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Review Article

The use of Bioceramic Cements in the Obturation of the Root Canal System

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Abstract:

As one of the main areas of Dentistry, Endodontics aims to repair periradicular tissues, allowing the affected tooth to reestablish its functions through its treatment. With this objective in mind, different types of root canal sealers (RCS) have been created in order to improve the healing of desired tissues. The main objective of this work is to analyze, through a literature review, studies on the use of second generation bioceramic cement in the voids of root canal systems, highlighting the essential properties in its clinical use, its advantages and disadvantages, and also compare its effectiveness with the oldest cements on the market. The methodology used was bibliographic research, exploring in sources such as research articles, meta-analysis and clinical trials published in Portuguese and English, selected through the search descriptors PubMed, Lilacs and Scielo. The results of the studies showed the efficacy in the use of bioceramic cement in the voids of root canal systems, since they have the ability to fill and seal, manifesting dimensional stability, avoiding the recontamination of the canals, among other benefits. However, in relation to retreatment, this type of sealer presented some difficulties in its removal when traditional techniques were used, being indicated to associate the use of mechanized techniques to improve its removal. It could also be observed the need for further studies in this area, as the analyzed studies have limitations, due to such types of cements being still relatively new to the market, meaning that the long-term success rate of the treatment is still unclear.

Key words: root canal sealers; hydraulic root canal sealer; root canal treatment; bioceramics; bioactivity

Abbreviations:

RCS : Root Canal Sealers

SC obturation : Single Cone Obturation Technique

CSBS : Calcium Silicate-Based Sealers

MTA : Mineral Trioxide Aggregate Sealers

Introduction

The endodontic treatment can be simplified into three main phases: the coronal access, the cleaning and shaping of the canal and the obturation of the root canal system, with neither phase being of greater importance than the other. However, as Siqueira [1] states, a special attention to the obturation phase must be given due to the need of eliminating empty spaces previously occupied by the pulp tissue, that can serve as voids to the proliferation of unwanted microorganisms. In order to improve the tridimensional sealing of the root canal and to promote further healing of the periradicular tissue new types of RCS's, such as bioceramic cements, have been created. These new materials have increased adhesive capabilities due to its ability to produce hydroxyapatite, which provides a direct bond between the dentin and the cement, known as tubular diffusion, as stated by Reyes-Carmona [2].

These materials also have further benefits, since they use the moisture naturally present in the dentinal tubules to commence and complete their setting reaction, due to their hydrophilic and insoluble nature. They are also nontoxic, biocompatible and chemical stable in biological ambient, which make then ideal for use by Dental professionals as Zamaprini [3] described.

Such characteristics are desirable for RCS, however, bioceramic sealers also have undesirable features, especially in regards to the retreatment therapy of the root canal. As stated by Bek Kurklu [4] it is not known how the bioceramic pastes are removed and how they affect the adhesion of self-etch adhesives on coronal dentin, which can be a challenge for the Dentist aiming to rehabilitate a tooth that needs devices such as intracanal poles, that requires for partial removal of the Gutta-Percha and endodontic cement from the root canal.

It is also primordial to emphasize that bioceramic sealers were first developed to be used in conjunction with cold obturation technique, in particular with the single cone obturation technique (SC obturation), as Donnermeyer [5] states in his systematic review, meaning that the Dentist should diverge from the traditional lateral condensation obturation technique. Therefore, according to Alegre [6], the common view of maximum Gutta-Percha material and minimal sealer became obsolete, as bioceramic cements have superior flow, antibacterial and biological capabilities when compared to traditional sealers, meaning that a high sealer proportion was no longer though as a disadvantage.

On the other hand, Schilder [7] observed that during the SC obturation the gutta-percha and calcium silicate-based sealer requires a low condensation pressure, making this type of obturation incapable of adequately filling any complicated root canal anatomy. For this reason, modern bioceramic sealers complement the SC technique, filling empty spaces in the canal that are difficult to access with the single Gutta-Percha cone. Therefore, the aim of this article is to evaluate previous articles, researches and meta-analyses about the performance of such RCS. Moreover, more data is required in order to have a complete understating about the long-term results of these materials.

Ideal RCS Properties

For the purpose of a successful endodontic treatment, an RCS should have specifics characteristics that allow them to thrive in the obturation of the canal. Authors such as Grossman [8] described the ideal proprieties that any root canal filling material must have:

I. The material should be easily introduced into the root canal.
II. It should seal the canal laterally as well as apically.
III. It should not shrink after being inserted.
IV. It should set slowly.
V. It should be impervious to moisture.
VI. It should be bactericidal or, at least, should discourage the growth of bacteria.
VII. It should be radiopaque.
VIII. It should not stain the tooth structure.
IX. It should not irritate periradicular tissues or affect the tooth structure.
X. It should be sterile, or easily and quickly sterilized immediately before insertion.
XI. It should be easily removable from the root canal if necessary.

With these goals in mind, a bioceramic cement must also comply to a certain level of requirements, such as:

a) Biocompatibility. Biocompatibility is an essential requirement for any RCS, as such materials will have some level of contact with vital tissue. Williams [9] defined it as the ability of a material to achieve a proper and advantageous host response in specific applications, meaning that the material should not trigger any adverse response from the patient organism when applied. Most bioceramic sealers are considered to be biocompatible, as most of them have calcium phosphate in their composition, an inorganic material present in hard tissues such as bone and teeth. Consequently, works such as Haddad [10] concluded that many bioceremic cements have the potential to promote bone regeneration when extruded through the apical foramen during root canal filling or when used for repairs of root perforations.

b) Setting Time. The ideal setting time for any RCS sealer is enough time for the Dental Professional to properly obturate and seal three-dimensionally the canal. It is important to observe that a slow setting time could result in irritation in biological tissues, as most RCS produce some degree of toxicity until being completely set. Some Bioceramic manufactures even imply that their sealers can accelerate their setting time when in contact with moisture present in the dentinal tubules, which is a different behavior when compared to traditional RCS. Yang [11] explained in his patent that while the normal setting time for bioceramic RCS is four hours, in patients with particularly dry canals, the setting time might be considerably longer, implying that the amount of moisture in the dentinal walls is affected by the use paper points, presence of smear layer, tubular sclerosis or any fact that may interfere with how damp the root canal is during its obturation.

c) Flow. This is an important property that allows the material to enter narrow spaces present in the canal, such as irregularities of the dentin, isthmus, accessory canals, and voids, that the Gutta-Percha is not able to enter. Entities such as the International Organization for Standardization (ISO) [12], described that the RCS should have a flow rate of not less than 20 mm. This means that cements with superior flow rate have a greater capability of penetrating lateral, accessory and many others ramifications of the canal, that may serve as proliferation areas for microorganisms.

d) Solubility. Solubility refers to ability of the material dissolving itself in the presence of water. According to ADA [13], the solubility of a root canal sealer should not exceed 3% by mass. In endodontics, this means that sealers with high solubility rate are undesirable, since moisture can lodge itself in dentil irregularities, voids and anatomic variations.

e) Radiopacity. Raman [14] explained that is also known as Radiodensity, and it can be resumed as the ability of a material to be visible in a radiographic exam. For RCS, they should be sufficiently radiopaque in order to be distinguishable from adjacent anatomical structures and other dental materials. According to the ISO, the minimum radiopacity for an RCS is based on a reference standard of 3.00 mm of aluminum.

f) Adhesion. This property is defined as the capability to adhere to the root canal dentin and promote Gutta-Percha cone adhesion to the RCS and the dentin wall. There is no standard to measure the adhesion of an RCS, however, such materials should have enough adhesion to the dentinal walls in order to properly seal the root canal three-

dimensionally, impeding the microleakage of the obturation as Schwartz [15] highlights.

g) Discoloration of Tooth Structure. As the tooth is an aesthetic organ, an RCS should not interfere in the tooth coloration. Studies of this specific topic, such as Ioannidis [16], emphasizes that when an excess of sealers is not removed from the coronal dentin of the pulp chamber, they can affect the dental chroma structure.

h) Antimicrobial Properties. One of the most important properties for any RCS refers to the ability to prevent the proliferation of any source of microorganism in the root canal. According to Desai [17], the key antimicrobial to RCS´s properties of lie in their alkalinity and release of calcium ions, that stimulate repair through deposition of mineralized tissue. There are two main methods to evaluate the antibacterial activity of bioceramic-based RCS, the agar diffusion test and direct contact testing, as both Tanomaru-Filho [18] and Morgental [19] asserted in their articles.

i) Retreatability. Retreatbility refers to how difficult is to remove completely an RCS in order to retreat the root canal, this is necessary when the length of the obturation is insufficient or when the obturation does not properly seal the canal. For a successful retreatbility endodontic treatment it is fundamental for the complete removal of any material used in the obturation of the root canal, such as RCS. Nevertheless, as previously assessed, bioceramic RCS have a strong adhesion into the dentinal walls, which requires different protocols for its removal as shown by Martins [20] in his work about the use of mechanical systems and irrigation protocols with chemical agents to remove filling materials.

Types of Bioceramic Sealers

In order to analyze and understand the use of bioceramic sealers, it is necessary to know the different types and compositions currently available in the market. They can be segregated into four main compositions: Calcium Silicate-Based, Mineral Trioxide Aggregate (MTA), Tricalcium Silicate and Calcium Phosphate-Based Sealers.

a. Calcium Silicate-Based Sealers. Unlike conventional root canal sealers, Calcium Silicate-Based Sealers (CSBS) have a particular setting process, as described by Donnermeyer [5], they produce calcium hydroxide by hydration, which affects water sorption and solubility. Therefore, these materials can use moisture present in the canal to accelerate their setting time creating a mineral layer that induces a chemical bond with dentin walls, which contributes to their sealing ability as Silva Almeida [21] infers in his systematic review of in vitro studies. Authors such as Asawaworarit W [22] concluded that the calcium silicate sealer exhibited a better seal after complete setting when compared to traditional RCS.

b. Mineral Trioxide Aggregate Sealers (MTA). According to Cervino [23], MTA sealers were developed for dental root repair in endodontic treatment and it is formulated from commercial Portland cement, combined with bismuth oxide powder for radiopacity. They represent an optimum option for pulp capping, perforation repair, root-end filling and apical barrier producers due its bioactive properties, however, Parirokh M [24] implied that its long setting time and difficult handling properties are among its recognized downsides. It is also important to emphasize that there are different compositions for MTA sealers, with studies like Ahuja L [25] evaluating the apical microleakage of MTA RCS and other materials, highlighting that the ProRoot® MTA from Denstply Sirona have calcium silicate-based materials, while the MTA Fillapex from Angelus does not.

c. Tricalcium Silicate Sealers. These materials aim to have the save advantages as CSBS, interaction with the root canal wall, alkalinity with antimicrobial potential activity and the ability to set in a wet field, while having a different composition. One particular advantage when compared to CSBS is the ability to be used with both warm and cold obturation techniques, depending on the commercial product, as Aminoshariae [26] affirmed.

d. Calcium Phosphate-Based Sealers. Similar to Tricalcium Silicate Sealers, Calcium Phosphate-Based Sealers aim to replicate the same clinical properties as CSBS. Nonetheless, there are a plethora of Calcium Phosphate Sealers in the market, with some even having Calcium Silicate in their composition. Overall, these materials may improve the sealing ability, as Zamparini [27] concluded in his work, since they deposit Calcium Phosphate at the material-root dentine interface, which could promote bone and periodontal tissue regeneration in situations such as endodontic surgery.

Discussion

Authors such as Nagas [28], Zang [29] and Chybowski [30] identified in their respective works that bioceramic sealers have been introduced into endodontics mainly due to their biocompatibility. This ability is fundamental for the repair of periradicular tissue as Jung [31] described in his ex vivo study of the biocompatibility of root canal sealers on human periodontal ligament cells. In relation to both chemical and physical properties of the bioceramic RCS, Zamparini [32] in his meta-analysis and Lee [33] in his review exposed that these RCS have excellent flow, dimensional stability, adhesion and enough setting time for the Dental professional to successfully repair the desired tissues. Out of the main characteristics of such RCS, the biocompatibility and adhesion or sealing potential are the biggest advantages of bioceramic sealers when compared to conventional RCS. As previously stated, biocompatibility refers to the ability to heal vital tissue without any harm, while the sealing of the root canal is fundamental to ensure long term success of the endodontic treatment. Ferreira [34] evaluated the dentinal tubule penetration of two tricalcium silicate–based sealers in an ex-vivo study using a confocal laser scanning microscopic. This research, revealed the correlation between the obturation technique and the sealer, where the warm obturation technique may cause the sealer to lose moisture due to the heat generated during obturation, affecting the adhesion and flow of the material, corroborating with past researches like Camilleri [35]. With the different compositions of bioceramic RCS, confocal laser scanning microscopy studies like Martins [36] are fundamental to understand that calcium silicate–based sealers have different behaviors to tricalcium silicate–based sealers. In her research, Martins showed that the results suggest that the lateral condensation technique promoted a higher percentage of root canal perimeter penetrated by a ready-to-use CSBS than the single cone technique in the apical segment of mandibular premolars after endodontic retreatment, opposing the results obtained by Ferreira. Both articles present themselves as relevant studies for the Dentist, as they give scientific support for different obturation techniques. Ghoneim [37], in his comparative study, stated that in relation to the resistance to fracture in endodontic treated teeth, bioceramic cements have increased strength when compared to epoxy resin-based sealers and glass ionomer cements. It is also primordial to analyze clinical studies about the use of bioceramic

sealers, as demonstrated by Li [38] in his research about the clinical outcome of iRoot SP extrusion in root canal treatment and Toubes [39] in her two case report about the use of Bio-C Repair for root perforation management. Both authors concluded that their respective sealer used during each research proved a successful material, with the iRoot SP overall success rate for teeth with sealer extrusion being 95.8%, with 69.4% healed, 26.4% healing, and 4.2% unhealed in Li´s study and Toubes´s Bio-C Repair demonstrating that could be an effective therapeutic alternative to MTA, as observed at one-year follow-ups. Regarding the retreatability of such materials, Jamleh [40, 41] evaluated in two studies different retreatbility scenarios, which implies that bioceramic RCS requires a special attention from the Dentist, as they are significantly harder to completely remove when compared to traditional RCS. Firstly, Jamleh [40] assessed the influence of bioceramic RCS on force and torque generation during retreatment, and then compared the retreatability of the AH Plus and TotalFill bioceramic sealer in latter research [41]. In both studies were used mechanized instruments, which emphasizes the need for specific techniques in order to have a successful retreatment therapy of bioceramic sealers.

Conclusion

After the analysis of several articles and researches, it is clear that bioceramic cements are a valuable tool for the dentist, as they have desirable characteristics, like their physical and chemical properties with considerable few drawbacks as other literatures reviews like Lim [42] concluded.

These materials can be used in a plethora of situations, such as root perforations, normal endodontic therapy and sealer extrusion. They can also have a higher healing and sealing ability when in contrast with resin epoxy sealers, with increased success rate as they have a low cytotoxicity, but a general higher bioactivity, due to the liberation of Calcium as demonstrated by Badawy [43].

Their retreability still is the main disadvantage in comparison to other types of sealers, however, the outcome of this study through the evaluation of many articles is that bioceramic cements are an excellent filling material when used correctly.

Conflict of Interest

The authors declare the absence of any conflict of interest.

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