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Influence of Different Proportions of External Irrigation During the Er,Cr:YSGG Laser Irradiation on Wear and Roughness of Root Surface

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Abstract

Introduction: The aim of this study was to evaluate the influence of different levels of external irrigation during irradiation with an erbium, chromium: yttrium-scandium-gallium-garnet (Er,Cr:YSGG) laser on the roughness and wear of dental tissue during scaling procedures.
Methods: Twenty-Five uniradicular bovine teeth had the proximal surfaces planed and divided into 3 regions: upper, middle and lower. The upper region was treated with hand instruments, the middle region was not treated and served as a control, and the lower region was treated by the Er,Cr:YSGG laser. The teeth were randomly divided into five groups according to the different proportions of external irrigation used during the laser irradiation: G1: 10%; G2: 20%; G3: 30%; G4: 40% and G5: 50%. The samples were analyzed for roughness and wear on the root surface irradiated with the laser.
Results: There were no differences in the surface roughness and wear parameters between the groups irradiated with the laser, but the laser irradiation produced a rougher surface of the dentin than treatment with hand scaling.
Conclusion: Changes in the external irrigation level did not influence the wear and roughness of root surfaces treated with an Er,Cr:YSGG laser.
Keywords: Dental scaling; Laser; Roughness; Tooth wear.

Introduction

Scaling and root planing (SRP) by hand instruments is the most established treatment for periodontitis.[1] However, this treatment has limitations in promoting total debridement on the root surface due to difficult access areas, such as deep pockets and furcations.[2] In addition, the clinical success of scaling is highly dependent on the manual skills of the operator.[3]

Some alternative tools to facilitate SRP have been proposed, such as sonic instruments,[4] ultrasonic instruments[5] and lasers.[6] The alternative use of lasers has been proposed due to some advantages, such as hemostasis,[7] selective calculus removal[8] and antibacterial effects.[9] However, different types of radiation can lead to harmful thermal effects on the root surface[10,11] and can also promote a rough root surface.[12]

The erbium, chromium: yttrium-scandium-gallium-garnet (Er,Cr:YSGG) laser emerged with indication for caries removal and cavity preparation, and its use was approved by the U.S. Food and Drug Administration (FDA) (2002) for bone cutting and resection procedures. The wavelength (2.78 µm) of this laser results in a high degree of its energy being absorbed by water. Thus, it acts in mineralized tissues by vaporizing the water present in the interprismatic tissue, which reduces any thermal effects that may be harmful to the dental pulp and the periodontium, especially when used without external irrigation.[13] When used on the surfaces of root canals, the Er,Cr:YSGG laser promotes smear layer removal and the opening of dentinal tubules[14] and also promotes removal of tooth tissue[15] and root surface calculi[16] with no thermal damage.[14-16]

Some parameters may affect the amount of tissue removed and the root roughness after irradiation with lasers, such as energy,[17,18] the laser tip angle relative to the root surface[15] and the amount of water expelled during irradiation.[13] One study reported that increasing the amount of irrigation water promoted more dentin removal during irradiation with the erbium: yttrium-aluminum-garnet (Er:YAG) laser,[19] and another study showed that water irrigation contributes to the ablation caused by irradiation

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with the Er,Cr:YSGG laser.[13] However, we do not know the actual effect of the proportion of water irrigation on dentin removal and root roughness during the scaling with the Er,Cr:YSGG laser.

Since excessive tooth tissue removal may endanger the retention of a tooth,[17] also, as the roughness parameter may indicate the need for a supragingival polishing in order to prevent biofilm accumulation,[20] this present in vitro study aimed to assess the effect of different irrigation proportions during irradiation with the Er,Cr:YSGG laser on the roughness and wear of dentin tissue during scaling procedures.

Methods

Sample Preparation and Group Divisions

Twenty-five healthy monoradicular bovine teeth were used in the present study. The teeth were cleaned in distilled water and stored in phosphate-buffered saline (PBS) at pH 7.0 to maintain hydration until the experiment was performed. The proximal surfaces of the teeth were planed using a polishing machine, and 3 grooves were subsequently made using a cylindrical drill mounted on a high-speed motor under a copious external irrigation. The first groove was made at the cementoenamel junction, the second groove was 5 mm below the first groove, and the third groove was 5 mm below the second groove, thereby delimiting 3 areas on the root surface at the proximal side of each tooth: an upper, a middle and a lower region (Figure 1A).[21] Each predefined region was subjected to a different treatment. The upper region was treated with SRP, which consisted of 50 cervical-occlusal traction movements using a hand curette (Gracey 5-6, Hu-Friedy, Chicago, IL, USA) by a single operator. The middle region was not subjected to any treatment, and the lower region was irradiated with the Er,Cr:YSGG laser (Waterlase YSGG, BIOLASE Technology, San Clemente, CA, USA) with a wavelength of 2.78 µm; the tip used was the G4 which is 600 µm in diameter and 4 mm in length, power of 1.0 W and frequency of 20 Hz in 10% air for 30 seconds at a 30° angle from the root surface, in a pulsed mode. The teeth were then divided into 5 groups, each with 5 teeth, depending on the irrigation level used during the laser irradiation applied to the samples: G1: 10%; G2: 20%; G3: 30%; G4: 40%; and G5: 50%.

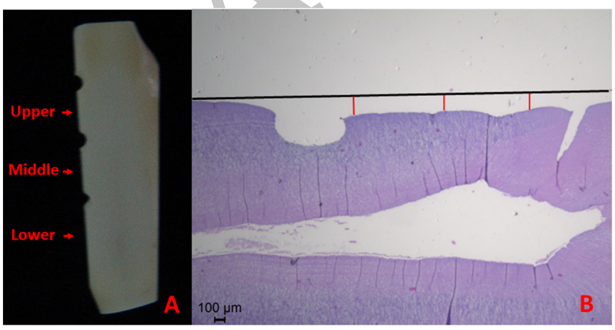

Figure 1. (A) Model of the Sample Used in This Study. The upper region was always by scaling and root planing (SRP) with hand curette, the middle region was not subjected to any treatment, and the lower region was irradiated with the Er,Cr:YSGG laser; (B) Histometric Analysis. A parallel line to the control region surface was inserted to the image, and the distance from that line to the test regions was recorded using 3 measurements 500 µm from each other.

Roughness Analysis

The surface roughness measurements (Ra and Rz) were recorded on each sample surface using a profilometer (Surftest SJ-401, Mitutoyo Sul Americana Ltda, Santo Amaro, SP, Brazil) with an accuracy of 0.01 µm. Three measurements were performed for each region of each sample, at different sites within a predetermined and similar area. For each reading, the device needle ran 1.5 mm always in a single direction with a cutoff of 0.8 mm. The arithmetic mean of the 3 measurements was used as a reference value for the roughness of each evaluated area.

Root Wear Analysis

After analyzing the roughness, the teeth were decalcified in Morse solution (50% formic acid + 20% sodium citrate) for three months to undergo routine histological processing and to obtain the 6-µm-thick paraffin sections that were later stained with hematoxylin and eosin. Nine slides with 4 sections each were obtained from each tooth: 3 slides were obtained from the block surface, 3 from the central portion of the block and 3 from the deep part of the block. The first slide analyzed was selected by lot (numbered from 1 to 3), and the next slide analyzed was always the third from the reference slide. Thus, 3 sections approximately 145 µm from each other were analyzed.

The pieces selected for analysis were photographed at 50x magnification under a light microscope (Leica - Reichert Diastar Products & Jung, Wetzlar, Germany) and were analyzed using a specific program for image analysis (ImageJ, Sigma Scan Pro, Jandel Scientific, San Rafael, CA, USA). A parallel line to the control treatment surface was added to the image, and the distance from that line to the treated regions was recorded using 3 measurements 500 µm from each other. The arithmetic mean of these measurements provided the amount of wear observed in each image. The result for each proximal surface was the arithmetic mean of the 3 slides evaluated from each tooth (Figure 1 B).[21]

Statistical Analysis

Graphpad Prism 5 software (San Diego, CA, USA) was used to perform the statistical analysis. Data generated by wear and roughness analyses were numerical; therefore, the Shapiro-Wilk normality test was used to assess whether the data were distributed according to the central limit theorem. The normality test indicated that the data were normally distributed ($P > 0.05$); thus, the one-way analysis of variance (ANOVA) parametric test along with the Tukey test were used for the inferential analysis. All tests were applied with a 95% confidence level.

Results

The water emission level of the Er,Cr:YSGG laser external reservoir did not promote significant differences between groups regarding roughness and wear on tooth tissue. Comparing the results between the lasers and SRP, laser irradiation promoted higher degrees of roughness in the dentin tissue than scaling with a hand instrument ($P < 0.05$). However, no difference was demonstrated on the tooth wear between both treatments. Table 1 displays the means and standard deviations of the Ra and Rz roughness values (μm), and Table 2 shows the means and standard deviations for dental wear values (μm).

Discussion

This study aimed to evaluate the influences of different proportions of external irrigation during irradiation with an Er,Cr:YSGG laser on the roughness and wear of dentin tissue during scaling procedures. Samples irradiated with the laser exhibited similar levels of wear and roughness regardless of the level of water used for irrigation. Additionally, hand instrumentation promoted less roughness on the dentin surface than laser irradiation.

The ablation mechanism of the Er,Cr:YSGG laser is defined as a photomechanical ablation. This type of ablation occurs due to the sudden evaporation of water from the interprismatic substance, which causes microbursts of the hard tissue and the elimination of hydroxyapatite crystals at temperatures below their melting point, without causing thermal damage to the dentin/bone tissue.[22] It has been suggested that the external irrigation source could influence the wear of hard tissues in addition to preventing tissue overheating.[13] A previous study reported that the internal water concentrations in enamel and dentin did not influence the ablation effects of Er:YAG and Er,Cr:YSGG lasers, but that, increased amounts of external irrigation water caused greater dentin removal during irradiation with the Er:YAG laser.[19] It was also reported that irrigation water contributes to the ablation caused by irradiation with the Er,Cr:YSGG laser.[13,19] Our study found that different water concentration levels during irrigation did not produce different degrees of dentin wear and roughness on root surfaces, but it does not reject the hypothesis that external irrigation contributes to the ablation mechanism promoted by the Er,Cr:YSGG laser.

Table 1. Means and Standard Deviations of the Ra and Rz Roughness Values (μm) of All Groups

Group	Ra	Rz
SRP	1.91 ± 0.52*	3.59 ± 0.83*
G1	4.85 ± 3.70	18.86 ± 12.58
G2	8.07 ± 1.47	35.89 ± 6.46
G3	6.94 ± 2.26	31.02 ± 7.45
G4	5.95 ± 1.62	26.67 ± 7.50
G5	7.04 ± 2.54	30.17 ± 10.23

*$P < 0.05$ - Lowest roughness value among all groups. ANOVA along with Tukey test.

Table 2. Means and Standard Deviations of Wear Values (μm) of All Groups

Group	Wear (μm)
SRP	169.83 ± 24.86
G1	151.80 ± 45.50
G2	142.20 ± 28.42
G3	139.30 ± 36.81
G4	185.10 ± 49.90
G5	155.3 ± 26.39

The results of this study demonstrated that the laser irradiation promoted higher degrees of roughness in dentin tissue compared to scaling with a hand instrument. The roughness of the dentin surface is a matter of great importance because when roughness is present in a supragingival region, it can lead to biofilm build-up.[23,24] Thus, polishing of previously irradiated areas is required to reduce the chances of dental plaque accumulation.[20] When irradiation is applied in the subgingival region, which is not in direct contact with the oral environment, this roughness may benefit healing processes because rough surfaces can increase the adhesion of blood components[15] and fibroblasts from the periodontal ligaments.[25] However, it should be taken into consideration that after periodontal treatment, the root surfaces that were once located below the gingival margin will eventually become located above the gingival margin due the retraction of the inflamed gingiva [26]

This pattern has been demonstrated in previous studies that compared the roughness of surfaces irradiated with an Er,Cr:YSGG laser[15] or an Er:YAG laser[8] with hand scaling. The rougher texture on root surfaces irradiated with an Er,Cr:YSGG laser may be a result of its thermomechanical ablation mechanism, in which the abrupt evaporation of water from the interprismatic substance promotes micro-explosions that remove hydroxyapatite crystals.[27] Thus, by irradiating the dentin tissue, which comprises 3 types of dentin (i.e., tubular, peritubular and intertubular) with different concentrations of water, the ablation may have occurred unevenly, which may have produced a surface with a higher degree of roughness.[15]

Another factor that may have contributed to this lower roughness of samples treated with hand tools is that the active tips of hand instruments cover a larger surface area, which allows a more uniform approach for hand tools on root surfaces.[28]

Regarding wear, the results did not show significant differences between groups irradiated with the laser or treated by scaling with hand tools. Other studies have reported some parameters that may affect the amount of tissue removed after irradiation with lasers, such as power,[16,18] the laser working angle relative to the root surface[15,17,18] and the amount of water expelled during irradiation.[13,19] In the present study, the power[16] and working angle[15] parameters that produced the lowest root wear in these studies were used, which may explain the lack of differences regarding wear between groups, demonstrating that the wear effect promoted by the irradiation water is a factor of secondary importance when compared to the irradiation energy and working angle parameters.

Thus, although some studies have reported that the external reservoir water expelled during irradiation is important during ablation promoted by the Er,Cr:YSGG laser,[13,19] the present study revealed that changing the external irrigation parameters of the Er,Cr:YSGG laser does not change dentin wear rates. Thus, it is suggested that external irrigation can be used without concern for excessive wear that could occur due to the increased level of water expelled during irradiation. In addition, it is noteworthy that studies have shown that the use of lasers without adequate cooling can lead to thermal damage to the dentin tissue, which can induce the formation of toxic compounds that can harm the periodontal repair/regeneration.[10,11] Because of this possibility, irrigation should always be used to prevent thermal damage to root surfaces that may hinder the tissue repair/regeneration process or may affect the pulp vitality of the dental element.

Conclusion

The findings of this study show that the water emission level of the Er,Cr:YSGG laser external reservoir does not change the roughness or wear of the tooth tissue.

Conflict of Interest

The author has no conflict of interest to declare.

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