Revolutionary Advances, Part 2: Active Disinfection

Wyatt Simons, DDS

This is part 2 of a 3-part article series. Part 1 of Dr. Simons' article was published in the May 2011 issue of Dentistry Today *and can be found in our archived articles at our Web site, dentistrytoday.com.*

Figures 1a to 1d. In teeth that are commonly thought of as "single-rooted teeth," Figures 1a to 1d represent apical pulpal anatomy present within premolars. Note the apical bifurcations, deltas, communications and multiple ports of exit that are commonly present.[2]

Modern endodontic treatment has been shaped by revolutionary improvements in our armamentarium. This article is the second in a 3-part series that highlights the areas of endodontics that have been impacted the most by these recent advances. The first article in this series demonstrated how 3-dimensional (3-D) evaluation of root canal systems and their surrounding structures with cone beam computed tomography allows for precise diagnosis as well as aids in guiding successful treatment. This second article illustrates advances in disinfection that contribute to a more thorough, 3-D disinfection of the entire root canal system. Finally, the third article in this series will discuss recent advances in our ability to provide an accurate and consistent 3-D seal of the entire root canal system.

INTRODUCTION

The necessity to achieve thorough disinfection of diseased pulpal systems is well understood and documented.[1] Our relentless aspiration to eliminate all irritants within a diseased pulpal system remains a committed objective. Unfortunately, our ultimate goal to completely disinfect the root canal system has not yet been practical. Hence the terminology of disinfection opposed to sterilization. The challenge of dissolving tissue and killing or eliminating all bacteria from deep complexities that exist within the randomness that is pulpal anatomy has been a difficult challenge to overcome. Figures 1a to 1d reveal original anatomy of premolars reconstructed from a microcomputed tomography technique.[2] Adding to the challenge of pulpal anatomy is the porosity of the dentin and the ability of bacteria to penetrate and flourish within the root structure. However, our pursuit for complete disinfection through root canal treatment has gained significant advancement with the help of recent technological improvements. In addition to improving debridement, these innovative advances have greatly increased our potential to safely and actively disinfect even the most anatomically complex spaces.

This article outlines modern modalities of irrigation, current irrigants, and proposes a protocol for their delivery and activation after shaping the root canal system.

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SHAPE DICTATES DISINFECTION

Pioneering clinicians who have come before us have blazed the trail that guides our current principles and techniques. Likewise, carving the trail during shaping of the root canal system guides successful disinfection. Shape sets the stage for effective disinfection because the space that is established allows for disinfectants to reach full potential. Although "*Cleaning and Shaping*" are done concurrently, there is value that comes when considering disinfection as beginning after the desired shape has been accomplished.[3] Said differently, there is greater potential to fulfill 3-D disinfection of the entire root canal system after the *instrumentable* aspect of the root canal system has been addressed. Traditional endodontic techniques are based on the theory that files shape and irrigants clean.[4] This statement highlights the knowledge that there are *uninstrumentable* areas of pulpal anatomy. Figure 2a illustrates some of these uninstrumentable areas of pulpal anatomy. This complicated mandibular molar contains branches that communicate among the main systems, fins, and multiple portals of exit. Although this type of anatomy is difficult, we are empowered to more effectively engage such complexities with our irrigants through modern irrigation techniques after the main systems have been opened. Figure 2b is an annotative model of a similar tooth, which assists in visualizing these complexities.[5]

When establishing the desired shape of the root canal system, it is logical to respect a balance between the shape needed to accomplish sufficient disinfection and the need to conserve tooth structure. Individual practitioners have preferences in this regard; however, one proponent that seems to be widely accepted is the need for a deep apical shape. This need for a deep shape stems from physical and biologic standpoints. Anatomical studies have shown that there are an increased frequency of lateral ramifications present at the apical region of canals.[6] Microbiology studies have documented that diseased pulpal systems are more advanced and virulent at this critically important apical zone.[7] Figure 3a demonstrates a safely produced deep apical shape, which aided in the treatment of this common apical branching. Figure 3b gives example of the reproducible healing potential that occurs when these apical lateral systems are disinfected.

The amount and time of use of an irrigant also holds great value in disinfection.[8]

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Figure 4 illustrates a good reservoir of irrigant that promotes high levels of disinfection. In this modern era of efficient shaping techniques it is beneficial to remember that a shaped system does not equal a cleaned system. Many clinicians have routinely accounted for this by utilizing a postshaping *soak time*. This *passive soak time* has evolved into a time for a more *active* form of 3-D disinfection.

ENDOVAC TECHNOLOGY

Few devices come along that can truly be considered game changing advances to a field of specialty. The EndoVac system (Discus Dental) can be considered such a device for the irrigation and disinfection of endodontic procedures. This system utilizes vacuum forces to produce negative pressure irrigation. Although the concept of negative pressure irrigation has been around for some time, this innovative device now allows for its widespread use. Figures 5a to 5d are views of the various components of this system. Negative pressure irrigation harnesses vacuum forces for the safe delivery of irrigants to the apical region of root canal systems.[9] In addition to safely avoiding traditional complications related to positive pressure delivery of irrigants, this technological advancement has had an overwhelming impact on the efficacy of irrigation.[10] Furthermore, the EndoVac system's inherent ability to directly remove pulpal tissue, debris, and bacteria increases levels of debridement.[11,12] Like shape, debridement sets the stage for higher levels of disinfection.

The EndoVac technique has shown particular aptitude in delivering irrigant to the critically important apical region.[9] The EndoVac system delivers the disinfecting solution to the coronal aspect of the pulpal system and draws the solution to the apical region by way of evacuation. This technology overcomes the limitations of solution surface tensions and possible complications related to air bubbles inhibiting delivery of irrigants to deep, difficult to reach areas of pulpal systems.[13] This complication of traditional irrigation has the potential to occur in the closed system of a root canal when sodium hypochlorite (NaOCl) interacts with tissue or debris. When this occurs, an accumulation of vapor (termed apical vapor locks) may be produced which can inhibit further progression of NaOCl to apical zones of the root canal system.

The ability of the EndoVac to successfully deliver irrigant to the critically important apical region has emboldened clinicians to aggressively yet safely disinfect at or near the terminus. Clinical experience has also shown efficacy in establishing drainage from periradicular tissues in cases of acute swelling. Figures 6a to 6c demonstrate the EndoVac's ability to remove intracanal debris, as it was instrumental in retrieving this separated instrument from around the curve of this mandibular second molar. In addition to facilitating the delivery of solution to all levels of the root canal system, it has been shown that the continuous movement of the solution increases microbial hydrolysis.[14]

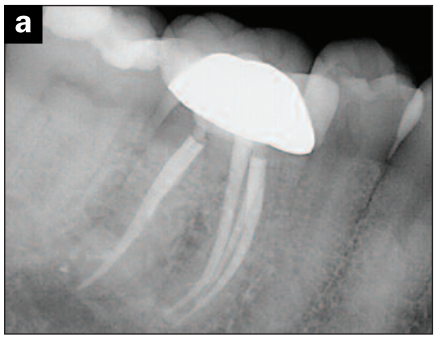

Figure 2a. Mandibular molar with complex uninstrumentable areas of pulpal anatomy. Note the communications between the main systems, fins and multiple portals of exit.

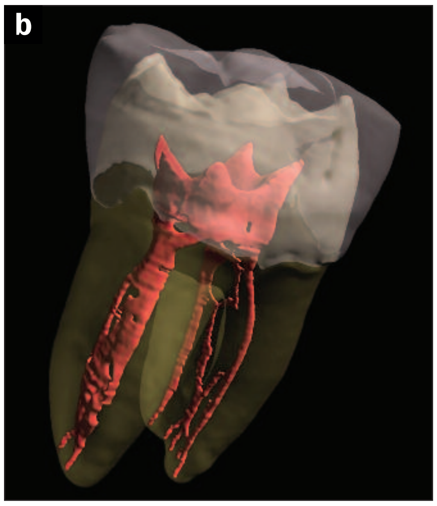

Figure 2b. An annotative model of a similar tooth further illustrating the complexity that exists within the randomness that is pulpal anatomy.[5] (Courtesy Dr. Eric Herbranson, Leandro, Calif.)

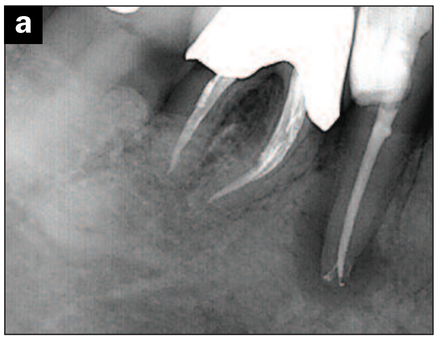

Figure 3a. Deep apical shape helped facilitate thorough disinfection of this premolar's apical delta.

Figure 3b. One year healing noted after successful disinfection of the complex apical anatomy present.

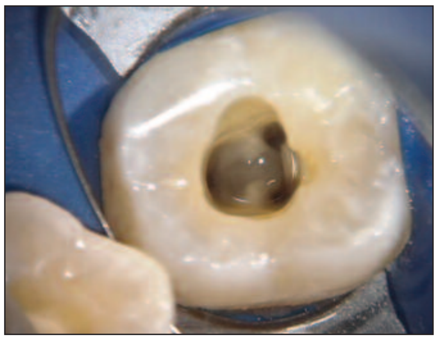

Figure 4. Good reservoirs promote increased levels of disinfection during active disinfection.

Table. Active disinfection table. Proposed sequence for the delivery and activation of irrigants to be done after shaping the root canal system

Postshaping Disinfection
1. NaOCl with the Macro EndoVac for one to 5 minutes**.**
2. NaOCl with the Micro EndoVac at or near the apex for one to 5 minutes.
3. EDTA delivered to the entire root canal system for a one minute soak.
4. NaOCl delivered to the entire root canal system with the Micro EndoVac System.
5. EndoActivator utilized for one to 5 minutes**.**
Methods for Final Rinse and Soak
1. NaOCl or alcohol.
2. MTAD: passive soak for 5 minutes and final rinse.

ENDOACTIVATOR

Increasing the efficacy of our irrigants helps overcome obstacles that are inherent within difficult to reach, intricate anatomy of pulpal systems. Attempts have been made to establish techniques and devices that help us prevail over the limitations that are present from the randomness that is root canal anatomy. At the forefront of methods to activate solutions for penetration into these complex spaces is the EndoActivator system (DENTSPLY Tulsa Dental Specialties). Figure 7 shows this sonically driven system designed to produce a hydro-

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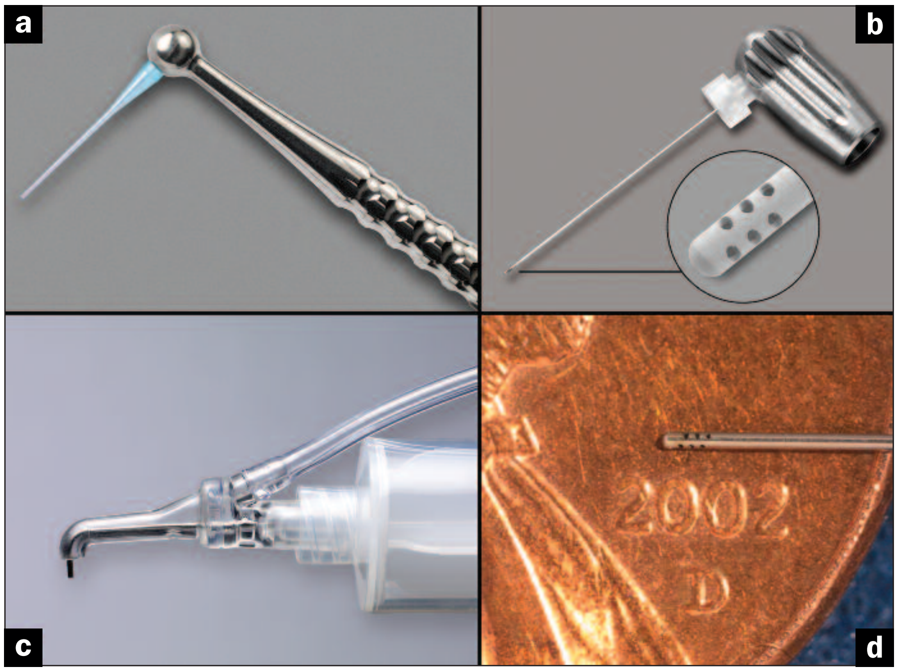

Figures 5a to 5d. The EndoVac (Discus Dental) irrigation system. **(a)** The macrocannula. **(b)** The microcannula. **(c)** The master delivery tip. **(d)** Prospective of the size of the microcannula, 0.32 mm in diameter. (Courtesy of Dr. John Schoeffel, Dana Point, Calif.)

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dynamic phenomenon. The increased exchange of irrigant produced by the EndoActivator, illustrated in Figure 8, enhances disinfection by improving solution circulation and penetration into anatomically complex spaces.[15] In addition to increasing the penetration of our solutions, the forces generated may increase the biological activities of our irrigants. This safe activation of irrigants allows for bombardment of the solutions into remote, difficult to reach areas that exist within the recesses of pulpal systems. Figures 9a and 9b illustrate the challenge of reaching such small spaces that are distant from the main pulpal system. Even in vital cases, this holds significant importance, as retained tissue inhibits complete obturation. Moreover, this retained tissue serves as a future nutritional source for bacteria and therefore greatly impacts failures. In addition to the need to reach these remote areas of pulpal anatomy, our efforts need to extend even further. Bacteria have been shown to penetrate and colonize within dentinal tubules of an infected root canal system.[16] Figure 10 is a scanning electron micrograph of the anatomy of dental tubules. Bacterial have been shown to commonly penetrate into these tubules within diseased root canal systems.[17]

For the impact of the EndoActivator to reach its full potential, it has been shown to obtain its greatest results in a shaped root canal system.[18] Again, disinfection starts with shape; optimal results of our irrigation techniques come secondarily to the shaping of the main system. Once the clinician navigates the main river, he or she guides the path to allow hydrodynamic disinfection to better penetrate the minor brooks and streams that flow from the main systems. Again, in the effort to achieve the goal of eliminating bacteria from an infected root canal system, removing bacteria serves the same function as killing them. This becomes particularly important when considering biofilms that flourish in diseased root canal systems. Biofilms are established colonies of bacteria that adhere to the root structure with a protective polysaccharide matrix. These microecologies can be resistant to passive irrigation techniques. In an effort to maximize the potential of our irrigants the EndoActivator has considerable potential to disrupt these intracanal biofilms.[19] This activation of our solutions has been shown to have the capacity to dislodge and break apart these biofilms thereby putting them into suspension for elimination. This holds particular importance for uninstrumentable areas of pulpal systems.

Figures 6a to 6c. Case demonstrating the capacity of the EndoVac to assist in the removal of separated instruments.

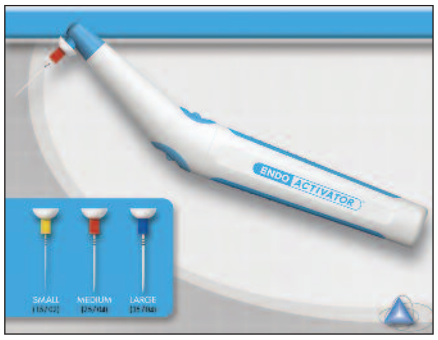


Figure 7. The EndoActivator system (DENTSPLY Tulsa Dental Specialties).

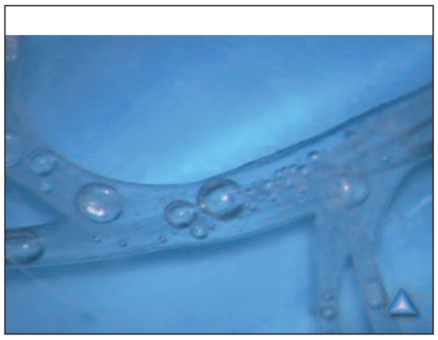
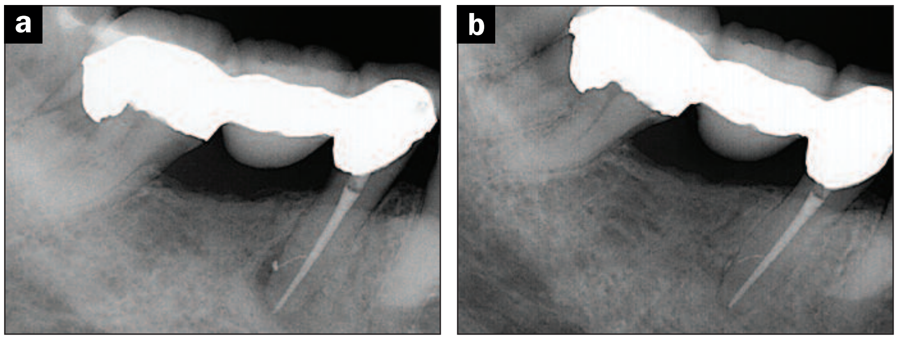


Figure 8. As illustrated here, the EndoActivator allows for a bombardment of irrigant to penetrate into confined spaces through Increased fluid exchange. (Courtesy of Dr. Clifford Ruddle, Santa Barbara, Calif.)



Figures 9a to 9b. Illustration of an infected lateral system that extends far from the main root canal system.

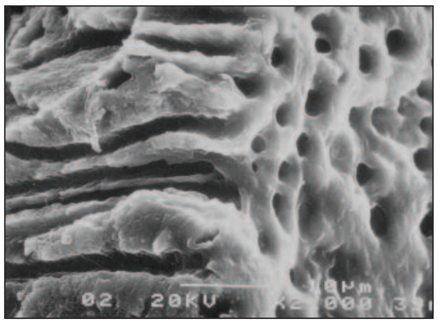


Figure 10. Scanning electron micrograph of surface dentin and the dentinal tubules that extend inward from root canal walls. (Courtesy of Dr. Elio Berutti, Torino, Italy.)

> *Thorough, 3-D disinfection of the entire root canal system continues to be central to the focus of endodontic....*

IRRIGANTS

In addition to questions related to the benefits of these modern irrigating systems, many clinicians ask questions related to the benefits of various irrigants available. Commonly asked questions are related to which, when, how, how much, and for how long these solutions should be used. For a comprehensive look at these modern irrigation systems, there is value in reviewing the irrigants that these systems employ. Some of the things to consider when evaluating irrigants are antibacterial properties, potential substantivity, debridement and dissolution abilities, physical properties (such as surface tension), effect in removing the smear layer, potential to damage root structure, effect on sealability, and financial feasibility. Some attributes of commonly used endodontic irrigants are outlined below.

Sodium Hypochlorite

NaOCl is the most commonly used irrigant today. It has a tremendous ability to dissolve tissue.[20] When NaOCl interacts with vital or necrotic tissue, the free chloride released digests proteins down to amino acids.[21] NaOCl does have good antibiotic potential but it does not have the ability to kill all bacteria known to be present within root canal systems.[22,23] It has been shown to have the capacity to penetrate into extremely fine pulpal ramifications.[24] NaOCl has a high cytotoxcity and therefore has the potential to cause significant injury to periradicular tissues if inadvertently delivered beyond the confines of the root.[25] Additional factors that have positive impacts on the efficacy of NaOCl are increasing freshness, concentration, and temperature.

ETHYENEDIAMINETETRAACETIC ACID

Ethyenediaminetetraacetic acid (EDTA) is a chelating agent. It demonstrates its greatest impact on removing the smear layer. A smear layer of debris is formed along the canal walls upon shaping the root canal systems. Seventeen percent aqueous EDTA has been shown to remove the smear layer in one minute within a well-shaped pulpal system.[25] Removing the smear opens up dentinal tubules which allows for deeper penetration of our irrigants as well as a cleaner surface for the adaptation of gutta-percha and sealer.[17,26] However, it is important to use aqueous EDTA judiciously, as it has been shown to erode canal walls by weakening the protein matrix of dentin.[28]

MTAD

MTAD is a mixture of a tetracycline isomer, citric acid, and a detergent. It has been shown to be a potent smear layer remover when used after NaOCl.[28] MTAD does not have an erosive nature against dentin like EDTA, it claims to have sustained antibacterial properties, and the detergent is postulated to coagulate microscopic

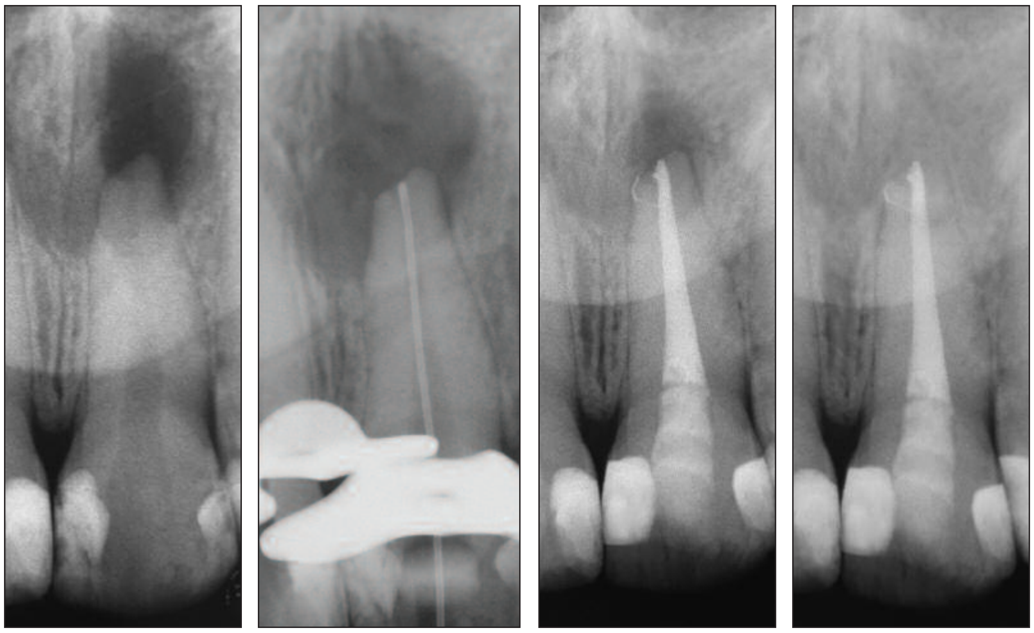


Figure 11. Case demonstrating the capacity of the EndoVac Microcannula to reach the apex of pulpal systems. (Courtesy of Dr. Fillippo Santarcangelo, Bari, Italy.)

debris into suspension for removal. Its recommended use is as a final irrigant.

CHLORHEXIDINE

Chlorhexidine has been advocated as a potential irrigant due to its broad-spectrum of antibacterial action, substantively, and low toxicity.[20,30,31] It has not found widespread clinical use over other solutions because it is unable to dissolve tissue, it lacks impact to the smear layer, and it does not kill all bacteria.

SEQUENCE OF POST-SHAPE ACTIVE IRRIGATION

The Table proposes a protocol for effective irrigation as an example of *a technique* that allows for high levels of disinfection in a reproducible manner. There are many schools of thought related to the ability to achieve the same endpoint. The proposed protocol should be taken as an example of one type of irrigating technique, not to be confused with a so-called universal protocol for irrigation. The time frames outlined should be considered as a minimum recommendation and should increase when considering factors related to anatomical complexities and microbiologic implications of established disease.

This protocol takes into account the need to ensure that irrigants are comprehensively delivered to the entire root canal system. The need to safely ensure delivery of irrigants to the apical region of the tooth contributes to the comprehensive activation of our irrigants. Figure 11 is a case by Dr. Fillippo Santarcangelo, which highlights this practice.

Once again, high levels of disinfection are accomplished once the desired shape of the instrumentable aspect of the root canal system has been accomplished. It is recommended that individual shaping techniques be done within a voluminous reservoir of NaOCl with continual replacement upon recapitulation of files. During the shaping phase of treatment, there is also benefit that comes from utilizing EDTA lubricants, such as RC Prep, in concert with NaOCl. The EDTA decreases surface tension and helps to keep tissue and debris in suspension for removal. This aids in cleaner canals by avoiding unwanted accumulation of debris such as dentinal shavings that are produced upon shaping the root canal system.[32,33]

CLOSING COMMENTS AND FUTURE DIRECTIONS

Thorough, 3-D disinfection of the entire root canal system continues to be central to the focus of endodontic improvements, as we remain unsatisfied with "achieving effective reduction" of irritants. However, the physical and biologic obstacles that contribute to decreased successful outcomes have challenged us. Our humbling observation of the infinite anatomical configurations present and the tenacity of the bacteria that contribute to endodontic disease have fueled this continued pursuit of higher levels of disinfection. Many other areas show promise in contributing to safe, active, 3-D disinfection, which illustrate the expansiveness of this focus. Lasers and photoactivated systems have been around for some time, but they have not received wide clinical use. However, these systems may mature and become more popular if they demonstrate clinical relevance in destroying microbes. We know the limitations of current rotary files to directly reach the complex morphology of root canal systems. Some current shaping techniques commonly employed reach less than 50% of canal walls.[34] There has been effort in a new direction of 3-D shaping that strives to increase this percentage. Physically scrubbing more surface area of pulpal walls augments the efficacy of disinfection.[35] Other solutions and techniques may emerge that show greater overall efficacy then those employed today. The hope that we will one day be able to completely eradicate all of the harmful irritants within a diseased root canal system is alive and well. Conquering this next frontier will undoubtedly contribute to even higher successful outcomes of endodontic procedures.✦

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Dr. Simons received his doctorate in dental surgery from the University of the Pacific, Arthur A. Dugoni School of Dentistry in 1999. Dr. Simons completed his postdoctoral specialty training in the field of endodontics at Boston University in 2001. Dr. Simons does extensive teaching in the field of endodontics including live patient demonstrations at Signature Specialists, which he founded in 2004. He is a Diplomate of the American Board of Endodontics and he maintains a private practice in San Clemente, Calif. He has published several articles in national and international journals. Dr. Simons holds an adjunctive facility position in the Endodontic Department at the University of the Pacific, Arthur A. Dugoni School of Dentistry. He can be reached at (888) 905-ROOT or visit him at sigspecialist.com.

Disclosure: Dr. Simons reports no disclosures.

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