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EFFECTS OF SIZE AND OPERATING MODE OF SONICALLY OSCILLATING FILES ON IRRIGANT EXTRUSION

Sonik Uçların Boyutunun ve Çalışma Modunun Irrigant Taşmasına Etkisi

Selen KÜÇÜKKAYA EREN, Ahmet KELEŞ, Özgür UYANIK,

Behram TUNCEL, Emre NAGAS

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ABSTRACT

Objective: The purpose of this study was to evaluate the effects of size and oscillation frequency of sonic tips on irrigant extrusion during activation.

Materials and Methods: Twenty artificial maxillary molar tooth models were used in this study. The palatinal canal of each model was prepared up to final apical size of #40. Each specimen was mounted on a glass vial filled with saline solution to simulate a periapical lesion. The initial weights were measured using an analytical balance with 10^{-5} g accuracy. Then, a series of irrigations were conducted according to the size (15/.02, 25/.04, 35/.04) and operating mode/speed (low, medium, high) of the sonic tips. In control group, the irrigant was delivered by placing the needle tip at the access cavosurface, without the insertion and activation of the sonic tip. The mean weights of apically extruded irrigant were calculated by subtracting the mean initial weights from the final weights of test apparatus. Data were statistically analyzed by the Kruskal-Wallis and Siegel Castellan tests.

Results: The use of 15/.02 tips resulted in higher irrigant extrusion than the control only at high speed while the 35/.04 tips only at low speed ($p<0.05$). The 25/.04 tips presented higher extrusion than the control with all operating modes ($p<0.05$). At high speed mode, both the 15/.02 and 25/.04 tips were associated with higher irrigant extrusion than the 35/.04 tips ($p<0.05$).

Conclusion: Both the size and oscillation frequency of the sonic tips had significant effects on irrigant extrusion during sonically activated irrigation.

Keywords: apical extrusion, EndoActivator, irrigation, sodium hypochlorite, sonic activation

ÖZ

Amaç: Bu çalışmanın amacı irrigant aktivasyonu sırasında kullanılan sonik uçların boyutunun ve titreşim sıklığının irrigant taşmasına etkisini değerlendirmektir.

Gereç ve Yöntemler: Bu çalışmada 20 adet yapay üst molar diş modeli kullanıldı. Her bir modelin palatinal kanalı apikal çap #40 olacak şekilde genişletildi. Periapikal lezyonu taklit etmek için her bir diş modeli salin solusyonu ile dolu cam şişelere yerleştirildi. İlk ağırlıklar 10^{-5} g hassasiyetindeki hassas tartı ile ölçüldü. Sonrasında sonik ucun boyutu (15/.02, 25/.04, 35/.04) ve uygulama modu/hızı (düşük, orta, yüksek hız) esas alınarak irrigasyon protokolleri uygulandı. Kontrol grubunda irrigasyon herhangi bir sonik uç kullanmadan ve aktivasyon yapılmadan iğne ucunun giriş kavitesinin girişinde tutulması ile gerçekleştirildi. Apikalden taşan irrigantın ortalama ağırlığı, test düzeneğinin başlangıç ağırlığının ortalamasından, final ağırlığının ortalamasının çıkarılmasıyla hesaplandı. Veriler Kruskal-Wallis ve Siegel Castellan testleri analiz edildi.

Bulgular: Kontrol grubuna kıyasla, 15/.02 uçlar sadece yüksek hızda daha fazla irrigant taşmasına yol açarken, 35/.04 uçlar düşük hızda neden oldu ($p<0,05$). 25/.04 uçlar tüm hızlarda kontrol grubuna göre daha fazla irrigant taşması gösterdi ($p<0,05$). Yüksek hızda 15/.02 ve 25/.04 uçlar, 35/.04 uç kullanımına göre daha fazla irrigant taşmasına neden oldu ($p<0,05$).

Sonuç: Sonik aktivasyon sırasında kullanılan sonik ucun hem çapı hem de titreşim sıklığı irrigant taşmasını anlamlı ölçüde etkilemektedir.

Anahtar Kelimeler: apikal taşma, EndoActivator, irrigasyon, sodyum hipoklorit, sonik aktivasyon

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

INTRODUCTION

One of the primary goals of root canal treatment is to clean and disinfect the root canal system via the mechanical and chemical effects of irrigants on the removal of microorganisms and tissue remnants.[1] However, while conventional irrigation with syringes has been accepted as an efficient method of irrigant delivery,[2] the mechanical flushing action created by this method is relatively weak and thorough cleaning of inaccessible canal extensions and irregularities in the root canal system is difficult to achieve.[3] Irrigant agitation has been recommended to facilitate the dispersion and replenishment of irrigants in the root canal system.[4] In this regard, sonic and ultrasonic devices have been extensively tested as irrigant agitation equipment.[2,4]

Low-frequency irrigation with sonic activation produces smaller shear stresses and generates greater back-and-forth tip movement than ultrasonic irrigation.[2] Sonic activation generates mechanical agitation at the tip of files, and sideway oscillation disappears when the movement of the sonic file is constrained, resulting in pure, longitudinal file oscillation.[2,4] This mode of action has been found to increase the tissue-dissolving activity of irrigants[5] and enhance root canal cleaning.[6] The EndoActivator System (Dentsply, Tulsa Dental Specialties, Tulsa, OK) is a sonically driven irrigant activation system that uses frequencies in the range of 160-190 Hz.[7] This device comprises a portable handpiece and disposable flexible noncutting polymer tips of three different sizes (15/.02, 25/.04, 35/.04) and is operated at three different modes/power settings (low speed, medium speed, high speed).[7]

Sodium hypochlorite (NaOCl) is accepted as the primary irrigant of choice because of its tissue-dissolving capability and strong antimicrobial properties.[8] However, it is extremely caustic in contact with vital tissue, and its extrusion through the apical foramen can cause severe pain, a burning sensation, and periapical tissue damage.[9] Therefore, a balance between safety and effectiveness should be maintained when irrigation is performed. The action of NaOCl should be restricted within the root canal system, but it should also penetrate the full extent of the canal to exert its favorable actions.[10]

The extent of extrusion has been reported to be related to several factors, including apical preparation size, irrigation technique, depth of needle insertion, and irrigant flow rate.[11,12] The size and oscillation amplitude of tips that are used for irrigant activation may also affect the amount of apical extrusion. However, the literature on the effects of size and operating mode of sonically oscillating files on irrigant extrusion is limited. Therefore, the purpose of this study is to evaluate the effects of size and oscillation frequency of sonic tips on the apical extrusion of NaOCl during sonic activation. The null hypothesis tested is that the size and oscillation frequency of the sonic tips do not affect the amount of extruded irrigant.

MATERIALS AND METHODS

Specimen Preparation

Twenty artificial maxillary molar tooth models with open access cavities (VDW, Munich, Germany) were used in this study. The buccal roots of each model were removed with burs (Edenta Ag Dental Products, Haupstrasse, Switzerland) and the coronal orifices of the buccal canals were sealed with a cyanoacrylate adhesive (Zapit, DVA, Anaheim, CA, USA). A size 15 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was introduced into the palatinal canal until it was just visible at the apical foramen to facilitate working length (WL) determination. The WL was determined 1 mm short of this measurement. The palatinal canal of each model was prepared using ProTaper rotary files (Dentsply Maillefer) up to F4 mounted on a torque-controlled reduction handpiece (X-Smart, Dentsply Maillefer) at a speed of 300 rpm and torque of 3 N/cm. Irrigation was performed with 2 mL of 2.5% NaOCl (Werax, İzmir, Turkey) between each instrument. After completion of the preparation, the canals were irrigated with 5 mL of 2.5% NaOCl and dried with paper points (Dentsply Maillefer).

Test Apparatus

Irrigant extrusion was determined using a glass vial model. The rubber stoppers of the glass vials were adjusted by a heated instrument to create a hole through the center for holding the specimen in upright position. Then, the specimens were inserted into the rubber stoppers and fixed to the stoppers from the cementoenamel junction using the cyanoacrylate adhesive. The vials were filled with 10 mL saline solution. The specimen–rubber stopper unit was fitted into the mouth of the vials by allowing the suspension of the apical part of the palatinal root within the vial. Each vial was vented with a sterile 27-gauge needle (Ultradent, South Jordan, UT, USA) alongside the rubber stopper to equalize the air pressure inside and outside the vial.

Irrigation Procedures

Aluminium foils were used to cover the vials to prevent the operator from viewing irrigant extrusion during the irrigation procedure. To ensure that any apical extrusion occurred was solely from the tested irrigation system, 30-G side-vented needle (Max-i-probe, Dentsply, Rinn, Elgin, IL, USA) was used to passively fill the canals with 2.5% NaOCl by placing the needle tip at the entrance of access cavity immediately before sonically activated irrigation. Then, a sonic tip of EndoActivator (Dentsply, Tulsa Dental Specialties, Tulsa, OK) was placed at 2 mm from the WL and activated while irrigant continued to be given from the canal orifice. A pumping action with 2-mm to 3-mm vertical strokes was also used to agitate the irrigant. A total of 4 mL irrigant was activated with the sonic device for 60 seconds. A series of irrigations were conducted on the same 20 specimens according to the tip size and operating mode (Table 1). A new polymer tip was used every 4 measurements. In control group, 4 mL of irrigant was delivered by placing the needle tip at the entrance of access cavity, without the insertion and activation of the sonic tip. During the delivery of the irrigant, a suction tip was placed near the access cavity for the aspiration of excess irrigant. Finally, each root canal was dried with paper points.

Table 1. The tip size and operating mode of the sonic device in the groups (n=20)

Groups	Tip Size	Operating Mode (Speed)
1 (Control)	-	-
2	15/.02	Low
3	15/.02	Medium
4	15/.02	High
5	25/.04	Low
6	25/.04	Medium
7	25/.04	High
8	35/.04	Low
9	35/.04	Medium
10	35/.04	High

Determination of Apically Extruded Irrigant

Before the irrigation procedures, each test apparatus (the glass vial-specimen-rubber stopper unit) was numbered and weighed using an analytical balance with 10^{-5} g accuracy (Radwag, Radom, Poland) thrice. The mean values were calculated and accepted as initial weight. After each irrigation procedure, aluminium foils were removed and each test apparatus was reweighed thrice. Then, the mean values were calculated and accepted as final weight. Apically extruded irrigant was calculated by subtracting the initial weight of the apparatus from the final weight. Because the same models were used repeatedly in all groups, each model was reestablished and weighed as described above, before starting a new group.

In the present study, a single operator performed the root canal preparation and irrigation procedures and a second operator who was blinded to the groups performed the weight analyses.

Statistical Analysis

Data were analyzed by the Kruskal-Wallis and Siegel Castellan tests. The level of significance was set at p = 0.05. All statistical analyses were performed using SPSS software (SPSS 22 for Windows, SPSS Inc., Chicago, IL, USA).

RESULTS

The descriptive statistics of the distribution of irrigant extrusion amount in the groups are shown in Table 2.

Table 2. Descriptive statistics of the distribution of irrigant extrusion amount in the groups

Groups		Mean (g)	Median	Minimum	Maximum
Control		0.001[a]	0	0	0.004
15/.02	Low	0.003[a,1,❖]	0.001	0	0.018
	Medium	0.013[a,1,2,❖]	0.004	0	0.127
	High	0.054[b,2,❖]	0.014	0	0.292
25/.04	Low	0.008[b,1,❖]	0.008	0	0.018
	Medium	0.025[b,1,2,❖]	0.008	0	0.164
	High	0.026[b,2,❖]	0.019	0	0.168
35/.04	Low	0.005[b,1,❖]	0.004	0	0.011
	Medium	0.004[a,1,❖]	0.002	0	0.014
	High	0.004[a,1,#]	0.003	0	0.009

[(a)(b)(1)(2)(∵)]Different superscript letters indicate significant differences between each experimental group and the control. Different numbers indicate significant differences among the operating modes of each sonic tip. Different symbols indicate significant differences among the sonic tips at each operating mode.

Significant differences in the amount of extruded irrigant beyond the apex were observed among the groups ($p<0.05$). The use of 25/.04 tips resulted in higher irrigant extrusion than the control group with all operating modes ($p<0.05$). There were no significant differences between the control group and 15/.02 tips at low and medium speed ($p>0.05$), while 15/.02 tips resulted in higher irrigant extrusion than the control group at high speed ($p<0.05$). The use of 35/.04 tips presented similar irrigant extrusion to the control group at medium and high speed ($p>0.05$), while resulted in higher irrigant extrusion than the control group at low speed ($p<0.05$). The apical extrusion was significantly higher at high speed mode than low speed when the 15/.02 and 25/.04 tips were used ($p<0.05$). There were no significant differences in the extrusion amount among the opeating modes when the 35/.04 tips were used ($p>0.05$). At high speed mode, both the 15/.02 and 25/.04 tips were associated with higher irrigant extrusion than the 35/.04 tips ($p<0.05$), while there were no significant differences among different tips at low and medium operating modes ($p>0.05$).

DISCUSSION

Inadvertent NaOCl extrusion during root canal treatment and its sequelae have been reported in many case reports.[13-15] Although the minimum amount of extruded irrigant that may exert clinically significant effects remains unclear, the goal of work in this area is to minimize this incident. In the present study, the effects of size and oscillation frequency of sonic tips on the apical extrusion of NaOCl during sonic activation were evaluated and both parameters were found to be significant in irrigant extrusion. Therefore, the null hypothesis was rejected.

Based on the present findings, irrigant activation with 15/.02 and 25/.04 tips caused higher amounts of extrusion at the high-speed mode than at the low-speed mode. This result was expected as, in principle, a higher frequency causes a higher flow velocity.[16] In contrast to the present findings, a previous study in which only 15/.02 tips were used and the canals were prepared to an apical size of #35, compared the low- and high-power settings of the EndoActivator System in terms of irrigant extrusion and found no significant difference between them.[12] Different results among studies can be attributed to variability in the study designs, including apical preparation size, duration of irrigant agitation, and agitation type (intermittent or continuous).

In intermittent irrigation, the irrigant is delivered to the root canal by a syringe needle and then activated with the use of an oscillating instrument.[2] The continuous irrigation technique provides an uninterrupted supply of fresh irrigation solution in the root canal while reducing the time required for irrigant activation.[2] In the present study, sonic agitation was performed while the irrigant was delivered from the coronal canal orifice continuously as described in previous studies.[17,18] This described irrigation technique has shown to be effective in eliminating the microbial content of the root canals.[18]

According to the current results, the use of 35/.04 tips presented similar irrigant extrusion at three operating modes but resulted in less extrusion than the other sonic tips when operated at high speed. One explanation for this result can be a decrease in irrigant flow in the canal when 35/.04 tips are used. Although each canal was enlarged to an apical size of #40 to test all three available tips of the sonic system, the 35/.04 tips may have had less space around them for oscillation than the other tips. In a previous study, the 25/.04 and 35/.04 tips were tested in teeth with apical preparation sizes of #35 and #55, respectively, and no significant difference was found between them in terms of irrigant extrusion.[19] However, that result could be attributed to the apical preparation size rather than the size of the sonic tips. According to a recent study, the 15/.02 and 25/.04 tips of the same sonic system presented similar results in terms of root canal cleaning efficacy when operated at both low and high speed.[7] In that study, the 35/.04 tips could not be tested because the apical size of each model was enlarged to #30.[7] Although the 35/.04 tips were associated with less extrusion in the present study, this result should be interpreted with caution as these tips may lead to inferior canal cleaning compared with the other tips because of the decreased irrigant flow around them. Of note, the use of 35/.04 tips at high power setting was found to be more effective than other combinations in removing stained collagen from the canal surface and this result was attributed to increased energy applied to the irrigant as a result of greater tip rigidity.[20]

Several methods have been used to mimic periapical tissue resistance during irrigant extrusion *in vitro*. Although periapical tissues may act as a natural barrier to prevent apical extrusion *in vivo*, several studies have neglected the possible effect of periapical tissues by evaluating extrusion into vials full of air.[17,21,22] According to a previous study, the vial filled with water represented the clinical situation better than the vial completely filled with ambient air.[23] In the present study, a glass vial model filled with saline solution was used to determine apical extrusion similar to previous reports.[24-26] NaOCl accidents have been reported to generally occur in teeth with periapical pathology.[27] Although the exact amount of pressure in the apical area of teeth is unknown, the model used in the current study may simulate some degree of apical resistance of a periapical lesion.

Other factors considered earlier in the root canal treatment process, such as irrigation during root canal instrumentation, may affect the potential for apical extrusion. In the present study, the root canals were instrumented and irrigated between each instrument before being placed in the test apparatus to allow for direct comparison of the final irrigation procedures only. To minimize considerable variations between the groups and produce a reliable and comparable anatomic baseline, artificial tooth models were used in this study. Similar to previous studies, the same models were reused in all groups because no detectable degradation was expected with sonically activated irrigation.[12,23,28]

CONCLUSIONS

Within the limitations of this *in vitro* study, both the size and oscillation frequency of the sonic tips can be concluded to exert significant effects on extrusion during sonically activated irrigation. Sonic activation with the 15/.02 tips at low and medium speed and with the 35/.04 tips at medium and high speed presented results comparable with those of the control in terms of irrigant extrusion. Clinically, selection of a technique that reduces the amount of apical extrusion should be a part of the decision-making process for the final irrigation system to apply. In this regard, the information obtained from the present study may contribute to future clinical applications of the technology. However, further research is required to evaluate whether these methods provide adequate cleaning effects during final irrigation of the root canal system.

Conflicts of interest

The authors declare no potential conflicts of interest with respect to the authorship and/or publication of this article.

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Corresponding Author

Selen KÜÇÜKKAYA EREN

Hacettepe University

Faculty of Dentistry

Department of Endodontics

Sıhhiye, Ankara/Turkey, 06100

Phone : +90 312 305 22 60

Fax : +90 312 310 44 40

E-mail : selenkkkaya@yahoo.com