Evaluation the Efficacy of Er:YAG Laser in Removing the Smear Layer During Endodontic Treatment

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Abstract

Successful root canal treatment depends on the cleaning and disinfecting of root canal before obturation. The study aimed to evaluate the effectiveness of Laser-activated irrigation (LAI) Er:YAG laser with EDTA 17% and distilled water in removing the smear layer and enhancing the results of endodontic treatment.

90 human extracted single-rooted teeth were included. Root canal preparation was done using rotary instruments with irrigation 5.25% NaOCl. Teeth were randomized into 30 teeth in 3 groups; the first experimental group received Er:YAG laser (a 17 mm 400-µm conical tip, 10 Hz, 0.5W, 40 mJ) + EDTA 17% for 1 minute, the second experimental group received EDTA 17% for 1 minute and the control group received Er:YAG laser + distilled water for 1 minute. Teeth were bisected longitudinally, and root canal was examined in coronal, middle and apical regions for smear layer removal by scanning electronic microscope. Data were analyzed statistically by SPSS software.

The smear layer removal was higher in all regions of walls of root canal when combined EDTA 17% with Er:YAG laser. Comparison between regions showed that smear layer removal was better in coronal, middle regions than apical region in both groups ($P<0.05$)

Er:YAG laser has proved its efficacy when combined with EDTA 17% in removing smear layer and debris from the root canal surface, due to activation of the irrigant solution.

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Introduction

Successful root canal treatment depends on two main factors, the first one is the precise knowledge of anatomy and morphology of root canal system and the second which is so important is the cleaning and disinfecting of root canal before obturation. The purpose of root canal disinfection is to remove the tissue remnants, bacterial biofilms and the smear layer [1, 2]. The smear layer is formed during mechanical instrumentation of root canal and covers the canal walls. This smear layer contains microorganisms, necrotic tissues and dentinal remnant. This layer constitutes an obstacle to the delivery of irrigants and chemical agents to the root canal system and creates a barrier between the root canal surfaces and filling materials. Removal of smear layer and debris provides better sealing of filling materials to root canal surfaces [3, 4].

Many irrigants and chemical agents were used to remove the smear layer such us Sodium hypochlorite 5.25%, Ethylene Diamine Tetra-acetic Acid (EDTA) 17%, citric acid 10% and chlorhexidine gluconate 2% [5]. Many studies have investigated these agents in removing the smear layer. They demonstrated that they have a limited capacity in removing the smear layer from the dentinal walls especially from the apical third of the root canal [5-9]. This has prompted researchers to investigate the efficiency of laser in different wavelengths and various parameters in endodontic treatment for removing the smear layer and disinfecting the root canal. It has proved that laser in combination with irrigants can penetrate the dentinal walls better than using irrigants alone and reach to all parts of root canal [10-13].

Erbium: Yttrium-Aluminum-Garnet (Er:YAG) laser, which was approved by the Food and Drug Administration (FDA) has proved its

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efficiency in nonsurgical endodontic treatment, it provides the most suitable wavelength (2,940 nm) for cleaning and disinfecting the root canal [14, 15]. Er:YAG laser acts through photoablation with minimal thermal effects on the dental hard tissue and the laser energy is absorbed by water molecules [16, 17]. Various studies have conducted to evaluate the efficiency of Er:YAG with different protocols and different parameters and various tips alone or in combination with irrigants and they proved that this combination results in removing the smear layer, eliminating the bacteria, opening the dentinal tubules and that leads to better seal of filling materials [2, 18-20]. The aim of this study was to evaluate the effectiveness of Laser-activated irrigation (LAI) Er:YAG laser with EDTA 17% in removing the smear layer and improving endodontic treatment outcomes.

Materials and methods

The study was designed as randomized in-vitro study and approved by the ethical committee of Peoples' Friendship University of Russia.

The study included 90 extracted human teeth, after they fulfilled the inclusion criteria: (A) Teeth were extracted due to periodontal diseases or for orthodontic treatments, (B) teeth have a single root canal and mature apex and (C) the absence of root resorption or any endodontic treatment which was determined by apical radiographs for each tooth. Teeth were cleaned and stores in physiological saline solution till use.

Root canal preparation

Access cavity was prepared using diamond burs (FKG Dentaire SA, Switzerland), root canal working length was recorded by using a K-file 15. Teeth apices were sealed with was to prevent the flowing of irrigants throw them. Root canal preparation was done using technique Crown Down with rotary files Protaper Next (Dentsply® Sirona, USA), the irrigation was done between each file with 1 ml of 5.25% Sodium hypochlorite (NaOCL), and then the teeth were randomized into 3 groups as follow:

The first test group (Group I): 30 teeth received 10 ml of (EDTA 17%) using syringe with 27G endo irrigation needle double side vent (Sulzer, Kiel, Germany) and Er:YAG laser was applied for 60 seconds through the root canal at a wavelength of 2,940 nm with following parameters: a 17 mm 400-µm conical tip, repetition rate at 10 Hz, output power 0.5W, energy 40 mJ. Laser tip was inserted 4-5 mm in the root canal. Water cooling was done during the procedure to prevent the dentine overheating. The second test group (Group II): 30 teeth received 10 ml of (EDTA 17%) for 60 seconds using syringe with 27G endo irrigation needle double side vent (Sulzer, Kiel, Germany)

The control Group (Group III): 30 teeth received 10 ml of (EDTA 17%) for 60 seconds using syringe with 27G endo irrigation needle double side vent (Sulzer, Kiel, Germany) received distilled water using syringe with 27G endo irrigation needle double side vent (Sulzer, Kiel, Germany) and Er:YAG laser was applied for 60 seconds through the root canal.

The teeth were bisected longitudinally to buccal and lingual segments, then one of the segments was selected randomly and bisected into three parts; coronal, middle and apical part of root canal, to be scanned by electronic microscope (SEM) (VEGA 3 SB, Tescan Orsay Holding, Kohoutovice, Czech Republic). Samples were dried and coated with Platinum using a sputter coater (AJA ORION 8, AJA International INC, California, USA) the samples were scanned by SEM at a magnification of 25,000X for each (Coronal, middle, apical) region of root canal.

The evaluation of SEM micrographs was carried out by two examiners in a single-blind assessment. The evaluation of smear layer removal was recorded according to Hulsmann et al. [21] as following scores:

Score 1: No smear layer, dentinal tubules open.

Score 2: Small amount of smear layer covering the root canal, many dentinal tubules are opened

Score 3: Smear layer and debris covering the root canal walls and a few dentinal tubules are opened

Score 4: The surface of root canal covered completely with smear layer; no dentinal tubules open.

Score 5: Heavy smear layer and debris covered the root canal surface.

Statistical analysis

The data was collected and analyzed by SPSS statistical software v.22. For comparison between the control and test groups, Mann-Witney U test was used. For comparison between the three parts of root canal, Kruskal

Wallis test was used. Statistical significance was set at 0.05.

Results

In group (EDTA 17% for 1 minute) the smear layer removal was higher in coronal region of root canal than middle and apical regions. (Figures 1, 1-B, 2-B, 3-B) the results showed score 1 in 6.7% and score 2 in 53.3% in the coronal region, while score 1 hasn't shown in other regions of root canal walls. (Table 1)

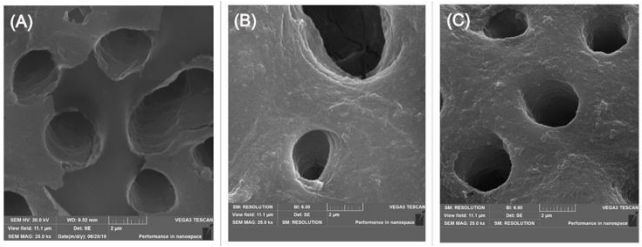

Figure 1. SEM (x 25,000) of coronal third of root canal (A) EDTA 17% + Er:YAG group, (B) EDTA 17% group, (C) Distilled water + Er:YAG group.

Scores	EDTA 17% + Er:YAG			EDTA 17%			Distilled water + Er:YAG		
	Coronal	Middle	Apical	Coronal	Middle	Apical	Coronal	Middle	Apical
Score 1	93.3%	76.7%	56.7%	6.7%	0	0	87.9%	68.4%	25.1%
Score 2	6.7%	23.3%	30%	53.5%	13.3%	16.7%	12.1%	22.9%	44,3%
Score 3	0	0	10%	40%	43.4%	16.7%	0	8.7%	22.5%
Score 4	0	0	3.3%	0	30%	30%	0	0	8.1%
Score 5	0	0	0	0	13.3%	36.6%	0	0	0

Table 1. The scores percent % in control and test groups.

In EDTA 17% + Er:YAG laser for 1 minute (Group I), the specimen showed higher removal of smear layer in all parts of root canal walls (Figure 2, 1-A, 2-A, 3-A). Score 1 was reported in 93.3%, 76.7% and 56.7% in coronal, middle and apical region of root canal, respectively. (Table 1) In distilled water + Er:YAG (Group III), the SEM scans showed better results of removing the smear layer in the coronal and middle thirds of the root canals (Figure 3, 1-C, 2-C, 3-C). Score 1 was found in 88% in coronal third and 68% in middle third, while in the apical third score 2 was higher in 44%.

Groups	Test	P Value
EDTA 17% + Er:YAG	Kruskal Wallis Test	0.003
EDTA 17%	Kruskal Wallis Test	0.000
Distilled water + Er:YAG	Kruskal Wallis Test	0.008

Table 2. Comparison between coronal, middle and apical regions of root canal in control and test groups.

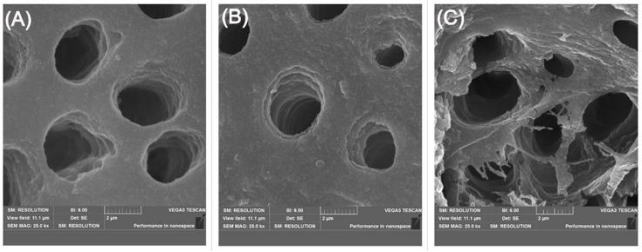

Figure 2. SEM (x 25,000) of middle third of root canal (A) EDTA 17% + Er:YAG group, (B) EDTA 17% group, (C) Distilled water + Er:YAG group.

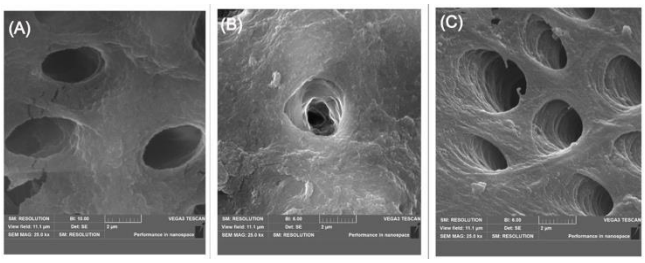

Figure 3. SEM (x 25,000) of apical third of root canal (A) EDTA 17% + Er:YAG group, (B) EDTA 17% group, (C) Distilled water + Er:YAG group.

When compared the scores of root canal removal between coronal, middle and apical regions in the control and test groups, Kruskal Wallis Test has showed statistical differences in the groups ($P < 0.05$) (Table 2) and when analyzed the differences between regions, Mann-Whitney U test demonstrated that in Group I, the smear layer removal was higher in coronal regions than apical regions ($P < 0.05$), while no statistical differences was observed between the middle and apical regions in ($P > 0.05$) in both test groups. (Table 3)

Groups	Root canal regions	Test	P Value
EDTA 17% + Er:YAG	Coronal + Middle regions	Mann-Whitney U	0.07
	Coronal + Apical regions	Mann-Whitney U	0.00
	Middle + Apical regions	Mann-Whitney U	0.06
EDTA 17%	Coronal + Middle regions	Mann-Whitney U	0.00
	Coronal + Apical regions	Mann-Whitney U	0.00
	Middle + Apical regions	Mann-Whitney U	0.08
Distilled water + Er:YAG	Coronal + Middle regions	Mann-Whitney U	0.03
	Coronal + Apical regions	Mann-Whitney U	0.00
	Middle + Apical regions	Mann-Whitney U	0.07

Table 3. Results of Mann-Whitney U of differences in control and test groups.

The comparison between groups in different regions of root canal walls showed statistical differences ($P < 0.05$), which means that Er:YAG + EDTA 17% remove the smear layer more than using Er:YAG + distilled water and EDTA 17% alone. (Table 4)

Control and test groups	Test	P Value		
		Coronal	Middle	Apical
Group I & Group II	Mann-Whitney U	0.00	0.00	0.00
Group I & Group III	Mann-Whitney U	0.06	0.00	0.00
Group II & Group III	Mann-Whitney U	0.00	0.00	0.00

Table 4. Comparison between control and test groups in coronal, middle and apical regions of root canal.

Discussion

The golden standard protocol in root canal treatment is to clean and disinfect the root canal by eliminating the microorganisms from the infected main and lateral canals and creating a clean space for the filling materials. Using irrigants and chemical agents alone doesn't achieve this goal, due to the disability of these agents to eliminate the microbes and remove the smear layer and debris from the root canal walls[5,6]. About 30-45% of the root canal surface remains untouched by mechanical instrumentation, so the role of using irrigants is to compensate this problem [22-24]. On the other hands, laser treatment has proved its efficacy in endodontic treatment, and it was demonstrated that Er:YAG laser is the suitable laser for cleaning and disinfecting the root canal due to the absorption function of its wavelength by water and hydroxyapatite without any thermal effect [14, 15]. Er:YAG laser has been used in different protocols: Laser-activated irrigation (LAI) protocol is performed using a thin and long sapphire conical tip within the root canal with vertical movements. The mechanism of LAI is a pure cavitation phenomenon, which works as pulsed laser operation causes an expansion and implosion of vapor bubbles at the fiber tip and that creates a rapid movement of fluids in the root canal [2, 25]. The another protocol is Photon-Intiated Photocoustic streaming (PIPS) which applied by using a large and short tip with low energy on the access cavity of the root canal to potentiate an irrigant action into the root canal, this low energy helped to induce cavitation bubble expansion and collapse of the intra canal irrigant followed by hydrodynamic pressure. This pressure pushes the irrigants into the dentinal tubrles and lateral canals leading to clean and remove the smear layer and debris [18, 26].

In our study the LAI protocol was used with low energy to evaluate the effectiveness of Er:YAG laser activation (400-µm conical tip, 10 Hz, 0.5W, 40 mJ) of 17% EDTA and distilled water in two separate groups for 1 minute in removing the smear layer. The SEM scans showed that this combination was more effective than using EDTA 17% alone. The scans showed that EDTA 17% + Er:YAG removed the smear layer in different regions of the root canal. Although, the smear layer removal in apical region was less than coronal, this combination has approved its efficiency of creating a clean open dentinal tubule, and that related to the activation of Er:YAG Laser to EDTA solution and that leaded to increase the efficiency of cleaning action. The SEM scans at higher magnification (x 100.000) in coronal and middle and apical regions showed the efficient of Er:YAG in removing the smear layer (score 1) and opening the dentinal tubules without any thermal effects. This results are inconsistent with the results of Divito et.al., in which evaluated the efficacy of Er:YAG with EDTA 17% in removing the smear layer with different irradiation times, the study resulted that samples treated for 40 s with Er:YAG laser and EDTA 17% irrigation had the most effective removal of smear layer [18]. Another study was conducted by Reza et al. showed that Er:YAG was more effective in smear layer removal in coronal and middle regions of root canal when compared to Nd:YAG laser [12]. Todea et al. study has demonstrated that Er:YAG laser increases the efficiency in debridement and smear layer removal in all regions of the root canal [26].

Using Er:YAG laser for activation distilled water was effective in coronal and middle third than apical third, even though it was better than using EDTA 17% alone, these results are inconsistent with study of Ozbay et al. [19] in which they evaluated three types of lasers (Er:YAG, Nd:YAG, Er,Cr,YSGG) with distilled water, NaOCl 2.5% and EDTA 17%, and found that the samples irrigated with distilled water had greater smear layer scores when using Er:YAG. They concluded that regardless of the type of irrigant, laser activated irrigation enhances smear layer removal.

Using EDTA 17% alone for cleaning and removing the smear layer was less effective than laser. Nevertheless, it could be useful when using it for 1 minute with NaOCl, these results agreed with Spangberg study, in which showed that EDTA removes the smear layer within 1 minute of reaching the canal surface [27]. SEM scans in the middle region of the root canal

showed thicker smear layer at different magnifications.

According to the results, authors suggested that activating the EDTA irrigant or distilled water for 1 minute resulted in clean open dentinal tubules in all regions of root canal walls.

Conclusions

Within the limits in this study, Er:YAG laser has improved the results of root canal disinfection when combined with EDTA 17% and distilled water for 1 minute due to the activation of irrigant inside the root canal without any thermal effects. The removal of smear layer and debris was better in all parts of root canal walls and that enhances the endodontic treatment.

Declaration of Interest

The authors declare no conflict of interest.

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