

EFFECT OF FINAL IRRIGATION USING XP ENDO FINISHER FILE ON ORGANIC TISSUE DISSOLUTION FROM ARTIFICIAL GROOVES IN THE APICAL THIRD OF ROOT CANALS

Selen Küçükkaya Eren, DDS, PhD

Research Asistant, Department of Endodontics,
Faculty of Dentistry, Hacettepe University,
Ankara, Turkey

Hacer Aksel, DDS, PhD

Research Asistant, Department of Endodontics,
Faculty of Dentistry, Hacettepe University,
Ankara, Turkey

Sevinç Askerbeyli Örs, DDS

Research Asistant, Department of Endodontics,
Faculty of Dentistry, Hacettepe University,
Ankara, Turkey

Ahmet Serper, DDS, PhD

Professor, Department of Endodontics,
Faculty of Dentistry, Hacettepe University,
Ankara, Turkey

ABSTRACT

Background and Aim: The purpose of this study was to evaluate the effect of final irrigation using XP Endo Finisher file on tissue dissolution from simulated root canal irregularities and to compare its efficacy with ultrasonically activated irrigation (UAI).

Materials and Methods: The root canals of 70 maxillary central incisors were prepared and sectioned longitudinally. A standardized longitudinal intracanal groove was prepared in the apical thirds of 1 of the root halves. Human pulp tissues were collected, weighed and placed into the grooves. The reassembled specimens were randomly divided into 3 experimental groups (n=20) according to the final irrigation protocol: syringe irrigation (SI), UAI, and activation with XP Endo Finisher file. Ten specimens were served as control group in which the irrigation was performed with distilled water without activation. After completion of the irrigation, the pulp tissues were reweighed and the percentage differences in weights for each sample were calculated. Data were analysed using two-way repeated measures ANOVA and one-way ANOVA ($\alpha=0.05$).

Results: All experimental groups resulted in tissue dissolution, whereas no dissolution occurred in the control group. Irrigation with XP Endo Finisher file was associated with increased weight reduction compared with SI and UAI ($p<0.05$). No significant difference was found between the SI and UAI groups ($p>0.05$).

Conclusion: The final irrigation with XP Endo Finisher file was the most effective technique in the pulp tissue dissolution from standardized artificial grooves in the apical third of the root canals.

Correspondence

Selen Küçükkaya Eren, DDS, PhD

Department of Endodontics,
Faculty of Dentistry, Hacettepe University
06100 Sıhhiye, Ankara, Turkey,
Phone: +90 312 3052260
Fax: +90 312 3104440
E-mail address: selenkkaya@yahoo.com

Clin Dent Res 2018; 42(2): 57-63

Keywords: Activation, Irrigation, Tissue Dissolution,
Ultrasonic Irrigation, XP Endo Finisher.

Submitted for Publication: 04.08.2018

Accepted for Publication : 07.25.2018

XP ENDO FINISHER EĞESİ İLE YAPILAN FİNAL İRRİGASYONUN KÖKLERİN APİKAL ÜÇLÜSÜNDE HAZIRLANMIŞ OLUKLARDAKİ ORGANİK DOKUNUN ÇÖZÜNMESİNE ETKİSİ

Selen Küçükkaya Eren

Arş. Gör., Hacettepe Üniversitesi, Diş Hekimliği Fakültesi,
Endodonti Anabilim Dalı,
Ankara, Türkiye

Hacer Aksel,

Arş. Gör., Hacettepe Üniversitesi, Diş Hekimliği Fakültesi,
Endodonti Anabilim Dalı,
Ankara, Türkiye

Sevinç Askerbeyli Örs

Arş. Gör., Hacettepe Üniversitesi, Diş Hekimliği Fakültesi,
Endodonti Anabilim Dalı,
Ankara, Türkiye

Ahmet Serper

Prof. Dr., Hacettepe Üniversitesi, Diş Hekimliği Fakültesi,
Endodonti Anabilim Dalı,
Ankara, Türkiye

ÖZ

Amaç: Bu çalışmanın amacı, XP Endo Finisher eğesi ile yapılan final irrigasyonun köklerin apikal üçlüsünde hazırlanmış oluklarda yer alan organik dokunun çözünmesine etkisini incelemek ve bu etkinliği ultrasonik aktivasyon ile yapılan final irrigasyon (UAI) ile karşılaştırmaktır.

Gereç ve Yöntem: Yetmiş adet üst santral keser dişlerin kök kanalları genişletildi ve uzunlamasına ikiye bölündü. Herbir kökün bir yarısının apikal üçlüsünde standart oluklar açıldı. Toplanan pulpa dokuları tartıldı ve oluklara yerleştirildi. Kökler birleştirildi ve final irrigasyon protokolüne göre 3 deney grubuna rastgele olacak şekilde ayrıldı (n=20): standart irrigasyon (SI), UAI, ve XP Endo Finisher eğesi ile irrigasyon. Irrigasyonun sadece distile su ile yapıldığı 10 örnek kontrol grubu olarak ayrıldı. Sonrasında pulpa dokuları tekrar tartıldı ve ağırlık değişimi her bir örnek için yüzde olarak hesaplandı. İstatistiksel analiz tekrarlı ölçümlerde iki yönlü varyans analizi ve tek yönlü varyans analizi ile gerçekleştirildi ($\alpha=0.05$).

Bulgular: Tüm deney gruplarında doku çözünmesi gerçekleşirken, kontrol grubunda hiç çözünme gerçekleşmedi. XP Endo Finisher eğesi ile yapılan irrigasyon sonrası, diğer deney gruplarına göre daha fazla doku çözünmesi gerçekleşti ($p<0.05$). SI ve UAI arasında ise anlamlı fark yoktu ($p>0.05$).

Sonuç: XP Endo Finisher eğesi ile yapılan final irrigasyon protokolü kök kanallarının apikal üçlüsünde yer alan oluklardaki dokunun çözünmesinde en etkili yöntemdir.

Sorumlu Yazar

Selen Küçükkaya Eren

Hacettepe Üniversitesi, Diş Hekimliği Fakültesi,
Endodonti Anabilim Dalı
06100 Sıhhiye, Ankara, Türkiye,
Phone: +90 312 3052260
Fax: +90 312 3104440
E-mail address: selenkkaya@yahoo.com

Clin Dent Res 2018; 42(2): 57-63

Anahtar Kelimeler: Aktivasyon, Doku Çözünürlüğü, Irrigasyon, Ultrasonik Irrigasyon, XP Endo Finisher

Yayın Başvuru Tarihi : 08.04.2018

Yayına Kabul Tarihi : 25.07.2018

INTRODUCTION

The cleaning and disinfection of the root canal system is achieved by removal of debris, pulp tissue and microorganisms with the chemomechanical preparation of the root canals.¹ In this context, sodium hypochlorite (NaOCl) is used as the main endodontic irrigant due to its organic tissue dissolution and antimicrobial properties.² The elimination of residual pulp tissue, infected dentin or bacteria from the root canal system is important for the ultimate success of root canal treatment.³ However, inaccessibility of root canal irregularities such as resorptive defects, isthmuses and cul-de-sacs poses technical difficulties in complete debridement and predictable removal of the tissue present in these areas.⁴ The effectiveness of irrigation relies on the mechanical flushing action to remove debris and dissolve tissue.⁵ The flushing action created by syringe irrigation is relatively weak and increasing the volume of irrigant does not improve its efficacy.⁶

Irrigant activation has been recommended to effectively clean such irregularities without weakening the tooth structure.⁷ Ultrasonically activated irrigation (UAI) is one of the irrigant activation methods, which generates acoustic streaming and cavitation within the irrigation solution.⁸ UAI has been recommended to increase the ability of NaOCl to dissolve organic tissue.³

XP Endo Finisher file (FKG, La Chaux-de-Fonds, Switzerland) is a recently introduced irrigant activation system.⁹ The instrument has the small core size of #25, no taper and the alloy properties that enable the file to easily adapt the root canal anatomy by transformation to austenite phase, allowing the file to expand to 6 mm in diameter and to clean difficult to reach areas.⁹ Previous studies reported that XP Endo Finisher file effectively removed hard tissue debris, smear layer and calcium hydroxide from artificial grooves and simulated internal resorption cavities.¹⁰⁻¹² This file has the potential to be used for an effective root canal debridement during endodontic treatment of complex cases such as internal root resorption. However, the data regarding its effect on organic tissue dissolution are lacking. Therefore, the aim of this in vitro study was to assess pulp tissue dissolution from standardized artificial grooves in the apical third of root canals by irrigant activation using either XP Endo Finisher file or UAI. The null hypothesis was that there are no differences in pulp tissue dissolution from artificial grooves among the final irrigation protocols with syringe irrigation, UAI or XP Endo Finisher file.

MATERIALS AND METHODS

Following ethics committee approval (GO 17/852), 70 freshly extracted human maxillary central incisors and human dental pulps that were harvested from freshly extracted third molar teeth (18-25 year-old healthy donors) were obtained for the study.

Preparation of human dental pulp tissue samples

The coronal part of the human dental pulp tissues were harvested from freshly extracted human teeth (18-25 year-old healthy donors) (Figure 1A), washed in distilled water (DW), placed individually in 1.5 mL microcentrifuge tubes containing 1 mL of DW and stored at -20°C until they were used for the experiments. For the experiments, the frozen pulp fragments were allowed to thaw and removed from the tubes, blotted dry on absorbent paper, placed in new eppendorf tubes and weighed 3 times using a calibrated high-precision balance (Radwag, Radom, Poland). The weights were determined as the mean of 3 readings. The baseline weight of the fragments ranged between 5 and 8 mg.

Tooth selection and preparation of grooves

The extracted maxillary central incisors were assessed under 20x magnification using a dental operating microscope to exclude the teeth with open apices, resorptive defects and

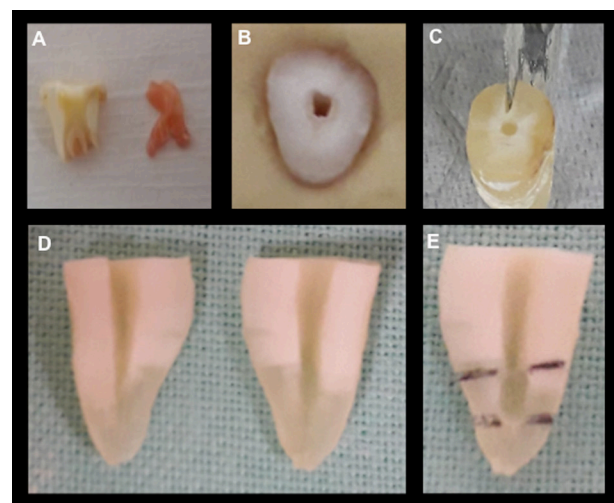


Figure 1. Preparation of the human dental pulp tissue and root samples. (A) Dental pulp tissues were harvested from the coronal part of freshly extracted human mandibular third molar teeth. (B) A specimen placed in its individual silicone mould. (C) A root sample with the longitudinal groove not reaching the canal. (D) The root halves after cleavage. (E) An artificial groove prepared at the apical part of the root half.

longitudinal fractures. The teeth were then confirmed for the presence of a single canal without previous root canal treatment, resorption or calcifications by preoperative radiographs taken from bucco-palatal and mesio-distal directions. Tooth length was standardized to 16 mm by cutting the coronal part using a slow-speed saw (Isomet Buhler, Lake Bluff, IL, USA). A #15 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was inserted in the root canals until it was visible through the apical foramen under magnification. Working length (WL) was established by reducing this length by 1 mm.

The artificial grooves were prepared as reported in previous studies.^{13,14} Accordingly, the apical 15 mm of the specimens was embedded in silicone impression material (Variotime, Heraeus Kulzer GmbH, Hanau, Germany) to create an individual mould for each sample (Figure 1B). The roots were then instrumented using ProTaper NiTi rotary files (Dentsply Maillefer, Ballaigues, Switzerland) up to F4 file. The root canal irrigation was performed with 1 mL of 5% NaOCl between the instruments using a syringe and a side-vented 30-G needle positioned at 2 mm short of the WL. After preparation, the roots were removed from the mould, and each root was cleaved into 2 fragments by preparing grooves on the buccal and lingual surfaces with a fine diamond disc without entering the root canal (Figure 1C). Then, the roots were split into 2 fragments using a disposable #15 scalpel blade (Figure 1D). For the standardization of the groove length and location, two lines perpendicular to root canal and the long axis to the tooth at the 2 and 6 mm from the WL as measured with a digital calliper were created using a fine-tip black marker in 1 of the root halves. The grooves (2-mm-wide, 2-mm-deep, and 4-mm-long) were then created with a 2-mm round diamond bur (Edenta Ag Dental Products, Hauptstrasse 7, Switzerland) (Figure 1E). After completion of the preparation, the root canals were rinsed with 3 mL of 5% NaOCl, 1 mL of 17% ethylenediaminetetraacetic acid (EDTA) and 3 mL of DW and dried with paper points.

One of the human dental pulp samples was subsequently placed inside of each longitudinal groove, and the root halves were rejoined and the teeth were positioned in their silicone moulds.

Root canal irrigation

The 70 reassembled roots were randomly allocated into 3 groups (n=20) and a control group (n=10) as follows:

The syringe irrigation (SI) group: The root canals were

irrigated using 3 mL of 5% NaOCl for 60 sec followed by 1 mL of 17% EDTA for 30 sec and finally 3 mL of NaOCl for 30 sec using a 27 G side-vented needle at 2 mm from the WL.

The ultrasonically activated irrigation (UAI) group: An ultrasonic tip (size #20, no taper) mounted on an ultrasonic unit (P5 Newton unit, Satelec Acteon, Merignac, France) at a power setting of 4 was placed at 2 mm from the WL. The root canals were irrigated with 3 mL of 5% NaOCl for 60 sec by continuous irrigant delivery using 27 G side-vented needle through the pulp chamber and activation with UAI, followed by 1 mL of 17% EDTA for 30 sec and 3 mL of 5% NaOCl for 30 sec.

The XP Endo group: XP Endo Finisher file was mounted in a torque-controlled endodontic motor (VDW Gold, Munich, Germany). The root canals were irrigated with 3 mL of 5% NaOCl for 60 sec using continuous irrigant delivery using 27 G side-vented needle through the pulp chamber and activation with XP Endo finisher file at 2 mm short of the WL with 800 rpm speed and 1 Ncm torque values, followed by 1 mL of 17% EDTA for 30 sec and 3 mL of NaOCl for 30 sec.

The control group: A total of 7 mL of DW was delivered using a 27 G side-vented needle at 2 mm from the WL for 120 sec. Following the irrigation procedures, all canals were flushed with 5 mL of DW and dried with paper points. The roots were disassembled, and the tissue samples were weighed in triplicate as previously described. The same operator performed root canal preparation, pulp tissue preparation and irrigation assays. A second operator who was blinded to group allocation of the samples dried the canals, disassembled the roots, rinsed, blotted dry, and weighed the pulp tissue samples. The percentage differences in weights for each sample after irrigation assay were calculated and the mean percentage loss was determined.

Statistical Analysis

Normal distribution of the data was verified using Kolmogorov-Smirnov test. The initial and final weight changes in each group were statistically analysed using two-way repeated-measures analysis of variance (ANOVA). The weight changes among the groups were statistically compared using one-way ANOVA. The statistical analysis was performed using the Statistical Package for the Social Sciences software (SPSS 20.0, SPSS Inc, Chicago, IL). A value of $p < 0.05$ was considered statistically significant.

RESULTS

Table 1 presents the mean and standard deviations for initial and final weights (mg), weight changes, and percentage of reduction for the groups after the irrigation assays. The baseline weight values among the groups were not statistically different from each other ($p>0.05$). The experimental groups resulted in tissue dissolution, whereas no significant loss in tissue weight was observed in the control group. There were significant differences among the groups in terms of weight reduction ($p<0.05$). The XP Endo group showed the highest weight reduction and it was followed by the UAI group ($p<0.05$). However, no significant difference was found between the UAI and SI groups ($p>0.05$).

DISCUSSION

Tissue debridement in root canal irregularities can be challenging and ineffective due to the inaccessible areas.¹⁵ Although NaOCl has a detrimental effect on the dissolution of the remaining pulp tissue, organic residues may lead to treatment failure¹⁶ and the activation of NaOCl has been recommended to enhance the debridement efficacy.¹⁷ Recent studies have shown superior effect of XP Endo Finisher file on root canal cleaning and disinfection of the root canals.^{10,18} In the current study, the effect of XP Endo Finisher file on the tissue dissolution was investigated and the results showed that XP Endo Finisher file presented the highest tissue dissolution compared with UAI and syringe irrigation. The null hypothesis that there was no significant difference in pulp tissue dissolution from artificial grooves among the tested groups was rejected. Several studies have investigated tissue dissolution ability of irrigation solutions.^{13, 19, 20} In a recent study epoxy resin

model was used instead of using extracted teeth,²¹ while in others tissue dissolution was evaluated by placing tissue in NaOCl solutions directly.^{22, 23} It is noteworthy to mention that such methodological designs may not simulate the exact clinical situation as dentin has buffering effect that reduces the tissue dissolution capacity of NaOCl.²⁴ To simulate this effect, dentin powder was placed into the test solutions in a previous study.²² However, this may also not reflect the clinical condition, since NaOCl was found ineffective at dissolving pulp tissue in the apical region of the root canals and narrow isthmus areas.²⁵ In the present study, artificial grooves were prepared within the root canals of teeth which represented a closed system that limits the flow of irrigant through the apical area.²⁶

The tissue dissolution possibly occurs during the entire period of chemomechanical preparation of the root canals. One of the limitations of the present study was to investigate only the effect of final irrigation procedures on tissue dissolution. Because of the experimental design of this in vitro study, it was not possible to prepare the grooves before the chemomechanical preparation of the root canals, as root canal preparation may lead to dislodgement or the removal of the tissue samples from the grooves. Therefore, to evaluate and compare the effect of final irrigation protocols on tissue dissolution from simulated grooves, a methodology similar to previous studies was conducted.^{13, 14} In previous studies, various types of tissue samples have been used including porcine muscle tissue,²⁷ porcine palatal mucosa,²⁸ bovine muscle tissue²⁹ and bovine pulp.²² Indeed, the reason for using these tissues instead of human dental pulp is related to their availability. However, most of these tissues are fairly dense with a high content of connective tissue fibres that require longer time to dissolve than

Table 1. The mean (SD) of the initial and final weights (mg), weight changes (mg), and percentage of reduction for the experimental groups

Groups	Initial weight	Final weight	Weight change (initial - final)	Percentage of weight reduction
Control (DW)	6.42 (0.69) ^{*a}	6.31 (1.09) ^{*a}	0.11 (1.06)	1.20 ^a
SI	6.60 (1.04) ^{*a}	3.85 (1.62) ^{#b}	2.75 (1.58)	41.62 ^b
UAI	6.32 (1.38) ^{*a}	3.49 (1.52) ^{#b}	2.83 (1.21)	45.60 ^b
XP Endo	6.73 (1.11) ^{*a}	1.71 (1.59) ^{#c}	5.02 (2.06)	73.24 ^c

Different symbol in each row indicate significant differences between initial and final weights ($p<0.05$). Different letters in each column indicate significant differences among the groups ($p<0.05$). DW: distilled water, SI: syringe irrigation, UAI: ultrasonically activated irrigation, XP Endo: XP Endo Finisher file.

human dental pulp tissue.³⁰ In the present study, fresh human dental pulp tissue was collected and the tissue samples were cut into similar weight for standardization. The use of human dental pulp tissue may enable the results obtained from experimental conditions to be adapted to the clinic more accurately.

The efficacy of NaOCl in tissue dissolution can be improved by increasing the pH.²⁷ Alkaline solutions have a powerful oxidative effect that results in greater tissue dissolution compared with acidic solutions.³¹ For this reason, the pH was kept at pH 12 in the present study as recommended previously.²⁷

In the present study, tissue dissolution was observed only in NaOCl treated groups while distilled water had no effect on tissue dissolution in agreement with previous studies.^{20, 28} The impact of mechanical agitation of the hypochlorite solutions on tissue dissolution has been emphasized previously.²² Several studies have reported that ultrasonic activation of NaOCl improved the tissue dissolution by increasing the penetration and replacement of the solution.^{21, 32} In the present study, ultrasonic activation of NaOCl resulted in similar tissue dissolution to SI. This finding might stem from the increased diameter of the root canal by the artificial grooves that can reduce the streaming and cavitation effect of UAI.³³ In addition, the streaming and cavitation might have occurred less likely in the apical area where the artificial grooves were located.²¹

Based on the present findings, the highest dissolution was achieved in the XP Endo group. Previous studies reported similar effects of XP Endo Finisher file and UAI on the removal of calcium hydroxide from artificial grooves in the apical part of the root canals.^{12, 34} Conversely, another study reported better cleaning efficacy of XP Endo Finisher file compared with UAI in immature root models.³⁵ The different findings might be related to the experimental design or the instrument properties itself. The XP Endo Finisher file can expand and adapt to the root canal anatomy owing to its metallurgy and the expansion of the file might have increased the mechanical effects of the file on tissue dissolution in the artificial grooves.

CONCLUSION

Within the limitations of this in vitro study, the final irrigation with XP Endo Finisher file was the most effective technique in tissue dissolution from the artificial grooves located at the apical third of root canals. The tissue dissolution effect of UAI was similar to syringe irrigation.

CONFLICT OF INTEREST

No author of this article has a conflict of interest, including specific financial interests, relationships, and/or affiliations relevant to the subject matter or materials included in the manuscript.

REFERENCES

1. Siqueira JF, Rôças IN. Clinical implications and microbiology of bacterial persistence after treatment procedures. *J Endod* 2008; 34: 1291-1301.
2. Zehnder M. Root canal irrigants. *J Endod* 2006; 32: 389-398.
3. Moorer W, Wesselink P. Factors promoting the tissue dissolving capability of sodium hypochlorite. *Int Endod J* 1982; 15: 187-196.
4. Hülsmann M, Peters OA, Dummer PM. Mechanical preparation of root canals: shaping goals, techniques and means. *Endod Topics* 2005; 10: 30-76.
5. Baker NA, Eleazer PD, Averbach RE, Seltzer S. Scanning electron microscopic study of the efficacy of various irrigating solutions. *J Endod* 1975; 1: 127-135.
6. Walters MJ, Baumgartner JC, Marshall JG. Efficacy of irrigation with rotary instrumentation. *J Endod* 2002; 28: 837-839.
7. Burleson A, Nusstein J, Reader A, Beck M. The in vivo evaluation of hand/rotary/ultrasound instrumentation in necrotic, human mandibular molars. *J Endod* 2007; 33: 782-787.
8. van der Sluis LW, Versluis M, Wu MK, Wesselink PR. Passive ultrasonic irrigation of the root canal: a review of the literature. *Int Endod J* 2007; 40: 415-426.
9. Trope M, Debelian G. XP-3D Finisher™ file—the next step in restorative endodontics. *Endod Pract US* 2015; 8: 22-24.
10. Elnaghy AM, Mandorah A, Elsaka SE. Effectiveness of XP-endo Finisher, EndoActivator, and File agitation on debris and smear layer removal in curved root canals: a comparative study. *Odontology* 2017; 105: 178-183.
11. Keskin C, Sariyilmaz E, Sariyilmaz O. Efficacy of XP-endo Finisher File in Removing Calcium Hydroxide from Simulated Internal Resorption Cavity. *J Endod* 2017; 43: 126-130.
12. Kfir A, Blau-Venezia N, Goldberger T, Abramovitz I, Wigler R. Efficacy of self-adjusting file, XP-endo finisher and passive ultrasonic irrigation on the removal of calcium hydroxide paste from an artificial standardized groove. *Aust Endod J* 2018; 44: 26-31.
13. Conde A, Estevez R, Loroño G, Valencia de Pablo Ó, Rossi Fedele G, Cisneros R. Effect of sonic and ultrasonic activation on organic tissue dissolution from simulated grooves in root canals

using sodium hypochlorite and EDTA. *Int Endod J* 2017; 50: 976-982.

14. Estevez R, Conde AJ, Valencia de Pablo O, de la Torre F, Rossi-Fedele G, Cisneros R. Effect of Passive Ultrasonic Activation on Organic Tissue Dissolution from Simulated Grooves in Root Canals Using Sodium Hypochlorite with or without Surfactants and EDTA. *J Endod* 2017; 43: 1161-1165.

15. Yang S-F, Rivera EM, Walton RE, Baumgardner KR. Canal debridement: effectiveness of sodium hypochlorite and calcium hydroxide as medicaments. *J Endod* 1996; 22: 521-525.

16. Siqueira J. Aetiology of root canal treatment failure: why well treated teeth can fail. *Int Endod J* 2001; 34: 1-10.

17. Lee SJ, Wu MK, Wesselink P. The effectiveness of syringe irrigation and ultrasonics to remove debris from simulated irregularities within prepared root canal walls. *Int Endod J* 2004; 37: 672-678.

18. Azim AA, Aksel H, Zhuang T, Mashtare T, Babu JP, Huang GT-J. Efficacy of 4 irrigation protocols in killing bacteria colonized in dentinal tubules examined by a novel confocal laser scanning microscope analysis. *J Endod* 2016; 42: 928-934.

19. Tanomaru-Filho M, Silveira BR, Martelo RB, Guerreiro-Tanomaru JM. Influence of Concentration and Agitation of Sodium Hypochlorite and Peracetic Acid Solutions on Tissue Dissolution. *J Contemp Dent Pract* 2015; 16: 876- 879.

20. Tartari T, Oda DF, Zancan RF, da Silva TL, de Moraes IG, Duarte MA, et al. Mixture of alkaline tetrasodium EDTA with sodium hypochlorite promotes in vitro smear layer removal and organic matter dissolution during biomechanical preparation. *Int Endod J* 2017; 50: 106-114.

21. Al-Jadaa A, Paque F, Attin T, Zehnder M. Necrotic pulp tissue dissolution by passive ultrasonic irrigation in simulated accessory canals: impact of canal location and angulation. *Int Endod J* 2009; 42: 59-65.

22. Guner MB, Arslan D, Usumez A. Tissue dissolution ability of sodium hypochlorite activated by photon-initiated photoacoustic streaming technique. *J Endod* 2015; 41: 729-732.

23. Haapasalo M, Wang Z, Shen Y, Curtis A, Patel P, Khakpour M. Tissue dissolution by a novel multisonic ultracleaning system and sodium hypochlorite. *J Endod* 2014; 40: 1178-1181.

24. Slutzky-Goldberg I, Hanut A, Matalon S, Baev V, Slutzky H. The effect of dentin on the pulp tissue dissolution capacity of sodium hypochlorite and calcium hydroxide. *J Endod* 2013; 39: 980-983.

25. Senia ES, Marshall FJ, Rosen S. The solvent action of sodium hypochlorite on pulp tissue of extracted teeth. *Oral Surg Oral Med Oral Pathol* 1971; 31: 96-103.

26. de Gregorio C, Arias A, Navarrete N, Del Rio V, Oltra E, Cohenca N. Effect of apical size and taper on volume of irrigant delivered at working length with apical negative pressure at different root curvatures. *J Endod* 2013; 39: 119-124.

27. Christensen CE, McNeal SF, Eleazer P. Effect of lowering the pH of sodium hypochlorite on dissolving tissue in vitro. *J Endod* 2008; 34: 449-452.

28. Naenni N, Thoma K, Zehnder M. Soft Tissue Dissolution Capacity of Currently Used and Potential Endodontic Irrigants. *J Endod* 2004; 30: 785-787.

29. Stojicic S, Zivkovic S, Qian W, Zhang H, Haapasalo M. Tissue dissolution by sodium hypochlorite: effect of concentration, temperature, agitation, and surfactant. *J Endod* 2010; 36: 1558-1562.

30. Zehnder M, Kosicki D, Luder H, Sener B, Waltimo T. Tissue-dissolving capacity and antibacterial effect of buffered and unbuffered hypochlorite solutions. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2002 ;94: 756-762.

31. Baker R. Studies on the reaction between sodium hypochlorite and proteins: 1. Physico-chemical study of the course of the reaction. *Biochem J* 1947; 41: 337-342

32. Niewierowski RS, Scalzilli LR, Morgental RD, Figueiredo JA, Vier-Pelisser FV, Borba MG, et al. Bovine Pulp Tissue Dissolution Ability of Irrigants Associated or Not to Ultrasonic Agitation. *Braz Dent J* 2015; 26: 537-540.

33. Macedo RG, Wesselink PR, Zaccheo F, Fanali D, Van Der Sluis LW. Reaction rate of NaOCl in contact with bovine dentine: effect of activation, exposure time, concentration and pH. *Int Endod J* 2010; 43: 1108-1115.

34. Wigler R, Dvir R, Weisman A, Matalon S, Kfir A. Efficacy of XP-endo finisher files in the removal of calcium hydroxide paste from artificial standardized grooves in the apical third of oval root canals. *Int Endod J* 2017; 50: 700-705.

35. Turkaydin D, Demir E, Basturk FB, Sazak Ovecoglu H. Efficacy of XP-Endo Finisher in the Removal of Triple Antibiotic Paste from Immature Root Canals. *J Endod* 2017; 43: 1528-1531.