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Using erbium-doped yttrium aluminum garnet laser irradiation in different energy output levels versus ultrasonic in removal of root canal filling materials in endodontic retreatment

Mehmet Omer Gorduysus[1], Hanin Al-Rubai[1], Basheer Salman[2], Deena Al Saady[1], Hiba Al-Dagistani[2], Sevda Muftuoglu[3]

[1]Department of Preventive and Restorative Dentistry, College of Dental Medicine, University of Sharjah, Sharjah, UAE, [2]Department of Oral and Craniofacial Health Sciences, College of Dental Medicine, University of Sharjah, Sharjah, UAE, [3]Department of Histology, Faculty of Medicine, Hacettepe University, Ankara, Turkey

Correspondence: Dr. Mehmet Omer Gorduysus
Email: momergorduysus@gmail.com

ABSTRACT

Objectives: The objective of this study was to evaluate the efficacy of erbium-doped yttrium aluminum garnet (Er:YAG) laser irradiation in different energy outputs versus ultrasonic in gutta-percha removal during the endodontic retreatment. **Materials and Methods:** A total of 21 extracted human lower premolars were divided into three groups ($n = 7$). Following the standardized preparation of the root canals with Wave One Rotary system and obturation with gutta-percha: Group I was treated with ultrasonic, Group II by Er:YAG laser with 40 mJ/Pulse, and Group III by Er:YAG laser with 50 mJ/Pulse for the removal of gutta-percha from the canals. Two extra teeth were treated by Er:YAG laser with 135 mJ/Pulse as control group. For all groups, time for gutta-percha removal was recorded. Samples were then splited into two halves and tested by scanning electron microscope and stereomicroscopic evaluation under different magnification power to observe the efficacy of each method used in the removal of gutta-percha. **Results:** Statistical analysis of Kruskal–Wallis suggested that there are significant difference between the groups in relation to removal time ($P < 0.05$) and 2 × 2 Mann–Whitney U-test among the groups revealed that there is no significant difference between 40 and 50 mJ laser outputs ($P > 0.05$), but ultrasonic versus 40 and/or 50 mJ laser outputs were significantly different ($P < 0.05$). **Conclusions:** Er:YAG laser beam was not so efficient when compared to ultrasonic to reach the deeper parts of the canals as it was asserted, thermal side effects and burning damages were observed on the root canal dentinal walls. Moreover, the delivery system was not flexible enough to compensate the curvature of the canal system even though we used more straight canals as the sample ones as well as more time-consuming than the ultrasonic and more clinical time, rendering it to be less efficient in the removal of the obturation material during endodontic retreatment procedures.

Key words: Endodontics, erbium-doped yttrium aluminum garnet lasers, gutta-percha removal, lasers, retreatment

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INTRODUCTION

Gorduysus *et al*. stated that lasers were introduced to the field of endodontics to improve the results achieved with traditional procedures using the light energy to increase cleaning efficacy and the removal of debris and smear layer from the root canals besides improving the decontamination of the root canal system.[1] Complete elimination of previous root canal filling material and debris from the root canal wall is essential for a successful retreatment in endodontics.[2,3] Hand or mechanical instrumentation, sometimes subsonic and ultrasonic devices are used for endodontic retreatment.[4,5] Retreatment procedures are generally time-consuming, challenging, complex, and sometimes complicated procedures. Dissolution of gutta-percha using solvents, softening by heat, mechanical removal techniques, sonic and ultrasonic are essential methods among the retreatment methodologies. Besides, some alternatives were introduced recently. Lasers are introduced for this purpose also, and according to some authors, they may have some advantages in comparing with the conventional techniques such as reaching the deeper portions of root canal, less risk of fracture and cracks on the dentinal walls, less clinical time and might be more efficient in removal of the obturation materials from the root canals. Erbium-doped yttrium aluminum garnet (Er:YAG) lasers are considered as low thermal effect lasers with low thermal damages with a relatively flexible fiber delivery system and smaller diameter laser tip for insertion into a root canal. Er:YAG lasers were stated as promising for removal of debris, smear layer, and obturation materials from the root canals with different energy outputs. Er:YAG laser is capable of ablating hard tissues, and according to some authors, this is without major thermal side effects.[6-8] The hard tissue ablation with Er:YAG laser is a thermomechanical effect induced by microexplosions of water molecules within the hard tissue; thus, Er:YAG laser can perform root surface debridement.[6-9] Most of the laser studies in the literature are related to endodontics for treatment of hypersensitivity in dentin, pulp capping, pulpotomy, apicoectomy, root canal cleaning, and shaping as well as laser Doppler flowmetry and some diagnostic studies but very limited articles on the removal of canal obstructions and retreatment.

The aim of this study is to evaluate and compare the ability of Er:YAG laser which is considered as one of the most promising techniques versus ultrasonic which is already an established option in retreatment methodology for many years in the removal of root canal filling materials as one of the current techniques.

MATERIALS AND METHODS

Sample preparation

A total of 21 extracted human lower premolars with relatively straight, single root canals were used. The pulp chambers were opened with 801 (001) round diamond bur (NTI-Kahla GmbH, Germany), working length was verified using size 15 k file to the apex with digital image (Digora) X-ray. Wave One rotary system, primary file was used in which the tip size is ISO 25 with an apical taper of 8% that reduces toward the coronal end to prepare the root canal. Copious irrigation with 5% sodium hypochlorite and EDTA before, during, and after preparation was done. The root canals were dried with the corresponding paper point of Wave One. Obturation was performed with the corresponding gutta-percha with lateral condensation technique and AH Plus (Dentsply, Germany) resin-based root canal sealer. Gutta-percha points were cut with heated plugger at the cervical line. Later, the teeth were kept at 37°C and 100% humidity for 3 days to ensure setting of the root canal filling material. All samples were bisected 11 mm from the apex by 898 (213) flame diamond bur (NTI-Kahla GmbH).

Experimental procedure

According to sample size analysis, the minimum number of the samples was calculated to be equal to 7 to have a valid statistical analysis. The samples were divided into three groups ($n = 7$). The first group was treated with ultrasonics, the second group by Er:YAG laser with 40 mJ/Pulse, and the third group by Er:YAG laser with 50 mJ/Pulse. During laser retreatment and ultrasonics retreatment, irrigation procedures were continuously used. In the removal procedure, gutta-percha removal was considered before sealer removal to make space for effective sealer removal in the later stages with other established removal techniques. Samples were then analyzed under scanning electron microscope (SEM) and stereomicroscope.

Ultrasonic retreatment

For the first group, ultrasonic device by SATELEC (P5 Newtron) and E25 ultrasonic tip was used. The power setting used was 11 under the application of water spray to remove the gutta-percha from the canals and working time was recorded.

Laser retreatment

Er:YAG laser irradiation was applied using Er:YAG laser apparatus Fotona with a very long pulse, wave length of 2940 nm, repetition rate frequency of 10 Hz, and a brand new straight fiber tip (PRECISO 300/14, part No.:85 330) was used.

For the second group, the root canal filling material was irradiated from the orifice of the root canal with an energy output of 40 mJ/Pulse with application of water spray to remove the gutta-percha from the canal and working time was recorded. Figure 1 depicts the changes shown while using 40 mJ/Pulse.

For the third group, Er:YAG laser irradiation with 50 mJ/Pulse was applied, the same laser apparatus (Fotona) and the same fiber tip (PRECISO 300/1, PART No.:85 330) were used. Figure 2, shows carbonized areas, melted dentin, and recrystallized zones in dentinal tubules orifices. An energy output of 50 mJ/Pulse with application of water spray was used for the removal of gutta-percha from the canal and working time was recorded.

As control group, two teeth were processed under the same conditions with 135 mJ/Pulse energy output, as shown in Figure 3.

Scanning electron microscope examination

All samples were channeled longitudinally on the external surface with a straight needle diamond bur avoiding penetration of root canals. Samples were carefully split with hammer and chisel into two halves. Later, the sample halves were submitted under:

1. SEM JEOL 6400 (Jeol Corporation, Tokyo-Japan) in 20 kV under ×12 up to ×10,000 different magnifications
2. Stereomicroscope LeicaMZ 16 DC320 Digital Camera to evaluate the surfaces and to see the effects of the laser and ultrasonic. The samples were photographed under different magnifications to represent the best views of their effects to the surfaces of the pulp canal.

Working time recordings were statistically evaluated with Kruskal–Wallis and Mann–Whitney U-tests to show the difference between the groups. To evaluate the microscopic findings, interexaminer reliability was ensured and the examiners were calibrated and

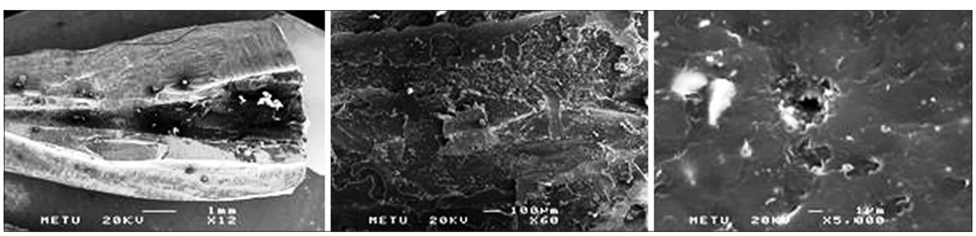

Figure 1: 40 mJ/pulse laser: Under the scanning electron microscope in different magnifications carbonized areas, melted dentin, recrystallized zones in dentinal tubule orifice were seen

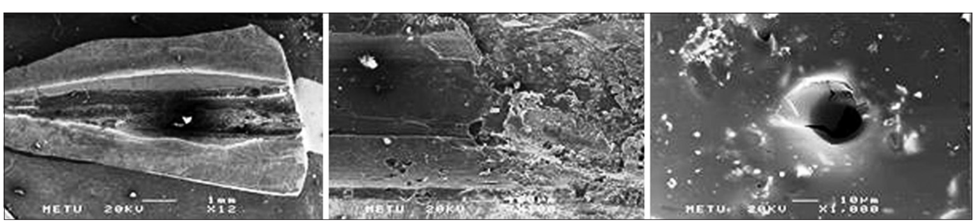

Figure 2: 50 mJ/pulse laser: Under the scanning electron microscope in different magnifications carbonized areas, melted dentin, recrystallized zones in dentinal tubule orifice were seen

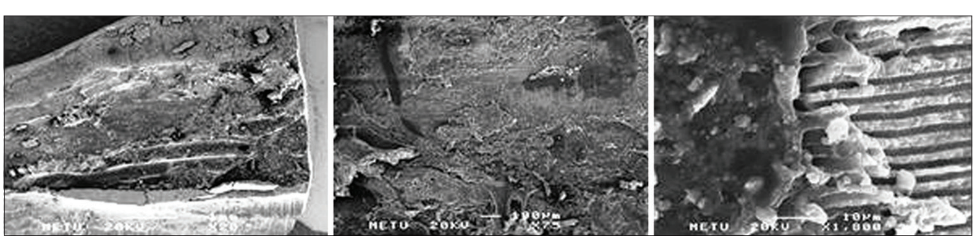

Figure 3: 135 mJ/pulse laser (control group): Under the scanning electron microscope in different magnifications heavily carbonized areas, melted dentin, recrystallized zones in dentinal tubule orifices and dentinal tubules were seen

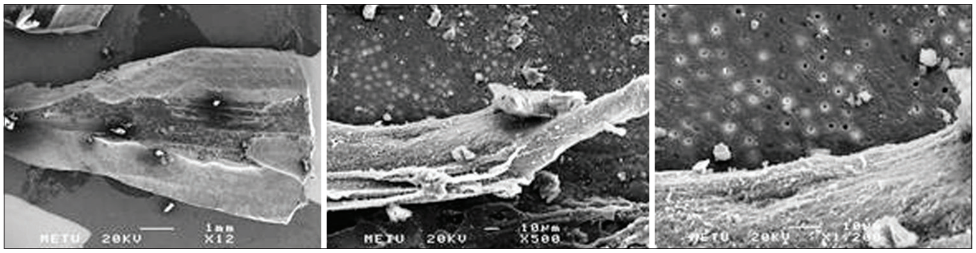

Figure 4: Ultrasonic: Under the scanning electron microscope in different magnifications, some carbonized areas, dentinal tubule orifices, and dentinal tubules were seen and the tubules observed are clearer and more identified

Figure 5: Stereomicroscope views: 50 mJ/pulse laser: Remaining gutta-percha and some carbonized parts were observed

followed the same guidelines to interpret the results. The homogeneity of the readers was evaluated with Kappa test to have consensus about the readings.

RESULTS

Removal time

According to Kruskal–Wallis test, the difference between the groups was statistically significant ($P < 0.05$). To evaluate the difference between the groups according to Mann–Whitney U-test (comparing the groups with each other one by one), ultrasonic and 40 mJ/Pulse different ($P < 0.05$) and also ultrasonic and 50 mJ/Pulse groups were significantly different ($P < 0.05$). There is no difference between 40 and 50 mJ/Pulse ($P > 0.05$). Average removal time for ultrasonic was 18.71, for the 40 mJ/Pulse was 77.42, [Figure 4] and for the 50 mJ/Pulse was 113.57 s.

DISCUSSION

To remove root canal filling material efficiently, the clinician can use ultrasonic instrumentation, and instruments include Gates-Glidden, gutta-percha removers, engine driven nickel-titaniums, solvents, and heating techniques.[10-13] All removal methods have advantages and disadvantages. Furthermore recently, it was reported that root canal filling materials could be effectively removed using Nd:YAG laser, but there were evident signs of temperature increases in the surrounding tissues due to heat generation as well as dentinal tubules being blocked with melted dentin and carbonization.[14,15] Due to the wavelength of Er:YAG laser, which is 2.94 μm with a high absorption rate in water, thus causing a smaller thermal effect on the surrounding apical tissues than other lasers.[16,17] For these favorable reasons, Er:YAG laser has been clinically used for various types of endodontic treatments.[18-22] In our study, we observed laser burns and carbonization because of the ablation. We noticed too, residues of gutta-percha and sealers, as shown in Figure 5, to be more in the apical portion even though all samples were horizontally bisected in 11 mm from the apex and to avoid the narrowness and curvature of the apical portions. Our results as well as the methodology were similar to the study of Tachinami and Katsuumi.[23] There were no differences in data between 40 and 50 mJ/Pulse energy outputs with regard to removal time, amount of remaining filling material, the degree of root canal dentin ablation, burn spots, and carbonized dentinal tubule orifices. As can be seen in Figure 6, the control group of 135 mJ/Pulse energy outputs, the situation was very dramatic, due to root canal dentin ablation and evidence of burn spots. In addition, dentinal tubules orifices were shown to

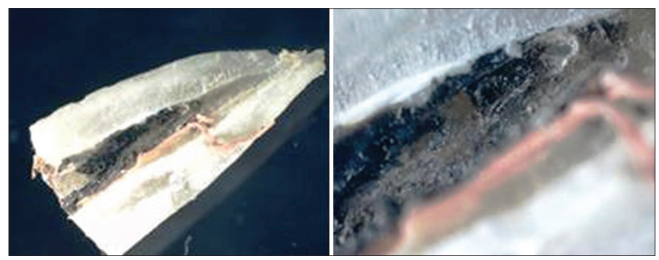

Figure 6: Stereomicroscope views: 135 mJ/pulse laser (control group): Root canal is seen after the removal of gutta-percha and heavily carbonized areas were observed

Figure 7: Stereomicroscope views: 50 mJ/pulse laser: Carbonization was observed in <50 mJ/pulse laser and in 135 mJ/pulse laser (control group)

be carbonized as shown in Figure 7. In comparison, the stereomicroscope views of Ultrasonic usage in Figure 8 shows no evidence of carbonization, however, remnants of gutta-percha were observed in the canal. In this study, the thermal effects of laser irradiation to the periodontal tissues and the heat generation to neighboring tissues were not evaluated; however, based on the carbonization, we observed during the microscopic evaluations on the dentinal wall of the pulp canal, it suggests that the unwanted heat effect to the surrounding tissues cannot be neglected. The surface effect of laser was creating carbonized craters where it is applied in all cases. Furthermore, statistical evaluation was carried out in our study, and it shows that laser power levels should be higher than that of suggested levels. However, as level increases the carbonization, burning effect and obviously the thermal effect and the heat convection of laser will show some unwanted impacts on periodontium.[24] In comparison to the study of Yamazaki *et al*.[25] which they evaluated *in vitro* morphological changes in root canal walls and temperature changes at root surfaces as a result of intracanal irradiation by erbium, chromium:YSGG laser under various conditions. The study showed carbonization and cracks appeared in all irradiated areas. Their stereomicroscopic pictures were very similar to our pictures in the meaning of carbonized surfaces. Exposed dentinal tubule orifices were not clearly visible in the irradiated areas. Reports showing the effectiveness of the Er:YAG laser have been increasing. Laser irradiation could be used to remove debris and smear layer from root canals only by irradiation with water spray cooling. During the endodontic retreatment procedures, the cooling water spray is not able to reach to the deeper parts of the canal. The development of thinner and more flexible laser fibers will increase the number of applications for this laser in endodontics. Furthermore, those tips should be designed with the purpose of delivering the cooling water toward to the deepest parts, especially to the apical third. However, the advantages as well as limitations of the Er:YAG laser treatment have not yet been fully clarified. Removal of gutta-percha and sealer from the root canals is the major part of endodontic retreatment and the aim is to remove as much filling material as possible. The remnants of filling material pressed against the root canal walls after using the laser tip and ultrasonic tip seem more efficient. Furthermore, using ultrasonic tips in combination with solvents would increase the efficiency of the amount of removed gutta-percha as weight.[26] In our study, based on our results, the ability of Er:YAG laser in removal of root canal obturation material, i.e., gutta-percha is limited, at least we can state and speculate that its ability is still to be proven clinically significant when compared to ultrasonic or other practical retreatment methods in endodontics. Er:YAG laser seems more time-consuming in removal of gutta-percha with the risk of burnings on the dentinal wall. Timewise to increase the efficacy the frequency and energy of the pulsations need to be increased, but it may cause more carbonization as it was seen in our control group and may harm dentine and the periodontium. Tactile sensation is important for an endodontist, and unfortunately, Er:YAG laser retreatment in endodontics does not provide a sufficient tactile sensation while processing in the canals. This point can be seen as another limitation during the endodontic applications because it might not permit any modification and manipulation skills during the applications to the operator.

Figure 8: Stereomicroscope views: Ultrasonic: After ultrasonic use to remove gutta-percha, there was not any evidence of carbonization but still some remaining gutta-percha was observed in the canal

CONCLUSIONS

Er:YAG laser beam was not so efficient as ultrasonic to reach the deeper parts of the canals and not so practical. Dentinal walls' burnings, carbonizations, and damages were observed. The delivery system (laser tip) was not as long and flexible enough to compensate the curvature of the canals although we examined relatively straight canals. Using laser as a retreatment option is more time-consuming than the ultrasonic system. Moreover, it was less efficient in the removal of the obturation material such as gutta-percha and sealers, especially in the curved canals, because of the penetration problems during the endodontic retreatment procedures and should be avoided. It seems that laser use in endodontic retreatment procedures is less efficient and does not represent any superior clinical practical alternative to ultrasonics. In addition, the side effects and complications such as the burning of dentinal tubules, and carbonization, restrains the practitioner to use laser in retreatment procedures. Laser retreatment needs further improvement and more studies to be conducted as it might be promising for the future. Perhaps, more flexible, tapered and thinner laser tips are needed to be designed. Lasers can be designed and improved for retreatment purposes. Based on the results of our study, we concluded that using Er:YAG lasers for the retreatment purposes for of removal gutta-percha cannot be the first choice in comparison to the other techniques which are already used in daily practice even though these options have their restrictions and side effects, but they are noted to be less than the lasers.

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Conflicts of interest

There are no conflicts of interest.

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