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Original Research Paper

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BIOCERAMIC SEALERS IN ENDODONTICS: A LITERATURE REVIEW

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ABSTRACT Bioceramic-based root canal sealers have emerged as a transformative development in endodontics over the past two decades. This review meticulously examines recent advancements in bioactive ceramics employed in endodontic procedures, emphasizing their multifaceted physical, chemical, and biological attributes as well as their diverse applications. A thorough analysis of contemporary scholarly literature has been undertaken to elucidate pivotal studies concerning bioceramic-based root canal sealers. These materials, esteemed for their biocompatibility and superior physicochemical properties, are utilized in various roles, including as cements, root repair substances, root canal sealers, and filling agents. Notable advantages include enhanced biocompatibility, potential augmentation of root strength post-filling, antibacterial efficacy, and effective sealing. Although recent innovations have addressed several limitations inherent in previous endodontic materials, there remains a critical need for randomized, double-blind clinical trials of adequate duration to substantiate their long-term efficacy and delineate definitive clinical outcomes.

KEYWORDS :

INTRODUCTION

Root canal sealers play an indispensable role in endodontics by occluding voids, patent accessory canals, and multiple foramina; establishing a robust bond between the filling material and the root canal wall; and serving as a lubricant to facilitate the insertion of the filling core while sealing residual bacteria [1]. Given their profound biological and technical significance, extensive research has been dedicated to elucidating their chemical and physical properties since their advent in the early twentieth century [2]. Sealers are categorized based on their primary chemical constituents, including zinc oxide eugenol, calcium hydroxide, glass ionomer, silicone, resin, and bioceramic-based sealers.

While numerous studies have scrutinized root canal sealers collectively [2] or by specific compositions such as zinc oxide eugenol [3], calcium hydroxide [4], glass ionomer [5], and resin-based sealers [6], there is a notable deficiency of comprehensive reviews focusing on bioceramic-based sealers. The incorporation of bioceramic technology into clinical practice, which has gained broader acceptance over the past thirty years, encompasses materials such as alumina, zirconia, bioactive glass, glass ceramics, hydroxyapatite, and calcium phosphates [7]. These materials are categorized as bioactive or bioinert based on their interaction with living tissues [8]. Bioactive materials, such as glass and calcium phosphate, promote the development of durable tissue [9], whereas bioinert materials like zirconia and alumina elicit minimal biological responses [8]. The stability of bioactive materials determines their potential degradability.

The pioneering use of calcium phosphate as a bioceramic restorative dental cement was first documented by LeGeros et al. [10], followed by Krell and Wefel's comparative study of experimental calcium phosphate cement and Grossman's sealer [11]. Although no significant performance disparities were identified, the experimental sealer proved less effective in apical sealing [12]. Subsequent research by Chohayeb et al. indicated that calcium phosphate-based sealers exhibited superior adaptability to dentinal walls relative to gutta-percha [13]. Calcium phosphate cement has since been effectively employed in endodontic procedures, including pulp capping [14], apical barrier formation [15], periapical defect repairs [15], and bifurcation perforation repairs [16].

Bioceramic materials are lauded for their biocompatibility, which precludes tissue rejection [9], and their calcium phosphate content, which enhances setting properties and adhesion to root dentin. However, a significant drawback lies in the challenges associated with removing these materials post-setting, which complicates retreatment or post-space preparation [17].

Ideal Properties

The bonding mechanism of bioceramic-based sealers to root dentin remains an area of ongoing research, with several proposed mechanisms for calcium silicate-based sealers:

1. Sealer particles infiltrate dentinal tubules, establishing

mechanical interlocking bonds [18].
2. The sealer's mineral content permeates intertubular dentin, forming a mineral infiltration zone following collagen denaturation induced by the alkaline sealer.[19][20]
3. Phosphate interacts partially with calcium silicate hydrogel and calcium hydroxide, generating hydroxyapatite along the mineral infiltration zone.[21]

Biocompatibility

Biocompatibility is a fundamental criterion for root canal sealers, given their role as permanent implants in direct contact with vital tissues.[2] A material's biocompatibility denotes its ability to elicit a favourable host tissue response without adverse effects such as toxicity, irritation, inflammation, allergy, or carcinogenicity.[22] Typically assessed through cytotoxicity studies, biocompatibility evaluations reveal that bioceramic-based sealers, enriched with calcium phosphate—a constituent of hard tissues—are generally biocompatible. These sealers exhibit potential for promoting bone regeneration, particularly when inadvertently extruded through the apical foramen or utilized for root perforation repairs.

Telli et al. demonstrated the biocompatibility of Sankin apatite in vitro, while Kim et al. reported an initial tissue response in rats that diminished over time. Comparative studies of Sankin apatite with experimental calcium phosphate-based sealers revealed varied inflammatory responses, with Sankin apatite inducing more severe reactions compared to experimental sealers. Nonetheless, certain types of Sankin apatite exhibited superior biocompatibility. Capseal I and II demonstrated lower levels of tissue irritation compared to other sealers, with findings indicating reduced cytotoxicity and supportive effects on periapical dentoalveolar healing. Conversely, MTA-Fillapex exhibited significant cytotoxicity immediately after mixing, which moderated over time.

Retreatment

1) Effect of Obturating Materials and Techniques

In the studies reviewed, gutta percha was consistently used as the main filling material, though obturation techniques varied. Techniques included lateral compaction, continuous wave of condensation, and single cone method [23][24]. Research by Ma et al. found that using a different obturation technique led to more filling remnants in the apical portion after retreatment. Variations in results were also noted between studies comparing techniques such as warm vertical compaction and single cone, partly due to differences in tooth classes used.[25]

2) Effect of Retreatment Techniques

Retreatment techniques varied, with ultrasound tips, Gates Glidden drills, and heat application used for removing coronal filling material. These additional methods sometimes led to more debris in the apical third of the root canal. The effectiveness of rotary versus hand files, along with different solvents like chloroform, was also examined. Studies found no significant difference between rotary systems and manual files for sealer removal. However, the Photon Induced Photoacoustic Streaming (PIPS) technique notably improved the dislodgment of sealer remnants.[26]

3) Effect of Solvents During Retreatment

Solvents like chloroform were tested for their ability to dissolve endodontic sealers.

4) Comparison Among Sealers

Studies compared various sealers, including bioceramic types, AH Plus, and others. Generally, a significant amount of filling material remained post-retreatment, regardless of the sealer used. Endosequence BC Sealer and iRoot SP often left more remnants compared to AH.[27]

5) Ability to Reach Working Length and Attain Patency

The ability to reach the working length and attain patency was assessed. Achieving patency was consistently noted to enhance periradicular healing.[28]

6) Retreatment Time

The time required for retreatment varied. Differences in obturation and retreatment methods contributed to the variability in retreatment times. Despite longer times, successful retreatment was generally achieved.

In summary, the choice of obturating and retreatment techniques, the type of sealer used, and the solvents applied all impact the effectiveness and efficiency of endodontic retreatment.[29]

Setting Time

The setting time of root canal sealers is crucial for providing adequate working time while minimizing tissue irritation. [30] Variability in setting times is influenced by factors such as moisture in dentinal tubules and sealer composition. An average time of 7 days is proposed by Angelus Japan, in dental plaster molds.[31] For instance, Endo Sequence BC Sealer and iRoot SP's setting times are impacted by moisture, with Endo Sequence BC Sealer potentially requiring up to 168 hours under various humidity conditions. Comparative studies indicate that EndoSequence BC Sealer and iRoot SP have setting times comparable to other commercial sealers.

ADHESION

The term "adhesion" in the context of root canal sealers is defined as the sealer's capacity to bond to the root canal dentin and facilitate the adhesion of gutta-percha (GP) cones to each other and the dentin. Tagger et al. have posited that the term "bonding" should replace "adhesion" in this context,[32] as the interaction between substances is governed by mechanical interlocking forces rather than mere molecular attraction. Currently, no standardized methodology exists for quantifying the adhesion of a sealer to root dentin; hence, the adhesion potential of root filling materials is typically assessed through microleakage and bond strength evaluations.

The efficacy of a sealer in achieving an effective seal is intricately linked to its solubility as well as its bonding capabilities with dentin and root canal filling cones. Numerous studies have examined the sealing efficacy of various bioceramic-based sealers in vitro. Despite the disparate methodologies employed, the sealing performance of bioceramic-based sealers has generally been found to be satisfactory and comparable to other commercially available alternatives. Nevertheless, until recently, there has been a dearth of literature concerning the long-term sealing efficacy or clinical outcomes associated with bioceramic-based sealers.

Bond strength refers to the force per unit area necessary to debond the adhesive material from the dentin. Although no direct correlation has been established between leakage and bond strength, the bond strength test has garnered considerable attention due to the advent of the *monobloc* concept.[34] This concept involves the sealer forming a cohesive unit with both the core material and the dentinal wall, thereby enhancing sealing, and fortifying the root-filled tooth against fracture. A robust bond between the root canal sealer and root dentin is imperative for preserving the integrity of the sealer-dentin interface during post-space preparation and under tooth flexure conditions. Bioceramic-based sealers possess the capability to forge bonds between dentin and core filling materials. The bonding efficacy of iRoot SP to root dentin is on par with that of AH Plus and surpasses that of

Sealapex or EndoREZ sealers. Shokouhinejad et al. evaluated the bond strength of EndoSequence BC Sealer in comparison with AH Plus, both with and without a smear layer. [35] They found that EndoSequence BC Sealer's dislocation resistance was comparable to that of AH Plus, with no significant effect on the smear layer. Nagas et al. investigated the bond strengths of various sealers under differing moisture conditions within the root canal, concluding that bond strength is maximized in moist and wet canals, with residual moisture positively influencing sealer adhesion to radicular dentin.[36] Compared to AH Plus, Epiphany, and MTA-Fillapex, iRoot SP exhibited the highest resistance to dislodgment from the root dentin. Additionally, prior placement of intracanal calcium hydroxide was found to enhance the bonding of iRoot SP to root dentin, although the bond strength remained inferior to AH Plus and comparable to MTA-Fillapex in the absence of calcium hydroxide. This enhancement in bonding is attributed to the chemical interaction between calcium hydroxide and the iRoot SP sealer, which increases frictional resistance and/or micromechanical retention of the sealer. Endo CPM demonstrated significantly superior bond strength compared to MTA-Fillapex or AH Plus.

Testing the bond strength in the coronal third of the root canal reveals no significant differences among MTA-Fillapex, iRoot SP, and AH Plus. However, in the middle and apical thirds, iRoot SP and AH Plus exhibit equivalent bond strengths superior to MTA-Fillapex. Huffman et al. evaluated the dislocation resistance of ProRoot Endo Sealer, AH Plus Jet, and Pulp Canal Sealer from root dentin, both with and without immersion in simulated body fluid (SBF) [37]. The study concluded that ProRoot Endo Sealer exhibited greater bond strength than the other two sealers, particularly after SBF immersion. According to Huffman et al., the superior bonding of ProRoot Endo Sealer is attributed to the presence of spherical amorphous calcium phosphate and apatite-like phases, which enhance frictional resistance. The iRoot SP root canal sealer did not negatively affect the push-out bond strength of fiber posts cemented with self-adhesive resin cement. In comparison with Activ GP sealer (a glass ionomer-based sealer), iRoot SP was found to enhance the fracture resistance of endodontically treated roots in vitro, indicating a potentially superior bond strength of the sealer.

Flowability

Flowability affects a sealer's capacity to permeate and fill canal spaces. Various factors such as composition, shear rate, particle size, temperature, and time from mixing are related to the flowability of sealers [33] Bioceramic-based sealers generally exhibit favourable flowability, which is essential for achieving a comprehensive seal. The composition and additives influence flowability, with iRoot SP and EndoSequence BC Sealer displaying excellent flow characteristics.

Radiopacity

Radiopacity is crucial for visualizing sealers on radiographs, facilitating the assessment of their placement and identifying any discrepancies. Bioceramic-based sealers are typically radiopaque, aiding in the evaluation of root canal treatment efficacy and ensuring complete canal sealing. Candeiro et al. [38] reported the radiopacity of EndoSequence BC Sealer to be 3.83 mm. Endo CPM sealer was found to have a radiopacity of 6 mm due to the presence of bismuth trioxide and barium sulphate

Antibacterial Properties

Antibacterial properties are vital for preventing reinfection and promoting healing. Bioceramic-based sealers often possess antibacterial attributes due to their alkaline nature and calcium phosphate content, although the extent of this activity can vary among different sealers.

PEPTIDES

Antimicrobial peptides have recently garnered significant interest for their prospective applications in dental therapeutics aimed at combating oral biofilms [40].Numerous studies have highlighted these peptides as promising next-generation alternatives to conventional antimicrobial therapies within the oral cavity [41] Noteworthy examples include Peptide 1018 and DJK-5, which have demonstrated efficacy against oral biofilms These peptides exhibit remarkable capabilities in both inhibiting biofilm formation and eliminating pre-established oral biofilms . Their effectiveness extends beyond open biofilm platforms to encompass both single- and multi-species biofilms cultivated within dentinal tubules. The antimicrobial mechanisms of Peptide 1018 and DJK-5 involve binding to and catalysing the degradation of the second messenger nucleotide (p)ppGpp, which plays a pivotal role in biofilm formation and maintenance. Both peptides have demonstrated the ability to adhere to hydroxyapatite surfaces, with DJK-5 additionally exhibiting protease resistance and enhanced antibiofilm activity. When used in conjunction with traditional endodontic solutions such as sodium hypochlorite, chlorhexidine, and EDTA, these peptides have shown no adverse side effects.[42] Nonetheless, the complex and costly processes associated with the extraction, isolation, and purification of peptides render their large-scale production impractical for routine clinical use. However, a modified antimicrobial peptide 1018 has been reported to exhibit a high affinity for hydroxyapatite, demonstrating substantial antimicrobial and antibiofilm activity with significant reductions in biofilm volume.[43] Given the successful application of antimicrobial peptides on biofilms associated with hydroxyapatite and dentin, there is considerable potential for these peptides to be integrated into endodontic bioceramic materials to augment their antibiofilm properties.

Nanoparticles

The incorporation of nanoparticles into endodontic materials has been reported to enhance both their direct and diffusible antimicrobial properties, as well as their efficacy within dentinal tubules.[44] Recent advances include the synthesis of high-loaded antimicrobial drug-silica co-assembled particles (DSPs), which combine silica with octenidine dihydrochloride.[45] This innovative formulation has been shown to improve the antimicrobial performance of the EndoSequence BC sealer

Bioengineered chitosan nanoparticles have proven effective in deactivating bacterial biofilms and disrupting their extracellular polymeric matrix. These nanoparticles have demonstrated the capability to eradicate both mono-species and multi-species biofilms, presenting a promising antimicrobial and antibiofilm agent for root canal disinfection. Carboxymethyl chitosan has been identified as an effective surface modifier for dentin matrix, enhancing antibacterial efficacy.[46] As a bioactive biopolymer, engineered chitosan-based nanoparticles may modulate the host inflammatory response of macrophages and promote tissue healing. Chitosan's extensive use in biological scaffolds for bone regeneration [97,98] and tissue engineering underscores its potential utility in endodontic bioceramics. DaSilva et al. demonstrated that incorporating chitosan nanoparticles into zinc oxide-eugenol sealers inhibited biofilm formation at the sealer-dentin interface.[47] Given their high biocompatibility and broad application in bioengineering, chitosan nanoparticles hold promise as a supplement to various endodontic bioceramics.

Other nanoparticles, such as silver nanoparticles [48] and bismuth lipophilic nanoparticles [49] have also been employed in endodontics, displaying antimicrobial activities against single-species biofilms. Nonetheless, concerns regarding their cytotoxicity and impact on bioceramic materials necessitate further investigation.

CONCLUSION

Bioceramic-based root canal sealers demonstrate auspicious potential as endodontic materials. Nonetheless, inconsistencies in the empirical evidence expose the limitations of these sealers in meeting the exacting criteria of an ideal root canal sealer. The biocompatibility and biomineralization properties of these sealers may render them suitable for alternative applications, such as direct pulp capping and apical repair. Additional research is imperative to elucidate the clinical outcomes associated with their deployment in these contexts.

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