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Araştırma/ Research Article

EFFICACY OF VARIOUS LASER-ASSISTED IRRIGATION ACTIVATION TECHNIQUES ON CALCIUM HYDROXIDE REMOVAL[≠]

ÇEŞİTLİ LAZER DESTEKLİ İRRİGASYON AKTİVASYON TEKNİKLERİNİN KALSİYUM HİDROKSİT UZAKLAŞTIRMA ÜZERİNE ETKİSİ[≠]

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ABSTRACT

Aim: The present study aims to examine the impact of various laser-assisted irrigation activation techniques on the removal of $Ca(OH)_2$ from coronal and apical artificial grooves prepared in canal walls.
Materials and Methods: The root canal instrumentation procedures of sixty extracted mandibular premolar teeth were performed using ProTaper Universal system. The grooves were prepared in the coronal and apical regions of the root canals. $Ca(OH)_2$ was placed into the grooves for 1 week. Teeth were allocated into 4 groups according to the irrigation techniques of EDTA (n=15): needle irrigation, PIPS, Nd:YAG laser, and Er:YAG laser. The percentage of $Ca(OH)_2$ remnants was quantified using image analysing software (Image J). For the statistical analysis, one-way analysis of variance and post-doc LSD tests were used ($P = .05$).
Results: For apical grooves, PIPS and Er:YAG laser groups were statistically more effective than needle irrigation and Nd:YAG laser groups ($P < .05$). No significant difference was determined between PIPS and Er:YAG laser groups; needle irrigation and Nd:YAG laser groups ($P > .05$). For coronal grooves, all of the groups showed statistically similar results ($P > .05$).
Conclusion: Within the limitations of this laboratory study, Er:YAG laser and PIPS techniques enhanced $Ca(OH)_2$ removal ability of EDTA in apical region.
Key Words: irrigation, laser-assisted irrigation, irrigation activation, calcium hydroxide

ÖZ

Amaç: Bu çalışma çeşitli lazer destekli irrigasyon aktivasyon tekniklerinin kanal duvarlarında oluşturulmuş koronal ve apical yapay oluklardan kalsiyum hidroksit uzaklaştırma üzerine etkisini incelemeyi amaçlamaktadır.
Gereç ve Yöntem: 60 adet çekilmiş mandibular premolar dişin kök kanal enstrümentasyon işlemleri ProTaper Universal system kullanılarak gerçekleştirildi. Kök kanallarının koronal ve apikal bölgelerinde oluklar hazırlandı. Oluklara bir hafta süreyle $Ca(OH)_2$ yerleştirildi. Dişler EDTA'nın irrigasyon tekniğine gore 4 gruba ayrıldı (n=15): iğne irrigasyonu, PIPS, Nd:YAG lazer, ve Er:YAG lazer. $Ca(OH)_2$ kalıntılarının yüzdesi görüntü analiz yazılımı kullanılarak ölçüldü (Image J). İstatistiksel analiz için tek tönlü varyans analizi ve post-doc LSD testleri kullanıldı ($P = .05$).
Bulgular: Apikal oluklar için, PIPS ve Er:YAG lazer grupları, iğne irrigasyounu ve Nd:YAG lazer gruplarından istatistiksel olarak daha etkiliydi ($P < .05$). PIPS ve Er:YAG lazer grupları; iğne irrigasyounu ve Nd:YAG lazer grupları arasında istatistiskel farklılık belirlenmedi ($P > .05$). Koronal oluklar için, tüm gruplar benzer sonuçlar gösterdi ($P > .05$).
Sonuç: Bu laboratuvar çalışmasının limitasyonları dahilinde, Er:YAG lazer and PIPS teknikleri EDTA'nın apikal bölgede $Ca(OH)_2$ uzaklaştırma yeteneğini arttırdı.
Anahtar Kelimeler: irrigasyon, lazer destekli irrigasyon, irrigasyon aktivasyonu, kalsiyum hidroksit

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INTRODUCTION

The aim of the root canal treatment is to eliminate the microorganisms, their by-products and residual pulpal tissue from the root canal system and to fill the cleaned root canals.[1] Debridement of the root canal system and also the removal of intracanal medicaments are crucial procedures since the root canal space has complicated irregularities.[2] Calcium hydroxide [$Ca(OH)_2$] has been preferred in dentistry as a root canal dressing for a long while, and it has some advantages and disadvantages.[3-5] One of the disadvantages of $Ca(OH)_2$ is that it is hard to remove from the root canals.[6, 7] Remnants of $Ca(OH)_2$ may impair the bonding of root canal sealers to root canal wall and cause leakage to increase.[8, 9] Therefore, the removal of the medicament before obturation is important for long-term success of endodontic treatment.

Irrigation activation techniques such as using lasers, sonic and ultrasonic devices are recommended in order to enhance chemical and mechanical properties of irrigating solutions.[10-12] The cleaning mechanism of laser-assisted irrigation activation techniques is due to rapid movement of solutions. This movement occurs after expansion and implosion of vapour bubbles at the fibre tip caused by the pulsed laser operation. This effect is called the cavitation effect.[13, 14]

Different laser systems had been used for laser-assisted irrigation activation. Neodymium-doped yttrium aluminum garnet (Nd:YAG) and erbium-doped yttrium aluminum garnet (Er:YAG) laser are two of these laser systems.[15, 16] Nd:YAG laser has a wavelength of 1064 nm and it is absorbed partially in water.[16] Er:YAG laser has a wavelength of 1064 nm, and it is well absorbed in water and hydroxyapatite.[15] Photon-initiated photoacoustic streaming (PIPS) is a technique which requires using Er:YAG laser. In this technique, fiber optic conical-ended tip is placed in the coronal part of the canal.[15]

In the literature, there is no study which compares the influence of laser-assisted irrigation activation techniques including Nd:YAG, Er:YAG laser and PIPS on the removal of $Ca(OH)_2$ from artificial grooves prepared in root canals. Therefore, this study aimed to examine the impact of various laser-assisted irrigation activation techniques on the removal of $Ca(OH)_2$ from coronal and apical artificial grooves prepared in canal walls. The null hypothesis was that there would be no significant differences among laser-assisted irrigation techniques in regards to remnants of $Ca(OH)_2$ in the artificial grooves.

MATERIAL AND METHODS

Sixty intact mandibular premolar teeth were selected and stored in distilled water prior to experimental procedures. The inclusion criteria were that having mature apices, one root and one root canal. The exclusion criteria were that having caries, fractures, resorption, root canal filling or restoration. The teeth were decoronated, and 14-mm roots were prepared. For the working length measurement, a size 10 K-file (Dentsply Sirona, Ballaigues, Switzerland) was used. The root canals were instrumented using the ProTaper Universal system (Dentsply Sirona) up to F4. Root canal irrigation with 1 mL NaOCl solution (1%) was performed between the instruments.

A silicone material (Optosil; Heraeus Kulzer, Hanau, Germany) was used for fixing the roots in Eppendorf vials. The specimens were taken out from the silicon material, and a diamond disk was used for splitting of the roots into two halves longitudinally. Longitudinal grooves (3-mm long, 0.2-mm wide, and 0.5-mm deep) were prepared in the coronal region (at a distance of 9–12 mm from the apex) of the root canal wall of one half of each tooth and in the apical region (at a distance of 2–5 mm from the apex) of the root canal wall of other half of each tooth. For preparation of grooves, ultrasonic tips were used. Debris was removed from the root canals using a toothbrush. For final irrigation, 5 mL EDTA solution (17%) (Werax; Spot Dis Deposu A.Ş., Izmir, Turkey) for 1 minute and 5 mL NaOCl solution (1%) (Werax) for 2 minutes were used. The flow rate of EDTA was 0.083 ml/s, and the flow rate of NaOCl was 0.042 ml/s.

Application of $Ca(OH)_2$

$Ca(OH)_2$ medicament (Kalsin; Spot Dis Deposu A.Ş., Izmir, Turkey) was prepared by mixing with distilled water and filled into artificial grooves using a size 15 K-file (Dentsply Sirona). The root halves were reassembled, fixed with wax. The specimens were inserted into the Eppendorf vials. A cotton pellet and temporary filling (BMS Dental, Capannoli, Italy) were placed into canal orifices and the roots were kept at 37 °C with 100% humidity for 1 week. Teeth were allocated into 4 groups according to irrigation techniques (n = 15):

Needle irrigation group: 1 mL of EDTA solution (17%) was injected into the root canal in 10 s using a side-vented irrigation needle (30-G; Ultradent Products Inc, South Jordan, UT) with gentle back and forth movement. 1 mL solution was injected in 10 s and then the solution was left in the root canal for 10 s. The flow rate was 0.1 ml/s. This procedure was done six consecutive times. In total, irrigation with 6 mL of EDTA was performed for each root canal.

PIPS group: 1 mL of EDTA solution (17%) was injected into the canal in 10 s using a side-vented irrigation needle (the flow rate was 0.1 ml/s), and then the solution was irradiated with 2940 nm Er:YAG laser (LightWalker AT, Fotona, Ljubljana, Slovenia) at 1W, 20 Hz, and 50 mJ per pulse. A 300 µm PIPS fiber optic tip was placed in the coronal part of the canal. 1 mL of EDTA solution was injected in 10 s, and then 10 s of activation was performed. This procedure was done six consecutive times. In total, irrigation with 6 mL of EDTA was performed, and total irrigation activation time was 60 s for each root canal.

Er:YAG group: 1 mL of EDTA solution (17%) was injected into the canal in 10 s using a side-vented irrigation needle (the flow rate was 0.1 ml/s), and the solution was activated by 2940 nm Er:YAG laser (LightWalker AT) with a 300 µm optic fiber plain tip at 1W, 20 Hz, and 50 mJ per pulse. Following 10 s of irrigation, 10 s of activation was performed. This procedure was done six consecutive times. In total, irrigation with 6 mL of EDTA was performed and total irrigation activation time was 60 s for each root canal. During the activation, the optical fiber tip was inserted into the apical third of the canal. During the activation of the solution, movement was made in the up and down direction with a helical movement.

Nd:YAG group: 1 mL of EDTA solution (17%) was injected into the canal in 10 s using a side-vented irrigation needle (the flow rate was 0.1 ml/s), and then the solution was activated by 1064 nm Nd:YAG laser (LightWalker AT) with a 320 µm optic fiber plain tip at 1W, 20 Hz, and 50 mJ per pulse. Rest of the procedures were similar with Er:YAG group.

In all groups, irrigation needle was placed into the root canal up to 2 mm from the apical reference point of the working length.

In all groups, following completion of irrigation and activation of EDTA, root canals were irrigated using 5 mL distilled water and dried with paper points. Digital images of root halves were obtained using a dental operating microscope (OPMI Pico; Carl Zeiss Meditec, Jena, Germany) at 31.25× magnification (2.5× magnification factor and 12.5× ocular magnification).

The amount of remnants of $Ca(OH)_2$ and total amount of the grooves were quantified using an image analysing software (Image J;http://imagej.nih.gov/ij/). The pixel count of the area of remnants of $Ca(OH)_2$ and the area of the grooves was calculated and the percentage of $Ca(OH)_2$ remnants were calculated (Figure 1).

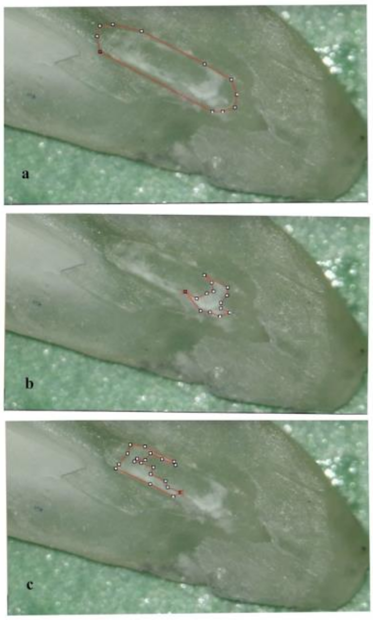

Figure 1. (a) the area of the groove, **(b,c)** the area of remnants of $Ca(OH)_2$

Statistical analysis

For all statistical analyses, SPSS version 20 (SPSS Inc., Chicago, IL, USA) was used. Levene's homogeneity and Komolgov Smirnov tests were used for homogeneity and normality, respectively. One-way analysis of variance was used for analysis of the data. LSD test was used for multiple comparisons. The level of significance was set at $P < .05$.

RESULTS

The mean percentage of $Ca(OH)_2$ remnants in apical grooves was 67.68% for the needle irrigation group, 41.74% for PIPS group, 29.12% for Er:YAG group and 65.07% for Nd:YAG group. PIPS and Er:YAG laser groups were statistically more successful than needle irrigation and Nd:YAG laser groups ($P < .05$). No significant difference was determined between PIPS and Er:YAG laser groups; needle irrigation and Nd:YAG laser groups (P > .05) (Figure 2).

The mean percentage of $Ca(OH)_2$ remnants in coronal grooves was 35.93% for the needle irrigation group, 28.47% for PIPS group, 24.73% for Er:YAG group and 30.95% Nd:YAG group. All of the groups showed statistically similar results in terms of $Ca(OH)_2$ remnants in coronal grooves (P > .05) (Figure 3).

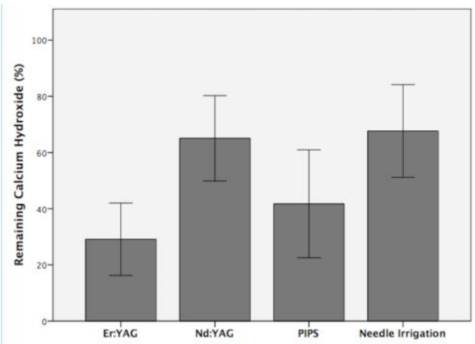

Figure 2. Graphical demonstration of the percentage of the remaining $Ca(OH)_2$ in apical grooves

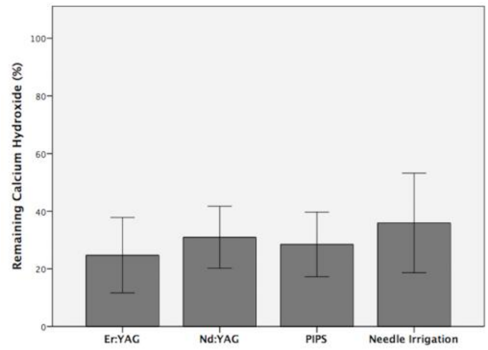

Figure 3. Graphical demonstration of the percentage of the remaining $Ca(OH)_2$ in coronal grooves

DISCUSSION

$Ca(OH)_2$ has antimicrobial effect on most of the microorganism species which are responsible from endodontic diseases.[1, 17] This makes $Ca(OH)_2$ most preferred intracanal medicament. [1, 17] Removal of $Ca(OH)_2$ remnants is necessary prior to filling of root canals.[6-9] However, none of the irrigation techniques can provide complete removal of $Ca(OH)_2$ remnants.[7, 10, 11, 18] The aim of this study was to examine the impact of various laser-assisted irrigation activation techniques on the removal of $Ca(OH)_2$ from artificial grooves prepared in root canal walls. The results of the present study demonstrated that PIPS and Er:YAG laser groups were statistically more successful than needle irrigation and Nd:YAG laser groups (P < .05); no significant difference was determined between PIPS and Er:YAG laser groups (P> .05); no significant difference was determined between needle irrigation and Nd:YAG laser groups (P> .05) in regards to the removal of $Ca(OH)_2$ remnants from apical grooves.The results for coronal grooves showed that no significant difference was determined among groups (P>.05). Therefore, the null hypothesis was not accepted.

The absence of statistically significant difference among groups in regards to $Ca(OH)_2$ removal from grooves in coronal region (P > .05) can be attributed to the fact that debriding of root canals is easier in coronal third than in apical third. Yang et al.[19], Motiwala et al.[20], Denna et al.[21] were also showed that the irrigation techniques were more successful in coronal region compared to the apical region. These results are in accordance with the results of the present study.

Needle irrigation is the most preferred technique of irrigation procedure.[22] It was demonstrated that irrigating solutions cannot reach further than 1 mm from the tip of the irrigation needle.[23] This can cause less debriding of the apical part and make it difficult to remove the intracanal medicaments from the especially apical region of the root canals. This can explain why needle irrigation group was not as successful as PIPS and Er:YAG laser groups in apical grooves.

Cavitation effect basically occurs due to the formation of bubbles in irrigating solutions.[14] Absorption of Er:YAG laser irradiation by hydroxyapatite and water is high.[24, 25] The energy, which occurs after absorption of Er:YAG laser irradiation by water, results in evaporation.[26, 27] The vapour bubble expands and forms a void in front of the laser light.[14] In addition to this effect of Er:YAG laser, Nd:YAG laser does not have an efficient wavelength for cavitation.[28] This may explain why $Ca(OH)_2$ remnants in the apical grooves was less in PIPS and Er:YAG laser groups than Nd:YAG laser and needle irrigation groups (P < .05). According to our literature search, although there are many studies with regard to the influence of different irrigation techniques on $Ca(OH)_2$ removal, there is no study examines various laser-assisted irrigation activation techniques in terms of $Ca(OH)_2$ removal. Therefore, a direct comparison with previous studies cannot be performed. Arslan et al.[10] found that PIPS showed higher success in removal of $Ca(OH)_2$ remnants than needle irrigation. This result is in harmonious with the results of the present study. Yang et al.[19] showed that laser-assisted irrigation activation techniques were improved the removal of $Ca(OH)_2$ remnants. Laky et al.[29] were also showed that PIPS technique provided better results compared to the needle irrigation. These results can support the results of the present study. Kaptan et al.[30] found no significant difference between Er:YAG laser activation and needle irrigation techniques. This result is not in accordance with the results of the present study. The differences between the results of the studies may be attributed to different laser parameters.

In PIPS technique, conical-ended fibers are used. When used with a water-absorbing middle infrared laser (Er:YAG or Erbium; Chromium, Yttrium-Scandium-Gallium-Garnet), shock waves into the irrigating solution occur due to absorption of laser energy, and thus conical-ended fiber enhances cleaning effect of irrigating solutions.[14, 31-33] George et al.[34] reported that when used with the same laser system and the same irrigating solution, conical-ended fibers showed higher success than plain fibers in regards to the removal of smear layer. In the present study, PIPS group showed similar results with Er:YAG group, although fiber tip was placed in the coronal part of the canal. This result may be explained by the use of conical-ended fiber in PIPS group.

The experimental setup,[6, 7, 10] which was used in previous studies, was used in the present study. This design provides standardization of the size and location of the grooves. Artificial grooves may also provide simulation of the irregularities in the root canals, where the remaining $Ca(OH)_2$ is high. On the other hand, the irregularities in the root canals are much more complex and cannot simulate thoroughly using this model. In the present study, the percentage of remaining $Ca(OH)_2$ was calculated using an image analysing software. This provides a standardized evaluation, but does not allow the researchers investigate $Ca(OH)_2$ diffused into the dentinal tubules. This method had been used in previous studies.[10, 35] Scoring of the $Ca(OH)_2$ remnants is another method for the comparing of the irrigation activation systems. This method had also been used in many studies.[36-38] However, pixel counting provides more sensitive evaluation compared to the scoring method.

Rödig et al.[39] concluded that chelating agents such as EDTA and citric acid are more effective in the removal of $Ca(OH)_2$ remnants from root canals, and the usage of NaOCl did not improve the result. Distilled water is not capable of dissolving $Ca(OH)_2$.[39] When NaOCl is used alone, it is inadequate in the removal of $Ca(OH)_2$.[6] The superiority of chelating agents compared to the other irrigation solutions has been demonstrated in previous studies.[40, 41] Therefore, EDTA was used as an irrigating solution in the present study since it assists removal of $Ca(OH)_2$ remnants.

Recently, in order to enhance the effect of PIPS technique, a new shock wave enhanced emission photoacoustic streaming (SWEEPS) technique was introduced. This technique aims to emit synchronized laser pulses and therefore it provides to improve the collapse of vapor bubbles.[42] Adding this new technique as another group to the previous study could have strengthened the scientific aspect of the study. This may be the limitation of the present study.

CONCLUSION

Within the limitation of this laboratory study, Er:YAG laser and PIPS techniques enhanced $Ca(OH)_2$ removal ability of EDTA in apical region.

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