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Evaluation of 532 nm Laser Effect on Dental Enamel Dissolution: *In Vitro* Study

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Abstract

Purpose: to evaluate the effect of various Nd:YAG frequency doubled laser parameters on the acid dissolution and the progression of *in vitro* caries like lesions in human enamel.

Materials and Methods: Human extracted caries free upper first premolar teeth were collected for this study. The irradiated teeth were divided into two groups. The first group was irradiated with continuous Nd:YAG laser radiation, and the second group was irradiated with chopped Nd:YAG laser radiation. For the first group, power and exposure time were changed while for the second group power and number of pulses were changed. The spot diameter was kept constant for all the samples.

Results: using 1.5 W and 3 seconds (exposure time), best results among the continuous group were obtained, while in the chopped group using 1.5 W and 3 pulses gave better result. The percent reduction in lesion depth in this study was up to 26% in the continuous group, whereas in the chopped group was up to 44%.

Introduction

The use of laser irradiation in caries prevention was first suggested by Stern and Sognnaes using a ruby laser (Stern and Sognnaes, 1972). Since then, many investigations related to the application of other lasers, such as argon, CO_2, and Nd:YAG lasers in the area of preventive dentistry, have been carried out (Hossain et al, 2001).

Westerman et al and Powell et al have indicated that dental hard tissues treated with an argon laser seemed to be more resistant to artificial caries than the control surface (Wigdor et al, 1995). Regarding the Nd:YAG laser, it has been reported that human enamel irradiated by this laser, especially with black ink as an initiator, was more resistant to acid decalcification than unlased enamel (Huang et al, 2001). Moreover, many studies have already been carried out to evaluate the effect of CO_2 laser irradiation on the ultra-structure of dental enamel and the enhanced resistance to artificial caries formation of lased enamel (Featherstone et al, 1997, 1998; Kantorowitz et al, 1998; Konishi et al, 1999).

The purpose of the present study was to determine the effect of Nd:YAG frequency doubled laser irradiation on the acid dissolution and the progression of in vitro caries like lesions in human enamel.

Materials and Methods

Forty eight human extracted, caries free upper first premolar teeth were selected for this in vitro study, 45 of these teeth were used for experiments, while the remaining 3 teeth were used as control.

The buccal and lingual surfaces were examined with a dissecting microscope to

ensure that these surfaces were free of clinically detectable white spot lesions.

Following a fluoride-free prophylaxis, a circle of 3 mm in diameter was placed on the buccal surfaces. The samples were divided into continuous and chopped groups. The continuous group included 27 teeth; it was divided into three subgroups A, B and C according to the difference in the power. Each subgroup was divided into another three groups according to the difference in the exposure time.

These samples were irradiated with the continuous mode (CW) 2nd harmonic Nd:YAG laser (from NIDEK GREEN YAG LASER, Model GYC-1500, Japan). This laser system emits a green beam of 0.532 µm wavelength, in TEM_{oo} output mode. The output power level in CW mode may be varied from 50 to 1500 mW. The exposure time was varied from 0.02 to 3 seconds. Also this laser system has a repeat mode from 0.2 to 1 second in steps of 0.2 seconds.

The output powers which were used in the continuous group were 0.5, 1, and 1.5 W. The exposure times were 0.3, 1, and 3 seconds. The chopped group involved 18 samples and it was divided into three subgroups A, B and C according to the difference in the power. Each subgroup was divided into another two groups according to the difference in the number of pulses (the pulse width was 3 seconds with 0.2 second interval).

The samples were irradiated with the chopped mode 2nd harmonic Nd:YAG laser (0.532 µm). The output powers which were used in this group were 0.5, 1 and 1.5 W. The numbers of pulses were 2 and 3 pulses. The spot diameter was kept constant for all the samples, it was 3 mm.

After lasing, the samples were varnished with the nail varnish. The varnish was applied all over the surface of the tooth leaving the circle which was placed before on the buccal surface of the tooth, then the samples were immersed in 3.5 pH lactic acid solution and incubated at 37 ^{o}C for twenty-one days. A cutting disc with a water-cooling cutting machine was used for sectioning the acrylic blocks into sections passing through the centers of the buccal windows.

A polarized light microscope was used to examine the prepared slides under a magnification of 4X, and to measure the caries-like lesion depths. The lesion depths included the surface zone and the body of the lesion.

Results

Lesion depth changes in the continuous group

Figure (1) illustrates the measured lesion depth as a function of the power density of the CW Nd:YAG (frequency doubled) laser. There was a decrease in the lesion depth for group B1 (575 µm) and group C (500 µm) as compared with the control group (590 µm), whereas there was a slight increase in lesion depth for group A_1, (600 µm).

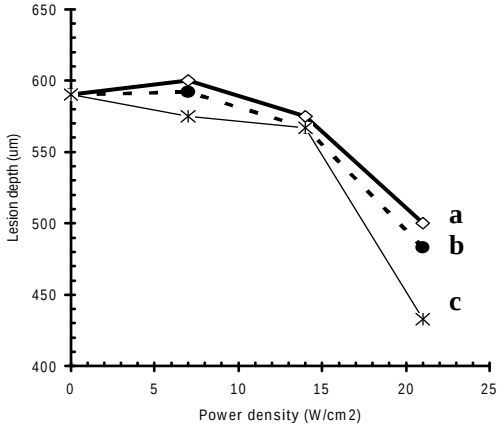

Fig. (1): The relation between the lesion depth and the power density in continuous group. Exposure time was **(a)** 0.3 s **(b)** 1 s and **(c)** 3 s.

Compared with the control group, there was a decrease in the lesion depth for group B2 (566 µm) and group C2 (483 µm), whereas the lesion depth for group A2 (591 µm) was approximately the same as for the control group.

There was a decrease in the lesion depth for group A3 (583 µm), group B3 (566 µm), and group C3 (433 µm) as compared with the control group.

Caries inhibition percentage in this study was calculated depending on the mean lesion depth of the control and the experimental group. The highest percent inhibition was 26.553 in group C3 as shown in Table (1).

Lesion depth changes in the chopped group

In the continuous group, the minimum lesion depth was measured at 1.5 W and 3 s exposure time, for that the exposure time of 3 s regarded as 1 pulse in the chopped group.

Table (1) The relation between the power density of the CW Nd:YAG (frequency doubled) laser radiation and the calculated caries inhibition percentage at a constant exposure time of 3 seconds .

Group	Power density W/cm^2	Caries inhibition Percentage
A_3	7.1	1.1
B_3	14.2	3.9
C_3	21.2	26.6
Control	0	0

Figure (2) illustrates the measured lesion depth as a function of the total energy deposited per unit area of the chopped Nd:YAG (frequency doubled) laser radiation. Compared with the control group (590 µm), there was a decrease in lesion depth for groups A3 (583 µm), and B3 (566 µm) while there was a sharp decrease in group C_3 (433 µm).

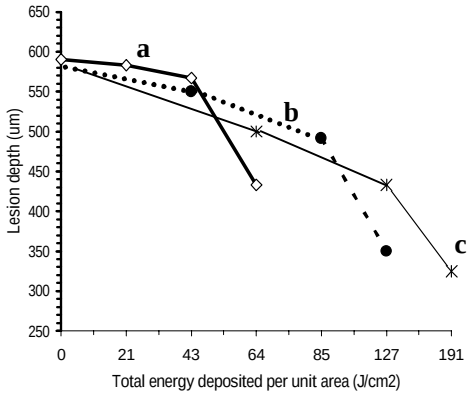

Fig. (2) The relation between the lesion depth and the total energy deposited per unit area in chopped group. Number of pulses was **(a)** one pulse **(b)** two pulses and **(c)** three pulses.

There was a decrease in lesion depth for group A4 (550 µm), B4 (491 µm) and C4 (350 µm) as compared with the control group.

For group (A5, B5, C5), three constant pulses were used. Compared with the control group, there was a decrease in the lesion depth for groups A5 (500 µm), B5 (433 µm), and C5 (325 µm).

The highest caries inhibition percentage was 44.9 observed in group C5, whereas for groups A5 and B5 were 15.3 and 26.6 respectively as shown in Table (2).

Photomicrographs were taken for the slides showing caries like lesion for control, C3, and C5 groups as in Figs. (3-5) respectively. In these figures the surface zone appears as a thin dark green area at the outer surface of the enamel, while the yellow area represents the body of the lesion, the translucent zone and the dark zone can't be easily detected from these lesions. The body of the lesion is the most obvious zone.

Table (2) The relation between the total energy of the chopped frequency doubled Nd-YAG laser deposited per unit area and the calculated caries inhibition percentage at 3 pulses (pulse width is 3 s).

Group	Total energy deposited per unit area (J/cm^2)	Caries inhibition percentage
A_5	63.693	15.3
B_5	127.389	26.6
C_5	191.082	44.9
Control	0	0

Discussion

The decrease in the lesion depth (Fig. 1) and the increase of the caries inhibition percentage (Table 1) as a result of increasing the power density could be attributed to the fact that the increase in the power output of the laser beam could lead to an increase in the total energy deposited per unit area of the evident beam. As a matter of fact, the beam spot size was kept constant. Consequently, the chemical composition of the exposed enamel will be affected, especially when the energy absorbed is high enough to drive organics and carbonate out of the enamel crystals and this will lead to the formation of a more acid resistant apatite crystals (Fried et al, 1997; Featherstone et al, 1998).

Feathersone et al, (1998) showed that the temperature at which carbonate is driven from the carbonated apatite is in the range of 400-600°C, also they found a direct correlation between carbonate loss in laser treated dental enamel and a corresponding reduction in the rate of acid dissolution. The loss of carbonate resulted in a mineral phase which more closely

resembles hydroxyapatite and is therefore less soluble than normal enamel at any given pH.

The decrease in the lesion depth and the increase of the caries inhibition percentage as a result of increasing the total energy deposited per unit area is due to the same previous causes but the decrease in caries-like lesion depth created in sound enamel in the chopped group is more than in the continuous group, this could be due to the fact that the second pulse interacted differently with the enamel surface than the first pulse as it is assumed in a study done by Fried et al. (1996). They measured the enamel surface temperature during and after individual pulses of pulsed CO_2 laser radiation. It may be that each pulse changes the optical and thermal properties of the surface until a certain balance is achieved. Also using pulsed lasers allowed for periods of relaxation in between the pulses to ensure safety of the pulp and the surrounding tissue.

The effect of enamel response to the laser which is used in this study seems to be photothermal effect because it is related to the heat generated during laser exposure, but the temperature rise *in vitro* is higher than *in vivo* because the surrounding soft tissue of the tooth would help dissipate generated heat.

It must be considered that the artificial caries system which is used in this study subjected the enamel to a continuous aggressive, cariogenic challenge without periods of remineralization and this system created lesions in enamel that were identical histologically to enamel caries formation in vivo. In contrast caries formation *in vivo* is characterized by periods of demineralization interspersed with periods of remineralization with oral fluids. Despite the continuous cariogenic challenge the lased enamel demonstrated a resistance to lesion formation.

Conclusions

From the present results, the following notes were concluded:

- In continuous group, it is observed that the increase in the power density of the CW Nd:YAG (frequency doubled) laser radiation lead to decrease in the enamel dissolution, also in chopped group, the increase in the total energy deposited per unit area and number of pulses had led to decrease in the enamel dissolution.
- Chopped mode laser gave better results in regard to enamel dissolution compared to continuous mode. The percent reduction in lesion depth reached to 44% in chopped group using 1.5 W and three pulses.
- Using 1.5 W, 3 s exposure time gave the best result among continuous group, while in chopped group using 1.5 W and 3 pulses gave better result.

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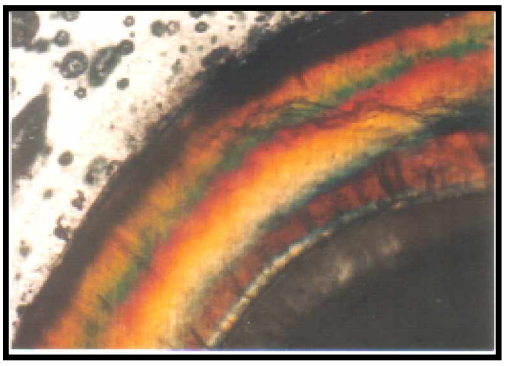

Fig. (3) Colored polarized light cross section of enamel caries like lesion in a control group (magnification 4 X).

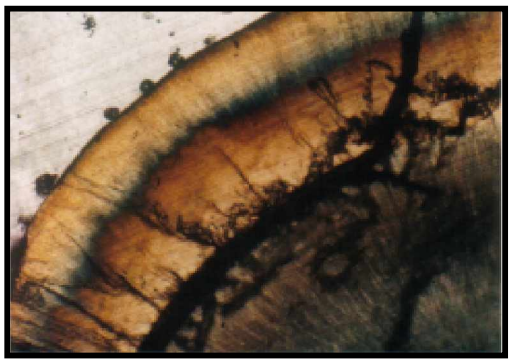

Fig. (4) Colored polarized light cross section of enamel caries like lesion in group C_3 (magnification 4 X).

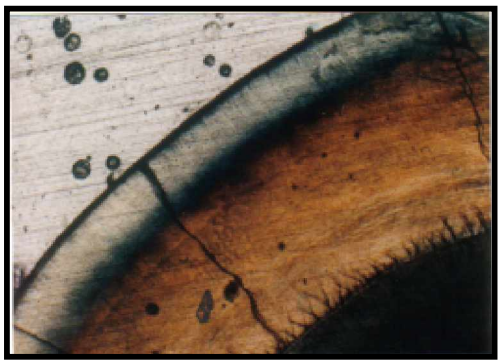

Fig. (5) Colored polarized light cross section of enamel caries like lesion in group C_5 (magnification 4 X).

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دراسة مختبرية لتقييم فاعلية الليزر ذو الطول الموجي 532 نانومترعلى اذابة طبقة ميناء السن

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الخلاصة يشتمل البحث تقييماً لفاعلية ليزر النديميوم ياك ذو التردد المضاعف في التقليل من أذابة ميناء الاسنان بالمواد الحامضية وزيادة مقاومتها لآصابة شبيهة بالتسوس . استخدمت لهذا الغرض مجموعة من الأسنان البشرية (الضاحك العلوي) تم قلعها حديثاً وقسمت الى مجموعتين : الاولى ، تم تشعيعها بنمط مستمر لليزر وبقدرات وفترات زمنية مختلفة للتشعيع . أما المجموعة الثانية فتم تشعيعها بنمط متقطع لليزر وتم التغيير في قدرة الليزر وعدد النبضات ،كان قطر منطقة التشعيع ثابتاً في كل النماذج . تم الحصول على أفضل النتائج في أسنان المجموعة الاولى لدى تشعيعها بقدرة 1.5 واط ولزمن تعرض أمده ثلاث ثوان ، وبالقدرة ذاتها لأسنان المجموعة الثانية ولكن بعد 3 نبضات كانت النسبة المئوية لتقليل عمق الاصابة في هذه الدراسة هو 26 % بأستخدام النمط المستمر و 44 % في حالة النمط المتقطع .