Original Article / Özgün Araştırma

# Effectiveness of Various Irrigation Protocols in Removing Calcium Hydroxide from Root Canals

## *Kalsiyum Hidroksitin Kök Kanallarından Uzaklaştırılmasında Farklı İrrigasyon Protokollerinin Etkinliği*

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### Abstract

**Objective:** The purpose of this study was to investigate the removal efficiency of calcium hydroxide (CH) by CanalBrush, Vibringe, laser-activated irrigation (LAI), conventional syringe irrigation (CSI), XP-endo Finisher, and passive ultrasonic irrigation (PUI) in the root canal walls.
**Materials and Methods:** Ninety-eight human mandibular premolar teeth were prepared. Root canals were filled with CH. The roots were divided into six experimental groups (n=15/group) according to the irrigation protocol used: group 1 (CSI), group 2 (Vibringe), group 3 (CanalBrush), group 4 (XP-endo Finisher), group 5 (PUI), and group 6 (LAI). The amount of residual CH in the canal walls for each canal third was scored. Data were analysed by using Kruskal-Wallis and Bonferroni-correction Mann-Whitney U tests.
**Results:** None of the investigated protocols renders the root canal walls free of CH remnants. Significant differences were found between tooth regions in terms of CH removal ($p<0.05$), and all groups except group 6 (LAI) showed more residual CH in the apical region. PUI and LAI eliminated significantly more CH than CSI from the middle and apical thirds of the root canal, respectively.
**Conclusion:** The activation of sodium hypochlorite with various devices increased CH removal at the apical and middle part of the canal. LAI and PUI produce better results in the apical and middle thirds, respectively.

**Keywords**
Calcium hydroxide, dental pulp cavity, endodontics, laser, ultrasonic

**Anahtar Kelimeler**
Kalsiyum hidroksit, diş pulpa boşluğu, endodonti, lazer, ultrasonik

**Received/Geliş Tarihi** : 06.05.2017
**Accepted/Kabul Tarihi** : 30.07.2017

doi:10.4274/meandros.04796

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### Öz

**Amaç:** Bu çalışmanın amacı, XP-endo Finisher, Vibringe, lazerle aktive edilmiş irrigasyon (LAİ), geleneksel iğne irrigasyonu (Gİİ) ve pasif ultrasonik irrigasyonun (PUİ) kök kanal duvarlarından kalsiyum hidroksit (KH) uzaklaştırma etkinliğini araştırmaktır.
**Gereç ve Yöntemler:** Doksan sekiz adet alt çene küçük azı dişinin kök kanalları prepare edildi ve KH ile dolduruldu. Kökler, irrigasyon protokolüne göre rastgele altı deney grubuna ayrıldı (n=15/grup): grup 1 (Gİİ), grup 2 (Vibringe), grup 3 (CanalBrush), grup 4 (XP-endo Finisher), grup 5 (PUİ) ve grup 6 (LAİ). Her bir kanal üçlüsü için kanal duvarlarında kalan KH miktarı skorlandı. Veriler, Kruskal-Wallis ve Bonferroni-düzeltmeli Mann-Whitney U testleri kullanılarak analiz edildi.

**Bulgular:** Araştırılan protokollerden hiçbiri kök kanal duvarlarını KH kalıntılarından tamamen arındıramamıştır. Grup 6 (LAİ) dışındaki tüm gruplarda apikal bölgede daha fazla artık KH tespit edildi ve bölgeler arasında anlamlı farklılık vardı (p<0,05). PUİ ve LAİ, sırasıyla kanalın orta ve apikal üçte birinde GİI'ye kıyasla anlamlı derecede daha fazla KH uzaklaştırdı.
**Sonuç:** Sodyum hipoklorit solüsyonun farklı cihazlarla aktivasyonu, kanalın apikal ve orta bölümünde KH'nin uzaklaştırılmasına katkı sağladı. PUİ ve LAİ, sırasıyla kanalın orta ve apikal üçte birinde daha iyi sonuçlar ortaya koydu.

## Introduction

Calcium hydroxide (CH), as an intracanal medicament, is frequently used in endodontics for various clinical conditions due to its biocompatibility, antibacterial capacity and ability to promote hard tissue formation, inhibition of osteoclastic activity, organic tissue dissolution, inflammation control and regenerative properties (1,2). Despite its many benefits, residual CH from its use in inter-appointment has harmful effects. Previous studies have shown that residual CH can act as a barrier between sealer and root dentin, thus preventing bonding of resin sealer adhesion to the dentin (3,4). CH should therefore be removed to avoid an effect on apical leakage (5,6). However, current protocols cannot completely remove CH from the entire root canal system because of the complexity of root canal anatomy (7-9). In order to optimise CH removal, various irrigation techniques and devices have therefore been established.

CH is typically removed from the root canal by irrigation with ethylenediaminetetraacetic acid (EDTA) and sodium hypochlorite (NaOCl) in combination with the use of a master apical file (MAF) or gutta-percha up to working length (WL). Phillips et al. (7) showed that passive ultrasonic irrigation (PUI) with or without MAF use removed significantly more CH than irrigation alone. These results are in line with findings obtained in previous studies (2,8). In a recent study, no significant difference was reported in the amount of remaining CH between PUI and sonic agitation groups in C-shaped root canals of mandibular molars (9).

A novel irrigation instrument, the XP-endo Finisher, has been introduced by FKG, Dentaire SA (La Chaux-de-Fonds, Switzerland). This instrument's design is similar to an ISO size # 25, 0.00 taper NiTi file. According to the manufacturer, this file improves the penetration of irrigants to the irregular area of the root canal system by expanding its reach to 6 mm in diameter (10-12). Another recently introduced sonic-activated device, the Vibringe system (Vibringe B. V. Corp, Amsterdam, Netherlands), has been developed to improve irrigation. Unlike other sonic devices, this system provides sonic activation of irrigation solutions in itself and transmits to the root canal through a needle (13-15).

Limited data are available in the literature on the compare of the efficacy of the Vibringe system, the XP-endo Finisher file and laser-activated irrigation (LAI) for CH removal from the root canal (16). The purpose of this study was to investigate the removal efficiency for CH of the XP-endo Finisher, Vibringe, PUI, LAI, CanalBrush, and conventional syringe irrigation (CSI) in the root canal. The null hypotheses were [1] that the removal of CH was not affected by irrigation protocols or [2] by the region of root canal (third).

## Materials and Methods

All participants provided written informed consent before the study began. After ethics committee approval from the Ethics Committee of Cumhuriyet University, Turkey (protocol no: 2017-01/14), ninety-eight single-rooted, completely formed apices, straight human mandibular premolar teeth were selected. Each tooth was radiographed in both mesiodistal and buccolingual directions to confirm the presence of one root canal, an intact apex, and no sign of internal/external resorption. The remains on the external root surface were cleaned with hand scalers, and teeth were placed in distilled water until use. The access cavity preparation was performed with a high-speed diamond burs under water cooling and a size 10 K-type file (Dentsply, Tulsa, OK, USA) was progressed through the canal until the tip of the file was just visible. The teeth were decapitated to a length of 15 mm with a WL of 14 mm. Canals were prepared with Reciproc rotary files (VDW GmbH, Munich, Germany) to a MAF size of R40. The flutes were cleaned with gauze after three pecking motions. During preparation, irrigation was performed with 10 mL 2.5% NaOCl (Whitedentmed, Erhan Kimya, İzmir, Turkey). The smear layer was removed using 5 mL of 17% EDTA (Imicryl Ltd., Konya, Turkey) for 60 s. Final flush was done using 5 mL of 5% NaOCl and root canals were dried with paper points. The roots were randomly divided into six experimental groups (n=15) and a positive control group (n=4), which did not receive any removal procedures, and a negative control group (n=4) in which CH was not applied.

CH (Ammdent, Punjab, India) was mixed with distilled water at a ratio of 1 powder: 1 liquid to a creamy consistency and placed into each canal using a Lentulo spiral (size 35). Two radiographs were taken from the buccolingual and mesiodistal direction to confirm complete filling of the root canals. The access cavities were temporarily closed with Cavit G (3M ESPE, Seefeld, Germany). The roots were then kept at 37 °C in 100% relative humidity for 3 weeks.

After this period, an R40 file (VDW, Germany) and 1 mL 2.5% NaOCl was used to obtain a pathway for irrigation needles and instruments.

Group 1 (CSI): Root canals were flushed with 10 mL of 2.5% NaOCl for 120 s via a 30-gauge double side-vented dental irrigation needle (i-TIPS, i-dental, Siauliai, Lithuania). The needle tip was placed 1 mm short of the WL and moved backwards and forwards.

Group 2 (Vibringe): 10 mL of 2.5% NaOCl was delivered and sonically activated via the Vibringe system (Vibringe B. V. Corp, Amsterdam, Netherlands). The needle tip was placed apically to within 1 mm of the WL without locking the canal walls and used with small in-and-out movements for 120 s.

Group 3 (CanalBrush): Root canals were irrigated with 5 mL of 2.5% NaOCl for 30 s and then brushed with a medium size CanalBrush (Coltene/Whaledent GmbH & Co. KG, Langenau, Germany) at 600 rpm for 60 s. A final flush with 5 mL of 2.5% NaOCl was performed for 30 s. A total volume of 10 mL of 2.5% NaOCl was used. CanalBrushes were inserted to 1 mm short of the WL and moved with small vertical movements.

Group 4 (XP-endo Finisher): The irrigation protocol was as for group 3 with the exception that an XP-endo Finisher (FKG, Switzerland) at 800 rpm with 1 Ncm was used. A total agitation time of 60 s with a total volume of 10 mL of 2.5% NaOCl was used. The tip of the file was positioned 1 mm short of the WL and moved backwards and forwards up to 7-8 mm without being used for the same point.

Group 5 (PUI): As for group 3, PUI was performed using an Irrisafe ultrasonic tip (size 25, 0.02 taper) (Satelec Acteongroup, France) coupled to the file-holding adapter of a Satelec P5 Newtron XS ultrasonic system handpiece (Acteon Group, Merignac, France). The ultrasonic tip was positioned 1 mm short of the WL and vibrated freely without locking the wall. A power setting of 9 was used for duration of 60 s. When the level of irrigating solution in the canal decreased, NaOCl was refreshed. A total volume of 10 mL of 2.5% NaOCl was used.

Group 6 (LAI): The irrigation protocol was as used in group 3 with the exception that an Er:YAG laser (Kavo Key 3+, KaVo, Biberach, Germany) with a 2940 nm wavelength, panel output power of 1 W, pulse frequency of 10 Hz, energy per pulse of 100 mJ, and energy density of 142.8 J/cm$^2$ was used with the laser system. The root canals were irrigated with 5 mL volume of 2.5% NaOCl, and a laser tip (28 mm in length and 300 µm in diameter quartz tip) was positioned into the canal 1 mm short of the WL and moved in a circular motion from the apex to the crown at a speed of 2 mm/s during irradiation. The irradiation protocol was performed for 20 s with a 20 s interval. The total irradiation time was 60 s. NaOCl levels were replenished during irradiation if needed. A 5 mL volume of 2.5% NaOCl was used for the final flush.

The irrigation solution was placed into the canal using a 30-gauge double side-vented needle (i-TIPS, Lithuania) for all groups. The canals were dried with paper points, a longitudinal groove was prepared on the lingual and buccal surface using a diamond disc under dry conditions without penetrating the canal and the root was split into halves using a chisel and hammer.

The amount of remnant CH on the root canal walls was evaluated under a stereomicroscope (Zeiss Stemi 2000-C, Carl Zeiss MicroImaging, Göttingen, Germany) with 10× magnification (Figure 1). Images were obtained using a digital camera (AxioCam ERc5s, Germany) and coded before evaluation to ensure that the evaluators were blinded to their identities. The amount of remnant CH in each root canal third was scored by two dentists using the following numeric evaluation scale, as described by Gambarini and Laszkiewicz (17): score 1, the canal walls are empty or exhibit a few small CH particles; score 2, the canal is covered with several small agglomerations of CH; score 3, less than 50% of the canal is covered with CH; score 4, CH is present in more than 50% of the canal

**Figure 1.** The view of root under the stereomicroscope at 10× magnification. Conventional syringe irrigation group at apical region score 5, at middle region score 1, at coronal region score 3

**Table 1. Multiple comparisons between groups**

| Groups | Kruskal-Wallis statistical analysis median [IQR] | | |
|---|---|---|---|
| | Coronal | Middle | Apical |
| G1 (CSI) | 2 [2-3]$^{A}$ | 2 [1-3]$^{A,a}$ | 3 [3-4]$^{B,a}$ |
| G2 (Vibringe) | 2 [1-3]$^{A}$ | 2 [1-2]$^{A,a}$ | 3 [2-3]$^{B,ac}$ |
| G3 (CanalBrush) | 2 [1-2]$^{A}$ | 2 [1-2]$^{A,a}$ | 3 [3-3]$^{B,ac}$ |
| G4 (XP-endo F) | 2 [1-2]$^{A}$ | 2 [1-3]$^{A,ab}$ | 3 [2-3]$^{B,ac}$ |
| G5 (PUI) | 1 [1-2]$^{A}$ | 1 [1-2]$^{A,b}$ | 2 [2-3]$^{B,c}$ |
| G6 (LAI) | 2 [2-3]$^{A}$ | 1 [1-2]$^{B,ab}$ | 1 [1-2]$^{B,bc}$ |

Different uppercase letters in the same raw indicate a statistically significant difference (p<0.05) and different lowercase letters in the same column indicate a statistically significant difference (p<0.05)

IQR: Interquartile range, CSI: Conventional syringe irrigation, PUI: Passive ultrasonic irrigation, LAI: Laser-activated irrigation

walls; and score 5, the root canal walls are almost completely or completely filled with CH. Before scoring, the two endodontists jointly assessed 30 randomly selected specimens for calibration purposes. In the case of discrepant scores, a consensus was reached by discussion.

**Statistical Analysis**

Analyses were performed using SPSS 19.0 (IBM SPSS Statistics 19.0, SPSS Inc., an IBM Co., Somers, NY, USA). Cohen's kappa coefficient was used to determine inter-examiner agreement. The Kruskal-Wallis test was used to compare the non-normal data among groups. For multiple comparisons between the pair-wise groups, the Bonferroni-correction Mann-Whitney U test was used. A p value <0.05 was considered significant.

## Results

Results from the two examiners were in good agreement (kappa value=0.786). All the negative control samples resulted in a score of 1, and all the positive control samples resulted in a score of 5. Data shown as median and interquartile ranges of the groups are shown in Table 1. Significant differences were observed between tooth regions in terms of CH removal (p<0.05). With the exception of LAI, more residual CH in the apical region was observed in all groups. None of the investigated protocols produced complete elimination of CH from the canal walls. There were no significant differences among the protocols at the coronal part (p>0.05). PUI was more efficient than the other protocols (p<0.05), except for LAI and XP-endo Finisher (p>0.05) at the middle part. LAI was more efficient than the other techniques on the removal of CH from the root canal surfaces in the apical region, but the only significant difference was observed between CSI and LAI (p<0.05).

## Discussion

The present study investigated the effectiveness of CSI, CanalBrush, XP-endo Finisher, Vibringe, LAI and PUI in removing CH from root canal walls. According to our results, LAI and PUI were more effective in eliminating CH in the apical and middle regions of the root canal. Therefore, the null hypothesis [1] that the removal of CH was not affected by irrigation protocols was rejected. The apical third was the most critical part of the root canal in terms of CH removal in all experimental groups except for LAI, and significant differences were observed between root regions for the removal of CH. Therefore, the null hypothesis [2] that the removal of CH was not affected by the region of root canal (third) was rejected.

CH is a widely used intracanal medicament due to its antibacterial, therapeutic and biocompatible properties, among others (18,19). However, previous studies showed that incomplete removal of CH before completion of canal obturation results in it functioning as a barrier between the root canal sealer and dentin walls, thus increasing sealer penetration into the dentinal tubules (3,20).

Different devices and protocols have been developed to improve the debris removal effect of irrigants. However, no standard protocol for activating the irrigants has been described to date. Recently, the use of LAI with pulsed middle infrared erbium chromium: yttrium-scandium-galliumgarnet (Er,Cr:YSGG) and erbium: yttrium-aluminium-garnet (Er:YAG) lasers has been suggested as a suitable protocol for activating irrigation solutions. In this technique, laser activation of the irrigant creates a cavitation, large elliptical vapour bubbles and pressure waves. The vapour bubbles generated expand 1.600-fold to move the irrigant out of the canal. These bubbles explode after 100 to 200 ms and a secondary cavitation effect occurs whereby pressure develops and sucks irrigation fluid back into the canal (21). Limited information on the effects of LAI on removal of CH is described in the literature. Li et al. (22) investigated the effectiveness of four irrigation protocols in removing CH from the root canal. They reported that PUI and photon-induced photoacoustic streaming (PIPS) were more effective than the other protocols investigated. In a similar study by Kustarci et al. (23), the LAI group was shown to leave significantly less residual CH than a needle group. The results from the present study are supported by this finding. However, Arslan et al. (24) reported that PIPS was more effective than another technique (PUI) in removing CH from the simulated standard grooves in the apical third of straight root canals. The differences between this outcome and our results may reflect different variables in study design, such as (i) the laser and parameters employed and (ii) the irrigant used. Furthermore, the superiority of the PIPS technique in removing debris from root canals has been demonstrated in previous studies (25,26).

As for LAI, ultrasonic agitation techniques are based on the transmission of acoustic energy to an irrigation solution. This energy can induce acoustic streaming and cavitation of the irrigation solution (27). In previous studies, it was shown that mechanical agitation of irrigant was more effective for removing CH than irrigation without agitation (4,28,29). This agitation increased the penetration of irrigant to the irregular canal areas. At the same time, the effectiveness of ultrasonic activation on the removal of CH was shown to depend on the irrigant and paste vehicle used (4,22,24). In line with findings reported by previous studies, we showed that PUI left less CH residue than CSI (22,24,30). In contrast to these results, Balvedi et al. (31) found that there were no significant differences between PUI and syringe irrigation in terms of CH removal at the apical third.

In our study, continuous irrigant supply from the handpiece was not employed. PUI with continuous irrigation has a mechanical flushing effect on the remove of debris from the apical to the coronal region. Thus, further investigations with a similar experimental set-up should be performed to evaluate the effectiveness of PUI, with or without continuous irrigation, on the removal of CH.

An endodontic microbrush is another device to improve irrigation efficacy for the removal of medicament or debris from the root canal. CanalBrush (Coltene/Whaledent GmbH & Co. Langenov, Germany) is a flexible polypropylene microbrush available in three sizes (small, medium and large). Tasdemir et al. (28) reported that CanalBrush removed significantly more CH than CSI with manual dynamic activation. In contrast to these results, Gorduysus et al. (32) showed that CanalBrush packed the apical root third with CH remnants. In the present study, CanalBrush removed more CH than CSI, but no significant differences were found between CSI and CanalBrush techniques in any third of the canal.

Vibringe, a novel sonic device (Vibringe B.V. Corp, Netherlands) was used for sonic activation of 2.5% NaOCl. This device uses patented sonic flow technology that causes acoustic streaming in the root canal and operates at a low frequency (13,14). In a previous study, it was concluded that the Vibringe system removed more debris than CSI from simulated root canal irregularities (14). However, Johnson et al. (15) stated that Vibringe was not superior to CSI when comparing debridement efficacies. Similarly, the present study showed no significant differences between Vibringe and CSI for CH removal in all segments. Given that no information is available on Vibringe efficiency in removal of CH from the root surface, further investigation of this device is required.

The XP-endo Finisher is a novel NiTi file for improving the efficacy of the final irrigation procedure. The canal must be shaped with at least an ISO 25 file in order to use the XP-endo Finisher. The instrument is stabile in martensite form at room temperature and can therefore be bent to the desired shape. The instrument changes its phase to austenite at body temperature (11,12). The effects of the XP-endo Finisher on CH removal have been studied only a few studies. Keskin et al. (16) reported that both the XP-endo Finisher and PUI were superior to CSI and that there were no significant difference between them for the removal of CH from artificial internal resorption cavities. Uygun et al. (33) investigated the effectiveness of the PUI, XP-endo Finisher, and a TRUShape 3D conforming file in removing CH from root canal irregularities. They observed that the XP-endo Finisher and PUI were superior the needle irrigation group and no significant difference between them. Leoni et al. (34) showed that there were no significant differences between PUI and the XP-endo Finisher in removing debris from the root canal surface. Alves et al. (10) stated that the enhanced cleanliness of the root canal wall achieved using the XP-endo Finisher after root canal retreatment was statistically significant. In the present study, the XP-endo Finisher removed less CH in the apical third than in other regions. This result is in line with the findings reported by previous studies (35,36), and can be attributed to a change in instrument shape to a spoon upon rotation in the canal, and expansion of the middle part of the instrument by more than its tip.

To date, various irrigation solutions, used alone or in combination, such as EDTA, NaOCl, chlorhexidine, water and saline have been investigated for removing CH (4,23,24,30). In the present study, 2.5% NaOCl was used as an irrigant. A previous study showed that the use 2% NaOCl resulted in less residual CH than the use of water (4). In another study, by Tasdemir et al. (28), no significant difference was reported between conventional syringe delivery of NaOCl with EDTA and NaOCl alone. However, in contrast to these results, Kustarci et al. (23) showed that 17% EDTA, 1% peracetic acid and QMix 2in1 was more effective than 2.5% NaOCl for CH removal from artificial grooves created in the apical section of root canals. Similarly, it was reported that NaOCl with EDTA removed significantly more CH than NaOCl alone (3). However, no general consensus has been reached on the most effective irrigant for the removal of CH.

The apical third exhibited higher amounts of residual CH than the middle and coronal thirds in all tested groups, except for the LAI group. This result is in line with the findings of previous studies (22,32,37), and may be related to the accumulation and transfer of residual CH to the apical region, which has a smaller canal area and smaller volume of irrigation solution, as well as to the anatomic complexity of the apical third (32,35,38). The action and circulation of irrigants may therefore be hindered (39).

**Study Limitations**

One limitation of the current study is the use of the split longitudinally technique. Although this technique has been widely reported in previous studies (24,28,30,31) for determining the amount of remnant medicament or root filling material on the root canal walls, its major limitation is its destructiveness and loss of remnants during root separation (9,40). Three-dimensional imaging permits root canal system scanning without tooth destruction (1,9,22,37). However, it was reported that small amounts of residual CH could not be determined using micro-computed tomography (22).

## Conclusion

Within the limitations of the study, none of the investigated irrigation protocols (PIU, LAI, CanalBrush, Vibringe and CSI) were capable of eliminating all CH from the root canal. All protocols removed similar amounts of CH from the coronal region. The activation of 2.5% NaOCl using different instruments enhanced CH removal from the apical and middle parts of the canal. Our results show the effectiveness of PUI and LAI for the removal of CH at the middle and apical sections of the root canal, respectively.

**Ethics**

**Ethics Committee Approval:** Ethics Committee approval for this study was obtained from the Ethics

Committee of Cumhuriyet University, Turkey (protocol no: 2017-01/14).

**Informed Consent:** It was taken.

**Peer-review:** Externally peer-reviewed.

**Authorship Contributions**

Concept: H.G., İ.Ö., Design: H.G., İ.Ö., Data Collection or Processing: H.G., İ.Ö., F.B., Analysis or Interpretation: H.G., İ.Ö., F.B., O.D., Literature Search: H.G., İ.Ö., F.B., Writing: H.G., O.D.,

**Conflict of Interest:** No conflict of interest was declared by the authors.

**Financial Disclosure:** The authors declared that this study received no financial support.

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