Clinical applications of bioceramic materials in endodontics

Drs. Marga Ree and Richard Schwartz explore current premixed bioceramic materials

Abstract

Introduction: Bioceramic materials are currently available in three forms: sealer, paste, and putty, and have a variety of clinical applications. Some are premixed, and some require manual mixing. They are fairly new to endodontics and not well understood by most clinicians. The purpose of this article is to discuss the current premixed bioceramic materials, give an overview of the literature, and present five clinical cases in which they were used successfully.

Methods: Five cases were selected in which bioceramic materials were used for retreatment, perforation repair, and periapical surgery. Recalls up to 2 years are presented.

Conclusions: This case series shows that bioceramic materials can be used successfully to manage a variety of clinical scenarios and offer some potential advantages over other materials. In each case, treatment resulted in elimination of clinical symptoms and bone healing.

Educational aims and objectives

The aim of this article is to give an overview of current premixed bioceramic materials and how they can be used successfully in endodontic treatment.

Expected outcomes

Endodontic Practice US subscribers can answer the CE questions on page XX to earn 2 hours of CE from reading this article. Correctly answering the questions will demonstrate the reader can:

- Recognize the drawbacks of traditional obturating methods.
- Realize several advantages of bioceramic materials over MTA.
- Identify certain benefits of bioceramic materials to endodontic treatment.
- See some information on studies regarding endodontic premixed bioceramic materials.
- Realize various treatment options involving bioceramic materials through clinical cases.

Introduction

Root canal filling (obturation) is performed after the microbial control phase of treatment with the goal of entombing the remaining bacteria inside the root canal system, preventing the influx of apical fluids and preventing reinfection from the oral cavity.[1] A variety of core and sealer combinations have been used, including silver cones, gutta-percha, and resin-based materials in conjunction with a variety of root canal sealers, mineral trioxide aggregate (MTA) products, and recently, bioceramic (BC) materials.

Traditional obturating methods do not provide an effective seal. They shrink on setting, have little or no adhesion to dentin, and are not dimensionally stable when they come in contact with moisture, leading to dissolution and leakage over time. In recent years, new materials have been developed that overcome some of these shortcomings.

MTA is a cement that is not sensitive to moisture and blood contamination.[2] It is dimensionally stable, expands slightly as it sets, and is insoluble over time.[2] It has antibacterial properties, due to its high pH during setting, and is biocompatible.[2,3] It is considered the material of choice for perforation repair, root-end fillings, pulp caps, pulpotomies, and obturation of immature teeth with open apices.[4] These are all situations where the presence of moisture may affect the quality of the root canal filling. When MTA comes in contact with tissue fluids, it releases calcium hydroxide that can interact with phosphates in the tissue fluids to form hydroxyapatite. This property may explain some of the tissue-inductive properties of MTA and may contribute, along with slight setting expansion, to its good sealing properties.[5-8]

MTA is described as a first-generation bioactive material. It has many advantages, but also some disadvantages .[2,3] The initial setting time is at least 3 hours. It is not easy to manipulate, resulting in considerable wasted material, and is hard to remove. Clinically, both gray and white MTA stain dentin, presumably due to the heavy metal content of the material or the inclusion of blood pigment while setting.[9,10] Finally, MTA is hard to apply in narrow canals, making the material poorly suited for use as a sealer. Efforts have been made to overcome these shortcomings with new compositions of MTA[11-13] or with additives.[14,15] However, these formulations affect MTA's physical and mechanical characteristics.

Bioceramics

Bioceramics are inorganic, non-metallic, biocompatible materials that have similar mechanical properties as the hard tissues they are replacing or repairing. They are chemically stable, non-corrosive, and interact well with organic tissue. During the 1960s and 1970s, the materials were developed for use in the human body. They are used in many medical applications, such as joint replacement, bone plates, bone cement, artificial ligaments and tendons, blood vessel prostheses, heart valves, skin repair devices (artificial tissue), cochlear replacements, and contact lenses.

Bioceramics in endodontics

Bioceramic materials used in endodontics can be categorized by composition, setting mechanism, and consistency. There are sealers and pastes, developed for use with gutta-percha, and putties, designed for use as the sole material, comparable to MTA. Some are powder/liquid systems that require manual mixing. The authors have found the mixing and handling characteristics of the powder/liquid systems to be very technique sensitive, and a deterrent to their use. Premixed bioceramics require moisture from the surrounding tissues to set. The premixed sealer, paste, and putty have the

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advantage of uniform consistency and lack of waste. They are all hydrophilic.

In 2007, a Canadian research and product development company (Innovative BioCeramix, Inc., Vancouver, Canada), developed a premixed, ready-to-use calcium silicate based material, iRoot® SP injectable root canal sealer (iRoot® SP). Some time later, they developed two other products with similar compositions, but different consistencies: iRoot® BP injectable root repair filling material (iRoot® BP) and iRoot® BP Plus injectable root repair filling material putty (iRoot® BP Plus).

Since 2008, these products have also been available as EndoSequence® BC Sealer™, EndoSequence® Root Repair Material (RRM) Paste™, and EndoSequence® Root Repair Material (RRM) Putty™ (Brasseler, USA Dental LLC). Recently, these materials have also been marketed as Totalfill® BC Sealer™, TotalFill® BC RRM Paste™, and TotalFill® BC RRM Putty™ (Brasseler USA Dental LLC) (Table 1).

The manufacturer states that the three forms of bioceramics are similar in chemical composition (calcium silicates, zirconium oxide, tantalum oxide, calcium phosphate monobasic, and fillers), have excellent mechanical and biological properties, and good handling properties. They are hydrophilic, insoluble, radiopaque, aluminum-free, and high pH, and require moisture to harden. The working time is more than 30 minutes, and the setting time is 4 hours in normal conditions, depending of the amount of moisture available.

RRM putty and RRM paste are recommended for perforation repair, apical surgery, apical plug, and direct pulp caps. BC sealer is recommended for use with gutta percha. The primary difference between RRM paste and BC sealer is that RRM paste is more viscous.

Studies on endodontic premixed bioceramic materials

To date, approximately 50 studies have been published on premixed bioceramic materials in endodontics. The vast majority have shown that the properties conform to those expected of a bioceramic material and are similar to MTA.

Biocompatibility and cytotoxicity

Several in vitro studies report that BC materials display biocompatibility and cytotoxicity that is similar to MTA.[16-26] Cells required for wound healing attach to the BC materials and produce replacement tissue.[17] In comparison to AH Plus® (Dentsply) and Tubli-Seal™ (SybronEndo), BC sealer showed a lower cytotoxicity.[16,17] On the other hand, one study concluded that BC Sealer remained moderately cytotoxic over the 6-week period,[27] and osteoblast-like cells had reduced bioactivity and alkaline phosphatase activity compared to MTA and Geristore® (DenMat).[28]

pH and antibacterial properties

BC materials have a pH of 12.7 while setting, similar to calcium hydroxide, resulting in antibacterial effects.[29] BC Sealer was shown to exhibit a significantly higher pH than AH Plus[30] for a longer duration.[31] Alkaline pH promotes elimination of bacteria such as E. faecalis. In vitro studies reported EndoSequence Paste produced a lower pH than white MTA in simulated root resorption defects,[32] and EndoSequence Paste, Putty, and MTA had similar antibacterial efficacy against clinical strains of E. faecalis.[33]

Bioactivity

Several studies evaluated bioactivity. An in vitro study on the effects of iRoot SP root canal sealer suggested that iRoot SP is a favorable material for cellular interaction.[34] Exposure of MTA and EndoSequence Putty to phosphate-buffered saline (PBS) resulted in precipitation of apatite crystalline structures that increased over time, suggesting that the materials are bioactive.[35] Human dental pulp cells exhibited optimal proliferation and mineralization on the surface of iRoot BP Plus.[36] iRoot SP exhibited significantly lower cytotoxicity and a higher level of cell attachment than MTA Fillapex, a salicylate resin-based, MTA particles containing root canal sealer .[37] EndoSequence Sealer had higher pH and greater Ca^{2+} release than AH Plus[30] and was shown to release fewer calcium ions than BioDentine® (Septodont) and White MTA.[38] It was reported that MTA may provide more inductive potential and hard tissue deposition than iRoot SP.[39] The clinical significance of these findings is uncertain, however.

Bond strength

A number of studies evaluated bond strength. One study reported that iRoot SP and AH Plus performed similarly, and better than EndoREZ® (Ultradent) and Sealapex™ (SybronEndo).[40] Another study found that iRoot SP displayed the highest bond strength to root dentin compared to AH Plus, Epiphany®, and MTA Fillapex, irrespective of moisture conditions.[41] In a push-out test,

Material	Brand	Abbreviation	Composition	Manufacturer
Bioceramic Sealer	iRoot SP Injectable Root Canal Sealer ----------------------------- EndoSequence BC Sealer TotalFill BC Sealer	iRoot SP EndoSequence Sealer TotalFill Sealer	Tricalcium silicate, dicalcium silicate, calcium hydroxide, zirconium oxide, phosphate monobasic, filler and thickening agents	Innovative Bioceramix Inc. (IBC) Vancouver, British Colombia, Canada ----------------------------- Brasseler USA Dental LLC, Savannah, GA
Bioceramic Root Repair Material Paste	iRoot BP Injectable Root Repair Filling Material ----------------------------- EndoSequence Root Repair Material (RRM) Paste TotalFill BC RRM Paste	iRoot BP EndoSequence Paste TotalFill Paste	Tricalcium silicate, dicalcium silicate, zirconium oxide, tantalum pentoxide, calcium phosphate monobasic and filler agents	Innovative Bioceramix Inc. (IBC) Vancouver, British Colombia, Canada ----------------------------- Brasseler USA Dental LLC, Savannah, GA
Bioceramic Root Repair Material Putty	iRoot BP Plus Injectable Root Repair Filling Material ----------------------------- EndoSequence Root Repair Material (RRM) Putty TotalFill BC RRM Putty	iRoot BP Plus EndoSequence Putty TotalFill Putty	Tricalcium silicate, dicalcium silicate, zirconium oxide, tantalum pentoxide, calcium phosphate monobasic and filler agents	Innovative Bioceramix Inc. (IBC) Vancouver, British Colombia, Canada ----------------------------- Brasseler USA Dental LLC, Savannah, GA

Table 1

the bond strength of EndoSequence Sealer was similar to AH Plus and greater than MTA Fillapex.[42] When iRoot SP was used with a self-adhesive resin cement, the bond strength of fiber posts were not adversely affected.[43] Smear layer removal had no effect on bond strengths of EndoSequence Sealer and AH Plus, which had similar values.[44] The presence of phosphate-buffered saline (PBS) within the root canals increased the bond strength of EndoSequence Sealer/gutta percha at 1 week, but no difference was found at 2 months.[45] Because of the low bond values in these studies, it is doubtful that any of these findings are clinically significant.

Resistance to fracture

iRoot SP was shown in vitro to increase resistance to the fracture of endodontically treated roots, particularly when accompanied with bioceramic impregnated and coated gutta-percha cones.[46] Fracture resistance was increased in simulated immature roots in teeth with iRoot SP,[47] and in mature roots with AH Plus, EndoSequence Sealer, and MTA Fillapex.[48] Similar results were reported for EndoSequence Sealer and AH Plus Jet sealer in root-filled single-rooted premolar teeth.[49]

Microleakage

Microleakage was reported to be equivalent in canals obturated with iRoot SP with a single cone technique or continuous wave condensation, and in canals filled with AH Plus sealer with continuous wave condensation.[50] Similar microleakage values were reported for sealers that contained calcium hydroxide, methacrylate resin and epoxy resin, as well as iRoot SP and AH Plus.[51] EndoSequence paste was similar to white MTA in preventing bacterial leakage of E. faecalis[52] or preventing glucose leakage[53] in vitro. In contrast, EndoSequence Putty was found to leak significantly more than ProRoot MTA in a study using a bacterial leakage model.[54]

Solubility

High levels of Ca^{2+} release were reported from in a solubility from iRoot SP, MTA Fillapex, Sealapex, and MTA-Angelus, but not AH Plus. Release of Ca^{2+} ions is thought to result in higher solubility and surface changes.[55] However, the study tested the materials following ANSI/ADA spec. no. 57 which is not designed for premixed materials that require only the presence of moisture to set. This could be the reason for the difference in findings in this study and in vivo observations.

Retreatment

Removal of EndoSequence Sealer and AH Plus were comparable in a study comparing hand instruments and ProTaper Universal retreatment instruments.[56] None of the filling materials could be removed completely from the root canals, however.[57] Micro-computed tomography showed that none of the retreatment techniques completely removed the gutta-percha/iRoot SP sealer from oval canals.[58]

Clinical studies

A randomized clinical trial evaluated iRoot BP and white ProRoot MTA as direct pulp-capping materials. The study evaluated clinical signs/symptoms and histological pulp reactions, such as inflammation and mineralized bridge formation. No significant differences were found in pulpal inflammation, or in the formation or appearance of a hard tissue bridge. However, clinical sensitivity to cold was significantly less for teeth treated with MTA ($P < 0.05$). All teeth formed a hard tissue bridge, and none of the specimens in either group had pulpal necrosis.[59]

Clinical cases

Patient No. 1 was a 47-year-old white male who was referred for a second opinion on a radiolucency in the lower anterior area. It had been present since 2000 (Figure 1A), but had increased in size since 2008 (Figure 1B). He presented with swelling and severe pain. His medical history was noncontributory. Clinical examination revealed that teeth Nos. 24, 25, and 26 were restored with large composite restorations, and were all tender to pressure and percussion. Tooth No. 23 was non-tender and responded normally to pulp tests. There were no significant probing depths. A radiographic examination revealed a large periapical radiolucency associated with teeth Nos. 23, 24, 25, and 26 (Figure 1C). In addition, the teeth were structurally compromised. The endodontic diagnosis was previous root canal treatment with acute apical periodontitis in teeth Nos. 24, 25, and 26. The existing endodontic treatment in teeth Nos. 24, 25, and 26 was 12 years old. Because there was reason to suspect the presence of one or more untreated canals, a CBCT scan was performed (Kodak 9000 3D; Carestream Dental), which suggested the presence of lingual canals in all three endodontically treated teeth (Figures 1D-1F).

The patient was presented with two treatment options:

1. Extraction of teeth Nos. 24, 25, and 26 and replacement by a 3-unit, implant supported bridge
2. Nonsurgical retreatment of teeth Nos. 24, 25, and 26

The patient chose the second option. Upon access, there was drainage of pus from tooth No. 25, and subsequent drainage of blood from teeth Nos. 24, 25, and 26 (Figures 1G-1H). It took two appointments to remove the root canal fillings and negotiate the untreated canals. After each appointment, the canals were dressed with calcium hydroxide (UltraCal® XS, Ultradent) (Figure 1I). At the third appointment, the patient was completely asymptomatic, and the swelling had resolved. There was still some moisture from the periapical tissues seeping into the canals. Therefore, it was decided to use a hydrophilic sealer (EndoSequence BC sealer, Brasseler, USA Dental LLC), since it is not sensitive to moisture,[41] in conjunction with gutta percha to obturate all lower incisors (Figure 1J). After root canal treatment was completed, the teeth were

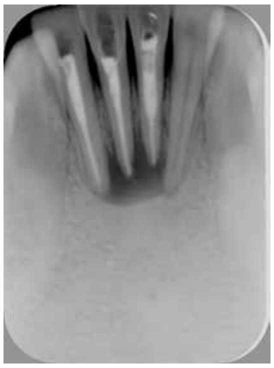
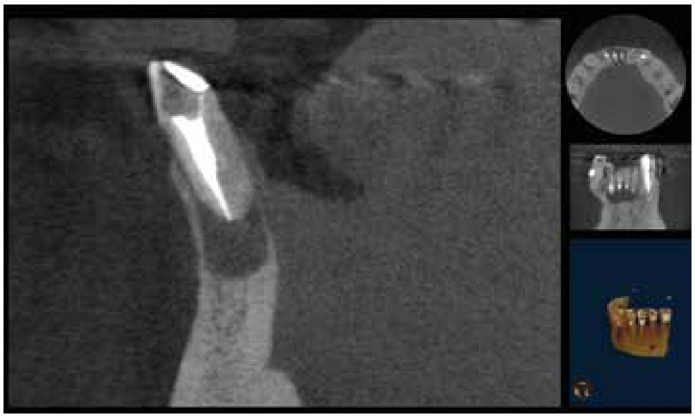
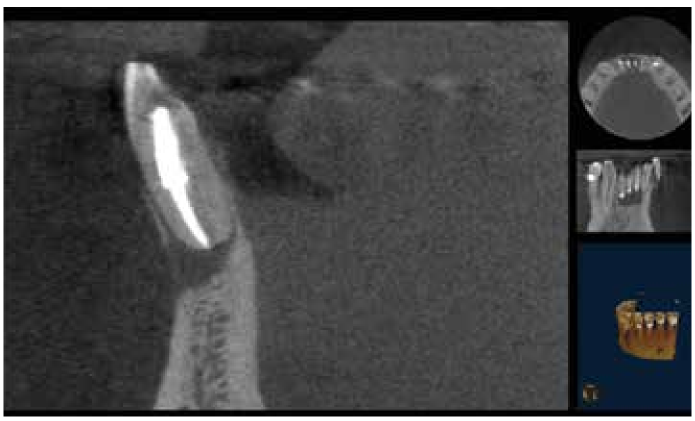


Figure 1A: Radiograph of three root canal treated lower incisors and associated radiolucency

Figure 1B: Eight years later, the radiolucency has increased in size

Figure 1C: Radiograph at 12 years showing the radiolucency was unchanged. Endodontic treatment was carried out in the mandibular left canine for unknown reasons





Figures 1D-F: Representative slices of a CBCT scan showing untreated lingual canals in all three lower incisors

Figure 1G: Upon access, there was drainage of pus from tooth No. 25

Figure 1H: Clinical picture showing drainage of blood from teeth Nos. 24, 25, and 26

Figure 1I: The teeth were dressed with calcium hydroxide

Figure 1J: The root canals were filled with gutta percha and EndoSequence Sealer

Figures 1K-1L: Postoperative radiographs show the teeth restored with fiber posts and composite resin

Figure 1M: Recall radiograph after 1 year, showing the radiolucency has significantly decreased in size

restored with a fiber post (DT light post; RTD, Saint Egreve, France) and composite (LuxaCore®, DMG America) (Figures 1K-1L).

The 1-year recall showed a significant reduction of the periapical radiolucency (Figure 1M). The patient was asymptomatic, and there was no evidence of endodontic disease or significant probing depths.

Patient No. 2 was a 57-year-old white female who was referred for endodontic treatment of tooth No. 2. Her chief complaint was spontaneous pain and biting tenderness. Her general dentist diagnosed an acute apical periodontitis (Figure 2A), and started root canal treatment. During negotiation of the root canal system, a perforation was created in the apical portion of the mesiobuccal root (Figure 2B). Calcium hydroxide was placed, and the patient was referred for further treatment. Clinical testing confirmed that tooth No. 2 was tender to pressure and percussion. There were no significant probing depths. Radiographic examination revealed an apical radiolucency and extrusion of calcium hydroxide through the perforation (Figure 2C). The CBCT scan showed a very curved mesiobuccal root and extrusion of calcium hydroxide into the maxillary sinus (Figure 2D). She had no significant medical history. The preoperative diagnosis was incomplete endodontic treatment with lateral perforation and acute apical periodontitis.

Two treatment options were discussed with the patient:

1. Extraction and replacement by an implant
2. Nonsurgical endodontic treatment with the possible need for surgery

The patient chose the second option. At the first treatment session, the intracanal dressing of calcium hydroxide was removed, and the apical portion of the mesiobuccal canal was located and negotiated with prebent hand files (Figure 2E). All 3 canals were prepared to working length, and calcium hydroxide was placed.

At the second appointment, approximately 1 month later, the biting tenderness had subsided and the patient was asymptomatic. Two options were considered to repair the perforation:

1. Obturation of the entire mesiobuccal canal with MTA
2. Obturation of the entire mesiobuccal canal with gutta-percha and a bioceramic sealer

MTA is a material with many benefits, but one of its disadvantages is that it is difficult to effectively obturate long narrow canals, so this approach was rejected.

A concern with method No. 2 was extrusion of obturating materials into the perforation site and the maxillary sinus. EndoSequence BC Sealer was chosen because of its biocompatibility[17, 18, 22, 24, 37] and lack of sensitivity to moisture.[41] Once the cones were seated (Figure 2F), the downpack was performed using a System B™ heat source (SybronEndo), followed by backfilling with an Obtura gun (Spartan Obtura Endodontics). The access opening was restored with a bonded composite core material (LuxaCore; DMG, Hamburg, Germany), which was covered with a layer of a hybrid composite (Tetric® Ceram, Ivoclar Vivadent) (Figure 2G).

At the 1-year recall, the patient was asymptomatic, and periapical radiographs showed no evidence of endodontic disease with normal tissue architecture (Figure 2H).

Patient No. 3 was a 37-year-old white female who was referred for retreatment of tooth No. 18. The restorative treatment plan was for a crown. The patient was asymptomatic, and her medical history was noncontributory. Clinical examination revealed that tooth No. 18 was restored with a large composite restoration. The tooth was non-tender to pressure and percussion, and there were no significant probing depths. Radiographic examination revealed a periapical radiolucency

Figure 2A: Preoperative radiograph of No. 2 shows a periapical radiolucency

Figure 2B: Radiograph showing a perforation in the apical portion of the mesiobuccal root

Figure 2C: Calcium hydroxide was placed in the canals with some extrusion into the periapical tissues

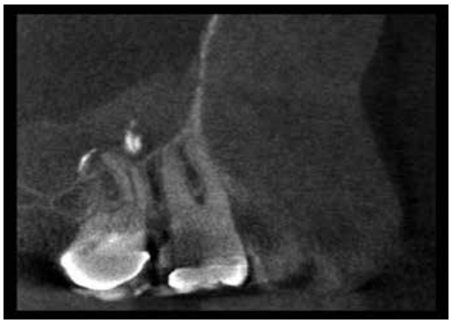


Figure 2D: CBCT slice showing extrusion of calcium hydroxide into the maxillary sinus

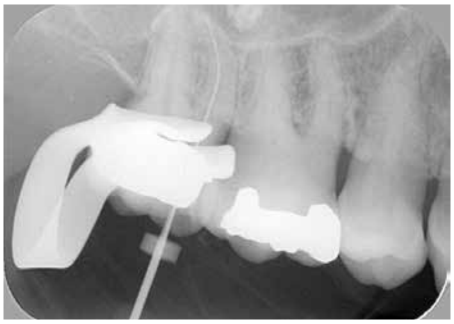


Figure 2E: Working length radiograph showing a file in the original mesiobuccal canal

Figure 2F: Cone-fit radiograph

Figure 2G: Postoperative radiograph showing the root-filled tooth restored with a composite core

Figure 2H: At 1 year, the radiolucency had decreased in size significantly, and the patient was asymptomatic associated with the distal root and extrusion of root filling material (Figure 3A). The endodontic diagnosis was previous root canal treatment with chronic apical periodontitis.

The patient was presented with three options:

1. No immediate treatment with eventual extraction of the tooth should it become symptomatic
2. Extraction and replacement with an implant
3. Nonsurgical endodontic retreatment followed by a crown

The patient opted for retreatment.

At the first treatment session, most of the existing root canal filling was removed. A small fragment of the silver cone remained in the mesiolingual canal (Figure 3B). Because there was no radiolucency associated with the mesial root, it was decided to leave the fragment in place. The extruded root filling material was retrieved from the periapical tissues using a Terauchi gutta-percha removal instrument (Hartzell and Son) (Figures 3C-3D). The distal and mesiobuccal canals were prepared to the working length, the mesiolingual canal was instrumented to the level of the fractured silver cone, and calcium hydroxide was placed in all canals (Figure 3E).

At the second session, the mesial canals were obturated with Resilon™ and Epiphany sealer (SybronEndo). The apical portion of the distal canal was filled with EndoSequence Root Repair Material Putty (Brasseler USA Dental LLC) using a Dovgan MTA carrier (Hartzell and Son) (Figure 3F) and a Dovgan endodontic condenser (Miltex) dipped in a small amount of EndoSequence BC Sealer to prevent sticking of the plugger to the putty. A moist cotton pellet was inserted on top of the putty, and the tooth was temporized (Figure 3G).

At the third appointment, it was verified that the apical plug of putty had fully set (Figure 3H). The tooth was restored with a fiber reinforced composite post

Figure 3A: Preoperative radiograph showing a radiolucency associated with No. 18 with extrusion of root filling out the end of the distal root

Figure 3B: An apical fragment of one of the silver cones separated and was left behind in the mesiolingual canal

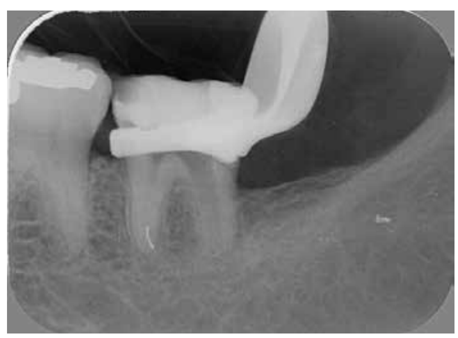


Figure 3C: The extruded part of the gutta percha in the distal canal has been retrieved from the periapical tissues using a Terauchi gutta-percha removal instrument

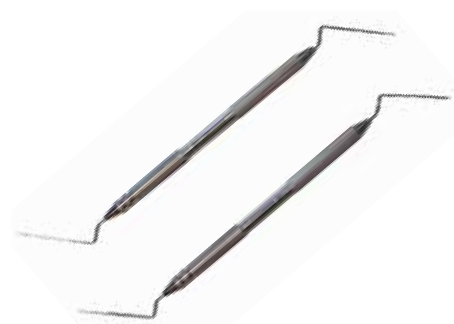


Figure 3D: Terauchi gutta-percha removal instruments

Figure 3E: Calcium hydroxide was applied to the canals

Figure 3F: A Dovgan MTA carrier

Figure 3G: The mesial canals were filled with Resilon and Epiphany sealer, and the distal canal was filled with EndoSequence Putty, leaving a space for a post in the distal canal

Figure 3H: The EndoSequence Putty was completely set

Figure 3I: Postoperative radiograph showing the obturated tooth, restored with a fiber post and composite resin core

Figure 3J: Two-year recall radiograph showing normal bony architecture

(DT Light-Post; RTD, Saint Egreve, France) and a bonded composite core material (LuxaCore) (Figure 3I).

At the 2-year recall, the patient had remained asymptomatic, and periapical radiographs showed no evidence of endodontic disease and normal tissue architecture (Figure 3J).

Patient No. 4 was a 41-year-old white male who was referred for retreatment of tooth No. 30 after the referring dentist had been unable to remove the existing root canal filling. His medical history was noncontributory. Clinical examination revealed tenderness at tooth No. 30 and no probings deeper than 3 mm with anesthesia. An endodontic access cavity had been prepared through the metal-ceramic crown and sealed with a temporary restoration. Radiographs showed a periapical radiolucency and removal of a significant amount of coronal tooth structure (Figure 4A). The diagnosis was previous root canal treatment with chronic apical periodontitis of tooth No. 30.

Two treatment options were discussed with the patient:

1. Extraction and replacement by an implant
2. Nonsurgical endodontic retreatment

The patient opted for retreatment. Upon access, a perforation was visible in the pulp floor, and there was drainage of blood from the perforation site (Figure 4B). In addition, two lateral perforations were identified in the apical one-third of the mesial canals (Figure 4C). The perforation in the pulp floor was repaired with EndoSequence RMM Putty (Brasseler USA) (Figure 4D). It took two appointments to remove the carrier-based

Figure 4A: Preoperative radiograph showing an endodontically treated mandibular first molar with substantial loss of coronal dentin and a radiolucency

Figure 4B: Upon access, there was bleeding from the perforation in the pulp floor

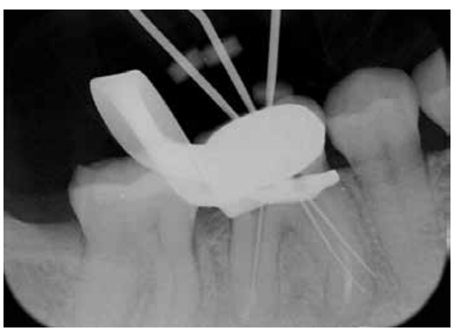


Figure 4C: Radiograph showing two lateral perforations in the mesial root

Figure 4D: Perforation in the furcation was sealed with EndoSequence Putty

Figure 4E: A Thermafill carrier was removed from the root canal system with a Hedstrom file

Figure 4F: The original mesiobuccal canal was negotiated

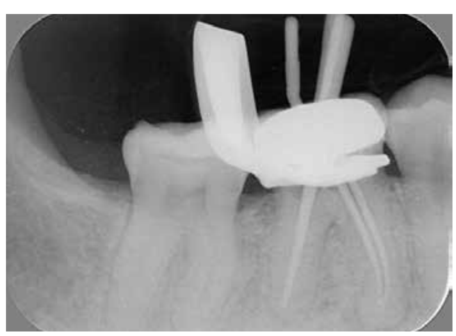


Figure 4G: Cone-fit radiograph

Figure 4H: The root canal system was filled with gutta percha and EndoSequence Sealer

Figure 4I-J: Postoperative radiograph from different angles showing the endodontically retreated root canals and a composite core

Figure 4K: At 1 year, the periapical lesion had decreased in size significantly root canal fillings (Figure 4E) and to relocate and negotiate the original canals (Figure 4F). After each appointment, the canals were dressed with calcium hydroxide (UltraCal XS; Ultradent). At the third appointment, the gutta-percha cones were seated (Figure 4G), and the root canal system was obturated with gutta percha and EndoSequence BC Sealer (Brasseler, USA Dental LLC) (Figure 4H). A composite core material (LuxaCore) was placed in the access opening, with a top layer of a hybrid composite (Tetric Ceram, Ivoclar Vivadent) (Figures 4I-J)

At the 1-year recall, the tooth was asymptomatic, the radiolucency had decreased in size, and probing depths were within normal limits (Figure 4K).

Patient No. 5 was a 47-year old white female with a noncontributory medical history. Her chief complaint was persisting discomfort after retreatment of tooth No. 14 1 year earlier. Clinical examination revealed tenderness to palpation and percussion. Radiographs revealed a periapical radiolucency and an apical transportation of the canals in the mesial root (Figure 5A). According to the endodontist who carried out the retreatment a year earlier, it was not possible to completely instrument MB2, and the apical portion was left untreated. The diagnosis was previous root canal treatment with acute apical periodontitis of tooth No. 14.

Treatment options were discussed with the patient, including these three:

1. Extraction
2. A second retreatment
3. Apical surgery

The patient chose a surgical approach. To obtain surgical access, an intrasulcular incision was made, and a labial full-thickness flap was reflected. A root-end resection was performed followed by a root-end preparation (Figure 5B) with a diamond coated ultrasonic tip (KiS tip #3D, Spartan Obtura Endodontics). After obtaining a dry field, the apical preparation was filled with EndoSequence RRM Putty (Brasseler, USA Dental LLC) (Figures 5C-5D), utilizing a Lee block and corresponding Lee carver (Hartzell and Son)(Figures 5E-5I). The flap was repositioned and sutured.

Healing was uneventful, and the 1-year recall showed resolution of the periapical lesion (Figure 5J).

Discussion

The authors have presented five cases in which a premixed bioceramic material was used to manage clinical situations that are not uncommon in an endodontic practice. In each case, treatment resulted in elimination of clinical symptoms and bone healing. It was shown that bioceramic materials can be

Figure 5A: Preoperative radiograph of tooth No. 14 revealing a periapical radiolucency and apical transportation of the canals in the mesial root

Figure 5B: Photograph of the resected mesial root and a root-end preparation carried out with an ultrasonic tip

Figures 5C-5D: EndoSequence Putty was applied as a root-end filling

Figure 5E: The Lee MTA block and Lee carver

Figures 5F-5G: The sharp blade of a Lee carver was used to pick up a pellet of the Root Repair Material Putty from the Lee block

Figures 5H-5I: A RRM Putty pellet was applied in a root-end preparation with a Lee carver. The pellet is formed in a Lee MTA block (different case than depicted in Figures 5A-5D)

Figure 5J: The 1-year recall radiograph showing a healthy tooth in full function used successfully in conjunction with gutta-percha, or as stand-alone materials. In all cases, the presence of moisture could have affected the quality of the root canal filling and the clinical result. Bioceramic materials are also a good choice for cases in which extrusion into the periapical tissues may damage vital structures, such as the maxillary sinus or the inferior alveolar nerve.

In the opinion of the authors, bioceramic materials have several advantages over MTA. Premixed bioceramic materials have better clinical handling properties. The difficulties in handling of MTA have been frequently reported by clinicians.[4] Another drawback of MTA is the potential for staining dentin, which has been shown in several in vitro studies,[10, 60, 61] clinical investigations ,[62, 63] and case reports,[9, 64] which have shown that both white and gray MTA cause discoloration. To date, there have been no reports of staining of dentin by bioceramic products, which has also been the experience of the authors.

Several studies report that bismuth oxide, which acts as a radiopacifier in MTA as a radiopacifier, [65, 67] may increase the cytotoxicity of MTA, because bismuth oxide does not encourage cell proliferation in cell culture.[66] Bioceramics contain zirconium oxide and tantalum pentoxide as opacifiers.[67] The presence of heavy metals may be another potential drawback of MTA. A recent study showed that MTA Angelus and Micro Mega MTA contained minor amounts of several metal oxides (aluminum, arsenic, beryllium, cadmium, chromium, and iron). Bioaggregate, from which bioceramic products are made (iRoot BP stands for "Injectable Root BioAggregate Paste"),[59] contains only trace amounts of aluminum, approximately 1/1000 of the amount found in MTA Angelus or Micro Mega MTA.[68] Innovative BioCeramix, Inc., Vancouver, Canada, also developed bioaggregate. There have been concerns about the retreatability of BC sealer, in particular when the gutta-percha cone is short of working length.[56] The material sets very hard, and there are no solvents available to soft it.

The majority of papers show favorable properties for bioceramic materials including biocompatibility, bioactivity, and antimicrobial properties. It has sealing properties similar to MTA, and some in vitro studies show that bioceramic materials increase resistance to fracture. While in vitro studies are promising, it is not clear if any of these results influence clinical success. Only well-designed, prospective outcome studies can answer this question.

REFERENCES

1. Sundqvist G, Figdor D, Persson S, Sjögren U. Microbiologic analysis of teeth with failed endodontic treatment and the outcome of conservative re-treatment. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 1998;85(1):86-93.
2. Torabinejad M, Parirokh M. Mineral trioxide aggregate: a comprehensive literature review — Part II — leakage and biocompatibility investigations. *J Endod.* 2010;36(2):190-202.
3. Parirokh M, Torabinejad M. Mineral trioxide aggregate: a comprehensive literature review — Part I — chemical, physical, and antibacterial properties. *J Endod.* 2010;36(1):16-27.
4. Parirokh M, Torabinejad M. Mineral trioxide aggregate: a comprehensive literature review —Part III – clinical applications, drawbacks, and mechanism of action. *J Endod.* 2010;36(3):400-413.
5. Camilleri J, Montesin FE, Brady K, Sweeney R, Curtis RV, Ford TR. The constitution of mineral trioxide aggregate. *Dent Mater.* 2005;21(4):297-303.
6. Sarkar NK, Caicedo R, Ritwik P, Moiseyeva R, Kawashima I. Physicochemical basis of the biologic properties of mineral trioxide aggregate. *J Endod.* 2005;31(2):97-100.
7. Bozeman TB, Lemon RR, Eleazer PD. Elemental analysis of crystal precipitate from gray and white MTA. *J Endod*. 2006;32(5):425-428.
8. Tay FR, Pashley DH, Rueggeberg FA, Loushine RJ, Weller RN. Calcium phosphate phase transformation produced by the interaction of the portland cement component of white mineral trioxide aggregate with a phosphate-containing fluid. *J Endod.*2007;33(11):1347-1351.
9. Belobrov I, Parashos P. Treatment of tooth discoloration after the use of white mineral trioxide aggregate. *J Endod.* 2011;37(7):1017-20.
10. Akbari M, Rouhani A, Samiee S, Jafarzadeh H. Effect of dentin bonding agent on the prevention of tooth discoloration produced by mineral trioxide aggregate. *Int J Dent.* 2012;2012:563203.
11. Antunes Bortoluzzi E, Juárez Broon N, Antonio Hungaro Duarte M, de Oliveira Demarchi AC, Monteiro Bramante C. The use of a setting accelerator and its effect on pH and calcium ion release of mineral trioxide aggregate and white Portland cement. *J Endod.* 2006;32(12):1194–1197.
12. Wiltbank KB, Schwartz SA, Schindler WG. Effect of selected accelerants on the physical properties of mineral trioxide aggregate and Portland cement. *J Endod.* 2007;33(10):1235–1238.
13. Ber BS, Hatton JF, Stewart GP. Chemical modification of ProRoot MTA to improve handling characteristics and decrease setting time. *J Endod.* 2007;33(10):1231–1234.
14. Kogan P, He J, Glickman GN, Watanabe I. The effects of various additives on setting properties of MTA. *J Endod.* 2006;32(6):569–572.
15. Jafarnia B, Jiang J, He J, Wang YH, Safavi KE, Zhu Q. Evaluation of cytotoxicity of MTA employing various additives. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2009;107(5):739-744.
16. Alanezi AZ, Jiang J, Safavi KE, Spangberg LS, Zhu Q. Cytotoxicity evaluation of EndoSequence root repair material. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2010;109(3):e122–125.
17. Zhang W, Li Z, Peng. Ex vivo cytotoxicity of a new calcium silicate-based canal filling material. *Int Endod J.* 2010;43(9):769-774.
18. Zoufan K, Jiang J, Komabayashi T, Wang YH, Safavi KE, Zhu Q. Cytotoxicity evaluation of Gutta Flow and Endo Sequence BC sealers. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2011;112(5):657-661.
19. Ma J, Shen Y, Stojicic S, Haapasalo M. Biocompatibility of two novel root repair materials. *J Endod*. 2011; 37(6):793-798.
20. Ciasca M, Aminoshariae A, Jin G, Montagnese T, Mickel A. A comparison of the cytotoxicity and proinflammatory cytokine production of EndoSequence root repair material and ProRoot mineral trioxide aggregate in human osteoblast cell culture using reverse-transcriptase polymerase chain reaction. *J Endod.* 2012;38(4):486-489.
21. Hirschman WR, Wheater MA, Bringas JS, Hoen NM. Cytotoxicity comparison of three current direct pulp-capping agents with a new bioceramic root repair putty. *J Endod.* 2012;38(3):385-388.
22. Willershausen I, Callaway A, Briseno B, Willershausen B. In vitro analysis of the cytotoxicity and the antimicrobial effect of four endodontic sealers. *Head Face Med.* 2011;Aug 10;7:15.
23. Damas BA, Wheater MA, Bringas JS, Hoen MM. Cytotoxicity comparison of mineral trioxide aggregates and EndoSequence bioceramic root repair materials. *J Endod.* 2011;37(3):372-375.
24. Mukhtar-Fayyad D. Cytocompatibility of new bioceramic-based materials on human fibroblast cells (MRC-5). *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2011;112(6):e137-142.
25. De-Deus G, Canabarro A, Alves GG, Marins JR, Linhares AB, Granjeiro JM. Cytocompatibility of the ready-to-use bioceramic putty repair cement iRoot BP Plus with primary human osteoblasts. *Int Endod J.* 2012;45(6):508-513.
26. Willershausen I, Wolf T, Kasaj A, Weyer V, Willershausen B, Marroquin BB. Influence of a bioceramic root end material and mineral trioxide aggregates on fibroblasts and osteoblasts. *Arch Oral Biol.* 2013;58(9):1232-1237.
27. Loushine BA, Bryan TE, Looney SW, Gillen BM, Loushine RJ, Weller RN, Pashley DH, Tay FR. Setting properties and cytotoxicity evaluation of a premixed bioceramic root canal sealer. *J Endod.* 2011;37(5):673-677.
28. Modareszadeh MR, Di Fiore PM, Tipton DA, Salamat N. Cytotoxicity and alkaline phosphatase activity evaluation of EndoSequence root repair material. *J Endod*. 2012;38(8):1101-1105.
29. Zhang H, Shen Y, Ruse ND, Haapasalo M. Antibacterial activity of endodontic sealers by modified direct contact test against Enterococcus faecalis. *J Endod.* 2009;35(7):1051-1055.
30. Candeiro GT, Correia FC, Duarte MA, Ribeiro-Sigueira DC, Gavini, G. Evaluation of radiopacity, pH, release of calcium ions, and flow of a bioceramic root canal sealer. *J Endod.* 2012;38(6):842-845.
31. Zhou HM, Shen Y, Zheng W, Li L, Zheng YF, Haapasalo M. Physical properties of 5 root canal sealers. *J Endod.* 2013;39(10):1281-1286.
32. Hansen SW, Marshall JG, Sedgley CM. Comparison of intracanal EndoSequence Root Repair Material and ProRoot MTA to induce pH changes in simulated root resorption defects over 4 weeks in matched pairs of human teeth. *J Endod.* 2011;37(4):502-506.
33. Lovato KF, Sedgley CM. Antibacterial activity of EndoSequence root repair material and proroot MTA against clinical isolates of Enterococcus faecalis. *J Endod.* 2011 Nov;37(11):1542-1546.
34. Zhang W, Li Z, Peng B. Effects of iRoot SP on mineralization-related genes expression in MG63 cells. *J Endod.* 2010;36(12):1978-1982.
35. Shokouhinejad N, Nekoofar MH, Razmi H, Sajadi S, Davies TE, Saghiri MA, Gorjestani H, Dummer PM. Bioactivity of EndoSequence root repair material and bioaggregate. *Int Endod J.* 2012 Dec;45(12):1127-1134.
36. Zhang S, Yang X, Fan M. BioAggregate and iRoot BP Plus optimize the proliferation and mineralization ability of human dental pulp cells. *Int Endod J.* 2013;46(10):923-929.
37. Güven EP, Yalvaç ME, Kayahan MB, Sunay H, Şahın F, Bayirli G. Human tooth germ stem cell response to calcium-silicate based endodontic cements. *J Appl Oral Sci.* 2013;21(4):351-357.
38. Han L, Okiji T. Bioactivity evaluation of three calcium silicate-based endodontic materials. *Int Endod J.* 2013;46(9):808-814.
39. Güven EP, TaŞ PN, Yalvac ME, Sofiev N, Kayahan MB, Sahin F. In vitro comparison of induction capacity and biomineralization ability of mineral trioxide aggregate and a bioceramic root canal sealer. *Int Endod J.* 2013;46(12):1173-1182.
40. Ersahan S, Aydin C. Dislocation resistance of iRoot SP, a calcium silicate-based sealer, from radicular dentine. *J Endod.* 2010;36(12):2000-2002.
41. Nagas E, Uyanik MO, Eymirli A, Cehreli ZC, Vallittu PK, Lassila LV, Durmaz V. Dentin moisture conditions affect the adhesion of root canal sealers. *J Endod.* 2012;38(2):240-244.
42. Sagsen B, Ustün Y, Demirbuga S, Pala K. Push-out bond strength of two new calcium silicate-based endodontic sealers to root canal dentine. *Int Endod J.* 2011;44(12):1088–1091.
43. Özcan E, Çapar ŞD, Çetin AR, Tunçdemir AR, Aydınbelge HA. The effect of calcium silicate-based sealer on the push-out bond strength of fibre posts. *Aust Dent J.* 2012;57(2):166-170.
44. Shokouhinejad N, Gorjestani H, Nasseh AA, Hoseini A, Mohammadi M, Shamshiri AR. Push-out bond strength of gutta-percha with a new bioceramic sealer in the presence or absence of smear layer. *Aust Endod J*. 2013;39(3):102-106.
45. Shokouhinejad N, Hoseini A, Gorjestani H, Raoof M, Assadian H, Shamshiri AR. Effect of phosphate-buffered saline on push-out bond strength of a new bioceramic sealer to root canal dentin. *Dent Res J (Isfahan).* 2012;9(5):595-959.
46. Ghoneim AG, Lutfy RA, Sabet NE, Fayyad DM. Resistance to fracture of roots obturated with novel canal-filling systems. *J Endod.* 2011;37(11):1590-1592.
47. Ulusoy ÖŞ Nayır Y, Darendeliler-Yaman S. Effect of different root canal sealers on fracture strength of simulated immature roots. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2011;112(4):544-547.
48. SaŞen B, Ustün Y, Pala K, DemırbuŞa S. Resistance to fracture of roots filled with different sealers. *Dent Mater J.* 2012;31(4):528-532.
49. TopçuoŞu HS, Tuncay Ö, KarataŞE, Arslan H, Yeter K. In vitro fracture resistance of roots obturated with epoxy resin-based, mineral trioxide aggregate-based, and bioceramic root canal sealers. *J Endod.* 2013;39(12):1630-1633.
50. Zhang W, Li Z, Peng B. Assessment of a new root canal sealer's apical sealing ability. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2009;107(6):e79-82.
51. Ersahan S, Aydin C. Solubility and apical sealing characteristics of a new calcium silicate-based root canal sealer in comparison to calcium hydroxide-, methacrylate resin- and epoxy resin-based sealers. *Acta Odontol Scand*. 2013;71(3-4):857-862.
52. Nair U, Ghattas S, Saber M, Natera M, Walker C, Pileggi R. A comparative evaluation of the sealing ability of 2 root-end filling materials: an in vitro leakage study using Enterococcus faecalis. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2011;112(2):e74-77.
53. Leal F, De-Deus G, Brandão C, Luna A, Souza E, Fidel S. Similar sealability between bioceramic putty ready-to-use repair cement and white MTA. *Braz Dent J.* 2013;24(4):362-366.
54. Hirschberg CS, Patel NS, Patel LM, Kadouri DE, Hartwell GR. Comparison of sealing ability of MTA and EndoSequence Bioceramic Root Repair Material: a bacterial leakage study. *Quintessence Int.* 2013;44(5):e157-62.
55. Borges RP, Sousa-Neto MD, Versiani MA, Rached-Júnior FA, De-Deus G, Miranda CE, Pécora JD. Changes in the surface of four calcium silicate-containing endodontic materials and an epoxy resin-based sealer after a solubility test. *Int Endod J*. 2012;45(5):419-428.
56. Hess D, Solomon E, Spears R, He J. Retreatability of a bioceramic root canal sealing material. *J Endod*. 2011;37(11):1547-1549.
57. Ersev H, Yilmaz B, Dincol ME, Daglaroglu R. The efficacy of ProTaper University rotary retreatment instrumentation to remove single gutta-percha cones cemented with several endodontic sealers. *Int Endod J.* 2012;45(8):756-762.
58. Ma J, Al-Ashaw AJ, Shen Y, Gao Y, Yang Y, Zhang C, Haapasalo M. Efficacy of ProTaper Universal Rotary Retreatment system for gutta-percha removal from oval root canals: a micro-computed tomography study. *J Endod.* 2012;38(11):1516-1520.
59. Azimi S, Fazlyab M, Sadri D, Saghiri MA, Khosravanifard B, Asgary S. Comparison of pulp response to mineral trioxide aggregate and a bioceramic paste in partial pulpotomy of sound human premolars: a randomized controlled trial. *Int Endod J.* 2013 Dec 11. [Epub ahead of print].
60. Boutsioukis C, Noula G, Lambrianidis T. Ex vivo study of the efficiency of two techniques for the removal of mineral trioxide aggregate used as a root canal filling material. *J Endod.* 2008;34(10):1239-1242.
61. Jang JH, Kang M, Ahn S, Kim S, Kim W, Kim Y, Kim E. Tooth discoloration after the use of new pozzolan cement (Endocem) and mineral trioxide aggregate and the effects of internal bleaching. *J Endod.* 2013;39(12):1598-1602.
62. Maroto M, Barbería E, Vera V, García-Godoy F. Dentin bridge formation after white mineral trioxide aggregate (white MTA) pulpotomies in primary molars. *Am J Dent.* 2006;19(2):75–79.
63. Percinoto C, de Castro AM, Pinto LM. Clinical and radiographic evaluation of pulpotomies employing calcium hydroxide and trioxide mineral aggregate. *Gen Dent.* 2006;54(4):258–261.
64. Jacobovitz M, de Lima RK. Treatment of inflammatory internal root resorption with mineral trioxide aggregate: a case report. *Int Endod J.* 2008;41(10):905-912.
65. Camilleri J, Montesin FE, Brady K, Sweeney R, Curtis RV, Ford TR. The constitution of mineral trioxide aggregate. *Dent Mater.* 2005;21(4):297-303.
66. Camilleri J, Montesin FE, Papaioannou S, McDonald F, Pitt Ford TR. Biocompatibility of two commercial forms of mineral trioxide aggregate. *Int Endod J.* 2004;37(10):699-704.
67. Park JW, Hong SH, Kim JH, Lee SJ, Shin SJ. X-Ray diffraction analysis of white ProRoot MTA and Diadent BioAggregate. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2010;109(1):155-158.
68. Kum KY, Kim EC, Yoo YJ, Zhu Q, Safavi K, Bae KS, Chang SW. Trace metal contents of three tricalcium silicate materials: MTA Angelus, Micro Mega MTA and Bioaggregate. *Int Endod J.* 2014;47(7):704-710.