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Endodontics

BIOCERAMIC SEALERS IN ENDODONTICS: A NEW ERA OF SEALING SUCCESS

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ABSTRACT Root canal therapy (RCT) is a widely used treatment to eliminate infection and preserve teeth with compromised pulp. The success of RCT depends on achieving a hermetic seal, which is facilitated by root canal sealers. Traditional sealers, such as zinc oxide-eugenol and resin-based materials, have limitations, including cytotoxicity, shrinkage, solubility, and weak bonding with dentin. Bioceramic-based sealers have emerged as an alternative due to their biocompatibility, bioactivity, and superior sealing ability. These sealers chemically bond with dentin, promote hydroxyapatite formation, and enhance periapical healing. Their alkaline pH provides antimicrobial properties, and they exhibit low solubility and slight expansion upon setting, ensuring long-term stability. However, their strong adhesion to dentin poses challenges during retreatment, making their removal more difficult than conventional sealers. Additionally, their response to heat varies, with some formulations exhibiting changes in flow and setting time. This review explores the composition, properties, advantages, and limitations of bioceramic-based sealers compared to traditional sealers, analyzing their role and retreatment challenges. While they present certain limitations, ongoing research aims to improve their removability and handling characteristics, positioning them as a promising material for modern endodontic practice.

KEYWORDS : bioceramic, root canal sealers, zinc oxide eugenol.

INTRODUCTION

Root canal therapy (RCT) is the preferred treatment for managing pulpal infections while preserving natural teeth. The success of RCT depends on the quality of root canal filling, which is influenced by the properties of the sealer(1). Sealers act as an interface between gutta-percha and dentinal walls, ensuring an airtight seal to prevent reinfection(2).

Traditional sealers, such as zinc oxide-eugenol, resin-based, and calcium hydroxide-based materials, have been widely used but present drawbacks like cytotoxicity, shrinkage, solubility, and weak adhesion(3). To overcome these limitations, **bioceramic-based sealers** were introduced, offering superior bioactivity, biocompatibility, and chemical bonding with dentin(3).

Bioceramic materials have been studied for decades. In 1969, **L.L. Hench** introduced Bio Glass, highlighting the potential of ceramics to bond with bone(4). Later, **LeGeros et al.** developed calcium phosphate-based bioceramic dental cement. In root canal applications, **Krell and Wefel** compared experimental calcium phosphate cement with Grossman's sealer, finding no significant differences in adhesion, tubule penetration, or apical seal(5).

Classification Of Bioceramic Root Canal Sealer:

1. **By Composition**
- **Calcium Silicate-Based** - e.g., BioRoot RCS, EndoSequence BC Sealer– Most common, promotes hydroxyapatite formation(6).
- **Calcium Phosphate-Based** – Enhances biocompatibility and osseointegration e.g., iRoot SP, and MTA Fillapex. (2).
- **Calcium Aluminate-Based** – Offers chemical stability and low solubility. e.g., Sure-Seal Root, and Bio-C Sealer. (6)

2. **By Setting Mechanism**
- **Hydraulic Sealers** – Set with dentinal moisture (e.g., EndoSequence BC Sealer)(6).
- **Non-Hydraulic Sealers** – Require external mixing e.g., MTA Fillapex, and Bio-C Sealer. (6).

3. **By Application**
- **Pre-Mixed Sealers** – Ready-to-use, consistent (e.g., Bio-C Sealer)(6).
- **Powder-Liquid Sealers** – Require manual mixing (e.g., BioRoot RCS)(6).

Properties Of Bioceramic Sealers

Mechanical Properties:

1. **Sealing Ability And Adhesion**

Bioceramic sealers chemically bond to dentin by penetrating the dentinal tubules and forming a mineral infiltration zone. This interaction strengthens the mechanical interlocking of the sealer with the dentin, significantly reducing the risk of microleakage—a common cause of RCT failure[3].

2. **Solubility And Dimensional Stability**

Solubility is a critical factor in determining the longevity of a sealer. Excessive solubility can lead to void formation, compromising the seal. Most bioceramic sealers have demonstrated low solubility and excellent dimensional stability, making them reliable choices for long-term root canal sealing. However, some bioceramic sealers, such as TotalFill BC Sealer, exhibit slightly higher solubility than others[5].

3. **Radiopacity And Flowability**

Radiopacity is essential for the radiographic evaluation of the root canal filling. Studies indicate that AH Plus, a resin-based sealer, has higher radiopacity than most bioceramic sealers. However, certain bioceramic formulations, like Dia-Root Bio Sealer, exhibit sufficient radiopacity for clinical use [5].

Flowability is another key property, influencing how well a sealer spreads within the root canal system. TotalFill BC Sealer and MTA Fillapex have demonstrated superior flowability, allowing them to penetrate lateral and accessory canals more effectively [5].

Biological Properties:

1. **Biocompatibility And Bioactivity**

Any root canal sealer must be biocompatible because the root filling material acts as a real implant that will come into direct touch with the essential tissue at the root's lateral and apical foramina, or indirectly through surface repair [7].

One of the major advantages of bioceramic sealers is their biocompatibility, meaning they do not provoke adverse immune reactions. These sealers enhance periapical healing by forming a chemical bond with dentin and promoting the deposition of hydroxyapatite, which facilitates natural tissue integration [2].

Another crucial property of bioceramic sealers is their alkaline pH (typically ranging between 10 and 12), which contributes to their antibacterial effects. The high pH environment helps neutralize residual bacteria in the root canal system, thereby reducing the chances of reinfection [2].

2. Dentinal Tubule Penetration And Antimicrobial Effectiveness:

Bioceramic sealers enhance dentinal tubule penetration due to their nanoparticle size, hydrophilicity, and bioactivity. Their excellent flow allows deeper penetration, especially when the smear layer is removed with EDTA. They release calcium and hydroxyl ions, promoting hydroxyapatite formation and improving the sealer-dentin bond. Their alkaline pH (~12) enhances antimicrobial properties, and slight setting expansion ensures a better seal. Compared to resin-based sealers, bioceramic sealers penetrate deeper, reducing microleakage and improving long-term endodontic outcomes. [8]

3. Bond Strength and Adhesive Interface Quality:

Premixed bioceramic sealers achieve strong adhesion through chemical bonding, hydroxyapatite formation, and slight setting expansion. Their deep tubule penetration and nano leakage resistance enhance seal quality, while their hydrophilicity ensures optimal performance in moist conditions. With bond strength comparable to or exceeding resin-based sealers, they provide a durable and reliable root canal seal [9].

Clinical Implications:

1. Role Of Bioceramic Sealer In Complex Crown-root Fractures:

Bioceramic sealers play a vital role in managing complex crown-root fractures by providing strong bonding, sealing, and bioactive properties [10]. They chemically bond with dentin, expand slightly to enhance adaptation, and prevent microleakage. Their bioactivity promotes hydroxyapatite formation, aiding periapical and periodontal healing, while their alkaline pH offers antimicrobial effects [11]. Bioceramic sealers are also moisture-compatible, making them effective in moist environments like fractured roots [10]. Their low solubility ensures long-term stability, making them ideal for sealing fractures, aiding fragment reattachment. However, their strong adhesion complicates retreatment, requiring specialized removal techniques [12].

2. Role Of Bioceramic Sealer In Inflammatory Internal Root Resorption:

Bioceramic sealers play a crucial role in managing inflammatory internal root resorption (IIRR) due to their bioactivity, sealing ability, and antimicrobial properties. Their alkaline pH creates an unfavourable environment for osteoclastic activity, helping to halt resorption [13]. Bioceramic sealers chemically bond with dentin, ensuring a hermetic seal that prevents bacterial infiltration and promotes tissue regeneration by stimulating hydroxyapatite formation [13][14]. Their moisture compatibility makes them ideal for irregular resorptive defects, enhancing adaptation and long-term stability. Additionally, their biocompatibility reduces inflammatory responses, promoting periapical healing [14]. Overall, bioceramic sealers provide an effective solution for arresting and managing IIRR while supporting dentin repair [15].

3. Post Operative Pain With Bioceramic Sealer:

Bioceramic sealers generally cause minimal post-operative pain due to their biocompatibility, bioactivity, and sealing ability [16]. Their alkaline pH creates an antibacterial environment, reducing inflammation and microbial irritation [17]. Unlike resin-based or zinc oxide-eugenol sealers, bioceramic sealers do not shrink or release toxic byproducts, minimizing periapical irritation [18]. However, factors like overextension, extrusion beyond the apex, or improper adaptation can lead to temporary discomfort [16]. Studies suggest that patients treated with bioceramic sealers experience lower post-operative pain compared to traditional sealers, making them a preferred choice for endodontic treatment.

4. Role Of Bioceramic Sealer In Open Apex Management:

Bioceramic sealers are effective in managing **teeth with an open apex**, commonly found in immature permanent teeth or cases of apical resorption [19]. Their **bioactivity stimulates hydroxyapatite formation**, promoting **apical barrier development** and aiding in apexification [20]. With **superior flowability**, they penetrate irregular apical anatomy, ensuring an optimal seal and preventing bacterial microleakage. Their **high pH** creates an antimicrobial environment, reducing reinfection risk [19]. Unlike traditional materials like calcium hydroxide, bioceramic sealers offer **enhanced biocompatibility**, exhibit **low solubility**, and maintain long-term stability without requiring multiple applications. Their **moisture tolerance** makes them particularly effective in open apex cases, providing a **predictable and durable** treatment approach [21].

5. Role of Bioceramic Sealer as a Repair Material for Perforation:

Bioceramic sealers are highly effective in perforation repair. Their bioactive properties enhance mineralization, strengthening dentin and ensuring long-term stability. With a premixed formulation and excellent flow, they offer easy application and uniform coverage [22]. Their high alkalinity provides antimicrobial benefits, reducing reinfection risks. Clinically, they are widely used for root, furcation, and lateral perforations, making them an essential material in modern endodontic therapy [21].

6. Thermal Effects Of Obturating Techniques On Bioceramic Sealer:

The characteristics and clinical performance of endodontic bioceramic sealers may be considerably impacted by heating. High temperatures have the potential to cause the thermal deterioration of organic substances that can change the film thickness, flowability, and setting time of the sealer [24,25]. Furthermore, the solubility of bioceramic sealers can be affected by heat; calcium silicate-based sealers show greater solubility when exposed to high temperatures, thus impairing their capacity to keep the root canal intact [26].

Warm vertical compaction techniques are commonly used in endodontics, but heating can affect the flow, setting time, and chemical composition of bioceramic sealers. Some formulations, like BioRoot RCS, exhibited reduced flowability after heat exposure, whereas others, such as EndoSequence BC Sealer, remained stable [24].

Irrigation Protocol Before Using Bioceramic Sealer:

A proper irrigation protocol is essential for optimizing the performance of bioceramic sealers in root canal treatments. The following sequence is recommended:

1. **Sodium Hypochlorite (NaOCl) (2.5%–5.25%)**: Utilize throughout instrumentation to dissolve organic tissue and disinfect the canal [27].
2. **Ethylenediaminetetraacetic Acid (EDTA) (17%)**: Apply as a final rinse to effectively remove the smear layer, enhancing sealer adhesion.[27][28].
3. **Chlorhexidine (CHX) (2%) (Optional)**: Offers additional antimicrobial benefits; however, avoid mixing with NaOCl to prevent precipitate formation.[29].
4. **Saline or Distilled Water**: Use for a final rinse to eliminate any residual irrigants, ensuring they do not interfere with the sealer's properties.[27]

It's crucial to leave the canal walls slightly moist before applying the bioceramic sealer, as these materials require moisture to set properly. Over-drying with paper points should be avoided to maintain the necessary humidity for optimal sealer performance.[28]

Implementing this protocol enhances the bonding and sealing capabilities of bioceramic sealers, contributing to the success of endodontic treatments.

QMix And Bioceramic Sealer In Root Canal Treatment:

QMix is a **dual-action endodontic irrigant** containing **chlorhexidine (CHX), EDTA, and a detergent**. It is designed to effectively remove the **smear layer**, kill residual bacteria, and enhance dentin permeability before obturation. When used in conjunction with

bioceramic sealers, it can improve sealer penetration and bonding, ultimately enhancing the success of root canal treatment (RCT) [7].

Role of QMix in Bioceramic Sealer-Based RCT

1. **Smear Layer Removal** – QMix effectively eliminates the smear layer, exposing dentinal tubules and facilitating better adhesion of bioceramic sealers[7].
2. **Antimicrobial Action** – The combination of CHX and EDTA helps in eradicating residual bacteria, reducing the risk of reinfection [7][8].
3. **Enhancing Sealer Penetration** – Bioceramic sealers are hydrophilic and require an open dentinal structure for maximum adaptation; QMix ensures better tubule penetration [8].
4. **pH Compatibility** – QMix does not interfere with the alkaline nature of bioceramic sealers, preserving their **bioactivity** and **antimicrobial properties [8]**.

Clinical Considerations

- QMix should be used **as a final irrigant** after sodium hypochlorite (NaOCl) to maximize its effects [7].
- Avoid **simultaneous use with NaOCl** to prevent precipitation of chlorhexidine by-products [7].
- Ensure **proper drying** before applying the bioceramic sealer, as excessive moisture can affect its setting [8].

The combination of **QMix and bioceramic sealers** enhances root canal disinfection, sealer adaptation, and long-term success of the treatment.

Use Of Bioceramic Sealer In Single-sitting Root Canal Treatment:

Bioceramic sealers have transformed single-sitting root canal treatment (RCT) due to their superior biocompatibility, enhanced sealing ability, and bioactivity. Their **hydrophilic nature** allows them to set in the presence of moisture, ensuring an optimal seal in a single visit. The **bioactive properties** promote dentin remineralization, enhance periapical healing, and prevent bacterial reinfection.[30]

Advantages In Single-Sitting RCT:

1. **Excellent Sealing & Adhesion:** Bioceramic sealers bond chemically with dentin, reducing microleakage [30].
2. **Faster Procedure:** Their premixed formulation allows easy application and eliminates the need for multiple appointments [31].
3. **Antimicrobial Action:** High alkalinity (pH 11-12) inhibits bacterial growth, reducing post-operative infections [26][27].
4. **Superior Biocompatibility:** Non-toxic, promotes healing, and reduces post-treatment inflammation [25].
5. **Moisture Tolerance:** Unlike traditional sealers, bioceramic sealers do not require a completely dry canal, making them ideal for immediate obturation [30].

The use of **bioceramic sealers in single-sitting RCT enhances treatment efficiency, ensures long-term success, and promotes faster healing**, making it a preferred choice in modern endodontic practice.

Challenges In Retreatment Of Bioceramic Sealers:

While bioceramic sealers provide excellent adhesion, their strong bond with dentin presents a challenge during retreatment. Materials used for root fillings operate as a mechanical barrier to separate necrotic tissue or bacteria that cause periapical inflammation to persist or discomfort following surgery. The majority of the material left over after retreatment is sealer, according to Wilcox et al. [32].

Several studies have reported significant residual material remaining on canal walls after retreatment procedures [32].

The use of ultrasonic and rotary instrumentation can aid in removal, but achieving complete elimination remains difficult. This factor must be considered when selecting a sealer, especially for cases where future retreatment may be necessary [32].

Potential Effects Of Bioceramic Sealer Extrusion:

1. **Inflammatory Reactions:** While bioceramic sealers are generally well tolerated, excessive extrusion into periapical tissues can trigger an inflammatory response, leading to discomfort and delayed healing.[33]
2. **Foreign Body Response:** In rare cases, extruded sealer may act as a foreign body, causing persistent inflammation or requiring surgical intervention.[15]
3. **Healing and Bioactivity:** Unlike traditional sealers, bioceramic sealers promote **osteogenesis and cementogenesis**, which may support periapical healing despite extrusion.[22]
4. **Postoperative Pain:** Mild to moderate pain may occur following extrusion, especially if the material reaches sensitive anatomical structures (e.g., inferior alveolar nerve, sinus cavity). However, symptoms often subside over time.[34]
5. **Radiographic Appearance:** Extruded bioceramic sealer appears radiopaque and may remain visible on radiographs for an extended period without necessarily causing clinical symptoms. [33]

Research And Innovation:

The future of bioceramic sealers lies in the development of formulations that enhance retreatability without compromising adhesion. Current research is also exploring the incorporation of nanoparticles to improve antimicrobial properties, sealing ability, and flow characteristics [1].

CONCLUSION:

Bioceramic-based root canal sealers have transformed endodontics by offering superior biocompatibility, bioactivity, and sealing properties. Their ability to form a chemical bond with dentin enhances treatment longevity, while their alkaline pH provides antimicrobial benefits. Despite challenges in retreatment and the effects of heating, bioceramic sealers remain one of the most promising advancements in root canal therapy.

For clinicians, selecting the right sealer depends on the clinical case, retreatment considerations, and desired biological interactions. As research continues, bioceramic sealers are expected to evolve further, refining their application in endodontic therapy [2].

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