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In Vitro Study of Temperature Changes in Pulp Chamber During Root Planing Procedure Using Er:YAG Laser

Blagovesta K. Yaneva¹, Plamen I. Zagorchev², Elena I. Firkova¹, Ivan T. Glavinkov¹

¹ Department of Periodontics and Oral Mucosa Diseases, Faculty of Dental Medicine, Medical University of Plovdiv, Plovdiv, Bulgaria

² Department of Medical Physics, Biophysics and Mathematics, Faculty of Pharmacy, Medical University of Plovdiv, Plovdiv, Bulgaria

Correspondence: B. Yaneva, Department of Periodontics and Oral Mucosa Diseases, Faculty of Dental Medicine, Medical University of Plovdiv, 3 Hristo Botev Blvd., 4002 Plovdiv, Bulgaria
E-mail: blagovesta.yaneva@gmail.com
Tel. +359 888 53 95 88

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Aim: To assess temperature changes at specified time intervals during Er:YAG laser scaling and root planing of surfaces with dental calculus.

Materials and methods: Fifteen single-rooted teeth with advanced periodontal disease were extracted and fixed in a cylinder thermostat filled with distilled water at constant temperature (35.5°C). A specially designed thermal probe (type K thermocouple) accurate to $\pm 0.1^\circ\text{C}$ over the range from 20°C to 80°C was fitted into the pulp chamber of tooth sample. Scaling and root planing of the mesial and distal root surfaces was performed using an Er:YAG laser (Lite Touch, Syneron Dental, Israel) with a wavelength of 2940 nm, provided with a chisel tip, and at the following settings: output energy 100 mJ and 50 Hz, duration of irradiation - 40 sec, the tip in contact mode oblique to the root surface at an angle of approximately 10-15 degrees and water spray level 5-6. The temperature inside the pulp chamber was measured every 10 sec.

Results: The temperature in the pulp chamber taken every 10 seconds and compared with the temperature of 35.5°C at baseline decreased by 1.6°C , 2.4°C , 2.5°C , and 2.5°C for the first, second, third and fourth measurement, respectively. These changes did not reach statistical significance.

Conclusion: The Er:YAG laser does not increase the temperature inside the pulp chamber. The assessed changes do not depend on the duration of irradiation which was kept within 40 seconds. Therefore, this treatment modality causes no thermal damage to the pulp under the above defined conditions and can be considered safe.

INTRODUCTION

The major goal of periodontal therapy is to eliminate microbial plaque, calculus and necrotic cementum on root surfaces thereby arresting the progression of the disease.¹ A wide variety of instruments with proven efficiency have been used in periodontics to achieve this goal.²

Lasers have been widely discussed recently as non-surgical treatment modality of periodontitis. The light Er:YAG lasers emit has a wavelength of 2940 nm, which has high absorption coefficient in water molecules and so provides the capability to be used both on soft and hard tissues such as enamel, dentin, cementum and bone. These lasers have proved their efficiency in removing calculus from the root surface without thermal side effects such as melting or carbonisation of tooth cementum.³ Moreover, there is convincing evidence of the

antibacterial effect of the Er:YAG lasers^{4,5} and of the advantages it has in various surgical therapies⁶.

Since the action of Er:YAG lasers is mainly based on the photothermal effect which increases temperature, it is important to know the dynamics of the intrapulpal temperature in using them. Therefore the aim of this study was to investigate in vitro the thermal changes in the pulp chamber during Er:YAG laser scaling and root planing.

MATERIALS AND METHODS

TEETH SAMPLES

Two surfaces were used in the study: the mesial and the distal surface ($n = 30$) of each of 15 single-rooted teeth with calculus extracted for advanced periodontal disease. The teeth were stored in 0.9% NaCl at 4°C to avoid dehydration. Prior to the beginning of the study the root canals were instrumented

with hand K-type files and reamers to ISO size 40 apically to make room for the thermal sensor that can gauge the temperature.

THERMOSTAT SYSTEM

The tooth sample was placed in a cylindrical micro-processor-controlled ultra-thermostat filled with distilled water at a temperature of $35.50^{\circ}\text{C} \pm 0.05^{\circ}\text{C}$; this was stirred vigorously during the experiment (**Fig. 1**). The temperature is selected in accordance with actual intrapulpal physiological temperature with means in the range of 35°C to 36°C .⁷

Figure 1. Experimental setting – a tooth sample in the thermostatic system. The thermal measurement system is placed in the pulp chamber of the sample.

TEMPERATURE MEASURING SYSTEM

Temperatures were measured using a digital thermometer (FLUKE 16, Thermometer, Fluke corporation, United States), linked with a specially designed thermal sensor (type K thermocouple) with an accuracy of $\pm 0.1^{\circ}\text{C}$ for the range from 20°C to 80°C . Thermodynamic equilibrium took only 200 ms to establish due to the very small mass of the sensor (<5 mg). As a result we could measure very accurately the temperature at every second (1000 ms). The thermometer was placed in the middle third of the root canal. This position was determined after it was found that the temperatures measured in the coronal, middle and apical third of the root canal were similar during laser operation (unpublished data).

ER:YAG LASER TREATMENT OF ROOT SURFACES

The mesial and distal root surfaces ($n = 30$) of the teeth were instrumented with Er:YAG laser (2940 nm, Lite Touch, Syneron Dental, Israel) with a

chisel tip, in contact mode, moving the tip in a continuous motion in the apical coronal direction and an angle of the tip of 10-15 degrees obliquely to the root surface (**Fig. 2**). Instrument settings were as follows: 100 mJ and 50 Hz (total 1.5 W) and constant water cooling (water spray).

Figure 2. Er:YAG laser irradiation of root surfaces in contact mode, continuously moving the tip in the apical coronary direction and at an angle of 10-15 degrees obliquely to the root surface.

STATISTICAL ANALYSIS

Statistical analysis was performed using SPSS v.17.0 (SPSS Inc, Chicago, IL, United States) and Prism GraphPad 3.0 (GraphPad Software, Inc, CA, United States). All data were analysed with detail analysis and comparative analysis.

The One Factor ANOVA variance analysis (One Way ANOVA) was used to compare the five groups of experimental results.^{8,9} The level of statistical significance was set and precise analysis was performed to find the differences between the groups using Bonferroni's Multiple Comparison Test.¹⁰

The data are presented as mean $\pm$ SDM.

RESULTS

Table 1 presents the results of the thermal measurements during Er:YAG laser instrumentation of root surfaces. The mean temperatures measured during laser scaling and root planing were lower than the baseline temperature of 35.5°C . Most of the similar studies reported a rise of intrapulpal temperature because they used the room temperature as a baseline temperature.¹¹⁻¹³ Unlike these studies the present study determined the baseline temperature taking into consideration the physi-

Table 1. Temperature changes at 10, 12, 30, and 40 seconds after beginning of root scaling with Er:YAG laser

Temperature	At baseline	10 sec.	20 sec.	30 sec.	40 sec.
Mean $\pm$ SDM	35.50 $\pm$ 0.00	33.95 $\pm$ 1.41	33.14 $\pm$ 2.10	32.97 $\pm$ 2.77	33.03 $\pm$ 2.61
Minimum	35.50	29.80	28.20	24.90	26.30
Maximum	35.50	35.70	35.90	34.85	34.90
Median	35.50	34.35	33.75	34.00	33.30

ologic intrapulpal temperature (35.5°C⁷) and hence a decrease of the temperature during laser treatment was recorded. The analysis of the dynamics of the temperature showed the following mean temperatures: 33.95 $\pm$ 1.41°C, 33.14 $\pm$ 2.10°C, 32.97 $\pm$ 2.77°C and 33.03 $\pm$ 2.61°C at 10, 20, 30, and 40 seconds, respectively, from the beginning of laser irradiation. Using One Way ANOVA a statistically significant difference was found between groups and this was analysed by the Bonferroni's Multiple Comparison Test. **Table 2** presents the results of the test. The temperature decreased considerably after 10, 20, 30 and 40 seconds of laser irradiation in comparison with the baseline temperature. And yet no statistically significant differences were found between the different time intervals.

DISCUSSION

The major effect that occurs when laser interacts with biological tissues is photo-thermal, when the energy of the laser beam transforms into heat. When the

temperature in laser irradiated water-containing target tissues rises as high as 100°C, the water molecules vaporizing in a process called ablation (**Table 3**). In solid tissues such as the enamel, dentin, cement, and calculus the evaporation of water molecules results in an expansion of the tissues, followed by micro-explosions in them which ablate the tissues.¹⁴

The Er:YAG lasers, which emit light with 2940 nm wavelength, yield the highest absorption by water molecules making them utilizable both in soft and hard tissues. Their efficiency in periodontal treatment has been demonstrated in lots of research studies – they have been successfully used in debridement of periodontal pockets, gingivectomy and frenectomy, periodontal surgery, bacterial decontamination, and calculus removal.³⁻⁶

Given their principle of action in the tissues, it is of great importance to take into account the increase of temperature during treatment, because if intrapulpal temperature gets increased by only 5-6°C, a substantial irreversible damage of the

Table 2. Data analysis using Bonferroni's Multiple Comparison Test

Bonferroni's Multiple Comparison Test	Mean difference	p
Control vs 10s	1.55	< 0.05
Control vs 20s	2.36	< 0.001
Control vs 30s	2.52	< 0.001
Control vs 40s	2.47	< 0.001
10s vs 20s	0.81	< 0.05
10s vs 30s	0.97	> 0.05
10s vs 40s	0.92	> 0.05
20s vs 30s	0.16	> 0.05
20s vs 40s	0.10	> 0.05
30s vs 40s	-0.05	> 0.05

Table 3. Laser energy and thermal effects on dental soft tissue

Tissue temperature (°C)	Effects
37-50	Hyperthermia; bacterial inactivation
>60	Coagulation, protein denaturation
70-90	Merging of lesion edges of the soft tissues
100-150	Evaporation, ablation
>200	Carbonation; tissue charring

pulp may ensue resulting in loss of tooth vitality.¹⁵ The results of our study suggest that intrapulpal temperature rises only a little during scaling and root planing with Er:YAG laser.

The elevation of the intrapulpal temperature is dependent on the following factors: the way the laser emits the light – in pulsed or continuous mode; whether the energy is delivered to the tissue in contact or non-contact mode; the laser beam wavelength; whether there is water or air cooling during operation, the duration of tissue irradiation; and how fast the operator moves his hand.¹⁶

The Er:YAG laser emits the light energy in the form of interrupted pulses allowing tissue relaxation between the pulses during which the temperature in the tissues returns to normal.¹⁷

The procedure is performed in the contact mode but with continuous movement of the operator's hand. Without this continuous motion the tissues run the risk of getting thermally damaged because of considerable accumulation of heat in them.

As it has been mentioned earlier, it is the wavelength of Er:YAG lasers that determines their high absorption coefficient in hard and soft tissues which means very shallow depth of energy penetration into the tissues (in the order of a few microns). That is why there are no adverse thermal effects on the tissues surrounding the treated field.¹⁸

The laser system is equipped with continuous water cooling, which prevents overheating of the tissues. The water coming out of the dental unit has a room temperature.

The duration of irradiation is of crucial importance for the heat accumulation in the tissues and their possible thermal damage. The results of our study suggest that if it is within 40 seconds we can achieve a significant decrease of intrapulpal temperature. These results are consistent with the results of other in vitro studies in which no excessive increase of temperature in the pulp has been reported.¹¹⁻¹³

CONCLUSIONS

When Er:YAG lasers are used in a scaling and root planing procedures, intrapulpal temperature does not increase if the operation conditions specified in the present study are observed (irradiation duration within 40 seconds). This makes it possible for the dental practitioners to perform continuous and safe treatment procedures with the Er:YAG laser.

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In vitro исследование изменений температуры в пульпарной камере при чистке и сглаживании поверхности корней при помощи Er:YAG лазера

Благовеста К. Янева¹, Пламен Ив. Загорчев², Елена Ил. Фиркова¹, Иван Т. Главинков¹

¹ Кафедра пародонтологии и ЗОЛ, Факультет стоматологии, Медицинский университет, Пловдив, Болгария

² Кафедра медицинской физики, биофизики и математики, Факультет фармации, Медицинский университет, Пловдив, Болгария

Для корреспонденции:

Благовеста Янева, Кафедра пародонтологии и ЗОЛ, Факультет стоматологии, Медицинский университет, Пловдив, Болгария
Бул. "Христо Ботев" 3, 4002 Пловдив Болгария
E-mail: blagovesta.yaneva@gmail.com
Тел. +359 888 53 95 88

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Цель: Целью настоящего in vitro исследования является установление температурных изменений в пульпарной камере через определённые интервалы времени при Er:YAG лазерной чистке поверхностей корней с наличием зубного камня.

Материал и методы: 15 однокоренных зубов с наличием заболевания пародонта удалены и размещены в цилиндрическом термостате, заполненном дистиллированной водой с постоянной температурой в 35.5°C. Специально изготовленный термосенсор (термопары Type K) с точностью $\pm 0.1^\circ\text{C}$ в диапазоне от 20°C до 80°C установлен в пульпарной камере. Чистка буккальных и лингвальных поверхностей корней осуществлена с использованием Lite Touch лазера (Syneron Dental, Israel) – длина волны 2940nm, chisel наконечник, настройки 100 mJ и 50 Hz, время воздействия - 40 sec, контакт с поверхностью корней под углом в 10 - 15° и постоянное водяное охлаждение. Температура в пульпарной камере измеряется через каждые 10 sec.

Результаты: Температурные изменения в пульпе, измеренные через каждые 10 секунд и сопоставленные с начальной температурой в 35.5 °C выявили понижение, соответствующее: 1.6°C для первого интервала, 2.4°C для второго интервала, 2.5°C для третьего и 2.5°C для четвёртого интервала. Данные изменения не являются статистически значимыми между собой.

Выводы: Er:YAG лазер (2940 nm) не повышает внутрипульпарную температуру и изменения не зависят от времени воздействия в рамках 40 секунд. Следовательно данный метод лечения не вызывает термических повреждений пульпы при определённых условиях и является безопасным.