

Improvement of Reparative Bioceramics in Endodontics - A Critical Review

Stella Maris de Freitas Lima^{1*}, Poliana Amanda Oliveira Silva² and Taia Maria Berto Rezende^{1,2,3}

¹Dental Course, Universidade Católica de Brasília, Brazil

²Post graduation in Health Sciences, Universidade de Brasília, Brazil

³Post graduation in Genomic Sciences and Biotechnology, Universidade Católica de Brasília, Brazil

*Corresponding author: Stella Maris de Freitas Lima, Professor of Endodontics, Universidade Católica de Brasília, Brazil



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ABSTRACT

The advent of bioceramics materials increases the possibility of reparative and regenerative processes in dentistry, and more precisely, in endodontics. Bioceramics materials presents biocompatibility, bioactivity, resistance to leakage, sealing ability, and biomineralization activity. Mineral trioxide aggregate (MTA) is a gold standard bioceramic material indicated for reparative procedures presenting high clinical success. MTA is used for pulp capping, pulpotomy, apexification, perforation, root resorption repair, regenerative endodontics, and apical surgery. The emergence of MTA demonstrated great potential in endodontic therapies, and modifications and improvements of this bioceramic gave rise to many other materials. New bioceramic materials are now available in several countries with distinct compositions. Although there is a concern regarding the modification of compounds and formulation of bioceramic materials for reaching better properties, distinct products produce the same effects of reduced leakage, biological activity, sealing ability, marginal adaptation and bridge formation. The biological properties of bioceramic materials are well defined in literature, but new formulations must be evaluated in longitudinal clinical cases, and systematic reviews and meta-analysis are needed to compare these products better. The present review demonstrates a summary of bioceramics properties, applications, improvements, and future directions in endodontics to maintain tooth longevity.

Introduction

The dental structure can be affected by physical, chemical, and biological events. Dental caries and trauma are the most frequent aggressions involving teeth [1]. Both circumstances can trigger pulpal responses and culminate in inflammation and/or tissue necrosis [2]. The necrotic pulp can be infected by many microorganisms that can mediate the inflammation and destruction of the tooth surrounding tissues [3]. Pulp and periradicular inflammation can also trigger root internal/external resorption and alveolar bone resorption [4,5]. Thus, several pathological conditions can affect dental structures and, the first intervention must be based on eliminating the aggression by treating trauma and/or infection (e.g., treating caries, restoring cavities, performing endodontic therapy). After tissue inflammation and repair should be stimulated, and a new tissue can be formed or replaced. For these reasons, medicine and dentistry are

in constant improvements involving machines, techniques, and materials for treating diseases and improving life quality. The advent of bioceramics materials increases the possibility of reparative and regenerative processes in dentistry, and more precisely, in endodontics. The present review demonstrates a summary of bioceramics properties, applications, improvements, and future directions in endodontics to maintain tooth longevity better.

Bioceramics Applications for Reparative Endodontics

Ceramics are inorganic non-metallic materials produced by heated raw minerals [6]. Bioceramics are materials composed of nanosphere particles of tricalcium silicate, tantalum pentoxide, dicalcium silicate, monobasic, amorphous silicon dioxide, and calcium phosphate [7]. Bioceramic materials include alumina and zirconia, bioactive glass, glass ceramics, calcium silicates, hydroxyapatite, re-

sorbable calcium phosphates, and radiotherapy glasses [8]. These materials presents biocompatibility [9], bioactivity [10], resistance to leakage, sealing ability [11], and biomineralization activity [12]. The presence of calcium silicate in these materials can reduce inflammation and induce tissue repair [13]. Calcium phosphate and bioactive glass induce the formation of hard tissue [14]. In addition, bioceramic materials contribute to tissue repair once it stimulates the secretion of morphogenetic cells, proteins, and growth factors such as bone morphogenetic protein and transforming growth factor-beta 1 [12]. Endodontic applications for bioceramic materials for reparative purposes demands several physicochemical properties (short setting time, high alkaline pH and calcium ion release, high mechanical strength, high radiopacity, moderate flow, low porosity, and solubility) and also biological properties (biocompatibility, induction of pulp cell differentiation, and antibacterial activity) to ensure its effectiveness [15,16].

However, current products commercially available do not demonstrate all these desirable properties, but there are products with favorable clinical results. Mineral trioxide aggregate (MTA) is a gold standard bioceramic material indicated for reparative procedures presenting high clinical success [17]. MTA was first cited in the 1990s as a calcium silicate cement [18]. Ever since, MTA is used for pulp capping, pulpotomy, apexification, perforation, root resorption repair, regenerative endodontics, and apical surgery [19]. MTA is a biocompatible and sealing material that can induce tissue repair (bone and dentin) [20]. The recommendations for bioceramics application involve repair or regeneration of pulp tissue, periodontal tissues and also dentin, and bone tissues. MTA is recommended for direct pulp capping and pulpotomy procedures as a material to cover exposed tissue and act as a barrier. The direct contact of MTA with pulp tissue can stimulate the healing and repair of the pulp through the induction of dentin bridge formation [21].

Bioceramics as MTA is indicated for regenerative endodontic therapy due to its potential to assist root development. The ability to seal, induce cell proliferation, differentiation, and biomineralization makes these materials the most suitable for blood clot top-sealing [22]. MTA allows adhesion, supports cell proliferation, and induce mesenchymal stem cell migration [23]. MTA is also recommended for the repair of areas where periodontal communication occurs (e.g., perforations and root-end filling) [21]. This recommendation is based on the properties of biocompatibility, dimensional stability, and sealing [24]. Indeed, MTA can block communications of the root canal and surrounding tissues.

The first commercial formulation of MTA was developed as a gray powder. However, gray MTA was developed into white MTA to overcome tooth discoloration [25]. Tooth discoloration occurs due to the presence of bismuth oxide, a radiopacifier that can produce metallic bismuth and oxygen [26,27]. Other disadvantages of MTA include long setting time, difficulties in handling, and high cost [13,28]. In addition, its properties also depend on manipulation. The ratio powder/water and entrapped air during mixing can be interfering and contribute to the waste of material [18].

Bioceramics Evolution in Endodontics

Over the years, many materials have been recommended to induce tissue repair of dental and periapical tissues (e.g., eugenol zinc oxide cements, glass ionomer cement, composite resins, amalgam, gutta-percha, calcium hydroxide) [29]. The emergence of MTA demonstrated great potential in endodontic therapies, and modifications and improvements of this bioceramic gave rise to many materials. New bioceramic materials are available in several countries with distinct compositions. Table 1 demonstrates some examples of bioceramic materials similar to MTA. Endosequence Bioceramic Root Repair Material (Brasseler, Savannah, USA) was developed as a premixed cement into a syringeable fast set putty to improve manipulation better and discoloration disadvantages [25]. Endosequence contains zirconium dioxide as a radiopacifier that do not form a precipitate in contact with collagen [27]. However, results regarding its potential of discoloration are distinct [30]. RetroMTA (BioMTA, Seoul, Korea) also presents a modification on its composition compared to MTA and do not present Portland cement, and used hydraulic calcium zirconia as radiopacifier [31]. This product has calcium carbonate and may present fast setting time (3 minutes) compared to MTA but it still demonstrated some discoloration potential [32]. Generex A (Dentsply Tulsa, Tulsa, USA) is similar to ProRoot MTA (Dentsply Sirona, New York, USA), but is mixed with gels instead of water [33]. Some studies demonstrated that tricalcium silicate from Generex A stimulates osteoblast growth and contributes to the formation of bone apatite in a similar manner of MTA [33,34]. Ceramicrote-D (Tulsa Dental Specialties, Argonne, USA) is composed of hydroxyapatite powder, phosphosilicate ceramics, and radiopaque cerium oxide, although it may also contain bismuth oxide as a radiopacifying agent [34,35]. It demonstrated sealing ability and alkalinity [35], handling properties similar to ProRoot MTA (Dentsply Sirona, New York, USA) and setting time of 150 minutes [33]. However, its biocompatibility is still controversial [34].

Table 1: Bioceramic materials from distinct countries and with distinct composition and formulations.

Material	Manufacturer	Composition	Radiopacifier
ProRoot MTA	Dentsply Sirona (New York, USA)	Bismuth oxide, tricalcium silicate, dicalcium silicate, tricalcium aluminate and calcium sulfate	Bismuth oxide
MTA Angelus	Angelus (Londrina, Brazil)	Tricalcium silicate, dicalcium silicate, tricalcium aluminate, calcium oxide, bismuth oxide	Bismuth oxide
MTA Repair HP	Angelus (Londrina, Brazil)	Tricalcium silicate, dicalcium silicate, tricalcium aluminate, calcium oxide, calcium tungstate liquid: water and plasticizer	Calcium tungstate
Generex A	Dentsply Tulsa (Tulsa, USA)	Bismuth oxide, tricalcium silicate, dicalcium silicate, and tricalcium aluminate with a mixing gel containing sodium lauryl sulfate and other undisclosed ingredients	Bismuth oxide
Ceramicrete-D	Tulsa Dental Specialties, (Argonne, USA)	Phosphosilicate ceramic, hydroxyapatite, cerium oxide, deionized water	Cerium oxide
Biodentine	Septodont (Saint-Maur-desFosses, France)	Tricalcium silicate, dicalcium silicate, calcium carbonate, calcium oxide, iron oxide and zirconium oxide	Zirconium oxide
EndoSequence Root Repair Material	Brasseler, (Savannah, USA)	Calcium silicate, monobasic calcium phosphate, zirconium oxide, Tantalum oxide, filler agent	Zirconium oxide
Endosequence BC Root Repair Material Fast Set Putty	Brasseler, (Savannah, USA)	Zirconium oxide, calcium silicate, monobasic calcium phosphate, calcium hydroxide and thickening agents	Zirconium oxide
RetroMTA	BioMTA, (Seoul, Korea)	Calcium carbonate, silicon dioxide, aluminium oxide, calcium zirconia complex	Calcium zirconia complex
TotalFill BC Root Repair Material (RRM)	FKG (Brasseler, Savannah, USA)	Calcium silicates, calcium phosphate monobasic, zirconium oxide, tantalum oxide and thickening agents	Zirconium oxide
NeoMTA Plus	Avalon Biomed (Inc. Bradenton, USA)	Tricalcium silicate, dicalcium silicate, and tantalum oxide liquid: water and proprietary polymers	Tantalum oxide

Biodentine (Septodont, Saint-Maur-desFosses, France) is composed of a mixture of tricalcium silicate, dicalcium silicate, calcium carbonate, iron oxide, and zirconium oxide, and a water-soluble polymer calcium chloride [36]. The radiopacity is attributed to zirconium oxide, but it might not provide a significant radiographic contrast [37,38]. Biodentine presents a short setting time (12 minutes) due to the presence of smaller particles, and the use of calcium chloride, an accelerator of chemical reactions [28]. This material releases calcium hydroxide induces restorative dentin synthesis, and also demonstrated antimicrobial activity [39,40]. Total Fill BC Root Repair Material (RRM, FKG Brasseler, Savannah, USA) is based on calcium phosphate, possess prolonged setting time (4 hours) but presented some limitations of handling and sealing ability compared to ProRoot MTA (Dentsply Sirona, New York, USA) [41]. NeoMTA Plus (Avalon Biomed, Inc. Bradenton, USA) is a tricalcium silicate, dicalcium silicate, and calcium sulfate powder mixed with a water-based gel. This product is based on tantalum oxide as a radiopacifying agent and possesses prolonged setting time for a prolonged effect of calcium and hydroxyl ions release [42]. There are other bioceramic materials available in the market with similar compositions and properties. Although there is a concern regarding the modification of compounds and formulation of bioceramic materials for reaching better properties, distinct

products produce the same effects of reduced leakage [24,43], biological activity [14,44], sealing ability, marginal adaptation [41] and bridge formation [7].

Future Directions

A great vast of studies regarding MTA and other bioceramic materials as regenerative materials for endodontics demonstrated its effectiveness. However, the emergence of new biomaterials is needed in dentistry, aiming to prolong tooth life expectancy and also systemic life quality. The improvements of formulation (e.g, the premixed formulation in a syringe, putty formulation) consist of significant advancement and also the concerns regarding tooth discoloration and compound modifications. However, manufacturers and researchers need to attend cases of reintervention were the removal of these materials is needed. In addition, high costs also must be a great concern to disseminate the beneficial use of bioceramics in daily practice better. The biological properties of bioceramic materials are well defined in many in vitro and in vivo studies, but new formulations must be evaluated in longitudinal clinical cases, and systematic reviews and meta-analysis are needed to compare these products better. Finally, several products present effective results even when compared to gold standard MTA, and the bioceramic choice should be based on professional experience [45].

Conflicts of Interests

none

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