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Original research article

Effect of temperature on the ability of XP-Endo Finisher to remove calcium hydroxide from root canal irregularities: *ex vivo*

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Abstract

Objective: The purpose of this study was to evaluate the effect of different environmental temperatures and irrigation solution temperatures on the calcium hydroxide (CH) removal efficacy of XP-Endo Finisher from root canal irregularities.

Materials and Method: Eighty-three teeth were instrumented and split longitudinally. Two standard grooves (apical and coronal) were prepared, and the roots were randomly divided into five experimental groups (n=15), a positive control group (n=4), and a negative control group (n=4). The grooves were filled with CH, the root halves were reassembled; the canal space was also filled with CH, and the teeth were stored for 14 days. Fourteen days later, CH was removed using one of the following irrigation protocols, where environmental temperature for Groups 1-4 and Group 5 were 37 °C and 21 °C, respectively: Group 1: Conventional needle irrigation with NaOCl at 21 °C; Group 2: Conventional needle irrigation with NaOCl at 37 °C; Group 3: XP-Endo Finisher with NaOCl at 21 °C; Group 4: XP-Endo Finisher with NaOCl at 37 °C; Group 5: XP-Endo Finisher with NaOCl at 21 °C. The amount of the remaining CH after the removal was examined and scored by using a stereomicroscope. The statistical evaluation was performed using Kruskal–Wallis and Mann–Whitney U tests with Bonferroni-correction.

Results: Group 3 and 4 removed significantly more CH than the other groups in the apical region ($p<0.05$). There were no significant differences between the groups in the coronal region ($p>0.05$). The removal of CH was not affected by the temperature of the irrigation solution ($p>0.05$); but it was significantly affected by the environmental temperature (Group 3 versus Group 5; $p<0.05$) and the CH removal technique (Groups 3 and 4 versus Groups 1 and 2; $p<0.05$).

Conclusion: While the temperature of the NaOCl solution did not play a significant role in the CH removal efficacy of XP-Endo Finisher, greater environmental temperature increased its activity.

Keywords: Calcium hydroxide; endodontics; temperature

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Introduction

Intracanal medication is an additional procedure performed in root canal preparation and irrigation in order to eliminate bacteria from the root canal system. Before the final obturation of the canal system, it is desirable to remove all medicaments from the root canal irregularities.[1] It was reported that calcium hydroxide (CH) residue could decrease the bond strength of root canal sealer to dentin, prevent sealer penetration into the dentin tubules and weaken the apical seal of zinc oxide-eugenol-based sealer.[2-4]

The complete removal of the medicament from the root canal system is a challenge and the most commonly chosen removal technique is the recapitulation of the root canal with a master apical file at working length (WL) which is followed by copious irrigation with ethylenediaminetetraacetic acid (EDTA) and sodium hypochlorite (NaOCl).[4,5] Sonic and ultrasonic devices, intracanal brushes, lasers, intracanal pressure change devices, and various irrigation solutions are also used for the medicament removal from the root canal.[1,5-10]

XP-Endo Finisher (FKG, Dentaire SA, La Chaux-

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de-Fonds, Switzerland) is a recently introduced irrigant activation file to improve the access of irrigants to the irregular areas of root canal.[11,12] This instrument's design is similar to that of an ISO size number 25, 0.00 taper NiTi file. This instrument is produced of a NiTi MaxWIRE alloy which gives it high flexibility. The instrument is at M-phase at room temperature; but when it is heated up to body temperature, it changes to A-phase and it takes on a spoon shape (C-shape) in the apical half of the file. The spoon shape allows the instrument to expand its reach by 6 mm in diameter, or to one hundred-fold that of a standard instrument of the same size. The file should be used at body temperature in order to activate and maintain the spoon shape according to the manufacturer's recommendation.

The efficacy of the XP-Endo Finisher on the removal of CH from the root canal surface has been investigated in previous studies.[11-14] However, no study has evaluated the effect of environment or solution temperatures during instrument use. Therefore, the aim of this *ex vivo* study was to investigate the effect of temperature (environment and solution) on the CH removal capacity of XP-Endo Finisher from standardized root canal irregularities. The null hypotheses were that the efficacy of XP-Endo Finisher on the removal of CH was not affected by: (1) environment temperature; and (2) solution temperature.

Materials and Method

Sample preparation

This study was approved by the ethics committee of Cumhuriyet University, Sivas, Turkey (Protocol no. 2017–01/15). Eighty-three human maxillary anterior teeth with straight roots were selected. Mesio-distal and bucco-palatal direction radiographs were taken of the teeth to confirm the presence of a single canal, completely developed apices, and the absence of previous endodontic treatment. The teeth were stored in a 10% formalin solution until use. The specimens were decoronated using low-speed diamond burs (Komet, Gebr. Brasseler GmbH & Co. KG, Lemgo, Germany) under water-cooling to achieve a standardized root length of 15 mm. The working length (WL) was determined to be 1 mm short of the apex using a #10 K-file (VDW, Munich, Germany). Therefore, the WL was adjusted to 14 mm. The roots were prepared with Reciproc rotary files (VDW) and a torque-controlled motor (Gold, Reciproc; VDW,) up to size R40 (40/0.06) at the WL, and irrigation was performed with 2 mL of 2.5% NaOCl after three pecking motions. Apical patency was checked with a #10 K-file.

The present test design was similar to those followed in previous studies.[6,8] The roots were fixed in a silicone material (Zetaplus soft, Zhermack Clinical, Badia Polesine, Italy) contained in Eppendorf tubes (Labosel, İstanbul, Turkey). The teeth were then removed from these tubes and a longitudinal groove was placed on the buccal and lingual root surfaces using a narrow diamond bur avoiding cutting the canal wall. A spatula was used to split the roots longitudinally. A number 1S Cavitron tip (Acteon, Merignac, France) was modified and inserted into an ultrasonic hand-piece (Newtron P5, Satelec, Acteongroup, Merignac, France) to create artificial, standardized grooves. Under a stereomicroscope (20× magnification; Zeiss Stemi 2000-C, Carl Zeiss MicroImaging, Göttingen, Germany) two standard grooves (0.2 mm in width, 3 mm in length, and 0.5 mm in depth) were cut in one segment 2–5 mm away from the apex in the apical part, and cut in the other segment 11–14 mm away from the apex in the coronal part to simulate uninstrumented canal extensions (Figure 1). The prepared grooves and root canals were irrigated with 5 mL of 17% EDTA, followed by 5 mL of 2.5% NaOCl for one minute while being activated with a medium size CanalBrush (Coltene/Whaledent, Langenau, Germany) to remove the smear layer and debris. The root canals were then dried with paper points. The specimens were randomly divided into five experimental groups (n=15), a positive control group (n=4) which did not receive any removal procedure, and a negative control group (n=4)

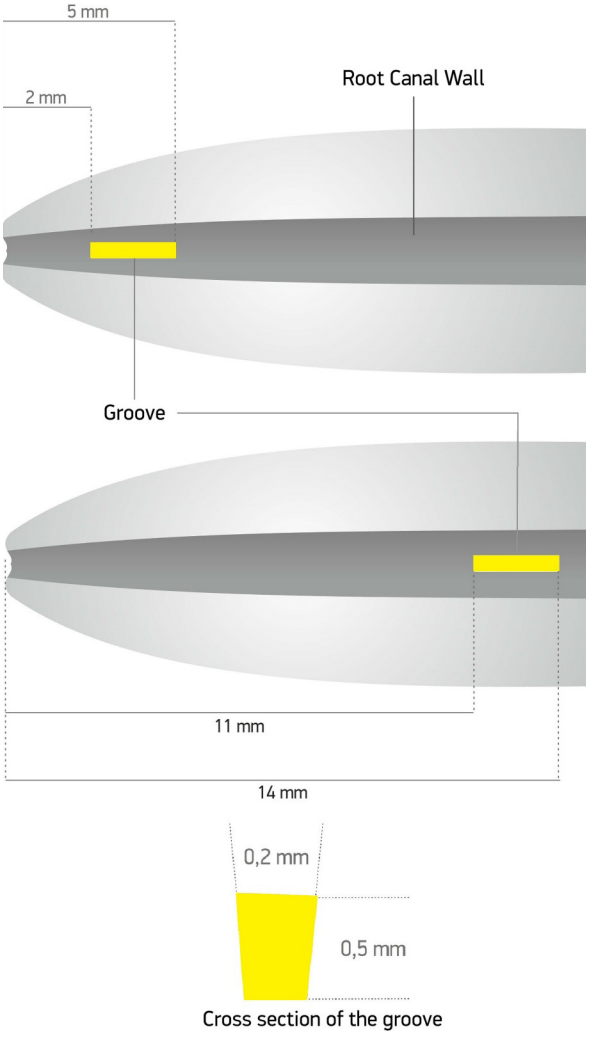

Figure 1. *A schematic representation of the location and size of the artificial standardized grooves*

Table 1. *Irrigation protocols for the study groups*

Groups	CH removal technique	Environmental temperature	Solution temperature
1	Needle irrigation	37 °C	21 °C
2	Needle irrigation	37 °C	37 °C
3	XP-Endo Finisher	37 °C	21 °C
4	XP-Endo Finisher	37 °C	37 °C
5	XP-Endo Finisher	21 °C	21 °C

in which CH was not applied. The grooves were filled with CH paste (Ammdent, Punjab, India) which was mixed with distilled water at a powder-to-liquid ratio of 1:1. Next, the roots were carefully re-assembled with wax whilst ensuring that none entered the root canal lumen. The root canals were fully filled with CH paste using a Lentulo spiral (Golden Star Medical Co. Ltd., Guangdong, China) and this was confirmed through radiographs. The roots were placed in their original silicone molds contained in Eppendorf tubes. The access cavities were sealed with Cavit (ESPE, Seefeld, Germany), and the specimens were stored at 37 °C and 100% relative humidity for two weeks.

Removal of calcium hydroxide

After the temporary fillings were removed from the roots, an R40 (VDW) file at WL and 1 mL of 2.5% NaOCl were used to obtain a space for irrigation needles and instruments.

The Eppendorf tubes containing the roots were embedded in a rubber dam sheet. The Eppendorf tubes in Groups 1-4 were tightly mounted on an apparatus in a dental thermal cycles device box (SD Mechatronik Thermocycler, SD Mechatronik GmbH, Westerham, Germany) which contained distilled water heated to 37 °C to simulate the oral environment (Figure 2). The Eppendorf tubes in Group 5 were fixed to a vise mounted on the laboratory table at room temperature (21 °C) to simulate the extraoral conditions. The environmental temperatures of Groups 1-4 and Group 5 were thus 37 °C and 21 °C, respectively (Table 1). These temperatures were controlled by using a thermal cycles device thermostat and a room thermostat, and further checked by using a noncontact infrared thermometer (Medisana 76120, Medisana AG, Neuss, Germany). If the temperature changed during the irrigation procedure, the procedure was repeated. One sample from Group 5 and two samples from Group 4 had to be repeated.

Both 37 °C and 21 °C NaOCl solutions were heated in an incubator before use.

Group 1: The root canals were irrigated with 10 mL of 2.5% NaOCl (21 °C) for two minutes via a 30-gauge double side-vented needle (i-Tips, i dental, Siauliai, Lithuania). The needle tip was placed 1 mm short of the working length.

Group 2: The irrigation protocol was the same as that for Group 1 with the following exception: 10 mL of 2.5% NaOCl at 37 °C was used.

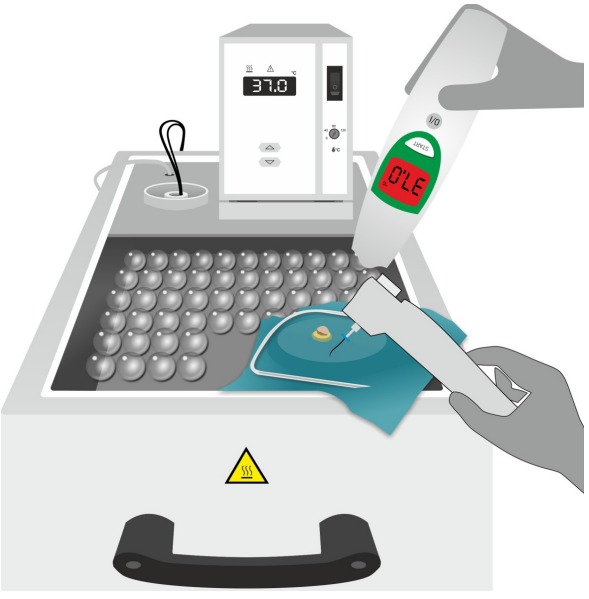

Figure 2. *The experimental setup used to simulate the oral environment in this study*

Group 3: The root canals were irrigated with 5 mL of 2.5% NaOCl (21 °C) and then the irrigation solution was activated with XP-Endo Finisher (FKG, Dentaire SA, La Chaux-de-Fonds, Switzerland) at 800 rpm with 1 Ncm for one minute. The file tip was placed 1 mm short of the WL and was slowly moved with in-and-out motions up to 7–8 mm. A final flush was done with 5 mL of 2.5% NaOCl (21 °C).

Group 4: The irrigation protocol was the same as that for Group 3 with the following exception: 10 mL of 2.5% NaOCl at 37 °C was used.

Group 5: The root canals were irrigated with 5 mL of 2.5% NaOCl (21 °C), and then XP-Endo Finisher was used in the same way as it was used in Group 3. A final flush was done with 5 mL of 2.5% NaOCl (21 °C).

For each specimen, 11 mL of 2.5% NaOCl was used in total and was delivered at a flow rate of approximately 0.08mLs^{-1}.

Scoring

The images of the grooves were obtained under a stereomicroscope (20× magnification, Zeiss Stemi 2000-C, MicroImaging, Göttingen, Germany) equipped

Table 2. *Distribution of the CH removal scores according to the root regions (median [interquartile range]) (n=15 for each group)*

Groups	Regions	
	Apical	Coronal
1	3 [3-3] ^{A,a}	3 [3-3] ^{A,a}
2	3 [2-3] ^{A,a}	3 [2-3] ^{A,a}
3	2 [2-2] ^{B,a}	3 [2-3] ^{A,b}
4	1 [1-2] ^{B,a}	3 [2-3] ^{A,b}
5	3 [3-3] ^{A,a}	3 [3-3] ^{A,a}

Different uppercase letters in the same column and different lowercase letters in the same row indicate statistically significant differences (p<0.05)

with a digital camera, (AxioCam ERc5s, Carl Zeiss Microscopy GmbH, Göttingen, Germany) and were coded before evaluation to ensure that the evaluators were blinded to their groups. The amount of remaining CH in the grooves was evaluated by two calibrated endodontists using a numeric evaluation scale described by van der Sluis et al.[6] Fifty randomly selected samples were used for the calibration of the observers. Total of 166 images was evaluated. Any disagreement between observers was discussed until a consensus was reached. The scoring system was as follows: score 0: the groove is entirely empty; score 1: CH is present in less than 50% of the groove; score 2: CH is present in more than 50% of the groove, but not its entirety; and score 3: the groove is completely covered with CH (Figure 3).

Statistical analysis

Kappa test was used to determine inter-examiner agreement. The Kruskal Wallis test was used to compare the non-normal distribution of data among the groups. Mann Whitney U test with Bonferroni-correction was used to conduct pair-wise multiple comparisons between the groups. A p value <0.05 was considered significant. The analyses were performed using SPSS 19 software (IBM SPSS Statistics 19, SPSS Inc., IBM Co., Somers, NY, USA).

Results

The inter-examiner agreement was 0.87 and the differences between the determined scores never exceeded one unit. None of the experimental groups showed a complete removal of CH remnants. All positive control samples resulted in a score of 3, and all negative control samples resulted in a score of 0.

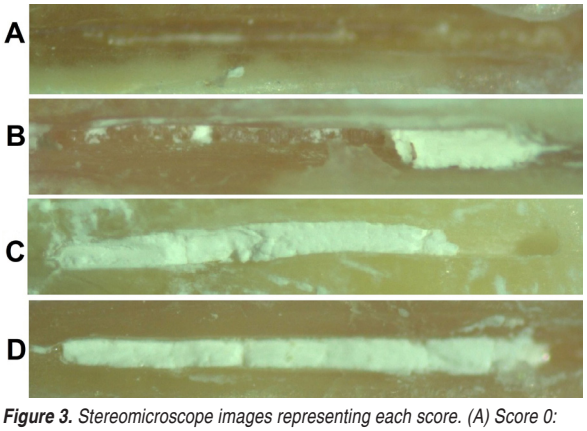

Figure 3. *Stereomicroscope images representing each score. (A) Score 0: groove is empty; (B) Score 1: less than half of the groove is filled with CH; (C) Score 2: more than half of the groove is filled with CH; (D) Score 3: groove is completely covered with CH*

Intra-group comparisons

Table 2 shows the distribution of scores according to the root regions. Regarding the intra-group comparisons, there was no significant difference between the root regions (apical versus coronal) for the removal of CH except for Group 3 and 4. In Group 3 and 4, significantly higher amount of CH was removed from the apical region than the coronal region (p<0.05; Table 2). In the apical region, the percentages of score 0 were 20% for Group 4, and 0% for the other experimental groups. In the coronal region, the percentages of score 0 were 0% for all the experimental groups.

Inter-group comparisons

Groups 3 and 4 resulted in significantly more CH removal from the apical region compared with the other groups (p<0.05). The Kruskal-Wallis test revealed no significant differences between the groups for the coronal region (Table 2; p>0.05). The removal of CH was not affected by the irrigation solution temperature (p>0.05) but the environmental temperature affected XP-Endo Finisher's activity at a significant level (p<0.05; Group 3 versus Group 5).

According to these results, the first null hypothesis (concerning the effect of the environmental temperature) was rejected and the second null hypothesis (concerning the effect of the solution temperature) was accepted.

Discussion

XP-Endo Finisher is in M-phase and has a straight shape when it is at 30 °C. When it is heated it changes to the A-phase and its shape becomes similar to a spoon because it is made from NiTi MaxWIRE alloy. XP-Endo Finisher has been tested for the removal of CH, double antibiotic paste, smear layer, debris or biofilm from root canal in previous studies.[11-17] To our knowledge, there has been no study comparing the effectiveness of XP-Endo Finisher at different temperatures for removing CH from root canal irregularities. In addition, previous

studies[12,13] have not provided information on the temperature at which XP-Endo Finisher was used. However, the manufacturer states that it shows efficacy by assuming a spoon shape when used at body temperature (37 °C). In the present study, XP-Endo Finisher was used at room temperature or at an environmental temperature of 37 °C. The results showed that XP-Endo Finisher used at an environmental temperature of 37 °C (Group 3) removed statistically more CH than at room temperature (Group 5) in the apical region; therefore, our first null hypothesis was rejected. In accordance with the manufacturer's instructions, the use of XP-Endo Finisher at body temperature may have allowed it to pass into the A-phase and assume a spoon shape. Consequently, assuming a hard and strong shape in its A-phase may have resulted in removal of more CH than that removed at the M-phase of the XP-Endo Finisher which is soft and ductile. Hence, researchers should pay attention to environmental temperature while working with these alloys under *in vitro* conditions. The use of these alloys at room temperature may not be reasonable and may not reflect the actual clinical situation.

In the present study increasing the NaOCl temperature promoted the CH removal capacity of both the conventional needle irrigation and XP-Endo Finisher in the apical region, but this did not make a statistically significant difference. The temperature increase of the NaOCl had almost no contribution to the removal of CH from the coronal region. Therefore, the second null hypothesis was accepted. There are no previous studies we can use as a reference to compare the results of XP-Endo Finisher used with NaOCl solution at different temperatures for removing CH; our results are not directly comparable with other study results.

The results of this study showed that there was a significant difference between XP-Endo Finisher and conventional needle irrigation techniques for CH removal at an environmental temperature of 37 °C. Uygun et al.[12] investigated the effectiveness of XP-Endo Finisher and TRUShape 3D Conforming File (Dentsply Tulsa Dental Specialties) for removing CH from root canal irregularities in coronal and apical parts of the root canal system. They reported that XP-Endo Finisher was superior to a needle irrigation group in removing CH regardless of the groove location. However, in the present study, XP-Endo Finisher removed significantly more CH than needle irrigation only in the apical region. Uygun et al.[12] used the XP-Endo Finisher with continuous irrigation, whereas in the present study, the XP-Endo Finisher was used alone. Continuous irrigation may therefore be the cause of the differences between the studies. Uygun et al.[12] also reported that XP-Endo Finisher removed more CH in the apical region than the coronal region. The reason for this may be related to how XP-Endo Finisher takes the form of a spoon in only the apical half of the file, and might not allow for adequate cleaning in the coronal region.

In the present study, the simulated root canal irregularities were prepared by using a modified Cavitron tip. The study design has been used by several other investigations.[1,6,8,9,12] The advantage of the technique is that it is simple, rapid, and reproducible. However, these standard irregularities with regular borders may not reflect natural irregularities.

CH is the most commonly used medicament for enhancing disinfection of the root canal system between appointments.[18] Systematic reviews have documented that passive ultrasonic irrigation (PUI) is superior to conventional syringe irrigation for CH removal.[10] Keskin et al.[11] reported that both PUI and XP-Endo Finisher were superior to conventional syringe irrigation and that there was no significant difference between them for the removal of CH from simulated internal resorption cavities. The superiority of passive ultrasonic irrigation and XP-Endo Finisher to conventional syringe irrigation was shown also in a debris removal study by Leoni et al.[14] The superiority of XP-Endo Finisher to conventional irrigation and file agitation techniques was also reported for curved root canals.[16]

In previous studies, water, NaOCl, and various chelating agents such as citric acid, maleic acid, and EDTA, along with other combinations, have been used to remove medicaments from root canal surfaces.[1,6,11,13] The superiority of chelating agents in CH removal compared to water and NaOCl is well known.[1,19] Use of NaOCl alone as an irrigation solution in the present study, was done in order to focus on the effects of the irrigation technique and temperature, rather than investigate the effects of the irrigation solution.

Conclusion

Within the limitations of the present study, it can be concluded that the use of XP-Endo Finisher facilitated the removal of CH from the standardized grooves in the apical region than the conventional needle irrigation method. The temperature of the NaOCl solution did not play a significant role in the CH removal efficacy of the XP-Endo Finisher, but the environmental temperature affected its activity at a significant level.

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XP-Endo Finisher'in kök kanal düzensizliklerinden kalsiyum hidroksit uzaklaştırma yeteneği üzerine sıcaklığın etkisi: *ex vivo*

Özet

Amaç: Bu çalışmanın amacı, XP-Endo Finisher'ın kök kanal düzensizliklerinden kalsiyum hidroksit (KH) uzaklaştırma kapasitesine sıcaklığın (çevre ve irrigasyon solüsyonunun) etkisini değerlendirmektir.

Gereç ve Yöntem: Seksen üç dişin kök kanalı genişletildi ve dişler uzunlamasına ikiye ayrıldı. İki standart yarık (apikal ve koronalde) hazırlandı ve kökler rastgele beş deney grubuna (n=15), bir pozitif (n=4) ve bir negatif kontrol grubuna (n=4) ayrıldı. Yarıklar KH ile dolduruldu, kök yarımları tekrar birleştirildi, tüm kanal KH ile dolduruldu ve dişler 14 gün boyunca saklandı. Daha sonra KH aşağıdaki irrigasyon protokollerine göre uzaklaştırıldı. Ortam sıcaklığı ilk dört grup için 37 °C, Grup 5 için 21 °C idi. Grup 1: geleneksel iğne irrigasyonu ile 21 °C'deki NaOCl, Grup 2: geleneksel iğne irrigasyonu ile 37 °C'deki NaOCl, Grup 3: XP-Endo Finisher ile 21 °C'deki NaOCl, Grup 4: XP-Endo Finisher ile 37 °C'deki NaOCl, Grup 5: XP-Endo Finisher ile 21 °C'deki NaOCl kullanımıydı. İrrigasyon işleminden sonra artakalan KH miktarı bir stereomikroskop ile incelenerek skorlandı. İstatistiksel değerlendirme, Kruskal-Wallis analizi ve Mann-Whitney U testi Bonferroni düzeltmesi kullanılarak yapıldı.

Bulgular: Grup 3 ve 4, apikal bölgede diğer gruplara göre anlamlı derecede daha fazla KH uzaklaştırdı ($p<0.05$). Koronal bölgede gruplar arasında fark yoktu ($p>0.05$). KH uzaklaştırılması, irrigasyon solüsyonunun sıcaklığından etkilenmedi ($p>0.05$) ancak çevre sıcaklığından (Grup 3'e karşı Grup 5; $p<0.05$) ve KH uzaklaştırma tekniğinden (Grup 3 ve 4'e karşı Grup 1 ve 2; $p<0.05$) önemli derecede etkilendi.

Sonuç: NaOCl solüsyonunun sıcaklığı XP-Endo Finisher'ın KH kaldırma etkinliğinde önemli bir rol oynamazken, çevre sıcaklığı etkinliğini arttırdı.

Anahtar Kelimeler: Endodonti; ısı; kalsiyum hidroksit