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Review Article

Literature review on zirconia post system

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ABSTRACT

Cast metal post and core systems have been reliably used for decades due to their excellent physical properties. However, the increasing demand for aesthetically pleasing and biocompatible restorations has spurred the development of tooth-colored post and core systems. Among these, zirconia post systems have gained popularity, offering a solution that combines strength with enhanced esthetics. The translucency of zirconia allows for seamless integration with all-ceramic crowns, maintaining a natural appearance and meeting patient expectations for visually appealing restorations.

In light of the growing interest in zirconia ceramic post systems, numerous in vitro studies have been conducted over the past 15 years to evaluate their performance. These studies have examined critical aspects such as retention, fracture resistance, and aesthetic advantages. Zirconia posts are celebrated for their ability to improve esthetics while providing sufficient strength and long-term durability.

Nevertheless, zirconia posts are not without limitations. Issues like achieving proper cementation and optimal adhesion remain active areas of research and clinical focus. This review article aims to consolidate existing data on zirconia posts, highlighting their retention, fracture resistance, aesthetic benefits, challenges, and cementation techniques to aid clinicians in their effective application.

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1. Introduction

Endodontically treated teeth with insufficient tooth structure are often restored with crowns. When there is inadequate dentin to support the restoration, a post-core is required to provide retention and stability.[1] While posts are intended to strengthen teeth, studies indicate that posts lacking sufficient resistance to rotational forces may weaken teeth, increasing the risk of root fractures.[2,3] To mitigate this risk, posts should possess an modulus of elasticity similar to dentin, enabling uniform stress distribution under occlusal loads. Posts must also balance firm cementation for retention with ease of removal for retreatment if needed.

Common materials like titanium, carbon, polyethylene fiber, and stainless steel are frequently used in the anterior region. However, when all-ceramic restorations are preferred, metal posts can compromise aesthetics and potentially lead to corrosion, causing issues such as metallic taste, oral pain, or allergic reactions. To address these concerns, non-metal posts, such as fiber-reinforced composite and yttrium-stabilized zirconia ceramic posts, have become popular.[4,5]

Zirconia posts, first introduced by Meyenberg et al., offer flexural strengths comparable to titanium or cast gold. Zirconia is valued for its chemical stability, high mechanical strength, toughness, and transformation toughening, which enhances its fracture resistance.[6,7]

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1.1. Advantages of zirconia posts

1. Chemical stability: Zirconia exhibits excellent chemical stability, making it resistant to corrosion and degradation
2. High mechanical strength and toughness: The material offers high strength and toughness, allowing it to withstand significant functional loads.
3. Young's modulus: Zirconia's elastic modulus is similar to that of stainless steel, providing a balance between flexibility and rigidity.
4. Aesthetic benefits: The tooth-colored, translucent appearance of zirconia makes it ideal for use with all-ceramic crowns, particularly in the anterior region. This aesthetic advantage is crucial for patients with high lip lines or thin gingival tissue.
5. Strength for severely damaged teeth: Zirconia is suitable for teeth with extensive coronal damage, as it offers superior strength compared to composite materials, which may deform under load.

1.2. Disadvantages of zirconia posts

1. Difficult removal: Zirconia posts are challenging to remove during retreatment. Grinding them away is nearly impossible, and ultrasonic vibration removal can lead to a temperature increase, potentially damaging the root.
2. High rigidity: Zirconia's high elastic modulus can transfer stress to the less rigid dentin, increasing the risk of root fractures, particularly vertical root fractures. This makes zirconia less suitable for patients with bruxism.
3. Lack of failure desirability: While wear, loss of retention, or post fracture are preferable to tooth fractures under intraoral forces, zirconia's rigidity predisposes it to cause tooth damage instead.

2. Discussion

2.1. Material properties

2.1.1. Crystallography and phase transformation in zirconia ceramics

At standard pressure and temperature, zirconia is naturally monoclinic. As the temperature increases, its structure transforms to tetragonal above 1170 °C and cubic above 2370 °C. However, upon cooling, zirconia undergoes a reversible tetragonal-to-monoclinic phase transformation, accompanied by a 3-5% volume increase. This substantial volume change induces cracks, making pure zirconia unsuitable for applications requiring structural integrity.

To overcome this limitation, tetragonal zirconia is stabilized at normal temperatures by alloying it with oxides like CaO, MgO, and Y_2O_3. These oxides promote more symmetric cubic and tetragonal lattice structures, reducing the stresses caused by the t-m transformation while preserving the desirable mechanical properties of the tetragonal phase. Controlled chemical additives and heat treatments enable the creation of a microstructure with tetragonal zirconia "precipitates" embedded in cubic zirconia grains during cooling.[8,9]

Three types of toughened zirconia materials arise from the t-m transformation:

1. Dispersion-toughened ceramics: Zirconia particles are dispersed in another matrix, such as alumina or mullite, forming ZrO_2-toughened alumina and ZrO_2-toughened mullite. These ceramics achieve t-phase stability through particle size, shape, and distribution. A notable example is In-Ceram Zirconia, a composite of glass and polycrystalline ceramic used in dental applications.
2. Partially stabilized zirconia (PSZ): PSZ contains stable cubic zirconia with intragranular tetragonal zirconia precipitates. Stabilization is achieved using dopants like CaO or MgO in lower concentrations. Mg-PSZ is a commercial example employed in dental ceramics.[10]
3. Tetragonal zirconia polycrystal (TZP): Fine-grained zirconia with low Y_2O_3 concentrations retains up to 98% metastable t-phase. Examples include 3Y-TZP and nano-scale Ce-TZP composites, widely used in dentistry for their mechanical properties and processed using CAD-CAM technologies.[11]

2.1.2. Post space preparation

Post space preparation principles for zirconia posts are similar to other post systems. The principles of post space preparation for zirconia posts align closely with those for other post systems. It is essential for clinicians to have a thorough understanding of root canal anatomy to prevent excessive shaping. Low-speed drills should be employed to minimize the risk of perforation. The post length should ideally measure two-thirds of the root canal length, ensuring that post space preparation does not compromise the integrity of the remaining root canal filling. When a smaller-diameter post is required, a more rigid material like zirconia can provide a significant advantage.[12]

2.2. Adhesion of zirconia to substrates: Factors and techniques

When evaluating the adhesion of zirconia to substrates, several factors come into play, including surface pretreatment, the resin cement used and artificial aging.

2.3. Zirconia surface pretreatment

2.3.1. Significance of surface modification

The majority of studies emphasize the necessity of modifying the zirconia surface before applying luting cements, as such pretreatments significantly enhance bond strength. Surface pretreatment techniques fall into three categories:

1. Mechanical
2. Chemical
3. Mechanochemical

2.4. Mechanical surface pretreatments

2.4.1. Sandblasting

Sandblasting is a widely used method that enhances micromechanical retention by increasing surface energy, wettability, and roughness. However, excessive particle size or pressure can induce microcracks, weaken mechanical properties, and lead to phase transformation from tetragonal to monoclinic, reducing long-term reliability. Despite these risks, controlled sandblasting remains effective for increasing initial bond strength.[13]

2.4.2. Silica coating

Zirconia's nonpolar, silica-free surface limits traditional silane treatments. Techniques like tribochemical silica coating (TSC) aim to create a silica-rich surface for silanization. While TSC improves initial bond strength, its durability remains questionable due to weak physical bonds between silica and zirconia, which can degrade under clinical conditions.[14]

2.4.3. Laser treatment

Laser methods (e.g., Er:YAG, CO_2) aim to create rough surfaces for bonding. However, they often cause microcracks and phase transformations, weakening zirconia. While some studies report promising results with specific laser types, lasers are not yet a reliable mechanical pretreatment.[15]

2.4.4. Acid etching and plasma spraying

Unlike glass ceramics, zirconia does not respond well to acid etching due to its lack of a glassy matrix. Plasma treatments have also shown limited success in improving long-term adhesion due to hydrolytic degradation and impurities.[16]

2.5. Chemical surface pretreatments

Chemical approaches rely on primers and adhesives containing functional monomers, like 10-MDP, which form chemical bonds with zirconia. Universal adhesives containing 10-MDP enhance adhesion and are often used alongside mechanical pretreatments like sandblasting. However, hydrolytic degradation of 10-MDP reduces bond durability over time, highlighting the need for combined mechanical and chemical strategies.[17]

2.6. Mechanochemical surface pretreatments

Combining mechanical and chemical treatments, such as tribochemical silica coating followed by silane application, improves bond strength and durability. Studies indicate that silica-coated alumina particles create less aggressive surfaces and stronger chemical bonds, leading to better long-term performance compared to sandblasting alone.[16,18]

2.7. Selection of cement

The use of resin cement varies significantly among the various studies,[19,20] as no standardized protocol exists for selecting materials for bonding to zirconia. Although recommendations differ regarding the specific cementation material, it is widely acknowledged that resin cement is essential for effectively bonding zirconia to tooth structure.

Zinc phosphate and glass ionomer cements provide only weak adhesion to zirconia, whereas resin cements containing 10-MDP exhibit superior adhesion and durability, even under aging conditions. Self-adhesive resin cements combined with MDP primers demonstrate a synergistic effect, achieving higher bond strengths compared to non-MDP-containing alternatives. However, relying solely on chemical bonding may compromise clinical performance, highlighting the need for additional mechanical retention to achieve optimal results.[21]

2.8. Impact of artificial aging on bond strength

Artificial aging, often simulated through liquid storage and thermocycling, assesses hydrolytic degradation and long-term adhesion. Variations in aging protocols (e.g., cycle numbers, storage liquids) complicate comparisons across studies. Consistent methodologies are essential to standardize results.Thermocycling generally reduces adhesion over time. Resin cements containing MDP demonstrate the best resistance to aging, while glass ionomer and Bis-GMA-based cements show significant performance declines.[22]

3. Conclusion

The clinical success of a zirconia post relies on proper cementation, making it vital to determine the surface treatment that maximizes resistance between the zirconia post and resin cement. Effective surface modifications, such as airborne particle abrasion or 10-MDP primer application, enhance both mechanical and chemical bonding. Combining these methods often provides superior results, ensuring stronger adhesion and long-term stability. Identifying the optimal surface treatment is essential for achieving durable and successful outcomes in restorative dentistry.

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None.

5. Conflict of Interest

None.

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