Journal of Dental Health and Oral Research

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Editorial

Bioceramic Sealants: A Review

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Received Date: 30-11-2022; **Accepted Date:** 20-12-2022; **Published Date:** 27-12-2022

Editorial

Bioceramic sealants are considered an advantageous technology in modern endodontics. The aim of this article is to highlight the characteristics of bioceramic sealants and to compare them with other root system sealing materials. An extensive search of the endodontic literature was conducted to identify publications related to bioceramic sealants. The results of laboratory and clinical studies on the biological and physical properties of bioceramic-based sealants, as well as comparative studies with other sealants, were evaluated. Several studies evaluated different properties of bioceramic-based sealants, including physical properties, biocompatibility, sealability, adhesion, solubility and antibacterial efficacy. Bioceramic-based sealants were

Citation: Niculescu M, et al. Bioceramic Sealants: A Review. J Dental Health Oral Res. 2022;3(3):1-8.

DOI: https://doi.org/10.46889/JDHOR.2022.3311

found to be biocompatible and comparable to other commercial sealants. Clinical outcomes associated with the use of bioceramic-based root canal sealants are not established in the literature.

In modern dentistry, the endodontic field is improving with new materials and methods. In 2007, the American Endodontic Association adopted the term regenerative endodontics [1]. It promotes the idea of bioactive materials, these are materials that are durable in contact with tissues and have the ability to produce changes at the interface with them, producing their regeneration. In other words, the focus has been on materials that promote tissue regeneration rather than tissue healing [2].

The main indications for these materials are pulp and hard tissue regeneration: pulp capping, pulpotomy, apexogenesis, apexification, endodontic sealants, perforation repair and retrograde endodontic filling materials.

The introduction of bioceramic materials has brought a great advantage in the new paradigm of endodontic therapy due to their biocompatibility and excellent physiochemical properties. Bioceramics, categorized as bioinert, bioactive and biodegradable are biocompatible ceramic compounds through their similarity to biological hydroxyapatite [1]. They produce, through hydration, different compounds, including mineral hydroxyapatite that induces a regenerative response of the tissue they come into contact with. In addition to being biocompatible, bioceramics also have an antibacterial effect. This property is the effect of in situ precipitation that occurs after the setting time. This phenomenon leads to bacterial sequestration. They also form porous powders containing nanocrystals 1-3 nm in diameter, preventing bacterial adhesion. Sometimes apatite crystals contain fluoride ions and have an antibacterial effect. They can also be combined with synthetic hydroxyapatite [3].

The aim of this paper is to perform a literature review of the main bioceramic materials commonly used in endodontics and their characteristics.

Table 1. Ideal properties of bioactive materials, according to Kamil Zafar [2]:

1. Adequate hardness
2. Antimicrobial properties
3. Biocompatibility
4. Bioactivity (ability to stimulate and modulate native tissues)
5. Dimensionally stable
6. Easy handling
7. Ability to seal
8. Does not become sensitive to moisture

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9. Does not resoak
10. Non-toxic, non-carcinogenic, non-genotoxic
11. Radio-opac

In a study by Baghdadi, et al., experiments on a bioceramic-based endodontic sealant were reported to improve the physicochemical properties by reinforcement with each of three different nanomaterials: Multi-Walled White-Walled Carbon Nanotube Nanomaterials (MWCNTS), Titanium Carbide (TC) or Boron Nitride (BN) in two weight percent (1 wt%). and 2 wt%). The 1 wt% composites had significantly shorter initial and final cure times compared to BioRoot™ RCS pristine ($p < 0.05$). The 2 wt% composites had longer initial set times but significantly shorter final set times than BioRoot RCS ($p < 0.05$) [4].

Lee, et al., undertook a study in which three bioceramic sealants (EndoSequence BC sealer, EndoSealMTA and MTA Fillapex) and three epoxy resin-based sealants (AHPlus, AD Seal and Radic-Sealer) were tested to evaluate the physicochemical properties: flowability, final setting time, radiopacity, dimensional stability and pH change. One-way ANOVA and Tukey's post-hoc test ($P = 0.05$) were used for data analysis [5]. In MTA Fillapex sealer had the highest flow and BC Sealer showed significantly lower flow than the others ($P < 0.05$). BC Sealer and MTA Fillapex did not set under wet incubator conditions even after 1 month. EndoSealMTA had the longest setting time of the measurable materials and Radic-Sealer and AD Seal showed a shorter setting time than AH-Plus ($P < 0.05$). AH-Plus and EndoSeal MTA had statistically higher values and Fillapex MTA had statistically lower radiopacity ($P < 0.05$). BC Sealer had the highest alkaline pH in all evaluation periods. Samples of 3 epoxy resin-based sealant sets and EndoSeal MTA showed a significant increase in pH over the 4-week experimental period. In conclusion, the bioceramic and epoxy resin-based epoxy sealants exhibited clinically acceptable physicochemical properties, but BC Sealer and MTAFillapex were not fully cured [5].

Many studies have examined the interaction between bioceramic materials and dental pulpal stem cells [1].

ProRoot MTA has been shown to increase osteoblast, fibroblast, cementoblast, odontoblast and pulp cell differentiation. Due to their difficult handling, among other disadvantages such as long setting time, alternative materials were sought. Biodentine and TheraCal LC are bioceramic materials introduced later in dentistry for use in vital pulp therapy due to their consistency, easy handling and composition (tricalcium silicate).

Biodentine was specially created Septodont (France) as a dentine replacement material. Indications: treatment of resorptions, root perforations, direct tooth trimming procedures, apexification, retrograde fillings and dentine replacement.

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BioAggregate (Innovative BioCeramix Inc, Canada) has similar properties to MTA cement, marginal sealing, superior adhesion and pulp regeneration. Clinical application of BioAggregate as a luting agent promotes dentin mineralization and then stimulates reparative odontogenesis in injured dental pulp tissue. It is non-toxic to human cells and has also been shown to induce differentiation of human Periodontal Ligament (PDL) fibroblasts [2].

Generex A (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA) is similar to MTA, but is obtained by mixing with single gels instead of water. It is indicated for retrograde fillings and in case of perforation. It has superior resistance against washout, compression strength, good radiopacity [3].

Studies using RT-PCR analysis comparing bioceramic materials with MTA have shown significant positive results in favour of the bioceramic materials studied. All studies comparing bioceramic materials with themselves to which an additive was added showed positive results in favour of bioceramic materials combined with an additive. Studies comparing bioceramic materials with non-bioceramic materials did not show positive results for the bioceramic material studied [1].

Using ARS staining, the bioceramic material was compared with MTA, showing negative results for the bioceramic material. When a bioceramic material was compared with the same bioceramic material in combination with an additive, positive results were obtained for the bioceramic material containing the additive.

Endodontic cements and endodontic sealers must ensure a perfect seal of the endodontic system to prevent microleakage. In order to achieve good adhesion to the dentinal walls of the root canal, the latter must be perfectly dry. It has been observed that using MTA for endodontic obturation gave good results even if the canals were not perfectly dry. For complex cases where endodontic drugs (calcium hydroxide or antibiotics) were used, it was found that they had to be completely removed from the canals to obtain a good seal [3].

Studies evaluating the sealing ability of bioceramic-based sealers have concluded that these sealers have satisfactory adhesion results, have the ability to create adhesion between dentin and gutta-percha. The adhesion achieved by iRootSP to dentin is comparable to that of AH Plus and stronger than Sealapex or EndoREZ. Adhesion strength testing in the coronal third of the root canal shows no significant difference between MTAFillapex, iRoot SP and AH Plus. However, in the central and apical thirds, iRoot SP and AH Plus have superior equivalent adhesion to MTA-Fillapex. Nagas, et al., as cited by Aziz concluded that the sealing power of a sealer is highest in wet canals; the presence of residual moisture positively affecting root canal adhesion [6]. Compared to AH Plus, Epiphany and MTA-Fillapex, iRoot SP had the highest resistance to dislodgement from root dentin. Furthermore, pre-placement of intracanal

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calcium hydroxide improved the adhesion of iRoot SP to root dentin; however, adhesion was less than that of AH Plus and comparable to that of MTA-Fillapex in the absence of calcium hydroxide.

In a study by Razmi, et al., on 18 extracted human premolars, the effect of canal dryness on the bond strength of bioceramic sealants and epoxy resin after irrigation with sodium hypochlorite or chlorhexidine was evaluated. The bond strength of resin-based sealants was not affected by the irrigation solution; however, channel moisture negatively affected the bond strength of AH-Plus. CHX reduced the adhesion strength of BC sealant [7].

Another study by Al-Haddad in 2017 evaluates the effect of canal moisture on bioceramic sealants on 24 extracted teeth [8]. The sealants were evaluated before mixing and after the socket using X-ray Riffraction (XRD), Energy Dispersive Analysis (EDX) and Scanning Electron Microscope (SEM) methods. XRD analysis showed that Fillapex MTA is composed of bismuth trioxide, calcium silicate and tricalcium aluminate. The wet strength was reduced. Endosequence BC contained mainly calcium silicate, hydrated calcium silicate, zirconium and calcium hydroxide. The wet condition showed a small increase in hydrated calcium silicate. EDX showed changes in elemental concentrations as a function of different wet conditions. The surface morphology was different depending on the different moisture conditions [8].

It has been studied the biocompatibility of these materials. Most bioceramic sealants are biocompatible because they contain calcium phosphate which is also the main anorganic component of hard tissues (tooth and bone). Studies have shown that bioceramics have the ability to induce bone regeneration when unintentionally extruded beyond the apex during endodontic fillings or when used in the treatment of perforations. EndoSequence BC, iRoot SP and MTA-Fillapex exhibited moderate toxicity when used freshly mixed; however, cytotoxicity reduced over time until the socket was complete [7].

The setting of the bioceramics should allow for proper handling of the material, but too slow setting can cause irritation to nearby tissues. In the case of EndoSequence BC Sealer or iRoot SP, the setting reaction is catalysed by the presence of moisture in the dentinal tubules. The setting occurs in 4 hours, but in patients with dry canals, this may be longer. Loushine, et al., reported that EndoSequence BC Sealer requires at least 168 hours before full cure under various moisture conditions, as assessed by the Gilmore needle method. On the other hand, Zhou, et al., reported a cure time of 2.7 hours [9]. The setting reaction of EndoSequence BC Sealer is a two-phase reaction: in the first phase, monobasic calcium phosphate reacts with calcium hydroxide in the presence of water to form water and hydroxyapatite; in the second phase, the water in the dentinal tubules together with that resulting from the first phase contributes to the hydration of the calcium silicate particles to trigger a hydrated calcium silicate reaction.

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Candeiro, et al., studied the penetration ability of two endodontic cements (Endosequence BC Sealer and AH Plus) using 26 maxillary premolars that had 2 canals. Six lateral canals with two diameters (0.06 and 0.10 mm) were created in each root and filled with single crowns [10]. The teeth were divided into two groups; the first group used Endosequence BC Sealer and the second, AH Plus. Periapical radiographs were taken and a scale from 0 to 4 was used to assess the penetration of the sealer into the root canals. It was observed that Endosequence BC Sealer showed similar ability to penetrate lateral canals as AH Plus [10].

Haddad, et al., in their study evaluated and compared the sealant thickness and interface fit of bioceramic sealants (Sankin Apatite III, MTA Fillapex, EndoSequence BC) on root dentin versus AH Plus. EndoSequence BC had the highest thickness significantly compared to MTA Fillapex and AH Plus. The coronal level had significantly fewer interfacial gaps compared to the apical and middle levels. Bioceramic had more gaps compared to AH Plus, with no significant differences between them [9].

Wang, et al., evaluated the dentinal tubule penetration and sealing ability of iRoot SP bioceramic sealant on 42 extracted lower incisors. The penetration degree of iRoot SP into dentinal tubules was statistically higher than AH Plus in both the single-unit technique and the vertical hot filling technique at 2 mm to the apex ($P < 0.05$). Regardless of the filling technique used, iRoot SP can achieve comparable filling quality and better penetration into dentinal tubules than AH Plus. Given the good bioactivity of iRoot SP, it can contribute to improving the sealing of the root canal system [11].

The study by Angerame, et al., undertaken on 30 extracted monoradicular teeth filled mononically with BC sealer using three different techniques (1. R40 cone reaching the entire LL 2. R40 cone reaching 1 mm shorter than the LL and 3. Non-standardized gutta-percha cone reaching the entire LL) concluded that in all groups the gaps were minimal and predominantly external. The fewest voids were found in group 1 and groups 2 and 3 had a higher rate of sealing throughout the canal and in the apical portion. The BC sealer had satisfactory sealing ability, uniform distribution and minimal voids [12].

Marija Simundić Munitić, et al., conducted 37 studies that examined the antibacterial effect of bioceramic salts. Several *in-vitro* studies have shown that bioceramic sealants can have varying degrees of antimicrobial activity, but it is not possible to draw a conclusion about their comparative effectiveness or to recommend one sealant over another [13].

Naji Kharouf, et al., compared the physicochemical properties, filling capacity and antibacterial activity of a premixed calcium silicate-based sealant with those of a bioceramic powder-liquid sealant. Ceraseal (CS) and BioRoot (BR) materials were analysed using electron scanning

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electron microscopy and energy dispersive X-ray spectroscopy at 7 and 14 days of immersion in distilled water [14].

The filling capacity of the two materials, as well as the water contact angle, solubility, flowability, roughness, crystalline microstructure, pH and compressive strength were also evaluated. The antibacterial results were evaluated by agar diffusion as well as by direct tests. All results were statistically analyzed using one-way or two-way analysis of variance tests. Statistically significantly lower percentages of significant voids were observed for CS at 2 and 8 mm WL compared to those for the BR group, while no significant difference was observed at 5 mm WL. The BR sealant exhibited higher alkaline pH, rougher surface, lower water contact angle values, lower flowability and higher solubility compared to CS. BR exhibited a globular and acicular crystalline microstructure, while CS exhibited a globular and floral crystalline microstructure up to 72 h. No statistical difference was found for compressive strength between the two sealants. BR and CS showed no antibacterial effect against Enterococcus faecalis after 3 h, while both showed antibacterial capacity after 24 and 72 h. BR showed higher antibacterial activity after 24 hours. Sealants may play an important role in controlling bacterial growth. In addition, CS may have a higher filling capacity and lower solubility than BioRoot sealant due to its specific chemical composition and mixing method [14].

In his study, Darade L, et al., claimes that Endosequence BC Gutta-Percha (which is gutta-percha points impregnated with nano-particle BC) used with Endosequence BC sealer under a hydraulic condensation technique have the advantages that the remaining moisture in the canal and the natural moisture in the dentine enhaces setting of the cement; antimicrobial properties (pH >12); the sealer expands, it doesn't shrink and it is insoluble in tissue fluids [15].

Also claims that BC sealers do not shrink, but slightly expand during setting and if the canal is overfilled during the obturation, BC will not induce inflammatory response.

Keywords

Sealants; Bioceramics; Tissue Regeneration; Bioceramic Materials

Contribution Note

All the authors equally contributed to the drawing up of the present paper.

Conflict of Interest

The authors did not report any potential conflicts of interest in research, authorship and/or publication of this article.

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DOI: https://doi.org/10.46889/JDHOR.2022.3311

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Niculescu M | Volume 3; Issue 3 (2022) | JDHOR-3(3)-073 | Editorial

Citation: Niculescu M, et al. Bioceramic Sealants: A Review. J Dental Health Oral Res. 2022;3(3):1-8.

DOI: https://doi.org/10.46889/JDHOR.2022.3311