
CO₂ Laser for Photorejuvenation

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Abstract

The CO₂ laser is a powerful tool in the fight against aging including extrinsic aging. The operation of this laser is based on the principle of selective photothermolysis. Water is the main target of CO₂ lasers operating at a wavelength of 10.600 nm, in the infrared portion of the electromagnetic spectrum. The rejuvenation observed after CO₂ laser treatment is the result of several phenomena that occur after laser interaction with the skin: collagen contraction and neocollagenesis, photodamaged skin removal, and peripheric thermal damage. The most frequent complications are infections, hypo- and hyperchromia, synechiae, and scarring. Fractionation of lasers greatly diminished the risk of complications that are more frequent in more aggressive treatments and when the laser is applied to non-facial areas. Although several devices and techniques to treat photodamaged skin have been developed, resurfacing with the CO₂ laser remains the gold standard for the treatment of photoaged skin.

Keywords

Lasers • Carbon dioxide • CO₂ laser • Laser ablation • Photorejuvenation • Adverse effects

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Introduction

The CO₂ (carbon dioxide) laser is a powerful tool against aging, including extrinsic aging that includes the cutaneous signs of aging that are not related to age, but to external factors the most important of which are chronic sun exposure and smoking. Contrary to what occurs with chemical peels, the CO₂ laser allows an abrasion with strictly controlled depth, which makes laser abrasion or resurfacing a safer procedure that, in experienced hands, gives the doctor and his patient a great satisfaction. Although a variety of techniques and devices to treat photodamaged skin has been developed, resurfacing with the CO₂

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laser remains the gold standard for the treatment of photoaged skin (Duplechain 2013; Kilmer et al. 2006; Hafner and Salomon 2006; Hunzeker et al. 2009).

CO₂ Laser for Photorejuvenation

Basic Concepts

The operation of the CO₂ laser is based on the principle of selective photothermolysis, developed by Parish and Anderson in 1983. This principle, which is a direct derivation of quantum theory, says that, in order to obtain tissue ablation, it is important that the tissue receives a very high amount of energy in a very short time period. Water is the main target of CO₂ lasers that operate at a wavelength of 10.600 nm, in the infrared portion of the electromagnetic spectrum. When a CO₂ laser beam focuses on the skin, it vaporizes the affected cells after they experience a temperature rise up to 100 °C in 640 mcs (Omi and Numano 2014). The improvement of the cosmetic appearance observed after resurfacing can be attributed to various factors. The first is tissue ablation by direct removal of the upper portions of wrinkles after each successive laser exposure. This ablation results from the combination of tissue vaporization in the treated area that produces a thermal coagulation necrosis of the cells below and thermal denaturation of proteins of the extracellular matrix (Khatri et al. 1999). CO₂ lasers remove between 25 and 50 μm of tissue in each pass (Weinstein 1998). This means that the clinical improvement observed in the wrinkles should also be attributable to other reasons.

During the laser abrasion procedure, immediate contraction of the skin can be observed. Although part of this contraction is due to dehydration by water evaporation, the instantaneous retraction of collagen can also occur, since it is known that collagen shrinks when exposed to temperatures above 60 °C (Fitzpatrick 1996). However, although collagen contraction by dehydration or retraction lasts only 14 days after resurfacing, a continued improvement up to a year can be seen in patients (Seckel et al. 1998).

This improvement appears to be a result of the deposition of newly formed collagen and reorganization of the dermis, the extent of which appears to be dependent on the residual thermal damage caused by the laser (Khatri et al. 1999).

The rejuvenation observed after CO₂ laser treatment is therefore a result of several phenomena that occur after laser interaction with the skin: collagen contraction and neocollagenesis, photoaged skin removal, and peripheral thermal injury (Campos and Gontijo 2010; Omi and Numano 2014). It is noteworthy that immediately after the procedure, collagen contraction occurs, and 3–6 months after the laser is applied to the skin, there is a new contraction secondary to the remodeling of collagen (Tierney and Hanke 2011). Electron microscopy studies revealed a decrease in the average diameter of collagen fibrils consistent with deposition of collagen type III after performing fractional laser (Berlin et al. 2009).

History

The CO₂ laser was one of the first lasers to be used. It was initially developed in 1964 by Patel and colleagues at Bell Labs in the USA. It was considered the ideal laser for surgical treatment due to its high affinity for water (Kaplan 2007).

In the early 1990s, the CO₂ laser was the biggest advance among the treatments for epidermal ablation and subsequent induction of a new skin with a more youthful appearance. Later pulsed CO₂ with a computerized scanner were used with excellent results. These first CO₂ lasers were fully ablative and even though they provided extremely satisfactory results, the need for sedation, the great down time period, and the greatest risk of complications such as scarring and dyschromias gave way to fractional resurfacing.

The ablative fractional laser was introduced in 2006 and is responsible for localized disruptions in the epidermis while keeping the skin around intact. Fractionation permits deeper layers of the skin to be reached (up to 1,500 μm) depending on the amount of energy delivered to tissue. Despite the indisputable greater security of fractional laser

compared to fully ablative CO₂, the results achieved are not as efficient for rejuvenation and acne scars (Kaplan 2007).

Indications and Contraindications

Skin rejuvenation is the best indication for CO₂ laser treatments. It can be used not only on the face but also on extra-facial areas like the neck, chest, hands, and arms due to fractionation. Besides rejuvenation, CO₂ laser devices have been used to treat several other conditions such as surgical and acne scars, stretch marks, actinic keratoses, seborrheic keratoses, warts, rhinophyma, sebaceous hyperplasia, nevi, and angiofibromas (Hunzeker et al. 2009; Omi and Numano 2014).

CO₂ laser should be used with caution in higher phototypes (IV above) and is contraindicated in black skin. It should not be done in patients with keloids, vitiligo, and photosensitizing diseases and in patients with active infections including herpes virus infections. It should not be done in patients taking anticoagulants, and it is recommended to wait 6 months after completion of oral isotretinoin before undergoing CO₂ laser treatment.

Laser Procedure

Pre-laser

Patients should be carefully oriented about the procedure. The average downtime from the daily activities varies from 3 to 7 days depending on the intensity of treatment. Antiherpetic therapy is particularly necessary in cases of recurrent herpes history and when more aggressive parameters are to be used. Either acyclovir, famciclovir, or valacyclovir can be administered starting 3 days before the procedure and being maintained up to 4 days following the procedure or after complete epithelialization has taken place.

During the Laser

The duration of each application depends on the ability of the laser surgeon. Care should be taken to ensure that the patient is comfortable during the

procedure. Naturally, potent topical anesthesia should be applied and fully and carefully removed before lasing. Often it is necessary to use tumescent anesthesia and nerve blockade. Devices that release cold air and application of ice bags on the treated area can be useful to help the patient tolerate the treatment.

Post-laser

Immediately after the procedure, cold compress of saline or thermal water may be used. Healing creams and vaseline may also be used. The use of topical antibiotics is controversial. Sunscreens and makeup can usually be used after the third day. Close monitoring of patients is of the utmost importance for early identification of any complications (Figures 1, 2 and 3).

Side Effects and Their Management

The incidence of complications was greatly reduced with the laser fractionation. However, they may still happen especially in more aggressive treatments and when extra-facial areas are lased (Duplechain 2013; Campos and Gontijo 2010). According to Shamsaldeen et al. (2011) and Campbell and Goldman (2010), complications occurred in 15% of the patients treated.

The most commonly reported complication is transient hyperpigmentation, which takes place between 5% and 83% of patients, especially those with darker skin (types III and IV on the Fitzpatrick classification) (Fitzpatrick et al. 1996). In another series with 749 patients, the most common complication was persistent erythema, which occurred in all patients after the laser. After erythema, hyperchromia occurred in 32% of these patients (Berwald et al. 2004). Hyperpigmentation usually appears between 2 weeks and 2 months after the disappearance of erythema. Depending on the degree of skin irritation, topical tretinoin and hydroquinone should be started between 2 and 6 weeks after the procedure or immediately after completed re-epithelialization, in case of post-inflammatory hyperpigmentation (Ratner et al. 1999).

Fig. 1 Before and after CO₂ Laser

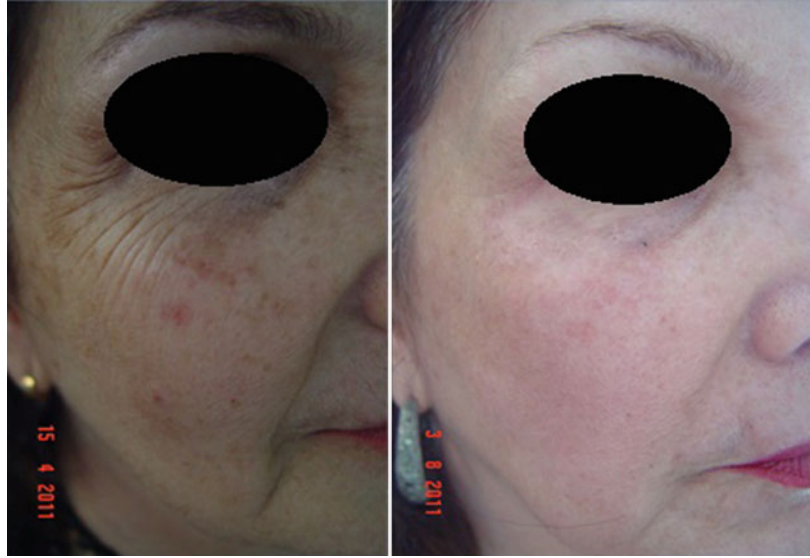
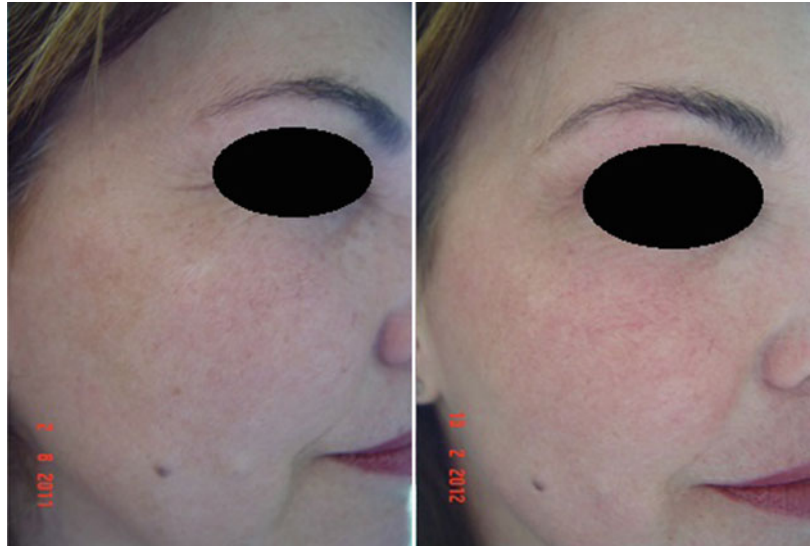


Fig. 2 Before and after CO₂ Laser



Infections can also complicate resurfacing between 2 and 10 days after the procedure, increasing the risk of hypertrophic scars. *S. aureus*, *P. aeruginosa*, *S. epidermidis*, and *Candida* sp. are the most common agents. The presence of pustules in the early postoperative or pain indicates the need of cultures and antibiograms to search for these agents. In mice, CO₂ laser resurfacing reduces the microbial count of microorganisms as compared to the

normal skin flora, which can explain the rarity of infectious complications in practice (Manolis et al. 2006). Infection with *Candida* species can be controlled with oral or topical antimycotics such as itraconazole or fluconazole. Some recommend the systematic use of an imidazole derivative in all patients after the laser. Similarly, herpesvirus infections can be seen, usually in the first week after the procedure (Ratner et al. 1999).

Fig. 3 Before and after CO₂ Laser



Hypopigmentation, when it occurs, tends to be a late and permanent phenomenon in extremely photoaged patients after the disappearance of erythema. There is evidence suggesting that the suppression of melanogenesis instead of melanocytes destruction is the most important mechanism (Helm and Shatkin 2006; Hunzeker et al. 2009.).

Synechiae may occur when two adjacent areas have lost their epithelium and remain in constant contact during the re-epithelialization process and are more often observed on the upper eyelids. Acne and milia occur in up to 83.5% of patients, especially those with very oily skin and when very thick sunscreen products are used. The most feared complication is the formation of hypertrophic scars. They occur only rarely and are usually due to improper selection of patients for resurfacing, poor technique, carelessness, or infection in the immediate postoperative period. The more predisposed individuals are those who were on systemic isotretinoin up to a year before resurfacing or who have keloids. Another complication appearing in patients previously subjected to blepharoplasty or rhytidectomy is ectropion. Although ectropion may be transient, it does not always involute spontaneously and sometimes requires surgical correction (Ratner et al. 1999; Rendon-Pellerano et al. 1999) (Figs. 1, 2, and 3).

Take Home Messages

- CO₂ laser is the gold standard treatment of photodamaged skin.
- CO₂ laser has water as a target and operates at a wavelength of 10.600 nm.
- CO₂ laser promotes collagen contraction and neocollagenesis addition to removing the photodamaged skin.
- Fractional CO₂ laser application is a safe procedure and has a low complication rate.
- Treatment of extra-facial areas may be associated with increased risk of complications.

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