

## ENDODONTICS

# Improving Irrigation and Root Canal Disinfection

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### INTRODUCTION

With the arrival of NiTi engine-driven files and mechanized instrumentation systems, root canal instrumentation became exponentially faster and somehow more predictable compared to manual instrumentation techniques. However, with the popularization of these files in recent decades, a breach between speedy preparation and infection control becomes evident, especially regarding the time and volume of irrigating fluid during the operation. Nevertheless, it is undeniable that the technical advance arising from NiTi engine-driven files has benefited the endodontic technique. The question is what is more important, speed or infection control? Naturally, the answer lies in infection control efficiency, without which the repair process will be impossible.

Rapid canal shaping impairs the quality of cleaning and disinfection processes based on the sodium hypochlorite (NaOCl) action principle. It does not provide the time necessary to accomplish either and gives even less time to guarantee the volume and renewal of the irrigating liquid, which can compromise the main objective of the treatment.<sup>1</sup> This realization has triggered a change in the primary goal of root canal preparation. Mechanical instrumentation currently provides access to the apical morphology of the canal. It allows irrigants to flow, which is expected to accomplish most of the cleaning and disinfection. Therefore, the focus gradually shifted from types of irrigants to delivery methods and ways to enhance their effectiveness within the intricate root canal system.

The ideal mechanical preparation should uniformly debride and enlarge the entire perimeter of the root canal. However, micro-CT-based studies show inadequate canal preparation with engine-driven files (Figure 1) despite their design or kinematics (rotation or asymmetric reciprocation movements). As a result, microorganisms that remain on unprepared dentin walls may have the opportunity to recolonize the canal system, compromising the treatment outcome.<sup>2,3</sup>

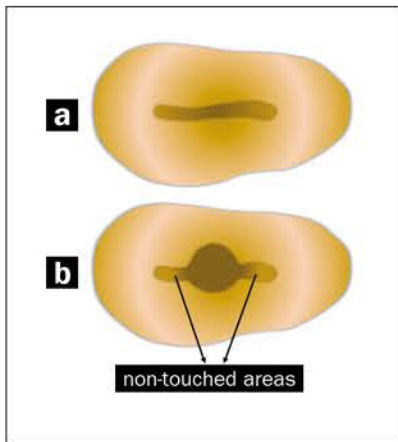
Another critical point to be considered is to clean the

canal space while preserving the maximum sound structure of the tooth. As already noted, current endodontic instruments have not evolved sufficiently to the point of adapting perfectly to the anatomy of the root canal during their use. Thus, the unnecessary removal of sound dentin tissue results from any preparation protocol currently available because of the need to reach all the root canal walls. Even performing more minor dentin-cutting maneuvers with small instruments—the minimally invasive preparation—does not seem to reduce unnecessary dentin removal significantly<sup>4</sup> and can compromise proper cleaning and root canal disinfection.<sup>5</sup>

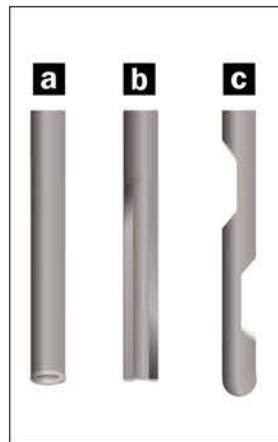
A side effect of mechanical preparation is hard-tissue debris accumulation,<sup>6</sup> which carries the likelihood of being more clinically relevant than the smear layer. Engine-driven shaping produces and packs dentin debris into irregular areas of the canal space, with a sizable accumulation of debris in fins, isthmuses, and irregularities with ramifications of the complex canal network. In addition, non-removed debris could easily harbor bacteria biofilm from the disinfection procedures and reduce the antiseptic activity of the irrigating solution.<sup>7-9</sup>

### THE QUINTESSENTIAL IMPORTANCE OF IRRIGATION

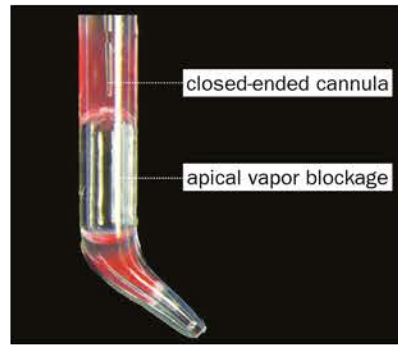
From a didactic point of view, the endodontic technique is divided into separate steps or phases so that the student can understand and practice systematically; from a clinical standpoint, the process is quite different. Cleaning and shaping should be seen as one single procedure. Mechanical instrumentation opens the way for the action of chemical disinfection through the use of irrigating solutions and intracanal medicaments. The initial cleaning of root canals is commonly performed by mechanical instrumentation, which removes the large bulk of the pulp tissue, the necrotic debris, bacterial biofilms, and/or a previous root filling. Unless this bulk material is first removed, no further cleaning is possible. Nevertheless, it is prudent to state that final intracanal disinfection mainly depends on the physicochemical



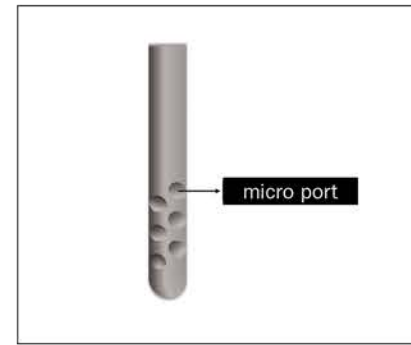
**Figure 1.** (a) Representation of a micro-CT cross section of a ribbon-shaped canal space. (b) Engine-driven file action after instrumentation, leaving non-touched areas.



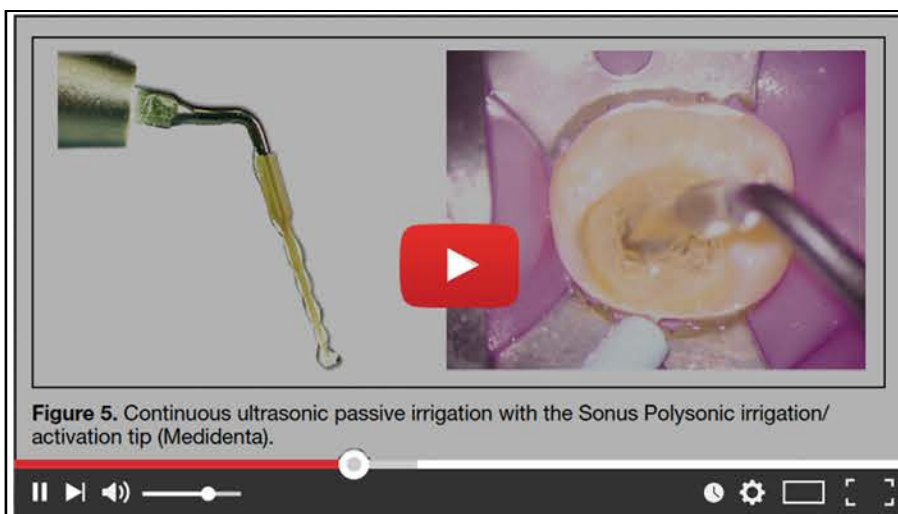
**Figure 2.** Representation of different end types of cannulas: (a) open-ended; (b) notched-ended; and (c) side vented, close-ended.



**Figure 3.** Vapor lock or blockage in a 0.50-mm (ID) capillary glass tube.



**Figure 4.** Representation of the EndoVac (Kerr) end cannula.



**Figure 5.** Continuous ultrasonic passive irrigation with the Sonus Polysonic irrigation/activation tip (Medidenta).



**Figure 6.** The iVac system (Pac-Dent) includes (a) 0.35-mm cannulas (green), (b) 0.50-mm cannulas (yellow), (c) rings, (d) S-type insert, (e) low-vac and high-vac connectors, (f) angled capillary tips, (g) small tubes, and (h) a long tube.

activity of irrigation. Reaching areas not touched during the mechanical preparation with NaOCl solution is necessary to dissolve the biofilm and remaining necrotic tissues. When instruments fail to prepare the canal walls in complex canal systems, such as in molars or even oval canals, the chemical action of sodium hypochlorite is the last opportunity to gain control of the infectious contingent within the root canal system.

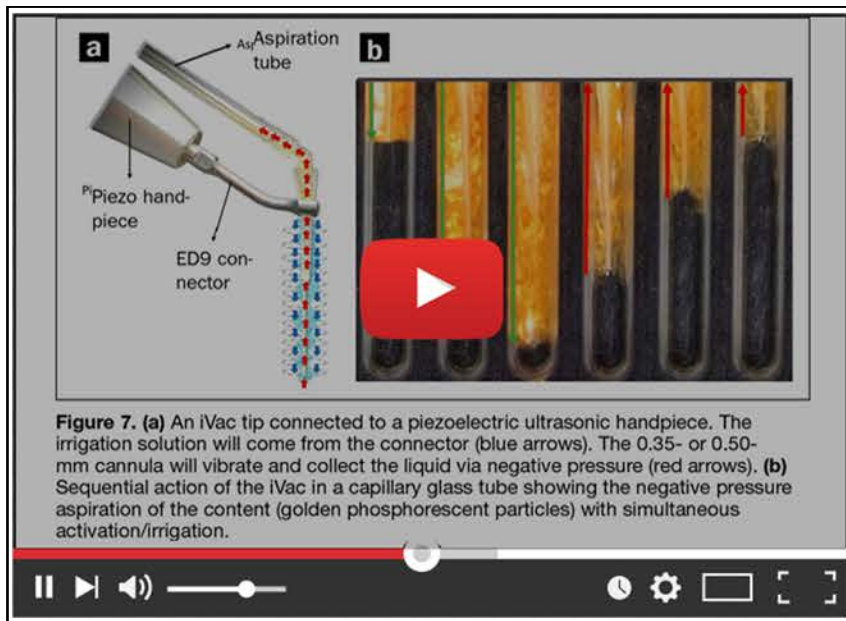
Recent histological and micro-CT analysis studies have determined that the instrumentation leaves around 40% of the walls untouched.<sup>10,11</sup> Furthermore, the conventional irrigation technique with a syringe and an open-ended cannula does not solve the problem. There is conclusive evidence in the literature that more effective irrigation techniques related to accessing irrigation fluids in critical areas—for instance, the last apical millimeters and isthmuses and irregularities—should be used instead of the conventional irrigation technique.<sup>12,13</sup>

It seems paradoxical that, on the one hand, instrumentation techniques have undergone an extraordinary evolution with NiTi instruments capable of cutting significant amounts of dentin in short periods, yet on the other hand, the NaOCl solution requires a more extended time than that required by mechanical instrumentation to reach its full potential.<sup>14-16</sup> The result is that the root canal is shaped but not properly cleaned and disinfected.

In the syringe-cannula classic irrigation method, irrigants are delivered deeply into the canal space using positive pressure irrigation through a cannula connected to a syringe via applying finger pressure on the syringe plunger, which pushes the irrigant solution through the cannula into the canal space by directly injecting the solution. In contrast, the suction cannula simultaneously aspirates it. The high flow rate used to introduce the

irrigant into the canal results in technique-related factors that increase irrigant pressure at the apical portion of the canal when open-ended cannulas are used. This can sometimes extrude the solution periapically, resulting in tissue damage and postoperative pain. The proper frequency of such accidents is unknown as many of them may not be reported. Minor extrusion incidents might even remain undetected due to the absence of severe symptoms. A 2008 survey of endodontists in the United States indicated that nearly half of the respondents (42%) had experienced at least one NaOCl accident during their practice careers.<sup>17</sup> The extrusion accident, and its consequences, explain why most clinicians often avoid a closer approach to the working length while irrigating with NaOCl solution. Regarding its efficacy, conventional syringes and open-ended cannula irrigation leave a large amount of debris clogged in the irregularities of the root canal system and do not efficiently deliver the irrigant solution into the apical third of the canal.<sup>18</sup>

Modifications in the distal end of the irrigation cannulas were carried out to minimize the problem of accidental NaOCl extrusion. This allowed the use of



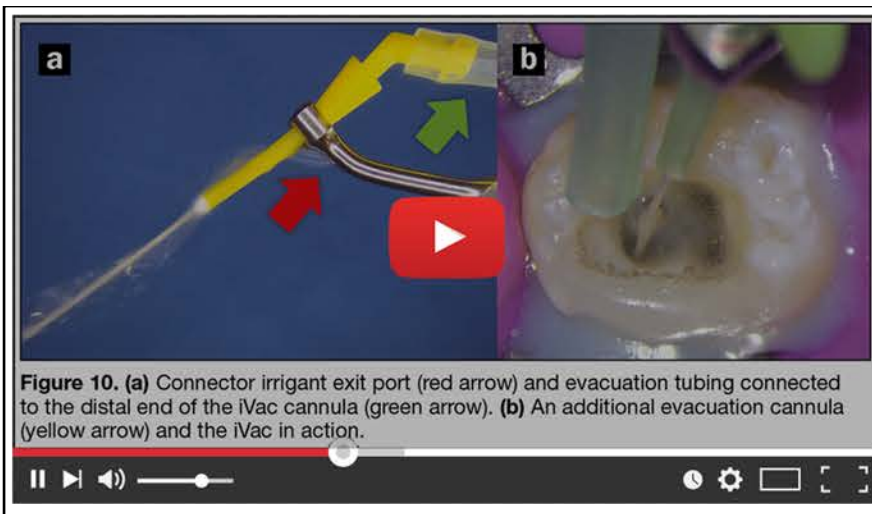
**Figure 7.** (a) An iVac tip connected to a piezoelectric ultrasonic handpiece. The irrigation solution will come from the connector (blue arrows). The 0.35- or 0.50-mm cannula will vibrate and collect the liquid via negative pressure (red arrows). (b) Sequential action of the iVac in a capillary glass tube showing the negative pressure aspiration of the content (golden phosphorescent particles) with simultaneous activation/irrigation.



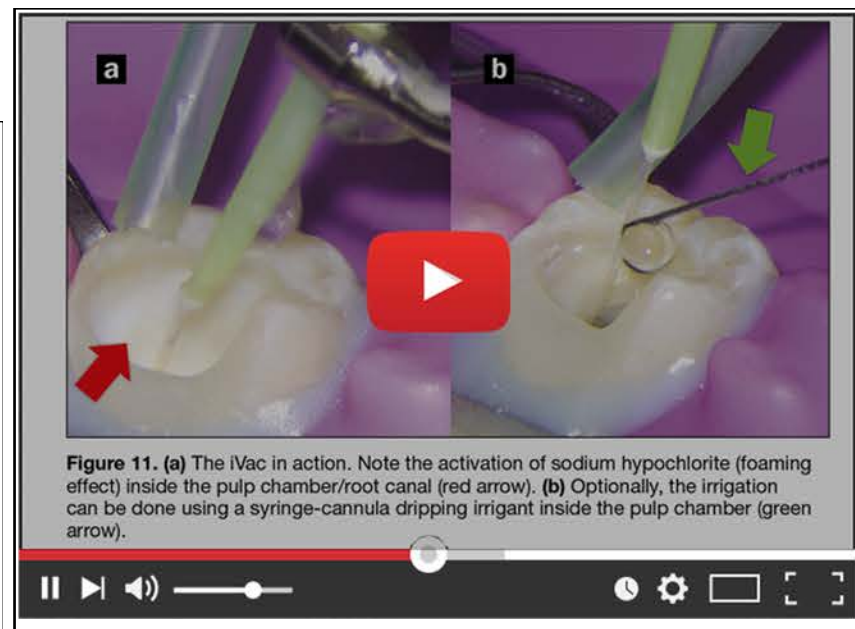
**Figure 8.** The 0.35-mm (green) iVac cannula.



**Figure 9.** The iVac piezoelectric unit (Pac-Dent).



**Figure 10.** (a) Connector irrigant exit port (red arrow) and evacuation tubing connected to the distal end of the iVac cannula (green arrow). (b) An additional evacuation cannula (yellow arrow) and the iVac in action.



**Figure 11.** (a) The iVac in action. Note the activation of sodium hypochlorite (foaming effect) inside the pulp chamber/root canal (red arrow). (b) Optionally, the irrigation can be done using a syringe-cannula dripping irrigant inside the pulp chamber (green arrow).

these closed-ended cannulas in a position closer to the working length, resulting in the development of lower liquid pressure at the apical foramen compared to open-ended cannulas. The modification directly affects the irrigant flow rate, the most frequently reported technique-related factor in extrusion accident case reports. Closed-ended, open-side cannulas (Figure 2, right) vary in diameter, length, and tip design. Because of its lateral laminar flow (and not contiguous along the long axis of the cannula), safety is improved. However, it has a negative impact on the effectiveness of irrigation in some areas of the canal, predominantly in the last apical millimeters.

Additionally, it is well documented that a “dead water” or stagnation zone is produced between the tip of the closed-end cannula and the apex, where no flow of irrigation occurs,<sup>19-21</sup> resulting in the accumulation of debris in this region.<sup>22</sup> This phenomenon, known as the “vapor lock effect or blockage” (Figure 3), has been confirmed in both in vitro and in vivo studies.<sup>23,24</sup> Its origin is attributed to the interaction between the trapping of air bubbles caused by the irrigation distribution (positive pressure) and the gas production created by the chemical reaction of NaOCl with organic tissues. As a result, a vapor lock could theoretically block the irrigant from flowing toward the apical third. The phenomenon is described as the difficulty of irrigant solution dispersion in a narrowed space such as the root canal.

#### APICAL NEGATIVE PRESSURE IRRIGATION

There is substantial evidence showing that the apical negative pressure irrigation (ANPI) method can improve the cleaning and disinfection process and

the overall safety of the irrigation procedure.<sup>25-30</sup> ANPI efficiency depends on the suction cannula’s positioning at the canal’s apical region, which aspirates the irrigating solution supplied in the pulp chamber. The first commercial irrigation system using ANPI (EndoVac [Kerr]) became available in 2007. The irrigating solution circulates through the canal by creating a negative apical pressure in the working length and generating a rapid apical-oriented fluid stream that allows the use of a greater volume of the solution than conventional irrigation and better control of the apical extrusion. Despite the efficacy shown, the EndoVac included design drawbacks severely limiting its clinical practice use. One of the features is the micro-cannula end, which consists of 12 micro-ports within the first 1 mm near the distal end with a diameter of 0.10 mm (Figure 4). The port’s diameter is minimal and frequently clogs due to dental pulp fragments and cut dentin debris being sucked into the ports during use.<sup>31</sup>

#### SONIC AND ULTRASONIC IRRIGANT ACTIVATION

The effectiveness of irrigation relies on both the mechanical flushing action and the chemical ability of irrigants to dissolve the tissue and control the infection. Sonic and ultrasonic activation/irrigation techniques are designed to create acoustic microstreaming and transient cavitation that push the irrigant laterally into the irregularities of the canal. Acoustic microstreaming is defined as a rapid movement of fluid in a vortex motion, generating shear stresses that enhance debridement. Transient cavitation causes bubbles that, when collapsing, produce radiating shockwaves and a rise in temperature, increasing effi-

ciency.<sup>32-35</sup> In addition, studies reported that both sonic and ultrasonic devices might remove the smear layer<sup>36,37</sup> and have better disinfection ability<sup>38,39</sup> compared to conventional irrigation. One of the most used techniques is passive ultrasonic irrigation (PUI). “Passive” refers to the noncutting action of the tip or ultrasonic insert used in the procedure. PUI uses a K-file type insert or a smooth file attached to a connector and an ultrasonic handpiece in through which vibration is supplied.

After the completion of mechanical preparation, PUI can be used in either intermittent or continuous mode. In the intermittent option, the canal is first filled with the chemical solution using a syringe and cannula. Next, an ultrasonic insert is activated in the canal up to 2 mm from the working length. The tip is moved passively with an in-and-out motion to avoid binding with the root canal walls. Although sonic or ultrasonic activation performs better than conventional irrigation, some limitations, such as not reaching the last apical millimeters and only moving the residues inside the canal and not removing them, are still controversial points in this technique.

Continuous ultrasonic passive irrigation is achieved by simultaneously and continuously delivering irrigation during ultrasonic activation through the irrigation insert (Figure 5), in contrast to intermittent PUI, which needs manual (syringe and cannula) replacement of the liquid inside the canal. The chemical solution (NaOCl or EDTA) is housed in a reservoir or in attached irrigant bottles placed on the ultrasonic unit. The irrigant will be continuously dispensed, providing a fresh reactant for the irrigation’s chemical reaction. By constantly using a new reactant, the chemical reaction will always favor tissue dissolution, keeping a high concentration of chlorine (in the case of NaOCl) and a high concentration of chelating action (in the case of EDTA) in the canal.<sup>40,41</sup>

#### PUTTING EVERYTHING TOGETHER FOR A NEW APPROACH

The iVac System (Pac-Dent) (Figure 6)<sup>42</sup> brings a new approach to some limitations of the irrigation/activation systems previously discussed. The method continuously delivers the irrigation liquid to the entire working length without apical pressure, alongside concomitant ultrasonic activation and a safe evacuation via negative pressure (Figure 7). The iVac system consists of a non-tapered 0.35- or 0.50-mm-diameter polymer cannula (Figure 8) self-threaded to a piezo ultrasonic connector (iVac S or iVac E [Pac-Dent]). The connector will be coupled to a piezoelectric ultrasonic handpiece, providing vibrations to the iVac cannula and delivering concomitant irrigation from the reservoir (Figure 9). The vibration will help carry the irrigation fluid throughout the canal extension, alongside the external cannula surface, and be recollected via the apical opening. The iVac piezo ultrasonic connector has a passageway that provides a continuous flow path for delivering fluid to the pulp chamber and root canal, projecting the liquid at the polymer cannula’s external surface through an opening near the threading housing (Figure 10a, red arrow). The other end of the iVac cannula will be connected to the evacuation tubing (Figure 10a, green arrow), creating negative pressure powered by the standard evacuation equipment. Additional evacuation is necessary since the volume of liquid during irrigation will be bigger than the negative pressure suction capacity (Figure 10b).

There are some unique aspects regarding the iVac system. First, the polymer cannula has a single continuous evacuation path that creates negative pressure, allowing a large volume of irrigation fluid to reach the working length without being extruded. Second, the configuration of the cannula assembly transfers ultrasonic vibrations, which provide a microstreaming effect and proper activation of the irrigation liquid. Third, the connection with the piezoelectric handpiece provides continuous automated irrigation flow that doesn’t require secondary assembly with a syringe or an irrigation pump (Figure 11). Finally, the iVac polymer cannula is disposable, and the iVac ultrasonic connector can be cleaned, appropriately sterilized, and reused. The iVac system can be used with the majority of piezo ultrasonic units on the market.

Aiming to solve the clogging problem encountered by the previously cited EndoVac (Kerr) system, the iVac features an aspiration cannula with an outer diameter of 0.35 mm and an inner diameter of 0.15 mm. The latter offers supe-

rior suction capacity compared to EndoVac, with the advantage of being less likely to clog. In addition, the simultaneous ultrasonic vibration helps move debris and fluid removed from the canal inside the cannula.

The system features continuous flush irrigation, providing an uninterrupted supply of fresh solution during the procedure, reducing the time required for final irrigation compared to PUI, and achieving better results in removing debris from the apical third.<sup>43</sup> The iVac cannula provides the same level of ultrasonic vibration as the metal tips used in the PUI. However, they are more flexible and do not break during use. In addition, metallic inserts for PUI are usually designed using a K-file as a base, showing unintentional dentin removal. Furthermore, by using a polymer cannula, the chances of separating the cannula within the canal are low, if any.

#### CLOSING COMMENTS

The perceived importance of irrigation on the outcome of root canal treatment has grown considerably over the last decade. It seems paradoxical that mechanical instrumentation creates more debris during the action of the instruments and doesn’t reach areas of the canal due to the anatomy of the root canal system. Effective cleaning comes from the irrigation liquids, which must be appropriately used by respecting appropriate volume, time of action, and concentration. In addition, the full extension of the canal to the apical foramen must be achieved, especially with NaOCl. Even the best irrigating solution would be pointless if it could not reach its targets in the root canal system in sufficient amounts.<sup>44</sup>

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*Disclosure:* Dr. Ramos reports no disclosures.



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