Bioceramic dispersion root filling
Revision of legacy obturation protocols

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Despite the fact that degradation and dissolution of gutta-percha and sealer jeopardise positive treatment outcomes, these legacy materials are still used in diverse protocols for root filling canals. This paper reviews the historical cognitive dissonance in endodontics; the biochemical seal created by gutta-percha and sealer diminishes over time with negative sequelae and yet, they remain the gold standard of obturation. Bioceramics possess physical, chemical and biologic properties that demonstrate the ability to overcome the limitations of traditional root filling materials. They are bioinert (non-interactive with biological systems), bioactive (interactive with surrounding tissues) and biodegradable (eventually replaced or incorporated into tissue). These properties facilitate conservative root canal shaping, thus preserving natural tooth structure (Figs. 1a–d).

Objectives of root filling

Debridement, disinfection and the prevention of reinfection are the mandates of root filling. Endodontic disease is a biofilm-mediated infection. The most common endodontic infection is caused by surface-associated growth of microorganisms. The application of the biofilm concept to endodontic microbiology depends on understanding the pathogenic potential of root canal microflora, which require new approaches for disinfection.2,3

Fig. 1a: Bioceramic scaffolds are porous structures that facilitate cell penetration and tissue-in-growth. Fig. 1b: Scanning electron microscopic (SEM) evaluation of root section filled with gutta-percha and AH Plus Root Canal Sealer. Note the gap between the gutta-percha, the sealer and the dentine (attribution Drs Ørstavik and Eldeniz).

Fig. 1c: Canals were filled with EndoSequence BC Sealer and sectioned at sequential distances from the apex. The gutta-percha cone facilitates dispersion of the sealer into the apical seat and irregularities of the root canal space (attribution Drs Trope and Debelian). Fig. 1d: Microstructure of calcium orthophosphate cement after hardening. Mechanical stability is provided by the physical entanglement of crystals.
There are three basic requirements for a root filling material:

1. Prevent coronal leakage after the root canal is filled and the final restoration placed.
2. Entomb surviving microflora in the interfacial dentine so they cannot reassert their presence and communicate with the periradicular tissues.
3. Prevent influx of periapical fluids to provide nutrients for residual microflora in the root canal space.

**Gutta-percha and sealer**

Gutta-percha was discovered in 1656 by John Tradescant and introduced to medicine by Dr William Montgomerie in 1831. In 1867, GA Bowman used gutta-percha cones as the sole material for root filling. It was not until 1925 that UG Rickert recommended the use of sealer with a GP cone.

The clinical performance of classic root filling materials substantiates what Aristotle expressed as historical truth; practical individuals study not the eternal principle, but the relative and immediate application. In vitro, in vivo and clinical outcome studies done on single cone or lateral condensation techniques demonstrate failure of their primary function, sealing. Salivary hydrolytic enzymes have the ability to break down the coronal seal. Microbial products destroy and decompose gutta-percha, resulting in the loss of adaptation of gutta-percha to canal walls, thereby reducing the coronal seal and by extrapolation, the apical seal.

**History: lateral condensation**

Lateral condensation techniques enhance the ability to control the length of the root filling. However, if there is poor canal preparation, inadequate application of pressure or a mismatched spreader and gutta-percha cone, residual spaces between the gutta-percha cones are filled with sealer. Lateral condensation has a low core/sealer ratio, which potentiates apical leakage. Sabeti et al. found no difference in treatment outcomes when a root filled canal was compared to a canal left empty.

**Fig. 2:** Chart shows in vitro evaluation of saliva penetration in the root canals. The seal achieved with gutta-percha alone is indistinguishable from the negative control (attribution Drs Khayat et al.). **Fig. 3:** Table shows expansion/shrinkage of popular sealers. Silicone and epoxy-resin sealer expand slightly before shrinking. By contrast, bioceramic sealer expands slightly on setting but does not shrink.

**Fig. 4a:** Chemistry associated with the hydration reaction of bioceramic material (calcium silicates) with water (moisture present in canal and tubuli) creates calcium silicate hydrate and calcium hydroxide. **Fig. 4b:** Precipitation reaction of the bioceramic (calcium phosphate). The hydroxyapatite co-precipitated within the calcium silicate hydrate phase produces a composite-like structure, reinforcing the set cement. The bioactivity of the calcium-silicate-based materials has been shown to produce mineralisation within the subjacent dentine substrate, extending deep within the tissues (attribution Dr Martin Trope).
This study and others emphasise the poor quality of current root filling techniques and the importance of a coronal restoration for positive treatment outcomes. Furthermore, there is an overriding technical flaw with lateral condensation; overzealous application of apically directed pressure can result in vertical root fractures.15–17

**The Schilderian epoch**

Dr Schilder’s transgressive articles, *Vertical Compaction of Warm Gutta-Percha and Filling Canals in Three Dimensions*, address technical adjustments to traditional obturation techniques. Warm vertical condensation enabled gutta-percha to replicate the microstructural anatomy of the root canal space to a demonstrably greater degree than any previous technique.18, 19 Despite the enhanced rheology, gutta-percha neither adhered to nor penetrated the interfacial dentine. The sealer was integral to achieving a positive treatment outcome. Schilder and Goodman20 established the hypothesis that warm vertical condensation pushed a greater volume of filler material into the apical space and theoretically the material would not shrink on cooling; however, regardless of enhanced gravitometrics, leakage studies on gutta-percha alone and gutta-percha and sealer showed their inability to create an impervious apical seal.21

**Carrier-based obturation**

The prototype of carrier-based thermoplasticised gutta-percha obturators was developed by Dr WB Johnson in 1978. Traditionally, the beta formulation of gutta-percha was used for its improved stability, hardness and reduced stickiness. Alpha phase gutta-percha was chosen for CB as it demonstrates low viscosity, it flows with less pressure or stress and creates a more homogenous filling.22
The latest iteration of carrier-based obturators is GuttaCore (Dentsply Sirona), a system made entirely of gutta-percha with a core obturator prepared with cross-linked gutta-percha. This method of obturation appears to have significantly less voids and gaps than lateral compaction.\textsuperscript{23}

The volume of sealer is the weak link in the chain of success; volume must be minimised by the density of the core/filler regardless of the technique used. With the new array of equipment for identifying, shaping and cleaning the root canal space, reliance on ineffective materials and techniques mandate a paradigm shift in root filling. When tested in an \textit{in vitro} model, microbes will permeate the length of the canal space in two hours if only gutta-percha is present in the canal without sealer. The leakage can be delayed for up to thirty days with the use of sealer. Traditional sealers generally shrink on setting and wash out in the presence of tissue fluids\textsuperscript{24} (Fig. 3), whereas bioceramic sealer do not.

**Bioceramic nano-technology: the reckoning**

Bioceramic materials (calcium phosphate) include alumina, zirconia, bioactive glass, hydroxyapatite and resorbable calcium phosphates.\textsuperscript{25–29} They are used as joint or tissue replacements in both medicine and dentistry as they are chemically and dimensionally stable, biocompatible and osteoconductive. Bioceramic sealers are composed of tricalcium silicate, dicalcium silicate, colloidal silica, calcium phosphate monobasic, calcium hydroxide and a thickening agent. Zirconium oxide is used as the radiopacifier and the material is aluminium-free. The chromogenic effects of all root sealers increase when excess sealer is not removed from coronal dentine of the pulp chamber.\textsuperscript{30}

Bioceramics are ideal for use in endodontics as they are not affected by moisture or blood contamination and, therefore, technique sensitivity is not an issue, unlike most other sealers where moisture negates their performance. Being that they are hydrophilic, residual moisture in the canal and dentinal tubuli are biochemically a positive factor. In the context of creating an impervious seal, they are dimensionally stable and expand slightly on setting, ensuring a long-term seal due to the hydration reaction forming calcium hydroxide and later dissociation into calcium and hydroxyl ions.\textsuperscript{31} \textit{In vitro} testing by Prati and Gandolfi stated that bioceramic materials can expand by 0.2–6\% of their initial volume.\textsuperscript{32} In addition, they are shown to penetrate into dentinal tubules at a greater degree than AH Plus in both single cone and warm vertical techniques at 2 mm to apex (P <0.05).\textsuperscript{33}

Bioceramic material may be an essential element in indirect and direct pulp capping and pulpotomy procedures that are an integral part of endodontic therapy’s goal of maintaining the vital pulp to ensure a healthy peri-iradicular periodontium. For all these reasons, premixed bioceramic materials are seen as an alternative material of choice for pulp capping, pulpotomy, perforation repair, root end filling and obturation of immature teeth with open apices, as well as for sealing root canal fillings of mature teeth with closed apices.\textsuperscript{34, 35}

When setting, the pH of the bioceramic is above 12 due to a hydration reaction forming calcium hydroxide and dissociation into calcium hydroxide and hydroxyl ions, which could explain the antibacterial properties of bioceramics (Fig. 4a). The release of calcium hydroxide and its interaction with phosphates on contact with tissue fluids forms hydroxyapatite. This may explain the osteoconductive potential of the material (Fig. 4b).\textsuperscript{36} Calcium phosphate is the main inorganic component of the hard tissues (teeth and bone). Consequently, the literature notes that many bioceramic sealers have the potential to promote bone regeneration. The amount of Ca\textsuperscript{2+} released from EndoSequence BC Sealer is far higher than that from AH Plus mainly after seven days. A concordance was also observed between pH and the amount of Ca\textsuperscript{2+} released in both analysed materials. A possible explanation for the high amount of Ca\textsuperscript{2+} released by bioceramic cements could be associated with setting reactions, including hydration reactions of calcium silicates.\textsuperscript{37}
A scientific paradigm shift in root filling

As the root filling paradigm shifts to bioceramic sealers, the practitioner can execute a bio-minimalistic antimicrobial protocol for root canal treatment, leaving a thicker and stronger root. Bioceramic sealer is used with a dedicated gutta-percha cone impregnated and coated with nanoparticles of bioceramic, thus eliminating the gap between the core and sealer. This combination has been shown to be similar or better than conventional endodontic sealers as observed in *in vitro* and *in vivo* animal studies.38

Bioceramic dispersion protocols

- In order to ensure an exact shape at the apical terminus (circular or ovoid) and intimacy of fit of the bioceramic nanocoated gutta-percha cone, an .02 stainless steel file is used to refine the apical seat.
- The gutta-percha cone designed for use with bioceramic sealer is fit to working length is impregnated with bioceramic nanoparticles, mated to the taper of the prepared canal, EndoSequence BC Points (Brasseler USA, Figs. 5a & b).
- When used with anatomically dedicated files (XP-3D Shaper and Finisher (Brasseler USA), the apical seat created minimises sealer extrusion (tug back is not required).
- Traditional compaction techniques require maximal volume of the gutta-percha core and minimal volume of sealer. Bioceramic dispersion root filling requires minimal gutta-percha and maximal sealer volume.
- 0.05 mm of the apical tip of the dedicated gutta-percha cone is removed to prevent sealer extrusion.
- The master apical file coated with sealer is used in a counter clockwise motion to deposit sealer at the apical seat.
- An aliquot of EndoSequence BC sealer is injected into the coronal and middle thirds of the root canal space using Intra Canal Tips designed for the sealer cartridge (Fig. 6).
- A lentulo spiral positioned no less than 2 to 3 mm short of the apical seat is used to flow the sealer down the tip of the spiral (slow-speed in forward mode) (Fig. 7).
- The gutta-percha cone delivers the bioceramic sealer from the coronal reservoir to the apical seat without heat or pressure; the bioceramic capillary condensation of sealer adheres to the interfacial dentine and disperses into the dentinal tubuli to develop an impervious apical and intracanal seal (Figs. 8a & b, Figs. 9a & b).
- In contrast to lateral condensation, carrier-based obturation and warm vertical condensation, the gutta-percha cone must be delivered slowly and incrementally to length. The preservation of dentine resulting from the integration of the XP-3D file system and the EndoSequence BC gutta-percha point is shown in the postoperative radiograph (Fig. 10).
- Calibrated “beds” are developed for footings or cementation of fibre posts. The fibre post (.04 taper) determines the depth of the post channel created by the instrumentation before the obturation. This drill-less method prevents additional intracanal dentinal weakening. Fibre posts with a #50 tip and .04 taper are invariably the maximum size necessary in molars and premolars. In anterior teeth, the tip size is dependent on the intracanal diameter.

Conclusion

All variables in an equation are interdependent. In the case of endodontic success, each procedural event is accountable for positive treatment outcomes; however, regardless of its importance, if a concomitant event does not provide a suitable biologic conclusion, failure ensues. Biominimalism in root canal space preparation requires a root filling material that replicates the internal anatomy of the root canal space, adheres to interfacial dentine and creates an impervious, irreversible seal at all portals of exit. The last mile of the bioceramic endodontic marathon will be to obviate the need for a gutta-percha core of any formulation.

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

about

Dr Kenneth Serota graduated with a DDS from the University of Toronto Faculty of Dentistry in Canada in 1973 and received his Certificate in Endodontics and Master of Medical Sciences from the Harvard–Forsyth Dental Center in Boston in Massachusetts in the US. Active in online education since 1998, he is the founder of the ROOTS endodontic forum and the NEXUS interdisciplinary forum. Dr Serota is an adjunct clinical instructor in the University of Toronto postdoctoral endodontics department.