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Bioceramics as Root Canal Sealers: A Review

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Abstract: ***Epoxy resin-based sealers which are currently widely used have limitations, including possible mutagenicity, cytotoxicity, inflammatory response, and hydrophobicity. Recently, bioceramic-based sealers containing calcium silicate and calcium phosphate attracted considerable attention because of their physical and biological properties such as their alkaline pH, chemical stability within the biological environment, and lack of shrinkage. Bioceramic materials containing calcium phosphate, enhances the setting properties of bioceramics and results in a chemical composition and crystalline structure similar to tooth and bone apatite materials, thereby improving sealer-to-root dentin bonding. This review focuses on advantages, mechanism of action,classification and detailed insight into individual bioceramic sealers currently used along with their properties.***

Keywords: Bioceramic sealer, Calcium silicate, iRoot SP, BiorootRCS

1. Introduction

The most ideal outcome of an endodontic treatment is the three-dimensional obturation of the endodontic spaces which permanently separates the root canal content from the periapical tissues thus preventing chronic irritation and foreign body reactions by material components[1].Root canal sealers are used in conjunction with a biologically acceptable semi-solid or solid core material so as to achieve a fluid tight seal of the root canal system. Root canal sealers help to seal off the voids, patent accessory canals, multiple foramina, to form a bond between the core of the filling material and the root canal wall, and it also acts as a lubricant during the placement of the core material [2]. The chemical and physical properties of endodontic sealers have been the subject of considerable attention since their development due to their biological and technical importance[3]. Sealers are categorized according to their main chemical constituents: zinc oxide eugenol, calcium hydroxide, glass ionomer, silicone, resin, and bioceramic-based sealers. Bioceramic based sealers were introduced in endodontics due to their superior physico-chemical and biological properties over the traditional endodontic sealer.

2. Bioceramic as a sealer

Bioceramic, a term introduced for an important subset of biomaterials includes materials that can be classified as bioinert, bioactive or biodegradable according to the interaction with surrounding tissues[4]. These include alumina and zirconia, bioactive glass, glass ceramics, calcium silicates, hydroxyapatite and resorbable calcium phosphates, and radiotherapy glasses[5].The setting reaction of calcium silicates results in the precipitation of calcium phosphate, which can encourage bioactivity and tissue growth after contact.Since calcium silicate sets by reacting with water provided by tissue fluids and is stable in water or humid conditions, sealers based on calcium silicate have also been announced as hydraulic sealers.

2.1Advantages

- Excellent biocompatibility properties due to their similarity with biological hydroxyapatite[6].
- Intrinsic osteo-inductive capacity due to their ability to absorb osteo-inductive substances when there is a bone healing process adjacent to it.
- Function as a regenerative scaffold of resorbable lattices that provide a framework which eventually dissolved as the body rebuilds tissue.
- Achieves excellent hermetic seal, form a chemical bond with the tooth structure and exhibits good radiopacity[7].

2.2 Mechanism of Action

The suggested mechanism of action for bioceramic sealers are:

1) Tubular diffusion of the sealer particles into the dentinal tubules that results in mechanical interlocking bonds[8].
2) Infiltration of the mineral content of the sealer into the intertubular dentin, producing a mineral infiltration zone with a strong alkaline sealer after denaturing the collagen fibres[9].
3) Partial reaction of phosphate with calcium silicate hydrogel and calcium hydroxide, produced as a result of the reaction of calcium silicates in the presence of the dentin's moisture forming hydroxyapatite along the mineral infiltration zone[10].

2.3 Classification

Bioceramic-based root canal sealers are classified according to their major constituents, are identified in Table 1. Table 2provides a list of CSBS available on the international

market and gives an overview aboutproduct delivery and compositions.

Table 1: Classifications of bioceramic sealers [11]

Type	Brand name
Calcium silicate based sealer(CSBS)	iRoot SP EndoSequence BC Sealer
MTA-based sealer	MTA Fillapex Endo CPM sealer, MTA-Angelus, ProRoot Endo Sealer
Calcium phosphate-based sealer	Sankin apatite root canal sealer (I, II, and III),Capseal (I and II)

Table 2: CSBS available on the international market and gives an overview about product delivery and compositions [12]

Sealer	Manufacturer	Delivery	Composition
iRoot SP	Innova_veBioceramix, Vancoucer, Canada	1-component materials	zirconium oxide, dicalcium silicate, tricalcium silicate, calcium phosphate monobasic, calcium hydroxide, filler, thickening agents
Endosequence BC Sealer	Brasseler USA, Savannah, USA		zirconium oxide, dicalcium silicate, tricalcium silicate, calcium phosphate monobasic, calcium hydroxide, filler, thickening agents
Total Fill BC Sealer	FKG Dentaire, La Chaux-de-Fonds, Switzerland		calcium silicates, calcium phosphate monobasic, zirconium oxide, tantalum oxide and thickening agents
Endoseal MTA	Maruchi, Wonju, Korea		calcium silicates, calcium aluminates, calcium aluminoferrite, calcium sulfates, radiopacifier, thickening agents
MTA-Fillapex	Angelus, Londrina, PR, Brazil		Salicylate resin, diluting resin, natural resin, bismuth trioxide, nanoparticulate silica, MTA, and pigments
Well-Root ST	Vericom, Gangwon-Do, Korea		calcium aluminosilicate, zirconium oxide, filler, thickening agent
Nano-Ceramic Sealer	B&L Biotech, Fairfax, USA		calcium silicates, zirconium oxide, filler, thickening agent
EndoSequence BC Sealer Hi-Flow	Brasseler USA, Savannah, USA		Zirconium Oxide, Tricalcium Silicate, Dicalcium Silicate, Calcium Hydroxide and fillers
Ceraseal	Meta Biomed Co., 270, Chungcheongbuk-do, South Korea		Calcium silicates, zirconium oxide, thickening agent
Endo CPM	EGEO SRL, Buenos Aires, Argentina	2-compontent materials	*Powder*: mineral trioxide aggregate, bismuth oxide, barium sulfate, silica dioxide *Liquid*: aqueous solution of calcium chloride, sodium citrate, propylenglycolalginate, propylenglycol
Tech BioSealer	Endo Isasan SRL, RevelloPorro, Italy		*Powder*: White Portland cement, bismuth oxide, anhydride, sodium fluoride *Liquid*: Alfacaine SP solution (4% articaine + 1/100.000Epinephrine
BioRoot RCS	Septodont, Saint-Maur-des-Fossés, France		*Powder*: tricalcium silicate, zirconium oxide, povidone *Liquid*: aqueous solution of calcium chloride and polycarboxylate
ProRoot ES	Dentsply, York, USA		*Powder*: tricalcium silicate, dicalcium silicate, calcium sulfate, bismuth oxide&tricalcium aluminate *Liquid*: water, viscous water-soluble polymer
NeoMTA Plus	Avalon Biomed Bradenton,USA		*Powder:*tricalcium silicate, dicalcium silicate, tricalcium aluminate, calcium sulphate& gypsum *Liquid:* Water based gel with thickening agents and water soluble polymers.

2.3.1 Endo-CPM-Sealer

This was introduced in 2004, to combine the physicochemical properties of a root canal sealer with the biological properties of MTA. End-CPM had an antibacterial effect against E. faecalis before setting but it did not maintain antibacterial activity after setting[13]. Calcium carbonate was added to reduce the pH from 12.5 to 10.0 after being set so as to restrict the surface necrosis of cells in contact with the material, resulting in the deposition of mineralized tissue[14]. Addition of calcium chloride to MTA reduces setting time, improves sealing ability and facilitates the insertion into cavities without interfering with its biocompatibility[15].

2.3.2 MTA Fillapex

MTA Fillapex is a resin MTA-based root canal sealer that has nanosilicate particles[16].The working time is about 30 minutes and the complete setting time is approximately two to 4.5 hours. MTA Fillapex has a high flow rate (27 mm) and a low film thickness, so it easily penetrates the lateral and accessory canals[17]. The significantly higher cytotoxicity of MTA Fillapex may be caused by the resin component or by other components of the sealer[18].

2.3.3 Endoseal-MTA

This sealer which is devoid of resin has MTA as its main ingredient. It is eugenol-free and will not impede adhesion

inside the root canal. This premixed, injectable endodontic sealer fills the root canal system including accessory and lateral canals due to its outstanding flowability. Endoseal MTA has a radiopacity greater than 3 mm aluminium thickness and setting time of about 12.31 minutes. It showed lesser expansion than epoxy resin-based sealers when immersed in water for 30 days. However, it exhibits inferior biocompatibility compared to BioRoot RCS on human periodontal ligament cells (PDL)[19].

2.3.4 ProRoot Endo Sealer

In ProRoot Endo Sealer, a calcium silicate-based endodontic sealer has water soluble polymeradded to MTA that increases the flow even at high powder to liquid ratio. It is to be used in conjunction with root filling material in either cold lateral warm vertical or carrier-based filling technique. It exhibits biocompatibility when in contact with physiologic solution and[20] there is release of calcium and hydroxyl ions from the set sealer liquid which is responsible for its bioactivity[21]. It also possesses favourable cytotoxicity and thus causes minimal tissue irritation when extruded through the apical constriction[22].According to Huffman et al the dislocation resistance of ProRoot Endo sealer was independent of location of radicular dentin and was more than AH Plus and pulp canal sealer[23].

2.3.5 iRoot SP

iRoot SP is a premixed ready-to-use injectable calcium silicate aluminium-free-based root canal sealer with similar composition to White MTA. It showed an alkaline pH up to 7 days after setting and was capable of killing E. faecalis in an antibacterial investigation[24]. It has radiopacity greater than 3 mm aluminium thickness[25].Solubility of iRoot SP was also higher compared to other BC materials.It has been shown that fresh iRootSp had significantly higher toxicity compared to ProRoot MTA in a filter diffusion test [26] and higher amounts of residual filling material after retreatment were found for iRoot SP compared to epoxy resin based and zinc oxide–eugenol-based sealers. It also exhibits deeper dentinal tubule penetration, higher push-out bond strength compared to other CSBS and higher resistance to fracture than epoxy resin-based sealers[13].

2.3.6 Endosequence BC Sealer

Endosequence BC Sealer (BCS), based on calcium silicate is an insoluble, radiopaque and aluminum-free material which requires the presence of water to set and harden filling and sealing. It is a premixed ready-to-use injectable material developed for root canal for use in the single cone and lateral condensation technique[27].The working time can be more than 4 hours at room temperature. Setting time is 4 hours. However, the setting time can be more than 10 hours in very dry root canals.

2.3.7 Endosequence BC Sealer HiFlow

A new formulation of Endosequence BC Sealer has been modified into Endosequence BC Sealer HiFlow (BCHiF)to obtain a suitable calcium-silicate based sealer to use in warm canal filling techniques. BCS and BCHiF had the same elemental composition. Carbon, Oxygen and Silicon showed similar percentage in both sealers, buts a variation was found in the amount of Calcium and Zirconium. However, according to the manufacturer, it shows lower viscosity when heated and is more radiopaque than Endosequence BCS. BCHiF had similar results to its predecessor BCS in terms of cytocompatibility, cell migration, cell adhesion and bioactivity potential[28].

2.3.8 Total Fill BC Sealer

TotalFill BC Sealer is a pre-mixed ready-to-use injectable bioceramic paste developed for permanent root canal filling and sealing application. It is insoluble radiopaque and aluminium free material basen on calcium silicate composition. It revealed a higher cell proliferation and collagen type I adhesion in comparison with AH Plus or MTA Fillapex[18]. TotalFill recorded higher observations of complete apical healing, compared to AH-Plus[29].

2.3.9 BioRoot RCS

BioRoot RCS is powder/liquid hydraulic tricalcium silicate-based cement recommended for single cone technique or cold lateral condensation root filling. Heating BioRoot RCS to 250 °C for 30 or 60 s to simulate the effect of warm vertical compaction techniques did not affect the chemical structure but heating upto 250 °C for 11 min resulted in a weight loss of 15% of BioRoot RCS[30]. It has a radiopacity greater than 3 mm aluminium thickness, flow greater than 17 mm and film thickness lesser than 50 µm. It has a setting time of approximately 5 h. It has solubility over a 6-month period when stored in phosphate buffered saline[31]. It has a higher calcium ion release than other CSBS and a long-term alkaline activity[32]. Immersion of BioRoot RCS in phosphate buffered saline led to a surface precipitation of calcium hydroxyapatite in vitro, which is an evident indication for the bioactivity of CSBS.The Push out bond strength (POBS) ofBioRoot RCS was inferior compared to AH Plus when used according the single-cone technique [33].The use of EDTA as a final irrigant had an adverse impact on the POBS of BioRoot RCS, whereas chlorhexdine enhanced the dislodgement resistance[34]. BioRoot RCS showed low toxicity and genotoxicity onPDL cells and are proven to be biocompatible on human PDL cells and gingival fibroblasts [19].

2.3.10 NeoMTA Plus

NeoMTA Plusis a new finer powder tricalcium silicate material and has tantalum oxide (Ta2O5) as a radiopacifying agent that is mixed with a water-based gel that imparts good handling properties.The powder-to-gel mixing ratio can be varied and a thin consistency can be used as an orthograde sealer or a thick mixture for root-end filling[35].

2.3.11 Cera seal

Cera seal is calcium phosphate based bioceramic sealer dispenced using a pre-mixed syringe CeraSeal has high pH (12.73) with a setting time about 3.5 hour and radiopacity less than8mm. It exhibit significant release of calcium ions and have higher cell viability and induce greater migration rate than endoseal[36].

2.3.12 Cera Fill RCS

Cerafill RCS root canal filling and sealing material is a ready to use injectable premixed filling and sealing material which is based on bioceramic technology. It is an alumina free radiopaque calcium silicate based material with

excellent handling characteristics and superior physical properties which requires water to set and harden.

2.3.13 Well Root ST

Well Root ST is a premixed, injectable sealer and delivered to root canals by injection without contaminating the access cavity. Well Root ST contains zirconium oxide as radio pacifier, calcium silicate and thickening-filling agents. Well Root ST caused clinically perceptible discolouration in 4 weeks, similar to MTA Fill apex and Dia-Proseal[37].It showed decreased cell viability by time in fresh media, which might be a result of their high pH in the fresh state and it showed significantly higher cell viability at 3 days.Well Root ST was found to be the most effective for attachment of human periodontal ligament stem cell on the set surface [38].

2.3.14 Nano Ceramic sealer(NCS)

It has good cytocompatibility although less than Bioroot RCS. These results confirm that there are differences between commercially available bioceramics suggesting that unknown filler and thickening agents could play an important role in terms of biocompatibility[19].Nano-ceramic sealer showssignificantly increased cell viability for 7 days. It shows favorable cell attachment and proliferation because of its smooth surface.It has favorable initial osteoblastic potential, which is more beneficial for initial periapical healing [38].

3. Conclusion

Potent antibacterial activity, absolute biocompatibility, osseoconductivity, ability to achieve excellent fluid tight seal in constantly wet environment, formation of chemical bond with dentin, insolubility in tissue fluids, expansion during time of set, very good radiopacity, easy handling are the features that make bioceramic-based sealers an up-to-date alternative to current “golden” standard of multi-phase (guttapercha— epoxy sealer) warm techniques. However, further studies are required to assess the clinical outcomes associated with the use of these sealers.

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