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The Roughening Effects of Er:YAG, Nd:YAG, and KTP Laser Systems on Root Dentin Surface

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ABSTRACT

Objectives: Present study aimed to evaluate the roughening ability of different laser systems on the middle and apical third of roots.

Materials and Methods: Sixty extracted human single-rooted single canal mandibular premolar teeth were randomly assigned to 3 groups (*n*=20). Standardized preparation and sterilization procedures were performed. The samples were irradiated with Er:YAG, Nd:YAG, and KTP laser systems. The laser irradiations (1.5 Watt) were applied with a spiral motion, starting 1 mm short of the apex and then moving coronally for 10 sec, interleaved with 15-sec recovery intervals for each irradiation. This process was repeated twelve times. The roots that were standardized in the same length and thicknesses were divided parallel to the longitudinal axis. Then, the middle and apical 1/3 surface roughness values of each root section were measured using a profilometer and SEM analysis was performed. The data obtained were analysed using the two-way analysis of variance (ANOVA) and Tukey post-hoc tests.

Results*:* According to measurements obtained from middle and apical 1/3 surfaces; Although, the statistically highest roughness value was determined after Nd:YAG laser ($p<0.05$), the statistically lowest value was detected following the Er:YAG laser irradiation ($p<0.05$).

Conclusions: In light of the present study, all laser systems caused significant roughness in surfaces. Therefore, laser systems should be carefully applied in human root canals.

Keywords: Laser; Endodontics; Nd:YAG; Er:YAG; SEM.

Er:YAG, Nd:YAG ve KTP Lazer Sistemlerinin Kök Dentin Yüzeyindeki Pürüzlendirme Etkisi

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ÖZ

Amaç: Bu çalışma, köklerin orta ve apikal üçlüsünde farklı lazer sistemlerinin pürüzlendirme kabiliyetini değerlendirmeyi amaçlamıştır.

Gereç ve Yöntemler: Altmış çekilmiş tek kök tek kanallı insan mandibular premolar dişler rastgele olarak 3 gruba ayrıldı (n=20). Standart preparasyon ve sterilizasyon prosedürleri uygulandı. Örnekler Er:YAG, Nd:YAG ve KTP lazer sistemleri ile ışınlandı. Lazerlerle ışınlama (1,5 Watt) apeksin 1 mm yukarısından spiral hareketlerle başlanarak koronale doğru 10 sn boyunca uygulandı ve her ışınlama sonrası 15 sn beklenildi. Bu prosedür 12 kez tekrarlandı. Eşit uzunluk ve kalınlıkta standardize edilen kökler dişin uzun aksına paralel olacak şekilde ayrıldı. Daha sonra, her kök kesitinin orta ve apikal 1/3 bölgelerinde meydana gelen yüzey pürüzlülük değerleri profilometer kullanılarak ölçüldü ve SEM analizi uygulandı. Elde edilen veriler, iki yönlü varyans analizi (ANOVA) ve Tukey post-hoc analiz testleri kullanılarak analiz edilmiştir.

Bulgular: Orta ve apikal 1/3 yüzeylerinden elde edilen ölçüm sonuçlarına göre; istatistiksel olarak en yüksek pürüzlülük değeri Nd:YAG lazer sonrası tespit edilmesine rağmen ($p<0,05$), istatistiksel olarak en düşük değer Er:YAG lazer ışınlama sonrasında tespit edildi ($p<0,05$).

Sonuçlar: Bu çalışmanın ışığında, tüm lazer sistemleri önemli ölçüde yüzey pürüzlülüğüne neden oldular. Bu nedenle, lazer sistemleri insan kök kanallarında dikkatle uygulanmalıdır.

Anahtar Kelimeler: Lazer; Endodonti; Nd:YAG; Er:YAG; SEM.

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Introduction

Success in endodontic treatments depends on many factors. One of the most important of these factors is root canal disinfection. For this purpose, many methods and materials have been tried and brought to the world of endodontics. One of the most important pieces of equipment that advanced technology has brought to dentistry in recent years is lasers.[1,2] The word laser is the short description of "light amplification by stimulated emission of radiation". This word is a description of each laser tool-specific feature and this definition is the basis for the future use of lasers in dentistry, especially in endodontics. Laser has been preferred because of the following reasons: light hand tool, ease of use, controllable and well-focused characteristics of the beam, ease of working comfortably in every corner of the mouth, ease of sterilization of parts that contact with the patient, implementation of the system in a cheap and time-consuming way.[3,4] The common purpose of using different types of lasers is to provide effective disinfection against bacteria, viruses, fungi, and spores. In this context, the use of lasers in the field of endodontics has recently gained popularity.[5] The most used lasers in this field are Er:YAG, Nd:YAG, Diode, and KTP lasers. Different laser systems, such as argon lasers, diode lasers, HeNe lasers, Nd:YAG lasers, Ho:YAG lasers, Er:YAG lasers, and CO_2 lasers, are confirmed for use in dental practice. Different laser systems have different usage areas according to the target tissue and the qualifications of the laser system.[3,4] Diode lasers are efficient in endodontic disinfection procedures due to the affinity of their wavelengths for bacterial cells. Er:YAG and CO_2 lasers were found to be the most effective laser systems in the manner of cavity opening. These laser systems allow for working with less energy in carious tissue than in solid hard tooth tissue. Thus, with the power-adjusted laser system, it is possible to remove only rotten tissue without making any changes to healthy tissue. On the other hand, KTP (potassium-titanyl-phosphate) lasers are the most efficient both for surgical and bleaching procedures.[6,7] However, there has not been enough study on the mechanical effects of these laser systems on root canals. Based on this shortcoming, our study aims to evaluate and compare the roughening ability of different laser systems on the middle and apical tripartite regions of the root canal.

Materials and Methods

Teeth Samples

In the present study, periapical radiographs of 60 extracted teeth in the mesiodistal and buccolingual directions were taken. The teeth were extracted due to periodontal disease, orthodontic, or prosthetic treatment planning. The mandibular premolar human teeth with a single root and single canal were used. Debris and soft tissue remnants on the tooth surfaces were removed and all teeth were stored in 0.1% thymol at 9°C until use.

Root Canal Preparation

The crowns of the teeth were removed with a diamond fissure bur (Diatech Dental AG, Heerbrugg, Switzerland) under water-cooling with a root length of approximately 14-16 mm to standardize the working lengths. Working length was determined by retracting 1 mm from the distance at which the #10 K-file was seen from the apical foramen. The teeth were prepared using the Protaper Next Nickel-Titanium (Ni-Ti) (PTN, Dentsply Maillefer, Ballaigues, Switzerland) rotary file system. 2 ml 5.25% NaOCl (Imicryl Dental, Konya, Turkey) was used at each file change during root canal preparation, 10 ml 17% EDTA (Imicryl Dental, Konya, Turkey) was used when preparation is complete and followed by 10 ml 2.5% of NaOCl. As final irrigation, the root canals were irrigated with 10 ml of distilled water and dried with paper points. All irrigation protocols were performed using with endo activator to eliminate the whole smear layer.

Experimental Groups
Laser Irradiation

Teeth were randomly divided into 3 main groups with different laser systems as Er:YAG, Nd:YAG, and KTP lasers.

Nd:YAG and KTP Group: Root canal surfaces were irradiated using an Nd:YAG (Smarty A10, DEKA M.E.L.A. SRL, Italy) and a KTP (SmartLite D, DEKA M.E.L.A. SRL, Italy) laser systems. The parameters used were 100 mJ, 15 Hz, and 1.5 W with repeated pulse mode. A 200 µm fiber optic energy delivery system was started with spiral movements 1 mm above the apex and applied for 10 seconds towards the coronal, and 15 seconds waited after each irradiation. This procedure was repeated 12 times (A total time of 5 min.).

Er:YAG Group: ER:YAG (Smarty 2940D, DEKA M.E.L.A. SRL, Italy) laser systems' parameters used were 100 mJ, 15 Hz, and 1.5 W. The sapphire endodontic tip was inserted 1 mm short of the apex, the laser was continuously irradiated from the apical to the coronal ends in slow and circling movements (approximately 3 mm/s) it is scanned for 5 min.

Roughness Measurement Procedure

All tooth roots were divided into two parts parallel to the long axis of the tooth in the buccolingual direction and embedded in acrylic resin. Surface roughness values occurring during the middle, and apical 1/3 regions of each root section were determined with a digital hardness tester SJ 301 (Mitutoyo, Tokyo, Japan) Ra (arithmetic mean of roughness -µm) before and after preparation. SEM analyses were performed on root canal surfaces after laser applications (Figures 1, 2, and 3). In addition, graphs of the roughening of the root canals after laser applications were obtained (Figures 4, 5, and 6). The obtained data were analysed using one-way analysis of variance (ANOVA) and Tukey post-hoc analysis tests.

Results

The mean values (standard deviation) of all groups together with their statistical comparisons obtained for the roughness effect of 3 different laser systems into the internal surface of the root canal are presented in Table 1. According to the measurement results obtained from the middle and apical 1/3 surfaces; although statistically the highest roughness values were detected after Nd:YAG laser ($p<0.05$), statistically the lowest values were detected after Er:YAG laser irradiation ($p<0.05$).

Discussion

Root canal disinfection plays a very critical role in endodontic treatment. Endodontic disinfection has been the main subject of many classic studies in dentistry. Thus, root canal cleaning procedures have been studied by many researchers up to the present. Residual bacteria is one of the greatest challenges in endodontic disinfection. It's known that the complete elimination of bacteria in root canals is not possible yet it can be decreased to a level that can lead to the success of endodontic therapy.[7] Different root canal disinfection techniques have been used in endodontic practice.[1,8] Recently, researchers have shown an increased interest in laser implications in dental practice as well as endodontic practice.[9] Therefore, the present study was designed to determine the effect of the roughening ability of different laser systems including Er:YAG, Nd:YAG, and KTP laser systems on the middle and apical third of the root dentin by using a scanning electron microscope (SEM). The present study has shown that Nd:YAG laser exhibited the highest roughness value on the root dentin surface and the Er:YAG laser irradiation showed statistically the lowest roughness value on the root dentin surface. This finding was also reported by Pirnat *et al.*[8] as they conducted that Nd:YAG laser cause more reduction to particular bacteria and provided better disinfection compared to the diode laser in their study. Another highlight in increasing the antimicrobial effects of Nd:YAG lasers in especially deeper layers.[10] These studies support evidence from previous observations.[7,11] The high-value results can be on account of the intermittently produced radiation through a pulsed energy input. In Nd:YAG laser systems, each pulse has a very short and high energy peak, up to 1000 W, however, the average energy output is much lower. In addition, the 1064 nm radiation emitted by the Nd:YAG laser is primarily absorbed by dark pigments. The use of black dye was therefore used in several studies to enhance the effect of lasing.[9] Sapphire tips were chosen in the previous study because of their high transmission for NIR wavelengths.[8] Romanos *et al.*[12] have compared the effectiveness of two laser tips (sapphire chisel and radial firing period) on temperature change after laser irradiation; they concluded that sapphire was more advantageous when compared to the other. It's also remarkable that laser systems have photothermal effects as well as photochemical effects. An important finding about Nd:YAG lasers are their substantial photothermal properties. Thus, attention is required when studying with Nd:YAG lasers because of the possible damage to the dentin surface and periradicular tissues. Ramsköld *et al.* conducted that dentin and water have different heat absorbing and conducting levels and they noted that water requires nearly four times more energy than dentin to raise the temperature to the same degree. In conclusion, thy reported that dry and wet root canals absorb energy differently.[9] This is important according to the disinfection mechanism of Nd:YAG lasers because heating the microenvironment is the main approach to removing bacteria in root canals.[5] This outcome is contrary to that of Meire *et al.* who found that Er:YAG lasers have a better potential in disinfecting the root canals. They also noted that Nd:YAG lasers have enhanced penetration ability in dentinal tubules and have a better potential in reaching these areas in root canals.[5] In addition, irradiance is effective in the antimicrobial property.[5] To our knowledge, there are limited studies about laser roughening effects on root canal dentin to compare with the present study. Following the present results, previous studies[13] have demonstrated that Nd:YAG lasers induced the furthest mechanical changes on both dentin and enamel surface. Nevertheless, they reported that Nd:YAG laser caused changes in mineral substance on both surfaces.[13] Supporting of present study' results, Nd:YAG lasers cause a meaningful roughness on the dentinal surface.[14]

Araki *et al.*[15] demonstrated the efficacy of Er:YAG laser irradiation on the microbiological apical biofilm and they reported that the Er:YAG laser caused a roughening effect on the dentin surface. Additionally, it was reported in another study that, there can be a difference in surface roughness between each laser system due to uncertain reasons. Furthermore, differences can be an account of the properties of laser devices and the density of the energy as well as the differences in evaluation techniques.[13] Shoji *et al.* reported that applying Er:YAG laser on root surfaces caused open dentinal tubules and this technique provided cleaner canals compared to the other techniques. They also reported that the reason for the cleanliness of the root canals is that the Er:YAG laser is a near-infrared laser that conduces to photo vaporization property which breaks down the dental tissue because of its emission.[16] In another study, Er:YAG laser technique was compared to traditional techniques on root surface roughening and conducted that the laser technique caused a meaningful roughness without damaging underlying tissues. This might be because the laser technique opens dentinal tubules and perform as an etching agent.[17] Also, Armengol *et al.*[18] proved that Er:YAG laser caused greater changes and roughness on the root canal dentine surface. As a result of these studies that supported the present study's result Er:YAG laser has a notable roughening effect on root canals. In addition, although that laser type may cause less roughening effect than other tested lasers, it can be preferred during root canal treatments.

Further optimization of irradiation parameters should improve the overall success rate of laser-assisted endodontic treatment. A recent study[8], targeted analysing the potential photodamage effect on a sub-cellular level, and aimed at analysing the spot and area temperature rises with the help of thermal imaging in sound and infected dentin could help to optimize the already established procedure.

In light of the present study, all types of laser systems provided remarkably applicable effects on root canal inner dentin walls. Specially, these laser-type roughening approaches used in the present study may prefer to increase the adhesion of adhesive cement in prosthodontic practices and also between dentin wall and canal filling materials in endodontic treatments. Considering these advantages, either prosthodontic or endodontic treatments may become more successful in the long term. However, SEM observation showed that laser irradiation produces mechanical modifications or root dentin surface, which can provide a disinfection effect. Previous research has shown that human root canal dentin can be altered by Er:YAG, Nd:YAG, and KTP laser systems. Since this laser radiation causes mechanical changes on the root dentin surface, a better disinfection procedure can be obtained.

Conclusion

Within the limitations of the previous study, our results support the use of laser systems on dentin surface roughening when carefully used. However, more extensive clinical studies are needed to determine the extent of any benefits gained by laser roughening.

Table 1. Mean (Standard Deviation) together with their statistical comparisons, were obtained from all groups.

Groups	Medium Roughness Mean (SD)	Apical Roughness Mean (SD)
Er:YAG laser	$0.549 (0.240)^{A,a,b}$	$0.214 (0.240)^{A,d,e}$
Nd:YAG laser	$1.161 (0.374)^{B,a,c}$	$0.669 (0.193)^{B,d,f}$
KTP laser	$0.768 (0.147)^{C,b,c}$	$0.415 (0.114)^{C,e,f}$

By the two-way ANOVA, F = 44.329; p = 0.000 ($p < 0.05$).

Capital letters indicate the difference between regions of the root, and lowercase letters the statistical difference between lasers. Value with the same superscript letter indicates a statistically significantly different at $p > 0.05$ by Tukey's Test.

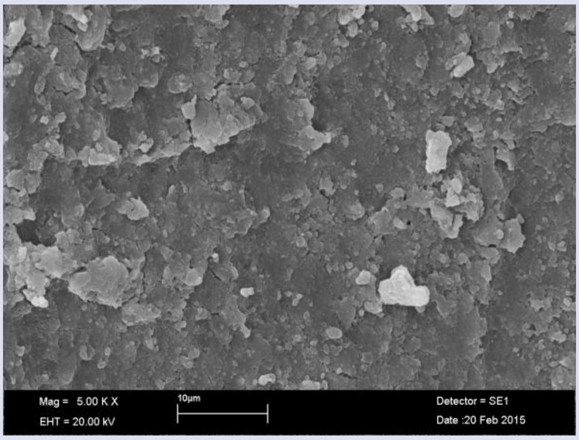

Figure 1. SEM micrograph of dentin surface treated with 3.5 W laser in Group Nd:YAG (original magnification ×2.50 k).

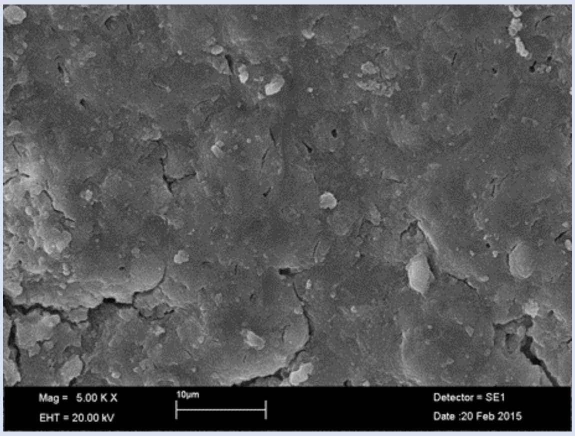

Figure 2. SEM micrograph of dentin surface treated with 3.5 W laser in Group Er:YAG (original magnification ×2.50 k).

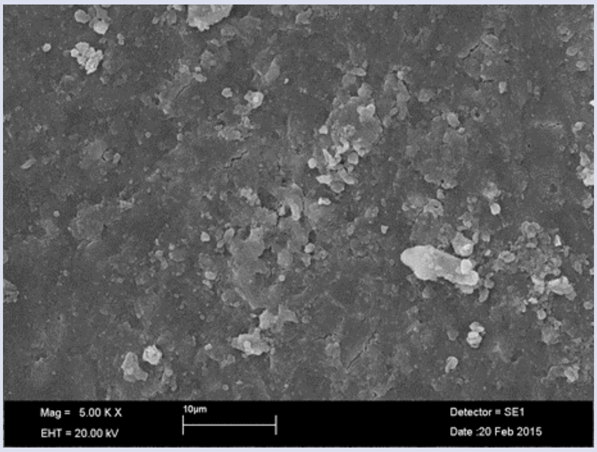

Figure 3. SEM micrograph of dentin surface treated with 3.5 W laser in Group KTP (original magnification ×2.50 k).

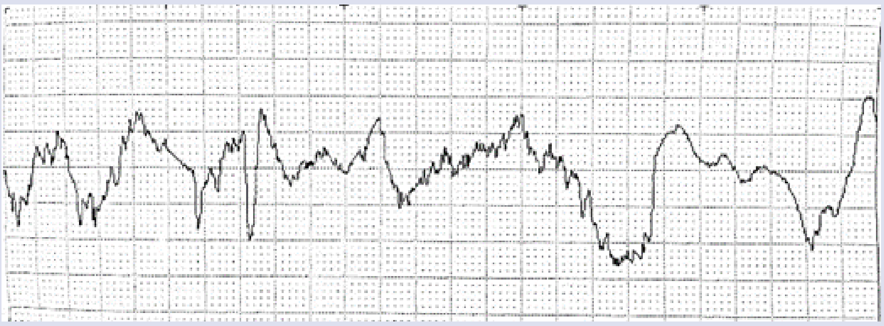

Figure 4. Root dentin roughening graphic of Nd:YAG laser.

Figure 5. Root dentin roughening graphic of Er:YAG laser.

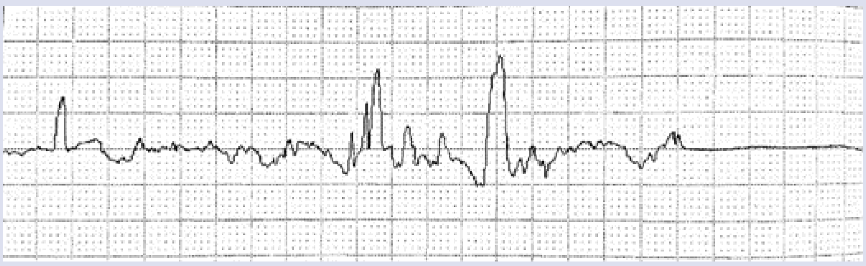

Figure 6. Root dentin roughening graphic of KTP laser.

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