N. A. Tilfah et al., Iraqi J. Laser B 2, 39- 46 (2003)

Iraqi J. Laser, Part B, Vol. 2, pp. 39- 46 (2003)

IRAQI JOURNAL OF LASER

CO_2 Laser Evaluation as a Surgical Aid in the Management of Oro-Facial Lesions

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(Received 00 November 2003; accepted 00 December 2003)

Abstract: The biological effects of the carbon dioxide (CO_2) laser were evaluated using the specific absorption of CO_2 laser by biological tissue to achieve temperature – mediated localized injury. The clinical application of CO_2 laser as a surgical aid in the treatment of several oral and maxillofacial tumours and lesions was evaluated, by using the laser in the focusing mode as a cutting tool, and the defocusing mode as a photocoagulator. Thirteen patients were included (having 14 lesions, 7 of these lesions were intra oral and 7 extra oral). The CO_2 laser was used as a cutting and photocoagulating tool. The results showed that the CO_2 laser was effective in minimizing the intra operative blood loss, especially in the treating of highly vascular lesions, it was also effective in reducing the post operative pain and swelling or edema, and on follow up, the patients had uneventful healing.

Introduction

Patel et al. first developed the CO_2 laser in 1964 (Abt et al.). It is a gas laser that emits a wavelength of 10.6 μm in the mid-infrared range of electromagnetic spectrum. Since the CO_2 laser is highly absorbed by water, there is little scattering, reflection in the skin or mucous membrane. High absorption of CO_2 laser in the cutaneous tissue results in a shallow penetration depth. By focused or defocused techniques, the CO_2 laser works in a non-contact mode, i.e. the hand piece never touches the tissue, and this lack of contact results in a loss of tactile feedback during surgery (Pick, 1997).

Laser – Tissue Interaction

Light interacts with matter by the processes of reflection, absorption, scattering, or transmission. Absorption or scattering of light by the irradiated matter result in an increase in the energy content of the matter. If the absorbed photon is not re-emitted or a photon with less energy than the absorbed one is reemitted, some energy remains, which is usually converted into thermal motion or heat in the absorbing matter.

Scattering of a beam of laser light by a medium does not always result in increasing the energy content and raising its temperature, especially when the irradiated medium is hetrogenous (biological tissue). The scattering phenomena may be multiple rather than single [Fuller TA]. The primary uniqueness of energy in the form of laser light energy both spatially as well as temporally coherence to cause very high level of local energy deposition, which can not be easily achieved using other sources of energy. The basic mechanisms of absorption and /or scattering of laser light are the photo-thermal and photochemical effects.

The absorption of light depends on the wavelength chromophore combination

(Mordon et al., 2001). There are two main factors that determine which of these basic interactions will occur; the first is the pulse width, which is simply the measure in time of the mean light pulse, delivered by laser and it is an independent parameter, the second is the optical penetration depth, which is the measure of depth of the laser beam penetration into the tissue (Evans, 1993).

In heterogenic media (biological tissue), the light is scattered very quickly within the tissue, causing a high concentration of energy close to the application point and this is beneficial, because energy is confined to a small-irradiated area.

The CO_2 laser has a relatively short penetration depth, which creates a precise irradiation zone, and its large pulse width causes it to interact thermally with the tissue (Catone and Halusic, 1997). This thermal interaction spreads heat beyond the irradiation zone, cauterizing the surrounding tissue making it an excellent surgical tool. The selection of a laser for a certain medical task involves many considerations such as the type of tissue interaction desired and the depth at which this interaction should occur.

Materials and Methods

This study was carried out to evaluate the CO_2 laser with certain parameters as a surgical aid in several surgical cases, for the purposes of CO_2 laser application in oral and maxillofacial surgery. The used materials were the laser device, ordinary surgical sets, and suture materials.

Laser device:

The device (BLITZ 50 SV) is equipped with a carbon dioxide laser source, with a Helium-Neon laser beam aligned coaxial with the CO_2 laser beam as a guide beam. The emission specifications are listed in Table (1).

Patients:

Thirteen patients with several oro-facial lesions were included in this study. The beam of the CO_2 laser was delivered by an articulated arm, with a beam profile of TEMoo. The powers used were ranged from 3 to 12 W, in a chopped mode, with frequency ranged between 1- 100 Hz. The alignment of the laser beam with the guide beam was checked by the application of the laser beam to a moistened wooden tongue depressor.

Table (1): Emission specifications of the CO_2 laser device used.

Laser	Wave-length (μm)	mode	Power (W)	Frequ-ency (Hz)
CO_2	10.6	CW	50	-
		Chopped		1 - 100
HeNe	0.632	CW	0.005	-

The patients were surveyed for age, sex, location of the lesions, and type of the lesions as in Table (2). The CO_2 laser parameters used in the surgical treatment of lesions were changed according to the type and site of the lesion. All patients were treated in the operating room, under general anesthesia via either naso-tracheal or orotracheal intubation, except one patient who was unfit for general anesthesia, so the excision was done under local anesthesia with intravenous sedation.Wet gauze was used as a hypopharyngeal pack. Wet towels were placed on the exposed skin of the patient's face.

Biopsy was taken from the excised tissue to be examined under light microscope to see the coagulative necrosis caused by the laser energy.

Results

The study is not a dependable statistical study, but mostly a clinical study for two reasons:

1. It is difficult to obtain similar cases with similar lesions, to be managed in different methods and to compare the results.
2. Most of the cases need more than one surgical session, with minimum interval of six months.

Bleeding from small vessels was controlled by pressure applied to the vessel and the laser then was applied directly to the site of bleeder so that as the pressure pack rolled of the vessel, the laser is applied immediately in a defocused

Table (2) : Parameters used with variable surgical pathologies and CO_2 laser end- probes as a cutting tool.

No.	Age (y)	Sex	Site	Type of lesion	Probe	Power (W)	Frequency (Hz)
1	25	Male	Lower lip	Hemangioma	5”	10	50
2	30	Female	Upper lip	Hemangioma	4”	8	50
3	7 mon.	Female	Upper eye lid	Hemangioma	4”	12	100
4	30	Female	Cheek	Port-wine hemangioma	4”	8	50
5	1	Male	Cheek	Giant hairy nevus	2”	5	100
6	17	Female	Forehead	Dermafibro-sarcoma	2”	5	100
7	52	Male	Forehead	Basal cell carcinoma	4”	6	100
8	54	Male	Cheek	Basal cell carcinoma	4”	6	100
9	50	Male	Nose	Squamous cell carcinoma	4”	6	100
10	19	Male	Palate	Neuro-fibroma	2”	8	100
11	57	Male	Gingiva	Giant cell granuloma	2”	10	100
12	45	Male	Gingiva	Giant cell granuloma	2”	10	100
13	3	Male	Tongue	Tongue tie	2”	3	100
14	57	Male	Tongue	Fibro-epithelial polyp.	2”	3	100

Table (3): The surgical efficiency of CO_2 laser used.

No.	Type of the lesion	Laser Hemostasis	Added Hemostasis
1	Upper right periorbital hemangioma	Negative	Bipolar cautary
2	Upper left lip hemangioma	Negative	Bipolar cautary
3	Lower lip hemangioma	Negative	Bipolar cautary
4	Port-wine hemangioma of left side of the face	Positive	
5	Giant hairy nevus of the right side of the face	Positive	
6	Dermafibro-sarcoma of the forehead	Positive	
7	Basal cell carcinoma- of the forehead	Positive	
8	Basal cell carcinoma- of the left cheek	Positive	
9	Squamous cell carcinoma	Negative	Bipolar cautary
10	Neuro-fibroma of the palate	Positive	
11	Giant cell granuloma of anterior mandibular ridge	Negative	Bipolar cautary
12	Fibro-epithelial polyp of the tip of tongue	Positive	
13	Giant cell granuloma of the right mandibular gingiva	Negative	Unipolar cautary
14	Tongue tie	Positive	

mode to photocoagulate the vessel. Larger blood vessels were clamped with a hemostat and either electrocoagulated or tied with a ligature. Table (3) shows the hemostasis efficiency of CO_2 laser in the surgical treatment of lesions and the indication for other hemostasis methods. A 43 % of lesions needed further hemostasis, while 57% of lesions did not need further hemostasis methods. Most of the patients were treated as a day case surgery, only patients with major vascular anomalies needed hospital admission and observation for 24 hours.

Case Reports

Using the principles of physics of laser armed with a basic knowledge of surgical pathology of defined lesions in the oro-facial region, the CO_2 laser is incorporated into the surgical techniques of the following cases:

Case 1:

A 30 years old female with port wine hemangioma of the left side of the face, was treated by CO_2 laser. Elliptical shaped excision was designed and mapped by ink to excise part of the lesion, extending from the left medial canthal area to the lower border of the mandible. The excision was done by CO_2 laser at 8 W, 50 Hz, using 4” end surgical probe. Two layers suturing using 3/0 catgut and 3/0 silk suture were used to close the wound. The patient had uneventful recovery (Fig. 1).

Fig. (1): A-The lesion preoperatively, **B**-Partial excision of the lesion via CO_2 laser **C** –Approximation of the wound edges and suturing.

Case 2:

The second case was a seven months - old female with upper right periorbital hemangioma of 5 cm in diameter. Partial excision of the lesion was planned for. The procedure was done using CO_2 laser at 6 W, 100 Hz, then at 10 W, 50 Hz for deeper penetration of the lesion to complete the excision. Bipolar cautery was used to coagulate vessels, which were not coagulated by laser. The patient had uneventful recovery (Fig. 2).

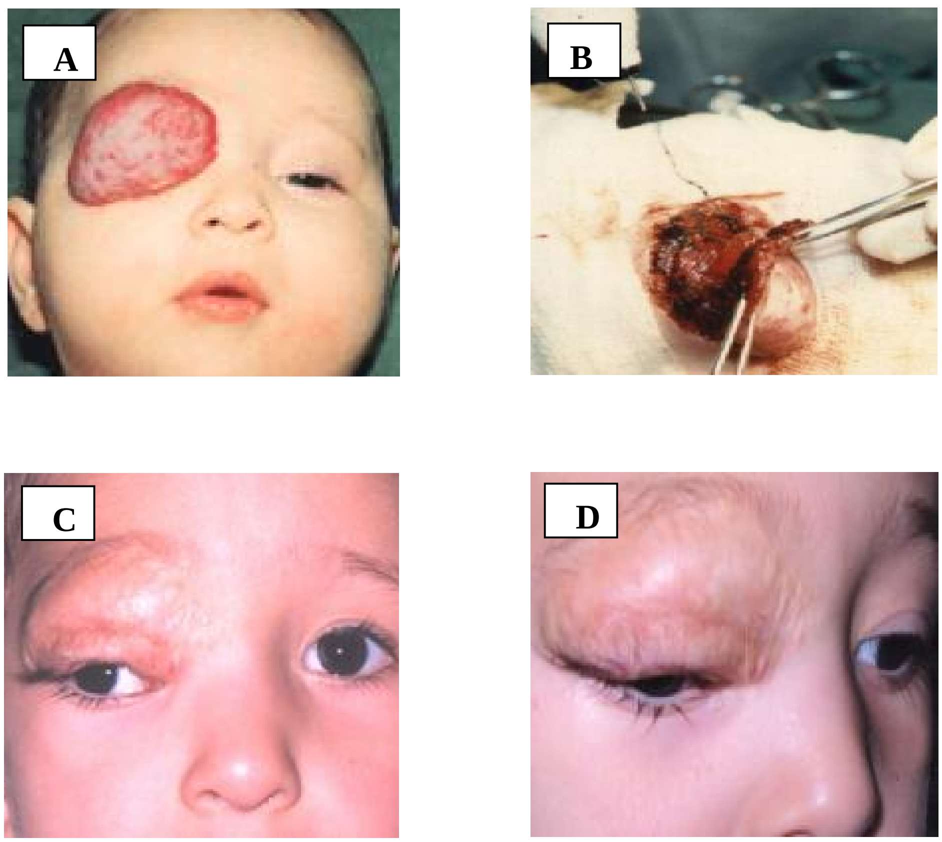

Fig. (2): A- the lesion preoperatively, **B-** bloodless debulking of the lesion via CO_2 laser, **C** and **D-** Skin grafting and eyelid movement after excision of the lesion.

Case 3:

One-year-old male with giant hairy nevus of the right side of the face was reported as case 3. Elliptical shape excision was designed and mapped to be excised from the lesion, extending from the right medial canthal area to the right angle of the mandible area using the CO_2 laser with 5 W, 100 Hz and the 2” end surgical probe. Two layers suturing using 3/0 catgut and 3/0 silk sutures closed the wound. The patient had an uneventful recovery, as shown in Fig. (3).

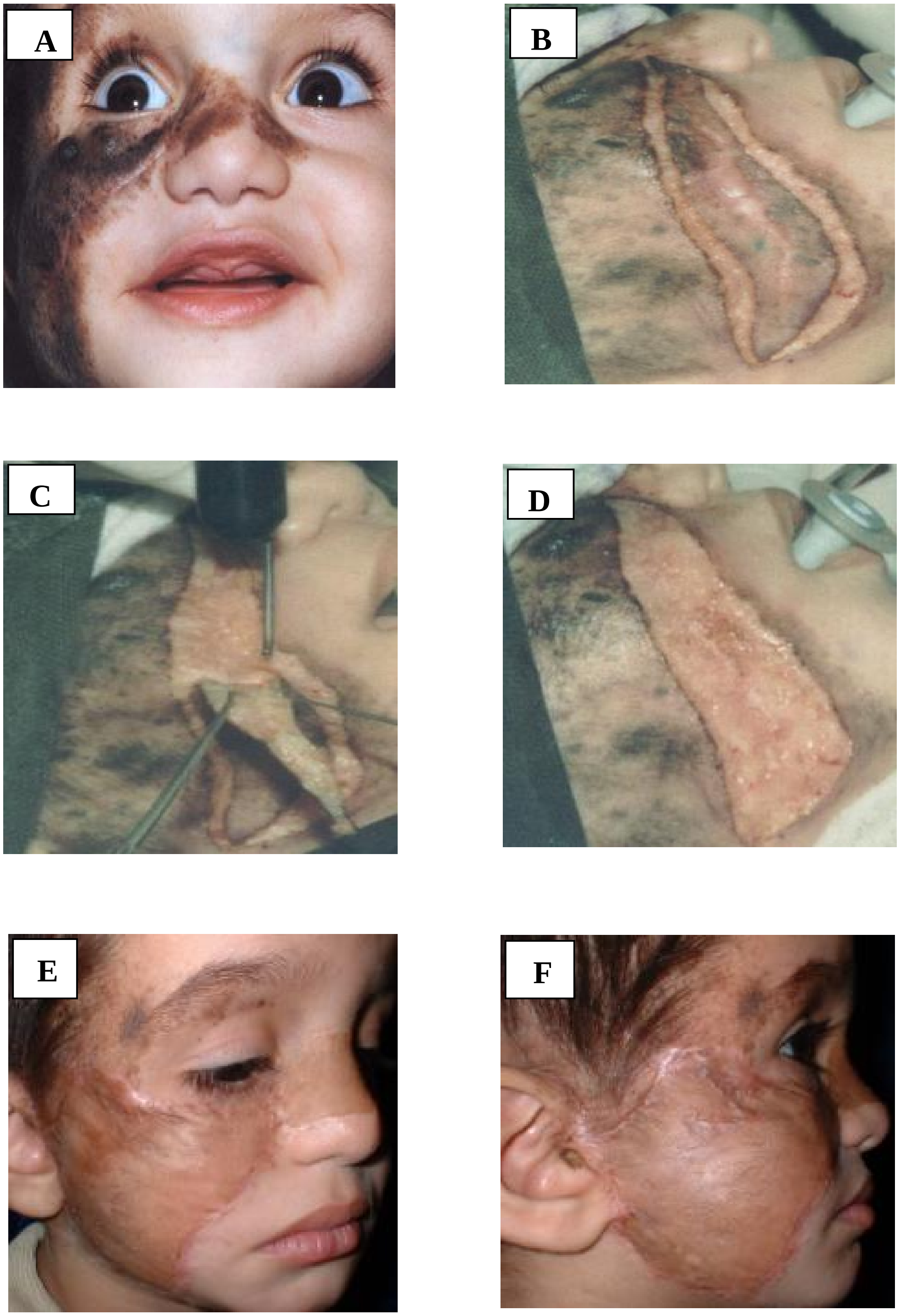

Fig. (3): A- the lesion preoperatively, **B**- CO_2 laser incision through the lesion, **C**- disecssion of the excised part from the lesion, **D**- bloodless partial excision of the lesion, **E** and **F**- complete lesion removal and skin grafting.

Discussion

Since the CO_2 laser is used in a non-contact fashion and no tactile sensation is felt, controlling the extent of the incision and ablation is based solely on several interacting factors related to the type of laser used, the intended target tissue, and the basic parameters of how the laser energy is being directed and controlled.

The skin and/or mucous membrane are a highly organized system composed of resident cells, extracellular matrix, blood vessels, circulating cells, sensory end nerves, and appendage; that all work together to maintain cutanuous integrity. The area, which is surrounding the laser incision in the target tissue that is irreversibly damaged due to the laser thermal effect, gives the character of coagulative necrosis (Fig. 4)

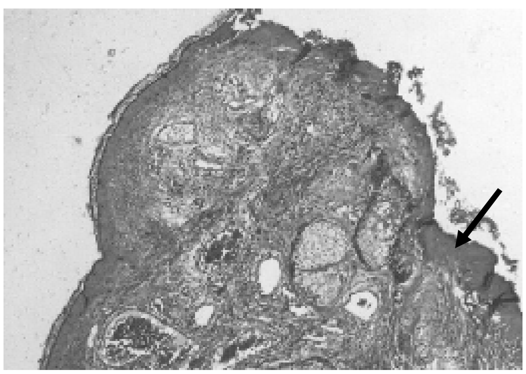

Fig. 4: Histopathological picture of the excised part. The arrow shows the coagulation due to laser cutting.

The positive effect of this coagulation that is any blood vessel smaller in diameter than the area of coagulation is sealed, providing hemostasis during surgery and sterility of the wound after surgery. For larger vessels, interruption of the incising process is required, by defocusing technique, to cause photo-coagulation to the area around the blood vessels. Also the shrinkage of the blood vessel itself reduces the blood flow within it, and then the area can be incised with better hemostasis. Brian and Jemshed proved that CO_2 laser effectively coagulates vessels up to 0.5mm in diameter as they are divided; therefore it is used for incisional surgery as a bloodless cutting tool for cutanuous surgery (Biesman and Khon, 2000).

In our series the failure to achieve complete heamostasis with laser was due to the larger blood vessels (i.e., more than 1.5 mm) met with during surgery, but using the initial defocused mode with a combination of high power , large spot size ,and low frequency (long pulse duration) resulted in shrinkage of the vessel diameter. This creates a diminished blood flow i.e., decreasing the cooling effect on the laser beam and thus aiding in the coagulation. It is more convenient, for persisting bleeding vessels, the use of other ways of hemostasis like bipolar coagulator or legation by sutures should be substituted.

Delayed healing is another manifestation of the coagulation effect of the laser beam on the irradiated tissue, which results in the obliteration of blood and hymph vessels in the irradiated tissue, leading to the interfere with the normal inflammatory process that initiates healing and wound repair, so the reduction of the wound repair mediators results in the delayed healing, but in spite of this delayed healing, laser wound healed with less scarring. Fisher and Frame observed that, within the irradiated areas, the healing epithelium proliferated over the fibrinous coagulation. We did not observe any problem regarding the healing presses of the laser wounds.

Laser gives an immediate sterilization at the surgical site, and it is difficult to refuse this clinical observation based on the action of the laser on the cellular architecture. Such action leads to decrease the population of the microorganisms in the wound. Due to the thermal build up at the operated site.

Our added observation is the decreased pain at the site of the incisions. This is well explained by the fact that laser will seal the fine nerve endings at the incision and consequently result in less postoperative pain.

Conclusions

1- It is important to advice that the laser device is an optical power generator and carefully considers the combination of laser wavelength, fluence and time of exposure.
2- Understanding the physics of the CO_2 laser and the complex interaction of the infrared laser energy with soft tissue are of critical importance for the surgeon.
3- The CO_2 laser can effectively coagulate small vessels during surgery,

and in spite of its efficiency in the superficial and thin skin incisions, the hemostatic ability is limited, because only the water in the surgical site will absorb its energy. There is no deep penetration energy of laser to provide heat for rapid vessel shrinkage.

4- The CO_2 laser can be considered as a surgical instrument used interchangeably with various other surgical devices. The treatment modality depends on the knowledge of the surgeon, training, and comfort level (equipment availability; treatment plan; desired outcome; patient demand; and cost).

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تقييم أستخدام ليزر ثنائي اوكسيد الكاربون كأداة جراحية في معالجة الاصابات المرضية في الفم والوجه

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الخلاصة **في هذا البحث ، تم تقييم التأثيرات الحيوية لليزر ثنائي اوكسيد الكاربون من خلال استغلال الامتصاص المميز لهذا الليزر من قبل الانسجة الحية لتحقيق جرح موقعي حراري محدد . أستخدم هذا الليزر كأداة جراحية مساعدة في معالجة بعض الاصابات المرضية والاورام في الفم والوجه والفكين ، وكان عدد الاصابات المرضية التي عولجت هي اربعة عشر اصابة مرضية ، سبعة منها داخل الفم والاخرى خارجه ، حيث استخدم الليزر كآلة قطع وتخثير ضوئي معا". النتائج اظهرت ان ليزر ثنائي اوكسيد الكاربون كان مؤثرا في تقليل النزف الدموي خلال العمل الجراحي ، اضافة الى كونه عامل مساعد في تقليل الاستسقاء والالم ما بعد الجراحة .**