original scientific full-length papers from peer-reviewed journals listed in PubMed, and discusses the research conducted on dental resin cements using the keywords "dental resin cements," "esthetic resin cement," "resin modified glass ionomer cement," and "resin cement."

- The main aim of this study was to research the impact of filler content on the flexural properties of resin luting agents and accordingly choose a suitable resin luting cement. This study was conducted by Mandava Ramesh Babu, Vajapeyayajula RaviKiran, V Vinod, Devabhaktuni Saraswathi, Venugopal N Rao.

Here, the researchers studied three resin luting agents, namely Calibra (Dentsply); RelyX ARC and Panavia F. For each of the material tests carried out, ten beam-shaped specimens (L × W × H: 30 × 8 × 2 mm) were made. The specimens were stored in distilled water for 24 hours at 37ºC. Then, the specimens were tested for flexural strength (MPa) and flexural modulus (GPa) using the three-point bending method on a universal material testing machine at a cross head speed of 0.5 mm/min. This test resulted in an increase in mean strength and elastic modulus, which was related to the filler loading of resin luting cements.

The researchers concluded the study by stating that the strength and performance of resin-cemented all-ceramic restoration can be enhanced by using a resin luting cement with increased filler content [49].

- This in vitro study, conducted by Nicolas Müller, Nadin Al-Haj Husain, Liang Chen, Mutlu Özcan, aimed to assess the influence of various bonding methodologies of different resin cements on zirconia, using different aging protocols. Afterward, randomly assigned zirconia specimens were subjected to three luting protocols: 1—in mold incremental build up; 2—in mold incremental build up with mold removal; 3—in mold non-incremental bulk build up. Five dual, photo- and chemical-cure resin cements—Tetric (Ivoclar), VariolinkEsthetic (Ivoclar), RelyXUniCem (3M ESPE), Panavia (Kuraray), and TheraCem (Bisco)—were applied to primed zirconia using photopolymerization protocols. Subsequently, the specimens underwent three aging methods: dry, thermocycling (5000 cycles; 5 to 55°C), and 3 to 6 months of water storage. Using a universal testing machine, the specimens were loaded under shear at a crosshead speed of 1 mm/min. Adhesion tests using the incremental or bulk method, with molds, showed the highest results, but removing the mold and subsequent aging caused a decrease in the adhesion of the resin cements tested on zirconia, likely due to water absorption, except for Tetric. The researchers conclude the study by stating that the adhesion of the tested resin cements to zirconia was influenced by the cement type, luting protocol, and aging [50].
- Conducted by Areti D. Vrochari, George Eliades, Elmar Hellwig, Karl-Thomas Wrbas, this study aimed to evaluate the degree of cure of resin cements in their self and dual curing mode. The self-etching, self-adhesive resin cements studied included RelyXTMUnicem (3MTM ESPETM AG), Multilink® Sprint (IvoclarVivadent® AG), MaxcemTM (Kerr Corporation), and BiscemTM (Bisco, Inc.), while the classic resin cement was Multilink® Automix (IvoclarVivadent® AG). Twelve specimens of each material were prepared at room temperature; six were treated as dual cure, and six were treated as self-cure, resulting in approximately low %DC for all twelve. However, questions arise about the successful clinical use of these materials due to the low %DC found, especially in scenarios involving light attenuation [51].
- Conducted by Amira Gehad Nagy, Omaima El-Mahallawy, Lomaya Ghanem, this in vitro study aimed to compare the effect of bioactive cement versus resin cement on the perceived shade of final ceramic restoration with and without the presence of a substrate. Forty plate-shaped samples of lithium disilicate ceramic (E-max CAD HT A1/C14 – 1.3 mm thick) were prepared, with a composite [52].

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