Comparison of the effectiveness of 3 irrigation devices for the cleaning of root canal walls instrumented with oscillatory and rotary techniques

Nadia de Souza Ferreira, PhD ▪ Carlos Henrique Ribeiro Camargo, PhD ▪ Renato Miotto Palo, PhD
Frederico Canato Martinho, PhD ▪ Ana Paula Martins Gomes, PhD

In this study, scanning electron microscopy (SEM) was used to evaluate the smear layer removal of 3 irrigation devices. The study hypothesis was that more contemporary side-vented needles and brush-covered needles are more efficient for smear layer removal of root canals than traditional needles. The aim of this study was to compare the effectiveness of these irrigation devices in the cleansing of root canals instrumented with oscillatory and rotary systems. Sixty single-rooted teeth were divided according to instrumentation and irrigation techniques into 6 groups. The teeth were prepared for SEM analysis to evaluate the cleansing of cervical, middle, and apical thirds. For all groups, the cleansing of the cervical and middle thirds was better than that of the apical third ($P < 0.05$). Regardless of the instrumentation technique, no statistically significant differences were found between the groups regarding the cleansing of root canal walls ($P > 0.05$).

Received: December 3, 2013
Accepted: April 4, 2014

Keywords: endodontics, irrigation, scanning electron microscopy, smear layer, root canal preparation

Irrigation during cleaning and shaping of the root canal system is of great importance in endodontic treatment.[1-4] Irrigation is complementary to instrumentation in facilitating removal of bacteria, debris, the smear layer, and residual pulp tissues from root canal systems, thus contributing to the success of endodontic treatment.[5,6]

The cleaning effectiveness of root canal irrigation depends on several aspects, including flow rate, fluid dynamics, flushing action, and type of irrigation delivery device. It also depends on the anatomy of the root canal system, such as the presence of curvatures, isthmuses, sulci, and ramifications; instrumentation, including adequate canal shape and cleansing effectiveness of the files; and chemical makeup of the irrigants, such as their antibacterial and fluid properties, volume, chelating potential, and ability to chemically dissolve tissue.[2,6-14]

Numerous investigations have been performed to evaluate the effectiveness of instruments, instrumentation techniques, irrigants, and methods of irrigation in canal debridement.[1,15-21] Most of this research demonstrated that the amount of debris still remaining in the root canal system after instrumentation and irrigation—particularly in the apical third—is critically affected by the mode of delivery.[9,22]

Different irrigation delivery devices are available for enhancing irrigant distribution and flow.[1,4] New irrigation delivery devices that exhibit different needle-tip designs have been developed. While there are a few published studies on the effectiveness of these devices, it has been reported that tips with a side-vented needle or a brush-covered needle are more efficient for disinfection of root canals than traditional needles.[1,4,18,21-23]

The aim of this study was to compare the effectiveness of 3 irrigation systems: a side-vented needle system (Endo-Eze AET, Ultradent Products, Inc.), a brush-covered needle system (NaviTip FX, Ultradent Products, Inc.), and a traditional needle system (NaviTip, Ultradent Products, Inc.) in the cleansing of root canal walls instrumented with oscillatory instrumentation (OI) (Endo-Eze Irrigator, Ultradent Products, Inc.) or rotary instrumentation (RI) (ProTaper Universal, DENTSPLY Maillefer).

Materials and methods

The study was carried out with the approval of the Universidade Estadual Paulista Institutional Ethics Committee (Protocol 066/2009-PH/CEP). Sixty single-rooted human uniradicular teeth of different dental groups (maxillary and mandibular central/lateral incisors, canines, and premolars) were used. To minimize the influence of this variable, the specimens were divided into groups so that there was a similar number of teeth from the different tooth groups within each experimental group. After extraction, the teeth were cleaned, stored in deionized water, and frozen until use. The crowns of all teeth were removed with double-faced diamond discs (KG Sorensen) to create a root length of 16 ± 0.5 mm.

Next, the specimens were divided into 6 groups (n = 10) according to the following instrumentation and irrigation techniques: Group 1, OI + Endo-Eze Irrigator; Group 2, OI + NaviTip FX; Group 3, OI + NaviTip; Group 4, RI + Endo-Eze Irrigator; Group 5, RI + NaviTip FX; and Group 6, RI + NaviTip.

Instrumentation protocols

Oscillatory instrumentation (Groups 1-3)

The cervical and middle thirds of the root canals were prepared with a crown-down technique using Endo-Eze files (Ultradent Products, Inc.) according to the manufacturer's instructions. The Endo-Eze files were adapted to the Endo-Eze contra-angle handpiece (KaVo Dental). K-files, size No. 15 or No. 20 (DENTSPLY Maillefer), were always used between each instrumentation. The lumen of the canal was identified by using a K-file size No. 10 (DENTSPLY Maillefer). Next, cervical interferences were eliminated with the 13/.60 instrument of the Endo-Eze system, according to the same principles of the crown-down pressureless technique. Instrumentation was continued by using an oscillating 13/.45 file, K-file (No. 15 or 20), oscillating 13/.35 file, K-file (No. 15 or 20), and an oscillating 10/.25 file to reach a depth of 3 mm shorter than the full length of the root canal, as calculated from preoperative radiographs. The apical preparation was performed by using 4 K-files up to size No. 45 until reaching the working length. The use of each instrument was followed by irrigation with 5 ml of 2.5% NaOCl solution by means of selected tips (according to the group selected).

Rotary instrumentation (Groups 4-6)
The ProTaper instruments were used in a crown-down manner from S1 up to a size F3, driven at 500 rpm with 3 N/cm of torque (Xsmart, DENTSPLY Maillefer). Shaping files were used passively in a lateral brushing movement to allow more contact with the internal walls of the canal. The preparation started with the introduction of an S1 file until slight resistance was felt. Next, an SX file was used to facilitate the placement of subsequent S1 and S2 files into the working length. Shaping was finished by sequential use of F1 and F2 files until reaching the working length. The use of each instrument was followed by irrigation with 5 ml of 2.5% NaOCl solution by means of selected tips (according to the group selected).

Irrigation protocols
Protocols for the irrigation of the 6 groups were established. In Groups 1 and 4 (Endo-Eze Irrigator), a 27-gauge side-vented needle was introduced 2-3 mm from the working length and was progressively advanced to 1 mm with concomitant delivery of irrigants. In Groups 2 and 5 (NaviTip FX), a 30-gauge NaviTip FX needle was used along the lines of the Endo-Eze protocol. In Groups 3 and 6 (NaviTip), a 30-gauge NaviTip needle was introduced 2-3 mm from the working length and was progressively advanced to 1 mm. During all irrigation procedures, a brushing movement was performed along the canal walls (with 6 mm amplitude reaching 1 mm short of the working length) with the concomitant delivery of irrigants. Final irrigation was performed with 1 ml of 17% EDTA for 3 minutes and neutralization with 5 ml of 2.5% NaOCl.

Cleanliness analysis
After root canal preparation, the specimens were longitudinally sectioned for a scanning electron microscopy (SEM) analysis of the cleaning procedure. For that purpose, 2 grooves were fabricated on the buccal and lingual aspects of the roots with double-faced diamond discs with care to avoid touching the root canal. Then the roots were externally rinsed with EDTA and saline solution, followed by cleavage with a chisel into 2 halves (mesial and distal) for SEM analysis.

The specimens were fixed in 2.5% glutaraldehyde for 1 hour and then dehydrated for 20 minutes each in 4 ethanol concentrations (25%, 50%, 75%, and 90%), then in absolute ethanol (100%) for 1 hour. The specimens were mounted on aluminum stubs, and metallization was performed with a thin gold-palladium coat (200 Å) in a high-pressure vaporizer (DV-502, Denton Vacuum, LLC—USA).

The success of the root canal cleaning was assessed by checking the quantity of open and closed tubules through SEM images (JSM-T330A, JEOL Ltd.). Representative areas of each root third were selected and photographed at 500X and 2000X magnifications. The images obtained at 2000X magnification were transferred to a Windows Paint (Microsoft) standard image editor for counting the open and closed dentinal tubules (Figure). Data related to the percentage of open tubules per mm^2 were statistically analyzed.

Statistical analysis
The data for the study variables were analyzed by descriptive and inferential statistics with the aid of software (Minitab for Windows 2007, Version 15.1, Minitab). A 2-way analysis of variance (ANOVA) test was used to compare the variability between groups. The significance level was set at 5% for rejection of the disproportion hypothesis between groups. The interaction effect was assessed by Tukey's multiple comparison test.

Results
Table 1 presents the mean and standard deviation values for the percentage of open dentinal tubules within each root third for each experimental group. All groups showed extensive cleansing of the root canal walls. With the application of Tukey's test, it was possible to observe the statistical difference between the root thirds analyzed ($P = 0.00001$) with a better cleansing achieved in the cervical and middle thirds compared to the apical third, using both OI and RI techniques. Regardless of the instrumentation technique, the 2-way ANOVA revealed no significant differences between the irrigation devices tested: Endo-Eze irrigator (side-vented), NaviTip, FX (brush-covered), and NaviTip (traditional) ($P = 0.2345$) (Table 2).

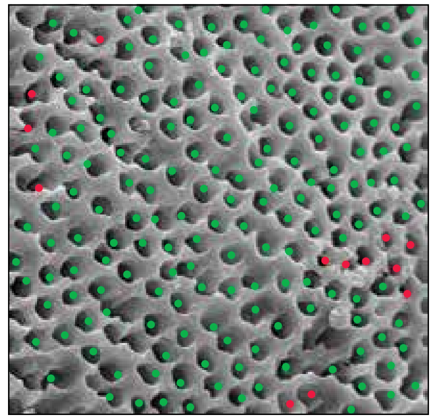

Figure. Model used for counting dentinal tubules. Red circles, open tubules; green circles, closed tubules. Red circles + green circles = total of dentinal tubules. Percentage of open tubules = number of open tubules/total number of tubules x 100. This percentage was used in the study for statistical analysis.

Discussion
The present study compared the effectiveness of 3 different irrigation delivery devices, namely, Endo-Eze irrigator (side-vented), NaviTip FX (brush-covered), and NaviTip (traditional) in the cleansing of root canal walls instrumented with oscillatory (Endo-Eze) and rotary (ProTaper) systems.

The SEM technique used in the present study has frequently been applied to evaluate the cleanliness of the root canal walls after root canal instrumentation.[1,4,18] These studies have been based on examination at 50X to 2000X magnification. A 2000X magnification was

Table 1. Descriptive statistics. The mean and standard deviation (SD) of the percentage of open tubules in the different experimental groups in each root third.

	Group 1		Group 2		Group 3		Group 4		Group 5		Group 6	
Root third	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cervical	81.25	20.79	74.64	24.40	71.31	13.26	83.08	12.35	75.11	14.76	84.61	9.12
Middle	65.17	18.60	70.97	13.93	74.95	10.00	81.59	5.79	82.86	7.76	83.29	12.63
Apical	61.48	20.93	61.91	20.38	49.31	23.04	62.57	29.06	62.63	12.42	60.72	20.55

Group 1, OI + Endo-Eze Irrigator; Group 2, OI + NaviTip FX; Group 3, OI + NaviTip; Group 4, RI + Endo-Eze Irrigator; Group 5, RI + NaviTip FX; Group 6, RI + NaviTip. Abbreviations: OI, oscillatory instrumentation; R, rotary instrumentation.

Table 2. Differences between the groups and root thirds assessed.

Group	Root third	Mean	Homogeneous groups
OI + NT	Cervical	1.01	AB
OI + NT	Middle	1.05	AB
OI + NT	Apical	0.77	B
OI + FX	Cervical	1.06	AB
OI + FX	Middle	1.01	AB
OI + FX	Apical	0.91	AB
OI + EE	Cervical	1.15	A
OI + EE	Middle	0.95	AB
OI + EE	Apical	0.91	AB
RI + NT	Cervical	1.18	A
RI + NT	Middle	1.17	A
RI + NT	Apical	0.90	AB
RI + FX	Cervical	1.06	AB
RI + FX	Middle	1.15	A
RI + FX	Apical	0.91	AB
RI + EE	Cervical	1.16	A
RI + EE	Middle	1.13	A
RI + EE	Apical	0.91	AB

Abbreviations: EE, Endo-Eze; FX, NaviTip FX; NT, NaviTip; OI, oscillatory instrumentation; RI, rotary instrumentation.

considered because it offered a higher view and detailed image of the canal wall surfaces compared to lower magnifications, thus allowing debris and the smear layer to be identified, along with tubule orifices.[24]

The effectiveness in the cleansing of the root canal walls was better achieved in the cervical and middle thirds when compared to the apical third of the root canals, a finding which is in agreement with previous studies.[1,4,18,25] The apical third is considered a particularly critical zone for the cleansing procedure.[1,4,18,26] The limited cleansing is not only attributed to the irrigation delivery device and irrigant themselves, but also to the instrumentation technique, particularly those ending in a limited apical diameter size, consequently compromising the deep penetration of the irrigation delivery device, flow rate, fluid dynamics, and flushing action.[1,4,6-10,12,18,26] In this study, the size of the needles tested were ≤ No. 30 gauge, and the roots were apically prepared to an ISO No. 30 file.

It has been reported that tips with side-vented or brush-covered needles are more efficient for disinfection of root canals compared to traditional needles.[4,18,21,22] Thus, the use of a side-vented needle device (Endo-Eze irrigator) was selected in order to evaluate a possible improvement in the cleansing of the root canal walls, particularly in the apical third. Although side-vented needle irrigation has been demonstrated to improve the hydrodynamic action of the irrigation flow as well as to prevent apical extrusion of debris, no significant improvement in the cleansing of root canal walls was observed between the side-vented needle device and the traditional needle device, as demonstrated by SEM analysis.[27,28] This finding is in agreement with other studies that reported a limited cleaning ability of side-vented needle devices within the apical third.[1,29] The results in this study might have been attributed to the different gauge sizes (EndoEze irrigator and NaviTip were 27 and 30 gauge, respectively). This may have resulted in the EndoEze irrigator exposing the canals to a lower volume and lower flow of irrigation solutions, thus leading to a limited performance.

It has been speculated that the NaviTip FX tip used in brushing mode might contribute to the cleansing of root canal walls by enhancing the chemical action of the irrigant.[18] However, no significant improvement in the cleansing of the root canal walls was actually achieved by the use of NaviTip FX compared to the NaviTip and Endo-Eze irrigators. This finding is in agreement with a study conducted by Al-Hadlaq et al, who compared the use of NaviTip FX to NaviTip at 200X magnification by means of a score based on the percentage of debris covering. They reported no difference between the 2 irrigators in removing debris from the middle and apical thirds.[1] Goel & Tewari compared the use of NaviTip FX to passive ultrasonic irrigation at 400X magnification based on open dentin tubules and reported no differences between them.[18] However, Zmener et al found that the NaviTip FX irrigation needle was more effective than NaviTip in the brushing movement at 1000X magnification based on the percentage of debris covering.[4] It is necessary to point out that it is not possible to reconcile these different studies due to the changed magnifications as well as the different cleansing protocols (the other studies being based on the presence of debris on the surface of several open dentin tubules).

Special concern also exists regarding the penetration depth of the irrigating needle in the cleansing of the root canal systems.[4,13,14] In the present study, for all groups the needle device was introduced 2-3 mm from the working length and was progressively advanced to 1 mm after root canal enlargement. It has been established that irrigation devices produce irrigant exchange no further than 1 mm beyond the needle tip.[2,30]

No statistically significant differences were found in the cleansing of the root canal walls when comparing the RI to the OI system. It should be noted that all canals were instrumented apically up to an ISO No. 30 file. This ensured a standardized apical tip preparation for all groups regarding both RI and OI techniques. Controversy exists surrounding whether OI systems—that provide movements in all directions with short amplitude—can be more adequate for root canal disinfection compared to RI systems, as rotary devices provide a better-centered instrumentation, which might be assumed not to touch all regions of the canal wall.[15,24]

Conclusion

Endo-Eze, NaviTip FX, and NaviTip irrigation delivery devices used with 2.5% NaOCl and 17% EDTA showed similar effectiveness in the cleansing of the root canal walls, and each can be recommended for both OI and RI systems.

Author information

Dr. Ferreira is an auxiliary professor, Federal University of Pelotas, Brazil. Drs. Camargo and Gomes are adjunct professors, Universidade Estadual Paulista, Sao Jose dos Campos, Brazil, where Dr. Martinho is an assistant professor. Dr. Palo is a professor, Paulista University - UNIP, Campinas, Brazil.

References

1. Al-Hadlaq SM, Al-Turaiki SA, Al-Sulami U, Saad AY. Efficacy of a new brush-covered irrigation needle in removing root canal debris: a scanning electron microscopic study. *J Endod.* 2006;32(12):1181-1184.
2. Boutsioukis C, Lambrianidis T, Kastrinakis E, Bekiaroglou P. Measurement of pressure and flow rates during irrigation of a root canal ex vivo with three endodontic needles. *Int Endod J.* 2007;40(7):504-513.
3. Haapasalo M, Endal U, Zandi H, Coil J. Eradication of endodontic infection by instrumentation and irrigation solutions. *Endod Top.* 2005;10:71-102.
4. Zmener O, Pameijer CH, Serrano SA, Palo RM, Iglesias EF. Efficacy of the NaviTip FX irrigation needle in removing post instrumentation canal smear layer and debris in curved root canals. *J Endod.* 2009;35(9): 1270-1273.
5. Smith CS, Setchell DJ, Harty FJ. Factors influencing the success of conventional root canal therapy—a five-year retrospective study. *Int Endod J.* 1993; 26(6):321-333.
6. Zmener O, Pameijer CH, Alvarez Serrano S, Hernandez SR. Cleaning efficacy using two engine-driven systems versus manual instrumentation in curved root canals: a scanning electron microscopic study. *J Endod.* 2011; 37(9):1279-1982.
7. Arvaniti IS, Khabbaz MG. Influence of root canal taper on its cleanliness: a scanning electron microscopic study. *J Endod.* 2011;37(6): 871-874.
8. Bystrom A, Sundqvist G. The antibacterial action of sodium hypochlorite and EDTA in 60 cases of endodontic therapy. *Int Endod J.* 1985;18(1):35-40.
9. Lee SJ, Wu MK, Wesselink PR. The effectiveness of syringe irrigation and ultrasonics to remove debris from simulated irregularities within prepared root canal walls. *Int Endod J.* 2004;37(10):672-678.
10. van der Sluis LW, Gambarini G, Wu MK, Wesselink PR. The influence of volume, type of irrigant and flushing method on removing artificially placed dentine debris from the apical root canal during passive ultrasonic irrigation. *Int Endod J.* 2006;(6)39:472-476.
11. Abou-Rass M, Patonai FJ Jr. The effects of decreasing surface tension on the flow of irrigating solutions in narrow root canals. *Oral Surg Oral Med Oral Pathol.* 1982;53(5):524-526.
12. Shuping GB, Orstavik D, Sigurdsson A, Trope M. Reduction of intracanal bacteria using nickel-titanium rotary instrumentation and various medications. *J Endod.* 2000;26(12):751-755.
13. Altundasar E, Nagas E, Uyanik O, Serper A. Debris and irrigant extrusion potential of 2 rotary systems and irrigation needles. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2011;112(4):e31-e35.
14. Sedgley CM, Nagel AC, Hall D, Applegate B. Influence of irrigant needle depth in removing bioluminescent bacteria inoculated into instrumented root canals using real-time imaging in vitro. *Int Endod J.* 2005;38(2): 97-104.
15. Hulsmann M, Rummelin C, Schafers F. Root canal cleanliness after preparation with different endodontic handpieces and hand instruments: a comparative SEM investigation. *J Endod.* 1997;23(5):301-306.
16. Jodway B, Hulsmann M. A comparative study of root canal preparation with NiTi-TEE and K3 rotary Ni-Ti instruments. *Int Endod J.* 2006;39(1):71-80.
17. Schafer E, Zapke K. A comparative scanning electron microscopic investigation of the efficacy of manual and automated instrumentation of root canals. *J Endod.* 2000;26(11):660-664.
18. Goel S, Tewari S. Smear layer removal with passive ultrasonic irrigation and the NaviTip FX: a scanning electron microscopic study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2009;108(3):465-470.
19. Gutarts R, Nusstein J, Reader A, Beck M. In vivo debridement efficacy of ultrasonic irrigation following hand-rotary instrumentation in human mandibular molars. *J Endod.* 2005;31(3):166-170.
20. Setlock J, Fayad MI, BeGole E, Bruzick M. Evaluation of canal cleanliness and smear layer removal after the use of the Quantec-E irrigation system and syringe: a comparative scanning electron microscope study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2003; 96(5):614-617.
21. Vinothkumar TS, Kavitha S, Lakshminarayanan L, Gomathi NS, Kumar V. Influence of irrigating needle-tip designs in removing bacteria inoculated into instrumented root canals measured using single-tube luminometer. *J Endod.* 2007;33(6)746-748.
22. Kahn FH, Rosenberg PA, Gliksberg J. An in vitro evaluation of the irrigating characteristics of ultrasonic and subsonic handpieces and irrigating needles and probes. *J Endod.* 1995;21(5):277-280.
23. Garip Y, Sazak H, Gunday M, Hatipoglu S. Evaluation of smear layer removal after use of a canal brush: an SEM study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2010;110(2):e62-e66.
24. Wu MK, Wesselink PR. Efficacy of three techniques in cleaning the apical portion of curved root canals. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 1995; 79(4):492-496.
25. Paque F, Barbakow F, Peters OA. Root canal preparation with Endo-Eze AET: changes in root canal shape assessed by micro-computed tomography. *Int Endod J.* 2005;38(7):456-464.
26. Paque F, Musch U, Hulsmann M. Comparison of root canal preparation using RaCe and ProTaper rotary Ni-Ti instruments. *Int Endod J.* 2005;38(1):8-16.
27. Adcock JM, Sidow SJ, Looney SW, et al. Histologic evaluation of canal and isthmus debridement efficacies of two different irrigant delivery techniques in a closed system. *J Endod.* 2011;37(4):544-548.
28. Yeter KY, Evcil MS, Ayranci LB, Ersoy I. Weight of apically extruded debris following use of two canal instrumentation techniques and two designs of irrigation needles. *Int Endod J.* 2013;46(9):795-799.
29. Keir DM, Senia ES, Montgomery S. Effectiveness of a brush in removing postinstrumentation canal debris. *J Endod.* 1990;16(7):323-327.
30. Tay FR, Gu LS, Schoeffel GJ, et al. Effect of vapor lock on root canal debridement by using a side-vented needle for positive-pressure irrigant delivery. *J Endod.* 2010;36(4):745-750.

Manufacturers

Denton Vacuum, LLC—USA, Moorestown, NJ
800.666.6004, www.dentonvacuum.com

DENTSPLY Maillefer, Tulsa, OK
800.924.7393, www.maillefer.com

JEOL Ltd., Welwyn Garden City, England
44.170.7377.117, www.jeol.com

KaVo Dental, Charlotte, NC
800.452.1472, www.kavousa.com

KG Sorensen, Cotia, Brazil
55.11.4777.1061, www.kgsorensen.com.br

Microsoft, Redmond, WA
425.882.8080, www.microsoft.com

Minitab, State College, PA
814.238.3280, www.minitab.com

Ultradent Products, Inc., South Jordan, UT
888.230.1420, www.ultradent.com