The inhibitory effect of CW CO_2 laser irradiation on caries like lesion initiation in sound root: an in vitro study

Muthenna Sh. Rajab. BDS, M.Sc*

Abstract:

This study aimed to assess the caries-preventive potential of various CW CO_2 laser parameters, and to explore the effect of the laser power density and the exposure time on the caries inhibition activity.

Roots of extracted human premolar teeth were irradiated with three various power densities (31.83, 63.59, and 127.32) W/cm^2. The CO_2 laser system emitted laser with 10.6μm in wavelength. All roots were subjected to caries like lesion formation by 3.5 pH lactic acid for 21 days. The roots after that were sectioned into ground cross sections and the lesion depths were measured using a graticule under a polarizing microscope.

CW CO_2 laser preventive treatments inhibited caries like lesion progression up to 79%. This effect was improved with increased power density within the limits of the examined laser parameters.

Conclusion:

1- CW CO_2 laser resulted in a significant inhibition of the root carieslike lesion. The inhibitory effect depends upon power density of the laser beam. The optimal chopped CO_2 laser parameters used for caries inhibition purpose are achieved with 127.32 W/cm^2 power density.

Key words:

CW CO2 laser, laser irradiation, caries like lesion, caries inhibition.

Introduction:

Possible applications of laser in dentistry have been suggested and studied for more than 30 years. Lasers have become more popular with dentists for soft-tissue surgery in recent years and were approved for limited hard tissue treatment of dental hard tissue to increase their resistance to caries [1-4].

In 1966, Stern et al [1], Sognnaes and Goodman described the effect of high-energy ruby laser on enamel. They report that pulses of 500 μs produced crater that were characterized by

* Assistant lecturer in the Department of Prosthetic Dentistry, College of Dentistry, Al-Mustansiria university

melting and recrystallization of the enamel. This enamel was less permeable than unlased enamel, resulting in reduced subsurface demineralization by lactic acid. Increased resistance of lased enamel to acid dissolution has also been demonstrated with low energy CO_2 and Nd: YAG laser light [1, 3, 5]. Yamamoto and Sato suggested that the increased acid resistance was due to a physical alteration in enamel permeability [3]. Nelson, Jongebloed and Featherstone suggested that the inhibitory effect was probably due to a combination of laser induced surface sealing, compositional changes in the enamel, and effects on the organic matrix [6].

The inhibitory effect of laser on surface demineralization may be applied in preventive dentistry, for example, the low energy laser irradiation of occlusal surface as a means of preventing fissure caries, and debridement of incipient caries [6-7]. In addition, powdered hydroxyapatite and various fluorides have been fused to enamel as potential fissure sealants [8].

In recent years, the effect and interaction of laser with dental hard tissues have been studied carefully. The overall objective of these was to determine optimal laser parameters for clinical caries prevention. These parameters should decrease the enamel susceptibility to caries without jeopardizing the pulp vitality. These studies demonstrated that small changes in these laser treatment parameters could result in significant change in the caries inhibition achieved [9-11].

The aim of this study is to evaluate the CW CO_2 laser inhibition of the root artificial caries like lesion within various parameters, and to explore the effect of the power density 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 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-and caries free. The surface of each root was covered with acid-resistant varnish leaving two circular windows of approximately (4-6) mm in diameter.

These teeth were separated in to 3 groups of 3(A-C) according to which laser parameters were applied, in addition to one group served as a control. In 1st group, the spot diameter is the variable. In 2nd group, the variable is the exposure time. The power is the variable in the 3rd group. Subgroups A1, A2 and A3 have the same parameters so they were considered as one subgroup. The samples were irradiated using CW CO_2 laser (BLITZ 50 SV, as a medical laser, Vicenza, Italy) with 10.6 μm wavelength (Table 1).

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

Group I	Power (W)	Exposure time (s)	Spot Diameter (mm)	Power Density (W/cm^2)
A1	4	0.8	2	127.32
B1	4	0.8	2.83	63.59
C1	4	0.8	4	31.83
A2	4	0.8	2	127.32
B2	4	0.4	2	127.32
C2	4	0.2	2	127.32
A3	4	0.8	2	127.32
B3	2	0.8	2	63.59
C3	1	0.8	2	31.83

Caries like lesions were created on all roots 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

A2 and A3 have the same parameters so they were considered as one subgroup. The samples were irradiated using CW CO_2 laser (BLITZ 50 SV, as a medical laser, Vicenza, Italy) with 10.6 μm wavelength (Table 1).

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

Group I	Power (W)	Exposure time (s)	Spot Diameter (mm)	Power Density (W/cm^2)
A1	4	0.8	2	127.32
B1	4	0.8	2.83	63.59
C1	4	0.8	4	31.83
A2	4	0.8	2	127.32
B2	4	0.4	2	127.32
C2	4	0.2	2	127.32
A3	4	0.8	2	127.32
B3	2	0.8	2	63.59
C3	1	0.8	2	31.83

Caries like lesions were created on all roots 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 CW CO_2 laser parameters.

The decreased lesions represent up to 79% inhibition of the caries process.

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

Group		Lesion Depth (µm)	Caries inhibition (%)
Group I	A1	125	79
	B1	558.33	4
	C1	616.67	-5
Group II	A2	125	79
	B2	308.33	47
	C2	335	43
Group III	A3	125	79
	B3	433.33	26
	C3	433.33	26
Control		583.33	0

Fig 1, 2 and 3 represent the behavior of the caries inhibition percentage as a function of the CO_2 power density and the exposure time for the three groups. They show that there is a direct relationship between them. The higher the power density (127.32 W/cm^2) produces the higher caries inhibition percentage (79%).

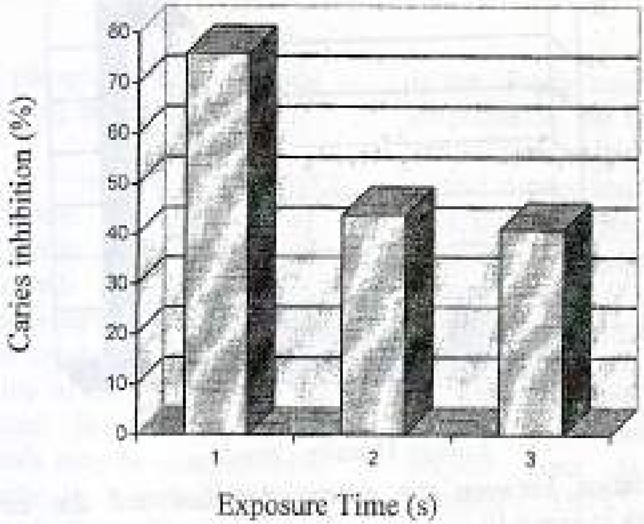

Fig (1): The relation between the power densities and the caries inhibition percentages in group I.

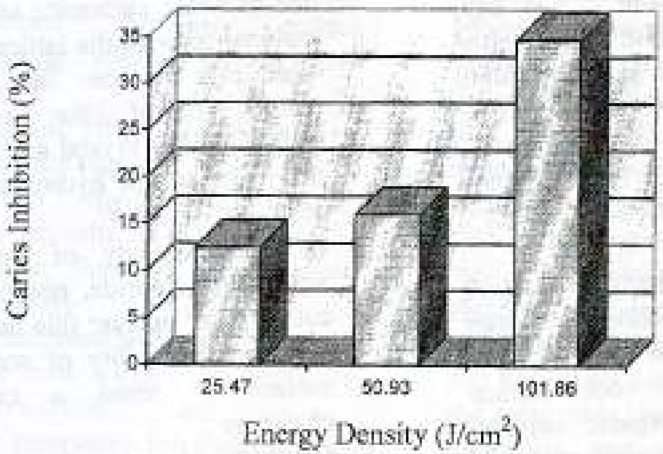

Fig (2): The relation between the exposure times and the caries inhibition percentages in group II.

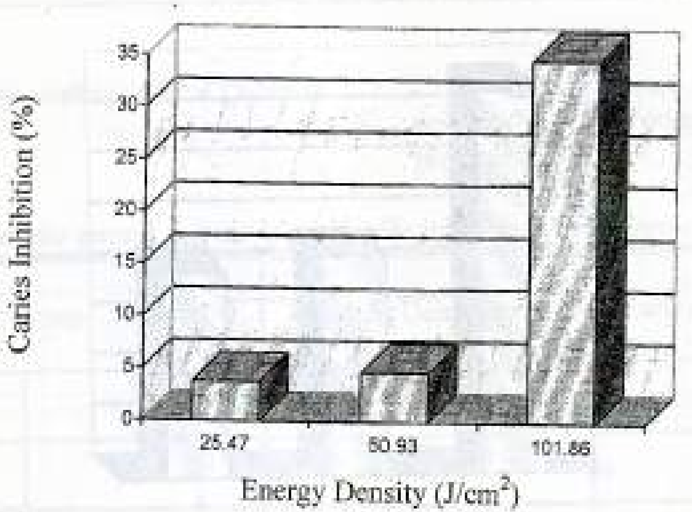

Fig (3): The relation between the energy densities and the caries inhibition percentages in group III.

Discussion:

A single exposure to CW CO_2 laser irradiation of sound root resulted in signified reductions in lesion depth up to 79% inhibition percentage. These findings are in good agreement with those reported for caries like formation in teeth with argon [11-15], Nd: YAG [2, 3] and CO_2 laser [16-21].

The enhanced caries resistance of root surface following laser irradiation may be due to many factors:

1. Alteration in the root surface composition: the organic content, the carbonate and water content of root surface are reduced. Reduction in the amount of carbonate increases root surface resistance to acid. The loss of water, carbonate and organic material reduces the lattice strain in lased root surface. This result in contraction of the a-axis of hydroxyapatite crystal and increases the resistance of hydroxyapatite to acid dissolution [22].
2. Increased affinity of lased root surface for fluoride, phosphate and calcium ion uptake: this factor may improve the ability of sound root surface to resist a cariogenic challenge [23].
3. Creation of microsieve network within the tooth structure: This may allowed the reprecipitation of

calcium, phosphate and fluoride released during caries formation [24-26].

4. Surface melting and recrystallization: This factor may lead to fusion of smaller root surface crystals into larger ones, thereby reducing the total surface area of the crystals and decreasing the solubility of the root surface to organic acid. In addition, these fused crystals may be composed of apatite with a lower carbonate content, which enhances the resistance to cariogenic challenge [27-29].
5. Decreased root surface permeability: The expanded denaturated proteins reduce micropores within the mineral structure [30, 31].
6. Bactericidal effect and elimination of the dental plaque [32].
7. Formation of calcium fluoride surface deposits in the presence of exogenous fluoride. This surface coating may:-

a. Act as diffusion barriers.
b. Reduce root surface solubility in acidic condition.
c. Act as reservoirs for fluoride rich reaction products.
d. Affect microorganisms in plaque, as well as protein desorping [33-36].

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 root surface 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 [37]. This may lead to decrease the root surface 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 root surface [37]. 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 root surface to fluoride, calcium and phosphate ions 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 root surface composition mechanism. When the temperature range between 650°-1100°C at the fourth layer, the carbonate content of the root surface is derived [38]. In this layer and the last two layers (2^{nd} and 3^{rd}), it may be true to suggest the alteration in the root surface 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 root surface that are identical histologically to root surface caries formation in vivo, one must consider that this system subjects the root surface 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 root surface 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 [39]. The pulp vitality is not affected [40]. Cooling the surface of the tooth in vitro with water decreased the pulpal temperature change [41, 42]. 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 conclude that:-

1) Short exposure time of CW CO_2 laser results in a significant inhibition of the enamel artificial caries like lesion.
2) The inhibitory effect depends upon the total power density of the laser beam. The optimal chopped CO_2 laser parameters used for caries inhibition purpose is achieved with approximately 127.32 W/cm^2 power density.

References:

1- Stern RH, Sognnaes RF, Goodman F: Laser effect on in vitro enamel permeability and solubility. JADA 1966; 73: 838-843.

2- Yamamoto H, Ooya K: Potential of YAG laser in caries prevention. J Oral Pathol 1974; 3(1): 7-15.

3- Yamamoto H, Sato K: Prevention of dental caries by acousto-optically Q-switched Nd: YAG laser irradiation. J Dent Res. 1980; 59(2): 2171-2177.

4- Featherstone JDB, Nelson DGA: Laser effects on dental hard tissue. Adv Dent Res. 1987; 1(1):21-26.

5- Nelson DGA, Shariati M, Glean R, Shield GP Fatherstone JDB: Effect of pulsed low energy infrared laser irradiation on artificial caries like lesion formation. Caries Research 1986; 20:289-299.

6- Nelson DGA, Jongebloed WL, Fatherstone JDB: Laser irradiation of human dental enamel and denting. New Zealand Dental Journal 1986; 82: 74-77.

7- Myers TD, Myers WD: The use of a laser for debridement of incipient caries. Journal of Prosthetic Dentistry 1985; 53:776-779.

8- Steward L, Powell GL, Wright S: Hydroxyapatite attached by laser a potential sealant for pits and fissures. Operative Dentistry 1985; 10:2-5.

9- Fried D, Seka W, Glena RE, Featherstone JDB: Thermal response of hard dental tissues to 9 through 11 μm CO_2 laser irradiation. Opt Eng 1996; 35(7): 1976-1984.

10-Fried D, Glena RE, Featherstone JDB, Seka W: Multiple – Pulse irradiation of dental hard tissue at CO_2 laser wavelength. In: Wigdor HA, Featherstone JDB, White JM, eds. Laser in dentistry [proceeding]. Bellingham, Wash: SPIE-The international Society of Optical Engineering 1995; 60:41-50.

11-Kantorowitz ZVI, Featherstone JDB, Fried D: Caries prevention by CO_2 laser treatment dependency on the number of pulses used. JADA 1998; 129: 585-591.

12-Fox JL, Yu D, Otsuka M, Higuchi WI, Wong J, Powell GL: Combined effects of laser irradiation and chemical inhibitors on the dissolution of dental enamel. Caries Res 1992; 26:333-339.

13-Powel GL, Higuchi WI, Fox JL, Yu D, Blankenau RJ: Argon laser effect on demineralization of human enamel. SPIE 1992; 1643: 347-349.

14-Westerman GH, Hicks MJ, Flaitz CM, Blankenau RJ, Powell GL, Berg JH: Effect of argon laser irradiation on caries like lesion initiation and progression in enamel. J Dent Res 1993; 72: 347 (#1948).

15-Hicks MJ, Flaitz CM, Westerman GH, Berg JH, Blankenau RJ, Powell GL: Caries like lesion initiation and progression in sound enamel following argon laser irradiation: an in vitro study. J Dent Child 1993; 60: 201-206.

16-Tagomori S, Morioka T: Combined effects of laser and fluoride on acid resistance of human dental enamel. Caries Res 1989; 23: 225-231.

17-Sato K: Relation between acid dissolution and histological alteration of heated tooth enamel. Caries Res 1983; 17: 490-495.

18-Nelson DGA, Wefel JS, Jongebloed WL, et al: Morphology, histology and crystallography of human dental enamel treated with pulsed low –energy infrared laser irradiation. Caries Res 1987; 21: 411-426.

19-Oho T, Morioka T: A possible mechanism of acquired resistance of human dental enamel by laser irradiation. Caries Res 1990; 24:86-92.

20-Love RM: The effects of laser irradiation of the dental tissues a review. NewZealand Dental Journal 1995; 91:134-137.

21-Meurum JH, Voegen JC, Rauhammaa-Makinen R, et al: Effects of CO_2 Nd YAG and CO_2-Nd YAG combination laser at high energy densities on synthetic hydroxyapatite. Caries Research 1992; 26: 77-83.

22-Blankenau RJ, Kelsey WP, Powel GL et al: Degree of composite resin polymerization with visible light and argon laser. Am J Dent 1991; 4:40-44.

23-Myers ML: The effect of laser irradiation on oral tissue J Prosth Dent 1991; 66:395-397.

24-Launay Y, Mordon S, Cornil A et al: Thermal effects of laser on dental tissue Laser. Surg Med 1987; 7:473-477.

25- Silver stone LM, Hicks MJ, Featherstone MJ: Dynamic factors affecting lesion initiation and progression in human dental caries II. Surface morphology of sound enamel and caries like lesion of enamel. Quintessence Int 1988; 19: 773-785.

26-Hicks MJ, Flaitz CM, Westerman GH, Blankenau RJ, Powell GL, Berg JH: Caries - like lesion initiation and progression around laser-cured sealants. American Journal of Dentistry 1993; 6(4): 176-180.

27-Westerman GH, Hicks MJ, Flaitz CM, Powell GL, Blankenau RJ: Surface morphology of sound enamel after argon laser irradiation an in vitro scanning electron microscopic study. Journal of Clinical Pediatric Dentistry 1996; 21 (1): 55-59.

28-Hicks MJ, Flaitz CM, Westerman GH, Blankenau RJ, Powell GL, Berg JH: Enamel caries initiation and progression following low flowence (energy) argon laser and fluoride treatment. Journal of Clinical Pediatric Dentistry 1995; 20(1): 9-13.

29-Hicks MJ, Flaitz CM, Westerman GH, Blankenau RJ, Powell GL: Root caries in vitro after low flowence argon laser and fluoride treatment. Compendium 199-18(8): 543-552.

30-Westerman GH, Hicks MJ, Flaitz CM, Blankenau RJ, Powell GL, Berg JH: Argon laser irradiation in root surface caries in vitro study examines laser effects. JADA 1994; 125:401-407.

31-Flaitz CM, Hicks MJ, Westerman GH, Berg JH, Blankenau RJ, Powell GL: Argon laser irradiation and acidulated phosphate fluoride treatment in caries like lesion formation in enamel an in vitro study. Pediatric Dentistry 1995; 17(1): 31-35.

32-Hicks MJ, Westerman GH, Flaitz CM, Blankenau RJ, Powell GL, Berg JH: Effects of Argon laser irradiation and acidulated phosphate fluoride on root caries. American Journal of Dentistry 1995; 8(1): 10-14.

33-Ogaard R: Effects of fluoride on caries development and progression in vitro. J Dent Res 1990; 69 (Spec Iss): 813-823.

34-Tencate JM: In vitro studies on the effects of fluoride on de-and remineralization. J Dent Res 1990; 69 (Spes Iss): 614-619.

35-Rolla G: On the role of calcium in the cariostatic mechanism of fluoride. Acta Odontol Scand 1988; 46: 341-345.

36-Rolla G: Topical application of fluoride on teeth new concepts of mechanism of interaction. J Clin Periodontol 1993; 20: 105-108.

37-Catone GA, Alling III CC: Laser application in oral and maxillofacial surgery in wavelength conversion effect -contact and free-beam laser surgery. 1st edition Pennsylvania USA WB Saunders Company1997; Pp. 65-70.

38-Wigdor HA, Walsh JT, Featherstone JDB, Visuri SR, Fries D, Waldvogel JL: Laser in dentistry. Laser Surg Med 1995; 16 (2): 103-133.

39-Yu D, Powell GL, Higuchi WT, Fox JL: Comparison of three lasers on dental pulp chamber temperature change. Journal of Clinical laser Medicine and Surgery 1993; 11 (3): 119-122.

40-Zack L, Cohen G: Pulp response externally applied heat. Oral Surg Oral Med Oral Pothol. 1965; 9:515-530.

41-Yu D, Powell GL, Fox JL, Mcclane RW, Higuchi WT: Pulpal temperature measurement for Nd YAG laser irradiation human tooth 3rd International Congress on Lasers in Dentistry 1992; Salt Lake City August 7 Abstract 74.

42-Rizoiu I, Levy GC: Efficiency of cooling mechanism during the exposure of enamel to a pulsed Nd YAG laser beam An in vitro study. SPIE Los Angeles Jan. 8 Abstract 1880 C-33.