Original Article

Comparative evaluation of penetration of sealers in dentinal tubules using passive ultrasonic irrigation and Erbium: yttrium-aluminum-garnet laser – A confocal laser scanning microscope study

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Abstract

Context: Smear layer clearance and sealer penetration into dentinal tubules play a crucial role in root canal treatment. Hence, efficient irrigation is a crucial component of the root canal debridement. This *in vitro* study's objective was to assess the effectiveness of passive ultrasonic activation and Erbium: yttrium-aluminum-garnet (Er: YAG) laser-activated irrigation on irrigation solution penetration and sealer penetration into dentinal tubules.

Aims: The aim of this study was to evaluate and compare the dentinal tubule penetration of epoxy resin-based sealer and bioceramic sealer after ultrasonic agitation and Er: YAG laser activation of the irrigant.

Settings and Design: This was an *in vitro* study.

Materials and Methods: Extracted tooth samples ($n = 42$) into 06 groups (Group A-F) with 7 samples in each group. Postobturation transverse section was made and assessed under a confocal laser scanning microscope for the total dentinal tubule penetration area and recorded as the mean apical, middle, and coronal penetration.

Statistical Analysis: One-way analysis of variance test, followed by *post hoc* was used.

Results: The intergroup comparison showed that Group E and Group F have significantly more penetration as compared to the controls and ultrasonic irrigation, $P < 0.001$ and $P < 0.01$, respectively.

Conclusions: Er: YAG laser with AH plus sealer has the highest penetration in all the sections of tooth, followed by CeraSeal sealer.

Keywords: AH plus sealer; CeraSeal sealer; confocal laser scanning microscope; dentin tubule penetration; erbium: yttrium-aluminum-garnet laser; ultrasonic irrigation

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INTRODUCTION

The fundamental prerequisites for successful root canal therapy are efficient chemomechanical preparation and three-dimensional obturation of the root canal system.[1] It

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is known that root canal instrumentation leaves a smear layer on the prepared canal walls, which may act as a breeding ground for bacteria. Because of these factors, efficient irrigation is a crucial component of root canal debridement since it would prevent the entire root canal system from becoming recontaminated.[2]

Brushes, hand-activated files or gutta-percha cones, sonic systems, ultrasonic systems, and laser activation systems are just a few examples of human agitation techniques and machine-assisted agitation tools that have been developed to improve the effectiveness of irrigation solutions.

Passive ultrasonic irrigation (PUI) generates acoustic microstreams at ultrasonic frequencies (25–30 kHz) to activate irrigation.[3]

Laser-activated irrigation effectively removes the debris and smear layer from more complex root canal systems by producing explosive gas bubbles with a subsequent cavitation impact. An Erbium: yttrium-aluminum-garnet (Er: YAG) laser is employed with the unique laser agitation technique known as photon-induced photoacoustic streaming. The highest-power spikes are produced by this method using low levels of energy and short microsecond pulse rates (50 s).[1,3,4]

Despite being a widely accepted obturating agent, gutta-percha is nonadhesive to the dentin regardless of the obturation procedure. To create an impermeable seal between the core material and the canal walls, sealers are used. It offers lateral and apical seals and fills the root canal dentine effectively.[5]

The purpose of this *in vitro* study was to assess the effectiveness of various irrigation techniques, including passive ultrasonic activation and laser-activated irrigation using an Er: YAG laser on the sealer penetration into dentinal tubules using confocal laser scanning microscope (CLSM).[3]

MATERIALS AND METHODS

The present study was an *in vitro* study conducted in the department of conservative dentistry and endodontics. The institutional review, scientific and ethical committee, wide letter no. DYPDCH/EC/DPU/299/86/2021 dated October 20, 2021, granted the study's scientific and ethical clearance.

Study commenced with the preparation and grouping of 02 different irrigant activation techniques namely-Er: YAG laser activation and ultrasonic agitation and 02 different types of sealers, namely AH Plus Sealer (Dentsply, Germany) and CeraSeal bioceramic sealer (Meta Biomed, Korea).

Procedure

Single straight-rooted extracted noncarious teeth with a single canal and closed apex with root curvature <25° ($n = 42$) were included in the study. The teeth were cleaned with an ultrasonic scaler and stored in distilled water. Decoronation was done with diamond discs to standardize the root length to 15 mm. ISO #10 K-file was inserted until visible at the apical foramen for the glide path.

After the access cavity preparation, canals were prepared using ProTaper Universe (Dentsply Maillifer) up to size F3. Specimens were irrigated with 2 mL of 3% NaOCl among each change of instrument.

To stop the irrigant from being forced through the apex during irrigation procedures, the apex was sealed with soft modeling wax. In the final wash, 5 mL of 17% EDTA (Prime Dental) and 5 mL of 5% NaOCl were applied for 1 min each. After the process, 5 mL of distilled water was used to irrigate the canal, and it was subsequently dried with paper points (Meta Biomed).

The samples were randomly divided into 04 groups ($n = 07$) depending on the irrigation activation protocol used including 02 groups of controls:

- GROUP A and B (Control): AH sealer and CS sealer alone as control
- GROUP C and D: PUI was performed using an ultrasonic activator (Ultra X, Eighteeth) with the "silver" tip at 45KHz. F3 paper point was used to dry the canal and obturated using F3 master cone with AH sealer and CeraSeal sealer (manipulated according to manufacturer's instructions), respectively
- GROUP E and F: An Er: YAG laser (Fotona, Ljubljana, Slovenia) was used to perform final irrigation using the laser irradiation protocol at a wavelength of 2940 nm. The very short-pulse mode was used to activate the laser at 0.9 W, 30 mJ per pulse, and 30 Hz. The laser system's air and water were turned off. The duration of activation was 1 min. F3 paper point was used to dry the canal and obturated using the F3 master cone with AH sealer and CeraSeal sealer (manipulated according to manufacturer's instructions), respectively.

*(0.1% wt Rhodamine B fluorescent dye was added to root canal sealer in all groups).

Postobturation assessment

After obturation, transverse sections of 1 mm were made using slow-speed diamond discs at 3 mm (apical), 5 mm (middle), and 8 mm (coronal) from the root apex. These sections were then observed under a CLSM. Digital images were imported into the ImageJ v1.53a software (National Institutes of Health, Bethesda, MD, USA.) program to measure the total dentinal tubule penetration area. The average value was recorded as the penetration depth of sealer for all the apical, middle, and coronal sections.

Table 1: Intergroup comparisons of apical mean penetration

Group	*n*	Mean	SD
AH control	7	421.36***	45.78
CS control	7	561.64***	56.82
AH + U	7	587.39**	196.17
CS + U	7	1262.96**	276.01
AH + L	7	1383.11**	181.30
CS + L	7	1117.07	392.73

***$P<0.001$ versus CS + L, **$P<0.01$ versus CS + L, one-way ANOVA, Tukey-Kramer multiple comparisons test. ANOVA: Analysis of variance, SD: Standard deviation

Table 2: Intergroup comparisons of middle means penetration

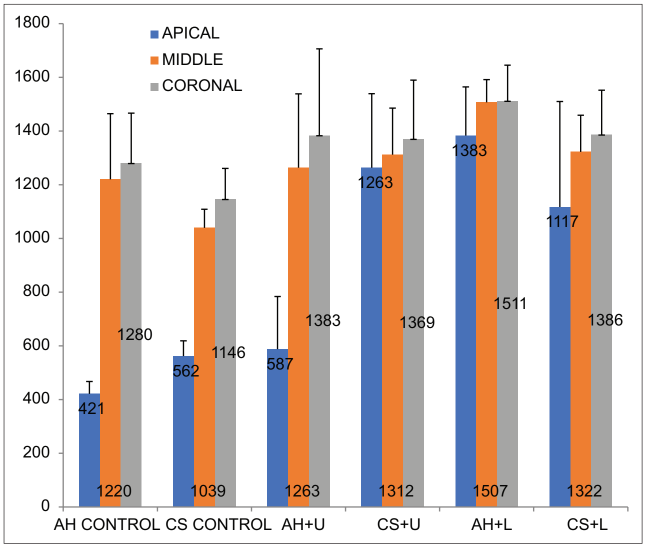
Group	*n*	Mean	SD
AH control	7	1219.50	245.11
CS control	7	1039.32	69.45
AH + U	7	1262.96	274.95
CS + U	7	1311.76	173.70
AH + L	7	1506.75***	84.58
CS + L	7	1321.79	137.10

***$P<0.001$ versus CS control, one-way ANOVA, Tukey-Kramer multiple comparisons test. ANOVA: Analysis of variance, SD: Standard deviation

Table 3: Intergroup comparisons of coronal mean penetration

Group	*n*	Mean	SD
AH control	7	1279.86	186.83
CS control	7	1145.71	114.64
AH + U	7	1383.11	322.42
CS + U	7	1369.45	219.78
AH + L	7	1511.29*	134.02
CS + L	7	1385.96	165.53

*$P<0.01$ versus CS control, one-way ANOVA, Tukey-Kramer multiple comparisons test. ANOVA: Analysis of variance, SD: Standard deviation



Graph 1: Intergroup comparison of the mean apical, middle and coronal penetration. The Intergroup comparison of the mean apical, middle and coronal penetration showed erbium: yttrium-aluminum-garnet (Er: YAG) laser activation + AH Plus Sealer and Er: YAG laser activation + CeraSeal sealer have significantly more penetration as compared to the controls and Ultrasonic Irrigation, P < 0.001, P < 0.01 respectively

Statistical analysis was performed using the one-way analysis of variance test, followed by *post hoc*.

RESULTS

Graph 1 shows the Intergroup comparison of the mean apical, middle and coronal sealer penetration.

The sealer penetration depths of the groups are shown in Tables 1-3. Laser activation group showed the highest penetration depth at the coronal (at 8 mm), middle (at 5 mm), and apical (at 3 mm), while irrigant penetration was less in the apical third (at 3 mm) in comparison to the middle third (at 5 mm) and coronal third (at 8 mm) in all three groups.

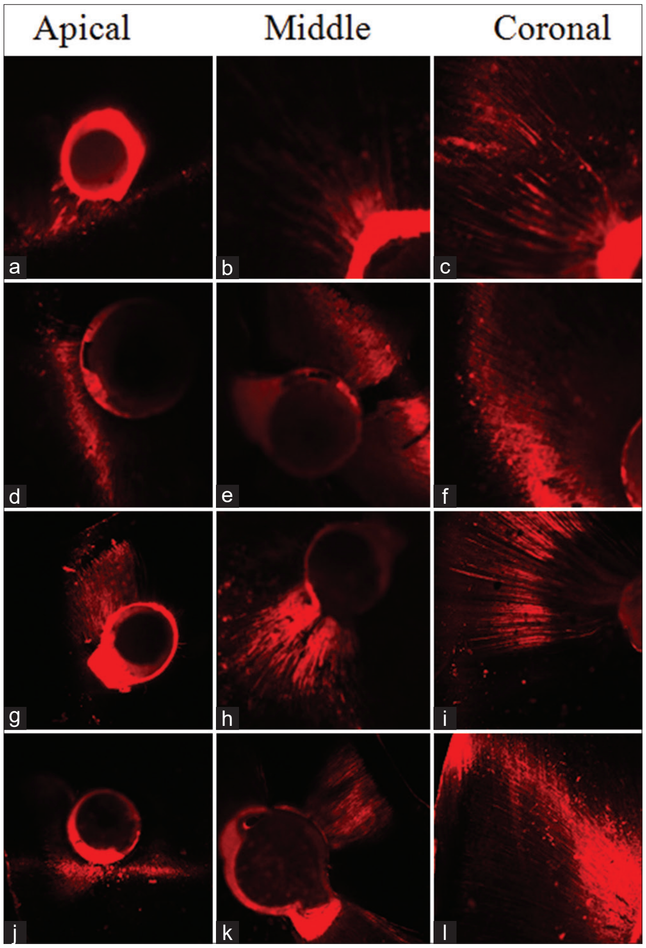


Figure 1: Confocal laser scanning microscope images of penetration depth of AH Plus and CeraSeal sealers at apical middle and coronal third levels. (Ultrasonic + AH Plus Sealer: (a) Apical third, (b) middle third, (c) coronal third. Ultrasonic + CeraSeal Sealer: (d) Apical third, (e) middle third, (f) coronal third. Erbium: yttrium-aluminum-garnet (Er: YAG) laser + AH Plus Sealer: (g) Apical third, (h) middle third, (i) coronal third. Er: YAG laser + CeraSeal Sealer: (j) Apical third, (k) Middle third, (l) Coronal third)

Figure 1 shows the CLSM images of the penetration depth of sealer penetration.

DISCUSSION

Disinfection of the root canal system is one of the main goals of root canal therapy. Endodontic instruments cannot completely shape and clean the intricate structure of the root canals during chemomechanical preparation, especially irregular and additional canals. The untreated areas could retain debris, bacteria, and their by-products. They may also prevent the root canal irrigants from penetrating all the way into the dentinal tubules.[1]

In addition, the root canal sealers' ability to adapt inside the dentinal tubules is negatively impacted by these regions. Inorganic and organic materials found in the smear layer created by the instrumentation of the root canal may be contaminated and harbor bacteria in the dentinal tubules.

By preventing recontamination of the root canal system and depriving remaining microorganisms of nutrition, smear layer clearance, and sealer penetration into dentinal tubules play a crucial role.[2]

Sealers aid in the binding, lubrication, and sealing of the gutta-percha as well as the lateral canal plugging. When in proximity to the bacteria, the sealer's components display antibacterial properties. If this is not done, there may be microleakage later, which could result in reinfection.[5]

In this study, we have tried to compare the irrigation techniques with two sealers, namely AH Plus and CeraSeal Sealers. The significance of activating irrigation solutions in addition to mechanical preparation in eliminating the smear layer has been stressed in numerous research in the literature. Due to its simplicity of administration, conventional needle irrigation (CNI) is frequently used in endodontics; however, because it only extends 1.5–2.0 mm past the needle tip, there is less contact between the irrigant and the apical region. In addition, the vapor lock effect, which occurs during CNI, causes air to become trapped in any portion of the root canal. It has been found that the vapor lock effect reduces contact of the solution with the entire root canal surface.[3]

According to reports in the literature, the PUI irrigation activation system can weaken endodontic biofilms, allowing sealers and irrigants to penetrate the dentinal tubules more effectively.[3] A small file or ultrasonic endo tip (ISO size 10–25), oscillating in the root canal using a piezoelectric ultrasonic device, can be used to perform passive ultrasonic agitation.[6] Due to the substantial acoustic microstreaming created, the endodontic irrigants are effectively activated and the organic material in the root canal system is also removed.[7,8] Therefore, in Groups C and D, we used passive ultrasonic irrigant activation.

To disinfect the root canal system during root canal therapy, dental lasers are frequently used.[8] Disinfection has been performed using a variety of lasers, including CO2, Nd: YAG, Er: YAG, Er: YSGG, argon, and diode lasers.[9] In the root canal, the laser's photothermal property can raise the temperature of the irrigant at any concentration.[10] Sodium hypochlorite's viscosity can be reduced and its capacity to penetrate root dentin is improved by raising the solution's temperature.[11] In addition, this study compares the CS and AH sealers (Groups A and B), both with and without the irrigant activation systems.

As digital and laser technologies advanced, Marvin Minsky developed the confocal microscopy concept to address the limitations of scanning electron microscope CLSM create images that are impervious to damage and have fewer artifacts. In our investigation, CLSM was used to estimate the depth of penetration.

Laser-activated irrigation using Er: YAG produces explosive vapor bubbles with a subsequent cavitation impact and effectively removes the debris and smear layer from intricate root canal systems.[12] The highest-power spikes are produced by this method using low energy levels and brief microsecond pulse rates (50 s). The irrigation solutions can move in three dimensions owing to the powerful photoacoustic shock wave. This method greatly improves the removal of the smear layer, debris, medications, or bacteria from the root canal walls as compared to conventional irrigation. It also results in greater root canal sealer and resin cement bond strength values.[1,3] Er: YAG laser-assisted irrigation was employed in Groups E and F of this investigation.

Based on the approach used in our research, the Er: YAG laser-induced irrigation had the greatest depth of penetration into the root dentin. This supports the earlier research employing Er: YAG laser-activated irrigation systems.[13,14] This method effectively removes the smear layer and debris from intricate root canal systems by producing explosive vapor bubbles with a subsequent cavitation impact.

The depth of penetration with this system was highly significant ($P < 0.001$) than Group A and B which were sealer alone and significant ($P < 0.01$) than the PUI in the apical sections and middle sections and coronal sections, respectively [Tables 1-3].

Er: YAG laser-activated irrigation with AH sealer (AH + L) (CS + L) outweighed the depth of penetration as compared to the PUI system with AH sealer and CS sealer.[15] [Graph 1] The ultrasonic endo file's reduced contact time with the root canal may be the cause of this.[16] Different dentin anatomical complexity may prevent an irrigant from penetrating into the dentinal tubules. Tubules are wider and more closely spaced in the coronal and middle thirds of the root canal and are narrower in the apical third.[17,18]

CONCLUSIONS

This study can be concluded that Er: YAG laser with AH Plus sealer has the highest penetration in all the sections of tooth, followed by CeraSeal sealer. Thus, it can be very well concluded that the Er: YAG laser irrigation is the best irrigant for dentin tubules.

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Conflicts of interest

There are no conflicts of interest.

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