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Evaluation of Calcium Hydroxide Removal Efficiency of Different Irrigation Techniques by Microleakage Assessment Using Computerized Liquid Filtration Method

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Research Article

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ABSTRACT

Aim: To compare the efficiency of conventional syringe irrigation (CI), sonic irrigation (SI), and passive ultrasonic irrigation (PUI) in removing pure and injectable calcium hydroxide (CH) from the root canals of mandibular second premolars by measuring the probable microleakage of residual CH particles in root canal obturation using computerized liquid filtration (CLF).
Materials and methods: Eighty instrumented mandibular second premolars were categorized into three experimental groups (n = 20 each) based on the irrigation method used for removing CH and a control group (n = 20) in which CH was not used. Each experimental group was divided into two equal groups (pure and injectable CH). After 1 week, CH was removed from the root canals, and the teeth were obturated. CLF measurements were performed 1 week after obturation. Nonparametric variables between two groups were compared using the Mann-Whitney U test, and the Kruskal-Wallis test was used to compare more than two groups.
Results: All experimental groups showed higher leakage values than the control group. The highest leakage values were evident in the CI group, and the lowest leakage values were found in the SI (EDDY) group. No significant differences were detected among the different forms of CH.
Conclusions: None of the analyzed techniques could completely remove CH from root canals, resulting in higher leakage values. Sonic irrigation with EDDY showed best leakage results in removing CH from root canals.

Keywords: Calcium Hydroxide, Computerized Fluid Filtration, PUI, EDDY, Apical Leakage.

Farklı İrrigasyon Tekniklerinin Kalsiyum Hidroksit Uzaklaştırma Etkinliğinin Bilgisayarlı Sıvı Filtrasyon Methodu Kullanılarak Mikrosızıntılarının Değerlendirilmesi

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ÖZ

Amaç: Alt çene ikinci premolar dişlere yerleştirilen saf kalsiyum hidroksit ile enjektabl kalsiyum hidroksiti kök kanallarından uzaklaştırmak amacıyla kullanılan geleneksel şırınga yıkaması, sonik irrigasyon ve pasif ultrasonik irrigasyonun etkinliğinin kök kanal dolgusunun içerisinde kalma ihtimali olan kalsiyum hidroksit artıklarının yaratabileceği mikrosızıntının Bilgisayarlı sıvı Filtrasyon Cihazı ile ölçülerek kıyaslanmasıdır.
Gereç ve Yöntem: Seksen adet şekillendirilmiş mandibular ikinci premolar dişler, kalsiyum hidroksitin kök kanallarından uzaklaştırılması için kullanılan yıkama yöntemine göre üç deney grubu ve kalsiyum hidroksit medikamenti kullanılmamış olmak üzere bir kontrol grubu olacak şekilde kategorize edilmiştir. Her deney grubu ise kalsiyum hidroksit taşıyıcılarına (distile su ve propilen glikol) göre iki adet alt gruptan oluşmaktadır. Kalsiyum hidroksit kök kanallarından 1 hafta sonra uzaklaştırılmış ve örneklerin kanal dolguları yapılmıştır. Kanal dolgusundan 1 hafta sonra Bilgisayarlı Sıvı Filtrasyon cihazı ile diş köklerinin apikal sızıntı değerleri ölçülmüştür. Normal dağılım göstermeyen (nonparametrik) değişkenler iki grup arasında değerlendirilirken Mann Whitney U Testi, ikiden fazla grup arasında değerlendirilirken Kruskal Wallis Testi kullanılmıştır.
Bulgular: Tüm deney grupları, kontrol grubuna göre daha fazla miktarda sızıntı değeri göstermiştir. En yüksek sızıntı değerleri geleneksel şırınga ile yıkama grubuna ait örneklerde görülürken, en düşük sızıntı değerli gösteren örnekler sonik (EDDY) irrigasyon grubuna ait örneklerdir. Kalsiyum hidroksitin farklı taşıyıcılarla karıştırılmasının sızıntı değerlerine bakıldığında istatiksel olarak anlamlılık göstermediği belirlenmiştir.
Sonuçlar: İncelenen irrigasyon yöntemlerinden hiçbiri kök kanallarından kalsiyum hidroksiti tamamen uzaklaştıramamıştır, bu da deney gruplarında daha yüksek sızıntı değerleri görülmesine neden olmuştur. EDDY ile yapılan sonik aktivasyonun kök kanallarından kalsiyum hidroksiti uzaklaştırmak için en etkili yöntem olduğu görülmüştür.

Anahtar Kelimeler: Kalsiyum Hidroksit, Bilgisayarlı Sıvı Filtrasyon, PUI, EDDY, Apikal Sızıntı.

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Introduction

Removal of microorganisms and their byproducts from infected root canals is an most important factor determining the success of root canal treatment.[1,2] In case of infected root canals, bacteria invade the entire root canal and irregularities, such as isthmuses, ramifications, and dentinal tubules, which are almost impossible to disinfect chemomechanically.[3,4]

Even with the improvements in the instrumentation procedures, no currently used method can completely disinfect the entire root canal structure.[5] Therefore, an intracanal medicament with high antimicrobial properties can provide better prognosis and treatment outcomes.[6,7] Calcium hydroxide is the most widely used intracanal medication due to its antimicrobial properties. It is used in multi-session endodontic treatments in combination with various techniques and recommended to remain in the root canal system for several days or weeks.[8,9]

Three-dimensional obturation of root canals is crucial for the success of endodontic treatment. Hence, before root canal obturation, the temporary intracanal medicament should be completely removed.[10] As a standard, CH is removed from root canals using CI with different irrigation solutions such as sodium hypochlorite (NaOCl) and ethylenediaminetetraacetic acid (EDTA). However, it is almost impossible to reach the irregularities in the root canal system and completely remove CH, particularly in the apical region, using CI.[11,12] Residues of CH in root canals affect the root canal sealers to infiltrate into dentinal tubules, which may result apical leakage, thereby jeopardizing treatment success.[13,14] Therefore, researchers have proposed several methods to effectively remove calcium hydroxide from root canals.

PUI has proven effective in the efficient removal of CH from the root canal system. It is used with an ultrasonic tip, positioned in the center of the root canal reaching the working length (WL), which is agitated passively. It has been stated that the acoustic irrigation provided by this technique can provide disinfection of infected root canals and its irregularities.[15] In many studies, passive ultrasonic irrigation has been shown to be highly effective in removing calcium hydroxide from root canals.[16,17]

EDDY (VDW, Munich, Germany) is a recently developed irrigation device that uses sonic agitation. It is used with a polymer tip using a conventional air scaler with a frequency of 6000 Hz. EDDY is comparable to PUI in removing smear layer and debris from root canals.[18] Further, EDDY was also found to be as effective as passive ultrasonic irrigation in a study examining the removal of calcium hydroxide from root canals.[16]

There are many different methods for measuring apical leakage of root canal fillings, such as dye penetration[19], bacterial penetration[20], radioisotope penetration[21], electrochemical means[22] and scanning electron microscopy.[23] However, the use of these techniques require that the samples be irreversibly destructed, making long term leakage measurements impossible. Therefore, the use of liquid filtration technique may be considered owing to samples being preserved.[24] The computerized liquid filtration method is based on detecting the movement of air bubble inside micropipette using light refraction. Measurements of fluid movement are controlled with PC-compatible software (Fluid Filtration'03, Konya, Türkiye), allowing to avoid user error.

Although there are many studies comparing the efficacy of different irrigation techniques in removing CH from root canals, no study has compared the efficiency of different irrigation methods in removing different forms of CH from the root canals through the measurement of leakage. Therefore, this study aimed to compare the efficiency of three different CH removal methods (CI, EDDY, and PUI) in removing two different forms of CH (pure and injectable CH) from root canals and compare the microleakage caused by residual CH particles using computerized liquid filtration (CLF). The null hypothesis was that different irrigation techniques and different forms of CH would have no effect on the amount of leakage.

Materials and Methods

Eighty human mandibular second premolars with straight root canals and fully developed apices and devoid of cracks, fractures, and caries, extracted for various reasons, were selected for this study under a protocol reviewed and approved by the Ethics Committee for Clinical Research of İstanbul University Faculty of Dentistry and stored in thymol solution (pH: 7). The coronal parts of the teeth were cut to standardize all specimens to 15 mm. Canal patency was verified using a #10 K-file (Dentsply Sirona, Konstanz, Germany) and working length (WL) was set 1 mm short of the length at which the tip of the file was visible at the apical foramen. Root canals were instrumented using ProTaper Next Ni-Ti (Dentsply Maillefer) rotary files according to the manufacturer's instructions up to X4 (0.06 taper/Size 40). Root canals were copiously irrigated with 2.5% NaOCl (Chloraxid, Cerkamed, Stalowa Wola, Poland). As the final irrigant, each canal was irrigated with 5 mL of 2.5% NaOCl, 5 mL of 17% EDTA (ENDO-SOLution, Cerkamed, Stalowa Wola, Poland), and 5 mL of distilled water. All root canals were dried using ProTaper Next paper points and subjected to subsequent procedures.

The prepared 60 specimens were randomly categorized into three experimental groups based on the irrigation technique used to remove CH (n=20 each). Each experimental group consisted of two subgroups based on the form of CH used (n = 10). For the control group (n = 20), the samples did not receive any form of CH application.

- Pure CH (Sultan HealthCare, Inc., Englewood, NJ, USA) was mixed with distilled water using a spatula to a paste structure for every specimen. A size 30 Lentulo spiral (VDW, Munich, Germany) was used at 5000 rpm to insert the CH paste into the root canals until the paste overextruded through the foramen.

- Injectable CH (UltraCal XS, Ultradent, South Jordan, UT, USA) incorporates a different type of CH carrier (propylene glycol). It is available in syringe form and was directly applied to the root canals until overextrusion of the paste was evident at the apical foramen. Thereafter, backfilling was performed.

Radiographs were obtained for all specimens to ensure all of the root canal space was completely filled with CH (Figure 1).

Root canal orificies were sealed with a cotton pellet and a temporary sealing material (Cavit G, 3M ESPE, St. Paul, MN, USA). The specimens were maintained at 37°C and 100% humidity for 1 week. The interim restoration was then removed for experimentation.

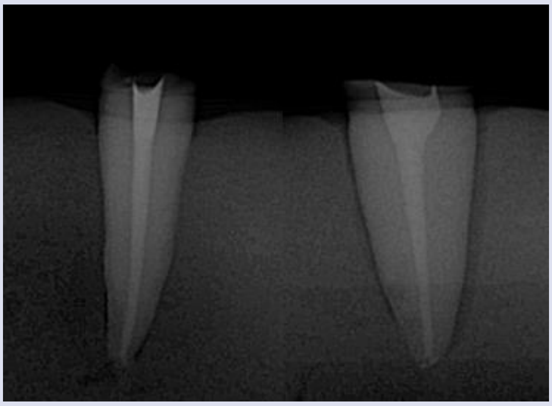

Figure 1. Radiographs of root canal filled with CH

Group A: Sonic activation using EDDY

The irrigant was activated with an air scaler (SONİCflex, KaVo, Biberach, Germany) at a frequency of 6000 Hz. The polymer tip was positioned 1 mm short of the WL and used up-and-down movements with an amplitude of 2–4 mm. First, 2.5 mL of 17% EDTA was injected in the root canal and activated for 30 s. This was repeated twice resulting in 1 min of activation and 5 mL of EDTA solution. Thereafter, 2.5 mL 2.5% NaOCl of was injected in the root canal and activated for 30 s. This procedure was done twice, resulting in 1 min of activation and 5 mL of NaOCl solution. As a result, irrigation with 10 mL irrigation solution and 2 min of activation were performed. 5 mL distilled water was used without activation for final irrigation.

Group B: PUI using Newtron P5XS (Satelec Acteon, France)

The activation of irrigation solution was made at a power setting of 6 according to the manufacturer using a #25 file (Irrisafe, Satelec Acteon, France). The tip of the file was positioned 1 mm short of the WL and verified to be free in the root canal. First, 2.5 mL of 17% EDTA was injected in the root canal and activated for 30 s. This was repeated twice, resulting in 1 min of activation and 5 mL of EDTA solution. Thereafter, 2.5 mL of 2.5% NaOCl was injected in the root canal and activated for 30 s. This procedure was done twice, resulting in 1 min of activation and 5 mL of NaOCl solution. As a result, irrigation with 10 mL irrigation solution and 2 min of activation were performed. 5 mL distilled water was used without activation for final irrigation.

Group C: CI

A side-vented needle (30G, NaviTip, Ultradent, South Jordan, UT, USA) was placed 1 mm short of the WL into the root canal. During irrigation, the syringe was moved using up-and down movements with an amplitude of 5 mm. Thereafter, 2.5 mL of %17 EDTA was injected in the root canal for 30 s. This was repeated twice, resulting in 1 min of irrigation and 5 mL of EDTA. Thereafter, 2.5 mL of 2.5% NaOCl was injected in the root canal for 30 s. This was repeated twice, resulting in 1 min of irrigation and 5 mL of NaOCl. As a result, irrigation with 10 mL of irrigation solution was performed for 2 min. 5 mL distilled water was used for final irrigation.

After experimentation, paper points were used to dry the root canals and obturated using a resin-based sealer (AH Plus sealer, Dentsply-Maillefer) and 40.02 standardized gutta-percha cone (DiaDent, DiaDent Group International Inc., Chongju, Korea) as master cone. The root canals were filled using 25 finger spreader was used for 20.02 accessory gutta-percha cones (DiaDent gutta-percha points, DiaDent Group International Inc., Chongju, Korea) with lateral condensation technique.

Group D: Control group

After instrumentation, root canals of 20 specimens were obturated without using any CH medicament.

After the obturation of the root canals, radiographs were obtained for all specimens to verify the quality of obturation. The access cavities of all specimens were temporarily sealed using a cotton pellet and an interim restorative material. Apart from the experimental and control groups, six teeth were instrumented to form the positive and negative control groups of CLF. To prevent leakage and serve as negative leakage controls, three specimens's external surfaces were covered with two layers of nail polish to prevent leakage. For positive leakage controls, remaining three specimens did not get any nail polish. All specimens were incubated in 100% relative humidity at 37°C for 7 days to mimic physiological conditions. Before performing CLF, the interim restoration was removed.

Computerized liquid filtration technique

To measure the apical leakage, CLF meter method which was previously described by Orucoglu *et al.*[24], was used. Schematic view of computer aided apical microleakage measurement setup of liquid filtration technique is shown in Figure 2. Microleakage measurements are transferred to the computer environment with information such as date, time, amount of movement via an interface (Figure 3). Each specimen was tested eight times during 2 minutes and the mean values were calculated.

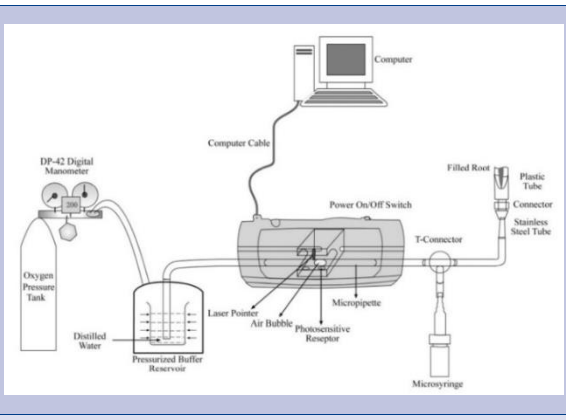

Figure 2. Schematic view of liquid filtration technique with computer aided apical microleakage measurement setup

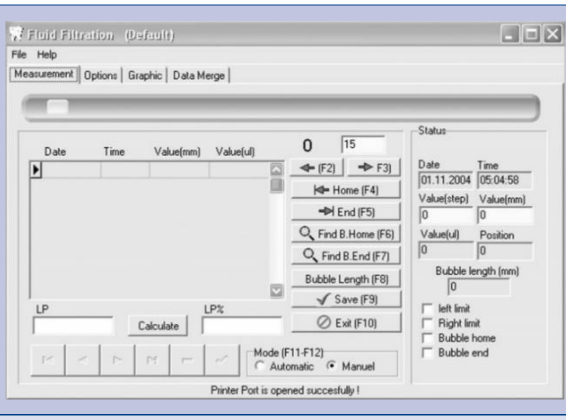

Figure 3. The liquid filtration program interface

Table 1. Apical leakage values for each experimental group

Irrigation method	Forms of calcium hydroxide	Leakage (µL/min × cmH_2O–L)	p
EDDY	Pure Injectable	0.001232 0.001194	0.722
Passive ultrasonic irrigation	Pure Injectable	0.002018 0.00182	0.15
Conventional irrigation	Pure Injectable	0.00301 0.002627	0.298
p			**p > 0.05**

Table 2. Mean, standard deviation, and median leakage values of experimental groups and the control group.

	Mean	Standard deviation	Median
EDDY	0.001211	0.000537	0.001128
Passive ultrasonic irrigation	0.001905	0.000359	0.001889
Conventional irrigation	0.002831	0.000387	0.002796
Control group	0.001109	0.000312	0.001134
p		**< 0.05**	

Statistical analyses

Statistical analyzes were performed with the help of SPSS version 17.0 program. The conformity of the variables to the normal distribution was examined by histogram graphics and the Kolmogorov-Smirnov test. While presenting descriptive analyzes, mean, standard deviation, and median values were used. In cases where the data did not show normal distribution, groups of 2 were evaluated with the Mann Whitney U test and groups of more than 2 were evaluated with the Kruskall Wallis test. Cases with a P-value below 0.05 were considered as statistically significant results.

Results

Each experimental group's apical leakage results are presented in Table 1. The results showed no statistically significant difference between the two forms of CH, regardless of the irrigation method ($p > 0.05$).

Statistically significant difference was shown in mean leakage values among all irrigation method groups, regardless of the different forms of CH ($p < 0.05$). The calculated mean, standard deviation, and median leakage values, regardless of the different forms of CH, are presented in Table 2. The highest leakage was evident in the specimens of Group C (CI), and the lowest leakage was evident in specimens of Group A (EDDY). Complete apical leakage was evident from positive leakage controls, and negative leakage controls showed no leakage.

Discussion

This study evaluated the probable leakage of CH residues from root canal obturations performed using three different irrigation techniques for removing two forms of CH from root canals using the CLF technique. There was no significant difference in leakage between the two forms of CH. However, the three different irrigation techniques for removing CH differed statistically in apical leakage. As a result, the null hypothesis was partially rejected. Although the CI technique for removing CH from root canals showed the highest leakage values, EDDY sonic irrigation showed the lowest.

In recent years, injectable CH formulas have been developed for ease of use and saving time for clinicians. These premixed formulas contain ingredients, such as propylene glycol, different from those in pure CH. Both these forms of CH have antimicrobial properties and high pH values; however, to date, no study has assessed the difference in the removal of different forms of CH from root canals and the probable microleakage caused by the residues of different forms of CH.

In general, copious irrigation combined with instrumentation using a master apical file is the most commonly used technique for removing CH from root canals[11,20] However, it has been proven ineffective in many studies.[11,12,25] CI procedures cannot clean root canal irregularities, such as isthmuses, lateral canals, and apical deltas, and CH may persist in these areas.[26,27] These persistent CH residues may lead to increased leakage, resulting in failure of endodontic treatment.[13,14] Belvedi *et al.*[27] showed that after using different irrigation techniques for removing CH from the cervical, middle, and apical thirds of the root canals, the apical thirds contained the maximum CH residues. In another study, different laser irrigation activation techniques were used to evaluate the effectiveness of calcium hydroxide removal in the artificial apical and coronal grooves prepared in the roots, and according to the result of the study, it was stated that there was more calcium hydroxide residue in the grooves in the apical region.[28] Therefore, it was inferred that removing CH from the apical region would be more difficult, and microleakage should be measured in the apical thirds of the roots.

Owing to the increasing concern regarding these potential problems, more effective irrigation methods, such as PUI, sonic irrigation, and laser irrigation, have been proposed. In our study, the efficacy of CI, EDDY, and PUI in removing pure (powder-liquid) and premixed injectable CH from root canals was analyzed using CLF.

There are several methods to detect leakage in root canals: bacterial penetration[20], dye penetration[19], radioisotope penetration[21], scanning electron microscopy.[23] Owing to the limitations associated with each method, a completely digital CLF technique was developed.[24] Therefore, we used this technique, in which small air bubbles caused by leakage are observed using laser diodes with computer control, allowing more objective results and preservation of the specimens.[24,29]

The results of this study show that none of the irrigation methods used could completely remove CH from root canals, regardless of the type of CH. This was inferred by comparing the amount of leakage from specimens of the control group, in which CH was not used, with that from specimens of the experimental groups. The findings of this study were consistent with the findings of previous studies.[30,31] There was no statistically significant difference between the types of CH in terms of leakage. In line with our findings, Donnermeyer previously reported that none of the tested methods, including PUI, Endoactivator, XP-endo Finisher, and CI, could completely remove the two types of CH from internal resorption cavities, and different forms of CH were comparable in terms of removal.[16] Belvedi *et al.* also reported that remnants of CH were found with both PUI and CI, regardless of the CH type.[27]

In this study, although specimens of Group A (EDDY) showed higher leakage than specimens of Group D (control), the difference was not statistically significant. However, there was a statistically significant difference among the experimental groups. Specimens of Group A (EDDY) showed the least leakage (0.001211), whereas the specimens from Group C (CI) showed the highest leakage (0.002831).

The efficiency of EDDY in CH removal has not yet been assessed using CLF. However, considerable potential of this sonic irrigation activation method at higher frequencies of 6000 Hz has been indicated in recent studies that assessed canal cleanliness.[32] In line with the results of these studies, the least leakage was evident in samples of Group A (EDDY) in our study. Donnermeyer explained the reason for favorable results with EDDY as the small, intense, and circular fluid movements created around the tip of the device with a more apically transmission of irrigation.[16]

The lowest leakage was evident in samples of Group B (PUI) after Group A (EDDY). These results showed that in terms of removing CH from root canals, PUI was more effective than CI. This result is consistent with those of other studies.[33,34] Keskin *et al.*[35] showed that PUI was superior to CI in removing CH from internal root resorption cavities. Additionally, Jiang *et al.*[36] proposed that PUI induced higher volume and velocity of irrigant and that might be the reason for its effectiveness.

Looking at the results of this study, all irrigation activation methods were significantly more effective than CI in terms of removing CH from root canals through leakage measurements. Therefore, these methods are recommended to increase the success rate of treatment. In addition, there was no significant difference between the different forms of CH in removal regardless of the irrigation method. However, the use of CH decreased the sealing ability after obturation.

Conclusions

None of the analyzed techniques could completely remove CH from root canals, and all specimens treated with CH showed higher leakage than the control group specimens, which were not treated with CH. EDDY was the most effective method for the removal of the two different forms of CH. Different forms of CH were comparable regardless of the irrigation technique used.

Within the limitations of this study, the effects that may occur due incomplete removal of CH from the root canals should be considered, and for this purpose, more effective irrigation activation methods may be recommended to be added in routine use. In future studies, the efficacy of other types of irrigation activation methods and different forms of CH in CH removal should be compared.

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