Effectiveness of a new endodontic irrigation system for removing smear layer and dissolving simulated organic matter

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Abstract

OBJECTIVES: The study aimed to evaluate the potential for dissolution of organic tissue in areas of simulated complexity and cleaning of root walls of the new iVac® endodontic irrigation system.

MATERIAL AND METHODS: Thirty mandibular premolars were evaluated by scanning electron microscopy before and after biomechanical preparation. Then, they were distributed according to the final irrigation protocol into groups with conventional irrigation, passive ultrasonic irrigation with metallic insert (PUI), and iVac® system, and new photomicrographs were obtained. For tissue dissolution analysis, glass capillaries filled with catgut were attached to the cervical and apical thirds of twenty prototyped upper incisors. They were weighed before and after the previously mentioned irrigation protocols. The data were statistically compared with a significance level of 5%.

RESULTS: The final irrigation provided greater cleaning of the walls in the cervical, middle, and apical thirds of the root canals ($P<0.05$), with no statistically significant difference between PUI and iVac®, regardless of the analyzed thirds. Both ultrasonic irrigation protocols dissolved a significantly greater volume than the conventional irrigation protocol ($P<0.05$), with no difference between the two protocols ($P<0.05$).

CONCLUSIONS: The iVac® system showed wall cleaning and tissue dissolution similar to PUI with a metallic insert, and both were superior to conventional irrigation.

CLINICAL RELEVANCE: The new irrigation system iVac is more effective than conventional irrigation and has similar wall cleaning and tissue dissolution to PUI.

Introduction

The biomechanical preparation of the root canal system involves using manual or mechanized endodontic instruments, associated with auxiliary chemicals [1]. Due to the bactericidal and dissolving properties of organic matter, sodium hypochlorite is the most used solution in endodontic therapy [2, 3]. Because of creating a layer of smear layer intrinsic to the instrumentation process, composed of organic and inorganic material [4], it is recommended to use irrigation protocols with chelating substances after biomechanical preparation.

Anatomical complexities are found in the different dental elements [5-8], so there is a need to use irrigation protocols that allow the diffusion of irrigating solutions since a large percentage of areas remain unprepared after instrumentation [9, 10]. In addition, the apical third of the root canals also presents greater difficulty in removing the smear layer and dentinal debris [11, 12].

Previous studies have shown that conventional irrigation, without using agitation methods, has low diffusion potential through the root canal system [13, 14], leading to endodontic therapy failure. Therefore, passive ultrasonic irrigation (PUI) is proposed as a stirring method of the irrigator solution due to acoustic transmission and transient cavitation [15]. In addition, PUI has a higher potential for dissolving organic matter and removing smear layer compared to conventional needle and syringe irrigation [13, 16, 17].

Recently, the iVac® irrigation system (Pac-Dent, Brea, CA, USA) was introduced to the market, which consists of a tip manufactured of high-performance medical grade polymer presented in two diameters, .35 mm, and .50 mm, which is coupled to a piezoelectric ultrasonic handpiece and perform agitation and aspiration with apical negative pressure at the working length level. However, no studies have evaluated the potential for cleaning and dissolving organic matter of irrigation protocols using this system. Therefore, this study aims to compare the cleaning of root walls and the dissolution capacity of organic matter in areas of simulated complexity after the PUI protocols (metal insert), iVac system, and conventional irrigation. The null hypothesis tested was that all irrigation protocols have a similar capacity to remove the smear layer and dissolve the organic matter.

Material And Methods

Evaluation of wall cleaning

All procedures performed in the present study were approved by the Ethics Committee on Research in Human Beings of the Faculty of Dentistry of Bauru (CAAE 62875122.6.0000.5417). The sample calculation was performed using the G * Power v program. 3.1 for Mac by selecting Anova Test. Data from a previous study [18] of intradental penetration of pastes. The size effect used in the present study was established (=1.66). The alpha type error of 0.05, a beta power of 0.80, and a radius of 1. A total of 9 specimens were needed per group. Due to the risk of losing specimens, a 10% higher number of specimens per group will be added, where 10 teeth per group will be used.

Thirty lower premolars with straight roots, fully formed apex, no cracks, fractures, and previous endodontic treatment were selected for the study. After performing the conventional coronary opening, root canal exploration was performed with the aid of a k#10 stainless steel endodontic instrument until foraminal output. The teeth were molded with condensation silicon in a metallic muffle to allow the repositioning of the parts during the experiment. Then, vertical channels were made on the vestibular and lingual surfaces, and the teeth were cleft. The mesial and distal halves were evaluated in the Scanning Electron Microscope (Aspex Express Fei Europe, Eindhoven, Netherlands), and photomicrographs of the cervical, middle, and apical thirds were obtained with an increase of 500 times.

Then, the halves were repositioned. The root canals were prepared up to diameter #50, taper .05, with Sequence Rotatory File CM Blue system (MK Life, Porto Alegre, Brazil) in reciprocating motion, using 5 ml of sodium hypochlorite 2.5% between each instrument. New photomicrographs were obtained after root canal preparation.

The teeth were randomly divided into three groups according to the final irrigation protocols used:

Group 1 (C) – Conventional irrigation with syringe and cannula: sodium hypochlorite 2.5% for 1 minute + EDTA 17% for 1 minute + final rinsing with distilled water without agitation. The Navitip 29G needle (Ultradent Co., Salt Lake, USA) with front opening was inserted at 3 mm of the working length.

Group 2 (PUI) – Passive Ultrasonic Agitation (metallic insert): sodium hypochlorite 2.5% for 1 minute + EDTA 17% for 1 minute + final rinsing with distilled water, with passive ultrasonic agitation with Irrisonic insert (Helse Ultrasonic, Santa Rosa do Viterbo, Brazil), coupled in NSK Varios 350 ultrasound (NSK, Tochigi, Japan) in power 1. The ultrasonic insert was inserted 1 mm of the working length.

Group 3 (iVac) – Ultrasonic agitation with iVac system: sodium hypochlorite 2.5% for 1 minute + EDTA 17% for 1 minute + final rinsing with distilled water, with agitation using the iVac system, coupled in NSK Varios 350 ultrasonic unit (NSK, Tochigi, Japan) in power 5. The IVAC point was inserted 1 mm of the working length.

After the final irrigation protocols, new photomicrographs were obtained from the root canals' surfaces, following the previously described parameters. All images were saved to digital files (TIFF format) and uploaded to Microsoft PowerPoint software (Microsoft Corporation, Redmond, USA). The images were divided into 100 squares using a digital grid to quantify wall cleaning. Each square represented an area of 27.5 X 27.5 μm2 (Fig 1). The number of squares with visible dentinal tubules, without a smear layer, was calculated, and the percentage of the clean area was obtained.

Tissue dissolution analysis

For tissue dissolution analysis, 20 prototyped upper central incisors (IM from Brazil, São Paulo, Brazil) were employed. Coronary opening and biomechanical preparation were performed, as previously mentioned. Two holes were made on the external surface of the root, one in the cervical third and the other in the apical third of the teeth, communicating the interior of the root canal with the external environment. Glass capillaries with 0.4 mm internal diameter and 10 mm long were embedded in the holes with the aid of photoactivated flow composite resin to allow stabilization. The capillaries were filled with chrome Catgut suture 4.0 (Bioline, São Paulo, Brazil) (Fig 2).

The teeth were randomly divided into groups according to final irrigation protocols. The samples were weighed on a precision scale (Shimadzu, Barueri, Brazil) before and after irrigation protocols. After irrigation protocols, the initial and final weights were subtracted to measure the volume of dissolved organic material.

STATISTICAL ANALYSIS

The data were submitted to the Komogorov-Smirnov normality test. The normal distribution was not observed for the cleaning analysis, and Friedman tests were used for intragroup comparison and the Kruskal-Wallis and Dunn tests for comparison between the groups. The distribution was normal to analyze the dissolution of organic matter. The T-Paired tests were used for intragroup comparison, and the ANOVA and Tukey tests were used for comparisons between the groups. The significance level was set at 5%, and GraphPad Prism 8 software (GraphPad Software Inc, La Jolla, USA) was used as a statistical tool.

Results

Table 1 shows the cleaning percentage's minimum, maximum, and median values before and after instrumentation and after irrigation protocols. In all groups, the final irrigation provided greater cleaning of the walls in the root canals' cervical, middle, and apical thirds ($P < 0.05$). In the comparison between the groups, there was no statistically significant difference, regardless of the thirds analyzed.

Table 1
– Minimum, maximum, and median values of smear layer cleaning percentage (%) before instrumentation, post instrumentation and post irrigation protocols.

	Initial			**Post-Instrumentation**			**Post-Irrigation**		
Grupos	**C**	**M**	**A**	**C**	**M**	**A**	**C**	**M**	**A**
C	0 (0–80) A, a	0 (0–12) A, a	0 (0–2) A, a	19 (0–90) A, a	19,5 (0–80) A, B, a	8,5 (0–50) A, a	91 (16–100) B, a	62,5 (10–100) B, a	78,5 (25–100) B, a
PUI	0 (0–26) A, a	0 (0–50) A, a	0 (0–20) A, a	17,5 (0–87) A, a	19 (0–88) AB a	33,5 (0–98) AB, a	99 (10–100) B, a	82,5 (45–100) B, a	63,5 (0-100) B, a
IVAC	0 (0–36) A, a	0 (0–22) A, a	4 (0–38) A, a	60 (0–94) AB, a	26,5 (0–90) A, a	21,5 (0–93) AB, a	95 (67–100) B, a	85 (46–100) B, a	78 (25–100) B, a

Different capital letters indicate statistic significant differences between the thirds in the intragroup comparisons ($P < 0.05$). Different lowercase letters indicate statistic significant differences between the groups in each third in the intergroup comparisons ($P < 0.05$).

Table 2 shows the values of the mean and standard deviation of the pre-and post-instrumentation weights and the percentage of dissolution of the analyzed groups. All irrigation protocols presented a significantly lower final weight than the initial ($P < 0.05$). Both agitation protocols dissolved a significantly larger volume than the conventional irrigation protocol without agitation ($P < 0.05$). No difference was observed between the two protocols with ultrasonic agitation ($P > 0.05$).

Table 2
– Mean and standard deviation of weight (mg) before and after irrigation protocols and the percentage of dissolution of the three groups analyzed.

	Initial (mg)	Post-Irrigation (mg)	% dissolution
C	777,3 ± 13,62 ^{a}	776,6 ± 13,73 ^{b}	0,07 +/-0,06^{A}
PUI	776,5 ± 14,72 ^{a}	771,0 ± 14,62 ^{b}	0,71 +/- 0,10^{B}
IVAC	783,1 ± 17,55 ^{a}	776,9 ± 17,42 ^{b}	0,78 +/-0,05^{B}

Lowercase letters represent significant differences in the intra-group comparisons in relation the initial and final weight in each group ($P < 0.05$). Capital letters represent a significant difference between the % dissolution in the inter group comparison. ($P < 0.05$).

Discussion

Irrigation during endodontic therapy has as its main objectives the reduction of microbial load, dissolution of organic and inorganic tissues, and reduction of friction between instruments and dentin walls [3]. The effectiveness of endodontic irrigation depends on factors such as needle insertion depth, final diameter of biomechanical preparation, volume and physical-chemical properties of irrigator solutions, and anatomical characteristics of root canals [11, 19, 20]. Different stirring methods are proposed to increase the diffusion capacity of irrigator solutions in areas of anatomical complexity and the apical third [15, 21, 22].

The present study evaluated wall cleaning and the ability to dissolve organic matter from two ultrasonic agitation methods. The null hypothesis was partially rejected since there were differences between irrigation protocols in the dissolution of organic matter.

Passive ultrasonic irrigation, using a metallic insert (Irrisonic), promoted better results regarding wall cleaning when compared to conventional irrigation without agitation. This result agrees with the results found by other studies in the literature [16, 18, 22]. This can be justified because PUI allows the diffusion of the solution through the root canal system, allowing the contact of the irrigator solution with the walls [15]. In addition, the phenomena of acoustic streaming and transient cavitation can help in the cleaning of root canals [23–25].

The study results showed that there was significant tissue dissolution regardless of the irrigation protocol. This can be justified by the potential to dissolve organic matter from sodium hypochlorite [19, 26]. In addition, PUI and iVac showed a higher percentage of dissolution than conventional irrigation, but with no difference between them. A similar dissolution action may have occurred due to the greater diffusion of the solution by this method, which may have directed a higher volume of sodium hypochlorite into the capillaries, and by the increase in temperature of the solution, which occurs during ultrasonic agitation, which is related to the increased potential for dissolution of organic matter of sodium hypochlorite [17, 27].

The present study presented a new experimental model to evaluate the dissolution of organic matter in areas of anatomical complexity. However, there are limitations related to the experimental model used. For example, the positioning of capillaries, angulation, and catgut characteristics do not accurately simulate the clinical characteristics. Therefore, new experimental models that allow the evaluation of tissue dissolution are necessary.

The iVac system was developed to be used during irrigation in endodontic treatment. The system allows irrigation and agitation of the solution, concomitantly with apical negative pressure aspiration. The iVac system provided better results than conventional irrigation regarding wall cleaning and was similar to PUI with an Irrisonic insert. Because it is more flexible than metal, the iVac high-performance medical-grade polymer tip allows it to work with higher amplitudes and be positioned close to the working length. In addition, it performs aspiration with negative pressure, which favors greater solution turbidity [28] and can prevent fluid extrusion beyond the apical foramen [29]. Unfortunately, due to the absence of studies published in the literature that analyzed this new irrigation system, it is not possible to compare the results of this research with those of other authors. However, the findings agree with the results of other authors who evaluated the EndoVac® system (Discuss Dental, Culver City, CA, USA), which also works by apical negative pressure [16, 28, 30].

There is still no consensus in the literature regarding the ideal irrigation protocol. Nevertheless, it is known that the use of agitation methods is related to better removal of smear layer and dentinal debris [31]. This is the first study in the literature evaluating the potential for wall cleaning and tissue dissolution of the iVac system. New studies evaluating this system regarding the dissolution of bacterial biofilm, cleaning of walls in teeth with apical curvature, and dissolution of organic matter in new experimental models, in addition to clinical work, are needed.

Conclusion

Under the experimental conditions of this study, we can conclude that the new iVac activation/irrigation system provided similar results regarding the cleaning of walls and dissolution of organic tissue in areas of simulated complexity than PUI with metal insert, both with better results than conventional irrigation without agitation.

Declarations

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Author contributions

Marco Antonio Hungaro Duarte, Murilo Priori Alcalde, and Rodrigo Ricci Vivan contributed to the conceptualization. Raimundo Sales de Oliveira Neto, Luana Arantes de Souza Lima, and Marco Antonio

Hungaro Duarte contributed to the methodology. Pedro Cesar Gomes Titato., and Luana Arantes de Souza Lima contributed to the investigation. Murilo Priori Alcalde, Rodrigo Ricci Vivan, and Marco Antonio Hungaro Duarte contributed to the formal analysis. Pedro Cesar Gomes Titato, and Raimundo Sales de Oliveira Neto contributed to data curation. Raimundo Sales de Oliveira Neto, Pedro Cesar Gomes Titato, and Luana Arantes de Souza Lima wrote and prepared the original draft. Rodrigo Ricci Vivan, Marco Antonio Hungaro Duarte, and Flaviana Bombarda de Andrade contributed to the review and editing of the study report. Marco Antonio Hungaro Duarte contributed to supervision. Murilo Priori Alcalde, and Marco Antonio Hungaro Duarte contributed to project administration. Marco Antonio Hungaro Duarte contributed to funding acquisition.

Conflict of Interest The authors declare that they have no financial and non-financial conflict of interest.

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Ethical approval This study was submitted to the Human Research Ethics Committee of the Bauru School of Dentistry – University of São Paulo (CAAE 62875122.6.0000.5417) and was in accordance with the ethical standards of the institutional and national research committee for human research.

Informed consent Not Applicable.

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Figures

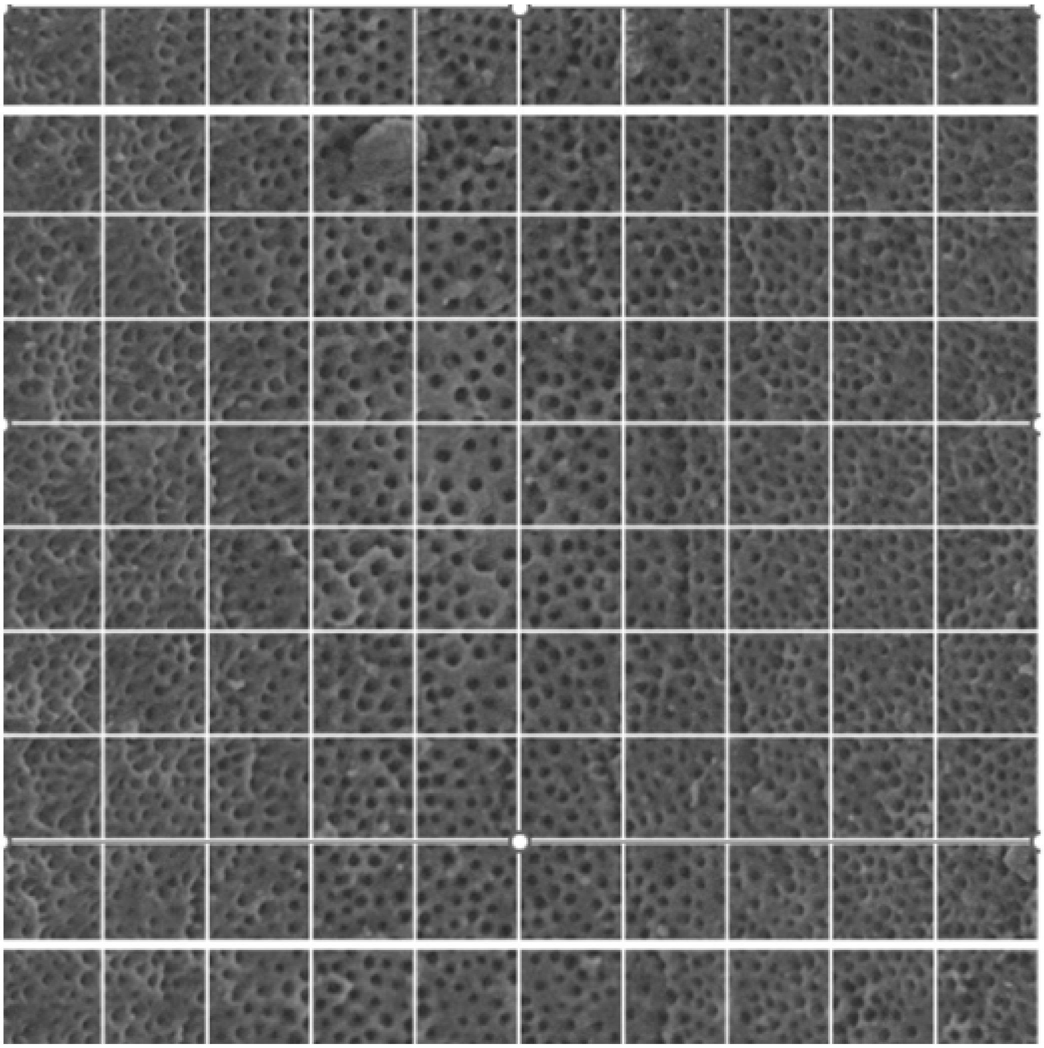

Figure 1

Representative image of photomicrography with the digital grid overlaps for the quantification of clean area (500x magnification)

Figure 2

Representative image of specimen with glass capillaries positioned in apical and cervical thirds and filled with Catgut suture thread