

Bioceramic Technology: Closing the Endo-Restorative Circle, Part I



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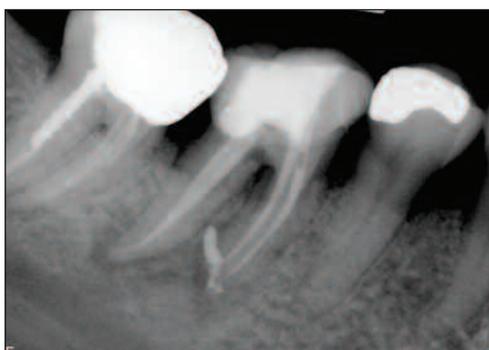
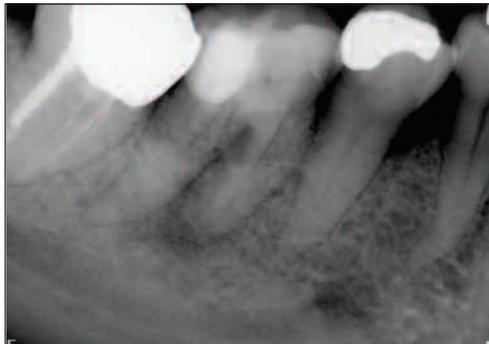
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One of the most significant advancements in endodontics has been our ability to see endodontics not as a lone standing entity but rather as part of a greater Endo-Restorative Continuum. Evidence of this relationship is the simple placement of a post. The practitioner who places a post in a tooth is in the exact same space as the individual who did the root canal. Therefore, it should be obvious that an intimate relationship exists between endodontics and restorative dentistry. Furthermore, regardless of how well the root canal was done, if the tooth is not properly restored, the entire complex will fail over time. All of us can agree with this.



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Another consideration for the long-term success of an endodontically treated tooth is the acceptance of the principle that excessive tooth removal in the coronal third of the root (during the endodontic preparation) will ultimately compromise the long-term retention of that tooth. The increased incidence of fractured teeth associated with an overzealous removal of coronal tooth structure during the root canal procedure is testament to this. This concept of not being overly aggressive has been universally accepted, and consequently, we have seen a shift to more conservative endodontic preparations, particularly in the coronal third of the root. This is a good thing! However, when viewed in hindsight, we realize that during the past fifteen years in endodontics, obturation dictated shape. In other words, we were creating shapes (generally wider in the coronal third) to accommodate specific obturation techniques. This is *not* a good thing! The goal in endodontics should be to satisfy all the biologic requirements of doing a root canal but to do it in such a manner as to enhance the long-term retention of the tooth. Yes, one of the reasons we shape a root canal is to expedite



Figures 1a to 1c. The following case demonstrates how an overfill with a bioceramic sealer will not hinder healing. **(a)** Pre-op x-ray. **(b)** immediate post-op x-ray. **(c)** Six-month recall. Courtesy of Dr. C. Ullman, Southern Vermont Endodontics.

obturation, but it should be done with minimal reduction of the hard structure of the tooth (especially the root). Anything that compromises the structural integrity of the root, and correspondingly, the long-term prognosis of the tooth, should be questioned and not done. The good news is that we have seen a myriad of changes in endodontic techniques and technology which now give the majority of dentists the ability to produce better endodontics without compromising the long-term retention of the tooth. Paramount among these changes is the introduction of advanced material science and, in fact, we previously

described it in the following manner: “The good news is that the arena of endodontic material science is continuing to evolve and, in fact, the game has changed. The game changer is the increased use of bioceramic technology; more specifically in endodontic obturation.”¹ But how does the introduction of bioceramics improve the retention of endodontically treated teeth and subsequently, close the Endo-Restorative circle? Let’s follow the tracks.

ESTABLISHING ENDODONTIC SYNCHRONICITY

Everything starts with the file and the basic endodontic preparation. The EndoSequence file system has given clinicians the ability to machine predictable shapes (using constant taper files) that ultimately leads to synchronicity between the preparation and the master cone (using laser verified cones to ensure accuracy). The most important factor in establishing endodontic synchronicity is that it reduces dramatically the need to widen the canal preparation in order to accommodate specific heated obturation techniques. Embracing this concept of endodontic synchronicity, and taking it to a more sophisticated level in obturation, are sealer-based obturation systems such as the Activ GP Obturation System and EndoSequence BC Sealer (Brasseler USA). These are sealers that do not shrink.

However, from a historical perspective, it is important to realize that Activ GP was the first one-cone technique to gain widespread acceptance. Activ GP has been and still is a system which utilizes improved glass ionomer technology (both as a sealer and as a special glass ionomer coated gutta-percha cone) to create a true one-cone obturation.² Activ GP obturation requires a minimal amount of sealer, rather than the excess that is utilized in other methods. This is because the system is precision based (synchronized). The net result is an obturation technique similar in results to other more popular methods but easier to use. In a study published in the Journal of Endodontics in 2008, Fransen et al,³ at Baylor University compared the sealing ability of single cone Activ GP with glass ionomer sealer to the warm vertical com-

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paction of gutta-percha with AH Plus Sealer (DENTSPLY) and to the warm vertical compaction of Resilon (SybronEndo) with Epiphany sealer (SybronEndo). Their conclusion was:³ “In summary, there was no statistically significant difference for any of the parameters tested between the 3 obturation systems tested. Based on these results, the single cone Activ GP/GI sealer system has potential as an obturation system to provide a seal comparable to that achieved with other popular obturation systems.”

As previously mentioned, synchronicity in endodontics can be established as a result of the accuracy created between the preparation and the master cone. Similar to the regular EndoSequence gutta-percha, all Activ GP points are laser verified (and calibrated) to precisely match the preparations made by the .04 or .06 constant tapered EndoSequence file system. The precision matching of the primary cone to the preparation (endodontic synchronicity) is very important with any obturation technique because the accuracy of the cone fit to the preparation minimizes the amount of tooth structure removed and reduces the amount of sealer. Furthermore, due to the predictability of shape associated with constant tapers, it may be stated that any true one-cone technique should be accomplished with a constant tapered preparation such as a .04 or .06. A variable taper technique is not recommended because its lack of shaping predictability (and its corresponding lack of reproducibility) will lead to a less than ideal cone fit. This lack of endodontic synchronicity is why all variable taper preparations are associated with thermoplastic techniques.

BIOCERAMIC TECHNOLOGY

While glass ionomer deserves credit in establishing a true one-cone filling technique, there have always been those clinicians who question the handling characteristics of the material. Also, there have been those dentists who do not care to mix any cements. They would prefer a pre-mixed delivery system, which they believe will ensure a consistent mix. While these folks may not like the specific material itself (glass ionomer), they do understand the concept and merits of a one-cone obturation technique. The good news here is that the entire concept of a one-cone obturation technique has taken a giant step



Figure 2. EndoSequence BC Sealer (Brasseler USA) comes premixed in a syringe.

forward, and this giant step is the introduction of bioceramic technology to the world of endodontic obturation.

The science associated with bioceramic technology has generated a number of biocompatible ceramic materials specifically designed for use in medicine and dentistry. Systematic research of ceramics for use in biomedical applications began in the early 1970s, and over the past forty years, the application of a variety of ceramics in biomedicine has greatly expanded.⁴ “Bioceramics” include alumina and zirconia, bioactive glass, glass ceramics, calcium silicates, coatings and composites, hydroxyapatite and resorbable calcium phosphates, and radiotherapy glasses.⁵⁻⁷

Bioceramics are widely used for orthopedic applications such as joint or tissue replacements and for coating metal implants to improve their biocompatibility. Additionally, porous ceramics such as calcium phosphate based materials have been used for filling bone defects. Even some basic calcium silicates such as ProRoot MTA (DENTSPLY) have been used in dentistry as root repair materials and for apical retrofills.

PHYSICAL PROPERTIES OF BIOCERAMICS

But why is there so much excitement associated with the expanded use of bioceramics in endodontics? Clearly the first answer is related to physical properties. Bioceramics are exceedingly biocompatible (nontoxic) and they are chemically stable within the biological environment. Also, bioceramics do not shrink upon setting. In fact, they actually expand slightly upon completion of the setting process. Furthermore (and this is very important in endodontics), bioceramics will not result in a significant inflammatory response if an overfill occurs during the obturation process or in a root repair (Figures 1a to 1c). A further advantage of the material itself is its ability (during the setting process) to form hydroxyapatite and ultimately establish a chemical bond between

dentin and the appropriate filling materials.

While the physical properties associated with bioceramics are very attractive to dentistry, what would be the specific advantages of a bioceramic if used as an endodontic sealer? From our perspective as endodontists, some of the advantages are: enhanced biocompatibility, the fact that it does not shrink, it does not resorb (which is critical for a one-cone technique), its high pH (12.8) during the initial 24 hours of the setting process (which is strongly anti-bacterial), its excellent sealing ability, the fact that it sets quickly (3 to 4 hours) and its ease of use (particle size is so small it can be used in a syringe).

The high pH makes this material very antibacterial during its setting period (the pH will decrease over the next few days). However, this is an important physical property for a cement, particularly if it is being used as an endodontic sealer.⁸ In fact, in another study by H. Zhang et al,⁹ it was noted that the BC Sealer (iRoot SP) killed all bacteria within 2 minutes of contact. This is very significant. The authors proceed to explain that its antibacterial effect might be a combination of high pH, hydrophilicity, and active calcium hydroxide diffusion.⁹

The introduction of a bioceramic sealer (EndoSequence BC Sealer) allows us, for the first time, to take advantage of all the benefits associat-



Figure 3. The particle size of BC Sealer is so small that a capillary tip may be used to deliver the sealer.

ed with bioceramics but to not limit its use to merely root repairs and apical retrofills (Figure 2). This is only possible because of recent nanotechnology developments (the particle size of BC Sealer is so fine [less than 2 μm], it can actually be used with a .012 capillary tip) (Figure 3).

This material has been specifically designed as a nontoxic calcium silicate cement that is easy to use as an endodontic sealer. This is a key point. In addition to its excellent physical properties, the purpose of BC Sealer is to improve the convenience and delivery method of an excellent root canal sealer while simultaneously taking advantage of its bioactive characteristics (it utilizes the water inherent in the dentinal tubules to drive the hydra-

tion reaction of the material, thereby shortening the setting time). Indeed, in a recent study by W. Zhang et al,¹⁰ “they found no difference in the ability of sealing root canals between iRoot SP using the single cone technique and AH plus using the continuous wave condensation technique. Possible reasons for the result could be that iRoot SP is based on a calcium silicate composition, which does not shrink during setting and hardens in the presence of water. The result was also confirmed by SEM.” As we know, dentin is composed of approximately 20% (by volume) water¹¹ and it is this water that initiates the setting of the material and ultimately results in the formation of hydroxyapatite. Therefore, if any residual moisture remains in the canal after drying, it will not adversely affect the seal established by the bioceramic cement. This is very important in obturation and is a major improvement over previous sealers.

Furthermore, Kossev and Stefanov¹² summarize this quite succinctly in their article, “Ceramic-Based Sealers as a New Alternative to Currently Used Endodontic Sealers.” They note the following:¹² “The use of bioceramic-based sealers with their features—osseoconductivity, hydrophilicity, adhesiveness and chemical bonding to the root canal dentinal walls—appears to be an effective approach to eliminate on long-term, the microspace, otherwise remaining

between the root canal walls and the materials filling the root canal. Such microspace is a potential place for possible microbial growth, because of microleakage observed with other kinds of sealers.”

BIOCERAMIC SEALER SETTING REACTIONS

The calcium silicates in the powder hydrate to produce a calcium silicate hydrate gel and calcium hydroxide. The calcium hydroxide reacts with the phosphate ions to precipitate hydroxyapatite and water. The water continues to react with the calcium silicates to precipitate additional gel-like calcium silicate hydrate. The water supplied through this reaction

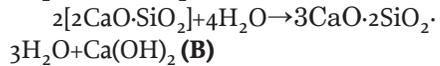
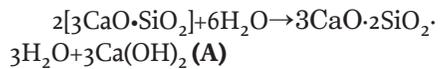
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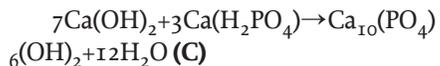
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is an important factor in controlling the hydration rate and the setting time as following:¹³

The hydration reactions (A, B) of calcium silicates can be approximated as follows:



The precipitation reaction (C) of calcium phosphate apatite is as follows:



For clinical purposes, the advantages of premixed endodontic cement (sealer) should be obvious. In addition to a significant saving of time and convenience, one of the major issues associated with the mixing of any cement, or sealer, is an insufficient and nonhomogenous mix. Such a mix may ultimately compromise the benefits associated with the material. Keeping this in mind, BC Sealer has been designed as a premixed bioceramic sealer that hardens only when exposed to a moist environment (such as that produced by the dentinal tubules). In terms of how the BC Sealer creates a bond, the following explanation should be helpful.

BIOCERAMIC SEALER (AND ROOT REPAIR MATERIAL) BONDING MECHANISM

The main component of dentin is hydroxyapatite, which has a hydroxy-group. When EndoSequence BC Sealer and/or the repair material are introduced into a root canal, they absorb water from the dentinal tubules. Then the setting reaction is initiated and it produces a composite of calcium silicate hydrogel and hydroxyapatite. The calcium silicate hydrogel will form a chemical bond with the hydroxyapatite because of the hydroxy-group. The hydroxyapatite formation in the sealer is a continuous crystal growth process (of hydroxyapatite on the dentinal walls). Therefore, both of the compounds will form strong chemical bonding with the dentin hydroxyapatite. When the smear layer is removed, the fresh hydroxyapatite structure of the dentin is in direct contact with the sealer, which creates the chemical bonding. This chemical bonding is, as well, accompanied by the micromechanical bonding of the nano-particles described.

Also, the BC Sealer will bond to a



Figure 4. The tip of the syringe should be inserted into the canal no deeper than the coronal one third.



Figure 5a. Pre-op x-ray of previously treated pre molar.



Figure 5b. Post-op x-ray demonstrating one-cone bioceramic technique. (Courtesy of Dr. B Trattner.)



Figure 5c. Pre-op of lower molar.

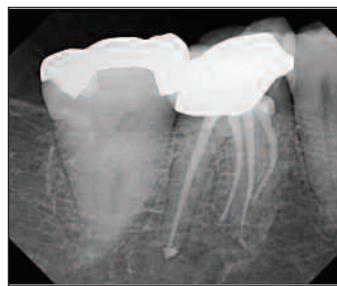


Figure 5d. Post-op of 4 canal lower molar (one-cone bioceramic technique). (Courtesy of Dr. A Nasseh).



Figure 5e. Pre-op x-ray of mandibular molar.



Figure 5f. Post-op x-ray of mandibular molar (one-cone bioceramic technique). (Courtesy of Dr. A Nasseh).



Figure 5g. Post-op x-ray of maxillary molar with palatal delta (one-cone bioceramic technique). (Courtesy of Dr. A. Fleury.)

coated cone with glass ionomer particles (Activ GP). The main composition of glass ionomer is calcium aluminate and calcium silicate compounds. The calcium silicates in BC Sealer hydrate with water to produce calcium silicate hydrate gel, which forms a chemical bond with the calcium aluminate and calcium silicate compounds on the surface of the Activ GP. This is in addition to the micromechanical bond created by the interlocking of the nanocomposite of the calcium silicate hydrate and the nanohydroxyapatite particles.

TECHNIQUE FOR BIOCERAMIC USE AS AN ENDODONTIC SEALER

The technique with this material is straightforward. Simply remove the syringe cap from the EndoSequence BC Sealer syringe. Then attach an Intra Canal Tip, or a capillary tip of your

choice, to the hub of the syringe. The Intra Canal Tip is flexible and can be bent to facilitate access to the root canal. Also, because the particle size has been milled to such a fine size, a capillary tip (such as a .012) can be used to place the sealer.

Following this procedure, insert the tip of the syringe into the canal no deeper than the coronal one third (Figure 4). Gently and smoothly dispense a small amount of sealer into the root canal by compressing the plunger of the syringe. Using a No. 15 hand file or something comparable (such as the master cone), lightly coat the canal walls with the existing sealer in the canal. Then coat the master gutta-percha cone with a thin layer of sealer and very slowly insert it to

nus. Either technique will deliver excellent results with multiple fins and anastomoses being filled with sealer.

The precise fit of the EndoSequence gutta-percha master cone (in combination with a constant taper preparation) creates excellent hydraulics and, for that reason, it is recommended that the practitioner use only a small amount of sealer. However, it is because of the excellent hydraulics and the small particle size, that the sealer flows easily into the fins and lateral canals. (The hydraulics generated are very similar to those created when cementing a custom fabricated post.) Furthermore, as with all obturation techniques, it is important to insert the master cone slowly to its final working length. Finally, here's more good news. The glass components in the bioceramic sealer bond to the Activ GP glass ionomer coated cones as well as to the new bioceramic coated cones. So, in essence, what we have is a bond to the canal wall as a result of the hydroxyapatite that is created during the setting reaction and we also have a bond between the ceramic particles in the sealer to the ceramic/glass particles in the coated cones (Figures 5a to 5g).

In part 1 of a 2-part series, we have introduced bioceramic technology and the benefits associated with its physical properties. Additionally, a technique has been described that will allow clinicians to predictably perform a one-cone technique. In part 2 of this article, we will further develop this concept of a one-cone technique as well as presenting multiple surgical and pediatric uses for bioceramics. ♦

length in the canal. The synchronized master gutta-percha cone will carry sufficient material to seal the apex. Another technique is to place the sealer into the coronal third with a syringe tip and then place some additional sealer onto a glass slab. Take the master cone selected and run it through the sealer (lightly coating the cone) and then introduce this additional sealer into the canal all the way to the apical third. Remove the cone, lightly coat it again with the sealer and slowly insert it all the way to the apical termi-

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Disclosure: Drs. Koch and Brave in association with Brasseler USA are the developers of the EndoSequence system.

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