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Investigating the Effects of Carbon Dioxide Laser Fluence on Oral Soft Tissue

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Abstract: This study investigates the surgical and thermal effects on oral soft tissues produced by CO_2 laser emitting at 10.6 micrometers with three different fluences 490.79, 1226.99 and 1840.4 J/cm^2. These effects are specifically; incision depth, incision width and the tissue damage width and depth. The results showed that increasing the fluence and /or the number of beam passes increase the average depths of ablation. Moreover, increasing the fluence and the number of beam passes increase the adjacent tissue damage in width and depth. Surgeons using CO_2 laser should avoid multiple pulses of the laser beam over the same area, to avoid unintentional tissue damage.

Introduction

Laser has been advocated for a wide range of surgical applications (Pick, 1993). Many areas of routine CO_2 laser use for soft tissue surgery have developed during the past 30 years, including orofacial surgery and periodontal applications (Pick and Colvard, 1993: Spencer *et al*., 1999). Advantages of this tool include precise cutting, minimal intra-operative haemorrhage, sterilization of the surgical area and healing with minimal scaring, postoperative pain and swelling (Evans *et al*., 1986: Pinheiro and Frame, 1994). The clinician should be able to predict and achieve specific incisional or ablational effects. The required range of incisional effects in soft tissue is extensive. Laser effects on adjacent and underlying tissues such as bone or tooth must be considered, as these tissues might be damaged by the thermal effects of lasers (Gopin *et al*., 1997).

Previous studies have demonstrated that laser effects on soft tissues are related to the absorption process of light in the tissues, and on the laser parameters used. The CO_2 laser at 10.6 μm is well absorbed by oral soft tissues due to its high water content (Wilder-Smith *et al*., 1997).

The objective of this investigation is to determine the incisional effects achieved in soft tissues using different fluences of CO_2 laser beam on animal oral soft tissues and the lateral thermal effects in adjacent tissues.

Materials and methods

Irradiation Protocol

Block specimens dissected out from the oral cavity of rabbits measuring approximately 16x10 mm freshly obtained from 18 male rabbits immediately after sacrifying them. Thirty mucosal specimens were subjected to continuous CO_2 laser in chopped mode. These thirty specimens were divided into three groups, 10 each. In each specimen three CO_2 laser incisions were made by 1 pass, 2 passes and 3 passes of laser fluence. Each pass of CO_2 laser beam was separated from its neighbor by 2 mm. The laser beam was passed over the same line of incision, thereby overlapping the previous exposure. All incisions were made at a rate of 4 mm/s. approximately, using focused beam. Irradiation time was 4 seconds along the whole length of the specimens. This time was fixed using a stopwatch. In this study, laser fluences used are 490.79, 1226.99 and 1840.4 J/cm^2.

Laser device

The laser device used was the ASA CO_2 surgical laser, which emits CO_2 laser beam of 10.6 μm wavelength and a He-Ne laser as an aiming visible beam. The beam is delivered to the target tissue through a handpiece, with a beam diameter of 0.2 mm. The pointing blade (spatula) attached to the distal end of the handpiece ensures the constant delivery of the focused beam at a specific diameter, when the blade tip rests against the tissue surface.

Sample processing

Immediately after laser irradiation, specimens were fixed in 10% buffered formalin and processed routinely, stained with Haematoxyllin and Eosin to be examined under light microscope.

Histologic evaluation

Five slides were made for each specimen and examined using a calibrating lens. Line of measurements is shown in Fig. (1).

Statistical methods

Analysis of variance (ANOVA) and t-test were used for analyzing the results.

AB: *Ablation depth*
HI: *Ablation width*
BC: *Depth of zone of thermal necrosis*
CD: *Depth of zone of thermal damage*
EF: *Width of zone of thermal necrosis*
FG: *Width of zone of thermal damage*
EG: *Tissue damage width*
BD: *Tissue damage depth*

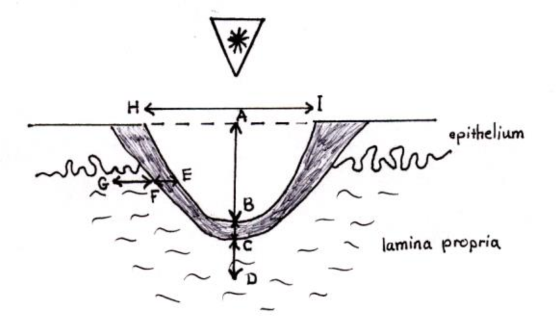


Fig. 1: Cross- sectional drawing of laser induced defect in the mucosa showing lines of measurements.

Results

The results of the investigation are listed in Table (1) which shows that the increasing in laser fluence and / or the number of beam passes cause an increment in the average depths of ablation (F = 15.798, df = 8 and P- value = 0.004). The relation between the number of beam passes and the ablation width was found to be statistically insignificant (F = 1.163, df = 8, and P-value = 0.374). For the three fluences selected, the mean ablation depth ranged from 340.2 μm for 1 pass to up to 1798.5 μm for 3 passes. On the other hand, increasing the laser fluence and the number of beam passes increase the tissue damage width significantly (F = 5.083, df = 8 and P-value = 0.051). The same behavior is true for the tissue damage depth (F = 22.736, df = 8 and P- value = 0.001). For example, when 1 beam pass at fluences of 490.79, 1226.99 and 1840.4 J/cm^2 is used, the mean tissue damage width ranged from 189.1 μm to 301.3 μm to 519.5 μm respectively.

The tissue mean damage depth using 1 beam pass at the same three fluences is ranged from 140 μm to 160.5 μm to 171.8 μm respectively. The cut defect resulting from one, two and three laser beam passes at a fluence of 490.79 J/cm^2 CO_2 laser on rabbit tongue is illustrated in Figs. 2. a and 2. b. An increased cutting depth is noticed.

Table (1)

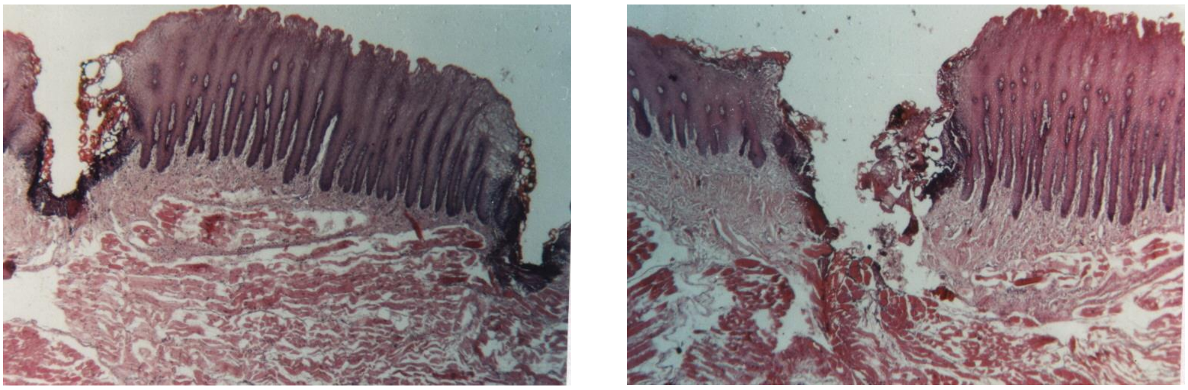
A. Measurements of oral mucosal defects induced by multiple CO_2 laser beam passes, in the same line of incision by the order of increasing fluences.

Fluence and number of beam passes	Ablation depth* (μm)	Ablation width* (μm)	Tissue damage width* (μm)	Tissue damage depth* (μm)
490.79 J/cm^2				
1 Pass	340.2	540.5	189.1	190.0
2 Passes	650.5	1001.3	341.2	250.0
3 Passes	750.9	1200.9	595.5	349.3
1226.99 J/cm^2				
1 Pass	1050.0	711.3	301.3	160.5
2 Passes	1351.0	781.5	533.0	401.0
3 Passes	1459.8	888.1	650.0	414.0
1840.4 J/cm^2				
1 Pass	1340.3	1105.1	519.5	171.8
2 Passes	1523.0	1021.4	535.5	395.9
3 Passes	1798.5	1017.0	700.7	439.5

* Mean value.

B. Analysis of variance (ANOVA)

ANOVA	F	df	P- value
Ablation depth	15.798	8	0.004
Ablation width	1.163	8	0.374
Tissue damage width	5.083	8	0.051
Tissue damage depth	22.736	8	0.001



(A) **(B)**

Fig. 2: (A) The cut defect resulting from 1 laser beam pass (right side) and 2 laser beam passes (left side) at fluence of 490.79 J/cm^2 CO_2 laser on rabbit tongue. **(B)** The cut defect resulting from 3 laser beam passes at the same laser fluence. (H&E x 8.3)

Discussion

The most informative part of this study was the association between increasing the number of CO_2 laser beam passes and the increase in tissue damage width. This can be explained in terms of the longer time of action at the same point due to the increased number of passes, giving enough time for the heat to be absorbed laterally, increasing thermal damage. The depth of ablation was also increased with each beam pass, while the width of ablation did not increase because the beam was passed over the same line each time. This is in agreement with Krause *et al*. (1997).

This effect is important clinically, because damage to the tissue by inadvertently passing the laser beam more than one time over the tissue may be more than increasing the actual energy density.

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دراسة تأثير ليزر ثنائي أوكسيد الكربون على أنسجة الشفاه الرخوة

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الخلاصة

هذه الدراسة تبحث عن تأثير أشعة ليزر ثنائي أوكسيد الكربون من حيث تأثيرها الحراري وفائدتها الجراحية ، ومعرفة عمق وعرض القطع النسيجي الحاصل من تأثير أشعة ليزر ثنائي أوكسيد الكربون . لقد أثبتت النتائج ان قوة الحزمة الليزرية المسلطة تؤدي الى زيادة عمق القطع في النسيج ، كما تتأثر الأنسجة المحيطة بمكان القطع بزيادة تكرار النبضة الليزرية . توصي الدراسة بأن يبتعد الجراح الذي يستعمل أشعة ليزر ثنائي أوكسيد الكربون عن تكرارية النبضة الليزرية عند المنطقة المشعة ذاتها لتجنب النتائج السلبية على النسيج .