

ENDODONTIC DISINFECTION TSUNAMI IRRIGATION

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There are enormous differences in opinion regarding the potential to three-dimensionally clean a root canal system. Elimination of pulpal tissue, bacteria when present, and their related breakdown products is directly influenced by a series of procedural steps that comprise start-to-finish endodontics. Regrettably, there is no single beacon of light to brightly illuminate the most proven clinical techniques essential for predictably successful endodontics. A review of the literature reveals virtually no agreement on a variety of fundamental clinical issues. As a single example, bacteria are ubiquitous in endodontically failing teeth, yet there is great controversy regarding the very methods used that directly influence their elimination.

There is ongoing debate regarding the irrigants, their sequence of use, and the intracanal volume required to promote three-dimensional cleaning. Confusion abounds as to the ideal strength, optimal temperature, and the extent of time required for any given reagent to fulfill its intended purpose. The debridement and disinfection of a root canal system is further dependent on the apical one-third taper and the terminal diameter of the final preparation; yet again, there is no consensus on how these interrelated preparation objectives serve to directly influence the exchange of any given irrigant. Even though rationale treatment approaches are available and precise techniques have been perfected, the dominant clinical reality is the best that endodontics has to offer is only sporadically delivered in everyday practice.

This article will briefly review the rationale for treatment and the endodontic objectives. Particular emphasis will be

placed on those factors that influence disinfection. The focus of this article will be on hydrodynamic disinfection and a clinical technique designed to facilitate this process.

RATIONALE FOR TREATMENT

Pulpal injury frequently leads to irreversible inflammatory conditions that potentially progress to ischemia, infarction, necrosis, and ultimately, complete pulp death. This phenomenon originates in a space exhibiting infinite anatomical configurations and intricacies along its length.¹ Root canal systems contain branches that communicate with the attachment apparatus furcally, laterally, and often terminate apically into multiple portals of exit (POEs).² Consequently, any opening from the root canal system to the periodontal ligament space should be thought of as a POE through which potential endodontic breakdown products may pass. Radiographically, it is fundamental to associate that lesions of endodontic origin (LEOs) arise secondary to pulpal breakdown and form adjacent to the POEs.³ Improvement in the diagnosis and treatment of LEOs occurs with the recognition of the interrelationships between pulpal disease flow and the egress of irritants along these anatomical pathways (*Figure 1*).⁴

ENDODONTIC OBJECTIVES

Except in rare instances, LEOs will routinely heal following the extraction because this procedure not only removes the tooth, but importantly serves to eliminate 100% of the contents of the root canal system. Like the extraction,



Figure 1a. A pre-operative film of a maxillary first bicuspid. A gutta percha cone traces a sinus tract and points to a lesion of endodontic origin.



Figure 1b. A 10-year post-treatment radiograph reveals excellent healing and confirms the importance of treating root canal systems.

endodontic treatment should be directed toward removing all the pulp, bacteria when present, and related irritants from the root canal system. The biological objectives of endodontic treatment are to eliminate the tooth as a source of irritation to the attachment apparatus. Schilder was the first to propose a logical set of mechanical objectives that promote three-dimensional cleaning and obturation of the root canal system. Discounting hopeless periodontally involved, non-restorable, or root-fractured teeth, complete endodontic treatment can approach 100% success.⁵ Properly restoring the endodontically treated tooth is essential for long-term success and is what Southard termed “the rest of the seal” (*Figure 2*).⁶

FACTORS INFLUENCING DISINFECTION

In the context of this article, the words “disinfection” and “cleaning” will be used interchangeably and will refer to complete debridement, the elimination of the smear layer, and the disruption and removal of the biofilm from all aspects of the root canal system.

Debridement refers to the elimination of the pulp tissue, bacteria when present, and their related irritants from the root canal space. A smear layer forms on the walls of the canal as a by-product generated by any instrument utilized to cut or sand dentin. Dentinal debris, in combination with a reagent, forms mud. Dentine mud should be considered a pathogenic cocktail, as it potentially harbors remnants of pulpal tissue, bacteria, and their related irritants. Bacteria are well known to invade the dentinal tubules and dentine mud has been shown to frequently block the lateral anatomy (*Figure 3*).⁷ This distinction is made as most colleagues think of a blocked canal as an apical misadventure that prevents a small-sized flexible file from easily sliding to, and minutely through, the terminus of the canal.⁸

Recently, there has been significant interest in biofilms and their role in endodontic prognosis.⁹⁻¹⁰ A biofilm is a structured community of bacteria enclosed in a protective, sticky polysaccharide matrix that can adhere to a root canal



Figure 2. Shaping canals facilitates both three-dimensional cleaning and obturation. Complete endodontic treatment is the foundation for perio-prosthesis.

surface. Further, planktonic, free floating organisms within biofilm fragments have been observed to disrupt, drift, and reattach to any surface within the root canal system, including within dentinal tubules.¹¹ On the external tooth surface, these biofilms are referred to as plaque. The methods commonly used to remove dental plaque potentially prognosticate the best approaches for removing an intracanal biofilm. Logically, three-dimensional cleaning procedures should be directed toward disrupting any given biofilm, breaking up this matrix, and moving this infected mass into solution so it can be eliminated from the endodontic space. The following factors, independently and in combination, serve to influence cleaning, and ultimately, treatment outcomes. These factors will be categorized into endodontic procedures, cleaning reagents, and hydrodynamic disinfection.

ENDODONTIC PROCEDURES

There are a series of procedural steps that comprise start-to-finish endodontics. Those procedures that directly influence cleaning will be identified and their role in cleaning the root canal system emphasized.

Access

Preparing the endodontic access cavity is a critical step in a series of procedures that potentially leads to the three-dimensional cleaning and obturation of the root canal system.¹² Access cavities should be cut so the pulpal roof, including all overlying dentin, is removed. The size of the access cavity is dictated by the anatomical position of the orifice(s). The axial walls are extended laterally such that the orifice(s) is just within this outline form. The internal walls are flared and smoothed to provide straightline access to the orifice and the underlying root canal system. Cleaning and shaping potentials are improved when instruments conveniently pass through the occlusal opening, effortlessly slide down smooth axial walls, and are easily inserted into a preflared orifice. Spacious access cavities are an opening for shaping and cleaning procedures (*Figure 4*).



Figure 3. This animation image demonstrates that shaping files produce dentine mud. Irrigation potential is limited when the lateral anatomy is obstructed.

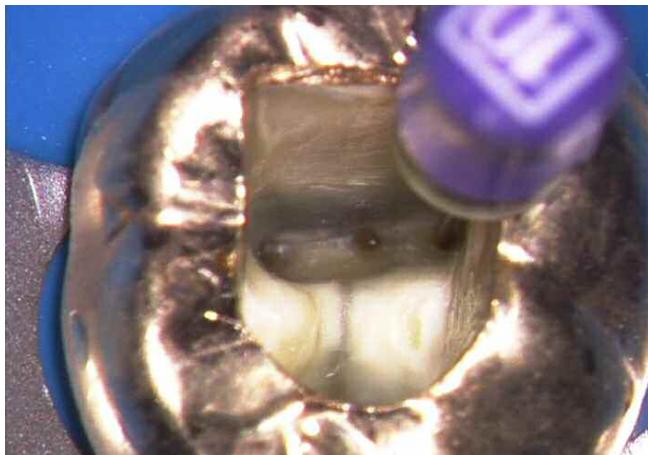


Figure 4a. A photo demonstrates access through a full veneer casting. Note this mandibular molar has three mesial orifices.

Shaping Facilitates Cleaning

Schilder outlined the mechanical objectives for preparing a canal that, when fulfilled, promote the biological objectives required for predictably successful results. Common sense tells us no two objects can occupy the same space at the same time. As such, all organic material must be eliminated to make space available for obturation materials. The breakthrough is to understand that unshaped canals cannot be cleaned. Shaping *facilitates* cleaning by removing restrictive dentin which allows for a more effective reservoir of irrigant. Shaping is the development of a “logical” cavity preparation that is specific for the anatomy of any given root. It is essential to appreciate that fully shaped canals hold a larger volume of irrigant that can potentially circulate, penetrate, and clean into all aspects of the root canal system.¹³⁻¹⁴ Ultimately, the long term retention of endodontically treated and restored teeth is optimized when there is a conscious balance between fulfilling the shaping objectives and preserving dentin.

Preparation Technique

The preparation technique utilized will influence irrigation and cleaning potential. As an example, the step-back, crown-down, and pre-enlargement techniques have been advocated for shaping canals. Each technique has been described in different ways, has something to offer, and was developed to advance canal preparation methods.¹⁵ Although each technique can theoretically produce the same final shape, each method is very different and has been designed to prepare a general region within the canal in a precise sequence. A major advantage of the pre-enlargement technique is that procedures are initially directed toward removing restrictive dentin in the coronal and middle one-thirds of the canal.¹³ Fortuitously, a pre-enlarged canal holds a more effective volume of irrigant, which in turn, improves the potential for its exchange when preparing the apical one-third of the canal.

The ability to clean a root canal system is further influenced by the cross-section of a file. Clinical evidence is growing that shows files with radial lands tend to scrape, burnish,



Figure 4b. A post-treatment film demonstrates straightline access and complete endodontics.

and trap more mud into the lateral anatomy, whereas files with cutting edges tend to cut dentin more cleanly. Two additional factors that influence the exchange of an irrigant and its potential to clean a root canal system are the taper of the preparation and the terminal diameter of a canal.¹⁶ The apical taper and terminal diameter of any given preparation are critically interrelated and serve to influence the exchange of irrigant, and hence, the potential to clean. The mechanical techniques employed need to respect the anatomy and should not needlessly over-enlarge the apical region of the canal. Dentists need to completely understand and fully appreciate that it is the files that shape a canal, but it is the irrigants that serve to clean a root canal system (*Figure 5*).

CLEANING REAGENTS

The intracanal reagents selected and their sequence of use are significant factors that influence cleaning. Scientific investigations are increasingly being directed toward identifying the best reagents, and their optimal strength and ideal temperature.¹⁷ Importantly, protocols must be developed to specify the frequency, volume, and time required for any given solution to clean a root canal system. The potential to debride and disinfect is further influenced by alternating between specific types of intracanal solutions, or using them in combination. Recently, what are termed “final rinse solutions” have emerged and their use advocated to enhance root canal cleaning. Examples of final rinse solutions include MTAD (*Dentsply Tulsa Dental Specialties*), Smear Clear (*SybronEndo Specialties*), and Chlorhexidine (CHX). Regardless, the most important reagents that are routinely used to clean a root canal system are sodium hypochlorite (NaOCl) and ethylenediaminetetraacetic acid (EDTA) (*Roth International*).¹⁸⁻²⁰ The following will describe these intracanal solutions utilized to achieve three-dimensional cleaning.

Sodium Hypochlorite

NaOCl in a concentration of 6% is a powerful and inexpensive irrigant that can potentially destroy spores, viruses, and bacteria, and importantly, has been shown to digest vital and

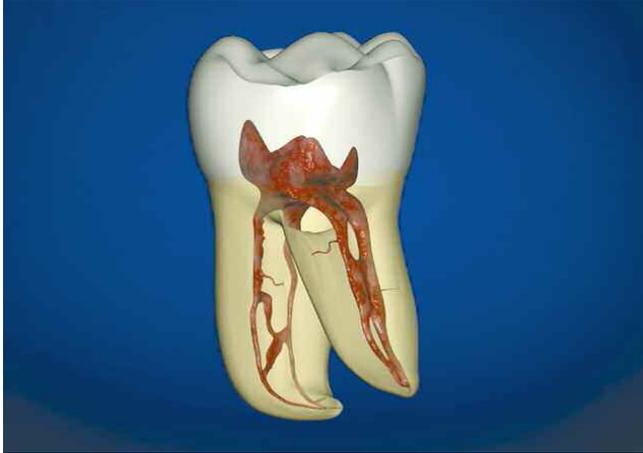


Figure 5a. This animated molar image demonstrates typical molar anatomy. Note the fins, anastomoses, and multiple portals of exit.



Figure 5b. This image shows that well-shaped canals encourage the exchange of irrigant. Active irrigation promotes 3-D cleaning and complete endodontics.

necrotic pulp tissue from all aspects of the root canal system (*Figure 6*).²¹ Studies have shown that warming NaOCl to approximately 60°C (140°F) significantly increases the rate and effectiveness of tissue digestion.²² The potential for an irrigant is maximized when it is *heated*, flooded into *shaped canals*, and given ample *time* to work.²³⁻²⁴ The frequency of irrigation is dictated by the amount of work that a particular instrument performs. In general, irrigate more frequently in tighter, longer, and more curved canals, and especially if the system is perceived to exhibit unusual anatomy. There is no agreement regarding the volume of irrigant required to clean a root canal system. Appreciate when an instrument is placed into a relatively small canal, the file tends to displace the irrigant. When the instrument is withdrawn, the irrigant flows back into the space the file occupied. As such, much of the shaping procedure is conducted in canals that hold minimal irrigant.

EDTA

Chelating agents containing EDTA are used to negotiate smaller diameter canals and to remove the smear layer from the walls of an expanding or finished preparation. In general, the purpose of a viscous chelator is to lubricate, emulsify, and to hold debris in suspension when initially negotiating and securing canals. The purpose of an aqueous chelator is to remove the smear layer during and after root canal preparation procedures. EDTA is a surfactant, which serves to lower surface tension, improving an irrigant's potential to circulate and penetrate. An aqueous 17% solution of EDTA flooded into a well-shaped preparation for one minute, after canal preparation procedures, has been shown to remove the smear layer.²⁵⁻²⁶ Importantly, studies show that alternating between solutions of NaOCl and EDTA during canal preparation procedures reduces the accumulation of debris and results in cleaner canals (*Figure 7*).²⁷⁻²⁹ An aqueous solution of EDTA promotes removing the smear layer, which is well known to block the dentinal tubules and lateral anatomy. Logically, if the smear layer is removed, then a potentially

tighter adaptation between the obturation materials and the dentinal walls of the preparation is possible.³⁰

PASSIVE/ACTIVE IRRIGATION

Passive irrigation is initiated by slowly injecting an irrigant into a canal. In this method, irrigant is passively dispensed into a canal through a variety of different gauged and flexible canulas. The canula is loose in the canal, which allows the irrigant to reflux and move debris coronally. Smaller gauged canulas can be chosen to achieve deeper and more effective placement.³¹ Certain canulas can be selected that dispense irrigant through their most distal end, whereas other canulas deliver irrigant through a closed-ended side port delivery system.³² Slowly injecting irrigant in combination with continuous hand movement will virtually eliminate NaOCl accidents. Passive irrigation has limitations because a static reservoir of



Figure 6. A histological section from a maxillary bicuspid confirms that files shape canals but it was the NaOCl that cleaned-out the lateral canal. (Courtesy of Dr. Gery Grey; Greenbrae, California)

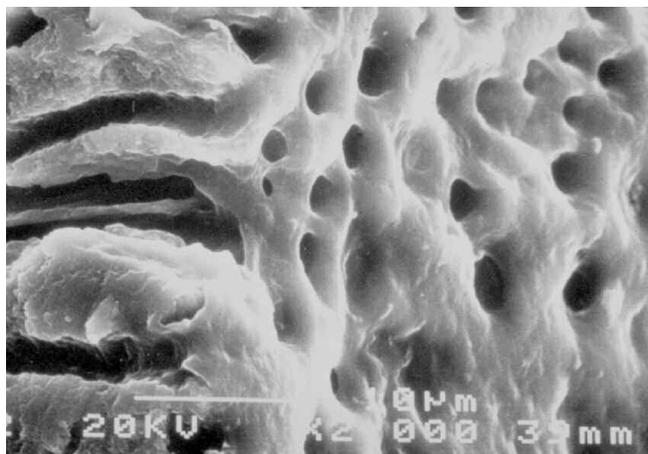


Figure 7. An SEM photograph demonstrates that canals prepared with heated full-strength NaOCl are clean. Note the tubules are free of organic debris. (Courtesy of Dr. Elio Berutti; Torino, Italy)

irrigant restricts the potential for any reagent to penetrate, circulate, and clean into all aspects of a root canal system.

Active irrigation is intended to initiate fluid hydrodynamics and holds significant promise to improve disinfection. There is increasing endodontic evidence to support that fluid activation, in well-shaped canals, plays a strategic role in cleaning and disinfecting into all aspects of the root canal system, including dentinal tubules, lateral canals, fins, webs, and anastomoses.³³⁻³⁵ The greatest focus today is on how to safely activate any given solution to maximize the hydrodynamic phenomenon. The traditional methods have included warming a reagent utilizing heat transfer devices, vibrating active and non-active metal instruments utilizing ultrasonic energy, and using electrochemically-activated solutions. Machtou demonstrated that gently pumping a well-fitting gutta percha master cone within a well-shaped canal significantly improved the displacement and exchange of any given reagent.¹⁴

There are several emerging methods that are receiving attention and are purported to enhance the exchange of an intracanal irrigant. These methods include the Navi-Tip FX canula (*Ultradent*), plastic rotary FTM files (*Plastic Endo*), EndoVac (*Discus Dental*), an irrigation/vacuum technique first described in the early 1990s and later demonstrated in the *Ruddle on Retreatment* DVD series,³⁶ IrriSafe, an ultrasonically driven metal file (*Acteon Group*), and ultrasonically driven metal canulas that deliver fluid.³⁷ Of increasing intrigue is a method to inactivate microbes utilizing photoactivated disinfection (PAD).¹¹ Clinically, this technique involves dispensing a photosensitizer solution, such as tolonium chloride, into a well-shaped canal. This intracanal irrigant targets specific bacteria by binding to or entering these microbial cells. A low power diode laser is utilized to hit the marked microbe and inactivate these invaders.

With all the methods identified, the challenge is still to penetrate, reach, and kill bacteria, which are well known to protect themselves within dentinal mud, their own secretions, and biofilms. Compounding the challenge to kill

microorganisms is their ability to hide within an anatomically complex space. The hydrodynamic phenomenon has been identified as perhaps the only way to induce biofilm adherence failure.^{11,38} Although the different methods identified are intended to promote disinfection, much of the current international work is focusing on those methods that promote the hydrodynamic phenomenon or effective fluid agitation. The goal of fluid agitation is to safely generate cavitation, acoustic streaming, and microstreaming within any given intracanal solution.

ULTRASONIC vs. SONIC ENERGY

When selecting a method to maximize fluid hydrodynamics, it is important to understand the frequently misunderstood differences and critical distinctions between ultrasonic and sonic energy. It is important to note there is no agreement or definitive evidence in the peer-reviewed literature to support one form of energy is superior to the other.³⁹⁻⁴² Van der Sluis has stated on the Roots website, "The streaming velocity of the irrigant is related to the cleaning efficiency, the higher the streaming velocity the higher the cleaning efficiency." Indeed, this observation is supported by the mathematical formula that prognosticates streaming velocity. Written in a more dental friendly manner, streaming velocity (v) = $2\pi fa^2/r$, where f = frequency, a = amplitude, and r = the radius of the instrument. Although this mathematical formula may not perfectly describe the streaming velocity within an optimally prepared root canal, it does identify the variables that linearly, exponentially, and inversely influence the hydrodynamic phenomenon. In accordance with this formula, maximizing the amplitude is especially intriguing because the greater back and forth movement of a vibrating tip exponentially influences the streaming velocity of a reagent.

The following is intended to briefly describe how each variable within the above formula serves to influence streaming velocity. Ultrasonic energy generates higher frequencies than those generated by sonic driven devices. The frequency may be thought of as the interval of time it takes a vibrating tip to move through one back and forth displacement cycle. Further, it is also well known that sonic energy generates significantly higher amplitudes, or greater back and forth tip movement, compared to ultrasonically driven instruments. Regardless of the energy source, a sinusoidal type wave of energy, with a given periodicity, is produced that travels over the length of an instrument. This oscillating wave of energy produces an amplitude of modulation. A graph of wave movement demonstrates a periodic curve of modulation that has peaks and valleys, as measured from its equilibrium value. A minimum oscillation of the amplitude may be considered a node, whereas a maximum oscillation of the amplitude represents an antinode. Another way to describe the back and forth movement of a vibrating tip is to think of its angular displacement as similar to that of a pendulum. The angle formed between a node and an antinode may be termed alpha (α); whereas, the angle formed between the peak and valley of successive antinodes may be considered 2α , or the total range of back and forth tip movement.³⁴

Ultrasonic energy generates multiple nodes and antinodes along the length of the object vibrated.⁴⁰ Because of this mechanism of action, the amplitude is undesirably dampened when the vibrating tip contacts the dentinal walls of a preparation.⁴³ It should be understood that any vibrating tip, even if pre-curved, will almost certainly contact dentin since virtually all canals, even when well-shaped, exhibit some degree of curvature. Contact between an ultrasonically driven tip and dentin results in a diminished amplitude, an undesirable decrease in tip movement, and an exponential reduction in streaming velocity. To date, all ultrasonically driven instruments are manufactured from metal alloys. Recognize some ultrasonically driven instruments are active, having cutting edges, whereas other instruments are nonactive in that their cutting edges have been reduced or eliminated. Regardless, vibrating any metal tip, even pre-curved, around a canal curvature invites ledges, apical transportations, lateral perforations, or broken instruments.

On the contrary, sonic energy produces lower frequencies compared to ultrasonic devices. However, research has shown, when a sonically driven instrument was loaded, the elliptical motion was eliminated, leaving a pure longitudinal file oscillation. This mode of vibration has been shown to be particularly efficient, as it was largely unaffected by loading and displayed large displacement amplitudes.³⁹ Even though the streaming velocity formula may not perfectly account for intracanal conditions, larger amplitudes exponentially influence the hydrodynamic phenomenon.

It has been postulated that even a well-shaped canal represents a relatively small cone-shaped volume. This argument presumes that there will be limited or insufficient space to produce an effective back and forth movement of the vibrating tip. Recall, ultrasonic energy produces high frequencies, but low amplitudes, compared to sonic energy. As has been stated, ultrasonic energy produces multiple nodes and antinodes along the length of a vibrating tip. This mechanism of action serves to decrease the back and forth movement of the tip when any portion of the instrument, even if pre-curved, contacts dentin. On the contrary, sonic energy produces just one single node and antinode over the entire length of the vibrated object.⁴⁰ As such, tip amplitude

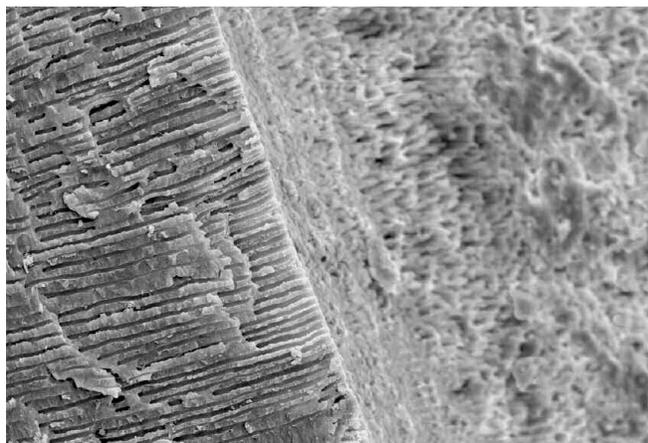


Figure 9a. An SEM image at 500X provides evidence that the EndoActivator System achieved complete debridement in this well shaped canal.



Figure 8. The EndoActivator System is designed to safely and vigorously energize the hydrodynamic phenomenon.

and the resultant tip movement are virtually unaffected by contact with dentinal walls.⁴³ In the final analysis, whether one chooses to utilize ultrasonically or sonically driven tips, the energy source selected should produce a safe, effective, and easy-to-use method for powerfully generating the hydrodynamic agitation of any given intracanal solution.

ENDOACTIVATOR SYSTEM

The EndoActivator System (*Dentsply Tulsa Dental Specialties*) is comprised of a handpiece and variously sized polymer tips (**Figure 8**). This sonically driven system is designed to safely activate various intracanal reagents and vigorously produce the hydrodynamic phenomenon. Importantly, sonic activation has been shown to be an effective method to improve disinfection.^{39,41-42} This technology is intended to provide a safer, better, and faster method to disinfect a root canal system compared to other currently available methods. Research has shown and is showing that the EndoActivator System is able to debride into the deep lateral anatomy, remove the smear layer, and dislodge simulated biofilm clumps within the curved canals of molar teeth (**Figure 9**).⁴⁴⁻⁴⁵

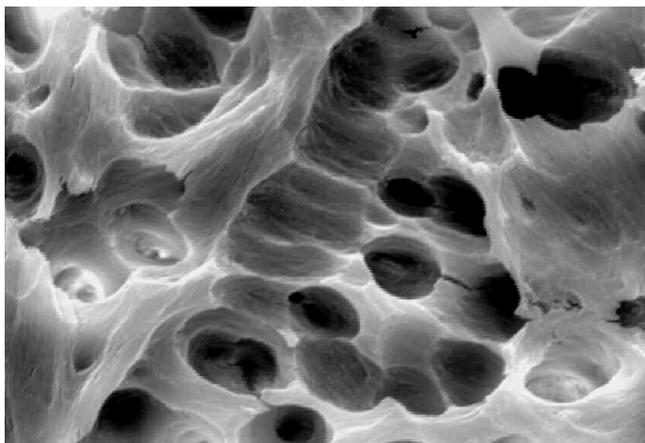


Figure 9b. An SEM image at 2,000X reveals deep lateral cleaning and that the EndoActivator System disrupted both the smear layer and biofilm. (Figures 9a-9b courtesy of Dr. Grégory Caron; Paris, France)

In a well-shaped canal, the clinical efficacy of the EndoActivator is immediately appreciated. During use, the action of the EndoActivator tip frequently produces a cloud of debris that can be observed within a fluid-filled pulp chamber. The primary function of the EndoActivator is to produce vigorous intracanal fluid agitation through acoustic streaming and cavitation. This hydrodynamic activation serves to improve the penetration, circulation, and flow of irrigant into the more inaccessible regions of the root canal system.⁴⁶ Cleaning root canal systems provides an opening for three-dimensional obturation and long-term success (*Figure 10*).

Research has shown that agitating a solution is a method to more effectively remove calcium hydroxide from experimental grooves within a prepared canal.⁴⁷ Preliminary research is showing the EndoActivator, utilizing polymer tips, is a safe and effective method to both adapt and remove calcium hydroxide from a shaped canal. Further, this technology may be used, in straight or more curved canals, to deliver mineral trioxide aggregate (*MTA, Dentsply Tulsa Dental Specialties*) into immature teeth exhibiting blunderbuss canals, or into perforating pathological or iatrogenic defects. In the retreatment situation, clinical trials have shown that the EndoActivator System serves to break up and dislodge remnants of previously placed obturation materials. The following will describe this technology and how to easily integrate the EndoActivator System into everyday practice.

SONIC HANDPIECE

The sonic handpiece is cordless, contra-angled, and ergonomic, and is used to drive the EndoActivator tips. The handpiece is operated by depressing the light-touch ON/OFF switch that activates the strong and flexible polymer tips. The 3-speed sonic motor switch provides options of 10,000, 6,000 and 2,000 cycles per minute (cpm). When the handpiece is activated, the power defaults to 10,000 cpm, which research has shown to be the recommended speed to maximize debridement and disruption of the smear layer and biofilm.⁴⁴⁻⁴⁵ The other lower speeds are selected based



Figure 10. This maxillary second bicuspid demonstrates exquisite and complete endodontics. The EndoActivator System was utilized to produce hydrodynamic irrigation. (Courtesy of Dr. Robert H. Sharp; Sacramento, California)

on different clinical applications and the power needed to effectively accomplish those tasks. The sonic motor is energized by, preferably, a single lithium battery. Depending on use, periodically install a new, fully charged battery to ensure optimal performance. For infection control, custom protective barrier sleeves have been designed to easily slide over the entire handpiece (*Figure 11*). It is important to not autoclave or submerge the handpiece in cleaning solutions; rather, simply wipe down the handpiece, as desired, with a mild detergent.

ENDOACTIVATOR TIPS

The EndoActivator tips have an easy snap-on/snap-off design and are color-coded yellow, red, and blue, corresponding to small, medium and large sizes, respectively (*Figure 8*). Specifically, the yellow, red, and blue color-coded activator tips closely correspond to file nomenclature sizes 20/02, 25/04, and 30/06, respectively. The tips are made from a medical-grade polymer, are strong and flexible, and are 22 mm long. Importantly, the polymer tips will not cut dentin, and as such, will not ledge, apically transport, or perforate a canal. The bowl-shaped, clean-guard serves to consolidate the protective barrier to maximize vision during clinical use. Each activator tip has orientational depth gauge rings positioned at 18, 19, and 20 mm. The EndoActivator tips are disposable, single-use devices that should not be autoclaved. At times, the orthodontic Bird Beak pliers (*Hu-Friedy*) can be used to place a smooth curve on any sized tip to facilitate their placement. Also, the apical extent of any given tip can be cut off and the overall length appropriately shortened to facilitate placement and treatment. The EndoActivator tip selected is placed over the barrier-protected driver and is simply snapped on to secure its connection to the handpiece (*Figure 12*).

Tip Selection

In fully prepared canals, a tip is selected that fits loosely and to within 2 mm of working length. A loose tip will be free to move, enhancing irrigation dynamics.³⁵ An underprepared canal or selecting a tip that is too large will serve to



Figure 11. Custom EndoActivator barrier sleeves are designed to slide over the entire handpiece, including the driver.



Figure 12. The Activator tip is selected, is placed over the barrier-protected driver, and will snap-on firmly to promote a secure connection.

dampen or restrict tip movement, which in turn will limit its ability to agitate a solution. Research has shown that just moving a tapered gutta percha cone or polymer tip up and down in short 2-3 mm vertical strokes in a tapered preparation produces a surprising hydrodynamic effect.^{14,44} When the selected tip moves toward the full working length, then its shape more closely approximates the shape of the prepared canal. This, in turn, serves to displace any given reagent laterally while allowing safe reflux coronally. Vibrating the tip, in combination with moving the tip up and down in short vertical strokes, synergistically produces a powerful hydrodynamic phenomenon. In general, 10,000 cpm has been shown to optimize debridement and promote the disruption of the smear layer and biofilm.⁴⁴⁻⁴⁵ When the clinical procedure has been completed, support the contra-angled neck of the handpiece, and remove the attached activator tip by pulling straight off. Together, the activator tip and barrier sleeve should be discarded.



Figure 13. This clinical image shows the EndoActivator System in use. Note the fluid activation and appreciate the potential for enhanced cleaning.

CLINICAL PROTOCOL

Although previously mentioned in this article, it must be re-emphasized the importance of shaping canals. Well-shaped and fully tapered canals hold an effective reservoir of irrigant that, when activated, can potentially circulate, penetrate, and digest tissue, and further serve to dislodge debris from all aspects of the root canal system. When utilizing the EndoActivator System, vigorous fluid agitation will be clinically observed within the pulp chamber (*Figure 13*). Although this turbulence is an exciting observation, scientific investigation has been required to understand the extent of this phenomenon within a well-shaped canal. As such, to better appreciate the hydrodynamic phenomenon below the orifice, various scientific experiments have been and are being conducted to visualize the results of cavitation, acoustic streaming, as well as primary and secondary streaming within a root canal system (*Figure 14*).^{34-35,48}

The Machtou group, in two different studies, have shown the benefits of the EndoActivator to debride tissue and remove the smear layer.⁴⁴ The hydrodynamic phenomenon results when a vibrating tip generates fluid activation and intracanal waves. As an example, in the physical world, underwater seismic activity releases energy that can induce a large wave formation called a tsunami. In the endodontic world, the metaphor is vibratory energy within a well-shaped and fluid-filled canal serves to induce intracanal waves. Random waves fracture, creating bubbles that oscillate within any given solution. These bubbles expand and become unstable, then collapse in what is termed an implosion. Each implosion radiates miniature tsunamis, or shockwaves that dissipate at 25,000 to 30,000 times per second.³⁷ Shockwaves serve to powerfully penetrate, break up potential bacterial infested biofilms, and wipe surfaces clean. Imploding bubbles serve to desirably increase the temperature and further generate significant pressure on an intracanal irrigant, which in a small microscopic space, serves to promote surface cleaning. Additional studies have



Figure 14. This image depicts a simulated root canal system. The Activator tip is used with a pumping motion to produce vigorous hydrodynamics.

shown that fluid hydrodynamics is the only mechanism to clean root canal surfaces and systems.^{11,14}

In a preliminary study, Gulabivala has shown that the EndoActivator removes simulated biofilms in extracted teeth. Further, he has shown that hydrodynamics is a function of the canal shape, the size of the activator tip selected, the activation time, the volume of irrigant, the motion of the activator, and the temperature of the irrigant.⁴⁵ Lambrechts' team states fluid activation in conjunction with PAD is an absolute must-have to maximize three-dimensional cleaning.¹¹

Following root canal preparation procedures, irrigate and flush the root canal space with a full strength solution of NaOCl, then suction to remove this reagent. Next, flood the pulp chamber with a 17% solution of EDTA and use the EndoActivator to agitate this intracanal solution for 60 seconds. Agitating an intracanal reagent serves to move debris into solution, and as such, requires voluminous irrigation and intracanal suction to remove this loose debris.³⁶ This process should be repeated for each canal and until the fluid in the pulp chamber is observed to be clear. Following the use of 17% EDTA, vacuum and remove this reagent. Irrigate with a full strength solution of NaOCl and use the EndoActivator to agitate this intracanal solution for 30 seconds. Logically, better cleaning improves the potential for complete obturation and long-term success (*Figure 15*).

FUTURE

It is exciting and turbulent times in clinical endodontics. In the future, successfully treated teeth will be attributable to complete endodontics, whereas failing teeth will be universally understood to be due to deficiencies in primary

treatment. One of the more significant advances in the years immediately ahead will be the development of specific methods that will promote three-dimensional cleaning. Innovative technologies will continue to emerge that will move the field of endodontics ever closer toward achieving the biological goal of complete disinfection. When our profession recognizes the importance of treating the entire root canal system, then we will be liberated from this last great controversy and endodontics will be fun. ▲

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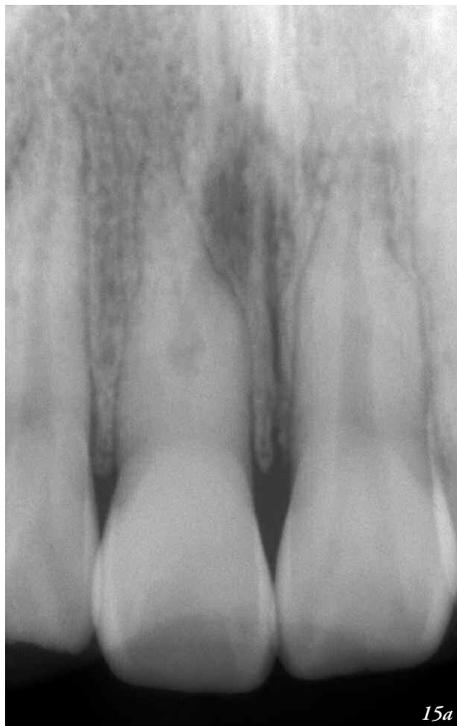


Figure 15a. A radiograph of this endodontically involved maxillary right central incisor reveals coronal calcification and middle one-third resorption.

Figure 15b. The post-treatment film demonstrates the result of shaping, activating fluids, and three-dimensional obturation.

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