Influence of needle and irrigation flow rate on root canal cleaning and apical extrusion of irrigant: Micro-CT analysis

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ABSTRACT

Introduction: needle and irrigation flow rate are important for proper cleaning of the root canal. **Aim:** to evaluate the influence of type of needle and irrigation flow rate on cleaning of root canal and simulated lateral canals and the apical extrusion of irrigant. **Methods:** Thirty-two resin teeth were used. After root canal instrumentation, four lateral canals were made at 2 and 7 mm from the apex. Root canals were filled with contrast solution. The root canals were irrigated with two types of needle, 29G and 31G, with different designs (side and apical opening) and two flow rates (2 or 5 mL/min), at 1 mm short of the working length. The volume of the contrast solution in the main and lateral canals after irrigation and apical extrusion of the irrigant (mm3) were evaluated by Micro-CT, in comparison with the initial analysis. Data in percentage were analyzed by ANOVA and Tukeys tests ($\alpha = 0.05$). **Results:** no difference among the irrigation protocols for contrast solution cleaning was observed. Higher volume of apical extrusion using needle 29G-apical opening and 5 mL/min in comparison with the same type of needle and 2 mL/min was observed ($p < 0.05$). **Conclusion:** all irrigation protocols were associated with root canals cleaning. Greater apical extrusion was observed for needle 29G-apical opening with higher irrigation flow rate (5 mL/min). **Clinical implications:** endodontic irrigation using a needle with apical opening and higher flow rate of solution may favor extrusion of irrigant to the periapical tissues.

Kwywords: Endodontics. Therapeutic Irrigation. Root Canal Preparation. X-Ray Microtomography

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Introduction

The root canal irrigation aims to clean and disinfect the root canal systems (RCS), removing dentin debris, microorganisms and their byproducts,[1,2] from the main and lateral canals, isthmus and areas unprepared by mechanical instruments.[3,4] The use of an irrigation needle in the apical third of the root canal is important for proper cleaning.[5] Therefore, a lower level of cleaning may occur with the use of larger diameter needles at greater distance from the dental apex.[6]

Sodium hypochlorite (NaOCl) is the most used solution in endodontics, due its antimicrobial property[7] and capacity for dissolving organic tissue.[1,8] Nevertheless, it is relatively cytotoxic[9] when in contact with the periapical tissues, in cases of apical extrusion.[9,10] Although extrusion of the irrigant solution is an adverse effect that should be avoided and relatively uncommon,[11,12] clinical cases of tissue damage and painful symptoms have been reported.[13]

The volume of irrigant solution may interfere in the occurrence of extrusion.[14] Moreover, the type of needle may influence the apical extrusion. Higher pressure of the irrigant has been reported when needles with apical opening were used.[15,16] Different systems and irrigation needles with side opening have been proposed to prevent apical extrusion of the irrigant solution.[5,17] The irrigation needle must be inserted at 1 mm short of the working length to ensure the solution exchange and cleaning ability.[18,19]

Irrigant flow rate is rarely mentioned as a factor contributing to irrigation effectiveness,[2] but flow rate is considered a significant factor and has been shown to influence the replacement of the irrigant in the RCS.[20] It may also influence the extrusion of irrigant solution into the periapical region.[21] There is no definition about the ideal flow rate in endodontic irrigation.[15]

Microcomputed tomography (micro-CT) has been used for evaluating the cleanliness of root canals.[19,22-24] This is a reproducible non-invasive technique,[23] that increases the reliability of the results.[24] The efficacy of two passive ultrasonic irrigation (PUI) methods and manual irrigation (MI) in RCS cleaning, using artificial teeth filled and contrast solution was evaluated. The authors concluded that PUI with intermittent or continuous flushing and MI with the needle placed 1 mm from the WL were efficient in root canal cleaning.[23]

Therefore, the aim of this study was to evaluate *in vitro* the influence of two types of needles and irrigation flow rates on the cleaning capacity and apical extrusion of irrigant in the root canal system (simulated canals), by tridimensional analysis in micro-CT.

Materials and Methods

The methodology used in this study is in accordance with Tanomaru-Filho et al.23 Thirty-two resin teeth with single and straight root canals (Dental Rossetto Ltda., Arujá, SP, Brazil) were used. The crowns were removed using a cutting machine (Isomet 1000 - Buelher Ltd., USA) to standardize the roots with a length of 14 mm. The apical foramen was standardized up to #20 K-file. Biomechanical preparation was performed by using Mtwo rotary system instruments (VDW, Endodontic Synergy, Germany): 10/.04, 15/.05, 20/.06, and 25/.06, followed by 25/.07. The working length (WL) was determined at 1 mm short from the root apex (13 mm). The apical root canal was enlarged using file 30/.05, 35/.04, and 40/.04. After each file change, the root canals were irrigated with 2 mL of 1 % sodium hypochlorite solution (NaOCl). Afterwards, four lateral canals were made in the middle and apical root canal thirds (at 2 and 7 mm short from the apex). A 0.20-mm cylindrical drill was used (Undercut series drills, Union Tool Co., Pluritec - Ind. e Com. de máquinas Ltda., SP, Brazil). The root canals were filled with a contrast solution (meglumine/sodium diatrizoate - Pielograf 76%, BerliMed S.A., Madrid, Spain) in association with propylene glycol (Pharmaceutical Sciences - UNESP, Araraquara, SP, Brazil) and bismuth oxide p.a. (Vetec Química Fina Ltd., RJ, Brazil) in the proportion of 1:1:1 by weight. Digital periapical radiographs were taken (Kodak RVG 6100 Digital Radiography System, France) to confirm the complete filling of root canals with the contrast solution. To evaluate the apical extrusion of the solution, the root apex was enveloped by resin device containing acrylic wool.

The specimens were randomly divided into 4 experimental groups (Table 1). All the irrigation procedures were performed by a single operator trained according the flow rate and the irrigation method. The protocols were performed 24 hours after filling the root canals with contrast solution.

In the first group, the root canals were irrigated using a 29G needle (NaviTip, Ultradent Products, USA) and 5 mL syringe (Ultradent Products, USA) with a flow rate of 2 mL/min, with simultaneous aspiration being performed by means of a tip 2.0 mm in diameter (White Mac® tip, Ultradent, USA). In all groups, the irrigation needle was positioned at 1 mm short of the WL, according to a previous studies[2,25]. In the second group, irrigation was performed in the same manner, but at a flow rate of 5 mL/min. In the third group, the root canals were irrigated with a 31G needle with side opening (NaviTip DS - Double Sideport, Ultradent Products, USA) at a flow rate of 2 mL/min and simultaneous aspiration. In last group, irrigation was performed with the same type of needle, but at a flow rate of 5 mL/min.

Micro-CT analysis

Micro-computed tomographic analysis was performed using Micro-CT SkyScan 1176 (Bruker - microCT, Kontich, Belgium) before and after the irrigation protocols. The scanning procedure prior to and after the irrigation was performed with 70-kV X-ray tube voltages; 385-μA anode current, and a 0.5-mm aluminum filter. The image capture parameters used were of voxel size of 34.96 μm with a 0.5° rotation step, using 360° rotations with exposure time of about 10 min per specimen. Each scan consisted of 721.tif images with 1000 × 668 pixels (per specimen). Digital data were further elaborated by reconstruction software (NRecon V1.6.4.7; SkyScan, Belgium) in three dimensions (3D).

The reconstructed images were superposed at the different periods and saved in the coronal, sagittal and transaxial planes using the Data Viewer software (V1.5.2.4; Bruker-MicroCT, Kontich, Belgium). The 3D reconstructed images were analyzed using the CTAn software (V1.11.8; SkyScan, Belgium) to obtain the volume of the contrast solution (mm3) before and after the irrigation protocols. The complete root canal system (total) and the middle and apical thirds were evaluated. The images were separated to be analyzed individually. This was limited to the area of interest (ROI), and the new ROI data were saved in separate folders. The binary values were recorded to be used later in the second scan of the same specimen (post-irrigation), with the aim of standardizing the measurements. Thus, it was possible to obtain a quantitative analysis of the contrast solution volume by using 3D plug-in analysis, which enables an automated calculation of the total volume (mm3) from the 3D images of binary selected objects.

The post-irrigation volume was analyzed in a manner similar to that provided in the aforementioned description of the pre-irrigation volume. The ratio between the values obtained was calculated as cleaning percentages for each group with the aim of showing the removal of contrast solution from RCS. Comparison among groups was realized by ANOVA and Tukey's post hoc tests at 5% level of significance.

Results

The total cleaning results (main and lateral root canals) and of the middle and apical thirds are presented in Table 2. There was no significant difference between the experimental groups ($p > 0.05$) in removing the contrast solution in the three parameters evaluated (total, middle and apical thirds).

Table 1. Experimental groups according to type of needle and irrigation flow rate

Needle / Design - Irrigation flow rate	n	Irrigant	Volume
29G / apical opening - 2 mL/min.	8	1% NaOCl	5 mL
29G / apical opening - 5 mL/min.	8	1% NaOCl	5 mL
31G / side opening - 2 mL/min.	8	1% NaOCl	5 mL
31G / side opening - 5 mL/min.	8	1% NaOCl	5 mL

The results of the extruded contrast solution into the periapical region, in volume (mm^3), are represented in Table 3. The 29G needle with apical opening and flow rate of 5 mL/min was associated with higher apical extrusion, than the same type of needle at a flow rate of 2 mL/min ($p < 0.05$). The 3D models reconstructed in the CTVol program, showing the differences between these two groups are represented in Figure 1.

Discussion

Our results showed that all the irrigation protocols promoted cleaning of the RCS, in agreement with the study of Tanomaru-Filho et al.[26], evaluating the removal of contrast solution from simulated root canals. The authors observed no difference in cleaning of the main canal when manual irrigation at 2 mm from the WL and passive ultrasonic irrigation

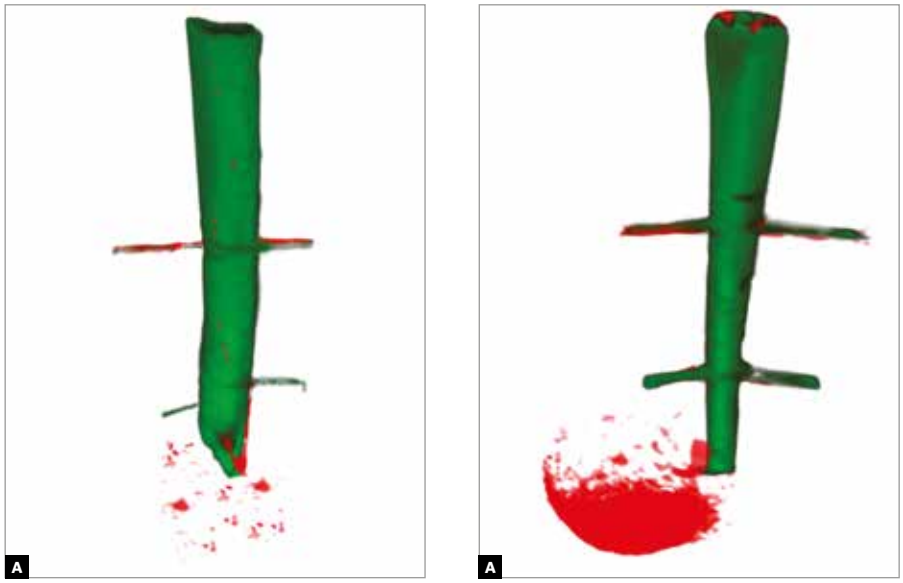

Figure 1. 3D Model created in CTVol software representing the groups using needle 29G with apical opening and flow rate of 2 mL/min **(A)**; and needle 29G with apical opening and flow rate of 5 mL/min **(B)**, respectively, before (green) and after (red) irrigation.

Table 2. Mean and standard deviation of percentage of total cleaning (main canal) and in middle and apical thirds

Needle / Design - Irrigation flow rate	Total	Middle third	Apical third
29G / apical opening - 2 mL/min.	83.00 (±7.13)^{A,a}	96.62 (±1.19)^{A,a}	83.10 (±14.39)^{A,a}
29G / apical opening - 5 mL/min.	89.05 (±6.29)^{A,a}	97.22 (±2.69)^{A,a}	89.85 (±7.10)^{A,a}
31G / side opening - 2 mL/min.	86.55 (±7.20)^{A,a}	97.30 (±1.59)^{A,a}	83.26 (±8.40)^{A,a}
31G / side opening - 5 mL/min.	88.75 (±3.51)^{A,a}	96.83 (±2.27)^{A,a}	83.12 (±8.65)^{A,a}

Equal capital letters in the same column represent similarity between groups and lower case letter in the same line represent similarity between main canal and thirds ($p > 0.05$).

Table 3. Mean and standard deviation of volume of apical extrusion of contrast solution

Needle / Design - Irrigation flow rate	Apical extrusion (mm3)
29G / apical opening - 2 mL/min.	0.62 (±0.57)^{b}
29G / apical opening - 5 mL/min.	1.43 (±0.66)^{a}
31G / side opening - 2 mL/min.	0.90 (0.24)^{a,b}
31G / side opening - 5 mL/min.	0.75 (0.48)^{a,b}

Different letters in the same line represent significant differences ($p < 0.05$).

were used. Similarly, the effect of different irrigation systems and activation of irrigant solutions in simulated lateral canals at 3 and 5 mm from the root apex was evaluated. The results showed a significant reduction in contrast solution in all the groups, as occurred in the present study.[3] However, positioning the needle close to the WL has been advocated to effectively clean the apical third of the root canal; because the irrigant seldom flows beyond 1 mm of the tip of the needle.[2]

The same volume of irrigant solution (5 mL) was used in the different methods, with different flow rates and needle diameters, placed at 1 mm short of the WL. This position was determined to promote more effective irrigation and cleaning in the apical third.[27] Therefore, the irrigation needle must be placed as closely as possible to the apical region for improved efficacy of cleaning the entire extension of the root canal.[18,19,28]

Using a similar methodology for evaluating cleaning, the influence of the root canal diameter and the diameter and type of irrigation needle on the efficacy of cleaning in the apical third was evaluated.[29] The authors concluded that the smaller diameter needles were fore efficient for cleaning the apical third, irrespective of their type. However, smaller diameter irrigation needles may promote higher pressure thereby increasing the risk of extrusion.[30]

Some authors have suggested that needles with side opening would allow more efficient cleaning of the root canal walls and the middle third[31,32] in comparison with those with apical opening, in disagreement with our results, in which there was no difference in the percentage of cleaning achieved by the irrigant solution between the middle and apical thirds. The divergence between our results in comparison with these studies may be due to the difference in the method of analysis, because our study used micro-CT, which may provide more detailed information on the quality of cleaning.

For evaluating apical extrusion of the irrigant solution, different methodologies have been used.[4-6,33] In the present study, acrylic wool was used to simulate the periapical tissues. Therefore, there was the presence of some resistance, making it possible to simulate the clinical condition and facilitating evaluation by micro-CT, without interference in the images.

The type and penetration depth of the irrigation needle may influence apical extrusion of the irrigant.[5] Needles with apical opening have been reported to cause a higher level of extrusion when compared with needles with side opening.[5,6,31,34] Inserting needles closer to the apex and using needles with wider diameters were associated with significantly more debris extrusion.[2] Accordingly, any root canal irrigation delivery system that reduces the risk of NaOCl extrusion into the periapical tissues would greatly benefit patient care. However, irrigation with a syringe and needle is still the method used most commonly.[12]

Psimma et al.[6] reported a significant influence of the type of needle, penetration depth and diameter of the apical preparation on the extrusion of irrigant solution. The results showed that the needle with apical opening positioned at 1 mm short of the WL caused a higher level of extrusion than that of the needle with apical opening positioned at 5 mm short of the WL.

However, in the present study, no difference was shown between the two types of needles evaluated, in agreement with previous studies that showed that needles with side opening did not avoid apical extrusion of the irrigant.[5,35] Moreover, our results showed that needle 29G with apical opening and flow rate of 5 mL/min presented higher apical extrusion values than the same type of needle at a flow rate of 2 mL/min, suggesting that the pressure may have more influence than the type of needle. Therefore, the two types of needles may be used safely and efficiently with adequate position and pressure.[35]

Conclusion

According to the methodology used, manual irrigation using syringe with different types of needle and irrigation flow rates presented efficient cleaning of the root canal system. Irrigation with needle 29G-apical opening and flow rate of 5 mL/min produced higher volume of extrusion when compared with the same type of needle using lower flow rate (2 mL/min).

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