Fracture Resistant Endodontic and Restorative Preparations

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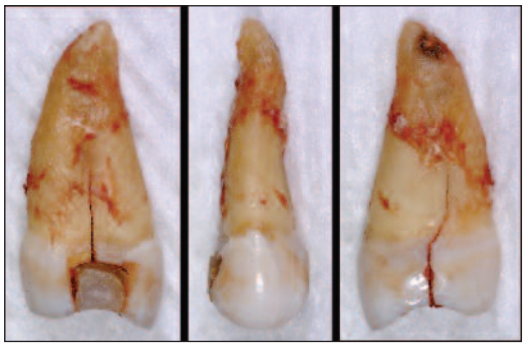

Figure 1. Case 1: Mural of a "conservative" distal occlusal composite combined with a "conservative" endodontic access and canal shape. Shortly after treatment was finished, the tooth split and required extraction. In the new era of tooth preparations, both restorative and endodontic shapes shown here are unacceptable.

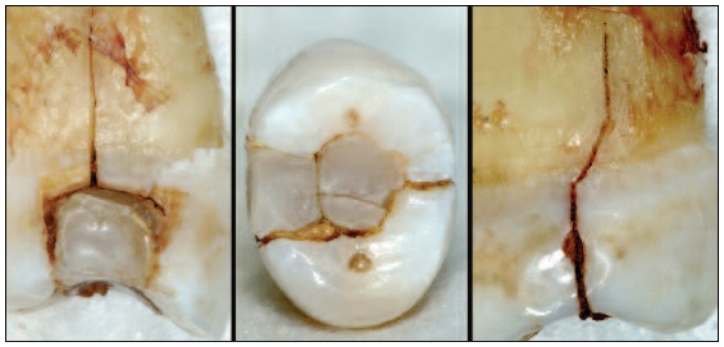

Figure 2. Second mural of Case 1: The crack initiates where the flexure (strain) is greatest; in this case the distal. Then it spreads mesially along the ditch between composite and tooth where massive stresses build, and distally up the root to the overly thinned fluting.

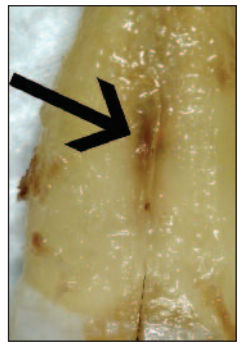

Figure 3. Case 1: The gutta-percha shows through in the fluting and the corresponding crack. Any hope of a second moment of inertia to avoid root fracture was lost with the canal enlargement.

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INTRODUCION

In 1890, G. V. Black proposed both a cavity classification system and cavity preparations that remain intact and the standard of care 120 years later. The consummate scientist that was G. V. Black, we can assume, would be shocked to find today we still cling to both of his systems in spite of advances in almost everything: photoelastic studies in stress and strain, modern engineering, adhesive materials, magnification, outcome studies, the epidemic of cracked teeth, computers, the telephone, and the list goes on and on.

In this article, we will explore a few cases that demonstrate the problems associated with current models of restorative and endodontic tooth preparations. The *new science of strong teeth* will be briefly outlined, serving as a platform for more in-depth discussions of both restorative cavity shapes and endodontic access and canal space management in future articles.

DR. CLARK

Stress, Strain, and Crack Initiation in Brittle Materials

Enamel is an extremely brittle material at 99% hydroxyapatite crystals. Dentin is a moderately brittle material at 70% hydroxyapatite. However, understand that brittle materials are not necessarily weak materials.[1] However, enamel and dentin are *easily weakened* materials. There is a significant difference. It is extremely rare that unrestored teeth fracture except as a result of blunt trauma. The formulas that determine whether or not a tooth will break after we cut the tooth are fairly simple, but the overall equation is very complex when the formulas are factored together along with complex issues like anatomy, restorations, endodontic shaping, and occlusion. Probably the worst thing we can do is cut across the occlusal of the tooth, from mesial to distal (mesial distal, distal occlusal, or mesial occlusal distal preparation) (Figures 1 to 3). This permanently changes the flexure (stiffness) of the tooth. The second worst thing would be to hollow out the tooth with round burs, large Gates Glidden burs and fat rotary files (exaggerated Schilder-style endodontics). Finally, the third worst thing we can do on an anterior tooth is then to cut an aggressive tissue level chamfer 360° around the tooth; harmful on vital teeth, worse on endo-treated teeth, and a death knell on hollowed out endo teeth with or without a post.

New Philosophy I: The Most Predictable Way to Make a Strong Tooth is Not to Weaken it in the First Place

Looking at the nature of glass can teach us quite a bit when we think about enamel and even dentin. Originally, scientists thought that glass was brittle because of microcracks in the glass. When glass "whiskers" were first observed, we realized that glass could be very flexible, as seen with fiberglass. The reason that traditional thicknesses of glass are brittle, we come to find out, is that there are planes that form areas onto which stress can build. We have also learned that air bubbles in glass *do not* make the glass weaker. Why does this matter in teeth? Interrupted cavity preparations leave the tooth much stronger than if you join them all together. This can be explained to a certain extent by the second moment of

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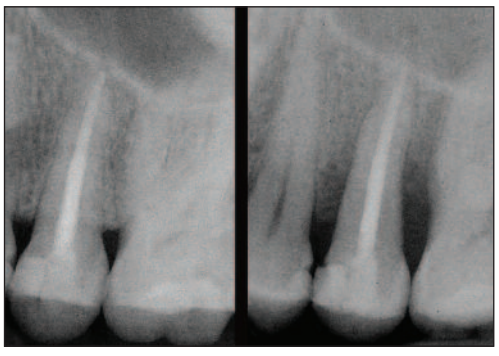

Figure 4. Case 1: Radiographs of No. 13. Left: 5 months previous taken at new patient examination. Right: radiograph of same tooth at time of emergent pain and extraction appointment. Significant bone loss is apparent. This shape, once considered appropriate, is easily 100% too wide in medial distal dimension in coronal and middle thirds.

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inertia. In an "*I* beam," the edges of the metal are thin but far enough from the "centroid" that bending (strain) or moment is resisted. The concept of moment can be further leveraged in endodontics with the uniform wall thickness proposition.

New Philosophy II: Own the Tooth

It is an absolute tragedy that this tooth in Case 1 (Figures 1 to 4) was lost. In the past, we blamed the patient for "not coming back for the crown." Today in my practice, cuspal protection with a direct composite onlay with 2 mm of cuspal coverage is provided at the time of endodontic therapy for all posterior teeth. It takes an extra 10 minutes. Just do it (Figures 5 to 9). If the patient can't afford to do the modern endo buildup (2 mm of cuspal coverage for posteriors) or an immediate onlay/crown, it is normally better to extract the tooth and tell the patient to start saving for an implant. What should the fee for direct cuspal coverage be? It is part of the buildup; if so inclined, you could add 10% to your endo buildup fee. Outcome studies have shown that at least 2 mm of cuspal protection with amalgam provides similar cuspal protection to a cast crown.[2-8] We can expect similar protection from cuspal coverage with composite. Whenever possible, interproximal cavity preparations should be disconnected from occlusal restorationons or the endodontic access (Figure 10).

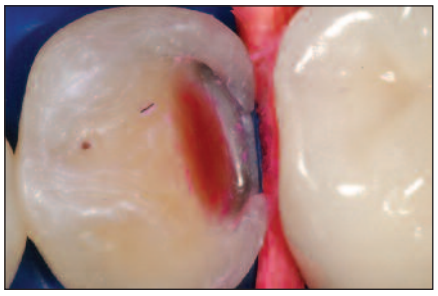

Figure 5. Case II: This deep caries bicuspid treatment will be treated with a direct composite onlay. It is the same design as used for endodontic onlays.

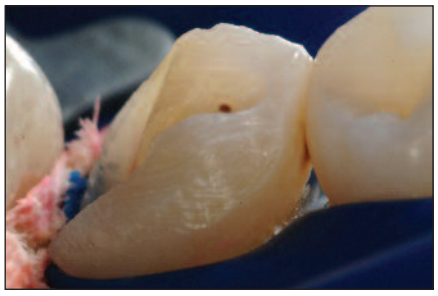

Figure 6. Case II: Lingual view of completed cuspal coverage composite preparation. No mechanical retention is needed. Extensive enamel rod engagement assures long-term viability of adhesion. Two mm of cuspal reduction and 3 mm of cuspal "wrap" on facial and lingual are ideal.

Figure 7. Case II: Low magnification view of Bioclear Matrix, wedge, and separator in place.

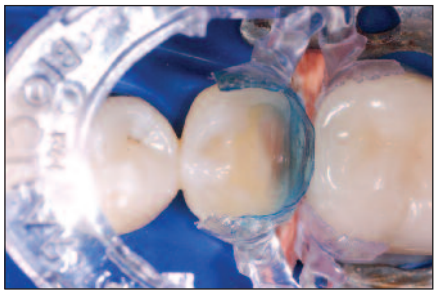

Figure 8. Case II: High magnification view of first layer, Filtek Bulk Fill (3M ESPE) (low stress-deep cure) placed and cured. Complex is now ready for final injection of a single increment of injection molded paste composite. *Note how the Bioclear Separator allows the composite to flow around the tooth yet seals off gingival line angles*.

Figure 9. Case II: Facial view of the finished direct composite direct onlay. Cusps are protected, C-factor is minimized, and the remaining tooth structure, independent of the composite, is much stiffer and stronger than the traditional G. V. Black preparation.

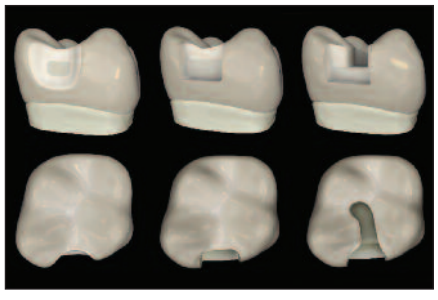

Figure 10. From left to right, The Clark Class II or saucer preparation leaves the tooth stronger than traditional retentive preparations Middle: the slot prep which has the worst of both preps, weakens the tooth, (albeit less than the G. V. Black) and has little resistance to lateral displacement. Right: G. V. black preparation is ideal for amalgam, but weakens the tooth badly.

New Philosophy III: We Understand That Dentin in Endo Teeth is Not Weaker, but Often Weakened by the Operator

Studies have shown that the dentin in endodontically treated teeth is very similar to that of vital teeth in terms of moisture content and strength.[9-11] When endo teeth split and break, it must therefore be blamed on the way that the dentin was cut, and not on the myth that endo teeth are brittle and dry.

What About Bonding and Adhesive Composite Materials—Don't They Strengthen the Tooth?

In a practical sense, no. Cuspal fracture rates are the same in amalgam and composite-restored teeth. Although some intercuspal splinting may be demonstrated in the lab immediately after composite placement, long-term protection of the tooth has not been demonstrated.

Figure 11. Apical view of an extracted and sectioned immature maxillary third molar. *Note the relative hollow tooth but with absolutely uniform root wall thickness. These young, hollow teeth have remarkable fracture resistance, and modern engineering explains the value of uniform wall thickness for tooth strength*.

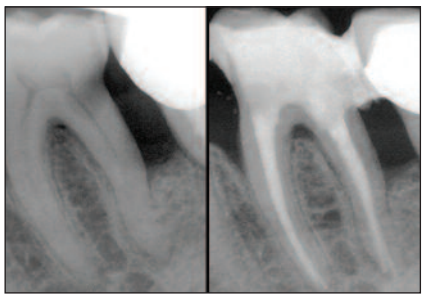

Figure 12. Anonymous endodontist has aggressively widened the delicate canals in the name of straight-line access and continuous taper. Structurally, the tooth is permanently crippled and doomed to restorative or fracture failure. This well-meaning but tragic expense of dentin must end now.

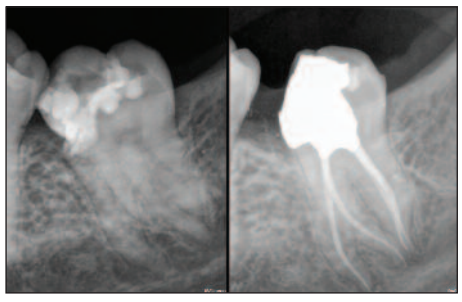

Figure 13. Case by Dr. Khademi. It was finished with size 20 SS White V Taper rotary files in all 4 canals. He used opportunistic access through the mesial caries and carefully maintained the precious pericervical dentin on the distal half of the tooth, with an excellent amalgam core.

Restoratively, It's Not the Size of the Hole, but the Shape of the Hole

The formula for determining stress concentration due to a cavity preparation is $(1+2\sqrt{\frac{L}{R}})$ where L is length of the cut and R is the radius of the cut. In simple terms, the longer the cut, the worse the cut. A long narrow cut, interestingly, is worse than a wide, round-bottomed cut. One reason that intracoronal composites do not protect the tooth from long-term from fracture gets back again to cavity design. A normal margin begins to ditch when in function. Once this occurs, the ditch essentially becomes the starting point for the crack. When it comes to stress accumulation in a brittle material, a ditch *is* essentially a crack.

Endodontic Shapes: The Uniform Wall Thickness Proposition

Uniform wall thickness is present in almost every natural root (Figure 11). Making a round shape in a nonround root, especially the coronal half of the root, dramatically affects the strain with consequent uneven stress concentrations. After a few months, years, or even decades, the dentin changes in these zones and we eventually see crack initiation in a significant number of these ovoid roots.

In Endodontics, Have We Moved From an Apical Stop Preparation to a Whole Tooth Stop Preparation?

In Figure 12, we see an incredibly enlarged access and canal shape. These continuous taper preparations ignore both the anatomy and the laws that govern tooth weakening. Why has this shape become so popular in North America? In essence, there is no longer an apical constriction to control the movement of gutta-percha. Instead, this allows the clinician to shape to and beyond the apex, and the obturation cone is controlled by the entire machined, conical root shape, not just the apical shape. This

Figure 14. SS White bur kit for modern endo access. The latch-grip surgical-length diamond burs are unique and far superior to soft iatrogenic surgical length round burs.

Figure 15. Endoguide bur kit with conical carbides. The tip shape is similar to the Fissurotomy burs used in minimally invasive restorative dentistry.

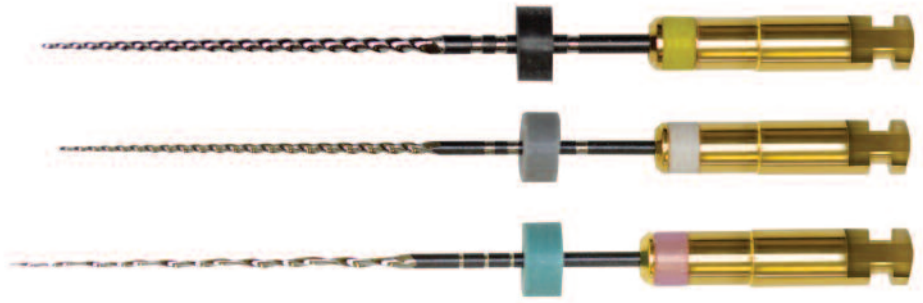

Figure 16. SS White V Taper (17 and 20) and glide path (13) files. Note the appropriate shaft size that will respect the coronal two thirds of the tooth.

has allowed clinicians, especially endodontists, to shape to the radiographic apex, which is now in vogue. Filling slightly short with an apical stop has become passé. Two problems here: first of all, the radiographic apex is a poor indicator of the actual foramen, so many cases filled to the radiographic apex are actually overfilled. Secondly, there is insufficient evidence suggesting that filling to the radiographic apex is better than filling slightly short or to the natural constriction. The problem is, most of the rotary file systems have been designed to satisfy the in vogue continuous taper shape, referred to as "the look."

ful. None of these are a replacement for pericervical dentin or 3-dimensional (3-D) ferrule. A 3-D ferrule is: (1) dentin height for retention of a crown, (2) dentin wall thickness, and (3) total occlusal taper of the crown preparation.

DR. HERBRANSON
The X Factor—Anatomy

A casual observer of tooth anatomy may think that most roots have a round cross section. The reality is that most roots are ovoid. How ovoid depends on the specific tooth; for instance, the upper canine root at the cervical line is 5% wider facial lingual than mesial distal, whereas the lower canine is 9% wider. The

The pulp chamber and canal shapes mimic the external shape of the tooth because dentine is laid down at a constant rate during tooth formation.

In contrast, Figure 13 demonstrates the anatomically respectful shape that can be achieved with a narrower rotary file shaft approach. SS White, the developer of minimally invasive burs such as the Fissurotomy bur and the Endoguide access burs (Figures 14 and 15) has introduced the V Taper rotary file system. The midcanal shaft size of these rotaries is less than 1.0 mm in diameter, which is widely regarded as crucial to avoid midroot weakening in smaller and ovoid roots (Figure 16).

Do We Strengthen an Endo Tooth With a Post and Crown?

Yes, and no. We *protect* the posterior tooth when we splint or cover the cusps, and in some cases, typically anteriors, a post is helplower incisors are about 7% wider. The upper premolars show the largest differences at about 30% wider facial lingual than mesial distal at the cervical cross section. The pulp chamber and canal shapes mimic the external shape of the tooth because dentine is laid down at a constant rate during tooth formation. So an ovoid root form will predict an ovoid pulp chamber, but the pulp chamber will proportionally be much longer and narrower that the external shape. For instance, an upper second premolar with an external mesial distal versus facial lingual difference of 40% could have a 400% difference in the pulp space. This configuration would carry much of the way down the root. This is common and somewhat obvious in lower anteriors and

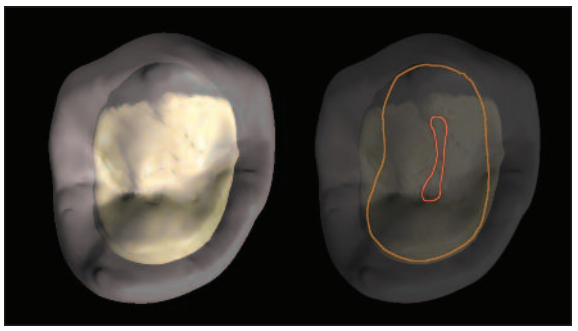

Figure 17. Occlusal view of an extracted maxillary bicuspid from the Brown and Herbranson 3D Atlas of Tooth Anatomy. Root and canal shapes are drawn on the occlusal.

Figure 18. Facial and mesial view of tooth in **Figure 17** from the Brown and Herbranson 3D Atlas of Tooth Anatomy. *Note the incredible discrepancy between the buccal lingual dimension and mesial distal dimension of the pulp space. These superovoid canals are often badly weakened with traditional shaping strategies and the most prone to catastrophic fracture following endodontics.*

upper premolars, less obvious in canines, and common but not obvious in molars (Figures 17 and 18).

Complicating this picture is the presence of concavities on many root forms, which effectively elongates the pulp spaces as well as changing their geometry from ovoid to kidney bean-shaped. These concavities are found on almost all teeth to some degree. Upper and lower premolars, lower anteriors, and all molars have varying degrees of root concavities that affect the internal size and shape of the pulp and upper canal shape. For example, the distal roots on lower molars and the lingual roots of upper molars frequently have significant concavities that are not obvious on conventional radiographs and are not well understood by most practitioners. This morphology can dramatically affect the appropriate treatment protocols. The one positive in this picture is that the canal space in the apical third tends to be round. The principles of dentine conservation require all these anatomy variations be taken into account when shaping the canals, during obturation and when placing restorative.

Figure 19. This radiograph, which has been shown as an example of endodontic excellence, demonstrates an extreme occlusal funnel that has obliterated excessive tooth structure in the coronal and middle thirds of the tooth.

DR. KHADEMI

If we think about "The 5 Mechanical Shaping Objectives," a set of concepts that are being questioned here in the ovoid or superovoid root form, we have some choices for these root forms, each with some risks and benefits:

1. *No shaping.* Stay small or leave "as is." No attempts are made at intentionally mechanically shaping or machining the middle and coronal root.

2. *Intentional shaping.* Impart a continuously tapering funnel or cone decreasing in cross-sectional diameter at every point apically and increasing at each point as the access cavity is approached. This requires intentionally cutting away healthy tooth structure to meet the shaping objective.

3. *Respectful shaping.* Attempt to make a "shape" that does not by design or intent create continuous taper. The canal system is merely instrumented without any preconceived idea of a required apical size or shape.

Each of these 3 treatment models comes out of the balance (or lack) of the 3 needs discussed in previous articles: (1) tooth needs, (2) operator needs, and (3) restoration needs. *Balance* needs to be restored to the treatment process that respects: (1) the operator needs in accomplishing the treatment objectives are appropriate given what we know about the case, (2) the tooth needs for long-term retention, and (3) the restoration needs from a fabrication and mechanical perspective.

No shaping would be the preferred option from a tooth needs standpoint, but with current instrumentation and obturation protocols available to serve the operator needs, it's simply not possible on most root forms. Regardless, we know that we cannot completely debride the canal system even with *intentional shaping.* Decades of literature with multiple instrumentation techniques and the attendant size and shaping end points, consistently show this. While these larger shapes and sizes may facilitate the operator needs for accomplishing those treatment objectives, those very objectives have not been tied to actual outcomes on a 10-to-20-plus-year time frame, let alone improved actual outcomes on those time frames. Thus the real effect of those efforts at intentional shaping directed toward achieving some kind of "look" may result in a tooth that exhibits what many might characterize as "endodontic excellence" yet is crippled in the process, even before the restorative needs are considered (Figure 19).

It is much better to cut multiple round and disconnected cavities. Remember, a long and continuous cut cripples the tooth.

In this nearly identical retreatment case (Figures 20 and 21) one notes coronal flaring not respectful of the root form and consequent gouging of both the mesial and distal internal walls that does not appear to have helped the original treating clinician attain a generally accepted treatment objective.

The Gates Glidden burs or other coronal shaping instruments generally used with intentional shaping procedures contributed nothing to the cleansing of a large volume of canal lumen both buccal and palatal, and contributed nothing to the shaping process either. One would like to think that they contributed to operator needs, but the evidence here suggests otherwise. This just cut away healthy tooth structure, and thinned the walls of this already compromised tooth. These nicks and dings create thin spots in the canal walls that act as stress concentration points that may contribute to crack initiation, and shorten the life of the tooth.

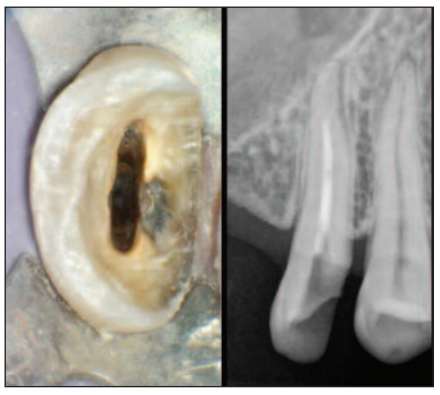

Figure 20. In this retreatment case, the initial impression is that the first treatment respected the ovoid canal anatomy. The cone beam in **Figure 21** says otherwise.

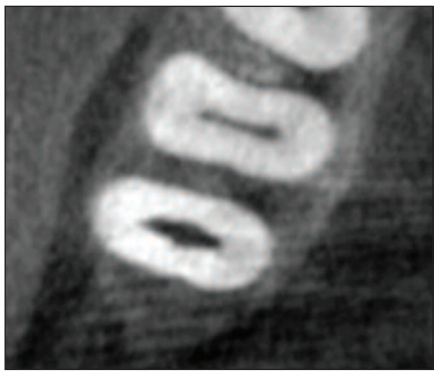

Figure 21. Carestream 9000 cone beam computed tomography reconstructed axial section of teeth No. 4 showing the Gates Glidden marks from coronal flaring. *Note the shape of the canal lumen on the adjacent untreated tooth.*

A *respectful shaping strategy* would use the enhanced vision of the dental operating microscope alongside of ultrasonics, EndoGuide burs, and light precurved hand filing or brushing with small rotary instruments without the intent of altering the existing middle and coronal shape present in the system.

The treatment philosophies presented here are not an update of the traditional endodontic technique. Drs. Clark, Herbransen, and I believe that the traditional round bur, tactile-based approach to endodontic access is fundamentally flawed. We are proposing a new approach of site-specific dentin conservation.

"Question yourself whenever you cut tooth structure. Very few of the endodontic techniques that we perform have sufficient evidence to support the dogmas that are the foundations of such techniques."[12]

CLOSING COMMENTS

In restorative dentistry, traditional G. V. Black cavity models must be discarded unless the operator is placing an amalgam restoration. Although this article is an introduction to the concept of strong teeth, a quick take home is to avoid "connecting the dots" when cutting cavity preparations. It is much better to cut multiple round and disconnected cavities. Remember, a long and continuous cut cripples the tooth. In endodontics, flaring the coronal two thirds of the tooth is now being questioned, especially in the middle of the tooth and most especially in a nonround root. Most of the rotary files on the market today are simply too wide in the coronal two thirds.✦

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Dr. Clark founded the Academy of Microscope Enhanced Dentistry, which is an international academy formed in 2002 to advance the art and science of microdentistry, microendodontics, microperiodontics, and dental microsurgery. He has also developed the Bioclear Matrix System, a comprehensive, tooth specific, clear anatomic matrix and interproximal restorative system. He can be reached at drclark@microscopedentistry.com.

Disclosure: Dr. Clark is the owner of Bioclear Matrix Systems and is a consultant to SS White Burs.

Dr. Khademi is an endodontist and pioneer of restoratively driven microendodontics. He can be reached at jkhademi@mydurango.net.

Disclosure: Dr. Khademi is a consultant for SS White Caresteam Dental.

Dr. Herbranson earned a BS from La Sierra College, a DDS from Loma Linda University, and a MS in endodontics from Loma Linda University. Dr. Herbranson is a cofounder and, until recently, was the executive director of Brown & Herbranson Imaging, a company that develops dental and human anatomy education software under the eHuman moniker. He is also the developer of the Xmount series of microscope camera mounts. With more than 30 years in practice, Dr. Herbranson is a dedicated clinical endodontist. He has made a significant contribution during the last 20 years as clinical assistant professor at the University of the Pacific School of Dentistry, where he lectures to students and special interest groups on endodontics, technology in dentistry, and microscope photography. His study of physics and 40 years experience in film and digital imaging provide him with an educated understanding of macro- and microphotography, and affords him a unique vision of endodontic education and image production. With his innovative approach and advanced imaging skills, Dr. Herbranson developed the unique processes and methodology for capturing images of human and dental anatomy now used as the basis for Brown & Herbranson Imaging's educational technology. Dr. Herbranson is the coauthor of the chapter on tooth anatomy in *Pathways of the Pulp*, and is a frequent speaker and educator at universities and conferences on the subjects of integration of new technology into dentistry, the use of software and computers in presentations, and surgical operation microscope photography. He can be reached at eherbran@hotmail.com.

Disclosure: Dr. Herbranson is a consultant for eHuman and SS White Burs.