Effect of chopped co_2 laser on enamel surface

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Abstract:

This study aimed to assess the caries-preventive potential of various chopped CO_2 laser parameters, and to explore the effect of the laser energy density on the caries inhibition activity on enamel surface in vitro.

Extracted human premolar teeth were irradiated with three various energy densities (25.47, 50.93, and 101.86) J/cm^2, by changing the number of pulses, the pulse duration, and the spot diameter. The CO_2 laser system emitted laser with 10.6μm in wavelength and 10Hz repetition rate. All teeth were subjected to carieslike lesion formation by 3.5 pH lactic acid for 21 days. The teeth after that were sectioned into ground cross sections and the lesion depths were measured under a polarizing microscope.

The result indicated that the chopped CO_2 laser preventive treatments inhibited carieslike lesion progression up to 36%. This effect was improved with increased total energy density within the limits of the examined laser parameters.

Keywords:

Chopped CO_2 laser, laser irradiation, carieslike lesion, caries inhibition.

Introduction:

The initial experimentation with laser in dentistry began almost forty years ago, when a group of dental scientists proposed that the ruby laser could be utilized for vaporization and ablation of caries [1]. These pioneers in laser research found that caries could be successfully removed with a laser device; the potential for thermal damage to the underlying pulpal tissue, adjacent soft tissue and osseous structures, however, was significant [2,3]. During the past decade, laser technology has made remarkable advances, with clinical application of laser technology in the treatment of soft tissue diseases in both medicine and dentistry becoming commonplace [1]. These advances were made possible by the improvement in laser design, which has allowed for precise control of the laser parameters. Most importantly, the ability to control the field effect of the laser has allowed for minimal transmission of thermal energy to adjacent tissues.

Recently, there has been a resurgence of interest in the role of lasers in prevention and treatment of enamel and dentinal caries [1]. At relatively high energy levels, it is possible to produce a surface melt and effectively seal an enamel or dentinal surface, while producing only 4° C increase in pulpal temperature [4].

The aim of this study is to evaluate the chopped CO_2 laser inhibition of the enamel artificial carieslike lesion within various parameters, and to explore the effect of the energy density, the number of pulses and the pulse duration of this laser on the caries inhibition activity in order to determine the optimal CW

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CO_2 laser parameters used for this purpose.

Materials and methods:

A total of twenty-four extracted newly erupted human premolar teeth were selected for this in vitro study. Following a fluoride -free prophylaxis, these teeth were examined under a light microscope at a magnification of 30X to ensure that they were defect free and caries free. The surface of each tooth was covered with acid-resistant varnish leaving two circular windows of approximately (4-6) mm in diameter on the buccal and lingual surfaces.

These teeth were divided in to 3 groups (I, II and III). Each groupwas subdivided into 3 subgroups (A, B and C) according to which laser parameters were applied, in addition to one group served as a control. The samples were irradiated using chopped CO_2 laser (BLITZ 50 SV, asa medical laser, Vicenza, Italy) with 10.6 μm wavelength and 10 Hz repetition rate. The total energy density was increased by increasing the number of the pulses, increasing the pulse energy, and decreasing the spot diameter in group I, II and III respectively (Table 1).

Table (1): Sample groups and the related chopped CO_2 laser parameters.

Group	Parameter		
Group I	*No. of Pulses*	*Pulse Energy Density (J/cm^2)*	*Total Energy Density (J/cm^2)*
A1	2	12.73	25.47
B1	4	12.73	50.93
C1	8	12.73	101.86
Group II	*Pulse Duration (s)*	*Pulse Energy Density (J/cm^2)*	*Total Energy Density (J/cm^2)*
A2	0.002	3.18	25.47
B2	0.004	6.37	50.93
C2	0.008	12.73	101.86
Group III	*Spot Diameter (mm)*	*Pulse Energy Density (J/cm^2)*	*Total Energy Density (J/cm^2)*
A3	4	3.18	25.47
B3	2.83	6.37	50.93
C3	2	12.73	101.86

Carieslike lesions were created on all teeth by immersing them in lactic acid solution (pH 3.5) at 37°C. following a period of 21 days, cross sections were prepared for polarizing microscope evaluation. Lesion depths were measured using a graticule supplied with the polarizing microscope. The measured lesion depths included the surface zone and the body of the lesion.

Results:

Table 2 gives the variation in mean lesion depths and caries inhibition percentage by various chapped CO_2 laser parameters.

In general, the laser-treated groups have significantly smaller lesion compared with the control group. These decreased lesions represent up to 33% inhibition of the caries process.

The higher the number of pulses in group I led to less carieslike lesion depths. The higher the pulse energy density produced a higher caries inhibition effect in group II and III.

Table (2): Sample groups and the related caries inhibition percentages.

Group		*Lesion Depth (μm)*	*Caries Inhibition (%)*
Group I	**A1**	466.67	20
	B1	391.67	33
	C1	375	36
Group II	**A2**	500	14
	B2	483.33	17
	C2	375	36
Group III	**A3**	554.17	5
	B3	550	6
	C3	375	36
Control		583.33	0

Fig 1 represents he behavior of the caries inhibition percentage as a function of the CO_2 energy density for groups I, II, and III respectively. They show that there is a direct relationship between them.

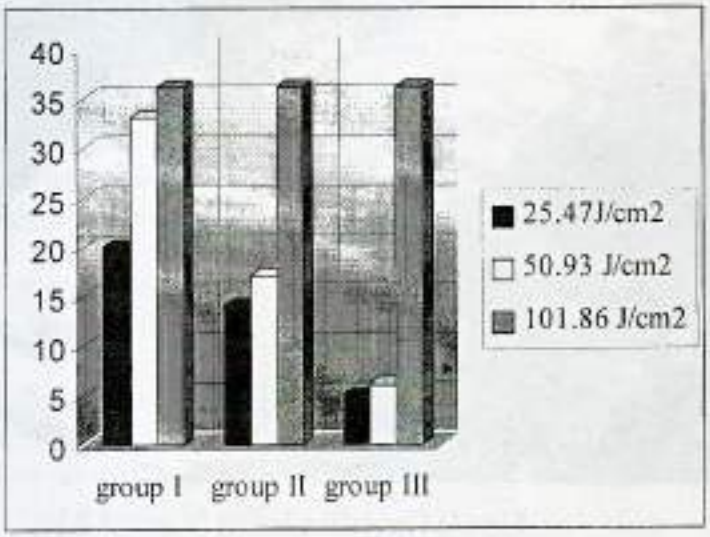

Fig (1) The relation between the energy densities and the caries inhibition percentages in groups I, II and III.

The higher the energy density (101.86 J/cm^2) produces the higher caries inhibition percentage (36%) fig 2.

Fig (2): Carieslike lesion in group C1.

The lower the energy density (25.47 J/cm^2) produces the lower caries inhibition percentage (5%) fig 3.

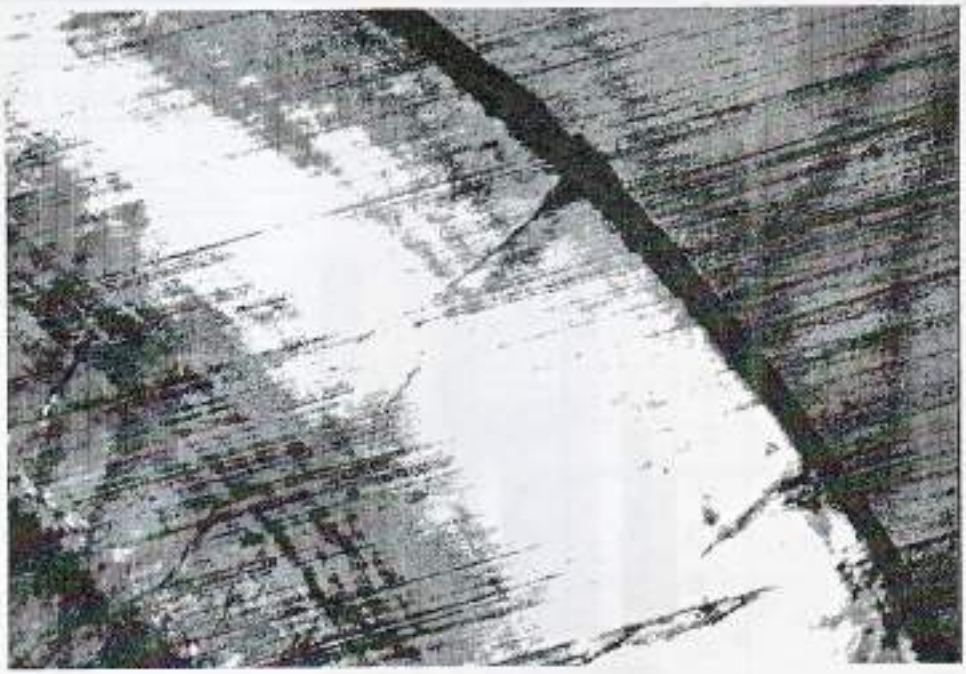

Fig (3) Carieslike lesion in group A3.

Discussion:

A single exposure to chapped CO_2 laser irradiation of sound enamel resulted in signified reductions in lesion depth up to 36% inhibition percentage. These findings are in good agreement with those reported for carieslike formation in enamel with argon ion [5-9], Nd: YAG [2,3] and CO_2 laser [10,11].

The enhanced caries resistance of enamel following laser irradiation may be due to many factors: -

1- Alteration in the enamel composition
2- Increased affinity of lased enamel for fluoride, phosphate and calcium ion uptake.
3- Creation of microsieve network within the tooth structure.
4- Surface melting and recrystallization.
5- Decreased enamel permeability.
6- Bactericidal effect and elimination of the dental plaque.
7- Formation of calcium fluoride surface deposits in the presence of exogenous fluoride.

Although the exact mechanism of caries resistance with laser irradiation is not clearly known, it seems to be a combination of the previously listed mechanisms at the same time, according to the depths and temperatures of the enamel layers. At the most inner layer there is a slight increasing in the temperature (60-100°C). The most prominent phenomena in this range of temperatures is the protein denaturation [12]. This may lead to decrease the enamel permeability. The second deepest layer is characterized by reaching 100°C, which is the temperature of water evaporation. Therefore water molecules are removed from the enamel [12]. Organic materials have been removed and ablated from the third layer when the temperature ranges from 100-650°C. The removal of the water molecules and the organic materials leads to formation of micropores. This gives us the right to suggest the creation of a microsieve network mechanism, when the released fluoride, calcium and phosphate ions repricipitate within the micropores. The mechanism of increasing affinity of the lased enamel to fluoride, calcium and phosphate ions could be applied also. At the same time the ablation of the water molecules and the organic material gives a reason to apply the alteration in the enamel composition mechanism. When the temperature range between 650°-1100°C at the fourth layer, the carbonate content of the enamel is derived [13]. In this layer and the last two layers (2^{nd} and 3^{rd}), it may be true to suggest the alteration in the enamel composition mechanism. Melting and recrystallization of the hydroxyapatite crystals is the character of the fifth layer, when the temperature exceeds the melting point of the hydroxyapatite (1280°C). Superficial calcium fluoride deposits formation and bactericidal effect and elimination of the dental plaque also characterize the fifth layer, which are two other mechanisms of the caries resistance.

Although the artificial caries system used in this study creates lesions in enamel that are identical histologically to enamel caries formation in vivo, one must consider that this system subjects the enamel to a continuous aggressive, cariogenic challenge without periods of remineralization. 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 remarkable resistance to lesion initiation.

It is important to know that the all sets of laser parameters used in this study produce temperature increment less than 5°C at the pulp side [4]. The pulp vitality is not affected irreversibly within this temperature [14]. Cooling the surface of the tooth in vitro with water decreased the pulpal temperature change [15]. The assumption is that in vivo, the temperature change would be lower than in vitro because of the effects of the saliva and the blood flow.

Conclusions:

From this in vitro study one can concluded that:-

1- Short exposure time of chopped CO_2 laser results in a significant inhibition of the enamel artificial carieslike lesion.
2- The inhibitory effect depends upon the total energy density of the laser beam.
3- The optimal chopped CO_2 laser parameters used for caries inhibition purpose is achieved with approximately 101.86J/cm^2 energy density.

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