Application of bioceramic materials in endodontic therapy: a brief review

Mohammed Abdullah Alnujaym1, Ahamad Sanad Almotiri1*, Alssady Mutlaq Alsubaie1, Nawaf Ibrahim Alradhyan1, Osama Abdullah Otain1, Ali Kamal Rehan2

ABSTRACT

Bioceramics (BCs) are materials that include vitreous ceramics, zirconia, bioactive glass, alumina, hydroxyapatite, resorbable calcium phosphate (CaP), and other materials. They have been utilized to fill bone defects, as root repair material, apical fill material, perforation sealing, endodontic sealers, and regeneration aids in dentistry. BCs have various advantages over other materials, including biocompatibility, BC nontoxicity, dimensional stability, and, most importantly, bioinertness in endodontic applications. There is a similarity of BC to hydroxyapatite in that they have an intrinsic osteoconductive action and the ability to initiate the regenerative responses in the human body. In endodontics, they can be broadly categorized into CaP, mixtures of calcium silicate and phosphates, hydroxyapatite-based, tricalcium, and calcium silicate-based. This review focuses on an overview of BCs; it furthermore provides a complete overview of individual BC material currently utilized in the fields of endodontics, as well as their features and applications.

Keywords: MTA, bioceramics, endodontic therapy, biocompatibility.

Introduction

Biocompatibility is a material’s ability to achieve an appropriate and useful host response in specific applications [1]. When any biomaterial is in contact with the host, a tissue response is predictable; a mutually acceptable coexistence of the biomaterial and the host tissues is needed [2]. Due to their resemblance to biological materials such as hydroxyapatite, many studies have agreed that bioceramics (BCs) have excellent biocompatibility [3,4]. In case of root repair, where there is no inflammation or pain or just minimal pain after an overfill during obturation, significant biocompatibility of BCs can be seen [5]. BC is a good biocompatible material with the tissue of the pulp and stimulates the formation of dentine bridge reparation; thus, it may be utilized as a capping material of the pulp; in vital pulp therapy cases, it was demonstrated to cause mineralization and produce odontoblastic differentiation linked with expression of genes. EndoSequence root repair material (ERRM) was compared to mineral trioxide aggregate (MTA) in terms of its effect on the development of dental pulp cells (DPCs). The proportion of the secretion of vascular endothelial growth factor, surviving DPCs, and proliferation rates were shown to be the same when cultured on both materials, implying that ERRM could be considered as a viable alternative to other pulp capping materials [6].

Biocompatibility of BCs

BC material have antimicrobial properties that have the ability to offer an impermeable seal to the root canal system, and should seal all portals of communication between pulpal and peri-radicular tissues and can stimulate regeneration of the periodontium, and at the same time, the material must be nonirritant, not cause tissue discoloration, nontoxic, and noncorrosive [7]. BCs have a wide range of applications in the orthopedics field, which include tissue or joint replacement, coatings that improve the biocompatibility of metal implants, and BCs...
utilized as a resorbable scaffold for tissue regeneration. Therefore, calcium phosphate (CaP) bases with porous ceramics are utilized for bone defects regeneration, such as calcium silicate materials like MTA or BC that are used as root repair materials [8]. The setting time of the BC sealer is influenced by the presence of moisture in the dentinal tubules. However, the quantity of moisture required for the setting reaction of the sealer is provided by dentinal tubules. Consequently, before obturation, there is no need to apply moisture to the root canal.

Furthermore, during the setting phase, the pH is highly alkaline (pH 12.9), which causes it to increase. This is an especially valuable property to have when using a BC as an endodontic sealer, and it is often considered a physical property [9]. The majority of the root canal sealers are BC-based. Since then, it was discovered to be biocompatible. The CaP present in the sealer is responsible for its biocompatibility [10].

**Hydraulic Condensation with BC Sealers**

The formation of a true bonding between the customized cone and the canal wall is a feature of some BC sealers using synchronized hydraulic condensation [5]. The BC sealer can bind to the ceramic particles in the Activa gutta percha (GP) cones and the BC particles in the new BC-coated cones. When combined with Activa GP cones, the BC sealer performed best [11]. A flexible intracanal tip can be used to place the BC sealer, and it provides additional benefits such as better access to the root canal. The BC sealer is inserted slowly, and the intracanal tip should not exceed the coronal by one-third. A thin BC sealer coats the master cone after removing the tip from the intracanal. Persistent canal taper, together with the accuracy of the gutta percha fitting in the canal, aids in achieving outstanding hydraulics [5]. BC sealer (BiorootTM, Septodont) possesses outstanding adhesion to dentin and gutta-percha points. Because of its hydrophilic nature, it creates a chemical interaction with dentin and forms hydroxyapatite in the presence of moisture. The nature of the bond between sealer and dentin depends on its chemical composition. Bioroot root canal sealer (RCS) interaction with dentin leads to the formation of metal leakage area. The zone mineral infiltration is the ion substitution layer that occurs at the junction of dentin and cement containing tricalcium silicate attached to a double effect of the cement-based calcium hydroxide released: alkaline acid etching followed by mineral distribution. Hence, it eliminates any space between the sealer and dental wall [12]. The development of new types of endodontic sealers and/or obturation core materials may overcome the microleakage associated with currently used materials and encourage the use of single-cone obturation techniques [13]. The principal hydraulic force in the hydraulic condensation technique is produced by synchronization, which is cementing a nearer master cone to the formed canal. It can be considered cold vertical condensation where gutta-percha acts as condenser and BC sealer as thermoplasticized gutta-percha [12]. Multiple factors influence the healing process of periapical lesions, and one of them is the type and features of the endodontic sealer. To promote the healing of chronic inflammations of endodontic origin by BC sealer, the pH should be increased and a strong seal should be created. They are highly biocompatible and indicated using a simple obturation technique - single cone hydraulic condensation. They possess good adhesion to the dentinal wall and antimicrobial properties. The survival of periodontal ligament cells and their ability to release considerable quantities of osteoblastic and blood vessel formation factors are maintained following direct contact with BioRoot RCS [14]. The system-B device was used to implement this obturation technique. The thermo-hydraulic-condensation (THC) technique is the name given to this method. THC uses system-B while altering the conventional obturation process, which leads to improved hydraulics throughout the down-pack. 

THC approaches resulted in the obturation of more lateral canals due to better thermal hydraulics. True, the technique works by increasing the time for the gutta-percha to flow in conjunction with the pressures obtained during the procedure. The heat source in system B can measure the temperature at the tip of its thermal transport device and supply a specific quantity of heat for an extended period of time. Thermal carriers, also known as Buchanan pluggers, were created with shapes that closely resemble the morphologies of tapering canal preparations. Those pluggers are available in four sizes that mimic the taper of non-standardized customized cones: fine, fine-medium, medium, and medium-large. Furthermore, these stainless steel heat pluggers are fairly flexible, enabling greater condensation, particularly in curved and narrow canals. The purpose of these heat carriers is to soften the gutta-percha [15].

**Bonding of BCs to Dentin**

In addition to being nontoxic, biocompatible, and non-shrinking, BCs are chemically stable and can produce hydroxyapatite and bond between sealer and dental wall [16]. The bond strength is the force that is expected to debond the adhesive from the dentinal tubules. The “monoblock” concept, in which the sealer connects to both the core material and the dentinal wall, forms a single unit that improves sealing and strengthens the root-filled tooth against fracture [17]. It is imperative for BC to bond properly with dentin; otherwise, it will not display adequate bioactivity [18]. The bond between the endodontic sealer and root dentin during mechanical forces caused by restorative procedures or in the preparation of post-space and tooth flexure either through the frictional retention or micromechanical adhesion helps in resisting dislodgment of the filling and maintains the integrity of the crucial interface and is advantageous for bonding of sealer to dentin [19]. In 2012, a research study concluded that BC sealer was more effective at bonding to root dentin than competing sealers under all moisture conditions [11]. In different words, the amount
of moisture required for the BC sealer to set should be supplied by the dentinal tubules, and it is not essential to add humidity to the canal before obturation. Insufficient water may have interfered with hydration, resulting in a poor and inadequate setting process [20]. A completely dry dentin wall can remove any remaining water from the tubules and affect the bonding properties of hydrophobic sealant because the tubules are completely dry [21]. The water inside the dentinal wall activates the sealer setting reaction. The sealer consists of calcium hydroxide, monobasic CaP, calcium silicate, and zirconium oxide [22]. During root canal obturation, sufficient flow and wetness are important qualities of root canal sealer to ensure adequate adhesion between the root canal walls and the main core filling material, resulting in a fluid-tight and microorganism-proof seal. To improve molecular attraction and allow chemical adhesion or micromechanical attachment, the sealer should have good binding with dentinal tubules and the core material [23]. Root canal sealers are necessary due to the abnormalities and irregularity in the root canal system and the size and diameter of the dentinal tubules. Sealants are used to seal the canal system by filling the anatomic irregularities, ramifications, accessory canals, and dentinal tubules, improving the adaptation of dentinal tubules with root filling material [24]. There is no common technique used to estimate the adhesion strength to the dentinal wall. Adhesive materials are regularly compared using bonding strength and microleakage tests. Although microleakage may be more significant for endodontic applications than bond strength, a strong bond between the sealer and the root dentin is required to maintain tooth structure integrity during post-space preparation and tooth flexure [23].

**Antimicrobial Properties of BCs**

Endodontic sealers are important for controlling endodontic infection by entombing residual microorganisms and preventing bacteria leakage and reinfection of the root canal system [25]. The filling materials with antimicrobial activity in a root canal are helpful in the effort to decrease the residual bacteria, prevent recurrent root canal infection, and help in the healing process of periapical tissues [26]. Treatment of root canal usually will decrease the microbes but does not remove all [16], BC has the standard to be biocompatible and supply antibacterial properties [3]. Multiple endodontic sealers are claimed to have antimicrobial properties [25]. A proper root canal filling and complete elimination of endodontic bacteria are essential for long-term endodontic treatment success. Although antimicrobial activity is a critical prerequisite for an endodontic sealer, most of them are incapable of providing full protection [3]. BC sealers usually provide an excellent antimicrobial activity [27]. BC sealer has an antimicrobial effect on bacteria such as Enterococcus faecalis, which is considered to be resistant to disinfection [28]. Furthermore, due to the biofilm’s limited nutrient sources, previous research has shown that the high sealing ability of BC cement can contribute to an additional antimicrobial effect [29]. The root canal sealers should be biocompatible, provide a tight seal, and possess an antibacterial effect. The antimicrobial properties of sealers may help stop persistent residual infection and microorganisms from re-entering the canals and increase the possibilities of successful endodontic treatment [30]. Root canal sealers cover the area between the GP and the dentinal tubules, overcoming the limits of GP cones and conventional obturation techniques. As a result of BCs, sealers have a good sealing ability. Their antimicrobial activity would be clinically beneficial in preventing bacteria from re-entering the canal and inactivating bacteria left in the canal following root canal obturation [31]. Nonetheless, sealers’ comparative antimicrobial efficacy is unknown, as are the models used to demonstrate their antimicrobial activity [25]. The antimicrobial properties of root canal sealers have been linked to the alkaline structure and calcium ion release. Alkaline materials enhance hard tissue mineralization and antibacterial activity [32]. Enterococcus faecalis survive in unforgiving environments, including high alkaline pH 11.1. It was also the most commonly used bacteria to evaluate the antimicrobial efficiency of root canal sealers linked to persistent periapical infections [33].

**Using BCs for Perforation Repair**

The complications and accidents in endodontic procedures, like root perforation, necessitate the application of biocompatible materials that help tissue repairing. In about 2%-12% of root canal treatments, accident root perforations occur [34]. Root canal perforations can happen iatrogenically due to post-space preparation and access cavity preparation or pathologically as a result of internal resorption and extensive caries during root canal treatment. If not repaired, such perforations can compromise the treatment outcome and lead to tooth loss [35]. The requirement of perforation repair materials significantly depends on whether the perforation is located inside or outside (intraarticular or extraarticular) of the root canal [36]. The prognosis of the root perforation is influenced by the size and extent of the defect, the duration of exposure to periradicular contamination, and the material used for the repair [34]. Perforation of multi-rooted teeth has a different prognosis than single-rooted teeth. A small perforation in the immediately sealed subcrustal bone has a strong prognosis and vice versa [35]. MTA is the gold standard for repairing endodontic perforations [4]. BC has undergone many changes in composition, such as particle size, and presentation, in response to tooth discoloration, handling difficulties, and long set times [34]. Endosequence BC comprises nanosphere particles that allow the material to pass through the dentinal wall and interact with the moisture within the dentinal tubules. When the material is set, this creates a mechanical bonding, giving it excellent dimensional stability. It
also has exceptional biocompatibility properties due to its high PH level [35]. Some endodontic complications, like root canal perforations or furcations perforation, can occur due to procedural mistakes, caused by a lack of professional knowledge or pathology concerns. If not treated appropriately, perforations in the root cause communication between the root canal and the periodontium, leading to the loss of the tooth [37].

**Conclusion**

The latest BCs had been compared in *in-vitro* and animal researches to reveal comparable or extra dependable outcomes than MTA. Clinical studies on perforation repair, vital pulp therapy, and apical surgery also show similar or better results. With the sealant-based filling, a retrospective clinical examination of 307 teeth with an average follow-up period of 30 months has a high success rate of 90.9%. To confirm the long-term effectiveness of the material, a higher level of evidence with randomized clinical trials is required. However, its hydrophilic nature, sealability, biocompatibility, antimicrobial property, bioactivity, and ease of delivery have made it a promising material for use in endodontics.

**List of Abbreviations**

<table>
<thead>
<tr>
<th>BC</th>
<th>Bioceramic</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPC</td>
<td>Dental pulp cells</td>
</tr>
<tr>
<td>ERRM</td>
<td>EndoSequence root repair material</td>
</tr>
<tr>
<td>MTA</td>
<td>Mineral trioxide aggregate</td>
</tr>
</tbody>
</table>

**Conflict of interest**

The authors declare that there is no conflict of interest regarding the publication of this article.

**Funding**

None.

**Consent to participate**

Not applicable.

**Ethical approval**

Not applicable.

**Author details**

Mohammed Abdullah Alnujam1, Ahamad Sanad Almotiri1, Alsady Mutlaq Alsubaie1, Nawaf Ibrahim Alradhyan2, Osama Abdullah Otain2, Ali Kamal Rehan2

1. Vision College of Dentistry and Nursing, Riyadh, Saudi Arabia
2. Assistant Professor of Endodontics, Department of Restorative Dental Sciences, Vision College of Dentistry and Nursing, Riyadh, Saudi Arabia

**References**

20. Carvalho CN, Grazziotin-Soares R, de Miranda Candeiro GT, Martinez LG, de Souza JP, Oliveira PS, et al. Micro push-
Application of bioceramic materials in endodontic therapy


