

# Investigation of the Efficacy of Passive Ultrasonic Irrigation Versus Irrigation with Reciprocating Activation: An Environmental Scanning Electron Microscopic Study

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## Abstract

**Introduction:** The objective of this *ex vivo* study was to compare the efficacy of passive ultrasonic irrigation (PUI) versus a new activation system using reciprocating motion (EasyClean [EC]; Easy Equipamentos Odontológicos, Belo Horizonte, Brazil) to remove debris from the root canal walls at 6 predetermined apical levels using environmental scanning electron microscopy. **Methods:** Mesio Buccal root canals of 10 mandibular molars were prepared with a 30/.05 final instrument. The specimens were embedded in flasks containing heavy body silicone, cleaved longitudinally, and 6 round indentations were made into the apical region of the buccal half at 1-mm intervals. The same specimens were used to prepare a blank control group (no debris), a negative control group (completely covered by debris), and 2 experimental groups: PUI and irrigation with reciprocating activation. Standardized images of the indentations were obtained under environmental scanning electron microscopy and assessed by 2 examiners. The amount of debris was then classified using a 4-category scoring system. The kappa test was applied to determine interexaminer agreement, whereas the Kruskal-Wallis, Dunn, and Friedman tests were used to compare scores. **Results:** The EC group had results statistically similar to those of the blank control group for all 6 root levels examined. The PUI group had results statistically similar to those of the negative control group for the 3 most apical levels and similar to those of the blank control group for the 3 most cervical levels. **Conclusions:** Activating the irrigant with a reciprocating system (EC) promoted more effective debris removal from the more apical regions of the root canal when compared with PUI. (*J Endod* 2016;■:1–5)

## Key Words

Debris, endodontic irrigation, environmental scanning electron microscopy, reciprocating motion, ultrasonics

The presence of debris adhered to root canal walls after endodontic instrumentation, particularly in the apical third, can be detrimental to subsequent steps of the endodontic treatment, leading to microleakage through the filling materials (1, 2) and failure of the disinfection process (3). Debris removal increases dentinal permeability, improving the effectiveness of the disinfection process (4).

Irrigation with activation using ultrasonic tips is a widely cited technique in the current literature. This technique is based on the premise that energy released by the instrument enhances the properties of the irrigation solution (5, 6) by cavitation and acoustic streaming (7–9). However, the effective occurrence of these phenomena is highly dependent on the power intensity of the device, the free space within the canal, and the total absence of interference on the tip (10). Because of the anatomic characteristics of the root canal, ultrasonic activation is less effective in the apical region than in the cervical region (11–16).

The introduction of mechanical agitation of the irrigant using electric motor-driven instruments with reciprocating motion provided a new option for debris removal in the root canal system, particularly in the apical third. Adopting the same principles of optimizing the action of chemical agents using instruments unaffected by contact with canal walls, by the space in which they operate or by the dispersion of forces within the canal, an acrylonitrile butadiene styrene (ABS) plastic instrument called EasyClean [EC] was developed (Easy Equipamentos Odontológicos, Belo Horizonte, Brazil [US patent pending 61/849,608]). The instrument has a size of 25/.04 and an “aircraft wing”-shaped cross section and operates with a reciprocating motion (ie, a 180° clockwise turn followed by a 90° counterclockwise turn).

Therefore, the objective of this *ex vivo* study was to compare the efficacy of passive ultrasonic irrigation (PUI) versus irrigation with reciprocating activation (EC) in the removal of debris from root canal walls at 6 predetermined apical levels during final irrigation of the canals determined by environmental scanning electron microscopy. The null hypothesis was that there would be no significant differences between the irrigation techniques tested.

## Materials and Methods

The study protocol (no. 694.151) was approved by the Research Ethics Committee of the São Leopoldo Mandic Center for Dental Research, Campinas, São Paulo, Brazil.

Ten human mandibular molars with completely formed roots and distinct mesial canal ends and without any vertical fracture or root resorption (whether internal or external) were selected from the Tooth Bank of the São Leopoldo Mandic School of Dentistry, Campinas, São Paulo, Brazil. The selected teeth were stored in a 0.1% thymol solution until use in the experiment. Based on the 4 study groups involved, the

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## Basic Research—Technology

minimally required sample size was 8 (17). Therefore, the 10 specimens used in each group were deemed sufficient.

After coronal access, a #10 Flex-R file (Miltex Inc, York, PA) was introduced into the canal using an oscillating motion until its tip became visible at the apical foramen. Buccolingual and mesiodistal radiographs were taken to determine the extent of the canal's curvature according to Pruett et al (18). Canals with a curvature between 15° and 20° were selected.

After establishing canal curvature, the real length of the specimen was determined with the aid of an endodontic ruler and rubber stop. The crowns were abraded from the occlusal surface down using a diamond disk (Horico Dental Hopf, Ringleb & Co GmbH & Cie, Berlin, Germany) until the rubber stop met the occlusal edge at 19.0 mm, thus standardizing the length of each specimen. One millimeter was then subtracted from this measurement to obtain a working length of 18.0 mm for all of the specimens. The mesiobuccal canal of each tooth was instrumented using the ProDesign Logic rotary system (Easy Equipamentos Odontológicos). The #10 Flex-R file was inserted up to the apical foramen followed by a 25/.01 file to achieve patency. A 30/.05 file was then introduced using an “in-and-out” motion up to the working length (18.0 mm). At each instrument change during the procedure, a #10 Flex-R file was used to confirm patency, and the canals were irrigated with 3 mL distilled water using a syringe and a 30-G NaviTip needle (Ultradent Products Inc, South Jordan, UT) positioned at the working length. The distal root was removed after instrumentation.

After preparation, a fine-medium gutta-percha cone (Odos de Deus, Belo Horizonte, Brazil) adjusted to a 0.30 tip diameter using a gutta-percha gauge ruler (Dentsply Maillefer, Ballaigues, Switzerland) was inserted into the mesiobuccal canal up to the working length. Two longitudinal grooves running the whole length of the mesiobuccal canal were cut into the mesial and distal walls using a 0.08 diamond disc (Horico Dental Hopf, Ringleb & Co GmbH & Cie) under a dental operating microscope (DF Vasconcelos, São Paulo, Brazil) at 8× magnification. The resultant grooves reached a depth close to the root canal yet without communicating with the main canal. After grooving, the roots were washed in running water to remove debris.

Using a diamond disc under constant irrigation, the dentinal walls were abraded to make the roots thinner, thereby reducing specimen moisture and its consequent interference in the process of obtaining images on environmental scanning electron microscopy. Roots were then embedded in heavy body silicone (Optosil Comfort Putty; Heraeus Kulzer GmbH, Hanau, Germany) up to the level of the cemento-enamel junction. After the silicone set, a vertical force was applied using a #24 spatula (SSWhite Duflex, Rio de Janeiro, Brazil) to cleave the specimen into 2 halves. The buccal part of the mesiobuccal canal was then removed using hemostatic forceps. Using a #15 K-type file (KEndo CC Cord; VDW GmbH, Munich, Germany) with an oscillating motion, round indentations approximately 0.15 mm in diameter by 0.05 mm in depth were created by exerting manual pressure perpendicularly to the buccal wall of the canal at 1-mm intervals starting from the apex to give a total of 6 round indentations at predefined levels: L1, L2, L3, L4, L5, and L6 (Fig. 1). The specimens were washed under running water for 1 minute to remove detritus.

By using this flask system with elastic material, it was possible to reassemble the 2 halves of the cleaved specimens and prevent the extrusion of the irrigant, thus simulating a closed system of irrigation and aspiration. By doing so, it was further possible to reuse the same 10 specimens in the different experimental groups of the study as follows.

### Blank Control Group

The specimens were immersed in an ultrasonic bath containing 5.25% sodium hypochlorite (NaOCl) solution for 3 minutes and then



**Figure 1.** Round indentations created on the apical third at 1-mm intervals.

in 17% EDTA for 3 minutes. Specimens were then washed with distilled water for 1 minute and oven dried at 80°C for 3 minutes; the areas containing the indentations were analyzed under an environmental scanning electron microscope (Phenom-World BV, Eindhoven, Netherlands) at 1750× magnification. The entire surface of the indentations was completely free of debris. After obtaining the blank control images, the same specimens were prepared for the negative control group as follows.

### Negative Control Group

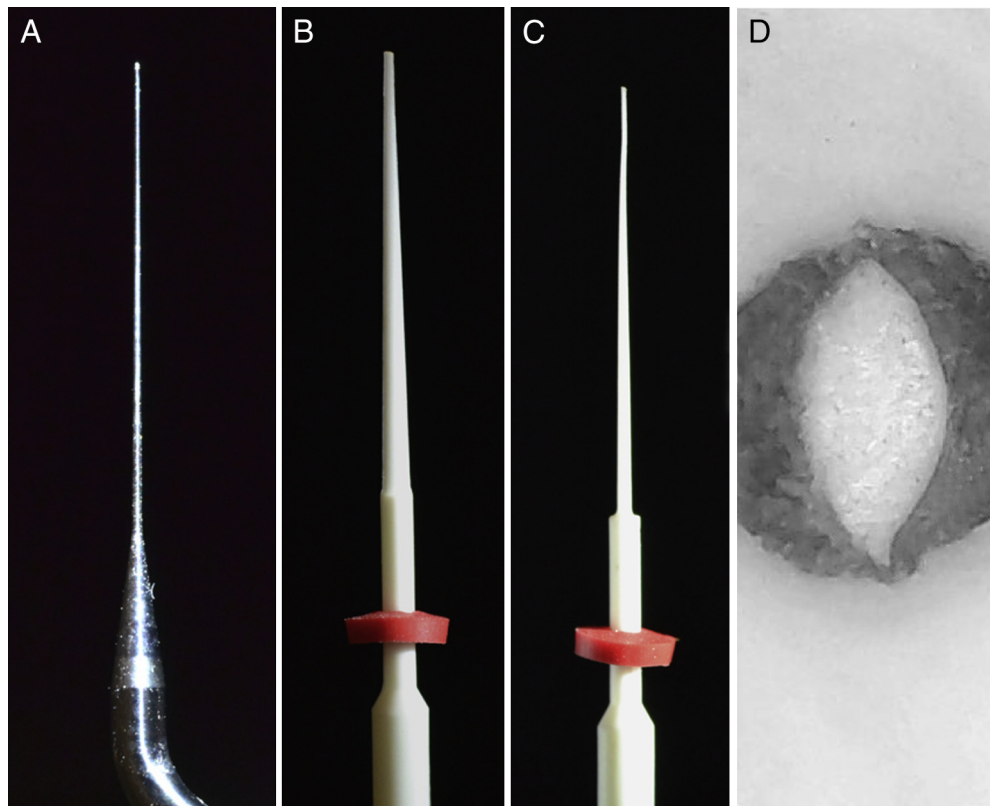
Using a low-speed round bur, the root of an additional tooth (not from the study groups) was abraded, and the removed dentin debris were collected and placed in a plastic container with 2.5% NaOCl solution. The dentin material collected was smeared over and into the grooves using a SingleTim brush (Voco, Cuxhaven, Germany). The specimens were dried, and environmental scanning electron microscopic images were obtained using the same procedure used in the previous step.

### Preparation of Experimental Groups

For the 2 experimental groups, the specimens were smeared with the dentin debris in the same manner as that used for the negative control group and placed back into their respective niches in the flask. The corresponding halves of the specimens were checked for a perfect fit by introducing a gutta-percha cone and taking a digital radiograph in both the buccolingual and mesiodistal directions.

### PUI Group

The irrigating needle was placed at the working length, and 2.5% NaOCl solution was dispensed until complete filling of the root canal was attained. PUI was then performed as previously described by van der Sluis et al (19). An Irrisonic E1 (20/.01) tip (Helse Indústria e Comércio, Santa Rosa de Viterbo, Brazil) (Fig. 2A) fitted to an ENAC ultrasonic handpiece (Osada Electric Co, Aichi, Japan) set to power 3 was placed 1.0 mm short of the working length and first activated with 5 mL 2.5% NaOCl followed by 5 mL 17% EDTA and lastly with 5 mL 2.5% NaOCl solution. All solutions were renewed and activated by 3 cycles



**Figure 2.** (A) Irrisonic tip; (B) EC tip, frontal view; (C) EC tip, lateral view; and (D) EC tip, cross-sectional view.

of 20 seconds. Finally, the canals were flushed using a 30-G needle and syringe containing 20 mL distilled water.

The specimens were then removed from their niches, processed, and analyzed adopting the same procedure used for the control groups. The second experimental group was prepared by resmearing the same specimens with dentinal debris.

### Reciprocating Activation Group Using EC

EC (Fig. 2B–D) was introduced up to the working length and operated with a reciprocating motion of a 180° clockwise followed by a 90° counterclockwise turn using an EasyEndo Motor (Easy Equipamentos Odontológicos). The sequence of the solutions and irrigation time were the same as those used for the PUI group and likewise for image processing and obtaining procedures.

### Assessment Criteria

The images were saved in a digital file, analyzed, and classified using a 4-category scoring system adapted from Gambarini and Laszkiewicz (20) as follows: score 1, open dentinal tubules, with no debris; score 2, open dentinal tubules, with debris covering less than 50% of the area; score 3, open dentinal tubules, with debris covering more than 50% of the area; and score 4, dentinal tubules covered by debris in 100% of the area examined.

### Data Analysis

Each image obtained was coded according to the group (negative control, blank control, PUI group, or EC group), the tooth (from 1 to 10), and the level at which the reading was taken (L1, L2, L3, L4, L5, or L6) (Fig. 3).

All of the images from the control and experimental groups for the same level were loaded into the Microsoft Office PowerPoint application (Microsoft Corporation, Redmond, WA) and displayed in slide format on an LCD monitor. Two independent examiners, previously calibrated and blind to the study, scored the images according to the assessment criteria outlined previously.

### Statistical Analysis

The level of interexaminer agreement was determined using the kappa test. The Kruskal-Wallis test was used to compare data on cleansing efficacy. Multiple comparisons were performed using the Dunn test when applicable. The Friedman test was applied to detect differences in cleansing promoted by each irrigation system at the different apical levels examined.

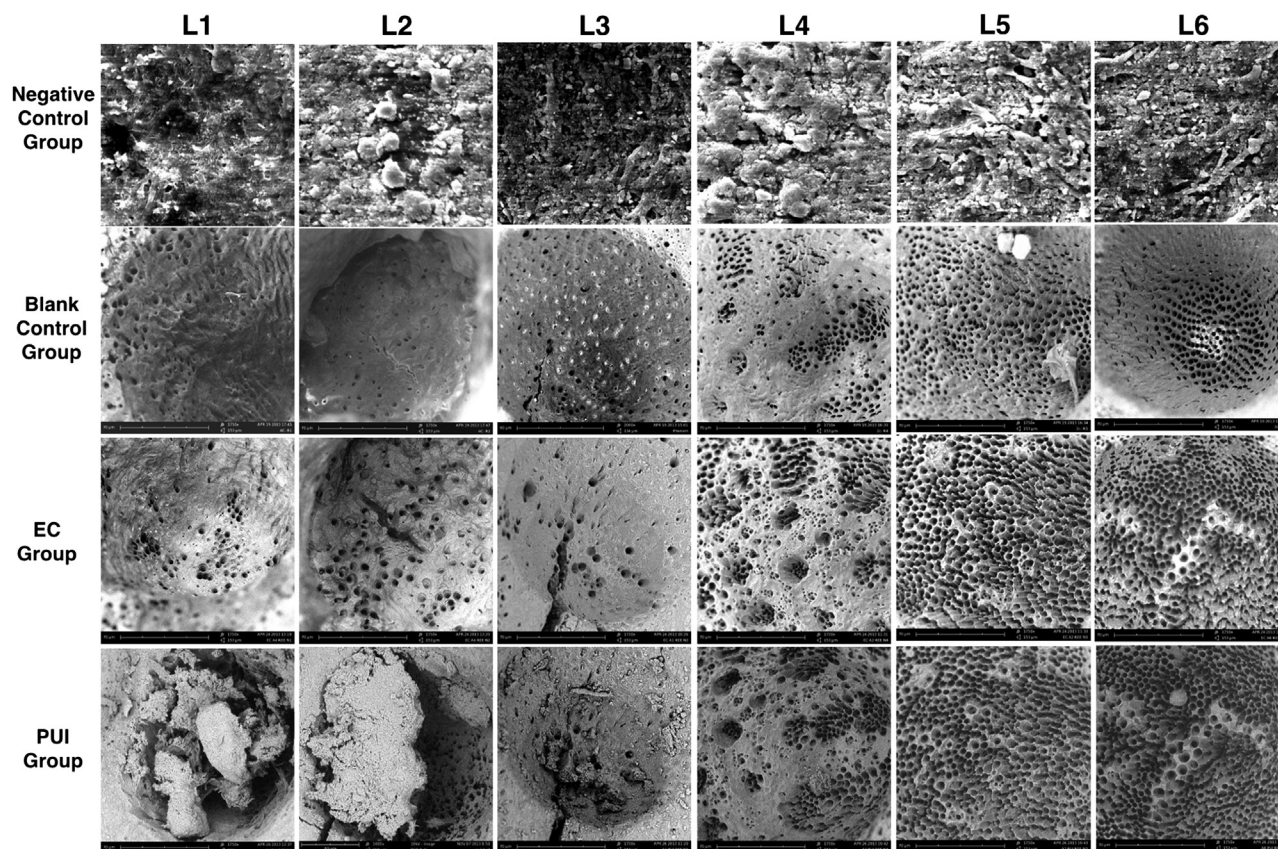
All statistical calculations were performed using the SPSS 20 (SPSS Inc, Chicago, IL) and BioEstat 5.0 (Fundação Mamirauá, Belém, PA, Brazil) software programs. The level of significance adopted was 5%.

### Results

The level of interexaminer agreement was excellent, attaining a kappa value of 0.88 (21). The median debris removal scores for the specimens from the study groups at the 6 apical levels examined and a statistical analysis comparing mean ranks and results of Kruskal-Wallis and Friedman tests are shown in Table 1.

A statistically significant difference was found between the irrigation techniques assessed in debris removal for the 3 most apical round indentations ( $P < .05$ ). No significant difference in debris removal was found between the reciprocating activation group and the blank control group for all apical levels analyzed ( $P < .05$ ). The PUI group had results statistically similar to those of the negative control group for the 3 most





**Figure 3.** Representative images of round indentations at 6 predefined levels of the apical third in specimens from the study groups. EC, final irrigation with reciprocating activation (EasyClean); blank control, immersion in ultrasonic bath; negative control, dentin debris smeared onto canal walls without removal.

apical levels and similar to those of the blank control group for the 3 most cervical levels.

## Discussion

Removal of the organic and inorganic components and disinfection of the root canal system are necessary for successful endodontic therapy. Studies have shown that the apical third of canals is the area with the largest amount of debris adhered to dentinal walls. This accumulation is attributed to the narrower diameter of the canal in this region, resulting in poorer penetration of irrigating agents and, therefore, less contact between canal walls and irrigants (22, 23).

Numerous studies using a variety of methodologies have been conducted to investigate the efficacy of different irrigation systems in cleansing the root canal system. In the present study, the procedures for preparing the specimens were adapted from the method used by Jiang et al (24). However, we used 4 round depressions and simply per-

formed a microscopic analysis of the specimens, adopting a dichotomous criterion (clean/not clean) for the observations.

The use of conventional scanning electron microscopy allows a highly detailed analysis of the specimens, but these must be discarded after analysis because of the processing involved. In contrast, environmental scanning electron microscopy operates at 5 kV and does not require the full metallization and dehydration of the specimens. Therefore, in addition to allowing direct observation at a high resolution, this microscopic technique allows visualization of the same specimen pre- and postexperiment. As a result, it eliminates the potential interference of anatomic variations, curvatures, and individual characteristics of the dentin present in the different specimens, allowing a more consistent assessment of results (25).

Furthermore, the predefined demarcation of the assessment site was identical in all the study groups, both experimental and control. Therefore, it was possible to fully standardize the reading process of the cleansing results of the irrigation techniques tested, rendering the

**TABLE 1.** Median Debris Removal Scores (in Parentheses) and Mean Ranks and Kruskal-Wallis and Friedman Test Results for Debris Removal in the 4 Study Groups at the 6 Apical Levels Analyzed

Group	Apical level						Friedman
	L1	L2	L3	L4	L5	L6	
Blank control	11.5 <sup>a</sup> (1.0)	10.5 <sup>a</sup> (1.0)	12.5 <sup>a</sup> (1.0)	13.0 <sup>a</sup> (1.0)	11.5 <sup>a</sup> (1.0)	13.0 <sup>a</sup> (1.0)	$P = .981$
Negative control	35.0 <sup>b</sup> (4.0)	34.0 <sup>b</sup> (4.0)	34.0 <sup>b</sup> (4.0)	35.0 <sup>b</sup> (4.0)	35.0 <sup>b</sup> (4.0)	35.0 <sup>b</sup> (4.0)	$P = .142$
PUI	22.7 <sup>b</sup> (2.0)	25.8 <sup>b</sup> (2.5)	23.0 <sup>b</sup> (2.0)	21.0 <sup>a</sup> (1.5)	21.2 <sup>a</sup> (2.0)	19.5 <sup>a</sup> (1.0)	$P > .999$
EC	12.8 <sup>a</sup> (1.0)	11.8 <sup>a</sup> (1.0)	12.5 <sup>a</sup> (1.0)	13.0 <sup>a</sup> (1.0)	14.3 <sup>a</sup> (1.0)	14.5 <sup>a</sup> (1.0)	$P > .999$
Kruskal-Wallis (a b)	$P < .001$	$P < .001$	$P < .001$	$P < .001$	$P < .001$	$P < .001$	—

EC, irrigation with reciprocating activation (EasyClean); PUI, passive ultrasonic irrigation.

Different superscript letters indicate a statistically significant difference (within the column).

assessment task less subjective. Thus, the method used in the present study allowed for images that were identical in regard to anatomy, site of analysis, and magnification, ensuring more rigorous comparison of the different groups (26, 27).

The present results were congruent with findings previously reported in the literature, revealing that PUI promotes more effective cleaning of intermediate portions of the canal than of the last few millimeters (28, 29).

According to Ahmad et al (30), in order for ultrasonic irrigation to be effective and for acoustic streaming to take place, it must operate within a space 3 times greater than the diameter of the tip used. Given that the present study used an ultrasonic tip size of 20, a minimum apical preparation corresponding to a size 60 tip would be required to allow ideal movement of the instrument tip. However, because of the anatomic features of the roots used, apical preparation was performed using a rotary instrument with a size 30 tip. This ultimately led to greater contact of the ultrasonic tip with canal walls, potentially having a negative impact on the conduction of ultrasonic energy. In contrast, the broader width of canals at more cervical levels because of both the anatomy and type of preparation allowed more effective cleansing because the ultrasonic tip was less confined.

The EC system is composed of a 25/.04 ABS plastic instrument designed to mechanically activate the irrigant and combines reciprocating motion with an "aircraft wing" design. The system cleans by agitation of the irrigation solution and also by mechanical drag of adhered debris. Because a mechanical movement is involved, the agitation action occurs along the whole length of the instrument unimpeded by contact of the instrument with canal walls. Moreover, because the instrument is made of ABS plastic, the risk of it deforming the canal walls is negligible, allowing introduction right up to the working length. These combined benefits likely contributed to obtaining cleansing levels similar to those observed in the blank control group.

The methodology used in this study was devised to reproduce a challenging clinical setting as closely as possible. Thus, mesial canals of mandibular molars with moderate curvatures were used because, in this case, having the irrigating solution reach the apical third is not an easy task.

The results of this study have shown that the final irrigation techniques differed in the level of cleansing promoted in root canal walls. Consequently, the null hypothesis was rejected. Although this was a preliminary *ex vivo* study on the EC system, the results suggest that this novel final irrigation system with reciprocating activation promotes effective cleaning of the apical third. Future studies are warranted to confirm the effectiveness of the system in terms of the degree of cleansing and overall disinfection of the root canal system, including isthmus areas; to investigate possible adverse outcomes, such as the extrusion of debris or the formation of vapor lock; and to assess the possible correlation of these variables *in vivo* with measures of clinical success.

## Conclusions

Based on the results of the present study, it can be concluded that the irrigation system with reciprocating activation (EC) produced cleaner walls compared with the passive ultrasonic method (PUI) regarding the efficacy of final irrigation of the apical third of the root canal.

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