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Physical and Biological Properties of Calcium Silicate Based Sealers: A Literature Review

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Abstract

The main aim of root canal therapy is the removal of microbial contaminants in conjunction with the total closure of the root canal system. Root canal sealers along with solid core material plays a major role in achieving the three dimensional sealing of the root canal system. Root canal sealers, although used only as adjunctive materials in the obturation of root canals, have been shown to influence the outcome of endodontic treatment. These sealers are binding agents which are used to adapt the rigid gutta-percha to canal walls and to fill up the voids, accessory canals and irregularities within the canal. A perfect combination of sealing ability and biocompatibility is what an ideal root canal sealer should possess.

The choice of sealer is not only dependent on its ability to create a sound seal, but it must also be well tolerated by the periradicular tissues and be relatively easy to manipulate so that its optimum physical properties can be achieved. Even though predictable clinical results have been obtained with the use of nonbonding root canal sealers there has been a continuous search for alternative sealers that bonds to root canal dentin as well as filling materials.

This literature review was conducted to survey the biological and physical properties of calcium silicate based sealers.

Keywords: Root canal sealers, Boiceramic sealers, calcium silicate based sealers, Physical properties.

Introduction

The long-term success of endodontic therapies relies on complete filling after root canal obturation. Microleakage is one of the main reason for endodontic failure, which occurs because of improper contacts between the sealer and the dentin, the gutta-percha and the sealer, or through voids within the sealer.

The poor adaptability of a sealer to the dentin is the primary factor resulting in reinfection of the root canal and microleakage.

Sealers can be categorized based on their basic chemical composition including zinc oxide eugenol, calcium hydroxide (CH), glass ionomer, silicone, resin and bioceramic based sealers[1].

Calcium and Silicate based Cements such as mineral trioxide aggregate (e.g., ProRoot MTA, Dentsply Sirona, York, USA) or Biodentine (Septodont, St. Maur-des-Fossés, France) have been introduced to the market over the past 20 years. These cements are used for many clinical applications such as pulp capping in primary and permanent teeth, root-end filling, perforation repair, and apical plug for teeth with open apices owing to their excellent sealing ability and biocompatibility. With regard to the favorable characteristics of calcium silicate-based cements, endodontic sealers based on the compositions of calcium silicates have been introduced later. In 2007 first bioceramic sealer based on calcium and silicate was introduced iRoot SP (Innovative Bioceramix, Vancouver, Canada). Since then, other products based on calcium silicates were available[2].

Many recently-introduced calcium silicate-based sealers including EndoSequence BC sealer and BioRoot RCS has been available as premixed and injectable biomaterial, exhibiting excellent radiopaque, very minimal shrinkage, insoluble, and hydrophilic (using moisture from the dentinal tubules to initiate and complete its setting reaction) characteristics.[3]

The treatment outcome for patients has enhanced by these advancements in bioceramic technology. Biocompatibility with high osteo-conductivity makes this class of dental materials ideal for endodontic application.[1]

Calcium silicates mainly belong to bioactive bioceramics as these durable materials capable of interact with surrounding tissue. Sealers based on calcium silicate can be called as hydraulic sealers due to the hydraulic setting reaction, meaning that calcium silicate sets by reacting with water provided by tissue fluids and then is stable in water or humid conditions. The biological properties of calcium silicates depend on the formation of calcium hydroxide as a by-product of this hydration reaction.[2]

These sealers contains monobasic calcium phosphates to facilitate reaction with calcium hydroxide to produce hydroxyapatite upon activation of the sealer by water. Hydroxyapatite is co-precipitated within the calcium silicate hydrate phase to produce a composite-like structure, reinforcing the set cement.[4] This article discuss about some of the important physical and biologic properties of calcium silicate based bioceramic sealers.

Physical properties

Setting time and solubility

Setting times for tricalcium silicate-based sealers, including EndoSequence BC Sealer, also known as iRoot SP have even been shown to exceed one month. However the setting times for BioRoot RCS, Bio-C, and CeraSeal sealers are 4, 3, and 3.5 h respectively.[5]

According to one study iRoot SP set within 2.7 h respectively 4.7 h under the same conditions.[2]

In a study significantly higher solubility was observed with tricalcium silicate sealers such as BioRoot RCS and TotalFill BC sealer in distilled water than comparable market sealers of different compositions. The solubility may be attributed to the formation of calcium hydroxide during setting of tricalcium silicates, which is dissolved in the ISO 6876 solubility test.

Overall, compared to epoxy resin-based sealers, solubility of CSBS was found to be higher. Solubility of iRoot SP was also higher compared to other BC materials.

Compared to freshly set sealer, solubility of set BioRoot RCS after 7 days was relative low.

A longterm investigation of solubility found that the solubility of BioRoot RCS was in accordance with the ISO 6876 requirements even over a 6-month period when stored in phosphate buffered saline.[2]

Retreatability

Although there very few studies on the solubility of tricalcium silicate-based sealers in organic solvents like halothane, one study evaluating re-treatment found that the re-treatment of maxillary incisors containing EndoSequence BC Sealer with chloroform, an organic solvent that was formerly commonly used, was more effective than without. However, the same study found compared with AH Plus, EndoSequence BC Sealer had significantly more residual material remaining after retreatment. Acids will dissolve tricalcium silicate-based sealers, but the solubility may be too slow for re-treatment. From a clinical perspective, more practical method for removing BC sealer is using ultrasonic instruments than solvents.[5]

Sealing ability

In a study Malhotra and Hedge investigated the marginal seal of the Biodentine, MTA-Angelus, white ProRoot MTA, and glass ionomer cement as root-end filling materials using extracted maxillary central incisors and methylene blue dye. The study concluded that microleakage was present in all the four tested samples. Biodentine showed least amount of apical dye microleakage. This may be because it is easier to use and sets faster and, therefore, reduces the risk of bacterial contamination. They also found that that the dye penetration in the MTA-Angelus and ProRoot MTA is similar (no statistical difference), followed by GIC. Moreover, they revealed that the microleakage values of MTA and GIC were similar to investigations that have been previously conducted.

a combined SEM and micro-CT evaluation of the sealing ability of different root canal sealers, revealed a similar volume of closed pores was observed between the EndoSequence BC sealer and the AH Plus, which indicated that tested sealers adapted or penetrated equally to the dentin in the coronal, middle, and apical sections. Similarly, Zhang, et al investigated the sealing ability of the iRoot SP sealer and the AH Plus sealer to the apical section of teeth roots using a fluid filtration method and SEM. And the study concluded that the iRoot SP using the single-cone technique and the AH Plus using the continuous wave condensation technique were equivalent in fluid leakage. SEM also revealed that both sealers provided gap-free and gap-containing regions within the canals.[3]

in astudy, lesser dye leakage was reported for iRoot SP compared to AH Plus. The combination of iRoot SP with C Points (polymer obturation cone with expanding ability after water sorption) (Endodontic Innovations Ltd., St. Austell, UK) resulted in lesser apical dye leakage than when combined with conventional gutta-percha single cones. No difference for apical leakage was found between iRoot SP and AH Plus by fluid filtration methods in several studies. However, a few studies reported higher apical leakage for iRoot SP compared to AH Plus. Another fluid filtration study showed, iRoot SP provided a better sealing ability than MTA Fillapex. A similar bacterial leakage of Enterococcus faecalis was found after obturation with iRoot SP compared to AH Plus in a study.

Obturation using Endo CPM caused and was associated with significantly higher bacterial leakage of E. faecalis compared to AH Plus and also significantly higher dye leakage compared to Sealapex (Kerr, Orange, USA) , MTA Fillapex or AH.[2]

Yang et al. studied the sealing ability of Capseal I and II using a field emission scanning electron microscope. The study showed that both Capseal I and II sealers infiltrated into the dentinal tubules and they were well adapted to the canal walls.[6]

Tooth discoloration

Endodontic therapy should not only focus solely on biological and functional aspects, but also must take aesthetic considerations into account. To reduce the risk of tooth discoloration, all endodontic sealers should be applied carefully in areas of aesthetic concern.

Bioceramic sealers may discolor the tooth into brown (in contact with NaOCl), gray (in contact with chlorhexidine) or even black (in contact with glutaraldehyde). To prevent discoloration,

bismuth oxide radiopacifier has now been replaced with other materials such as zirconia dioxide (zirconia) or tantalum oxide in bioceramic sealer formulations.

Regarding calcium silicate-based sealers, there are only few publications concerning tooth discoloration. In case iRoot SP was used for obturation, tooth discoloration was comparable to AH Plus in an in vitro study over a 6-month period. In athother study over a 2-month period the same results were found for Endoseal MTA.[2]

MTA-Fillapex, Endosequence BC, AH-Plus and Endoseal led to the least crown discoloration that was clinically undetectable compared to Roth 811 (a ZnO sealer).

The discoloration potential of bioceramic sealers when come in contact with Sodium hypochlorite irrigant is an important issue need to be concerned. As stated by Marciano, each material contains bismuth oxide in composition can cause discoloration in contact with sodium hypochlorite. It could be an issue to be concerned about MTA Fillapex and other bismuth oxide containing sealers. In addition, discoloration induced by MTA Fillapex and AH-26 sealers can be efficiently managed by internal bleaching.[1]

Antibacterial effect

Calcium silicate-based materials are known to have a high alkalizing ability as a result of the hydration process. A high (alkaline) pH value is of major significance in terms of antibacterial ability, biocompatibility, and osteogenic capacity. Alkaline materials, with a high pH, are likely able to neutralize the lactic acid secreted from osteoclasts, thereby preventing the absorption of mineralized tooth structure. In this way, hard tissue formation is induced by the activation of alkaline phosphates, favoring the healing process of periapical tissues in general.

Antibacterial activity of Endo CPM and MTA-Fillapex against Enterococcus faecalis using an agar diffusion test after mixing and a direct contact test after setting showed that the pH of the Endo CPM suspension was greater than that of MTA-Fillapex (>11); however, the bacterial inhibition zone produced by MTA-Fillapex was greater than that produced by Endo CPM.

MTA-Angelus sealer consists of tricalcium silicate, dicalcium silicate, tricalcium aluminate, tetracalcium aluminoferrite, bismuth oxide, iron oxide, calcium carbonate, magnesium oxide, crystalline silica, and residues (calcium oxide, free magnesium oxide, and potassium and sodium sulfate compounds). Several investigators have evaluated the antibacterial effect of MTA-Angelus. They found that this sealer has an antibacterial effect again Micrococcus lutes, S. aureus, Escherichia coli, Pseudomonas aeruginosa, and Candida albicans when compared to Portland cement.[6]

Biocombatibility

MTA-Fillapex is a bioactive root canal sealer consisting of two pastes. Paste A contains salicylate resin, bismuth trioxide, and silica and Paste B contains silica, titanium dioxide, MTA (40%), and resin. After mixing the material, a semipermeable structure is formed with MTA dispersed throughout. Therefore, according to some investigators, MTA activity is possible due to permeability of the mixed materials, in which alkaline pH explains its extended antibacterial action. Some workers have investigated the cytotoxicity of MTA-Fillapex and EndoSequence BC sealers in culture of mouse L929 fibroblasts. The results revealed that both the sealers had a moderate cytotoxicity effect when freshly mixed. They added that MTA-Fillapex showed cytotoxicity for all tested incubation periods. They explained these findings by its chemical composition.[6]

In an another study Genotoxicity of bioceramic-based sealers were found to be less than AH-Plus sealer. Both MTA and calcium silicate based cements were compatible with MG63 cells, and they were not cancer causing agents. Also MTA and Portland cements were found to be not genotoxic and were not able to induce cellular death.[1]

Furthermore, MTA-Fillapex has demonstrated irritating effects on subcutaneous connective tissue and bone tissue. Thus, according to some studies, despite of the presence of MTA, this material may not have biological advantages. A study by Jafari et al. revealed that MTA-Fillapex exhibited severe cytotoxicity on human fetal foreskin fibroblast cell line. However, it was observed that this cytotoxicity decreased over time until being completely set.[6]

iRoot SP is an injectable, premixed radiopaque, insoluble bioceramic root canals sealer. It is composed of calcium silicate, zirconium oxide, calcium phosphate, calcium hydroxide, filler, and thickening agents. Calcium silicate represents the main constituent that can generate calcium silicate hydrates in the presence of water, resembling Portland cement. Some investigators have compared the cytotoxic effects of MTA and iRoot SP on the cell viability, hard tissue deposition capacity, and odontogenic differentiation of human tooth germ stem cells using tissue culture. The results demonstrated that MTA and iRoot SP exhibited no cytotoxicity and induced stem cell differentiation into odontoblast-like cells, but Dycal (controls) caused cytotoxicity ($P < 0.05$) of almost all of the cells after 7 days. They added that MTA resulted in more efficient cell interaction and ability to stimulate mineralization process compared with iRoot SP.

Radiopacity

iRoot SP, BioRoot RCS, Endoseal MTA, and Endo CPM were reported to fulfill the requirements laid down in the ISOnorm 6876:2012 with a radiopacity greater than 3 mm aluminum thickness.

Candeiro et al reported the radiopacity of EndoSequence BC Sealer to be 3.83 mm. Endo CPM sealer was found to have a radiopacity of 6 mm due to the presence of bismuth trioxide and barium sulphate. Similarly, the presence of bismuth trioxide in MTA-Fillapex gives it a radiopacity of 7 mm.[9]

Adhesion

Root canal sealer adhesion is defined as its capacity to adhere to the root canal dentin and promote GP cone adhesion to each other and the dentin. strong bond between the root canal sealer and the root dentin is essential for maintaining the integrity of the sealer-dentin interface during the preparation of post-spaces and during tooth flexure.

Bioceramic-based sealers have the ability to create bonds between the dentin and core filling materials. The bonding of iRoot SP to root dentin is comparable to that of AH Plus and stronger than either Sealapex or EndoREZ sealers.[10]

Shokouhinejad et al evaluated the bond strength of EndoSequence BC Sealer compared to AH Plus in the presence and absence of a smear layer, finding that the dislocation resistance of EndoSequence BC Sealer was equal to that of AH Plus and with no significant effect on the smear layer.[11]

Testing the bond strength at the coronal third of the root canal shows no significant difference between MTAFillapex, iRoot SP, and AH Plus. However, in middle and apical thirds, iRoot SP and AH Plus have equivalent bond strengths superior to MTA-Fillapex.[12]

As compared with AH Plus, Epiphany, and MTA-Fillapex, iRoot SP had the highest dislodgment resistance from the root dentin.[13]

Conclusion

Bioceramic-based root canal sealers show promising results as root canal sealers. However, discrepancies in the results of these studies reveal that these sealers do not fulfil all of the requirements demanded of the ideal root sealer. Further studies are required to clarify the clinical outcomes associated with the use of these sealers.

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