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ORIGINAL ARTICLE

Eyelid skin tightening: a novel 'Niche' for fractional CO_2 rejuvenation

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Abstract

Background The periorbital area is a barometer of chronologic and environmental age for which patients usually seek rejuvenation; fractional CO_2 laser plays a key role among the variety of available dermatologic treatments.

Objectives The purpose of this study is to evaluate the efficacy and safety of Fractional CO_2 laser in eyelid tightening and periorbital wrinkles.

Methods Forty-five patients received a range of 2–3 treatments in the upper, lower eyelids and periorbital area with a fractional laser device. Photographs were taken before and after each treatment and 2 weeks, 4 weeks, 3 months, 6 months and 12 months after the final treatment. The results were judged by three dermatologists who had not taken part in the treatments.

Results One year after the last laser session, all patients showed global improvements in eyelid skin tightening: five patients (11.1%) achieved excellent improvement, 11 patients (24.5%) marked improvement, 15 patients (33.3%) moderate improvement and 14 subjects (31.1%) slight improvement. At the 1-year follow-up, the percentage of subjects with a lift in their eyebrows and consequently a widened palpebral fissure was 82.2 (37 patients), whereas 17.8% (eight patients) showed no eyebrow elevation.

Conclusions Fractional CO_2 laser treatments allow dermatologists to achieve notable improvements in eyelid skin tightening, and eyebrow elevation safely and without significant side-effects.

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Conflicts of interest

None declared.

Introduction

The periorbital region is like a barometer of chronologic and environmental age for which patients often seek cosmetic rejuvenation. Anatomic changes occurring in this region caused by ageing include laxity of eyelid skin, 'hypertrophic' orbicular oculi muscle, prominent orbital fat pads, and even descent of the forehead, eyebrows, and mid-face. Clinically photoaged skin is wrinkled, blotchy and leathery; eyelid laxity is often the cause of senile ectropion and entropion and may also cause epiphora and laxity of the medial and lateral canthal tendon. A variety of dermatologic treatments[1–16] are available for eyelid tightening and periorbital skin rejuvenation, such as topical therapy,[1] chemical peels[1–3], dermoabrasion,[1,4,5] botulinum injection,[1,6–10] radiofrequency[11–16] and laser resurfacing,[17,18] all with the relative benefits and risks (Table 1). Dermatologic surgery has been revolutionized with the development and clinical expansion of laser technology. Cutaneous laser resurfacing with carbon dioxide (CO_2) laser involves the vapourization of the entire epidermis as well as a variable thickness of the dermis. Water-containing cells in the epidermis and dermis can be preferentially targeted by laser light (a monochromatic 10 600 nm light). In addition to the layer-by-layer CO_2 vapourization, collagen shrinkage also results from thermal denaturation of type I collagen. The laser-induced dermal injury is thought to promote collagen deposition, with a wider zone of fibroplasia. The combination of vapourization, collagen shrinkage and collagen deposition accounts for the clinical improvement seen. Fractional photothermolysis has recently been introduced in laser technology[17,18] and given rise to new applications of CO_2 laser. This is a laser system that produces arrays of micro-ablative zones (MAZs) and micro-thermal zones (MTZs) of injury while sparing the surrounding tissue. As these MAZs and MTZs are surrounded by normal tissue, keratinocyte migration distance is shorter, healing is faster and the risk of side-effects is reduced: the most of which include transient and mild erythema, facial oedema, dry skin, flaking, sparse superficial scratches, pruritus and bronzing. The use of forced cold air during treatment has been shown to reduce discomfort.

Table 1 Dermatological non laser treatments currently in use for periorbital skin rejuvenation

Type of treatment	Description	Adverse effects
Topical therapy: tretinoin (retinoic acid)	The use of 0.05% and 0.1% tretinoin cream for 6 months leads to an increase in epidermal and granular layer thickness. The improvement seen in skin texture is attributed to hyaluronic acid deposition and compaction of the stratum corneum	A limited factor may be its tendency to cause skin dryness. Sometimes the patients report burning, itching and redness especially immediately after the application
Alpha hydroxy acids	They exert the epidermal effect at the stratum corneum–stratum granulosum junction. The increased skin thickness is caused by increased synthesis of glycosaminoglycans, collagen and elastic fibres. Included in this class of acids are glycolic, lactic, malic and citric acid. Higher concentrations of this acid are used for chemical peels	Almost when they are used as chemical peels, tend to have more severe side-effects including blistering, burning and skin discoloration, although they are usually mild and go away a day or two after treatment
Chemical peels: superficial peels Glycolic acid	Glycolic acid at 20–70% concentration is a more popular agent used for superficial c. peeling. It is usually performed in a series of 4–6 treatments at 1- to 6-week time of intervals to improve skin shallowness, dyspigmentation, fine wrinkles	Almost if it is used in higher concentration, it makes the skin more prone to sun damage. Another normal side-effects are swelling and a stinging sensation, skin dryness, flaking and scarring
Trichloroacetic acid	It is a versatile peeling agent because the concentration may be adjusted to achieve the desired depth of peel. Generally it is used at 15–20% concentration. Partial epidermal exfoliation occurs with 20% of TCA. The application causes transient frosting and erythema	Application of TCA causes transient frosting and erythema
Medium peels	Use of agents or a combination of agents to produce an injury depth down to the upper reticular dermis. For example, eyelid may be peeled with TCA 20–35%	Oedema with minimal discomfort is typical for the first 48 h. After partial resolution of the oedema, crust formation ensues, with epidermal separation occurring 4–8 days after the procedure
Deep peels	Involved the use of chemoexfoliants that penetrate to midreticular dermis. Indication for their use includes deep rhytides secondary to photodamage. An example is Baker's formula with phenol at 80%	Complications including prolonged erythema and post-inflammatory hyperpigmentation. Hypertrophic scarring can occur (also systemic damage such as cardiac arrhythmias for the systemic absorption of phenol)
Botulinum injection	Dermatology use of Botox has usually been limited to glabellar furrows, but its used has expanded to the treatment of forehead and periorbital rhytides. Use of this treatment either prior to or after periorbital laser resurfacing augments the effects of the laser and helps maintain the improved appearance of wrinkles. The treatment goal is muscle weakening, not paralysis	Reported adverse effects are: worsening of pre-existing fat herniations, temporary droop of the lateral lower eyelid, and skin redundancy beneath the lateral lower eyelid
Dermoabrasion	It is a process of surgical skin planning whereby a wire brush or diamond fraise attached to a rotary instrument is used to abrade the skin, effectively removing the epidermis and the upper and middle dermis, including the upper portions of adnexae. Re-epithelialization and repigmentation occurs from the adjacent hair follicles and residual adnexal structures	Because it is best to have an immobile and relatively rigid skin surface on which to work, eyelid and periorbital regions are almost impossible to treat with dermabrasion. Moreover, the procedure is bloody, rendering intra-operative visualization of the skin difficult
Radiofrequency	This is a non-invasive, no-surgical procedure to correct lower eyelid skin laxity; it produces volumetric tissue heating, which leads to an immediate conformational change in dermal collagen, tightening of the fibrous septae extending from the dermis to the subcutaneous tissue, and stimulation of dermal neocollagenesis. It is well tolerated	It is generally well tolerated. Reported as immediate and usually transient events are almost erythema and oedema (sometimes lasting). Others may be abrasions, hyperpigmentation, blistering, blanching and purpura. Less frequently scars and ulcerations may occur

The purpose of this study is to examine the efficacy and safety of the fractional CO_2 laser in eyelid tightening and periorbital wrinkles.

Materials and methods

A total of 45 patients, 39 women and six men, mean age of 56.3 (range 41–69 years), Fitzpatrick skin types I–III, mainly I and II, were treated with fractional CO_2 laser for a maximum of 1 year. The patients were enrolled in the study after obtaining a detailed personal history (skin type, clinical manifestations, health conditions, previous medications and life-style) and informed consent for treatment. The subjects presented the typical hallmarks of periorbital ageing such as expression lines, rhytides, wrinkles, eyelid skin laxity, dermatochalasis, lowered brows, lateral hooding and

prominent fat pads, plus a tired or not alert expression and the need for heavy make-up. The patients received a range of 2–3 treatments in the periorbital area at four weekly intervals, with the SmartXide DOT (DEKA-M.E.L.A., Calenzano, Italy) fractional CO_2 laser device. Each treatment session consisted of only one pass per area, many successive and consecutive pulses (1–5) in the same point (DOT) without moving the scanner ('scalpel effect') using the novel 'Pulse Stacking' function (Fig. 1). This function allows deeper penetration thanks to the possibility of repeating laser pulses with the same parameters over the DOTs during the same scanner passage; this particular function allows the fractional CO_2 laser to achieve many different effects, further enhancing its great versatility. The settings included: 15–18 W power, 500–800 μm DOT spacing, up to 350 μm spot size, 600–1000 μs dwell time, up to four stacking (Fig. 1). We started from the lowest parameters, 15 W, 600–1000 μs dwell time, Stack 1–2, up to the highest, 18 W, 600 μs dwell time, Stack 4, depending on the anatomical features of the periorbital areas such as the eyelid skin thickness, and the downtime tolerated by patients. In fact, only in few cases with clinically thicker skin, we chose increased parameters such as 18 W, 600 μs dwell time and Stack 3–4; because by analyzing the histological results, we discovered how the use of these 'extreme' parameters(18 W, 1000 μs dwell time and Stack 4), made it possible to reach a depth of 500 μm. The areas treated included the upper and lower eyelids as far as the eyelashes and the orbital rims and lateral periorbital skin. Several minutes before starting treatment, patients were administered three drops of topical ophthalmic anaesthetic, oxybuprocain, to the eyeballs to reduce discomfort, and two special spoon-shaped metallic shields (Cox II, Oculo-Plastik Inc., Montreal, Canada) were applied under the lower and upper eyelids with a rubber vacuum applicator to protect the eyes. Patients were instructed to avoid sun and cosmetics during the immediate post-procedural periods and to apply cool compresses, emollient creams and sunscreens until complete re-epithelization. An antibiotic ointment and antiviral cream was also applied to the target areas for 7 days after each laser session. Photographs were taken with a Canon digital camera and a polarized flash (Anthology System, DEKA-M.E.L.A.), before and after each treatment and 2 weeks, 4 weeks, 3 months, 6 months and 12 months after the final treatment. The pictures were standardized using the same camera, shooting setting, twin flash, ambient light and chin holder to guarantee the same distance. The results were judged by three dermatologists who had not taken part in the treatments and who assessed the performance of this fractional CO_2 laser by dividing the results into four categories of eyelid skin tightening improvement and periorbital fine-line and rhytide clearance and overall assessing of skin laxity and skin texture: 0–25%, 25–50%, 50–75%, 75–100%. The same photographs were used by the observers to evaluate the eyebrow elevation: a horizontal line was traced on the images from the medial to the lateral canthus, and a second line was drawn perpendicular to the horizontal ones, from the pupil to the midpoint of the eyebrow. This distance along the vertical line, between the pupil and the eyebrow, was considered the measure of eyebrow elevation. The observers quantified the elevation with the following elevation categories: 0–1, 1–2, 2–3, 3–4and >4 mm. Patients were asked for a subjective evaluation of the results by means of the following score: unsatisfied, not very satisfied, satisfied, very satisfied.

Results

One year after the last laser session all the patients observed global improvements in eyelid skin tightening, skin laxity, skin texture, and periorbital fine line and rhytide clearance(Figs 2–4) (Table 2): five patients (11.1%) achieved excellent improvement, 11 patients (24.5%) achieved marked improvement, 15 patients (33.3%) achieved moderate improvement and 14 subjects (31.1%) achieved

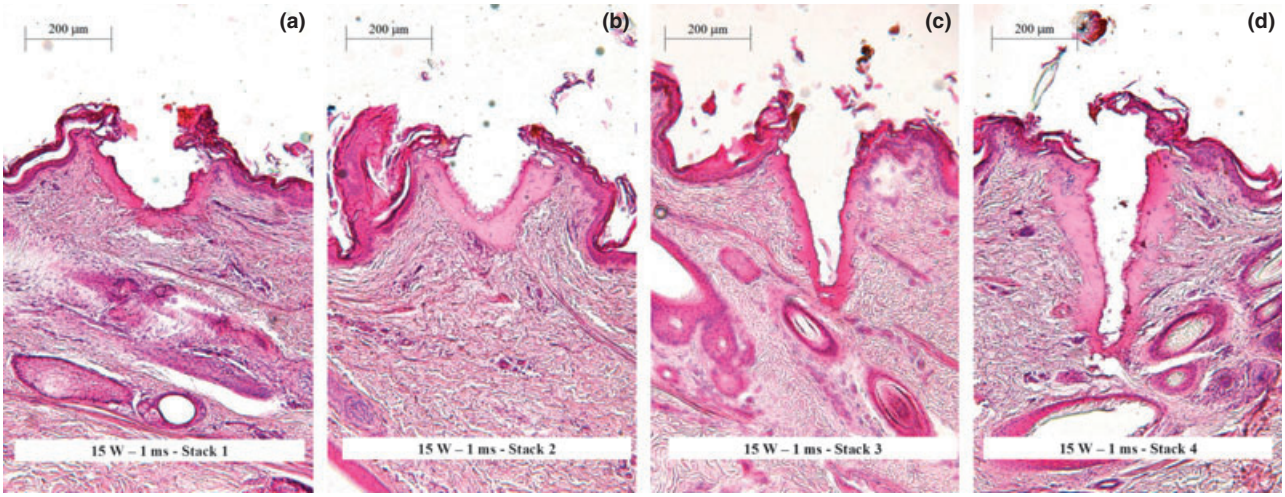


Figure 1 The Pulse Stacking mode in histological *ex vivo* specimens. (a) Stack 1 (b) Stack 2 (c) Stack 3 (d) Stack 4.

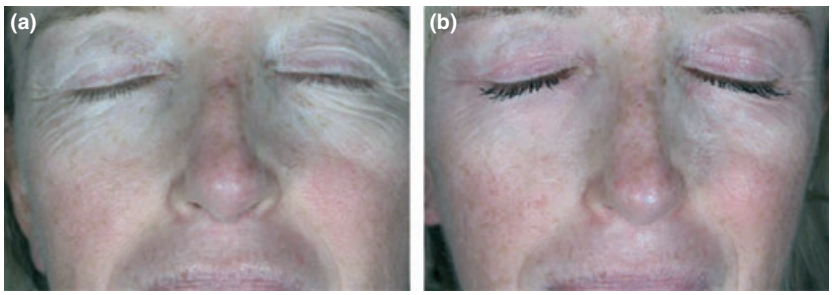


Figure 2 (a) At baseline. (b) Global improvements in eyelid skin tightening, skin texture and periorbital fine lines after fractional CO_2 laser treatments.

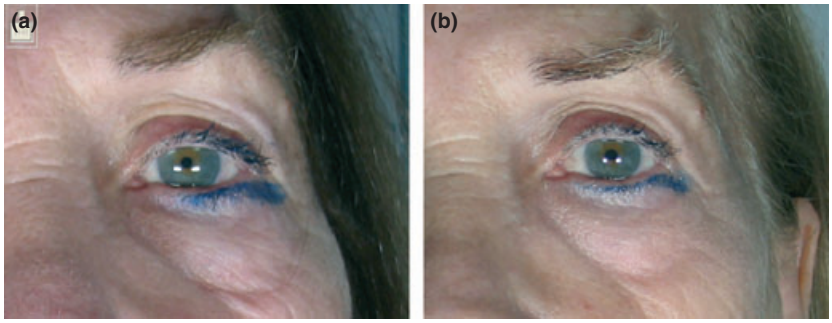


Figure 3 (a) At baseline. (b) Improvements in lower eyelid fine lines, a lift of upper eyebrow and a widened palpebral fissure after three fractional CO_2 laser treatments.

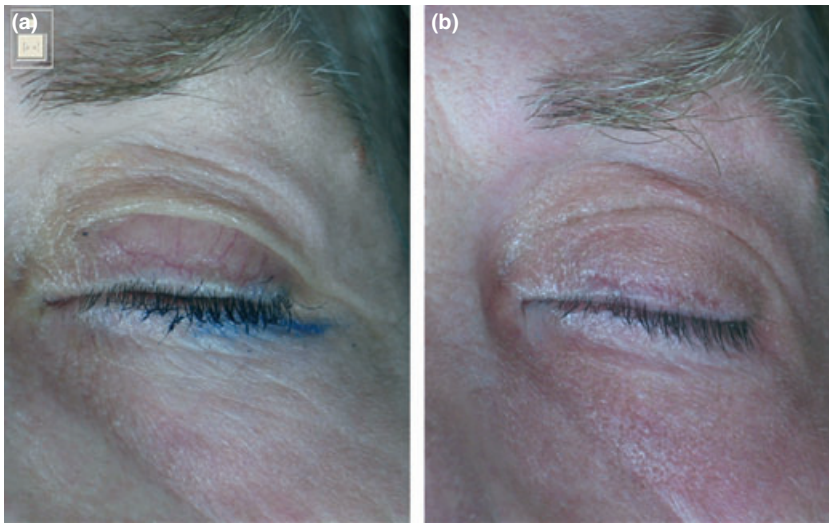


Figure 4 (a) A particular of Figure 3, at baseline. (b) It shows the improvements of the periorbital skin texture, after three treatments.

slight improvement. At the 1-year follow-up, 82.2% (37 patients) showed a lift in eyebrows and widened palpebral fissure (Figs 5–7), whereas 17.8% (eight patients) had no eyebrow elevation. Among the 37 patients with increased eyelid aperture, 20 (54.1%) obtained a brow elevation of 0–1 mm, 13 (35.1%) a brow elevation of 1–2 mm, three (8.1%) a brow elevation of 2–3 mm, one patient (2.7%) a brow elevation of 3–4 mm and no patients with an elevation exceeding than 4 mm after one year. The patients'

Table 2 Global improvements in eyelid skin tightening, skin laxity, skin texture, and periorbital fine line and rhytide clearance

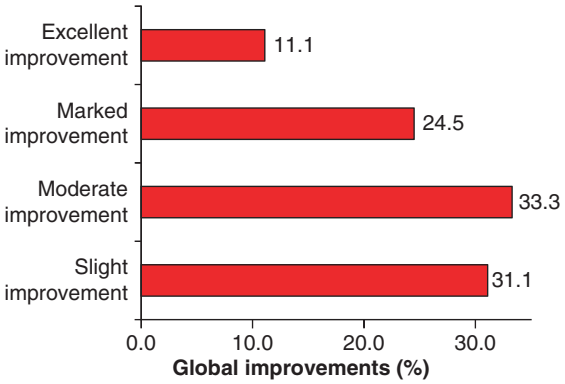
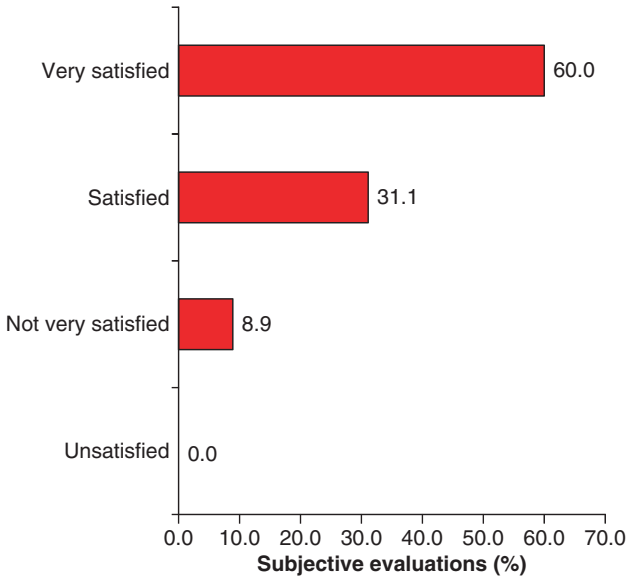


Table 3 Subjective evaluations show that the vast majority of subjects were satisfied or very satisfied



subjective evaluations were: 27 (60%) very satisfied, 14 (31.1%) satisfied, four (8.9%) not very satisfied with the results, whereas no patients were unsatisfied (Table 3). Four patients were not very satisfied, three as a result of long-term erythema (Fig. 8) produced by the use of higher parameters and slow healing which did not allow them to go out in public for the first 5 days after treatment;

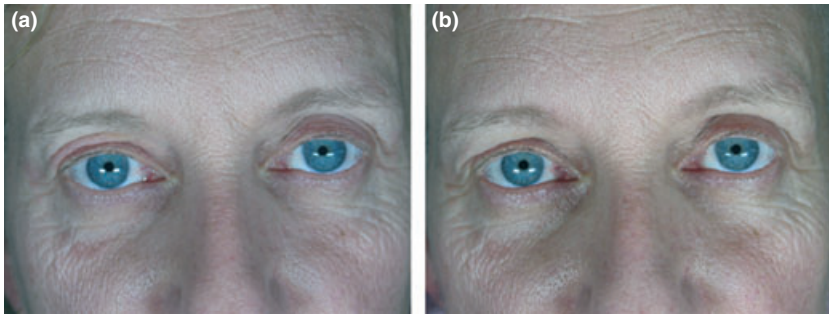


Figure 5 (a) At baseline, the patient shows a particular difference between the two palpebral fissures. (b) Improvements in upper eyelid fine lines and widened palpebral fissures after two fractional CO_2 laser treatments.

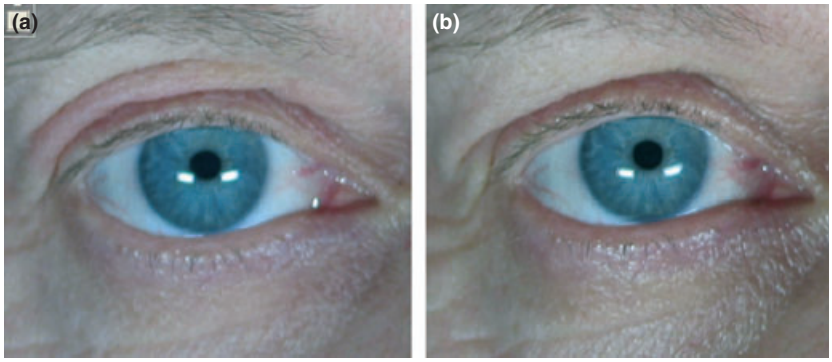


Figure 6 (a) Right eye of the patient in Figure 5, at baseline. (b) An upper eyebrow elevation and widened palpebral fissure, after two treatments.

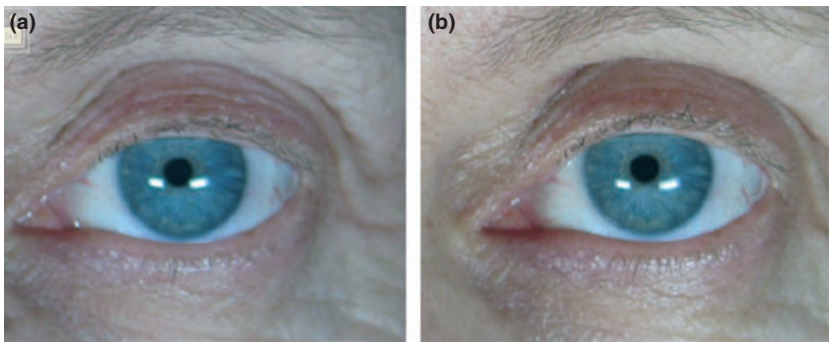


Figure 7 (a) Left eye of the patient in Figure 5, at baseline. (b) An upper eyebrow elevation and widened palpebral fissure, after two treatments.

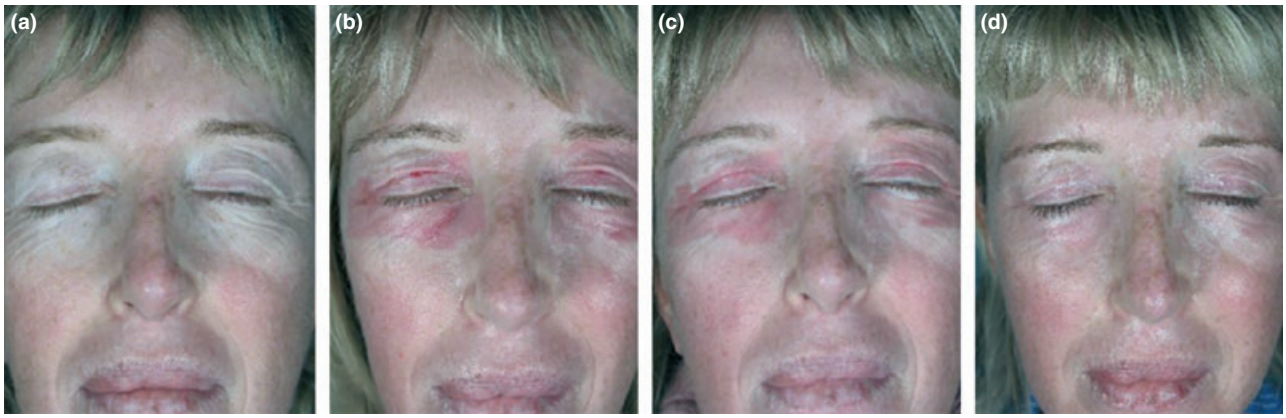


Figure 8 Long-lasting erythema during 3 months, which involved three patients of the study. (a) At baseline; (b) 2 weeks after the treatment; (c) 4 weeks after the treatment; (d) 12 weeks after the treatment.

Table 4 Reactions after fractional CO_2 treatment in 45 patients

Predictable side-effects	Duration (days)	No. patients
Redness	3–7	42
Long-lasting erythema	7–28	3
Purpura	7	1
Visible swelling	3–7	24
Crusting	3–5	8
Hyperpigmentation	–	0
Hypopigmentation	–	0
Blisters	–	0
Scars	–	0
Moderate to mild pruritus	4–8	6
Discomfort	1–2	3
Serious infections	–	0

the other patient was not very satisfied because of the results not corresponding to her expectations. Despite a few predictable side-effects (Table 4) such as redness, swelling, crusting (Fig. 9), mild pruritus, and discomfort, there were no serious adverse effects such as hyperpigmentation, hypopigmentation, blisters, scars or post-treatment infections in the majority of patients who were therefore very satisfied, especially in view of the clinical outcome. The post-treatment phase was very important for preventing adverse effects.

Discussion

The fractional CO_2 laser system enables faster healing, reduced downtime and risk of side-effects, and enhanced patient compliance. This laser corrects skin laxity, one of the most relevant factors in eyelid ageing; however, it cannot reduce or remove fat herniation or muscle hypertrophy of the eyelids for which surgical blepharoplasty is necessary.[19,20] Nevertheless, the fractional laser approach ensures excellent results for a large majority of subjects only with skin laxity who are seeking non-invasive treatment of the eyelids and the periorbital areas.[21] Thanks to its special features, the fractional CO_2 laser is able to achieve many different effects, further enhancing its great versatility. The scanner shape and the dimensions of the scanner mode can be adapted to treat difficult regions such as eyelid

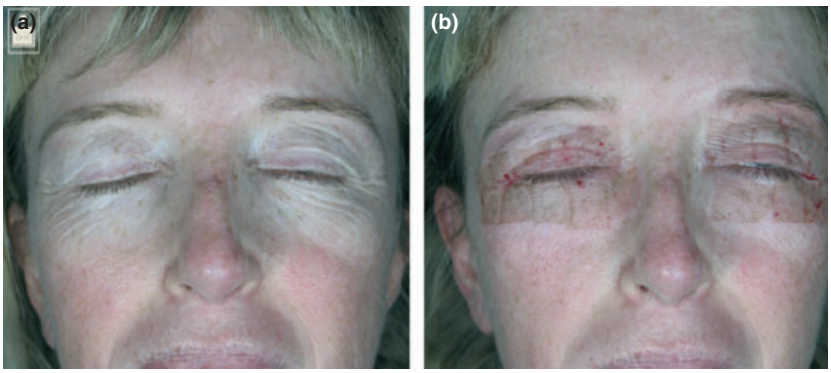


Figure 9 (a) At baseline. (b) Post-treatment fractional effect, crusting, in the treated area.

skin and the periorbital area. Another feature which increases its versatility is the possibility of selecting the distance (DOT spacing) between surrounding MAZs and MTZs, providing a resurfacing effect similar to the ablative technique with reduced spacing, or the more typical fractional effect, with greater spacing between the DOTs. The versatility of this device also derives from the 'Smart Pulse mode'; this function allows physicians to obtain two different effects in the target area to treat, depending on the patients needs and the type of treatment required. These are 'the ablative effect' and the 'thermal effect': the first, which depends mainly on the power (watts), is achieved with a fast release of high energy to the tissue causing rapid ablation of the epidermis and more superficial dermal layers; the 'thermal effect' depends mainly on the dwell time (μs) during which the heating of the deeper layers of the skin spreads to the surrounding areas and deeper areas of the micro-thermal zone (MTZ), continuing the laser effect. Thanks to the Smart Pulse mode the physician is able to deliver the desired amount of heat to the target tissue. A new important function that we have used in this study is the novel 'Pulse Stacking mode'. Each treatment session consisted of numerous successive and consecutive pulses (1–5) in the same point without moving the scanner ('scalpel effect'). This function allows deeper penetration thanks to the possibility of repeating the laser emissions, with the same parameters over the DOT before moving on to the next DOT during the same scanner passage (Fig. 1). The clinical results observed showed marked improvement with the introduction of the Pulse Stacking mode among the numerous specific functions of the fractional CO_2 laser as it allows for deeper ablations, conserving the same thermal effects but reducing relevant side-effects such as erythema. During fractional CO_2 treatment, the epidermis receives a sort of micro-ablation and heals in 24–48 h: the epidermal tissue recovery occurs rapidly via keratinocyte migration and extrusion of the damaged cells to the borders of the ablative and thermal zones; the keratinocyte migration occurs thanks to the presence of 'a reservoir' of partially differentiated cells with a high turnover and high mitotic index that are able to repair the tissue deprivation; the epidermal stratus corneum acts as a natural bandage that protects the tissue from external noxious factors while treatment effects continue in the deeper dermis. An acute phase occurs in the dermis during with the releasing of many proinflammatory cytokines and mediators, moderate collagen-fibre shrinkage and oedema. Hantash *et al.*[22,23] discovered how damaged dermal tissue is massed in columns of debris which move through the epidermis to the stratus corneum and then exfoliate. After this first phase, there is a proliferative phase with the recruitment of fibroblasts and deposition of new type III collagen fibres and dermal matrix; the last phase is characterized by collagen remodelling, when the thinner type III collagen fibres are replaced by type I collagen fibres.[24,25] The faster healing allowed patients to lead normal lives in public within the first week after the laser session, because there were no marked side-effects to hide and tolerate. Despite few predictable side-effects, the majority of patients were very satisfied, which suggests that they were able to tolerate the low downtime and side-effects associated with the laser procedure thanks to the degree of improvement achieved at the end of treatments.

Conclusions

Fractional CO_2 laser treatment can be regarded as a very promising technique in eyelid skin tightening, the reduction of periorbital fine lines, rhytides and eyebrow elevation, endowing a more youthful appearance to patients. This treatment is safe, without serious side-effects, with low downtime and increased patient satisfaction. These results can be achieved via the use of lower parameters, without the risk of side-effects from higher settings thanks to the system's Smart Pulse mode. The forecasting of results and downtime associated with skin rejuvenation treatments remains the great unknown because of the large number of variables involved. A remarkable advantage is the control of erythema associated with the Stack function, both in terms of absolute intensity and duration. These aspects are vitally important for reducing the period of 'social exclusion' imposed by the procedure. In

conclusion, our findings from clinical evaluations and experimental investigations suggest that by only irradiating a particular fraction of the total cross-sectional surface areas with the possibility of using four parameters (output power, dwell time, dot distance, Stack modes) in a flexible manner, fractional CO_2 laser preserves and enhances the efficacy of eyelid skin tightening while improving the side-effect profile.

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