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.

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. 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. It is dimensionally stable, expands slightly as it sets, and is insoluble over time. It has antibacterial properties, due to its high pH during setting, and is biocompatible. It is considered the material of choice for perforation repair, root-end fillings, pulp caps, pulpotomies, and obturation of immature teeth with open apices. 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.

MTA is described as a first-generation bioactive material. It has many advantages, but also some disadvantages. 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. 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 or with additives. 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
advantage of uniform consistency and lack of waste. They are all hydrophobic.

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.26-28 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.26,27 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).29

**pH and antibacterial properties**

BC materials have a pH of 12.7 while setting, similar to calcium hydroxide, resulting in antibacterial effects.26 BC Sealer was shown to exhibit a significantly higher pH than AH Plus® 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 crystal 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 Paste.15,16 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 Ca2+ release than AH Plus® 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,

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<th>Material</th>
<th>Brand</th>
<th>Abbreviation</th>
<th>Composition</th>
<th>Manufacturer</th>
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Table 1
Continuing Education

3 Endodontic practice

The bond strength of EndoSequence Sealer was similar to AH Plus and greater than MTA Fillapex. When iRoot SP was used with a self-adhesive resin cement, the bond strength of fiber posts were not adversely affected. Smear layer removal had no effect on bond strengths of EndoSequence Sealer and AH Plus, which had similar values. 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. 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. Fracture resistance was increased in simulated immature roots in teeth with iRoot SP, and in mature roots with AH Plus, EndoSequence Sealer, and MTA Fillapex. Similar results were reported for EndoSequence Sealer and AH Plus Jet sealer in root-filled single-rooted premolar teeth.

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. Similar microleakage values were reported for sealers that contained calcium hydroxide, methacrylate resin and epoxy resin, as well as iRoot SP and AH Plus. EndoSequence paste was similar to white MTA in preventing bacterial leakage of E. faecalis or preventing glucose leakage in vitro. In contrast, EndoSequence Putty was found to leak significantly more than ProRoot MTA in a study using a bacterial leakage model.

Solubility

High levels of Ca²⁺ release were reported from in a solubility from iRoot SP, MTA Fillapex, Sealapex, and MTA-Angelus, but not AH Plus. Release of Ca²⁺ ions is thought to result in higher solubility and surface changes. 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. None of the filling materials could be removed completely from the root canals, however. Micro-computed tomography showed that none of the retreatment techniques completely removed the gutta-percha/iRoot SP sealer from oval canals.

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.

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 (Endo-Sequence BC sealer, Brasseler, USA Dental LLC), since it is not sensitive to moisture, in conjunction with gutta percha to obturate all lower incisors (Figure 1J). After root canal treatment was completed, the teeth were
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

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 bio-ceramic 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. Endo-Sequence BC Sealer was chosen because of its biocompatibility\(^1\), \(^2\), \(^3\), \(^4\), \(^5\), \(^6\) and lack of sensitivity to moisture.\(^4\) Once the cones were seated (Figure 2F), the downpack was performed using a System B\(^\text{TM}\) heat source (SybronEndo), followed by backfilling with an Obtura gun (Spartan Obtura Endodontics). The access opening was restored with a bonded composite core material (Luxa-Core; DMG, Hamburg, Germany), which was covered with a layer of a hybrid composite (Tetric\(^\text{®}\) 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...
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 mesiobuccal 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.
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 (K&S 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
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 been frequently reported by clinicians. Another drawback of MTA is the potential for staining dentin, which has been shown in several in vitro studies, 10, 61 clinical investigations, 62, 63 and case reports, 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 as MTA as a radiopacifier, 65, 66 may increase the cytotoxicity of MTA, because bismuth oxide does not encourage cell proliferation in cell culture. 66 Bicarbonate contains 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).

Bioceramies include a bioceramic putty ready-to-use repair cement and a bioceramic paste ready to use with a syringe. 68 Bioceramic materials have several advantages over MTA. Premixed bioceramic materials have been frequently reported by clinicians. Another drawback of MTA is the potential for staining dentin, which has been shown in several in vitro studies, 10, 61 clinical investigations, 62, 63 and case reports, 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.

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