Bioactive materials are on the threshold of mainstream endodontics

“Two roads diverged in a wood,
and I took the one less traveled by,
And that has made all the difference.”
–Robert Frost

Three-dimensional “root filing” is unattainable with the materials used since the late 1800s. Gutta-percha has been and still is the core material of choice; however, even with the essential inclusion of a sealer, degradation and dissolution of both the gutta-percha core and the sealer will obviate long-term successful treatment outcomes.¹

This article takes a critical look at past and present methods for root filling. The clinician’s axiom of choice is to no longer persist with materials that fail to obtain permanent sealing of the root canal due to leakage from the oral cavity or, to effect a paradigm shift to a root filling protocol using bioactive bioceramic materials (Figs. 1a–1c).
Objectives of root filling

Currently, it is not possible to effect optimal sterilization of the root canal space, nor can biofilms be completely eradicated from the interfacial dentin. Thus, the aim involves three basic requirements from a root filling:

1. Stop coronal leakage after the root canal is filled and the final restoration placed.
2. Entomb surviving microflora in the interfacial dentin so that 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.2

Lateral- and carrier-based obturation

Many in vitro, in vivo and clinical outcome studies have been performed primarily on single cone or lateral condensation techniques. It is apparent that they fail in their primary function of sealing the root canal space long term.3–4

Sabeti et al found no difference in the outcome when a canal was root-filled compared to left empty. This study and others emphasize the poor quality of our current root filling techniques and the importance of the coronal restoration for successful root canal treatment outcomes.5–6

A study by Gihooly et al showed that multiphase gutta-percha obturation had significantly less apical dye leakage than lateral condensation in curved canals (P < 0.05).7 Success based on degree of density is not the issue as gutta-percha does not bond to dentin. Sealer remains the dominant concern re: leakage over the long term.

Fig. 2 shows that when tested in an 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

Human Saliva Penetration of Coronally Unsealed Obturated Root Canals

Fig 2. In vitro evaluation of saliva penetration of root canals. Note that the seal achieved with gutta-percha alone is indistinguishable from the negative control. (from Khayat et al).
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Sealer. The leakage can be delayed for up to 30 days with the use of sealer. Sealers are the materials in root canal filling that provide whatever resistance to leakage is achieved. Traditional sealers generally shrink on setting and wash out in the presence of tissue fluids (Fig. 3).

Results on the GuttaCore carrier-based system in combination with root canal sealer do not improve the microleakage resistance compared with Thermafil/Topseal filling and the Continuous Wave compaction technique. Gutta-percha, regardless of how it is biochemically reconstituted or introduced into the root canal space, is not an effective barrier to microbes. Furthermore, the volume of sealer is the weak link in the chain of success; volume must be minimized by the density of the core/filler regardless of the technique used. With the new array of equipment for identifying, shaping and cleaning of the root canal space, reliance on ineffective materials and techniques mandate a paradigm shift in root filling.

### The Schilderian Epoch

Dr. Schilder’s transgressive articles, “Vertical Compaction of Warm Gutta-Percha” and “Filling Canals in Three Dimensions,” addressed technical adjustments to traditional obturation techniques that enabled gutta-percha to replicate the microstructural anatomy of the root canal space to a demonstrably greater degree than any previous technique.

Despite the enhanced rheology, gutta-percha neither adhered to nor penetrated the interfacial dentin and it was sealer that was integral to achieving a positive treatment outcome, albeit short-lived. Schilder and Goodman established the hypothesis that a warm vertical condensation technique 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, the leakage studies on gutta-percha alone and gutta-percha and sealer and their inability to create an impervious apical seal are repeatedly demonstrated in the literature.

Microfractures are a complication of any instrumentation technique that requires significant preparation of the coronal portion of the canal to place a plugger/condenser (heated or otherwise) within 4mm of the working length. Furthermore, thinning of the root dentin by “imprinting a file size to accommodate a filling technique” will proportionally weaken the tooth, leaving a root susceptible to fracture.

### The future of bioceramic nanotechnology

Bioceramic materials include alumina, zirconia, bioactive glass, hydroxyapatite and resorbable calcium phosphates. They are used as joint or tissue replacements in both

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**Figure 3.** Table of expansion/shrinkage of popular sealers. Silicone and epoxy resin sealers expand slightly before shrinking. Note that by contrast, bioceramic sealer expands slightly on setting but does not shrink.
medicine and dentistry as they are chemically and dimensionally stable, biocompatible and osteoconductive.

The properties, in addition to being non-corrosive, are categorized as:
- Bioinert—non-interactive with biological systems.
- Bioactive—tissues that can undergo interfacial interactions with surrounding tissue.
- Biodegradable, soluble or resorbable—eventually being replaced or incorporated into tissues.

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.20

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 ions21–22 (Figs. 4a, 4b).

When setting, the pH of the bioceramic is above 12, which is due to a hydration reaction forming calcium hydroxide and later dissociation into calcium and hydroxyl ions (Figs. 4c, 4d), which may explain the antibacterial properties of the bioceramic.

The release of calcium hydroxide and its interaction with phosphates on contact with tissue fluids forms hydroxyapatite. This may explain the osteo-conductive potential of the material. Bioceramics are seen as today’s material of choice for pulp capping, pulpotomy, perforation repair, root-end filling and obturation of immature teeth with unformed apices.23

A scientific paradigm shift in root filling

Premixed bioceramic sealer is composed of dicalcium and tricalcium silicate, calcium phosphates (monobasic), colloidal silica, water-free thickeners and calcium hydroxide in combination with radiopacifiers
(zirconium oxide) and marketed in the U.S. as EndoSequence BC Sealer, (Brasseler USA, Savannah, Georgia). The sealer is similar in chemical composition (calcium silicates, zirconium oxide, tantalum oxide, calcium phosphate monobasic and fillers). They are hydrophilic, insoluble, radiopaque, aluminum-free, high pH, and require moisture to set. The singular most important feature is the gap between the sealer and the core is eliminated and as such the sealing of the root filling is optimally potentiated.24–25

The properties of the bioceramic sealer enact changes in the root filling procedure:

1. Being hydrophilic, naturally occurring moisture in the canal and tubuli is an advantage.
2. When unset, the bioceramic sealer has a pH above 12, thus its antibacterial properties are similar to calcium hydroxide.25 Setting is dependent on physiologic moisture in the canal; therefore it will set at different rates in different environments, but since it is a high pH, any delay in setting can arguably be beneficial.
3. The sealer does not shrink but expands slightly, and it is insoluble in tissue fluids.26

The afore-referenced properties should change the enduring—albeit antiquated—rule that the core material in root fillings should mask the deficiencies of the sealer by keeping it as thin as possible. In theory, the need for any core/filler material should prove debatable if it were possible to fill the canal homogeneously with bioceramic sealer. As it stands, the gutta-percha is used to deliver the bioceramic sealer through hydraulic condensation and the sealer can be the main component of the root filling. The gutta-percha is used primarily as the delivery device (plugger) to allow cold hydraulic movement of the sealer into the irregularities of the root canal and accessory canals. In addition, it will act as a pathway for post preparation and retreatment.

As the root filling paradigm shifts to bioceramic sealers, the practitioner can execute a biomimalistic antimicrobial protocol for root canal treatment leaving a thicker and stronger root. When the taper is not excessive and the gutta-percha point is used as a condenser to move the sealer into the canal irregularities and accessory canals, a radiographic picture consistent with the classic vertical condensation technique is seen (Figs. 5a, 5b).

**Technique troubleshooting**

As the EndoSequence BC sealer is premixed, storage should be at room (ambient) temperature. As discussed previously, unlike traditional sealers, the setting reaction of bioceramic sealers is initiated by moisture in the canal, therefore refrigeration is to be avoided.27 The booster tip of the XP-3D Shaper provides a unique apical seat, which will minimize sealer extrusion.

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**Fig 5a.** Radiograph of a root filled tooth showing EndoSequence BC Sealer hydraulically moved by the gutta-percha point apical terminus. Note that the cold hydraulic technique results in lateral canal “puffs” similar to the warm vertical condensation technique. (Courtesy of Dr. Gilberto Debelian)

**Fig 5b.** Molar filled using the cold hydraulic technique. Note the biominimalistic shaping of the coronal and middle third of the canals resulting from the use of the XP-3D Shaper and Finisher. (Courtesy of Dr. Frank Setzer)
The amount of sealer introduced into the canal should be controlled so that only a modest amount is expressed and expression of surplus is not introduced in the periapical region. The syringe delivery system should not be positioned greater than the interface of the coronal and middle third of the root canal. The bioceramic sealer flows easier than AH Plus and other sealers due to its particle size (< 2µ) and this mandates a degree of practice.

A nano-coated gutta-percha cone with a laser-verified tip for accuracy is mated to the canal preparation. Its purpose, unlike traditional compaction techniques, where the volume of gutta-percha needs to optimal to minimize the volume of sealer, is used to deliver the bioceramic sealer to the apical seat without heat or pressure; the bioceramic being bioactive and adherent to the interfacial dentin creates a true impervious apical seal.

Depending on the shape of the apical region (circular or ovoid) and the intimacy of fit of the master nano-coated gutta-percha cone, the master file used to apically gauge...
and size can be coated with sealer and introduced in a counter-clockwise manner to deposit the sealer at the apical terminus. The master cone coated with a thin layer of sealer is then slowly introduced to the apical seat to avoid trapping air or excess sealer and preventing it seating fully. The gutta-percha handle is severed with heat at the orifice or below for a canal footing or a post space (Figs. 6a–6d).

All variables in an equation are interdependent. In the case of endodontic success, each procedural event is accountable for the positive treatment outcome; however, regardless of its importance, if a concomitant event doesn’t provide a suitable biologic conclusion, failure ensues. The shrinkage and instability of root canal sealers have mandated their use in thin layers and necessitated techniques to ensure this requirement.

Biomimimalism in canal space preparation requires a filling material that replicates the internal anatomy of the root canal space, adheres to interfacial dentin and creates an impervious, irreversible seal at all portals of exit.

We are almost there; the last mile of this endodontic marathon will be to obviate entirely the need for a core point of any formulation.

References