

Comparative Safety of Various Intracanal Irrigation Systems

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Abstract

The objective of this project was to evaluate the safety of various intracanal irrigation systems by measuring the apical extrusion of irrigant. Twenty-two single canal, extracted mature teeth were instrumented and secured through the lid of a scintillation vial to collect apically extruded irrigant. A precision syringe pump delivered controlled amounts of irrigant at a constant flow. The irrigation systems used were EndoVac Micro and Macro Cannula, EndoActivator, manual irrigation with Max-I-Probe needle, Ultrasonic Needle Irrigation, and Rinsendo. Results were analyzed by using one-way analysis of variance with Scheffé test ($P < .05$). The EndoVac Micro and Macro cannulae groups did not extrude irrigant, and there was no statistically significant difference between these 2 groups and the EndoActivator group. Within the groups that produced extrusion, EndoActivator extruded statistically significantly less irrigant than Manual, Ultrasonic, and Rinsendo groups. There was no statistically significant difference among Manual, Ultrasonic, and Rinsendo groups. This study showed that the EndoVac did not extrude irrigant after deep intracanal delivery and suctioning the irrigant from the chamber to full working length. EndoActivator had a minimal, although statistically insignificant, amount of irrigant extruded out of the apex when delivering irrigant into the pulp chamber and placing the tip into the canal and initiating the sonic energy of the EndoActivator. Manual, Ultrasonic, and Rinsendo groups had significantly greater amount of extrusion compared with EndoVac and EndoActivator. (*J Endod* 2009;35:545–549)

Key Words

EndoActivator, EndoVac, RinsEndo, safety, ultrasonic needle

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Chemomechanical debridement is an important part of endodontic treatment. Elimination of pulpal tissue, microbiota and their by-products, and organic and inorganic debris removal by using instruments and intracanal irrigants are objectives of this important phase of treatment. Sodium hypochlorite along with ethylenediaminetetraacetic acid is able to achieve the goal of chemical debridement (1, 2). Sodium hypochlorite carries risk of extrusion into periapical tissues causing inflammation, ecchymoses, hematoma, and sometimes even necrosis and paresthesia (3–5). Accordingly, any root canal irrigation delivery system that reduces the risk of sodium hypochlorite extrusion into the periapical tissues would greatly benefit patient care.

In vitro studies have demonstrated that when root canals are instrumented and irrigated with patent apical terminations, extrusion of irrigants beyond the apical constriction is routine (6–9). Accordingly, the premise of this study was to create the worst case scenario for testing the potential of each device to extrude endodontic irrigants: a tooth with a patent apical foramen, not covered by either bone or membrane, and terminating in an atmospheric neutral environment.

The specific aim of this *in vitro* study was to compare the relative safety of various intracanal irrigation systems. The volume of irrigant that extruded beyond the minor diameter of the apical foramen was measured. The device's safety was then directly correlated to the amount of extruded irrigant. Five irrigation delivery and/or activation systems with different irrigation principles were included in this study.

The EndoVac apical negative pressure irrigation system (Discus Dental, Smart Endodontics, Culver City, CA) has 3 components: Micro cannula (MICRO) (test group 1) (Fig. 1B), the Macro cannula (MACRO) (test group 2) (Fig. 1A), and the Master Delivery Tip (MDT) (Fig. 1C-3). The MDT simultaneously delivers and evacuates the irrigant (Fig. 2). The Macro cannula is used to suction irrigant from the chamber to the coronal and middle segments of the canal. The Micro cannula contains 12 microscopic holes and is capable of evacuating debris to full working length. Nielsen and Baumgartner (10) concluded that EndoVac was significantly better for root canal debridement at the apical termination than positive pressure needle irrigation.

The EndoActivator (Advanced Endodontics, Santa Barbara CA) (test group 3) (Fig. 1D-1) uses sonic energy to irrigate root canal systems. This system has 2 components, a handpiece and activator tips (Yellow 15/02, Red 25/04, Blue 35/04). The battery-operated handpiece activates from 2,000–10,000 cycles/min. The manufacturer recommends using this device after completion of cleaning and shaping and irrigation of the canal with a manual syringe and an endodontic irrigation needle (11). On placing irrigant into the canal and chamber, passively fitting tips are activated at 10,000 cycles/min for 30–60 seconds. It has been reported that sonic irrigation is capable of producing clean canals (12, 13).

Manual irrigation with a side-ported needle (Max-I-Probe; Dentsply International, York, PA) (MAX) by using positive pressure (test group 4) (Fig. 1C-2) within 2–3 mm of working length is the most commonly used endodontic irrigation system. Instances of expressing irrigants into periapical tissues and causing significant tissue damage and postoperative pain have been reported with the use of positive pressure (3–5).

A unique Ultrasonic Needle system (UN) capable of delivering and agitating the irrigant simultaneously was used in this study (test group 5) (Fig. 1C-1). It has been observed that the needle can produce cavitations with high ultrasonic output in shaped canals by removing pulpal tissues and debris better than hand and rotary instrumentation alone from canals and isthmi (14).

Rinsendo (RE) (Air Techniques Inc, New York, NY) (test group 6) irrigates the canal by using pressure-suction technology. Its components are a handpiece, a cannula with a 7-mm-long exit aperture, and a syringe carrying irrigant (Fig. 1D-2). The

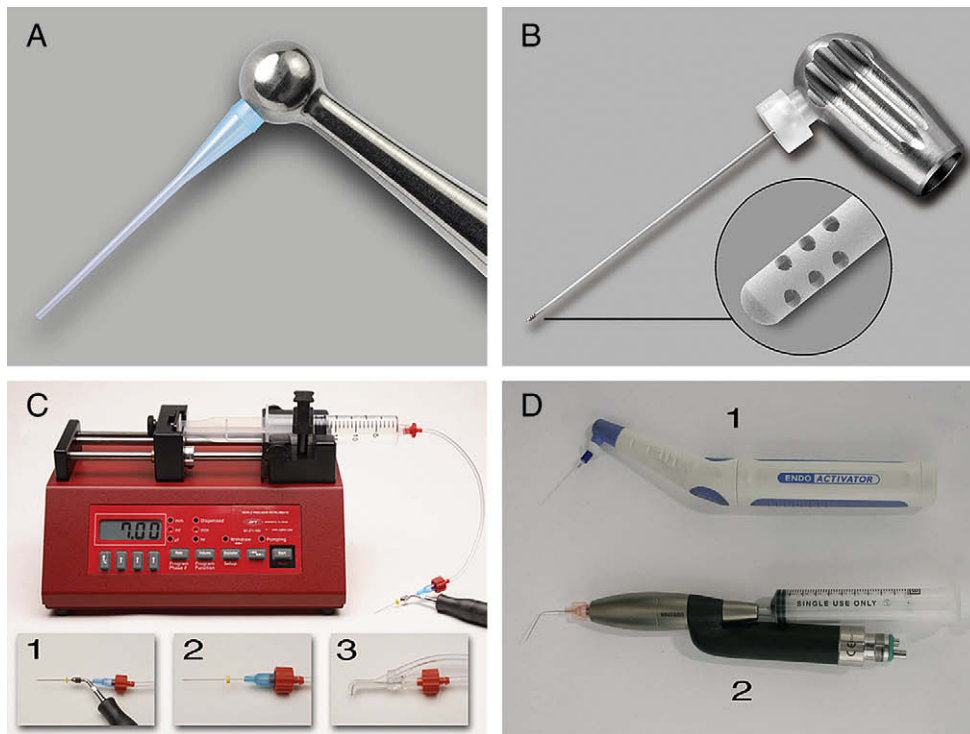


Figure 1. (A) The EndoVac plastic Macro and (B) stainless steel Micro cannulae are shown inserted in their respective titanium components. The Micro’s tip (enlargement) terminates with array of twelve 100- μ m holes (only 6 are visible) extending between an area 0.2–0.7 mm from the spherical end of the cannula. (C) PSP at top was used to deliver irrigant through (C-1) the ultrasonic needle, (C-2) the Max-I-Probe, and (C-3) the EndoVac’s MDT. (D1) The battery-operated EndoActivator is shown with a plastic activation tip inserted. (D2) The Rinsendo is shown fully assembled; it delivers irrigant via internal pneumatic pressure.

handpiece is powered by dental air compressor and has irrigation speed of 6.2 mL/min. Research has shown promising results in cleaning the root canal system. Periapical extrusion of irrigant has also been reported (15).

Materials and Methods

Twenty-two single-rooted, extracted maxillary central and lateral incisors with mature apices were selected. The same 22 teeth were used in all 6 groups to avoid variables of different canal anatomy and apical diameter. A consistent and known volume of irrigant was delivered to each pulp canal, and all apical extrusion was trapped in a collection vial similar to that of Brown et al (8). The percent difference between the extruded and delivered irrigant was calculated and analyzed.

Canal Preparation

After conventional access preparation, canals were shaped by using a crown-down technique with Endo Sequence, rotary nickel titanium instruments (Brasseler USA Dental Instrumentation, Savannah, GA) to a master apical file (MAF) size of #50/04. MAF is defined as the largest file that binds slightly at correct working length after straight-line access. Once the teeth were shaped to MAF, a micro capillary tip (Ultradent Products Inc, South Jordan, UT) was used to deliver 6.0% sodium hypochlorite through the prepared root canal space, until no visual evidence of intracanal organic tissue was found.

Test Units and Irrigant Control

The test units were prepared in the following manner (Fig. 3). The prepared teeth were mounted through a hole in the mating lid (Fig. 3A-1) of a removable 20-mL collection vial (Research Product Interna-

tional Corp, Mt Prospect, IL) (Fig. 3A-4) next to an atmospheric equalization 18-gauge needle (Ultradent Products Inc) (Fig. 3A-3). Both the tooth and the 18-gauge needle were secured and sealed to the lid by using light-cure composite resins (Esthet-X, Dentsply Caulk; Dentsply International, Milford, DE) and yellow sticky wax (Kerr Lab, Sybron Dental, Orange, CA) (Fig. 3A-2). The collection vial was dried and weighed on a digital scale (Sauter; August Sauter of America, New York, NY) and then securely screwed into the tooth/needle/lid assembly (8).

In all tests, irrigation was accomplished with room temperature tap water delivered to the pulp canal according to manufacturer’s instruction. To maintain irrigation consistency, a programmable precision syringe pump (PSP) (Fig. 1C) (Alladin, AL 1000; World Precision Instruments, Inc, Sarasota, FL) was used to deliver between 3.48 and 3.53 mL at the precise rate of 7.0 mL/min, except for the Rinsendo, because it contains its own pneumatic pump and irrigation syringe. A custom-made Fluid Recovery Trap (FRT) (Fig. 3A-5) collected coronally expressed irrigant in group 3 (Fig. 3C) or the irrigant flow through the Micro and Macro cannulae in groups 1 and 2 (Fig. 3A).

Testing Procedure

Group 1: Micro Cannula, EndoVac. The MDT was attached to the PSP to deliver irrigant into the pulp chamber (Fig. 3A-6). The micro cannula was attached to FRT (Fig. 3A-8), placed at full working length, and used according to manufacturer’s instructions.

Group 2: Macro Cannula, EndoVac. The Macro cannula was used as described in group 1. Its apical advancement ended wherever the intracanal diameter prevented its further apical extension.

Group 3: EndoActivator. The PSP was attached to irrigation needle that delivered irrigant into the pulp chamber (Fig. 3C). The

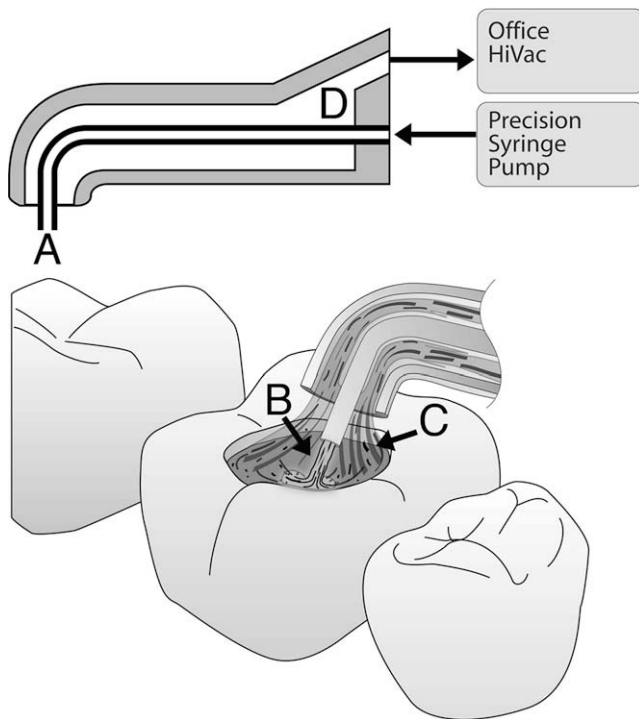


Figure 2. The EndoVac's MDT delivers irrigant from its stainless steel tip (A) into an access opening (B) and concurrently aspirates the excess (C) via its evacuation hood (D), thus ensuring a brimful access opening necessary for successful apical negative pressure irrigation. Because the MDT delivers more irrigant than is actually drawn through the Macro and Micro cannulae, it was necessary to measure the actual volume flow via an FRT (Fig. 3A). Fig. 3A shows the MDT as an abstract schematic without the detail shown here.

EndoActivator tip (35/04) was placed within 2 mm of WL and activated while moving in an up and down motion for 30 seconds.

Group 4: Manual Syringe and Max-I-Probe Needle. The 30-gauge Max-I-Probe needle attached to the PSP was placed 2 mm short of working length without binding and moved in an up and down motion during irrigation (Fig. 3B).

Group 5: Ultrasonic Needle Irrigation. The Ultrasonic unit used was Spartan MTS, 115 V (Obtura Spartan USA, Fenton, MO). The 25-gauge diameter, experimental beveled ultrasonic needle (Becton Dickinson & Co, Franklin Lakes, NJ) measured 1.5 inches in length and was mounted at a 45-degree angle to the ultrasonic handpiece. The PSP was attached to the ultrasonic needle, which delivered the irrigant. The ultrasonic needle was placed short of the binding point and moved in an up and down motion during irrigation (14).

Group 6: Rinsendo. Its syringe was filled with 3.50 mL of irrigant and weighed before and after the experiment to confirm the volume of the irrigant in the syringe. Rinsendo was operated at 45-PSI pressure. The cannula was placed into the coronal third of the canal without binding and moved up and down during irrigation (Fig. 3D).

Data Collection and Analysis

The volume of irrigant delivered into each pulp canal via the PSP was recorded from the pump's digital display. After each test, the lid assembly was separated from the collection vial, weighing the collection vial again and subtracting the pre-test tare weight to calculate the apical extrusion. Because the experiment was conducted at room temperature with water as the irrigant, no conversion between the weight and volume

was performed because the specific gravity of water at 25°C (77°F) is 1.00 at the second decimal place, reflecting the limit of the PSP's display. The percentage of extrusion in each test was calculated (Apical irrigant extrusion/Total irrigant delivered) and recorded. Results were analyzed by using one-way analysis of variance with Scheffé test ($P < .05$).

Results

At the end of the experiment 22 teeth were left. Four teeth were eliminated because of cracked roots resulting from desiccation.

The apical negative pressure group 1 (EndoVac Micro Cannula) and group 2 (EndoVac Macro Cannula) were the only ones that did not extrude irrigating solution into the collection vial (Fig. 4). There was no statistically significant difference between groups 1, 2, and 3 (EndoVac Micro, EndoVac Macro, EndoActivator). Group 3 extruded statistically significantly less irrigant compared with group 4 (Max-I-Probe Needle), group 5 (Ultrasonic needle), and group 6 (Rinsendo). There was no statistically significant difference among groups 4, 5, and 6. Group 6 extruded highest irrigant followed by groups 5, 4, and 3 (Fig. 5).

Discussion

Results of this study broadly correlated with studies by Lambriandis et al (6), Brown et al (8), Myers and Montgomery (9), and Roy and Laurence (16), which noted that irrigation with positive pressure resulted in periapical extrusion. This study also supports the result of Fukumoto et al (17) that negative pressure irrigation technique reduced periapical extrusion.

EndoVac Micro and Macro cannulae did not extrude irrigant through the apex. Because nothing was extruded, the amount of irrigant circulating through the Macro and Micro cannulae could be questioned. To address this concern, it was decided to collect the irrigants circulating through these components by using the FRT. Data from the FRT demonstrated that 82%–99% of the irrigant circulated through the Macro cannula, whereas 51%–54% circulated through the Micro cannula. The MDT was responsible for suctioning the coronal overflow (Fig. 3A-7) (Fig. 2).

Although Endoactivator extruded irrigant, the volume was very small, and the clinical significance is not known. However, the manufacturer's instructions at the time of research did not suggest the use of manual irrigation before using Endoactivator. In a recent publication by Ruddle (11), he suggested the use of intracanal irrigation before using EndoActivator. To relate these results to the manufacturer's instructions, groups 3 and 4 could be added together and then compared with the other groups. This would potentially make the differences between the EndoActivator and the EndoVac even greater.

The protocol for this study was designed to maximize the possibility of irrigant extrusion through an unrestricted, yet normal apex. It is understood that in clinical situations several factors might decrease the extent to which these systems extrude solutions. Periapical tissues and bone provide resistance to apical extrusion as well as non-patent canals. If quantities of periapical extrusion occurred clinically such as reported in this article, greater adverse treatment reactions associated with full-strength sodium hypochlorite would most likely occur. The model used most likely correlates, by design, to a canal that is open to atmospheric pressure, such as occurs when the apex of a tooth is extruding into the maxillary sinus with no apical covering or restriction (18, 19).

Because the basic goal of successful endodontic therapy is to eradicate microorganisms and other intracanal debris from the root canal system, the clinician must be able to deliver antimicrobial and tissue solvent solutions in predictable volumes safely to full working

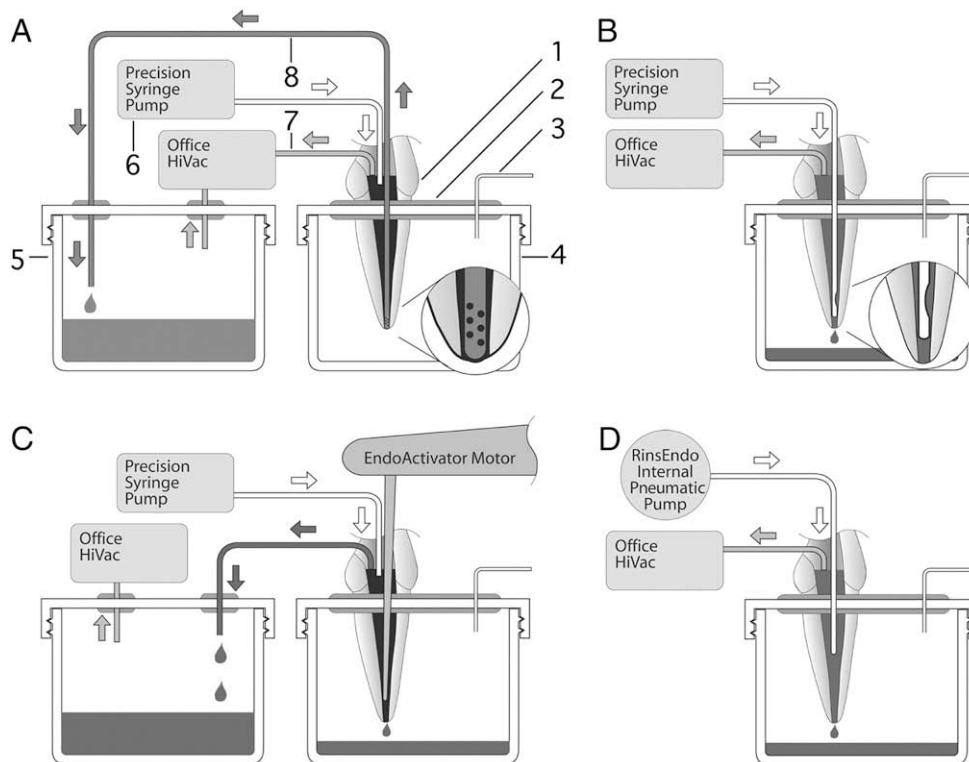


Figure 3. All tests used the same set of teeth (A-1), mounted and sealed via composite and wax (A-2) to a removable cap, perforated, and sealed with a pressure equalization cannula (A-3). This cap unit could be assembled and disassembled from apical extrusion collection vials (A-4). An FRT (A-5) was used in 2 test groups. Except for Rinsendo, all irrigant was delivered via a PSP (A-6). EndoVac’s (A) Macro and Micro (not shown) received irrigant at the access opening via the PSP, coronal excess was evacuated into the Hi-Vac (A-7), while the irrigant flowing through the Macro/Micro cannulae was trapped (A-8). (B) The Max-I-Probe and ultrasonic needles both received their irrigant from the PSP. (C) The EndoActivator received its irrigant at the access opening via the PSP, and coronal excess was trapped. (D) The Rinsendo delivered irrigant to its cannula via its internal pneumatic pump.

length. This goal seems to have been accomplished by using the EndoVac system in terms of safety (no apical extrusion) and volume (data from the FRT). Fear of a procedural error attributed to full-strength sodium hypochlorite extrusion might cause clinicians to use an inadequate flow of sodium hypochlorite at full working length (20), thus decreasing the efficacy of full-strength sodium hypochlorite at full working length. This observation is supported by a recent study testing positive and negative postoperative cultures (21) as well as studies examining intracanal debris and smear layer in the apical region (10, 17).

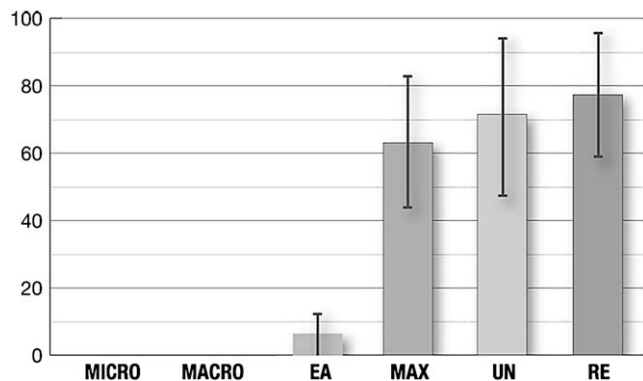


Figure 4. Percent apical irrigant extrusion by group. EA, EndoActivator.

Group Comparison		p Value
MICRO	MACRO	> 0.9999
MICRO	EA	0.9025
MICRO	MAX	< 0.0001*
MICRO	UN	< 0.0001*
MICRO	RE	< 0.0001*
MACRO	EA	0.8729
MACRO	MAX	< 0.0001*
MACRO	UN	< 0.0001*
MACRO	RE	< 0.0001*
EA	MAX	< 0.0001*
EA	UN	< 0.0001*
EA	RE	< 0.0001*
MAX	UN	0.6523
MAX	RE	0.0990
UN	RE	0.9014

Figure 5. Statistical group comparison with P value. EA, EndoActivator. *Statistical significance.

This study concluded that the EndoVac did not extrude irrigant after deep intracanal delivery and suctioning the irrigant from the chamber to full working length. EndoActivator had a minimal, although statistically insignificant, amount of irrigant extruded out of the apex when delivering irrigant into the pulp chamber, placing the tip into the canal, and initiating the sonic energy of the EndoActivator. Manual, Ultrasonic, and Rinsendo groups had significantly greater amounts of extrusion compared with EndoVac and EndoActivator groups.

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