Comparative Effectiveness of New Mechanical Irrigant Agitating Devices for Debris Removal from the Canal and Isthmus of Mesial Roots of Mandibular Molars

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Abstract

Introduction: The aim of this study was to compare the effectiveness of Easy Clean (Easy Dental Equipment, Belo Horizonte, MG, Brazil) in continuous and reciprocating motion, passive ultrasonic irrigation (PUI), Endoactivator systems (Dentsply Maillefer, Ballaigues, Switzerland), and conventional irrigation for debris removal from root canals and isthmus. **Methods:** Fifty mesial roots of mandibular molars were embedded in epoxy resin using a metal muffle; afterward, the blocks containing the roots were sectioned at 2, 4, and 6 mm from the apex. After instrumentation, the roots were divided into 5 groups ($n = 10$) for application of the final irrigation protocol using Easy Clean in continuous rotation, Easy Clean in reciprocating motion, PUI, Endoactivator, and conventional irrigation. Scanning electron microscopic images were taken after instrumentation and after the first, second, and third activation of irrigating solution to evaluate the area of remaining debris with image J software (National Institutes of Health, Bethesda, MD). **Results:** The protocol of 3 irrigating solution activations for 20 seconds provided better cleaning of the canal and isthmus. On conclusion of all procedures, analysis of the canals showed a statistical difference only at 2 mm; the Easy Clean in continuous rotation was more efficient than conventional irrigation ($P < .05$). On conclusion of all steps, the largest difference was observed in the isthmus in which the Easy Clean in continuous rotation was more effective than conventional irrigation at the 3 levels analyzed and the Endoactivator at 4 mm ($P < .05$). The PUI promoted greater cleaning than conventional irrigation at 6 mm ($P < .05$). There was no statistical difference between Easy Clean in continuous rotation, Easy Clean in reciprocating motion, and PUI ($P > .05$). **Conclusions:** Irrigating solution activation methods provided better cleaning of the canal and isthmus, especially the Easy Clean used in continuous rotation. The protocol of 3 irrigating solution activations for 20 seconds favored better cleaning. *(J Endod 2016;■:1–6)*

Key Words

Dentin debris, endodontics, scanning electron microscopy, ultrasonics

Significance

Although Easy Clean in continuous rotation showed no statistically significant difference at the end of every procedure in comparison with the other groups that promoted agitation of irrigating solution, Easy Clean showed higher debris removal percentages, especially in the isthmus region in the apical portion.

In addition to shaping the root canal, the aim of chemical-mechanical preparation is to eliminate vital or necrotic tissue, microorganisms and their products, and dentin debris resulting from instrumentation (1). However, in the majority of cases, complete elimination is difficult to achieve in the anatomically complex areas of the root canal system that are frequently inaccessible to the action of instruments (2, 3).

Among the anatomically complex areas, we highlight the isthmuses, defined as narrow extensions between 2 canals capable of harboring microorganisms and dentin debris resulting from instrumentation. These areas are difficult to access, making it challenging to clean them, and when this is not achieved, it may lead to endodontic treatment failure (4, 5). Therefore, irrigation plays a determinant role in cleaning both the main canal and isthmus. For this, 2 factors are important: penetration of the irrigant into all extensions of the root canal and the ability to penetrate into areas that are inaccessible to endodontic instruments (6, 7).

The method most used for irrigation is the conventional type with the use of an irrigating cannula with the front extremity or side coupled to a syringe. However, this method is extremely limited for cleaning the apical portion and areas such as isthmuses (5, 8). Therefore, new resources have emerged, and 1 of these devices is the sonic Endoactivator (Dentsply Maillefer, Ballaigues, Switzerland); this device has

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flexible polymer tips with 3 different diameters (15/02, 25/04, and 35/04), with the aim of promoting sonic agitation of the irrigant within the root canal in order to make cleaning more effective (9, 10).

Another resource is passive ultrasonic irrigation (PUI) for agitation of irrigating solutions, which uses an insert coupled to the ultrasound and induces the formation of cavitation and acoustic waves, improving the irrigant properties and cleaning ability in anatomically complex areas (11, 12).

Recently, a new plastic instrument (acrylonitrile butadiene styrene) called Easy Clean (Easy Dental Equipment, Belo Horizonte, MG, Brazil) was developed; it is similar to a rotary endodontic instrument, and its active part is in the shape of an "aircraft wing." The size of this device is 25/04, and it is recommended for use in reciprocating motion; it has shown good results in cleaning the mesial canal walls of mandibular molars with root curvature (13). However, in this particular study, the instrument was operated in reciprocating motion and analyzed only for cleaning the dentin wall of the main canal and not the interior of isthmuses.

A pilot study was conducted comparing 2 kinematics using the Easy Clean system (continuous rotation and reciprocating motion) for debris removal from the inner grooves of artificial acrylic teeth; it showed greater effectiveness when it was used in a rotary movement at low speed. In view of the foregoing and taking into account the importance of cleaning the areas of the isthmus, the aim of this study was to evaluate the capacity for dentin debris removal from the canal and the isthmus of the mesial root of mandibular molars provided by conventional irrigation, Endoactivator, PUI, Easy Clean in continuous rotation, and Easy Clean in reciprocating motion. The null hypothesis was that there would be no difference between these systems in the ability to clean the canal and isthmus, and the number of activations would not increase the cleaning capacity.

Methods

Sample Size Estimation

The sample size was calculated by using the G*Power v3.1 for Mac (Heinrich Heine, Universität Düsseldorf) program and selecting the Wilcoxon-Mann-Whitney test of the *t* test family. From data obtained in a pilot study with 20 teeth, the mean and standard deviation were used, and the effect size was established (ie, 1.25). The alpha type error of 0.05, a beta power of 0.80, and an N2/N1 ratio of 1 were also stipulated. A total of 10 samples per group were indicated as the ideal size required for noting significant differences.

Selection and Preparation of Teeth

Fifty mesial roots of mandibular molars that had a curvature not exceeding 5° and a completely formed apex were selected. The roots were examined by computed microtomographic imaging (SkyScan 1174; SkyScan, Aartselaar, Belgium) with a 19-mm voxel size, 50 kV, 800 mA, 0.8 rotation step size, and 1024 × 1304 resolution to verify the presence of the isthmus in apical millimeters 2, 4, and 6 so that only isthmuses classified as type II according to Hsu and Kim (14) were used. After coronal access, the working length was established by inserting a #10 K-file (Dentsply Maillefer) until its tip was observed in the foramen through a stereomicroscope (Stemi 2000C; Carl Zeiss, Jena, Germany) and decreasing 1 mm. After this, the root apex was sealed with utility wax.

Initially, a 2-piece metal muffle was made of aluminum according to the Bramante et al (15) methodology, allowing it to be disassembled. Transparent epoxy resin (Redelease, São Paulo, SP, Brazil) was put into this muffle, and then the tooth was inserted into it up to the cementoenamel junction. After resin polymerization, the muffle was opened, and the block with the tooth in it was removed. Markings were made corresponding to 2, 4, and 6 mm from the apex, and then cross-sectional cuts were made through these areas by using a 0.3-mm-thick diamond disc coupled to an Isomet cutter (Buehler, Lake Bluff, IL). The sections obtained were put into an ultrasonic bath with distilled water for 7 minutes to remove the debris originating from the cut. The sections were reassembled in the muffle, and the canals were instrumented with the Reciproc R25 system (VDW GmbH, Munich, Germany) in reciprocating motion complemented with the Mtwo 35/04 system (VDW GmbH) in continuous rotation, both driven by an electric motor (VDW GmbH). During instrumentation, the canals were irrigated with 5 mL sodium hypochlorite 2.5% (Super Globo, Rio de Janeiro, RJ, Brazil) using a 30-G Navitip needle (Ultradent, South Jordan, UT) inserted at the working length of 3 mm. After chemical-mechanical preparation, the sections were removed, and images were taken by scanning electron microscopy in the low vacuum mode (Aspex Express; Fei Europe, Eindhoven, Netherlands). After obtaining the images, the sections were mounted in the muffle, and teeth were randomly divided into 5 groups of 10 teeth each according to the irrigation agitation system:

1. The Endoactivator group: 2 mL sodium hypochlorite 2.5% was applied in the canals by using a syringe with a 30-G Navitip needle, and then the solution was activated in each canal for 20 seconds using the 25/04 tip of the Endoactivator system at 2 mm from the working length. This procedure was repeated 2 more times with a total of 6 mL sodium hypochlorite and 1 minute of sonic activation. Subsequently, the canals were irrigated with 2 mL saline solution.
2. The ultrasound (PUI) group: the procedure was similar to that used in the Endoactivator group, but the agitation was performed at 2 mm from the working length with the ultrasound insert Irrisonic 20/01 (Helse Dental Technology, Santa Rosa de Viterbo, SP, Brazil) coupled to an ultrasound unit (Gnatus Medical and Dental Equipment Ltda, Ribeirão Preto, SP, Brazil) in the Endo function and power setting of 2 according to the manufacturer's recommendations.
3. The Easy Clean in continuous rotation group: the procedure was similar to those used in the previous 2 groups, but the activation was performed at 2 mm from the working length using the Easy Clean instrument size 25/04 coupled to the counter-angle and operated with a micromotor at approximately 20,000 rotations per minute (KaVo Kerr Group, Charlotte, NC).
4. The Easy Clean in reciprocating motion group: the procedure was similar to Easy Clean in the continuous rotation group; however, an electric motor (VDW Silver, VDW GmbH) in reciprocating movement (Reciproc function) was used to agitate the irrigant solution.
5. The conventional irrigation group: 2 mL sodium hypochlorite 2.5% was applied in each canal with a 30-G Navitip needle at 20-second intervals at 2 mm from the working length without agitating the irrigant solution. Then, the same procedure was performed—irrigation 2 times and at the end the canals were irrigated with 2 mL saline solution.

In all studied groups, the sections were dismantled after each agitation; images were taken by scanning electron microscopy in the low vacuum mode at the end of the entire procedure, making analysis in a total of 4 different time intervals: after instrumentation and after the first, second, and third steps of agitation.

Analysis of the Images

The images were analyzed with Image J software (National Institutes of Health, Bethesda, MD), calculating the total area of debris in the canal and the isthmus after instrumentation and the value of the area with dentin debris present in the canal and the isthmus after each of the steps of agitation. Afterward, the percentage of debris remaining in the canal and the isthmus after each agitation in each group was calculated, taking into consideration the amount of debris present after instrumentation. To evaluate the area of debris of the canal and the isthmus, outlines of the mesiobuccal and mesiolingual canals and the isthmus were traced to determine the area of debris of the respective regions.

The Shapiro-Wilk test was used to verify the normality of the data, and absence of normality between values was found. The results of the percentage of dentin debris in both the canal and the isthmus were compared using the Kruskal-Wallis and Dunn tests for analysis between groups and the Friedman and Dunn tests for intragroup analysis. The level of significance was set at 5%.

Results

Table 1 shows in percentages the values of the median, minimum, and maximum of debris remaining in the isthmus after the first, second, and third steps of irrigating solution agitation with the different systems used in the study. None of the systems were shown to be capable of completely eliminating the debris in this region in all specimens. However, there was a decrease in the amount of debris as the number of agitation steps increased, irrespective of the level analyzed. At the end of the 3 agitations, Easy Clean in continuous rotation was shown to be more efficient than conventional irrigation at 2, 4, and 6 mm; it was also better than the Endoactivator at 4 mm ($P < .05$). Ultrasound was more efficient than conventional irrigation at 6 mm ($P < .05$) and did not differ statistically from the Endoactivator and Easy Clean in continuous rotation and reciprocating motion ($P > .05$).

Table 2 shows the values of the median, minimum, and maximum percentage of debris remaining in the root canal after the first, second, and third agitation steps with different systems. Unlike the situation observed in the isthmus region, at 6 mm the ultrasound group and Easy Clean were able to completely eliminate the debris after 3 agitation steps in some specimens. As occurred in the isthmus region, there was a gradual reduction in debris as the agitation steps were performed, irrespective of the millimeter analyzed. At the end of 3 agitation steps, a statistical difference was observed only at 2 mm where the Easy Clean system in continuous rotation was more efficient than conventional irrigation ($P < .05$). Easy Clean in continuous rotation, Easy Clean in reciprocating motion, the Endoactivator, and PUI presented no statistical differences at the end of every procedure ($P > .05$). Figure 1 shows representative images after instrumentation and after the first, second, and third agitation steps of the different systems used.

Discussion

This study evaluated cleaning of the canal and the isthmus provided by different irrigant agitation systems (Easy Clean in continuous rotation and reciprocating motion, ultrasound, Endoactivator, and conventional irrigation). Based off of the results, the hypothesis tested was rejected because there was a difference between the methods of agitation with regard to cleaning of both the canal and the isthmus, there were different levels of analysis, and the higher number of agitation steps increased cleaning of both the canal area and the isthmus.

The methodology of the muffle used in this study was first described by Bramante et al (15) and has been used in other studies that analyzed both the canal preparation and cleaning. It is a methodology that enables analysis of the same area at different stages of instrumentation and cleaning (16–18). Previous scanning of the teeth by

TABLE 1. The Median, Minimum, and Maximum Values of the Percentage of Remaining Debris Produced by Instrumentation on the Isthmus after the First, Second, and Third Activation with Different Agitation Systems

Groups/Level	2 mm			4 mm			6 mm		
	After first activation	After second activation	After third activation	After first activation	After second activation	After third activation	After first activation	After second activation	After third activation
Endoactivator	53.04^abA (9.44–99.59)	41.12^aAB (2.80–98.39)	22.78^abB (0.45–65.93)	80.38^abA (1.34–99.80)	49.14^abA (0.42–89.92)	18.48^aB (0.25–61.64)	79.52^aA (13.83–99.61)	29.57^abAB (1.48–90.28)	16.50^abB (0–37.59)
Ultrasound	83.56^aA (8.19–99.73)	40.12^aA (0.97–99.29)	14.99^abB (0.17–25.59)	42.71^abA (7.16–99.24)	18.75^abB (0.72–84.65)	4.98^abB (0.19–33.55)	42.36^aA (1.48–94.07)	16.50^abAB (0.19–74.93)	3.03^bB (0.15–31.44)
Easy Clean continuous	15.78^bA (1.98–99.28)	7.42^aA (3.50–48.83)	2.36^bB (1.08–14.57)	23.99^bA (5.85–86.55)	6.75^bAB (1.22–20.64)	2.19^bB (0.07–8.24)	42.70^aA (4.39–141)	9.03^bAB (0–64.61)	3.36^bB (0–22.83)
Conventional	70.14^aA (26.78–344)	36.08^aB (10.07–110)	24.99^aB (10.25–89.62)	93.30^aA (36.13–213)	61.65^aAB (26.76–136)	18.08^aB (9.83–51.92)	95.80^aA (30.27–99.93)	61.23^aAB (13.28–98.21)	20.40^aB (9.18–49.56)
Easy Clean reciprocating	45.51^abA (1.51–96.59)	28.60^aAB (1.44–58.99)	17.69^abB (1.34–40.19)	23.73^abA (5.18–100)	3.80^bAB (0.21–46.78)	2.39^abB (0–24.51)	50.03^aA (11.26–100)	20.49^abAB (2.77–49.33)	15.51^abB (0–41.76)

Different lowercase letters indicate statistical difference between the groups. Different capital letters indicate intragroup statistical difference.

TABLE 2. The Median, Minimum, and Maximum Values of the Percentage of Remaining Debris Produced by Instrumentation in the Canal after the First, Second, and Third Activation with Different Agitation Systems

Groups/Level	2 mm			4 mm			6 mm		
	After first activation	After second activation	After third activation	After first activation	After second activation	After third activation	After first activation	After second activation	After third activation
Endoactivator	35.17^{aA} (2.74–96.50)	18.62^{abA} (0.92–129)	3.39^{abB} (0–33.33)	19.53^{abA} (1.10–93.03)	3.20^{aAB} (0.37–37.88)	0.98^{aB} (0–16.13)	84.28^{aA} (10.88–376)	28.23^{aA} (0.76–81.48)	1.40^{aB} (0–16.70)
Ultrasound	33.68^{aA} (6.65–90.15)	13.29^{abAB} (5.54–44.42)	3.47^{abB} (0–27.04)	15.55^{abA} (1.64–150)	2.24^{aB} (0–67.30)	0.38^{aB} (0–21.25)	4.76^{bA} (0–132)	1.50^{aB} (0–41.75)	0^{aB} (0–26.26)
Easy Clean continuous	7.23^{aA} (1.11–41.37)	3.79^{bAB} (0.16–19.99)	0.26^{bB} (0–2.35)	11.49^{abA} (3.41–93.21)	2.03^{aAB} (0–61.26)	0.09^{aB} (0–5.78)	4.96^{bA} (1.46–156)	0.99^{aB} (0–54.48)	0^{aB} (0–7.27)
Conventional	40.17^{aA} (1.27–533)	20.06^{aA} (0.46–59.86)	8.71^{aB} (0–43.41)	68.09^{aA} (10.78–131)	22.21^{aAB} (2.80–66.30)	7.03^{aB} (0–25.32)	46.49^{abA} (7.09–334)	11.13^{aAB} (0–49.30)	3.11^{aB} (0–13.45)
Easy Clean reciprocating	21.64^{aA} (0.97–98.26)	13.95^{abAB} (0.74–97.28)	7.28^{abB} (0–26.77)	5.55^{bA} (0.94–208)	1.76^{aB} (0–31.09)	0.34^{aB} (0–12.02)	7.72^{bA} (0.81–95.38)	3.83^{aAB} (0.78–30.31)	0.79^{aB} (0–1.56)

Different lowercase letters indicate statistical difference between the groups. Different capital letters indicate intragroup statistical difference.

computed microtomographic imaging allowed the groups to be paired for the type of isthmus (II) and its location (2, 4, and 6 mm). Other studies have used volumetric analysis using computed microtomographic imaging (19, 20); however, because the radiopacity of human tooth dentin is the same as that of dentin debris, not all devices are able to perform this analysis.

Some studies have shown that conventional irrigation techniques have limited ability to remove dentin debris, especially in anatomically complex areas, corroborating the results of this study (21–23). This makes it necessary to use an auxiliary method in the cleaning process, with the aim of potentiating the removal of organic and inorganic substances from the canal and anatomically complex regions, such as the isthmus.

The canal cleaning results obtained in this study on the conclusion of every procedure showed that the debris removal capacity was similar for all systems, except in the 2-mm portion (apex) where the Easy Clean in continuous rotation was more efficient than conventional irrigation ($P < .05$). Easy Clean in reciprocating motion showed no statistically significant difference with the other studied groups as opposed to the situation recently observed by Kato et al (13) in which the Easy Clean was more efficient than PUI. This may have occurred because of the type of analysis performed. Although Kato et al analyzed the cleaning of irregularities in curved root canal walls, in this study only the cleaning in the main root canal was analyzed without curvature. It is important to observe that the percentage of dentin debris remaining in the canal after 3 agitation steps was significantly lower than it was in the isthmus, corroborating the results obtained by Adcock et al (21).

Regarding the results found in the isthmus region at the end of every procedure, the Easy Clean system in continuous rotation showed superior efficiency in removing debris in comparison with conventional irrigation at the 3 levels analyzed ($P < .05$). Despite the Easy Clean in continuous rotation having presented lower percentages of remaining debris than the Endoactivator, PUI, and Easy Clean in reciprocating motion, there was no statistical difference between them except at 4 mm where the Easy Clean in continuous rotation was better than the Endoactivator ($P < .05$). In the literature, no study was found evaluating the cleaning effectiveness of Easy Clean in the isthmus to enable comparison with the results of this study. However, the literature has shown the importance of cleaning the previously mentioned areas, and, if this is not achieved, it may lead to the failure of endodontic treatment (4).

The use of the Easy Clean system operated in continuous rotational motion was supported by a pilot study that showed greater effectiveness than when the Easy Clean system was operated in reciprocating movement. Despite no statistically significant results being shown between the kinematics used with Easy Clean, a lower percentage of remaining debris was observed when Easy Clean was used in continuous rotation. This probably happened because of the difference in rotational speed that produced turbulence of the irrigating solution, favoring debris removal from the isthmus. Furthermore, as the results showed, the agitation occurs throughout the instrument, thereby promoting similar cleaning all along the canal (13).

In the literature, there is no consensus about PUI promoting better cleaning of the root canal system than conventional irrigation. Although there are studies showing that PUI improved canal cleaning (23–25), other studies have shown no difference between these 2 methods of irrigation (26–28). These different results are probably caused by the different methods used as well as some important factors that must be considered (eg, the direction of oscillation of the ultrasonic insert; 29). In the present study, despite showing no significant difference at 2 and 4 mm, a lower percentage of debris remaining in the

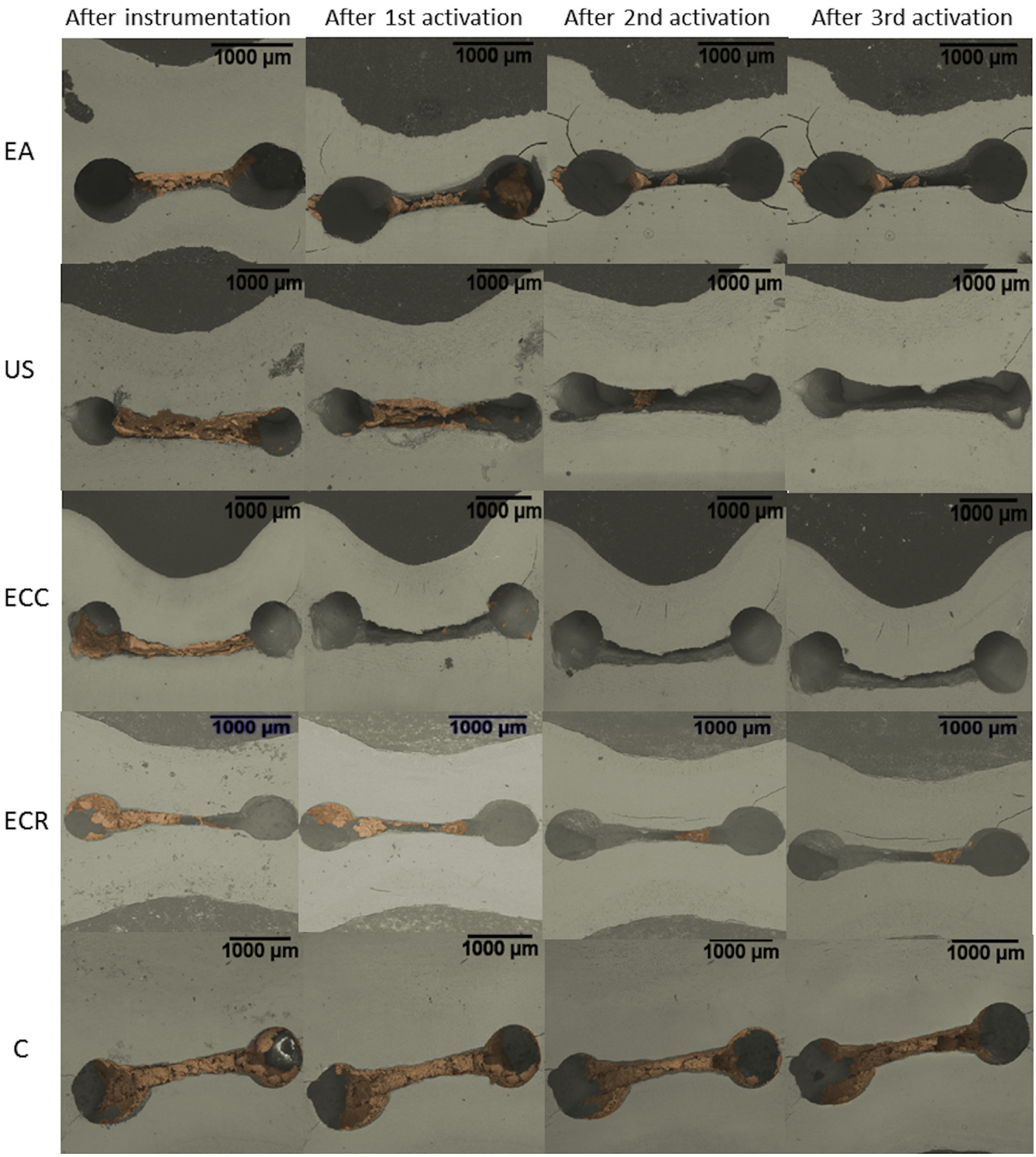

Figure 1. Representative images of the canal and isthmus region at 2 mm after instrumentation and after the first, second, and third agitations of the different systems used: Endoactivator (EA), ultrasound (US), Easy Clean in continuous rotation (ECC), Easy Clean in reciprocating motion (ECR), and conventional irrigation (C).

isthmus was observed at the end of the 3 agitation steps with PUI when compared with conventional irrigation.

With regard to the number of activations, when 3 agitation steps were used, better cleaning was found for all the systems analyzed. These results corroborate the findings of van der Sluis et al (11), who found the need for 3 agitation steps lasting 20 seconds, with renewal of the irrigant solution to achieve a better cleaning of both the canal and the isthmus, indicating the presence of a cumulative effect.

Conclusions

Based on the results obtained and within the limitations of the methodology used, the authors of this study concluded that the methods with agitation of the irrigating solution promoted better cleaning of the canal and the isthmus, especially with the Easy Clean system used in continuous rotation and at low speed. It is necessary to perform 3 irrigant agitation steps of 20 seconds each to ensure better cleaning of the canal and isthmus.

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The authors deny any conflicts of interest related to this study.

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