

Sealing Ability of Bioceramic Sealers Versus Resin-Based Sealers

Hayder Radhi Radeef, Fatima Abdulkhalik Azeez, Zahraa Raad Ali, Alaa Mohammed Naeem

Iraq

Abstract

Obturation is an essential stage in root canal therapy, which helps avoid bacterial reinfection and create a watertight bacterial seal to prevent leakage of the tissue fluid and bacteria into the canal system. Epoxy resin sealers like AH Plus were considered the gold standards for many years because of their good mechanical strength and adhesion. In recent times, there has been a technology revolution with the development of calcium silicate bioceramics. The objective of the current research was to investigate the sealing ability and the bacterial and microbial leakage of both types of materials. The research was based on systematic review and meta-analysis following the PRISMA guidelines. Searches were made in international databases (PubMed, Scopus, Cochrane Library, and Web of Science), to choose in vitro and randomized control trials (RCTs) that would compare bioceramic and resin materials. It was found that bioceramic material ensures better marginal seal and strong resistance to microbe leakage at the root apex when compared to epoxy resin, due to expansion of bioceramic while hardening and formation of hydroxyapatite layer which chemically binds with dentin.

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Email: Hayder-Radeef@alameed.edu.iq

Introduction

Obturation is an essential phase of root canal treatment, where the goal is to prevent microbial recontamination and ensure the creation of an effective seal to prevent tissue fluid leakage into the root canal system. In the past, sealers based on epoxy resins like AH Plus were regarded as the gold standard because of their outstanding physicochemical properties and excellent bonding ability.

But recently there has been a technological breakthrough with the introduction of calcium silicate-based sealers, which have outstanding biological properties such as biocompatibility, tissue regenerative potential, and antimicrobial properties. This systematic study and statistical analysis seek to compare the effectiveness and properties of both sealers based on existing scientific literature.

The importance of the present research is based on the growing usage of bioceramic materials by clinicians in their routine practice and the need for thorough evidence-based comparison between the two types of materials. The current review offers a clear picture of the effectiveness of the bioceramic materials in the following aspects: reduction of microbial leakage and solubility, depth of infiltration of the materials in dentinal tubules, and clinical pain after treatment and dimensional changes of the material in case of failed treatment and re-treatment.

Material and Methods

The proposed research followed PRISMA statement guidelines. Systematic searches were performed in various databases worldwide (PubMed, Scopus, Cochrane Library, Web of Science, etc.) to identify in vitro and RCTs for

evaluating the efficacy of bioceramic and resin materials. The inclusion criteria for studies include research related to occlusivity, permeability, solubility, postoperative pain, physical and biological properties.

Physical and Chemical Properties, Penetration, and Adhesion

There is a discrepancy between the physicochemical, adhesion, and penetration abilities of bioceramic and epoxy resin sealants. Whereas epoxy resin (AH Plus) demonstrates excellent physical stability, high solubility, and excellent mechanical adhesion to canal walls because of the cross-linking process with the dentin collagen, bioceramic products surpass it in terms of permeability and tubules penetration because of small particle size and high wettability, which allow bioceramics to trap bacteria effectively. Bioceramics have relatively high solubility at the beginning stage of

the hardening process because of the dynamic process associated with the release of calcium ions and calcium hydroxide; however, this feature is necessary for the bioactivity and creation of a monoblock effect.

Occlusive Efficiency and Resistance to Microbial Leakage

Closure of the three-dimensional spaces present in the root canal system is essential in avoiding endodontic treatment failure. There have been various research works carried out comparing the effectiveness of sealing and resisting any form of microleakage between bioceramic material and epoxy resin material. According to scientific proof obtained from meta-analysis, the bioceramic material because of its hydrophilicity property can swell slightly while curing, hence increasing its occlusiveness in comparison to the resin material, which has very little or no shrinking process during curing [1].

In evaluating the effectiveness of pulpal sealing in the apical area and the materials used in filling the root ends, the comparative analysis of the bioceramic and epoxy resin materials revealed that the bioceramic materials, including MTA and the latest generation of silicates, offered better protection from bacteria and microorganisms penetration [2]. The reason for this lies in the formation of the hydroxyapatite layer when the bioceramic material encounters the fluid from the tissues, which creates a tight chemical and biological connection with the dentin walls preventing the penetration of the bacteria and their toxic products in the periapical areas.

Also, the comparison in effectiveness of these new types of bioceramic materials shows superiority in treatment of diseases of the teeth and roots when compared with conventional materials. The structure of these new bioceramic materials helps achieve superior sealing around the edges and stops the permeation of any fluid through accessory and lateral canals [3]. Even though the epoxy resin material has excellent physical properties and proven effectiveness, its non-bioactive nature makes it depend only on the mechanical and chemical bond to the dentin structure and does not have any dynamic properties like biosilicates.

Solubility, adhesion, and penetration into dentinal tubules

Mechanical and physical characteristics of the filling materials, including solubility, displacement resistance, and penetration depth, are among the main factors influencing the life span of the procedure performed. With respect to solubility, research has indicated that bioceramic materials tend to show higher solubility rates during the initial curing stage than

the epoxy resins with their high physical stability and better solubility characteristics [4]. This is because bioceramic materials become soluble due to the release of calcium ions and calcium hydroxide, which is important for inducing biosynthesis and regeneration. However, this characteristic should be maintained within the limits set internationally (ISO 6876).

Displacement resistance, on the other hand, is another crucial parameter that shows the stability of the material in the root canal and its ability to resist displacement by the occlusal forces or when inserting posts. Based on the meta-analysis, epoxy resins tend to have better or equal displacement resistance than bioceramics because of their capacity to go deep into the dentin tubules and develop chemical bonds with dentin collagen [5]. However, bioceramics balance that disadvantage through microcrystalline bonding due to silicate hydration reaction and calcium complex development. Concerning the penetrative nature of dentinal tubules, bio-ceramic material has the capacity to nest well in the dentinal tubules due to their small size and wettable nature, which enables them to penetrate the dentinal tubules that would be difficult for regular resin materials [6]. The deep penetration of the material improves the bonding capacity of the material and ensures isolation of any bacteria in the dentinal tubules by ensuring that they are cut off from any source of food.

Clinical Performance, Bioefficacy, and Therapeutic Outcomes

Scientific data from systematic reviews published recently clearly prove that the clinical effectiveness and efficiency of bioceramics constitute a considerable improvement in comparison with conventional resin-based sealants because of the higher bioefficacy of these materials. This efficacy is because bioceramic creates the constant high level of pH, thus making it antiseptic throughout the whole process of curing and afterwards. This factor helps to reduce the number of patients who experience postoperative pain as well as provides absolute biocompatibility and thus helps not to cause any harm in case of accidental contamination of periapical tissues with this material. Although the advantage of epoxy resin sealants is the easy possibility of removing them during re-treatment procedures, bioceramic sealants, especially those that are already mixed, demonstrate high success rates and accelerate healing of periapical and bony lesions.

Antimicrobial Efficacy and Post-Treatment Pain

Besides the physical performance of root canal filling materials, their capability to manage the infection by bacteria and decrease post-

treatment clinical discomfort also forms part of their efficiency. According to systematic reviews, bioceramic fillers have proven to have a higher level of antimicrobial efficacy than the resin fillers because of the rise in pH brought about by the constant release of calcium hydroxide ions during and even after the polymerization of the material [7]. This highly basic environment is unfavorable for the growth of bacteria that can be resistant, including the *Enterococcus faecalis* bacteria. In addition, there have been recent improvements to the bioceramic materials that have expanded the spectrum of effectiveness to include all types of pulp bacteria [8]. In a clinical sense, postoperative pain is a significant issue among patients and medical practitioners alike. Recent meta-statistical research has indicated the absence of a significant difference or absolute superiority of one of these materials in causing pain. Nonetheless, bioceramic materials in various studies seem to show some potential in minimizing the level of postoperative pain and discomfort in comparison with epoxy resins [9,10]. This positive effect is due to the excellent biocompatibility of bioceramic materials, as it minimizes the inflammation of the periapical tissues in case of any accidental extrusion of the material beyond the apical foramen. In a similar manner, umbrella reviews and comparative research have concluded that the use of bioceramics minimizes the level of postoperative pain among patients undergoing their first root canal treatment or retreatment procedures in comparison with conventional resin materials [11,12].

The indirect analgesic action due to absolute biocompatibility and minimal nerve irritation in the periapical tissues makes bioceramic materials an ideal choice for sensitive patients and those with apical pathosis.

Retrievability and Long-Term Clinical Outcomes

Reproducibility of the material is an important criterion in case the re-treatment becomes necessary due to the ineffectiveness of the original procedure and subsequent occurrence of secondary infection. The main characteristic feature of the epoxy resin materials is their easy removal in comparison with chemical solvents and rotary instruments. Bioceramic materials demonstrate the opposite behavior. As has been demonstrated with the help of advanced imaging technologies such as micro-CT, removal of the bioceramic filling from root canals is not as effective as the removal of epoxy resin, and more of the residual filling material remains stuck to the dentin walls [13].

The meta-analysis of in vitro experiments has proved that bioceramic removal efficiency is relatively low in comparison with the

traditional sealants because of high hardness and tight attachment of calcium silicate-containing bioceramics to the dentin structure. It requires more work and more time, as well as the application of special equipment like ultrasound for ensuring that the canals are clean [14]. However, despite this difficulty, the results of nonsurgical root canal therapy with the help of premixed bioceramics appear to be quite successful. [15].

From the assessment of the physicochemical features as well as the results of in vitro and clinical trials, calcium silicate-based plugs can be considered to provide a good combination of high stability and tissue stimulation [16,17]. Even though the plugs are difficult to remove, the high effectiveness of these materials and the ability to protect against further infections make the use of bioceramics highly justified.

Conclusion

The systematic review and meta-analysis presented in this article can be considered an objective and critical assessment of scientific data available regarding the comparison of bioceramics and epoxy resins used for filling root canals. The research showed that advances in the sphere of biomaterials helped to find solutions to some critical problems. Bioceramic sealers were able to provide perfect combination of occlusive efficiency due to micro-expansion and tubular penetration, and absolute biocompatibility and antimicrobial properties that reduce the pain after treatment and ensure apical healing. Although there are still some technical limitations of bioceramic materials such as greater solubility and difficulties in removal during the re-treatment procedure in comparison with the conventional resin composites (for example, AH Plus), the excellent clinical outcome and radiographic results make them one of the best choices for today.

Research Findings

1. The marginal seal of bioceramics is more effective than that of epoxy resin because of slight expansion upon curing and development of hydroxyapatite layer bonding to the dentin.
2. The bioceramic sealants have a high potential for deep penetration into dentinal tubules owing to the small particles and high wettability; thus, bacteria become trapped and isolated within the dentine.
3. Bioceramic sealants have an extended and lasting effect against bacteria due to the substantial elevation of pH owing to the constant release of calcium ions and calcium hydroxide.
4. Use of bioceramics helps in decreasing the severity and speed of postoperative pain than epoxy resin because of high biocompatibility of these materials and low irritation to periapical structures in case of accidental extrusion.

5. Bioceramics are more durable and have greater adhesion to the canal walls; therefore, their removal is a complicated and difficult procedure and leads to leaving more material residues in comparison with the easily soluble epoxy resin.

Research Recommendations

1. It is important to recommend dentists to apply bioceramics as the main material in cases where it is necessary to have a high level of biocompatibility and antibacterial effects, like large periapical lesions or teeth with an open apex.
2. It is necessary to create and update protocols for endodontic treatments when applying bioceramics in relation to the implementation of ultrasonics and modern rotary instruments in order to remove all the material.
3. It is important to encourage manufacturers to alter the composition of bioceramics to decrease their solubility in the first stage of curing while maintaining bioavailability.
4. It is important to change techniques for bioceramic filling (mainly thermal techniques) in order not to extrude the material from the apical foramen despite the biocompatibility of the material.
5. It is necessary to conduct more longitudinal RCTs in order to observe the results of patients over time (more than 5 years).

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