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The Inhibitory Effect of CW CO_2 Laser on Carieslike Lesion Initiation on Sound Enamel: an In Vitro Study

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Key words
CW, CO_2 laser, enamel

Abstract

Although CO_2 laser irradiation can decrease enamel demineralization, it has still not been clarified which laser wavelength and which irradiation conditions represent the optimum parameters for application as preventive treatment. One of the important applications of the laser is as a caries inhibition treatment of the sound dental tissues. This study aimed to assess the caries preventive potential of various CW CO_2 laser parameters, and to explore the effect of laser power density, and the exposure time on the caries inhibition activity. Eighty one extracted human premolar teeth were irradiated with three output power: (1, 2, and 4) W, three spot diameter: (2, 2.83, and 4) mm, and three exposure times: (0.2, 0.4, and 0.8) sec of 10.6µm CW CO_2 laser. Three teeth were used as a control group. All teeth were subjected to carieslike lesion formation by 3.5 pH lactic acid solution for 21 days. The teeth after that were sectioned into ground cross sections and the lesion depths were measured under polarizing microscope. The lesion depths of experimental samples were compared with those of the control samples. A single exposure to CW CO_2 laser irradiation was found to be resulted in reduction of the carieslike lesion depths. These reductions were up to 61%. The inhibition activity was related directly to the power density and inversely to the exposure time of CW CO_2 laser radiation. The optimal parameters were $33W/cm^2$ power density and 0.2 exposure time. These finding should be reinforced with more laboratory, animal, and human studies with and without fluoride before clinical applications.

Introduction

Dental caries is still considered the most prevalent disease during childhood and adolescence, and its manifestation is found to be high in some individuals, even though a noteworthy decline in dental caries incidence has been documented worldwide in the last decades. Although fluoride is the most powerful treatment to prevent tooth decay, the development of new methods to control this disease completely is still necessary. [(1)]The possibility of making dental enamel more resistant to caries attack by irradiation with a CO_2 laser has been described for all its main wavelengths. [(2)] The9.6 µm wavelength has 10 times higher absorption in enamel (8,000 cm^{-1}) than the 10.6 µm wavelength (825 cm^{-1}) and has therefore been considered the most promising for use in caries prevention. [(3)] However, the lower absorption of the 10.6µm

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wavelength results in a higher penetration depth and can therefore affect a thicker enamel layer. For this reason, it has been suggested that the caries-preventive effect obtained with 10.6 µm could be longer-lasting. [4] Furthermore, the most recent studies have demonstrated that the irradiation of dentin with a 9.3µm CO_2 laser failed to show any statistically significant increase in acid resistance [5], whereas a continuous wave 10.6µm CO_2 laser was able to decrease the acid dissolution rate at higher power settings. [6] Therefore, it may be possible that the 10.6µm wavelength produces the more balanced caries-preventive effect in all dental hard tissues. The aim of this study is to evaluate the CW CO_2 laser inhibition of enamel artificial carieslike lesion with various parameters, and to explore the effect of the power density, exposure time, and spot diameter of this laser on the caries inhibition activity in order to determine the optimal CW CO_2 laser parameters used for this purpose.

Materials and Method

A total of 84 extracted newly erupted human premolar teeth were selected for this study. Following a fluoride free prophylaxis, these teeth were examined under a light microscope at a magnification of 30X to ensure that they were caries free. The enamel surfaces were covered with acid resistant varnish leaving two circular windows of (4-6) mm in diameter.These teeth were separated into three main groups of 27 (group I, II, and III). Each group was subdivided into nine subgroups of 3(A-I) according to which laser parameters were applied. These samples were irradiated with CW,10.6 µm CO_2 laser at 1,2, and 4 watts output powers, 0.2, 0.4, and 0.8 second exposure times, and at 2, 2.83, and 4 mm spot diameters; as shown in tables (1),(2), and (3). Three teeth were excluded from the laser irradiation in order to use them as a control group.Carieslike lesions were created on the enamel surfaces by immersing them in lactic acid solution (pH=3.5) at 37°C. Following aperiod of 21 days, cross sections were prepared for polarizing microscope evaluation. Lesion depths were measured and caries inhibition percentages were obtained from them.

Results

Table (4), (5), and (6) illustrate the measured lesion depth and calculated caries inhibition percentage corresponding to each subgroup of groups I, II, and III respectively.
Figure (1) represents the relation between the power density of the CW CO_2 laser radiation and the percentage of the caries inhibition. Increasing the power density in the range of 8-32 W/cm^2 (group I) led to increase in the caries inhibition percentage for each set of constant exposure time. For each power density, decreasing the exposure time led to increase the caries inhibition percentage.The same behavior was observed in group II when the power density ranged between 16-64 W/cm^2; figure (2).In group III, when the power density ranged between 32-128 W/cm^2, the behavior was different. As shown in figure (3); the increase of the power density led to decrease the caries inhibition percentage for each set of constant exposure time. The behavior of the caries inhibition percentage corresponding to the exposure time is still unchanged; decreasing the exposure time led to increase in the caries inhibition percentage.All subgroups showed much or less increase in caries inhibition activity more than the control. The maximum caries inhibition percentage (61%) was corresponding to subgroup G3.

Discussion

A single exposure to CW CO_2 laser irradiation of sound enamel resulted in reductions in lesion depth up to 61% inhibition percentage. These findings are in good agreement with those reported for carieslike formation in teeth with argon [4, 7-9], Nd: YAG [10], and CO_2 laser [5, 6].The inhibition of in vitro carieslike lesion progression achieved by laser treatment alone in this study represents one of the most promising findings ever reported in the literature for laser treatment. A single exposure to chapped CO_2 laser irradiation of sound root resulted in signified reductions in lesion depth up to 36% inhibition percentage. The enhanced caries resistance of enamel following laser irra-diation may be due to many factors [11-13]: -

1-Alterationin 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.

The exact mechanism of caries resistance with laser irradiation seems to be due a combination of some or all of previously listed factors at the same time, according to the depths and temperatures of the enamel layers. 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 inters-persed 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 [14]. The pulp vitality is not affected [15]. Cooling the surface of the tooth in vitro with water decreased the pulpal temperature change [16]. 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.

Table (1):- Laser parameters of group I.

Group	Exposure time (s)	Power density (W/cm^2)
A1	0.8	7.958
B1	0.8	15.898
C1	0.8	31.831
D1	0.4	7.958
E1	0.4	15.898
F1	0.4	31.831
G1	0.2	7.958
H1	0.2	15.898
I1	0.2	31.831
Control	0	0

Table (2):- Laser parameters of group II.

Group	Exposure time (s)	Power density (W/cm^2)
A2	0.8	15.898
B2	0.8	31.831
C2	0.8	63.662
D2	0.4	15.898
E2	0.4	31.831
F2	0.4	63.662
G2	0.2	15.898
H2	0.2	31.831
I2	0.2	63.662
Control	0	0

Table (3):- Laser parameters of group III.

Group	Exposure time (s)	Power density (W/cm^2)
A3	0.8	31.831
B3	0.8	63.662
C3	0.8	127.324
D3	0.4	31.831
E3	0.4	63.662
F3	0.4	127.324
G3	0.2	31.831
H3	0.2	63.662
I3	0.2	127.324
Control	0	0

Table (4):-Caries inhibition of group I.

Group	Lesion depth (µm)	Caries inhibition (%)
A1	566.67	3
B1	450	23
C1	383.33	34
D1	500	14
E1	400	31
F1	350	40
G1	458.33	21
H1	375	36
I1	325	44
Control	583.33	0

Table (5):- Caries inhibition of group II.

Group	Lesion depth (µm)	Caries inhibition (%)
A1	500	14
B1	400	31
C1	375	36
D1	400	31
E1	375	36
F1	350	40
G1	366.67	37
H1	350	40
I1	333.33	43
Control	583.33	0

Table (6):- Caries inhibition of group III.

Group	Lesion depth (µm)	Caries inhibition (%)
A1	450	23
B1	508.33	13
C1	500	14
D1	250	57
E1	316.67	46
F1	325	44
G1	225	61
H1	250	57
I1	300	49
Control	583.33	0

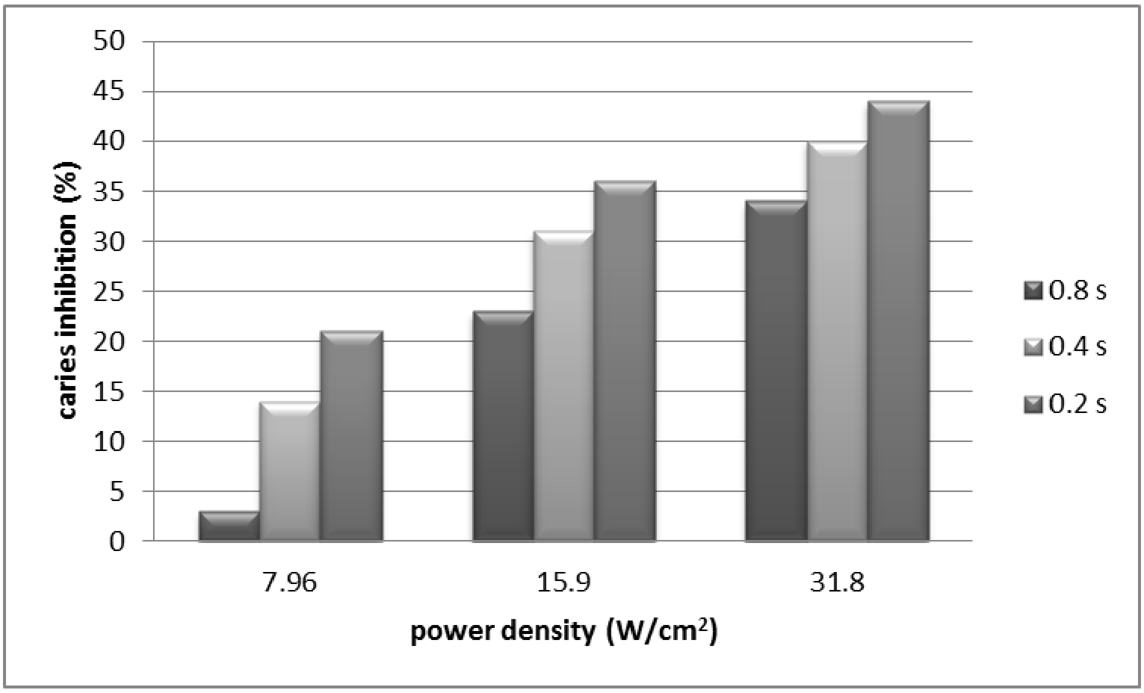

Fig. (1):- The relation between the power density and the caries inhibition percentage in group I.

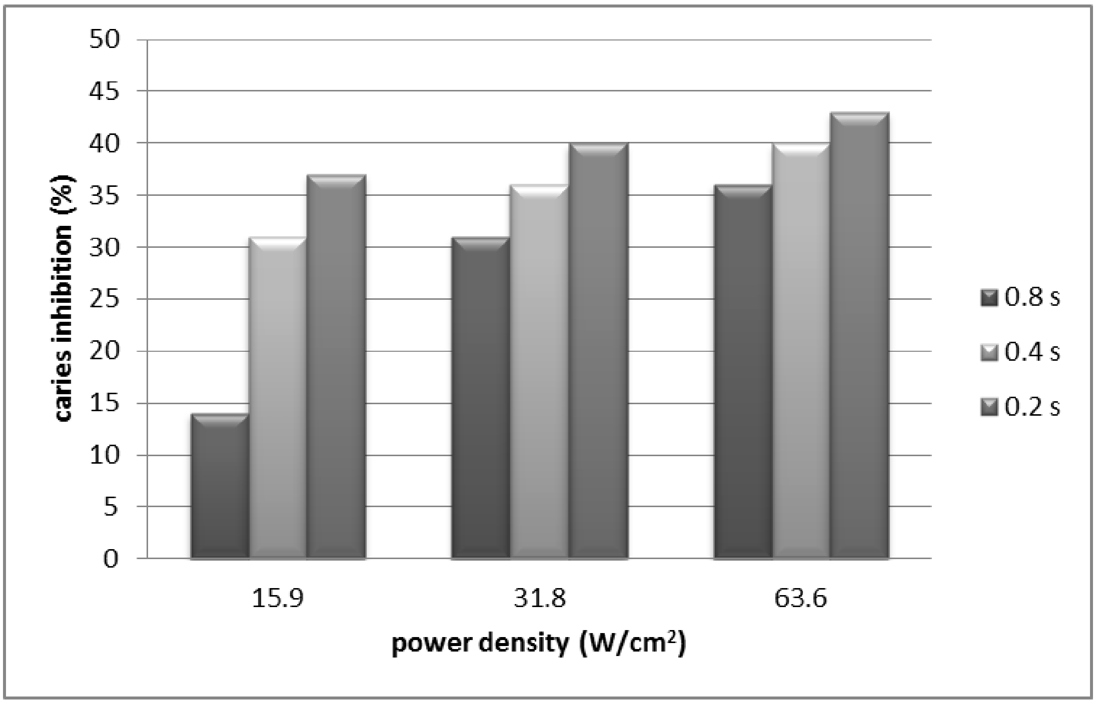

Fig. (2):- The relation between the power density and the caries inhibition percentage in group II.

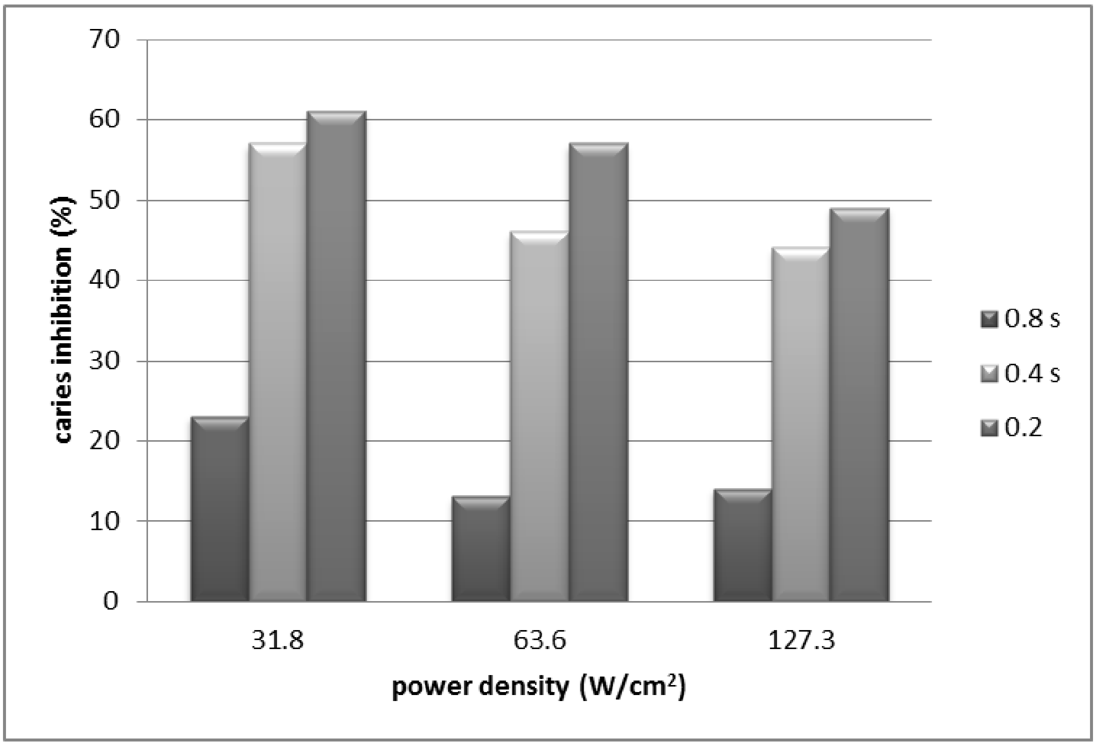

Fig. (3):- The relation between the power density and the caries inhibition percentage in group III.

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