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Computer Tomography Study of Enamel Samples Treated with Different Working Regimes of Er,Cr:YSGG Laser

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Abstract: *The Computed Tomography (CT) is a non-destructive method that provides high accuracy when examining internal and external parameters of the investigated objects.*

The aim of the study is by 3D CT to determine the depth and width of micro cavities in the enamel tooth surface, formed by laser ablation with different modes.

Material and Methods: The enamel surface of 40 dental samples was treated with the Er,Cr:YSGG laser Biolase, Waterlase, MD, USA in the following four regimes: (A) 1 W, 30Hz, 10% water, 15% air; (B) 1.25W, 10 Hz, 30% water, 30% air; (C) 1,5W, 20Hz, 30% water, 60% air; (D) 2,5W, 20Hz, 20% water, 60% air.

Results and Discussion: The statistical analysis of the measured depth of the cavities in the enamel surface revealed homogeneity in the first three groups and a significant difference of the three groups with the fourth. When we measuring the width of the formed cavities, as a result of laser ablation, the statistical analysis revealed differences between the four groups of teeth, treated with different ablation regimes.

Keywords: *Computer tomography, enamel samples, Er,Cr:YSGG Laser, analysis, micro cavities.*

1. Introduction

In modern dental practice, minimally invasive procedures are widely used. As an additional advantage is also the lack of need for anesthesia. Providing an adhesive bond to the enamel is widely used in dental restorative procedures that include veneers and external crown retainers.
Adhesion to enamel is achieved by acidic etching of this highly mineralized substrate [10]. This procedure increases the surface for adhesive bonding. Micro cavities are formed in the enamel, the composite penetrates into them and creates a tags. The adhesive bond to the enamel is a major process of the clinical success of a number of restorative procedures.
In recent years, Er:YAG and Er;Cr:YSGG lasers are widely used in dental medicine. The Er;Cr:YSGG laser beam selectively enters in tissues and is absorbed by water, hydroxylapatite and collagen. The highest absorption peaks of the laser energy in water are 3 μm and 10 μm. Different depth and width craters are formed [2,5,13]. This surface provides mechanical retention and increases the adhesion of composite cement to the solid tooth tissue and can replace the acid etching. In recent years, studies have been established with different laser radiation modes, but there is still no clarity about a preferred mode. Many experiments have been made, but the most promising modern method is the computerized tomography.
Computer tomography is a non-destructive method that provides high accuracy in examining internal and external parameters of the investigated object. It provides additional examination of the density of the investigated material and its microstructure. The application of the computer tomography is very effective for accurate information about the internal structure of the investigated object. The X-ray computed tomography has a high resolution image with a minimal resolution of 3 microns. The results obtained are presented in a 3D objects which consists of a series of consecutive 2D X-ray photos that are taken while the subject is rotated at 360º. After scanning, these images are reconstructed by computer tomography software to generate a 3D model of the scanned object. In addition, the reconstructed model contains all information about the microstructure of the surfaces and the internal structure. It is possible to monitor the computed tomography software on each surface.
The aim of the study was to evaluate with 3D computer tomography the depth and width of the micro cavities in the enamel tooth surface, formed by laser ablation under different working regimes of the laser.

2. Material and methods

Forty extracted third molar were stored in water and used for up to three months after extraction. The teeth were divided into four groups. The buccal enamel surface of the tooth samples was treated with the Er:Cr:YSGG laser Biolase, Waterlase, MD, USA in the following four regimes according to Kamenova's method [1]:

A. 1 W; 30Hz; 10% water; 15% air;
B. 1.25W; 10 Hz; 30% water; 30% air;
C. 1,5W; 20Hz; 30% water; 60% air;
D. 2,5W; 20Hz; 20% water; 60% air.

The laser tip was 1 mm away from the enamel tooth surface. The duration of the procedure was 15 seconds for each tooth. The laser beam was located perpendicular to the surface of all samples for maximum cutting efficiency. According to [14] the advantages of laser beam positioning perpendicular to the tooth surface are a clean surface of the substrate and a lack of debris. All teeth were scanned with 3D computed tomography. The tomography software was used to determinate the micro cracks surface values.

In order to compare the arithmetic mean values of the investigated variables, one-factor dispersion analysis of variance (One Way ANOVA) was performed. After the rejection of the zero hypothesis, Tukey's post-hoc tests were used. Statistical data processing was performed with IBM SPSS Statistics 20 (IBM - USA).

3. Results

Figure 1 shows a laser-treated tooth surface of the 3D tooth model represented by the computed tomography.

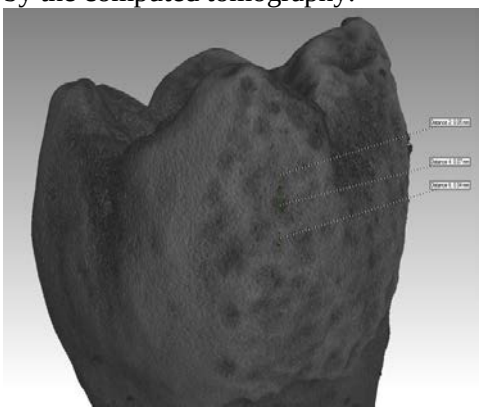

Fig. 1. 3D view of a tooth surface treated by laser ablation.

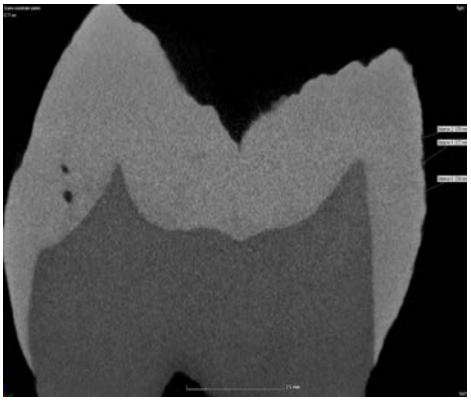

Fig. 2. Tomography section of tooth, treated with laser ablation.

On figure 2 is shown a tomographic section of the investigated tooth with measured depth and width of the retentive regions, caused by laser ablation.

Figure 3 shows the tomographic section of the tooth surface. The results of the measurements of the teeth treated with different laser ablation regimes are presented in Tables 1-6.

Table 1 shows measurements in depth of micro cavities of teeth after laser ablation for the four different regimes of operation and their average values.

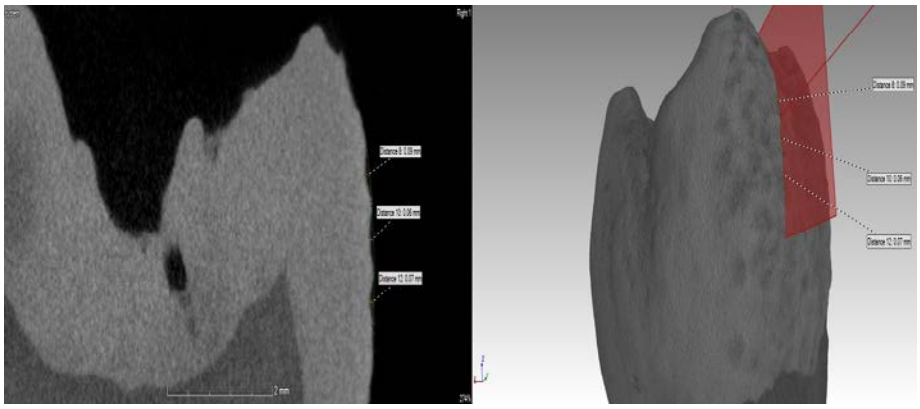

Fig. 3. Measurements of tooth in section view.

Table 1. Comparative analysis of the average values of micro cavities depth in the four regimes.

	Regime A	**Regime B**	**Regime C**	**Regime D**
1	0.04	0.05	0.04	0.13
2	0.04	0.07	0.07	0.11
3	0.04	0.04	0.06	0.10
4	0.04	0.09	0.04	0.20
5	0.04	0.06	0.06	0.13
6	0.04	0.07	0.03	0.11
7	0.04	0.04	0.03	0.10
8	0.02	0.07	0.04	0.20
9	0.05	0.07	0.07	0.06
10	0.04	0.06	0.06	0.12
n	10	10	10	10
Mean	0.039	0.062	0.05	0.126
$\sum X^2$	0.0157	0.0406	0.0272	0.176
St. Dev.	0.007	0.015	0.016	0.044

The results of the performed statistical analysis are shown in Table 2.

Table 2. Results of single-factor dispersion analysis for depth of micro cavities.

Source	**df**	**SS**	**MS**	**F**	**P-value**
Intergroup	3	0.046	0.015	24.7646	< 0.0001
Intragroup	36	0.022	0.001		
Total	39	0.068			

df- degrees of freedom,
SS- sum of squares,
MS- value of the middle squares,
F- F statistics.

The value **P** corresponding to the F-statistic of the dispersion analysis (ANOVA) is less than 0.05, which suggests that the depth of the micro cavities in one or more groups are significantly different.

The results of the post hoc tests for multiple comparison are shown in Table 3.

The statistical analysis results of the measured depth of the cavities shows a significant difference between the first three groups and the fourth group. The first three regimes demonstrate homogeneity and there is no significant difference between their values.

Table 3. Tukey HSD post hoc test results for micro cavities.

In pairs compares	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
A vs B	2.9362	0.1802368	insignificant
A vs C	1.4043	0.7315825	insignificant
A vs D	11.1064	0.0010053	*** p<0.01**
B vs C	1.5319	0.6817372	insignificant
B vs D	8.1702	0.0010053	*** p<0.01**
C vs D	9.7021	0.0010053	*** p<0.01**

Table 4 presents the measurements of the width of the teeth micro cavities after laser ablation in the four different regimes of operation and their values.

Table 4. Comparative analysis of average values of depth of micro cavities in the four regimes.

	Regime A	**Regime B**	**Regime C**	**Regime D**
1	0.16	0.26	0.31	0.55
2	0.13	0.37	0.46	0.54
3	0.15	0.42	0.24	0.57
4	0.3	0.45	0.19	0.52
5	0.11	0.58	0.52	0.55
6	0.13	0.46	0.2	0.54
7	0.16	0.3	0.28	0.57
8	0.14	0.71	0.42	0.52
9	0.42	0.38	0.46	0.49
10	0.18	0.33	0.24	0.65
n	10	10	10	10
Mean	0.188	0.426	0.332	0.55
$\sum X^2$	0.438	1.9788	1.2358	3.0414
St. Dev.	0.097	0.135	0.122	0.043

The results of the performed statistical analysis are shown in Table 5.

The value **P** corresponding to the F-statistic of the one-factor ANOVA is less than 0.05, which means that the width of the micro cavities in one or more groups differs significantly

Table 5. Results of single-factor dispersion analysis for depth of micro cavities width.

Source	df	SS	MS	F	P-value
Intergroup	3	0.700	0.234	21.0879	< 0.0001
Intragroup	36	0.398	0.011		
Total	39	1.099			

df- degrees of freedom,
SS- sum of squares,
MS- value of the middle squares,
F- F statistics.

The results of the post hoc tests for multiple comparison are shown in Table 6.

Table 6. Tukey post-hoc test results for the micro cavities width.

In pairs compares	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
A vs B	7.1529	0.0010053	*** p<0.01**
A vs C	4.3278	0.0207385	insignificant
A vs D	10.8796	0.0010053	*** p<0.01**
B vs C	2.8251	0.2078546	insignificant
B vs D	3.7267	0.0570846	insignificant
C vs D	6.5518	0.0010053	*** p<0.01**

In the four groups in which we measured the width of the formed cavities due to the different laser ablation regimes, there was no homogeneity of the results obtained in the statistical analysis. Significant variations between the first and second and the first and fourth groups are observed.

4. Discussion of the results

The frequency of laser devices represents how many seconds the pulse creates a wave. The frequency unit is a Hertz. A wide-frequency laser was used in our study because of its clinical relevance [3]. Another advantage of the laser we have used is that the frequencies can be determined by us. The aim of the studies that determine the frequency changes mainly refers to the increased heat. In [2] is found a lack of statistical difference at values ranging from 20Hz to 40Hz. We used different modes, ranging from 10 Hz to 30 Hz.
In [4] are observed small surface cracks on the surface of laser etched enamel, which in their opinion refers to 3W power. These cracks were also observed in [11], which used 5W and 6W power. According to [7] a possible explanation for the presence of cracks is the result of local thermal stress produced during the irradiation process. For laser ablation we used a power of 1W to 2.5W and we only observed micro cavities.

Surface cracks are also evident in studies [12, 13, 14]. Studies [6] demonstrate that the observed porosities increase the retention and are ideal for the penetration of composite cement. Er,Cr:YSGG laser ablation has the advantage of not raising the temperature due to water cooling and lack of vibration.

With Er,Cr:YSGG lasers, the enamel passes through physical changes that includes melting and recrystallization, thus forming many porosity structures. These lasers produce a very uneven surface with micro cavities resulting from the evaporation of water in the hydroxylapatite [5, 9, 11]. This causes surface irregularities similar to those of acidic etching with a depth of 10 to 20 μm, depending on the laser and energy, which is applied to the tooth surface [8, 10]. The depth of composite penetration has been studied by optical microscopy studies and small studies with confocal microscopes. It has been determined that the depth of penetration after acid etching is from 5 to 50 μm. Laser radiation causes thermal changes on the enamel surface, resulting in uneven cavities similar to acid etching [10] that are 10-20 μm in depth and can be used to prepare the enamel surface and subsequent adhesive cementation [13]. The infraction of the proportion of calcium to phosphorus and the reduction of the percentage of carbonates to phosphates is caused by laser radiation. It also reduces water content and organic ingredients, which increases dental resistance to tooth caries [7].

The comparative study of the four laser ablation regimes with a computer tomography demonstrated homogeneity of results in the study of the depth of the enamel cavities formed in the first three regimes. In the analysis of the width of the formed cavities, it was not established homogeneity with respect to the used regime.

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Компьютерное томографское исследование образцов эмали, обработанных различными рабочими режимами Er, Cr: YSGG лазер

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Резюме: *Компьютерная томография (CT) - это неразрушающий метод, который обеспечивает высокую точность при исследовании внутренних и внешних параметров исследуемых объектов.*
Целью исследования является 3D CT для определения глубины и ширины микрополостей эмаля на поверхности зуба, образованных путем лазерной абляции с четырьмя различными режимами.
Материал и методы: эмалевую поверхность 40 образцов зубов обрабатывали Er, Cr: YSGG-лазером Biolase, Waterlase, MD, USA в следующих четырех режимах: (A) 1 Вт, 30 Гц, 10% воды, 15% воздуха; (B) 1,25 Вт, 10 Гц, 30% воды, 30% воздуха; (C) 1,5 Вт, 20 Гц, 30% воды, 60% воздуха; (D) 2,5 Вт, 20 Гц, 20% воды, 60% воздуха.
Результаты и обсуждение: Статистический анализ измеренной глубины полостей на поверхности эмали показал однородность в первых трех группах и значительную разницу трех групп с четвертой. Когда мы измеряем ширину сформированных полостей в результате лазерной абляции, статистический анализ выявил различия между четырьмя группами зубов, обработанными различными режимами абляции.

Ключевые слова: *компьютерная томография, эмалевые образцы, Er, Cr: YSGG Laser, анализ, микрополости.*