Achieving a sufficient disinfection of the root canal system is a procedure that requires multiple steps. Among these, irrigation plays a key role, helping mechanical instruments to remove pulp remnants, debris and the smear layer from the root canal walls. Mechanical instrumentation alone cannot remove the totality of bacteria from the root canal system, and research published in the literature has demonstrated that untreated canal areas for individual canals can range from 10 to 50 per cent.\(^1\)\(^-\)\(^5\) These areas may shelter pulp remnants and bacteria, jeopardising the outcome of the endodontic treatment\(^6\) and leading to apical periodontitis.\(^7\) Irrigation of root canals works together with mechanical instrumentation in order to improve the removal of bacteria, pulp tissue, the smear layer and debris from the root canal system,\(^8\) thus reducing the risk of post-treatment disease.

Sodium hypochlorite has antimicrobial and tissue-dissolving abilities, but its capability of eliminating bacteria depends on several factors, among which penetration along the full length of the canal and fluid exchange play an important role.\(^6\)\(^,\)\(^9\) The anatomy of the root canal system, the irrigant delivery system, the depth of placement, the fluid properties and the volume of the irrigant affect its flushing action.\(^10\) The anatomical complexity of teeth has widely been investigated in the literature, and the root canal system is particular of interest because of its anatomy and variability (Fig. 1).\(^11\)

In vitro and ex vivo studies have shown the presence of bacteria in the dentinal tubules and cementum even after treatment, emphasising that the goals of total disinfection of the canal may not be achieved by cleaning and shaping only.\(^12\) The filling of the prepared root canal is a further step in endodontic therapy, preventing bacteria from re-entering the tooth and the periapex. The majority of obturating systems in endodontic therapy are composed of a core material and a sealer. The sealer should not only fill the gaps between the core material and the root canal wall, but also fill the surface irregularities of the root canal system (such as lateral canals and isthmuses) in order to achieve a tight seal (Figs. 2a & b).\(^13\) To overcome the problem of bacterial persistence in the root canal system, the market has progressively developed filling materials with antibacterial properties. The antibacterial nature of sealer is valuable because of the higher percentage of facultative anaerobes in failed root canal cases. Several resin-based and MTA-based compositions appeared, claiming to be able to destroy the bacteria left in the root canal dentine; nevertheless, the literature showed that antimicrobial sealers (above all, resin-based sealers) are more effective when freshly mixed and their activity reduces after setting\(^12\) and they thus cannot be relied on to prevent reinfection over time.

Achieving good instrumentation and cleaning of the root canal system is more difficult when curved canals have to be treated. Their anatomy can represent a problem for the penetration of instruments and can reduce their efficiency. The evolution of instruments used in the shaping of the canal system with the introduction of engine-driven nickel-titanium (NiTi) files brought about an improvement in the cleanliness of the root canal walls with respect to manual instrumentation, but a high percentage of the surface was still untouched.\(^14\)\(^-\)\(^16\) Moreover, mechanical instrumentation is not able to remove all of the smear layer deposited on the root surface, especially in the apical third or in the case of complex anatomies (Figs. 3a–d).\(^11\)
A recent review by Li et al. clearly states that it is important to realise that no filling material or technique can compensate for inadequate asepsis and disinfection procedures. For this reason, achieving good disinfection of the root canal system has to be a major objective for the clinician, particularly in curved canals.

The anatomy of teeth can make preparation extremely tricky, and mechanical preparation cannot reach all areas of the root. Irrigants too can have difficulty penetrating into narrow spaces, and the difficulty in reaching the most apical region of the canal with large volumes of fresh irrigant may result in poorer performance during cleaning. The most common method for delivery of the irrigating solution into the prepared canals is by means of a syringe and needle, according to general guidelines in order to maximise irrigation efficiency and avoid extrusion of irrigant into the periapical tissue. The majority of irrigation needles are made from steel and this material is not able to follow the anatomy of the root canal, particularly when curves are present. Consequently, the needle stops against one of the canal walls, decreasing the rate of fresh irrigant reaching the apical third and increasing the shear stress on the canal wall.

Endodontic irrigation benefits from the use of 5 ml syringes with Luer lock attachments that help the clinician work safely and with a constant flow. The choice of needle is a function of the diameter of the root canal: the needle has to be positioned within 1 mm from the working length, but it does not have to rub against the walls of the root canal (to decrease the risk of extrusion). The needle diameters recommended in endodontics are from 27 gauge to 30 gauge. They are sufficiently thin to be inserted into the root canal and they provide an irrigant flux ranging from 0.19 ml/s to 0.09 ml/s. Moreover, they may result in better exchange and cleaning.

Needles should be designed with dedicated tips and can be notched or side-vented. These shapes generally guarantee a laminar-controlled flow of the irrigating solution and permit safe placement of the tip in the apical third, because the fluid can flow towards the coronal part of the root. It has to be considered that the more violent the flow is, the greater the risk of extruding debris into the periapical tissue, and that open-end needles extrude more product than side-vented needles do. It also has to be said that the further the needle is from the working length, the lower the flux is.

Wall roughness does not affect laminar flow in the middle and coronal thirds of the canal; conversely, it increases the resistance when the flow is turbulent, modifying the flow pattern. The shear stress pattern on the canal wall decreases as needles move away from the working length, but the area affected by high shear stress becomes larger. This area surrounds the tip of the side-vented needle, and maximum shear stress is concentrated on the wall facing the needle outlet, while high stress is concentrated apically when an open-ended flat needle is used. The pressure developed at the apical foramen is higher with flat needles than with side-vented needles at the same depth.

Figs. 3a–d: Curved canals are challenging to shape, clean and fill. Fig. 4: The peculiar back-to-back side-vented design helps improve safety and efficiency of irrigation.

Figs. 5a–c: The flexible tip improves the ergonomics of the irrigation phase and allows rinsing of the canal system in teeth that present complicated anatomies.
Another point to be considered is that the irrigating solution needs to be replaced to maintain its efficiency; thus, a sufficient flow rate has to be established within the root canal. In order to reach this goal, the development of turbulent flow is the best way to achieve efficient irrigant exchange. A simple way to create a turbulent irrigant flow within the root canals is via the push–pull technique: alternating positive and negative pressure on the plunger of the syringe helps create a turbulence that promotes the irrigant exchange.

It has been demonstrated that using a syringe to inject the irrigant into the root canals, unfortunately, is not sufficient to achieve good disinfection, because irrigant exchange beyond the tip of the needle is limited with a conventional needle. The air trapped in the apical part of the root canal during irrigation (vapour lock effect) might also decrease the exchange of irrigants in this area, reducing the efficiency of irrigation. For this reason, the literature has reported the need for activation of the irrigating solution. Curved canals represent a challenge for the action of irrigants, because the fluid penetration is not as effective as in straight canals. For this reason, activating the irrigant is advised to achieve superior cleaning of these areas. According to Cunningham and Joseph, and Basrani and Haapasalo, increasing the temperature of the solution above 37 °C increases the antimicrobial activity of sodium hypochlorite. The temperature of the irrigant can be increased by preheating or agitation.

Technological advancements have influenced the agitation of irrigants, in particular for the final rinse before filling. The techniques available include ultrasonic activation, sonic activation and dedicated devices which generate negative pressure through a micro-cannula inserted to the working length, facilitating the apical flow of the irrigant. It seems that ultrasonic activation of the irrigant is the most studied and used method to reach this goal, because it increases the temperature of the solution, and by creating turbulence, it improves its cleaning efficiency in the apical third by 5 per cent and generates a continuous solution exchange. Technology has also improved microinjection techniques. For example, polymeric needles (e.g. IrriFlex, Produits Dentaires) have been developed that are able to guarantee both safety and efficiency of root canal cleaning owing to an innovative back-to-back side-vented design that improves the fluid dynamics in the canal.

Clinicians need cleaning to be effective, particularly in the final rinse of the root canal system in teeth that present difficult anatomies. As reported before, steel needles have significant drawbacks in curved canals because they have the tendency to block and engage the external walls of the canal. However, using a 30 gauge soft polypropylene needle allows superior flexibility compared with steel or even NiTi, following the anatomy of the root to the working length. Technological advancements are helpful for achieving superior cleaning of the root canal system, ensuring safe and efficient action of the irrigating solutions.

Editorial note: A list of references is available from the publisher.

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The use of pre-mixed bioceramic materials in endodontics

Dr Gilberto Debelian, Norway & Dr Martin Trope, USA

Introduction

Microbes within the root canal system are the cause of apical and periradicular periodontitis (endodontic disease). The absence of microbes ensures that apical periodontitis of endodontic origin does not occur. Therefore, the aim of endodontic treatment is to prevent microbial contamination of the root canal system and/or to remove enough microbes to ensure clinical and radiographic success. A common misconception is that endodontics encompasses only root canal therapy, retreatment or surgical treatment of post-endodontic disease. A major part of endodontics is maintaining the vital pulp to ensure a healthy periradicular periodontium. Thus, in addition to root canal therapy, indirect and direct pulp capping and pulpotomy procedures are integral parts of endodontic therapy.

Root canal therapy is divided into the microbial control phase (instrumentation, irrigation and intracanal medication) followed by the filling phase (root and top filling). With both antimicrobial and sealing properties, pre-mixed bioceramic materials are one of the few materials available in endodontics that contribute to both critical phases for endodontic treatment success.

Bioceramics

Bioceramics are ceramic materials specifically designed for medical and dental use. During the 1960s and 1970s, these materials were developed for use in the human body for 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 are inorganic, nonmetallic, biocompatible materials that include alumina, zirconia,
bioactive glass, composites, hydroxyapatite, resorbable calcium phosphates, and radiotherapy glasses.\textsuperscript{2–4} They are chemically stable and noncorrosive, and interact well with organic tissue.

Bioceramics are classified as:

- bioinert (noninteractive with biological systems);
- bioactive (durable in tissue that can undergo interfacial interactions with surrounding tissue); and
- biodegradable, soluble or resorbable (eventually replace or are incorporated into tissue).

There are numerous bioceramics currently in use in dentistry and medicine. Alumina and zirconia are bioinert ceramics used in prostheses. Bioactive glass and glass-ceramics are available for use in dentistry under various trade names. In addition, porous ceramics such as calcium phosphate—based materials have been used for filling bone defects. Some calcium silicates (mineral trioxide aggregate [MTA], ProRoot MTA Root Repair, DENTSPLY Tulsa Dental Specialties) and bioaggregates (DiaRoot BioAggregate, DiaDent) have also been used in dentistry as materials for root repair and for apical root filling.

**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 mixing and handling characteristics of the powder-liquid systems are very technique-sensitive and produce considerable waste. Pre-mixed bioceramics require moisture from the surrounding tissue to set. Pre-mixed sealer, paste and putty have the advantage of uniform consistency and lack of waste. These pre-mixed bioceramics are all hydrophilic.

![Fig. 4: A representative radiograph of a root-filled tooth with BC Sealer hydraulically moved with the gutta-percha point. Note that the cold hydraulic technique results in lateral canal puffs similar to those with the warm vertical technique.](image1)

![Fig. 5: Molar roots filled with BC Sealer cut at different distances from the apex (0.5, 1.5 and 3.0 mm). One gutta-percha point is used as a plugger to move the sealer using hydraulic pressure. Note that the irregularities are very well filled with the sealer.](image2)

![Fig. 6: Endodontic treatment of a maxillary molar and premolar, root canals filled with a single gutta-percha cone and BC Sealer.](image3)

![Fig. 7: Table of expansion and shrinkage of popular sealers with the addition of bioceramic sealer. The BC Sealer expands slightly on setting, but does not shrink.](image4)
Endodontic bioceramics are not sensitive to moisture and blood contamination and therefore are not technique-sensitive. They are dimensionally stable and expand slightly. When set, they are hard, allowing full compaction of a final restoration, and they are insoluble over time, ensuring a superior long-term seal. When setting, the pH is above 12 owing to the hydration reaction, which first forms calcium hydroxide and then dissociates into calcium (Ca²⁺) and hydroxyl ions (Figs. 1a & b). Therefore, when unset, the material has antibacterial properties. When fully set, it is biocompatible and even bioactive. When bioceramic materials come into contact with tissue fluid, they release calcium hydroxide, which can interact with phosphates in the tissue fluid to form hydroxyapatite (Fig. 1c). This property may explain some of the tissue-inductive properties of the material. For the reasons above, these materials are recommended for pulp capping, pulpotomy, perforation repair, root end filling, obturation of immature teeth with open apices, and sealing of root canal fillings of mature teeth with closed apices.

Available bioceramic materials in endodontics

There are several bioceramic materials and brands available in the dental market today. The most popular type used in endodontics are listed below:

Mineral trioxide aggregate

Few clinicians realise that original MTA is a classic bioceramic material with some heavy metals added. MTA is one of the most extensively researched materials in the dental field. It has the properties of all bioceramics; that is, it has a high pH when unset, is biocompatible and bioactive when set, and provides an excellent seal over time. It has some disadvantages, however. It requires mixing, resulting in considerable waste, is not easy to manipulate, and is difficult to remove. Clinically, both gray and white MTA stain dentine, presumably owing to the heavy-metal content of the material or the inclusion of blood pigment while setting. Finally, MTA is difficult to apply in narrow canals, making the material poorly suited for use as a sealer together with gutta-percha. 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.

Biodentine

Biodentine (Septodont) is considered a second-generation bioceramic material. It has properties similar to those of MTA and thus can be used for all the applications described above for MTA.

Its advantages over MTA are that it sets in a shorter period (approximately 10 to 12 minutes) and it has a compressive strength similar to that of dentine. A major disadvantage is that it is triturated for 30 seconds in a preset quantity (capsule), making waste inevitable, since in the vast majority of endodontic cases, only a small amount is required.

Endodontic pre-mixed bioceramics

In 2007, a Canadian research and product development company (Innovative Bio-Ceramix) developed a pre-mixed, ready-to-use calcium silicate-based material, iRoot SP injectable root canal sealer. Since 2008, these endodontic pre-mixed bioceramic products have been available in North America from Brasseler US as EndoSequence BC Sealer, EndoSequence BC RRM (Root Repair Material, a syringable paste), and EndoSequence BC RRM Fast Set Putty (Fig. 2). Recently, these materials have also been marketed as TotalFill BC Sealer, TotalFill BC RRM Paste and TotalFill BC RRM Putty/Fast Set Putty (Fig. 3) by FKG Dentaire. All three forms of bioceramic are similar in chemical composition (calcium silicates, zirconia, tantalum pentoxide,
calcium phosphate monobasic and fillers), and they have excellent mechanical and biological properties and good handling properties. They are hydrophilic, insoluble, radiopaque and aluminum-free, have a high pH, and require moisture to set and harden. The working time of the BC Sealer and BC RRM is more than 30 minutes, and the setting time is four hours under normal conditions, depending on the amount of moisture available. The recently introduced TotalFill BC RRM Fast Set Putty has all the properties of the original putty, but with a faster setting time (approximately 20 minutes). RRM putties and paste are recommended for perforation repair, apical surgery, apical plugging and vital pulp therapy. Pre-mixed BC Sealer is the only pure medical-grade bioceramic product available as a sealer for endodontic obturation. It has the same basic chemical composition as the other pre-mixed bioceramic products, but it is less viscous, which makes its consistency ideal for sealing root canals. It is used with a gutta-percha point with a surface impregnated with a nanoparticle layer of bioceramic. The gutta-percha is used primarily as the delivery device (plugger; Fig. 4) to allow hydraulic movement of the sealer into the irregularities of the root canal and accessory canals (Fig. 5).

Interestingly, when the taper is not excessive and the gutta-percha point is used primarily as a plugger to move the sealer into the canal irregularities and accessory canals, a radiographic image similar to that of the classical vertical condensation technique is often seen (Fig. 6). In addition, its surface bond to the sealer eliminates a critical pathway for coronal leakage of microbes if the coronal restoration has a defective seal. The gutta-percha also is used as a pathway for post-preparation or for retreatment if necessary.

Properties of the bioceramic sealer and potential changes in root filling technique:

1. The bioceramic sealer is highly hydrophilic and thus the natural moisture in the canal and tubules is an advantage, unlike most other sealers where moisture is detrimental to their performance.
2. When unset, the bioceramic sealer has a pH of above 12. Thus, its antibacterial properties are similar to those of calcium hydroxide. Setting is dependent on physiological moisture in the canal; therefore, it will set at different rates in different environments, but since it has a high pH, any delay in setting can be argued as a benefit.
3. The sealer does not shrink, but expands slightly, and is insoluble in tissue fluid (Fig. 7). Setting is dependent on physiological moisture in the canal; therefore, it will set at different rates in different environments, but since it has a high pH, any delay in setting can be argued as a benefit.
4. If used with a gutta-percha point that is impregnated and coated with nanoparticles of bioceramic, as suggested, it will bond to the core point, thus eliminating the gap between the core and sealer.

The properties listed above, particularly in the presence of a sealer that does not shrink and is insoluble in tissue fluid, should change the long-held rule that in root fillings the core material should take up as much space as possible in order to mask the shortcomings of the sealer and by keeping the sealer as thin as possible. In fact, if it were possible to fill the canal in a homogeneous way, the need for a core material at all is questionable.

Studies on endodontic pre-mixed bioceramic materials

To date, more than 70 studies have been performed on pre-mixed endodontic bioceramic materials. The vast majority of these studies have shown that the properties conform to those expected of a bioceramic material and are similar to those of MTA.

Biocompatibility and cytotoxicity

Several in vitro studies report that BC materials display biocompatibility and cytotoxicity that are similar to those of MTA. Cells required for wound healing attach to the BC materials and produce replacement tissue. In comparison to AH Plus (Dentsply Sirona) and Tubli-Seal (Sybron Endo), BC Sealer showed a lower cytotoxicity. On the other hand, one study concluded that BC Sealer remained moderately cytotoxic over the six-week period and osteoblast-like cells had reduced bioactivity and alkaline phosphatase activity compared with MTA and Geristore (DenMat).
A recent study comparing the results of apicoectomies done with MTA or bioceramic putty in dogs showed the bioceramic putty to be slightly better than the MTA, presumably owing to its superior handling properties.\textsuperscript{35} pH and antibacterial properties
BC materials have a pH of 12.7 while setting, similar to calcium hydroxide, resulting in antibacterial effects.\textsuperscript{36} BC Sealer has been shown to exhibit a significantly higher pH than AH Plus\textsuperscript{37} for a longer duration.\textsuperscript{38} Alkaline pH promotes elimination of bacteria such as \emph{Enterococcus faecalis}. In vitro studies have reported that EndoSequence BC RRM produced a lower pH than white MTA in simulated root resorption defects,\textsuperscript{39} and EndoSequence BC RRM, EndoSequence BC RRM Fast Set Putty and MTA had similar antibacterial efficacy against clinical strains of \emph{E. faecalis}.\textsuperscript{40}

Bioactivity
Several studies evaluated bioactivity. Exposure of MTA and EndoSequence BC RRM Fast Set Putty to phosphate-buffered saline resulted in precipitation of apatite crystalline structures that increased over time, suggesting that the materials are bioactive.\textsuperscript{41} iRoot SP exhibited significantly lower cytotoxicity and a higher level of cell attachment than did MTA-Fillapex (Angelus), a salicylate resin-based root canal sealer containing MTA particles.\textsuperscript{42} EndoSequence BC Sealer had a higher pH and greater Ca\textsuperscript{2+} release than did AH Plus\textsuperscript{43} and was shown to release fewer Ca\textsuperscript{2+} ions than did Biodentine and White MTA.\textsuperscript{43}

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).\textsuperscript{44} Another study found that iRoot SP played the highest bond strength to root dentine compared with AH Plus, Epiphany and MTA-Fillapex, irrespective of moisture conditions.\textsuperscript{45} In a push-out test, was similar to AH Plus and greater than MTA-Fillapex.\textsuperscript{46} When iRoot SP was used with a self-adhesive resin cement, the bond strength of fiber posts was not adversely affected.\textsuperscript{47} Smear layer removal had no effect on the bond strengths of EndoSequence BC Sealer and AH Plus, which had similar values.\textsuperscript{48} The presence of phosphate-buffered saline within the root canals increased the bond strength of EndoSequence BC Sealer/gutta-percha at one week, but no difference was found at two months.\textsuperscript{49} 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 used with bioceramic-impregnated and coated gutta-percha cones.\textsuperscript{50} Fracture resistance was increased in simulated immature roots in teeth with iRoot SP\textsuperscript{51} and in mature roots with AH Plus, EndoSequence BC Sealer and MTA-Fillapex.\textsuperscript{52} Similar results were reported for Endo  Sequence BC Sealer and AH Plus Jet sealer (Dentsply Sirona) in root-filled single-rooted premolars.\textsuperscript{53}

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.\textsuperscript{54} A recent study showed the superior sealing ability of EndoSequence BC RRM Fast Set Putty compared with gray MTA.\textsuperscript{55}

Solubility
High levels of Ca\textsuperscript{2+} release were reported from iRoot SP, MTA-Fillapex, Sealapex and MTA Angelus (Angelus), but not AH Plus. Release of Ca\textsuperscript{2+} ions is thought to result in higher solubility and surface changes.\textsuperscript{56} However, the study tested the materials according to ANSI/ADA
specification No. 57, which is not designed for pre-mixed 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 BC Sealer and AH Plus were comparable in a study comparing hand instruments and ProTaper Universal (Dentsply Sirona) retreatment instruments. None of the filling materials could be removed completely from the root canals, however. Microcomputed tomography showed that none of the retreatment techniques completely removed the gutta-percha and iRoot SP sealer from oval canals.

Clinical studies
A randomised clinical trial evaluated iRoot BP and white ProRoot MTA Root Repair as direct pulp capping materials. The study evaluated clinical signs and symptoms and histological pulp reactions, such as inflammation and mineralised 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.

Indications and case examples
The following section will illustrate endodontic clinical cases where the pre-mixed bioceramic material was used:

Indirect and direct pulp capping and pulpotomy of carious exposure
Historically, endodontists have not recommended vital pulp therapy on teeth where caries has exposed the pulp. The results of this procedure have showed poor results. However, these studies used calcium hydroxide as the pulp capping agent and amalgam as the coronal restoration; therefore, if the amalgam leaked, the calcium hydroxide base would wash out. This resulted in calcified canals—if the pulp survived—or necrotic pulps with infection and apical periodontitis. New studies and case series observations have shown that if the base used is antibacterial (such as calcium hydroxide), sets hard and—most critically—seals well, both indirect and direct pulp capping and pulpotomy procedures have a very good chance of a successful outcome. In relatively young patients, these should be the treatment of choice.

Case 1: Direct pulp capping
Figure 8 shows the preoperative radiograph of an apparently carious exposure on tooth #46 of a 20-year-old male patient. A diagnosis of reversible pulpitis was made based on the history and clinical examination. After anaesthesia and caries removal, the exposure was seen and covered with EndoSequence BC RRM Fast Set Putty. After the BC base had fully set, a bonded resin was placed and a post-operative radiograph taken. At the six-month follow-up visit, the tooth was asymptomatic and tested vital. Radiographically, no signs of pathology were noted.
Case 2: Pulpotomy

In this case (Fig. 9), the tooth tested vital, but showed clinical signs of irreversible pulpitis. Treatment with a full pulpotomy was chosen to improve the possibility the remaining pulp would survive and remain healthy. The preoperative radiograph showed extensive caries in the tooth and a slightly widened apical periodontal ligament. A full pulpotomy was performed using EndoSequence BC RRM Fast Set Putty. After the putty had set, a coronal restoration was placed, and an immediate post-operative radiograph was taken and viewed. At the one-year follow-up, the tooth was asymptomatic and the radiograph showed continued root development, a healthy apical periodontium, and importantly, no calcifications in the remaining pulp (as is often seen with a calcium hydroxide therapy). A radiograph taken of the contralateral tooth showed similar root development.

Case 3: Primary endodontic treatment of a nonvital pulp

This is a case of a mandibular first molar with signs and symptoms of a periapical lesion (Fig. 10). The tooth was treated over two visits with an intracanal medication (calcium hydroxide). Three weeks later, the obturation was carried out with BC Sealer and gutta-percha using a singlepoint technique. The one-year follow-up radiograph showed signs of periapical healing.

Case 4: Apicoectomy and retrofill

A patient presented with clinical symptoms and radiographic signs of post-endodontic disease (Fig. 11). It was determined that the crown and the post were well adapted and an apicoectomy was to be performed. After apicoectomy, the canal was instrumented with an ultrasonic tip to its length and until the tip of the post. The canal was filled with BC Sealer first and a 2 mm plug of BC RRM Putty was condensed inside the retrograde cavity. The one-year follow-up showed radiographic signs of advanced periapical healing.

Conclusion

Pre-mixed bioceramic materials are hydrophilic, do not shrink and are insoluble in tissue fluid. With both antimicrobial and sealing properties, pre-mixed bioceramics are unique materials available in endodontics that have changed the way we perform both vital pulp therapy and root canal therapy. For root canal therapy, they contribute to the success of both the microbial control phase (instrumentation, irrigation and intracanal medication) and the filling phase (root and top filling) of root canal therapy. This allows the practitioner to perform the microbial control without removing dentine unnecessarily, leaving a stronger root for restorative reconstruction. Premixed bioceramics are also an essential element in the indirect and direct pulp capping and pulpotomy procedures owing to their sealing ability and the fact that they do not discolour the surrounding dentine. Because of these properties, more vital healthy pulps can be maintained, ensuring a healthy surrounding periodontium. For these reasons, pre-mixed bioceramic materials are now the material of choice for pulp capping, pulpotomy, perforation repair, root end filling, obturation of immature teeth with open apices and sealing of root canal fillings of mature teeth with closed apices.

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Dr Martin Trope received his BDS in Johannesburg, South Africa, in 1976. In 1980, he moved to Philadelphia to specialise in endodontics at the University of Pennsylvania. After graduating, he remained as a faculty member until 1989, when he became Chair of Endodontontology at Temple University, School of Dentistry, Philadelphia. In 1993, he accepted the J.B. Freedland Professorship at the Department of Endodontics at the University of North Carolina at Chapel Hill School of Dentistry, US. Dr Trope is now a clinical professor at the Department of Endodontics of the University of Pennsylvania School of Dental Medicine. He is also in private practice in Philadelphia. Dr Trope has served as a director of the American Board of Endodontics. His work has been published in numerous journals and book chapters. In 2002, he was awarded the Louis I. Grossman Award for cumulative publication of significant research by the American Association of Endodontists. Dr Trope has created Next Level Endodontics on his extensive academic background and real-world experience in private practice.