The Influence of Er:YAG Laser on the Dissolution Rate and Morphology of the Root Cement

A scanning electron microscopic study

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Lasers can interact with dental tissues inducing changes in tooth characteristics, regarding the surface morphology and elemental composition. The alterations were observed in Calcium, Phosphorus, Sodium, Oxygen and Carbon elements, which influence the resistance and chemical properties of dental hard tissues. The thermal energy used by laser reduces water content of the tissues and as a consequence, the level of oxygen composition decreases after irradiation. Numerous studies had demonstrated its ability to ablate hard-tissues, without any detrimental thermal effects such as cracking or melting for the adjacent tissues. The aim of this article is to present the in vitro effects of Er:YAG laser in comparison with sonic, ultrasonic and manual instruments on the root cement during scaling and root planning, evaluated by scanning electron microscope. The study was conducted on extracted teeth, divided in four groups according to the method used for scaling and root planning. The specimens were analyzed by scanning electron microscopy and the morphological alterations of the cement were evaluated based on a scoring system. Data were statistically analyzed using Mann-Whitney test and the level of significance was set at $p<0.05$. We noted unfavorable results on the root cement after using Er:YAG laser as craters and cracks induced by heat. There was a greater amount of roughness on the root surface after Er:YAG was used for scaling and root planning compared to manual, sonic and ultrasonic methods. Despite favorable results obtained after the use of Er:YAG laser during periodontal treatment, further clinical studies are necessary in order to determine in which moment of the therapy these methods are most suitable.

Keywords: Erbium laser, scaling and root planning, root surface morphology

Laser represents a device that emits a beam of a certain wave length that can be focused and remains narrow over a long distance, exhibiting different reactions after contact with biologic tissues. Its properties are represented by reflection, absorbtion and scattering of the light depending on the wave length and the target tissue. The applications of lasers during periodontal therapy refer to calculus removal, decontamination of root surfaces and reduction of microorganisms. Some of the advantages of using lasers during periodontal therapy are related to better visualization and cutting, detoxification of periodontal pocket tissues and patient‘s higher satisfaction and confidence. Furthermore, the surgical access is less invasive and the wound scarring and contraction is reduced [1]. Erbium lasers have two wavelengths: Er,Cr:YSGG (erbium, chromium, yttrium-scandium-gallium-garnet) 2790 nm and Er:YAG (erbium: yttrium-aluminium-garnet) 2490 nm. The second one is considered to be the most promising laser for periodontal treatment due to its high water absorbtion which allows its efficacy in removing soft tissues and affinity for hydroxyapatite that makes it a good option for the treatment of hard tissues. Numerous studies had demonstrated its ability to ablate hard-tissues,without any detrimental thermal effects such as cracking or melting for the adjacent tissues [2-5].Scaling and root planning used in conjunction with laser therapy provides the removal of biofilm and calculus from deep periodontal pockets and eliminates microbial toxins by smoothing the radicular surface. Further on, a fibrin clot will develop in order to seal the pocket and after complete healing, the pocket depth will be reduced, due to epithelial reattachment of the gingiva. Diode and neodymium-doped yttrium-aluminium-garnet (Nd:YAG) lasers are highly absorbed by hemoglobin and therefore more suitable when coagulation is desired. Due to the effects of these lasers on pigmented tissues, they were extensively used in order to remove gingival pigmentation or to reduce bacterial populations of black-pigmented microorganisms [6].The aim of this article is to present the in vitro effects of Er:YAG laser in comparison with sonic, ultrasonic and manual instruments on the root cement during scaling and root planning evaluated based on scanning electron microscope (SEM) images.

Experimental part

Material and methods

We used 60 human teeth freshly extracted due to complications of dental caries or periodontal disease, which were stored in 4% formalin solution at 4^0C. The study was conducted based on principles of the Declaration of Helsinki. In order to have a good standardization we set as inclusion criteria the absence of caries or restorations and no history of any periodontal treatment, including scaling and root planning, prior to extraction. The teeth were randomly included in one of the following groups and the debridement of the cervical area and coronal third of the root was carried out with different methods as follows: Group A – ultrasonic scaling (Acteon Satelec), Group B -

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sonic scaling (SironaSiroair, KaVoSonicflex), Group C-manual scaling (GraceycurettesHu-Friedy Chicago IL, USA) and Group D-a laser device was used for scaling (Laser ErbiumYagLight Walker). The crowns were cut approximately 1 mm below the cement-enamel junction and the second cut was made at 6-8 mm distance, using a high speed diamond bur, under copious water cooling. The specimens were split in half longitudinally, introduced in copper rings with a diameter of 10mm, fixed with a composite resin and prepared for SEM examination according to a specific protocol. Each surface was evaluated prior and after preparation using a scanning electron microscope working at 5-10kV (JEOL 5200, JOEL Corp. Tokyo, Japan)and different magnifications (35X, 100X, 200X, 1000X)were recorded (fig.1).

Fig.1. Examination procedure using the scanning electron microscope JEOL - JSM-5200 (Sapientia University of Tirgu Mures)

The evaluation was carried out by two independent observers ina double-blind manner using a scoring system from 1-4 in order to evaluate the roughness and loss of dental hard tissue. The following criteria were used: 1-smooth radicular surface, no hard tissue lost, no trace of scaling instruments; 2-mild abrasion and uneven spots on the cement surface; 3-areas where a part of the cement is absent; 4-considerable amount of the tooth hard tissue is lost and evident traces of debridement instruments. The collected data were statistically analyzed with the Graph Pad Prism 7.03 and Mann-Whitney test, a value of $p < 0.05$ being considered statistically significant.

Results and discussions

The evaluation of specimens from group A, where the debridement was made using ultrasonic instruments, gave a mean score of 2.21, which means that the dental surfaces were characterized by complete removal of dental calculus, the presence of mild abrasion and localized uneven surface (fig. 2 and 3).

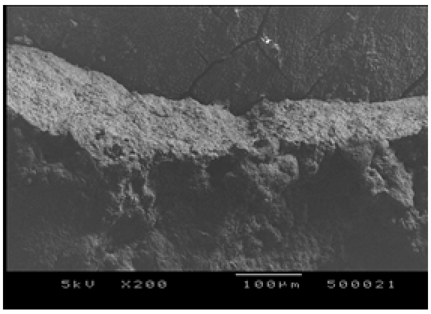

Fig. 2.SEM image showing the presence of the dental calculus on the root surface, prior to debridement

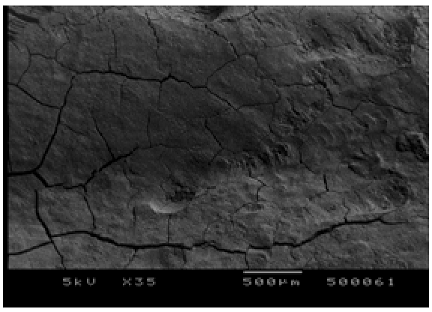

Fig. 3.Aspect of root cement after ultrasonic scaling and root planning. The SEM image shows the presence of mild abrasion and localized uneven surface of the radicular cement

In group B the scaling and root planning was made with sonic instruments and the mean score after SEM examination was 2.83. The morphological alterations were more intense compared with group A, as we noted areas were the radicular cement was excavated but the dental deposits were not completely eliminated (fig.4).

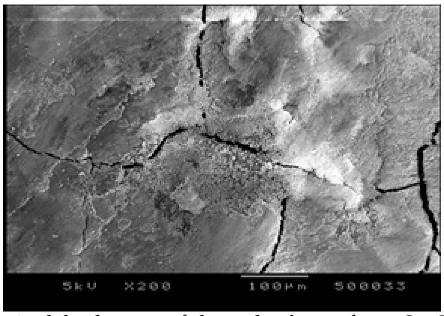

Fig.4. Sonic debridement of the radicular surface. On SEM images there are areas were the radicular cement was excavated but the dental deposits were not completely eliminated

The mean score obtained in group C, were we used manual debridement with Gracey curettes, was 1.53, which was the lowest value for roughness and loss of tooth substance recorded in our study. Most of the specimens exhibited smooth radicular surfaces, without traces from instruments or defects on the radicular cement. There were only a few areas with mild abrasion or uneven surface (fig.5).

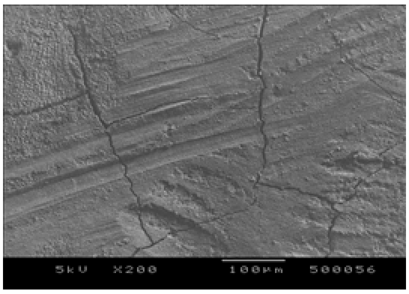

Fig. 5.Manual debridement using Gracey curettes. There are smooth radicular surfaces, without traces from instruments or defects on the radicular cement. There were only a few areas with mild abrasion or uneven surface

The last study group corresponded to specimens debrided with an Er:YAG laser, which showed the formation of specific micro-cavities on the radicular surface, with a mean score of 2.42.

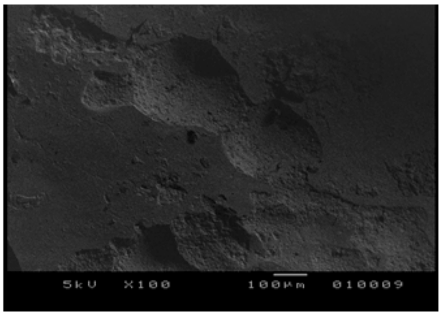

Fig.6. The SEM iages corresponding to the Er:YAG lasershowed the formation of specific micro-cavities on the radicular surface, with important loss of hard tooth substance

The comparison between the mean scores obtained for each study group is presented in table 1.

We noted statistically significant differences between groupB compared with groups A and B, but no differences between group B and D. Statistically significant differences we also noted between groups C and D, C and B, C and A.

For the treatment of periodontal disease, the mechanical therapy has been conventionally considered the main

Group	Number of specimens	Mean index value	Comparison between groups	P value
A	26	2.21	A-D	p>0.05
B	24	2.83	A-B	p=0.041*
C	27	1.55	B-C	P=0.028*
D	25	2.42	C-D	P=0.017*

Table 1
MEAN SCORING VALUES OF ROUGHNESS AND ROOT CEMENT LOSS RECORDED FOR EACH STUDY GROUP

important treatment, although the complete elimination of periodontal pathogens and optimal healing are not obtained exclusively by this kind of treatment. A clean and smooth radicular surface is a necessary condition that favors the healing process of marginal periodontitis and regeneration of tooth supporting tissues [7-9]. Besides chemotherapy and anti-inflammatory drugs, phototherapy applied using light-emitting diodes and lasers has been progressively combined with conventional scaling and root planning, in order to obtain proper debridement, decontamination and to promote tissue stimulation and wound healing [6]. As Er:YAG laser is highly absorbed by hydroxyapatite being more suitable for bone removal, others as diode and Nd:YAG are used due to the antibacterial effect or when coagulation is required. Early studies that focused on the use of Er:YAG laser on the root surface showed negative effects, as the formation of cracks or craters. The same aspect was observed in our study, due probably to insufficient water cooling. We noted the presence of small craters and the radicular surface, which were probably the result of micro-explosions of laser vapors which amplified the tension inside the dental hard tissues. Our study was conducted on extracted teeth, with a decreased amount of water compared to in vivo conditions, which could favor the appearance of small cavities after laser debridement. There were not statistically significant differences between group D compared to group A and B, but there was an important difference between group D and A. The advantage of laser is represented by the bactericidal action and good hemostasis. In a SEM study conducted by Frentzen et al (2002) the total cement removal from the root surface was measured to represent 22.5% in teeth treated with laser compared to 12.5% in teeth treated by conventional methods [10]. The authors reported also a greater volume of cement loss and root roughness when the scaling and root planning was performed with Er:YAG laser alone, compared to manual and ultrasonic instrumentation. These negative side-effects appear when the energy exceeds 50mJ/pulse, even if by copious water irrigation the adverse temperature raise effects are eliminated. Aoki et al [6] conducted a study on extracted teeth, comparing different power settings of Er:YAG lasers used for dental calculus removal; they observed that the ablation of dental hard tissue stayed within the root cement, an important proof to support the use of this instrumentduring clinical procedures. Nevertheless, an increased amount of cement and dentin loss should be taken into consideration during scaling and root planning in clinical situations.The complete removal of the cement in the coronal third of the root may result in the invasion of subjacent dentin by the microorganisms of the oral cavity, a process that might lead to dentin hypersensitivity or dental pulp irreversible inflammation. Ratka-Kruger et al compared the use of Er:YAG and sound debridement in the treatment of persistent periodontal pockets and found no significant differences regarding clinical and microbiological parameters between the study groups [8]. On the other hand, Yilmaz et al noted important differences regarding the clinical attachment level and reduction of pocket depth in sites treated with Er:YAG laser in addition to scaling and root planning versus sites treated by scaling and root planning alone[5].Numerous studies observed that the combination between curettes and ultrasonic instrumentation completely removed the cement from the root surfaces and allowed the decontamination from the smear layer created by hand instruments [11-14].In sonic scalers, the air pressure from the turbine of the dental unit is used to generate high frequency vibrations, between 6-8 kHz. Regardless of the position of the instrument tip in relation to the tooth, dental calculus is removed by localized hammering motion, which may be considered a potential advantage of sonic over ultrasonic scalers [15-17]. In ultrasonic scalers, depending on the type of the instrument, the generated vibrations are ranging between 20-45kHz. The instrument tip will have an elliptical motion and therefore, it is unlikely to remove the dental calculus uniformly, from all tooth surfaces. The defects resulting from the use of hand instruments depend on the number of tractions and applied force, which can be easily adjusted by the operator. During the maintenance therapy, even minor damage of the radicular surface can accumulate over time and become large deep defects, a situation that must be avoided as much as possible. In comparison with these techniques, the Er:YAG laser can be considered as one of the most versatile dental instrument, which can be effectively used in different fields of soft and hard tissue surgery. Its compact design and affordability could seek attention from dental professionals who wish to improve their clinical procedures and expand the medical services they offer.

Conclusions

Even though the favorable results obtained after periodontal treatment promote the use of lasers, we consider that further studies are necessary in order to determine in which moment of the therapy these methods are best suitable and appropriate. Despite the use of copious water cooling, we noted unfavorable results on the root cement after using Er:YAG laser as craters and cracks induced by heat. There was a greater amount of roughness on the root surface after Er:YAG was used for scaling and root planning compared to manual, sonic and ultrasonic methods.

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