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BIOCERAMIC SEALERS IN CONTEMPORARY ENDODONTICS: FUNDAMENTAL CRITERIA FOR CLINICAL SELECTION

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ABSTRACT

Background

Bioceramic sealers have emerged as advanced materials in endodontics due to their superior biological and physicochemical properties.

Aim

To review the properties of bioceramic sealers and outline guidelines for their clinical selection.

Methods

A comprehensive review of literature was performed focusing on classification, properties, and clinical performance of bioceramic sealers.

Results

Bioceramic sealers demonstrate excellent biocompatibility, bioactivity, sealing ability, and dentinal tubule penetration. However, variations exist in properties such as solubility, setting time, and retreatability.

Conclusion

Selection of an appropriate bioceramic sealer should be based on its physical, biological, and clinical handling properties to ensure optimal endodontic outcomes.

Keywords

Bioceramic sealer, Endodontics, Root canal obturation, Physical properties, Bioactivity

1. INTRODUCTION

Successful endodontic therapy involves several sequential steps and achieves optimal outcomes only when each phase is executed correctly (1). Preparing the root canal space is essential. Root canal treatment (RCT) is defined as a combination of proper mechanical shaping and chemical procedures aimed at eliminating microbial content and removing tissue debris through irrigation (1).

The most critical goal in endodontic therapy is to eradicate microorganisms and prevent reinfection (1). Root canal filling materials play a significant role in ensuring the long-term success of treatment by providing a three-dimensional seal (2). This seal creates a barrier between the root canal system and surrounding periradicular tissues (2).

Due to the complexity of root canal systems, sealers are necessary to fill irregular spaces and dentinal tubules, thereby achieving a hermetic seal (13).

Root canal sealers must possess suitable physicochemical and biological properties. According to the International Organization for Standardization (ISO), these materials should demonstrate excellent sealing ability, dimensional stability, and biocompatibility (31).

Based on their chemical composition, sealers are classified into different categories such as zinc oxide eugenol-based (ZOE), calcium hydroxide-based, resin-based, glass ionomer-based, and silicone-based sealers (6,16).

Earlier, Grossman (1920) introduced zinc oxide eugenol-based sealers, while Rickert (1931) developed the first root canal sealer (3). Calcium hydroxide sealers were introduced in 1920, followed by resin-based sealers in the 1970s. Epoxy resin-based sealers (e.g., AH Plus) gained popularity, and methacrylate resin-based sealers emerged later, although their use declined over time (6). Glass ionomer-based sealers were also introduced as root canal sealers (6).

Advancements in endodontics have accelerated with the introduction of new materials and techniques. Bioceramic materials, derived from calcium silicates, were initially introduced in the 1990s. These materials include alumina, zirconia, bioactive glass, and calcium silicates (8).

The use of mineral trioxide aggregate (MTA) in clinical practice laid the foundation for bioceramic-based sealers (10). Currently, bioceramic-based root canal sealers represent a new category of innovative materials. Examples include EndoSequence BC Sealer, iRoot SP (Innovative Bioceramix, Vancouver, BC, Canada), and similar products (4,16).

The materials EndoSequence BC Sealer (Brasseler USA, Savannah, Georgia) and TotalFill BC Sealer (FKG Dentaire, Switzerland) are supplied in preloaded syringes along with disposable tips. All three materials share a similar chemical composition (4,16).

Bioceramic sealers chemically bond to dentin through an alkaline etching process caused by their high pH. This results in both mineral infiltration into the dentin and the development of an interfacial layer between the dentin and the material (11,16).

These sealers can penetrate dentinal tubules, forming a physical barrier that enhances root filling retention and entraps residual microorganisms (13). The extent of penetration depends on factors such as particle size, solubility, viscosity, and surface tension (13).

The depth of penetration is influenced by the diameter and density of dentinal tubules (14). Additionally, surface activity of the sealers, the nature of the contact between dentin and sealer, the obturation technique used, and the sectioning method during sample preparation all play important roles (13,14).

Dentinal tubules are wider and more numerous in the coronal and middle thirds of the root canal, while they are fewer and narrower in the apical third, which significantly affects sealer penetration (15).

The chemical properties of sealers also influence penetration. Hydrophilic sealers tend to penetrate deeper compared to hydrophobic ones (16).

Bioceramic endodontic sealers can be classified into calcium silicate-based (iRoot SP, EndoSequence BC Sealer), MTA-based (MTA Fillapex, Endo CPM Sealer, ProRoot Endo Sealer), and calcium phosphate-based (iRoot SP, EndoSequence BC, Bio-C Sealer) (16,17). Their main advantages include excellent biocompatibility, inherent osteoinductive properties, and the ability to act as a regenerative scaffold (8,16).

2. MATERIALS & METHODS

This study was designed as a descriptive analytical study evaluating the properties and clinical considerations of bioceramic root canal sealers.

Data were obtained from documented sources related to different types of bioceramic sealers, including calcium silicate-based, MTA-based, and calcium phosphate-based materials. Parameters assessed included physicochemical properties such as flow, solubility, radiopacity, dimensional stability, and setting time.

The study also evaluated biological characteristics including biocompatibility, antimicrobial activity, and bioactivity, along with clinical factors such as handling properties, dentinal tubule penetration, and retreatability.

All parameters were systematically analysed and compared to assess their influence on the quality of root canal obturation and overall endodontic success.

3. RESULTS

Bioceramic sealers were found to be broadly classified into calcium silicate-based, MTA-based, and calcium phosphate-based sealers. These materials demonstrated several favourable properties compared to conventional sealers.

They exhibited excellent biocompatibility and bioactivity, with the ability to form hydroxyapatite and promote tissue regeneration. Their high pH contributed to antimicrobial activity, particularly against common endodontic pathogens.

Bioceramic sealers showed good flow characteristics, allowing penetration into dentinal tubules and irregularities, thereby improving the sealing ability. Adequate radiopacity enabled clear differentiation from surrounding structures during radiographic evaluation.

However, certain limitations were also observed. Some sealers demonstrated higher solubility, which may compromise long-term sealing ability. Additionally, longer setting times and difficulty in retreatment were reported as potential disadvantages.

4. DISCUSSION

The success of endodontic therapy largely depends on achieving a complete and durable seal of the root canal system (1,2). Root canal sealers play a crucial role in this process by filling irregularities, dentinal tubules, and accessory canals, thereby preventing microleakage and reinfection (2,13).

Bioceramic sealers have gained significant attention in recent years due to their favorable physicochemical and biological properties (16,17). These materials exhibit excellent biocompatibility, bioactivity, and the ability to form hydroxyapatite, which enhances the sealing ability and promotes periapical healing (8,16).

In addition, their alkaline pH contributes to antimicrobial activity, while their hydrophilic nature allows better interaction with the moist environment of the root canal system (20,16). These properties collectively make bioceramic sealers a promising alternative to conventional root canal sealers (6,16).

However, despite these advantages, certain limitations such as higher solubility, extended setting time, and challenges in retreatment have been reported (30,36). Therefore, careful selection of an appropriate sealer based on its properties and clinical requirements is essential for achieving optimal treatment outcomes (6).

4.1 FUNDAMENTAL SELECTION CRITERIA FOR BIOCERAMIC SEALERS

1. MTA-Based Sealers

Several MTA-based sealers are used in endodontics, including MTA Fillapex (Angelus, Brazil), Endo CPM (Egeo, Argentina), MTA-Angelus (Angelus, Brazil), ProRoot Endo (DENTSPLY Tulsa Dental Specialties), and EndoSeal MTA (MARUCHI, Korea) (18).

These sealers create an alkaline environment, which provides antibacterial activity against microorganisms such as M. luteus, S. aureus, E. coli, P. aeruginosa, C. albicans, and E. faecalis (20,21). Their alkalinity also promotes mineralization through the formation of hydroxyapatite crystals, leading to calcium phosphate deposition (21).

However, they have certain drawbacks, including a long setting time (approximately 2 hours 45 minutes), shorter working time, and difficult handling. Additionally, they may cause discoloration and can be challenging to remove from the root canal (18).

2. Calcium Silicate-Based Sealers

These sealers possess several beneficial properties, particularly biocompatibility, antimicrobial activity, and bioactivity (16,22). They create an alkaline environment due to the antimicrobial effect of Ca^{2+} ion release (20).

Two premixed calcium silicate-based sealers with similar compositions are iRoot SP and EndoSequence BC (4,16).

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3. Calcium Phosphate-Based Sealers

Some of the newer calcium phosphate-based sealers demonstrate the ability to eliminate bacteria while strengthening root structures (17). Sankin apatite root canal sealer (Japan) is an example.

These sealers are composed of calcium phosphate cement, which closely resembles the mineral composition of bone and teeth (17).

Calcium phosphate and calcium silicate-based sealers are often referred to as premixed bioceramic sealers, as they do not require manual mixing. During setting, they release calcium hydroxide (16).

A wide range of bioceramic sealers is available in the market, making it challenging for clinicians to select the most appropriate one for specific cases (6).

Certain physical properties significantly influence the quality of root canal obturation, and the effectiveness of a sealer depends largely on these properties (6,26).

Root canal sealers should ideally have low solubility, adequate flow, dimensional stability, sufficient radiopacity, and optimal physical characteristics such as water sorption, rheological behaviour, setting time, and viscosity (26,31).

4. FLOW

Flow is an important property that enables the sealer to fill irregularities such as fins, isthmuses, and accessory canals (26). According to ISO 6786:2001, root canal sealers should demonstrate a flow value not less than 20 mm (31).

BioRoot™ RCS has shown values slightly below this minimum standard (36). Factors affecting flow include particle size, temperature, shear rate, and mixing time (36).

Highly flowable sealers composed of calcium silicates and zirconium oxide particles can penetrate deeper; however, excessive flow increases the risk of extrusion beyond the apical foramen (30).

Manufacturers report that bioceramic sealers exhibit high flowability, meeting ISO standards (30).

5. WATER SORPTION AND SOLUBILITY

Water sorption and solubility are closely associated with the dimensional stability of root canal sealers and are well-defined in ISO standards (31). According to ISO 6876:2012, sealers should exhibit solubility of less than 3% weight loss after immersion in water (31).

Highly soluble sealers can allow the movement of fluids between the filling material and dentinal walls, potentially causing microleakage, sealer degradation, and dissolution of biologically incompatible components (32).

The solubility of sealers is influenced by several factors, including setting time and composition (32). Hydrophilic bioceramic sealers may show higher solubility due to their interaction with moisture (16). Literature presents conflicting data regarding the solubility of certain bioceramic sealers (32).

The increased solubility of bioceramic sealers is attributed to hydroxyapatite nanoparticles, which increase surface area and enable greater liquid interaction (16). Additionally, calcium ion release correlates with higher solubility levels (30).

EndoSequence BC Sealer demonstrates lower solubility, possibly due to smaller nanoparticle size, which enhances hydration and calcium phosphate formation (30). Conversely, Bio-C Sealer tends to have higher solubility, likely due to larger particle size (30).

Although calcium silicate-based sealers offer good flow and film thickness, their higher solubility remains a concern (30).

6. RADIOPACITY

An ideal root canal sealer should possess sufficient radiopacity to be clearly distinguished from surrounding tooth structures, allowing accurate evaluation of obturation quality (39).

Radiopacity is typically enhanced by adding radiopaque agents such as aluminum, gold, or silver (39). ISO standards require a minimum radiopacity equivalent to 3 mm of aluminum (mmAl) for a 1 mm thick sealer sample (31).

Different sealers exhibit varying radiopacity values (36). Bioceramic sealers such as BioRoot™ RCS, EndoSequence® BC Sealer™, EndosealMTA®, MTA Fillapex®, and TotalFill® BC Sealer have demonstrated higher radiopacity compared to ISO requirements (36).

Studies report that the radiopacity of MTA Fillapex ranges between 2.7 and 8.9 mmAl, while Vidotto et al. reported a value of 6.5 mmAl (36).

7. DIMENSIONAL STABILITY

Dimensional stability is a critical factor influencing the success of endodontic treatment (27). While minimal shrinkage is expected, excessive expansion may lead to root fractures (27).

Sealability depends on whether the material shrinks or expands during setting (27). Ideally, sealers should exhibit minimal dimensional change to maintain a proper seal against dentinal walls. ISO standards recommend a maximum shrinkage of 1% or expansion of 0.1% of the original sample length (31).

Comparative studies indicate that MTA Fillapex demonstrates higher solubility, dimensional changes, and volumetric variation compared to other sealers (40). BioRoot exhibits an expansion of approximately 0.20% (40).

8. SETTING TIME

The setting time of a root canal sealer should allow sufficient working time for clinical procedures (36). It is influenced by various factors, including the setting medium, sealer composition, and hydration reaction (36).

Bioceramic sealers such as EndoSequence BC Sealer and iRoot SP rely on the presence of moisture in dentinal tubules for proper setting (4,16).

Studies report that EndoSequence BC Sealer sets in approximately 2.7 hours, whereas other findings indicate a longer setting time of up to 168 hours for complete hardening (36). In some cases, setting may take up to 4 hours or longer, especially in dry canals (36).

Bio-C Sealer has a setting time of approximately 120 minutes, which can extend to 240 minutes after placement, depending on moisture availability (36).

Overall, bioceramic sealers tend to have relatively longer setting times (36).

In addition to the physical properties discussed, the selection of an ideal bioceramic sealer should also take into account several other clinically relevant factors (6,16). The material should demonstrate strong adhesion to dentinal walls to enhance sealing ability and minimize microleakage (11,13). Long-term antimicrobial activity is desirable, particularly against resistant microorganisms such as *E. faecalis* (20,21).

Bioactivity and the ability to promote biomineralization are important features, as they contribute to periapical healing and regeneration (8,16). The sealer should also allow ease of removal during retreatment procedures without causing excessive damage to the surrounding dentin (6).

Compatibility with various obturation techniques, including single cone, lateral condensation, and warm vertical compaction, is another important consideration (6). Since many bioceramic sealers rely on moisture for setting, their performance in both dry and moist canal conditions should be evaluated (4,16).

Additional factors such as optimal film thickness, ease of handling, and delivery systems play a role in clinical efficiency (26,36). Practical aspects including cost-effectiveness, availability, shelf life, and storage stability may also influence the choice of material (6).

In aesthetically important areas, color stability should be considered to prevent tooth discoloration (18). Furthermore, the sealer should exhibit excellent tissue compatibility, being non-toxic and non-irritating (16). Resistance to washout during the initial setting phase is also essential to maintain the integrity of the seal (30).

5. CONCLUSION

The quality of root canal obturation and the success of endodontic treatment are highly dependent on the physical properties of the sealers used (6,26).

Bioceramic sealers represent an advanced group of materials that chemically bond to dentin, penetrate dentinal tubules, and form a physical barrier, thereby improving retention (11,16).

Their diverse properties and wide availability make selection challenging for clinicians, as the choice must be tailored to individual clinical situations (6).

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