Evaluation of Two Laser Systems for Intracanal Irradiation

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ABSTRACT

The aim of this study was to determine safe parameters for intracanal laser irradiation. Single rooted extracted teeth were irradiated with the pulsed Er:YAG laser (2.94 μm) and Nd:YAG laser (1.06 μm). The teeth with remaining root thickness ≥ 1mm on the apical portion were selected and divided in eight groups according to the laser parameters: output energy of 40-100 mJ/pulse; repetition rate of 10-15 Hz. The root canals were irradiated for 4 periods with a 20s breaks in between with the fiber stationary 1mm from the apical foramen, during 3s (as considered optimal by Matsumoto) or from the apical to coronal surface in a continuous, circling fashion (as considered optimal by Gutknecht), with 2mm/s. Morphological changes were also observed by scanning electron microscopy.

Keywords: Intracanal Irradiation, Microorganism Reduction, Er:YAG, Nd:YAG

1. INTRODUCTION

The effect of various lasers as an alternative to mechanical methods of root canal treatment or as an adjunct to conventional endodontic preparation has been investigated in a number of studies, and many authors agree that neither method or instrument in particular is able to produce a canal completely free of debris[1]. Levy et al.[2] observed the improved debridement of laser-treated root canals as compared with results of conventional technique. The performance of this equipment, concerning safe and effective wavelength and energy levels related to temperature rise, morphological changes and microbial reduction, should be well documented before it becomes a current method of treatment.

The aim of this study was to determine safe parameters for intracanal laser irradiation, whose thermal effect did not exceed temperature safety threshold for adjacent periodontal tissues, and morphological related changes, by using thermocouple probe measurements and scanning electron microscopy, respectively.

2. MATERIALS AND METHODS

2.1. Tooth Preparation

Sixty single rooted extracted teeth (canines) were prepared mechanically up to file # 45, using a standardized technique[3]. Prior to investigation, the teeth were stored in distilled water. Teeth with a root wall ≥ 1mm on the apical portion were selected after X-ray measurement and divided in ten groups according to the type of laser and parameters of irradiation.

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2.2. Irradiation Parameters

For irradiation a commercially available pulsed Er:YAG laser, emitting at 2.94 µm, 250-500 µs pulse width (KEY® laser, KAVO, Biberach, Germany), and a Nd:YAG laser, emitting at 1.064 µm, 100 µs pulse width (American Dental Technologies, Pulse Master 1000, USA) were used. The laser light was delivered by a 375 µm (18 mm length) and 300 µm diameter fiber optic probes, respectively. Laser parameters were: output energy of 40-100 mJ/pulse; repetition rate of 10-15 Hz. The root canals were irradiated for 4 periods with a 20s break in between with the fiber stationary 1mm from the apical foramen, during 3s (as considered optimal by Matsumoto)[4] or from the apical to coronal surface in a continuous, circling fashion to irradiate dentinal tubules (2mm/s), as considered optimal by Gutknecht et al.[5] for Nd:YAG laser (table 1). Teeth were maintained in a 37 °C water bath and temperature changes recorded as root canal was lased. The total time for the irradiation was established for each specimen, according with the root canal length. The canals were dried by paper points before treatment and not subjected to air or water cooling during the procedure.

2.3. Temperature Measurements

Thermal changes during *in vitro* intracanal application of Er:YAG laser were measured by a 130 µm diameter copper-constantan (type T) thermocouple (Omega Engineering, Inc., Stamford, CA), that was in contact with the root surface at the canal working length (1mm from the apical foramen). The correct position of the thermocouple was checked by radiographic exam. In order to maximize temperature transference between the thermocouple and the root surface, the thermocouple was covered by a thermal conducting paste (Omegatherm 201, Omega Engineering, Inc., Stamford, CA). Test teeth were placed vertically in a 37 °C water bath with the crown above the water level. The signal from the thermocouple was amplified, digitalized by a lock-in (5RS10 Stamford Research System), transmitted to a PC and stored.

Remaining dentin thickness was further verified, after temperature measurements, by direct measurement of the teeth. Statistical analysis of the data by analysis of variance (ANOVA) was performed in order to verify significant difference ($p<0.05$) on root surface temperature rise among the groups.

2.4. Morphological Analysis

The crown of the specimens was resected at the cementum-enamel junction and two grooves were drilled longitudinally in the buccolingual plane of the root by a diamond disc and then the teeth were cleaved. The two fragments of each specimen were prepared for scanning electron microscopic analysis (Philips LX30 Eindhover, Holland).

3. RESULTS

3.1. Temperature Measurements

The maximum root surface temperature rises for all groups are shown in Table 1, and the graphics obtained during the measurements (4 repetitions with an interval of 20 seconds between each) can be observed on Figure 2.

Group	Laser	Energy (mJ) Output	Frequency (Hz)	Duration (s)	Mode, Velocity	Repetition	Interval (s)	Maximum Temp Rise - mean - (°C)
Group 1	Er:YAG	40	10	8-11*	Circular, 2 mm/s	4 times	20	2.20
Group 2	Er:YAG	80	10	8-11*	Circular, 2 mm/s	4 times	20	3.98
Group 3	Nd:YAG	60	10	8-11*	Circular, 2 mm/s	4 times	20	1.66
Group 4	Nd:YAG	100	10	8-11*	Circular, 2 mm/s	4 times	20	2.32
Group 5	Nd:YAG	60	15	8-11*	Circular, 2 mm/s	4 times	20	3.93
Group 6	Nd:YAG	100	15	8-11*	Circular, 2 mm/s	4 times	20	3.80
Group 7	Nd:YAG	60	10	3	Stationary	4 times	20	2.42
Group 8	Nd:YAG	100	10	3	Stationary	4 times	20	5.33
Group 9	Nd:YAG	60	15	3	Stationary	4 times	20	3.63
Group 10	Nd:YAG	100	15	3	Stationary	4 times	20	5.76

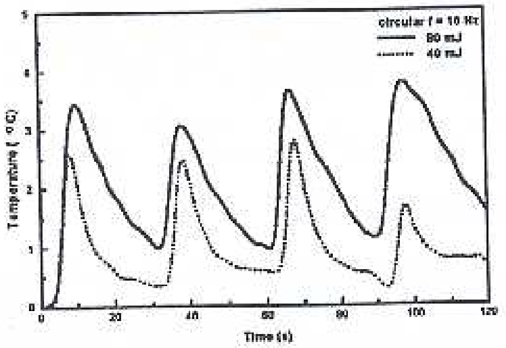
Table 1 – Irradiation parameters for intracanal irradiation and maximum root surface temperature rise. (*) depends of the root canal length.

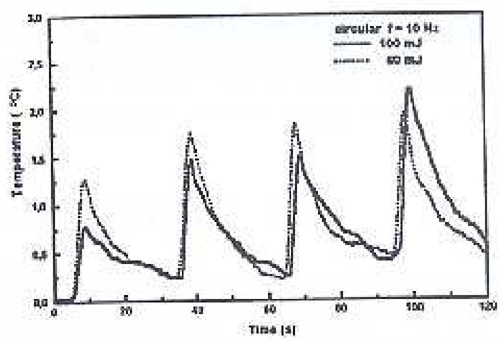
Er:YAG and Nd:YAG lasers, when irradiated in circular motion at 2mm /s produced temperature rises at the root surface below 5°C. Stationary irradiation of Nd:YAG laser at 1mm from the apical foramen produced temperatures above 5°C but below 10°C , only for the groups 8 and 10, where the laser energy was 100 mJ, for either 10 or 15 Hz.

Each tooth had four replicate measurements and the mean of the four measurements was used in the analysis. Analysis of variance (ANOVA) compared significant differences ($p<0.05$) on root surface temperature rise Results were considered statistically significant within the groups irradiated by Er:YAG laser (40 and 80 mJ) and for the groups (Nd:YAG laser), where the same laser energy, but different repetition rates (10 and 15 Hz) were used.

3.2. Morphological Analysis

Under the SEM, lased dentin showed different levels of canal debridement, including smear layer removal and morphological changes according to the energy level and repetition rate used. There was no indication of cracking in all of the samples using SEM. Er:YAG laser at 80 mJ, 10 Hz were more effective for debris removal (Figure 3B), producing a clean surface with a higher number of open tubules, when compared with the other laser treatment and the control – without laser treatment (3A). A decreased level on this capacity was observed when the energy was 40 mJ, although the exposition of the tubules was also very uniform at the entire root, from apical to cervical portion. Nd:YAG laser irradiated samples presented melted and recrystalized dentin and smear layer removal (Figure 3 C).





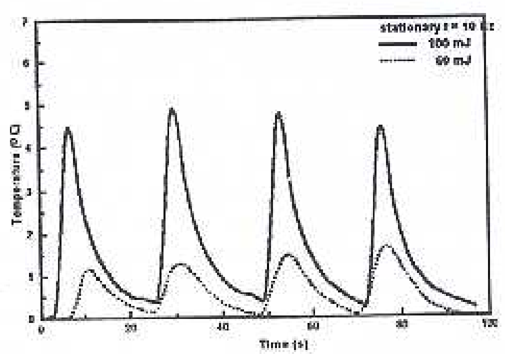


Figure 2 – Graphics obtained during laser irradiation and thermal measurements (4 repetitions with an interval of 20 seconds between each), circular application: (A) Er:YAG, 40 and for 80 mJ, 10 Hz, (B) Nd:YAG, 60 and 100 mJ, 10 Hz; (C) Nd:YAG, stationary application, 60 and 100 mJ, 10 Hz.

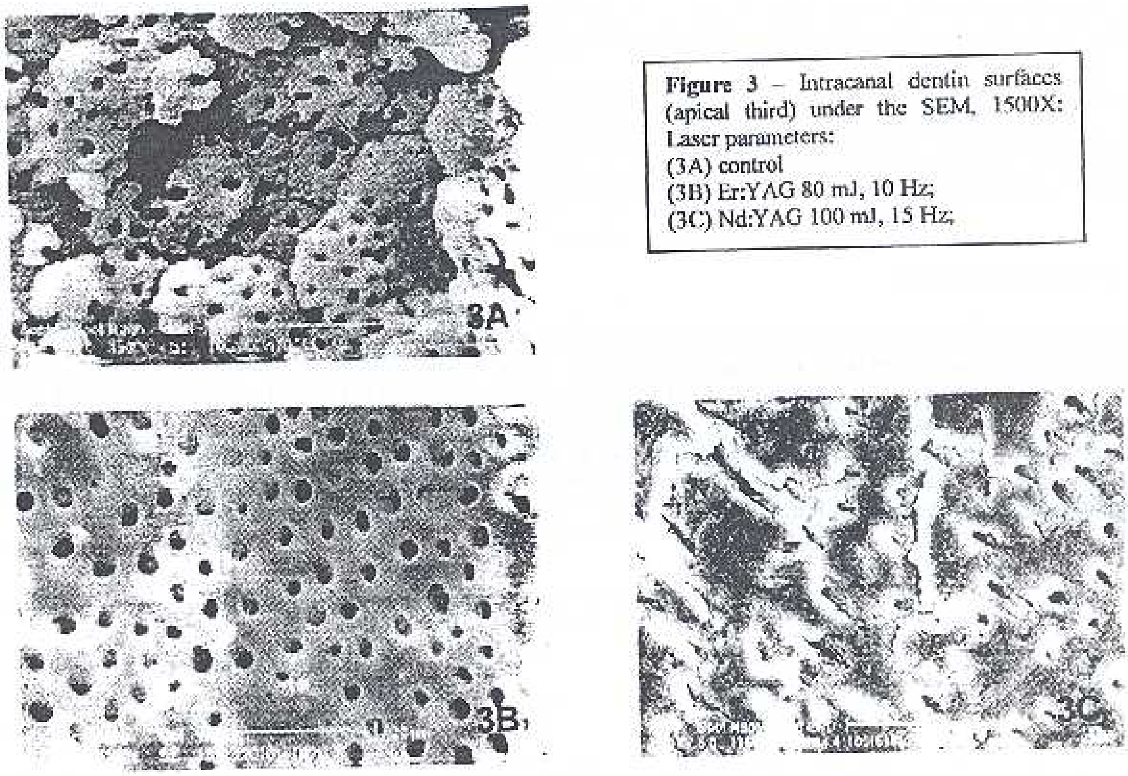


Figure 3 – Intracanal dentin surfaces (apical third) under the SEM, 1500X: Laser parameters:
(3A) control
(3B) Er:YAG 80 mJ, 10 Hz;
(3C) Nd:YAG 100 mJ, 15 Hz;

4. DISCUSSION AND CONCLUSIONS

The main purpose for using laser intracanal irradiation is the microbial reduction achieved by temperature rise. But excessive temperature rise, equal or beyond 10 °C (Eriksson and Sundstrom[6]), produced at the root surface can cause immediate or posterior damage to the periradicular tissues. More recently, Cohen et al.[7] conjectured that, if the change of temperature at the root surface is at or below 5°C, the probability of damaging the periodontal ligament, the cementoblast or the alveolar bone is minimized. According to Hibst et al.[8] (1997), the use of a highly absorbed laser light tends to localize the heating to a thin layer at the sample surface. Minimizing the absorption depth significantly decreases the risk of subsurface thermal damage, since less energy is necessary to heat the surface to the required temperature for a successful treatment. The remaining dental thickness of the irradiated root surfaces is also an important factor, directly proportional to the temperature rise. Although Nd:YAG, emitting at 1.064 μm, presents a higher penetration depth of the laser light when compared with the Er:YAG laser, both lasers demonstrated temperature rises that did not exceed safety thresholds for adjacent periodontal tissues. Er:YAG and Nd:YAG lasers, when irradiated in circular motion at 2mm/s produced temperature rises at the root surface below 5°C. Stationary irradiation of Nd:YAG laser at 1mm from the apical foramen produced temperatures above 5°C but below 10 °C, only for the groups where the laser energy was 100 mJ, for either 10 or 15 Hz. The results obtained in this work agree with the parameters precognized by Matsumoto[4] and Gutknecht[5] for the safe use of Nd:YAG lasers for intracanal irradiation, and with the parameters used by Hibst (1990, 1997)[9,10] that demonstrated bacterial reduction by Er:YAG with very controlled heating. Different studies also have been investigated morphological changes and root canal preparation as a result of laser irradiation[2,11]. The root canal walls irradiated by Er:YAG laser were free of debris, removed smear layer and open dentinal tubules, as recently reported by Harashima et al.[12] (1998). The scanning electron microscopic evaluation showed in this study, scanning electron microscopy analysis showed different modified patterns as a result of the different mechanisms of interaction laser-tissue by these two wavelengths.

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