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Biomimetic Endodontics: The Final Evolution?

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Traditional endodontics has been based on feel, not sight. Tactile proprioception was the only guide as burs and files were blindly inserted into pulp chambers and root canal systems (Figures 1 and 2). Together with radiographs and electronic apex locators this blind approach has produced surprising success; in the words of Dr. Eric Herbransen, "The endodontics succeeds often in spite of us." There is, however, a significant failure rate, especially long-term failure that is driving mainstream dentistry to aggressively extract natural teeth in favor of implants. The sting of clinical failure is a powerful motivator for change.

Ribbons, Sheets, and Banners



Figure 1. A traditional handpiece with typical visual obstruction of the internal aspect of the tooth.



Figure 2. Even hand files block good visualization of canal systems.



Figure 3. An immature maxillary molar is sectioned and viewed from the apical aspect.

One of the most distressing "hangovers" of the era of blind endodontics and endorestorative treatment is the belief that canal systems are straight, exit at the radiographic apex, and are round in cross-section. In reality, most canal systems curve and exit short of the radiographic terminus. A very large number, at least 50%, are ovoid or superovoid in cross-section. Figure 3 demonstrates that of the 3 roots and canal systems shown, only one is round.

As these canal systems mature they narrow into a variety of unpredictable ovoid shapes, often with smaller anastomosing canal systems.

The Evolution of Endodontic Shaping



Figure 4. This lower bicuspid was treated with a generous crown-down endodontic shape and suffered a retrograde root fracture within 3 years of the endodontic treatment.

Figure 5. This radiograph demonstrates a 31-year success with delicate shaping and crude obturation with silver points (tooth No. 14) and a 4-year failure with a large crown-down shape and heated gutta-percha (note the lesion on tooth No. 13).

As we journey through the past, we see that the original endodontic shape was established based mostly on hand filing, and filled with either silver points or cold lateral condensation of gutta-percha. Sargenti later introduced a more rapid approach that involved machine-driven instruments (rotary files) creating larger shapes with significantly more dentin removal. As of late, a crown-down approach is popular. The roots are rapidly and blindly machined. This can result in better obturation of the apical half because of improved penetration of irrigation during instrumentation and improved hydraulics during obturation. But at what cost (Figure 4)?

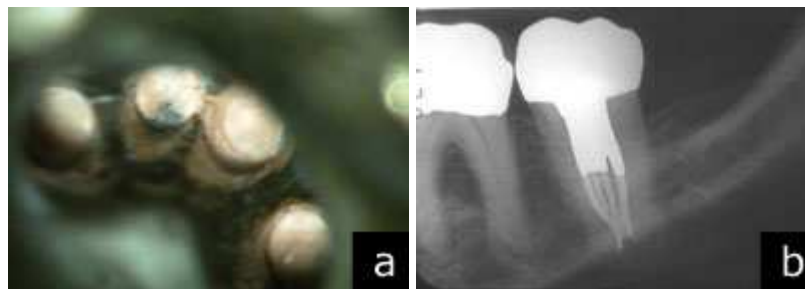
Is Crown-Down Endodontics Actually Better than Lateral Condensation?

The outcome studies are inconclusive, but what we do know is that the success rate today is no better than it was 40 years ago (Figure 5). The advantages of crown-down are often offset by the weakening caused by Gates Glidden burs and orifice shapers. The short-term thrill of the radiographic “puff of sealer” at the apex is lost when the tooth implodes a few years down the line. Residual dentin is directly related to long-term strength and has indisputably been shown as the key to long-term tooth retention. In contrast, the supposed strengthening of the root from a monoblock of bonded resin obturation, bonded core, and fiber post is proving to be inconsistent.¹ In short, preservation of pericervical dentin and ferrule girth trump all other factors. The theoretical goals of dentin bonding and monoblock are a poor substitute for delicate dentin preservation.

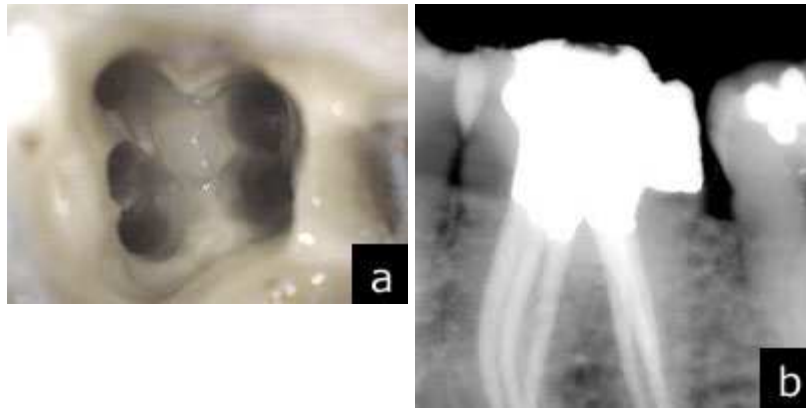
“Big Fat Round Roots” or “Delicate Arcing Fins”



Figure 6. This mandibular incisor appears frail with a radiographic image (a) or a lingual view (b). It appears husky with a mesial view (c and d). It is least twice as broad buccal-lingually.



Figures 7a and 7b. One variation of potential anatomy in an ovoid root (a); system branches in apical third of a C-shaped second molar (b).



Figures 8a and 8b. Another variation of ovoid roots, non-round systems branch into 5 systems in the coronal third. (Courtesy of Dr. John Khademi.)

Most of the post studies and crown-down technique diagrams are based on root forms from the maxillary anterior sextant, where big crown-down shapes and posts do relatively well. Unfortunately, in the rest of the mouth the long-term impact is unfavorable, and an anatomic or “biomimetic” shape is preferable (Figures 6 to 8).

Ovoid Canal Systems and Roots are Non-Round for a Reason

Rotary instruments and obturating points of gutta-percha are round because of the limitations of their mechanical nature. They create anatomically appropriate shapes in round roots, but fail in ovoid roots. Over the ages, the dynamics of occlusion and arch form have guided the development of human tooth roots such that at least half have ovoid roots.

Ovoid Shaping: Why and How

Why

Biomimetics is a treatment approach that has as its ultimate goal to retain as much of the natural tissue as is practical and also to mimic the physics and structures of the human body. There is nothing biomimetic about a stiff, round rod (prefabricated post) running through the center of an ovoid root. The natural ovoid root is essentially a stiff pipe deriving its strength from without, not within. The endodontic and endorestorative goal should be to mimic the pulp space that was present when the tooth was young. From that point, it can be argued that any secondary dentin that is deposited adds little additional strength because of the amorphous and irregular deposition pattern. This point is supported by the robust strength of young teeth with large pulp chambers and large radicular pulp spaces.

If a small, round access that does not disturb primary dentin can allow instruments to engage potentially significant complex anatomy (eg, a second or third major system and corresponding portals of exit), then the round access is acceptable. The reality of ovoid roots would seem to disagree with this approach. Creating a large, round access, which results in removal of primary dentin from the delicate, narrow portion of the root, is the common approach today. While this can allow access to complex branching of systems that occurs farther apically, it does not satisfy the more appropriate goals of anatomic, biomimetic dentistry. Additionally, the single, large, round endodontic shaping pattern often encroaches upon a fluting in the center of the root.

How: Visually Shaping Ovoid Systems



Figures 9 and 10. Several renderings contrast current endodontic shapes versus new, biomimetic, microscope-enhanced shapes. Figure 9 shows the preoperative pulpal space of the root, sectioned at the orifice, then shows a lateral condensation shape that does not weaken the root but also does not address the potentially complex anatomy. Next shows the new, aggressive, crown-down shape that weakens non-round roots. Figure 10a shows 2 potential shapes that are anatomic, address the complex anatomy, and yet do not weaken the tooth. Figure 10b shows the anatomic shapes in the second axis.



Figures 11. Buccal (a) and mesial (b) views of a fairly typical lower bicuspid. Sectioned root and dyed pulp (c) demonstrate an ovoid system that separates into 2 distinct canal systems in mid root. This type of branching has been described as similar to a wooden chair with the back and back legs representing the main canal system and the seat and front legs representing the often-ignored lingual system. Blindly inserted files cannot find the “seat and front legs of the chair.” Ovoid access provides excellent odds of visualization and engagement.



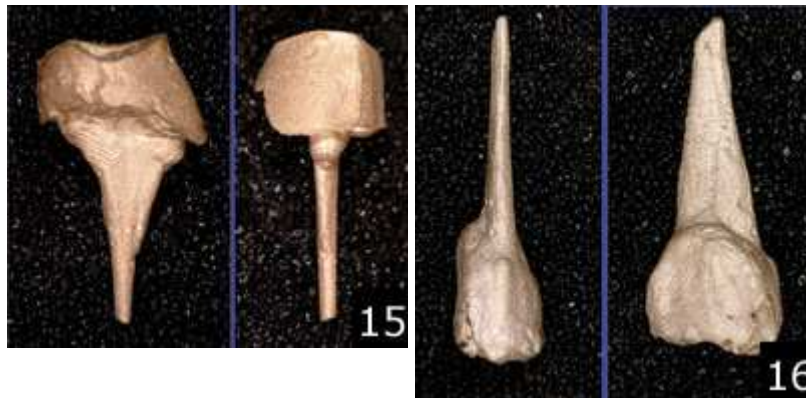
Figures 12, 13, 14. Contralateral bicuspid from the same patient as Figure 11 is shaped to follow the pattern of secondary dentin that has been described by Carr as resembling “glacial ice” in appearance under the microscope. One border of secondary dentin and primary dentin is outlined with arrows in Figure 12. Glacial ice is one of the many terms used to describe the many color and translucency features of secondary and tertiary dentin. The CPR 2D Diamond (Obtura Spartan) ultrasonic tip is pictured at 16x. Figure 13 depicts the much finer CPR 5D Diamond as the ovoid system is explored further apically with constant microscopic visualization. Note the ideal visual environment that is the hallmark of the microscope-ultrasonic combination. It allows for identification of dentin maps for the ultimate in dentin preservation. Figure 14 shows apical view at 16x after sectioning the root in the coronal third. Ovoid shaping has retained a thin border of secondary dentin.

The 3 components of ovoid shaping are (1) the operating microscope with powerful coaxial shadowless lighting, (2) ultrasonic instruments, and (3) an understanding of the anatomy of ovoid roots. Anatomic, biomimetic shaping cannot occur safely “by feel.” While attempts are possible with lesser technologies such as oculars (loupes), headlights, and rotary instruments, the era of microscope-enhanced dentistry ushers in new possibilities. It is time to embrace these previously unthinkable potentials in clinical accuracy (Figures 9 and 10). Figures 11 to 14 depict a fairly typical lower bicuspid. The canal system is ovoid in the coronal half and then bifurcates into 2 distinct canal systems in mid root. The unmodified, shrouded orifice and alignment of the buccal system will direct instruments into only that (buccal) system.

Traditional round access of this tooth will normally result in little to no cleaning, shaping, or obturation of the lingual canal system. All ovoid systems should be suspect for this type of anatomy, and at a minimum may have multiple portals of exit that may be not well-addressed with a single, round canal preparation.

Can't I just do this with loupes, head lamps, traditional handpieces, Gates Glidden burs, surgical length round burs, and rotary files? This question is asked at nearly every course that Dr. John Khademi and I teach. The answer in a word...no. The lack of coaxial shadowless lighting, magnification at less than 10x, the visual impairment of the bulky head of the traditional handpiece, the limitations of the flimsy shank of Gates Glidden burs, and the gouging effect of round burs together create the barbaric shapes of the past.

Smashed Cones and Trumpets



Figures 15 and 16. An endo-restorative casting with a smashed trumpet shape is demonstrated in facial and oblique views in Figure 15; it is from a lower bicuspid. In Figure 16 a smashed cone shape is pictured in 2 views from a maxillary second bicuspid.

The modern endodontic shape is often either a tapering cone or a trumpet. This is appropriate in Group One (round) canal system shapes. For the Group 2 (ovoid and super ovoid), the goal is to create a smashed trumpet or a smashed cone (Figures 15 and 16).

The Ideal Post and Other Myths

The ideal post is no post. Posts will remain a viable restorative modality, but unfortunately have been used to compensate for the unnecessary weakening that traditional endodontic access and shaping have inflicted on radicular and periradicular dentin. Too much attention is being paid to posts as the solution to endo-restorative treatment. Biomimetics is moving away from posts altogether. Following are 2 important myths that need to be addressed:

The dentin in nonvital teeth becomes brittle. Untrue! (Surprising to most.) Dentin in nonvital teeth performs the same as in vital teeth. When endodontics and restorative treatment can be performed delicately, the tooth should have a life expectancy similar to a vital tooth.²⁻⁴

A post strengthens the root. Also untrue. The purpose of a post is to retain the core in case of lack of ferrule. With delicate endodontic shapes and delicate axial crown preparations, research has shown the no post is as strong as with post, as long as adequate ferrule is present.⁵

Posts in Molars

Molars generally possess adequate internal retention to retain the core. Prefabricated post use is therefore usually unnecessary and should be avoided. The best post is no post if the core can be adequately retained by the stump and adequate ferrule is created to retain the crown or onlay.

Posts, Post Space, and Ovoid Canal Systems

Currently there are 6 options for restoring ovoid systems:

(1) Paste composite, amal-gam, or similar direct filling materials. These provide an acceptable result unless there is inadequate ferrule present. None of the products currently on the market possess sufficient fracture toughness to act as a "post."

(2) Use of a small, prefabricated post that lacks adequate resistance form.⁶ This provides an unacceptable compromise unless generous ferrule is present. Research has shown that resistance form is far more important for successful posts than is retention form.

(3) Modifying (enlarging) the canal system to fit a prefabricated post. Reaming an ovoid canal shape simply because posts are round is no longer acceptable. Current opinion leaders are rapidly moving toward the principle of little to no removal of dentin for creation of post space.

(4) Modification of the post to fit the canal shape. Grinding a large, round, metallic post into an ovoid shape is a bit time-consuming, requires pressure-indicating products, and requires high-level magnification and patience. This approach is not recommended for the new fiber posts. This is because all of the real strength of these posts is derived from uninterrupted fibers. "Carving" these posts will result in a severe compromise in flexural strength.

(5) Use of multiple small round posts. This approach remains reasonable. It can, however, be cumbersome and very challenging. The final result can often yield resistance form that is somewhat compromised.

(6) The endo-restorative buttress or casting. This is a new technique that is founded on microscopic visualization. These beautiful and often bizarre shapes follow the forms that nature originally created. The design gives ideal, varying moduli of elasticity from apical to occlusal that flexes in the apical portion but provides unparalleled stiffness in the build-up portion.

Summary

We are seeing a gradual evolution by a small but growing number of endodontists and general dentists toward delicate biomimetic, microscope-based shaping. This old-fashioned respect for periradicular dentin is paired with microscopes, ultrasonics, and an appreciation for root morphology.

Although no 2 roots are the same, general anatomic patterns allow the microscope-equipped clinician to search for major pulpal regions that will yield a high probability of cleaning and shaping the clinically available pulpal zones. There are complex, anatomically improbable, and clinically im-possible areas of pulp that are beyond the reach of even the most gifted hands. Regardless, the clinician has the responsibility to begin each procedure seeking perfection and joyfully finishing with excellence. The shapes that were introduced during the Schilder (crown-down) era have served as a transitional technique to allow the first real 3-dimensional compaction of gutta-percha. None-theless, endodontics is in the end a restoratively driven procedure. Large, arbitrary, round shapes create beautiful endodontics but can dramatically weaken the tooth. The shaping philosophy ad- vanced in this treatise allows perfectly adequate shapes to achieve the hydraulics needed for modern obturation. It will require different skills and materials to shape, pack, and restore the exotic architecture of nature. (See Tables 1 to 3.)

Table 1. The New Microscope-Enhanced Protocol.

1. Access with round-ended carbide or diamond burs.
2. Gross deroofing with larger, surgical length round burs.
3. Fine deroofing with Obtura Spartan CPR 2D diamond-coated ultrasonic tip.
4. Demouseholing with CPR 2D diamond-coated ultrasonic tip.
5. Deshroud with CPR 2D diamond-coated ultrasonic tip.
6. Provide straight-line access sweeping away from high-risk anatomy with the CPR 2D diamond-coated ultrasonic tip.

For Ovoid Systems

7. Sweep the coronal one fourth of the ovoid system with the CPR 2D diamond-coated ultrasonic tip.
8. Sweep the next one fourth or one half with the CPR 4D or 5D diamond-coated ultrasonic tip.
9. Irrigate, dry with the Stropko syringe, and then evaluate at 16x to 24x for multiple systems that branch in the apical half.
10. Insert appropriate, curved files, carefully maintaining patency.
11. Take radiographs from 3 angles.
12. Second opinion with apex locator.
13. Begin filing.

Table 2. Advantages of the New Microscope-Enhanced Protocol.

Advantages

Most files drop easily to the root terminus because the coronal restriction is actually the most common cause of a canal that feels “calcified.”

File breakage is extremely rare.

Tactile sense of the apical constriction is more accurate.

The canal system is shaped anatomically instead of simply creating a blind funnel.

A second set of radiographs is not needed. The “shortening” of the length of a curved canal system has already occurred before files are inserted and measured.

Instead of making a round coronal shape, the anatomically correct ovoid shape allows hand files and rotary files to be tipped buccally, lingually (or mesially and distally in some palatal roots) to predictably find, shape, and obturate the major canal systems branching buccal-lingually.

Ovoid shaping allows significant file curvature to be maintained as files are inserted to negotiate potential dog-leg portals of exit.

Ultrasonic advantages

The unique nature of the long, diamond-coated shape allows deroofing, demouseholing, and deshrouding without gouging. These gouges caused with round burs used without careful microscopic visualization weaken the tooth dramatically.

The bulky head of the handpiece is no longer a limiting visual impediment.

Table 3. Endodontic Shapes and Posts.

Round, mildly tapered roots or canal systems: Acceptable candidates for round shaping and prefabricated posts:	Ovoid and/or highly tapered roots that can be marginal candidates for round shaping and prefabricated posts:	Super ovoid and/or highly tapered roots that are usually poor candidates for round shaping and prefabricated posts:	Highly curved and/or delicate roots that are poor candidates for prefabricated posts:
○ maxillary central incisors	○ maxillary molars: palatal canal	○ mandibular molars: ○ distal canal systems	○ mandibular molar: mesial canal systems
○ maxillary canines	○ mandibular canines	○ mandibular incisors	○ maxillary molar: mesio-buccal, mesio-palatal (MB2), and distal canal systems
○ maxillary lateral incisors		○ mandibular bicuspid	
○ maxillary first bicuspid with 2 canal systems		○ maxillary second bicuspid	

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Disclosure: Dr Clark receives no royalties from microscope or ultrasonic sales.