Carbon Dioxide Laser Rejuvenation of the Facial Skin

Kasra Ziai, MD[a], Harry V. Wright, MD, MS[b,*]

KEYWORDS

• Laser • Carbon dioxide laser • Facial rejuvenation • Facial resurfacing

KEY POINTS

- It is imperative to identify the goals of the patient and his or her definition of an optimal outcome.
- A careful patient examination and a solid foundational understanding of basic laser physics are important to determine if the proposed intervention can meet those goals.
- Facial skin resurfacing is focused on reestablishing the smooth, elastic, and firm appearance characteristic of youthful skin.
- Advances in both technology, techniques, and pre and postoperative skincare allow for significant skin tightening, reduction in rhytid burden, high patient satisfaction, and a manageable side effect/complication profile.

INTRODUCTION

Aesthetic rejuvenation of the facial skin focuses on restoring the quality and contour of the skin with special attention to a regional harmony of the final outcome. As individuals age, the skin of the face and neck thins, loses elasticity, and develops dyspigmentations, textural irregularities, and rhytids as photoaging accumulates. Under the combined influences of gravity, the mimetic musculature of the face, soft tissue volume alterations, and physical habits (such as unfavorable sleep positioning or tobacco use) both fine and coarse creases develop. These changes characterize the individuals' dissatisfaction with the appearance of their facial skin and their desire to seek correction.

Various surgical and nonsurgical techniques are used alone or in combination to restore a youthful appearance to the facial skin and deliver the desired result of restoration. Laser resurfacing offers the advantage of improved control and reproducibility in comparison to traditional methods of chemical peeling and dermabrasion, though these are still used in aesthetic facial rejuvenation.[1,2] Although other types of therapy exist to target the components of photoaging (eg, erbium:yag, Nd:YAG, IPL, PDL, and so forth), one of the most commonly used treatments for resurfacing is the CO_2 laser. CO_2 lasers induce a thermal wound which provides the characteristic ability to both coagulate and induce intense collagen remodeling within the dermis.[3–5]

In this article, we focus on the fractionated CO_2 laser, long considered the gold standard for facial skin rejuvenation. Although many different devices exist, what follows is a description of how the senior author uses an Ultrapulse CO2 laser (UltraPulse Encore; Lumenis Ltd, Yokneam, Israel), customizing the procedure to each patient with the principles and rationale behind each protocol.

Funding/Support: None.
[a] Department of Otolaryngology–Head and Neck Surgery, The Pennsylvania State University, Milton S. Hershey Medical Center, Hershey, PA 17033, USA; [b] Wright Spellman Plastic Surgery, 5911 N. Honore Avenue, Suite 120, Sarasota, FL 34243, USA
* Corresponding author. Wright Spellman Plastic Surgery, 5911 N. Honore Avenue, Suite 120, Sarasota, FL 34243.
E-mail address: dr.hvwright@gmail.com

Facial Plast Surg Clin N Am 30 (2022) 331–346
https://doi.org/10.1016/j.fsc.2022.03.007

BASIC LASER PHYSICS

Lasers emit light energy that travels in a waveform, as does ordinary light. The wavelength is the distance between 2 successive peaks of a wave (**Fig. 1**). The amplitude is the height of the peak and is related to the intensity of the light. Frequency (or period) is the amount of time required for one full wave cycle.[6,7]

To understand laser function it is important for the operator to understand basic laser mechanics. If a photon—the unit of light energy—strikes an atom it boosts one of its electrons to a higher energy level. The "excited" atom is unstable and will reemit a photon as the electron drops to its original lower energy level, a process known as *spontaneous emission.* If that "excited" atom is struck by yet another photon, it will emit 2 photons that have the same wavelength, direction, and phase when the electrons revert to lower energy levels. One can see how a chain reaction may proceed from successive collisions, generating large volumes of coherent light. This process is known as *the stimulated emission* of radiation and is the underlying principle of laser physics.[8–10]

This laser energy is then "collimated"—made dense and parallel—by a system of opposing mirrors within the resonating chamber and then transmitted to the intended target by a delivery system (**Fig. 2**). Thus, laser light is organized, intense, and diverges very little as it travels, giving laser energy its characteristic constant intensity even over long distances.[10,11]

LASER-TISSUE INTERACTION

A laser can exert a spectrum of effects on biologic tissue, from the modulation of biologic function to vaporization, with the majority of clinically relevant systems using laser's thermal effects to coagulate and/or vaporize tissue.[8,12]

The effect of a particular laser on a specific tissue depends on the following 3 factors: tissue absorption, laser wavelength, and laser energy density.[6,12] The first 2factors are constant and inherent to the tissue and laser, respectively. Importantly the third factor, energy density, can be manipulated by the surgeon. It is critical that the operator has at least a basic understanding of laser-tissue interaction to provide maximal benefit to the patient and minimize risks.

As a laser beam impacts tissue its energy may be absorbed, reflected, transmitted, or scattered, and in laser skin rejuvenation absorption is most important. The extent of absorption depends on the chromophore content of the tissue. Chromophores are substances that absorb the energy of a particular light wavelength efficiently. For example, CO_2 laser energy is absorbed by soft tissues of the body because the target chromophore is water, which makes up 80% of soft tissue content. In contrast, the CO_2 laser has relatively minimal effect on bone (which has a low water content). Initially, as a tissue absorbs the laser energy, its molecules begin to vibrate. Absorption of additional energy causes protein denaturation, coagulation, and, finally, vaporization/ablation.[13,14]

As noted above, the modifiable factor affecting laser-tissue interaction is energy density. Energy density is equal to the power density of the incident beam multiplied by the exposure time. Power density is the power expressed in watts divided by the cross-sectional area of the laser beam (spot size), as in the following equation:

$$\textit{Power density} = \frac{\textit{Power}(W)}{\textit{Cross} - \text{sectional area of laser beam}(\textit{spot size})}$$

Power density may be seen as the amount of power (in watts) delivered to the area by the laser. Energy density, also known as fluence, simply adds the dimension of time and is expressed in joules/cm^2:

$$\text{Energy density} = \text{power density} \times \text{time}$$

Therefore, varying the spot size or the exposure time can alter the laser-tissue interaction effects (if all other factors are constant). As the spot size of a laser beam decreases (thereby increasing the power density) the amount of power reaching that particular volume of tissue increases. Conversely, as the spot size increases, the energy density of a laser beam decreases.[15–18]

Pulsing the laser energy is another method by which the surgeon can modify tissue effects via alternating periods of "power on" with periods of "power off." Because energy is not reaching tissue during the off periods, heat is allowed to dissipate during those intervals. If the off periods are longer than the thermal relaxation time of the targeted tissue, there is less risk of damaging the surrounding tissue by the conduction of heat. Energy can be pulsed by setting the time that the laser is on (for

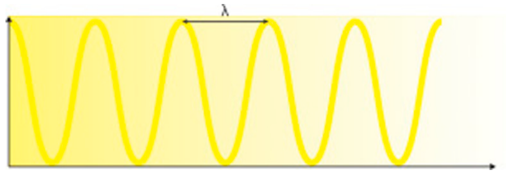

Fig. 1. Laser sine wave pattern. The wavelength (λ) is the distance between two successive peaks of a wave. (*From* Franck P, Henderson PW, Rothaus KO. Basics of Lasers: History, Physics, and Clinical Applications. *Clinics in plastic surgery.* 2016;43(3):505-513.)

example, 0.1 seconds). The energy can be shuttered, where the continuous wave is blocked during specified intervals by a mechanical shutter. In a superpulse mode, the energy is not simply blocked but is stored within the power supply of the laser during the off interval and then released during the on interval. Thus, the peak energy of the superpulse mode greatly exceeds that of the continuous or shuttered modes.[11,19–22]

TREATMENT CONCEPTS

Patients who may benefit from laser skin resurfacing include those with facial rhytids, textural irregularities, photoaging (including seborrheic and actinic keratosis, actinic cheilitis, and dyschromia), and scarring resulting from trauma, iatrogenic causes, or acne.[18,23,24] Patients who are predisposed to cancerous lesions of the face may benefit from prophylactic ablation of subclinical precancerous lesions (personal observation). Facial subunits or the entire face can be treated in one setting, and treatment can be performed concurrently with various other rejuvenation procedures including blepharoplasty and facelift.

Baker has developed a classification system that stratifies the aging process in the soft tissues of the neck and lower face (**Table 1**).[25] The Glogau scale[26] is a useful grading system for the classification of photoaging (**Table 2**) and the Fitzpatrick scale[27] is used to classify skin type and the patient's ethnicity that can determine the safety and effectiveness of resurfacing procedures (**Table 3**).

These classification systems are useful in treatment planning for facial rejuvenation and help develop the safest CO_2 laser protocol allowing for optimal skin resurfacing for each patient. For example, patients with a higher Fitzpatrick level have may be contraindicated for CO_2 resurfacing or have a higher risk of posttreatment dyspigmentation and scarring, and those with an advanced Glogau level may require more aggressive laser resurfacing or serial treatments in combination with other interventions to optimize rejuvenation. As aging is multifaceted, a multimodal treatment plan is often recommended and may include chemodenervation, skin resurfacing, liposuction/lipolysis, volumizing procedures, tightening, and so forth. It is important to identify the particular anatomic target(s) for correction as well as the patient's goals of treatment to determine the best course of rejuvenation and set realistic expectations.

Deep skin resurfacing is indicated for moderate to severe skin laxity characteristic of loss of elasticity, fine rhytidosis, and photoaging. Ideal candidates demonstrate appropriate skin type and skin condition, absence of contraindications, and (importantly) patient acceptance of procedure-specific risks and expected recovery.[28–31] The senior author prefers to treat Fitzpatrick skin types I–II but will treat type III (albeit less aggressively).

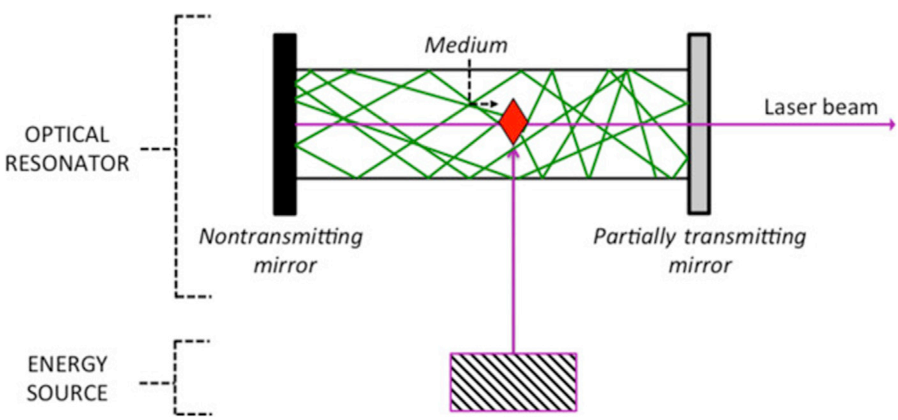

Fig. 2. Schematic diagram of laser component. Laser beam is generated by energy source, activating electrons of medium and subsequent release of protons. The Protons are then reflected by nontransmitting mirror and laser beam is released from partially transmitting mirror. (*From* Franck P, Henderson PW, Rothaus KO. Basics of Lasers: History, Physics, and Clinical Applications. Clinics in plastic surgery. 2016;43(3):505–-513.)

Table 1
Baker's classification of the aging process in the soft tissues of the neck and face

Baker's Classification	
Type 1	Slight cervical skin laxity with submental fat and early jowls
Type 2	Moderate cervical skin laxity, moderate jowls, and submental fat
Type 3	Moderate cervical skin laxity, but with significant jowling and active platysmal banding
Type 4	Loose redundant cervical skin and folds below the cricoid, significant jowls, and active platysmal bands

Importantly, patients must be willing to accept up to 2 weeks of downtime during the period of reepithelialization and accept the risks inherent to deep skin resurfacing. These include delayed healing, scarring, prolonged erythema, milia formation, and persistent dyschromia (hyper- and hypopigmentation).

Absolute contraindications include active skin infection or other inflammatory or neoplastic cutaneous disease, isotretinoin use within the past year, immunosuppression, melasma, pregnancy, lactation, history of keloids or severe herpes infections, the likelihood of poor compliance, patient nonacceptance regarding postop recovery and downtime, and unrealistic expectations regarding treatment benefits and outcomes.[32,33]

Relative contraindications include prior radiation therapy or deep burn in the treatment area, abnormal scarring, collagen vascular disease, diffuse hyperpigmentation, Koebnerizing skin conditions, inflammatory condition of the skin, severe skin sensitivity, severe lower eyelid skin laxity, and prior lower eyelid surgery.[30]

PRETREATMENT CONSIDERATIONS

Although there is no consensus for an exact protocol, in our practice we prefer to treat patients beginning the night before the resurfacing procedure with oral cephalexin (500 mg BID for 5 days), valacyclovir, and fluconazole to decrease the potential risk of postprocedural bacterial, herpetic, and fungal infections.[34–36] Although prophylactic antibiotic and antifungal therapy remain controversial.[37,38] Patients who are Fitzpatrick skin type III or are prone to postinflammatory hyperpigmentation are treated for 5 weeks prior to the procedure with a topical cream containing 0.1% tretinoin, 5% hydroquinone, and 0.5% hydrocortisone.[39–41]

Patients should arrange for a driver to and from the procedure if anxiolytics, monitored or general anesthesia, or periocular resurfacing are being used.

TREATMENT: SKIN PREPARATION

Treatment should be performed in a well-ventilated room with adequate lighting. In the operating room, CO_2 laser skin resurfacing may be performed concurrently with various other surgical procedures. In either case, the skin should be prepared gently with an appropriate antimicrobial solution per manufacturer protocol. Inflammable alcohol-containing antiseptic solutions should be

Table 2
Glogau photoaging scale

Group	Classification	Age	Characteristics
Group 1 (no wrinkles)	Mild	28–35	Mild pigmentary changes, No keratosis, Minimal or no makeup
Group 2 (wrinkles in motion)	Moderate	35–50	Early senile lentigo, early keratoses, early wrinkles, and parallel smile lines, wears some makeup
Group 3 (wrinkles at rest)	Advanced	50–65	Noticeable dyschromia, telangiectasia, deep wrinkles, visible keratosis always wear makeup
Group 4 (all wrinkles)	Severe	>60	Yellow-grey discoloration, extensive wrinkles, actinic keratosis ± history of skin malignancy, makeup cakes

Table 3
Fitzpatrick sun-reactive skin types

Skin Types	Skin Color	Tanning Response
I	Pale white	Always burns, never tans
II	White	Usually burns, tans with difficulty
III	Light brown	Sometimes burns, usually tans
IV	Moderate brown	Rarely burns, tans very easily
V	Dark brown	Very rarely burns, tans very easily
VI	Deeply dark brown/black	No burn, tans very easily

Skin types I and II are ideal candidates for CO2 laser skin resurfacing. Type III can be treated with CO2 laser but less aggressively.

avoided. The skin surface should be dry at the time of treatment.

TREATMENT: ANESTHESIA

One of the major challenges associated with laser resurfacing procedures is pain. CO_2 laser skin resurfacing can cause considerable discomfort/pain in comparison to other resurfacing procedures related to the deeper penetration and significant stimulation of dermal nerve fibers. This can be alleviated by using local or general anesthesia. Monitored anesthesia care (MAC) and general anesthesia are reserved for patients that appropriate anesthesia cannot be achieved by local anesthetics or in case of concurrent treatment with surgical procedures such as rhytidectomy.

There are multiple types of topical anesthetic agents available. One of the most commonly used topical anesthetic preparations is a Lidocaine 2.5% and Prilocaine 2.5% mixture, also known as EMLA (Astra Pharmaceuticals, Westborough, MA). Occlusion and a prolonged application will increase the penetration of EMLA cream. In most cases, the application of EMLA cream 1 to 2 hours before facial resurfacing can provide appropriate analgesia for most patients.[42,43] Topical anesthesia preparations can impact skin tissue impedance and can unpredictably affect laser-tissue interaction. This concern is related to the hydrophilic nature of topical anesthesia such as EMLA and water is the main chromophore for the CO_2 laser. However, in a study by Naouri and colleagues[44] authors did not find variability in the skin's response to CO_2 fractional resurfacing with the use of local anesthetic using high-resolution ultrasound imaging. This topic remains controversial. LMX4, LMX5, Topicaine®, Lidoderm®, and a mixture of Lidocaine 7% and Tetracaine 7% are among other commonly used topical preparations used for anesthesia.

It is not uncommon that patients will require additional anesthesia with nerve blocks (supraorbital, infraorbital, mental) or tumescent anesthesia that can be infiltrated in the lateral aspects of the face particularly in full-face CO2 laser resurfacing. Preprocedural anxiolytics (given 30 minutes before the procedure) can be helpful in patient comfort and reduce the total amount of local anesthetics necessary to maintain comfort. In a study on 200 patients undergoing CO_2 laser facial resurfacing, a combination of EMLA cream, oral diazepam (5–10 mg), and intramuscular ketorolac (30–60 mg) was demonstrated to provide adequate anesthesia in 95% of cases.[42]

Cold air cooling (cryoanesthesia) is another method to increase patients' comfort while performing laser resurfacing as well as the added benefit of thermal protection.[45,46] Cold air cooling can be used in combination with other local anesthesia methods to provide longer lasting anesthesia.

TREATMENT: SAFETY CONCERNS

The main safety concern in any laser procedure is thermal injury and the potential risk of fire. This is an environmental safety concern with a high risk in CO_2 laser procedures that can happen with fractionated oxygen levels above room air (>21%).[47,48] It is recommended to avoid supplemental oxygen (if possible) during the laser procedure. If the procedure is performed under general anesthesia and intubation is required, a laser-safe endotracheal tube should be used. Although most reported CO_2 laser-induced fires are related to oropharyngeal surgery. Cutaneous laser resurfacing seems to be safe. That being said, current recommendations suggest using a laser-safe endotracheal tube or wrapping the endotracheal tube with wet gauze. Additionally, a misfired laser beam can result in igniting patients', physicians', or assistants' clothing.[49] This risk can be mitigated by placing moist towels around the patient's head and neck during the procedure. Labeling the laser foot pedal, availability of fire extinguishers in the procedure room, having an assistant responsible for placing the laser in standby mode when not in use, and having warning signs at the entrance of the procedure room are other factors that can decrease the risk of thermal injury and fire.

Eye protection is required for both patient and physician/personnel. Metal eye/corneal shields should be used for all patients during the procedure to prevent injury to the cornea and retina. Topical ophthalmic drops are used to anesthetize the eyes then lubricating ophthalmic ointment is placed on the shields before insertion. Plastic eye shields are susceptible to thermal damage and should be avoided.[47,50] All procedure/operating room personnel should wear protective goggles with side shields to prevent direct or indirect (reflected from metallic surfaces) damage from the laser beam.

TREATMENT: DEVICE SETTINGS AND ENERGY DELIVERY

The Lumenis Ultrapulse Encore CO_2 laser offers 2 different delivery handpieces/scanners (Active FX and Deep FX) that are used individually or combined, based on the goals and the type of treatment necessary. The Active FX (or CPG) handpiece has a 1.3 mm spot size and delivers the laser beam energy in a nonsequential pattern that minimizes the risk of thermal damage. The Active FX handpiece is used for superficial ablation (fine rhytids, dyschromia, acne scarring) and usually penetrates up to the level of the superficial papillary dermis. It provides 7 different patterns (settings) with different size and density options and delivers energy from 2 mJ (150 mJ/cm2) to 225 mJ (169 J/cm2) and power ranging from 4.4 Hz to 600 Hz. Density settings can range from 1 to 9. Density 1 corresponds to 55% surface ablation while density 4 or greater corresponds to 100% surface ablation (density 2 and 3 correspond to 68% and 82%, respectively). The usual setting for facial resurfacing is 100 to 125 mJ and a density of 2 to 4. These settings should be adjusted for areas with thinner skin such as the periorbital and neck region (energy: 60–90 mJ, density: 1–3).[51,52]

The Deep FX handpiece is used for deep rhytids and scars to enhance collagen regeneration. The spot size for Deep FX (0.12 mm) is significantly narrower than Active FX and penetrates to deep dermis layers. It has four different patterns and six different size options. The settings for the energy range from 2.5 mJ to 50 mJ with the option for one pulse or two-stacked pulses. The usual energy setting for the face is 15 to 22.5 mJ with a density of 5% to 25%. Like Active FX, the settings should be adjusted for the periorbital and neck region (energy: 8–10 mJ, density 5%–15%). If combined with Active FX, then resurfacing with Deep FX should be performed first, followed by superficial resurfacing.

Facial skin resurfacing is focused on reestablishing the smooth, elastic, and firm appearance characteristic of youthful skin. The operator's technique and experience play an important role in achieving optimal results. During the procedure, the foot pedal should be placed in a comfortable position for the operator and the scanner should be held perpendicular to the target area. Immediate edema and pinpoint oozing can occur during CO_2 laser resurfacing that can be cleaned with sterile gauze soaked in saline.

TREATMENT ENDPOINT

The immediate endpoint in superficial CO_2 laser resurfacing (with or without deep resurfacing) is the removal of the epidermal layer of the skin and exposure of the papillary dermis that clinically is distinguishable with yellowing of the wound bed and pinpoint bleeding. If the depth of ablation does not extend beyond the epidermis into the papillary dermis then the likelihood of dramatic results is low, while deeper penetration of high energy laser beam beyond the papillary dermis carries the risk of scaring.

POSTTREATMENT WOUND CARE

During the initial healing period the treated skin must be kept moist with an occlusive dressing or ointment. The desiccated outer skin layers slough in approximately 4 to 10 days as the newly regenerated epithelium appears. Focal areas of slower healing apparent beyond postop day 10 may be spot treated with the same occlusive ointment. Antivirals, topical antifungals, and antibiotics may be continued. Postprocedural skin regimens vary greatly and there is no consensus as to a standard regimen. Following reepithelialization, the ointment is discontinued and both a light moisturizer and extracellular matrix modulators are started. Sun exposure and harsh wind conditions should be avoided for 6 weeks or more following epithelialization. Mineral-based camouflage makeup may be started within a week after reepithelialization, and nonirritating sunscreen may be applied as soon as 3 to 4 weeks.

CO_2 LASER SKIN RESURFACING AS A CONCURRENT TREATMENT

Historically, the combination of skin resurfacing (specifically chemical peels) and rhytidectomy has been a point of controversy and concern. The likelihood of damage to the already compromised blood supply of the raised skin flaps and subsequent skin flap necrosis resulted in recommendations against concurrent treatment. The increased time of recovery after rhytidectomy with full ablative resurfacing procedures was another contributable factor to advise against the combination of these procedures.[53–55]

Recent advances in laser technology including fractionated laser resurfacing and multiple studies demonstrating a low risk of complications with simultaneous therapy have shifted modern medicine to attest to the safety of concurrent CO_2 laser resurfacing with other aging face procedures (rhytidectomy, browlift, blepharoplasty).[56–58] In a meta-analysis of nine studies including 453 patients who underwent concurrent rhytidectomy and laser resurfacing, the reported rate of anterior skin flap necrosis was found to be less than 0.2% (only in one patient).[59]

In concurrent treatment, the usual laser settings for both Deep FX and Active FX are used except over the skin flaps. For Deep FX, the energy of 17.5 to 20 mJ with a power of 350 Hz and density of 15 is recommended. This is followed by Active FX resurfacing (energy: 80–135 mJ, power: 350 Hz, density: 3). However, when performing Active FX resurfacing over the skin flaps and neck the energy and density should be brought down to 60 to 70 mJ and a density of 2.[57]

AVOIDANCE AND MANAGEMENT OF COMPLICATIONS

All facial resurfacing procedures are associated with a risk of postoperative complications that are the result of damage to the skin surface and subsequent launch of the regeneration process. The fractional lasers induce less damage to the skin surface compared with ablative lasers and as a result, the complication rates are lower and less severe when the fractional laser is used for resurfacing procedures.[60]

Postinflammatory hyperpigmentation (PIH) is a common complication of laser resurfacing that usually occurs within the first 3 to 4-weeks posttreatment. It is more common in patients with Fitzpatrick III and higher. In a study of 961 laser resurfacing treatments, the rate of PIH was 33% among patients with Fitzpatrick V skin complexity in comparison to 2.5% in patients with Fitzpatrick III skin prototype.[60] The incidence of PIH can be minimized by pretreatment (3–8 weeks) of high-risk patients (Fitzpatrick 3 or higher) with retinoic acid, hydroquinone 4%, and hydrocortisone.[61] Treatment is by continuing the same regimen (if tolerated) for 2 to 3-weeks postprocedure.

Infections are another potential complication after skin laser resurfacing. Herpes simplex (HSV) eruptions (1.77%) are more common than fungal and bacterial infections after laser resurfacing. As mentioned before, all patients are started on valacyclovir, fluconazole, and cephalexin 1 day before their treatment in the senior author's practice but these treatments are controversial. If eruptions of herpes vesicles occur, 500 mg to 1 g of valacyclovir should be given daily until reepithelialization is completed (day 10).[62] Posttreatment bacterial infections are most commonly caused by staphylococcus aureus and treatment with 5 to 7 days of cephalexin is recommended. The most common cause of posttreatment fungal infection is candida which is treated with fluconazole (200 mg the first day, and then 100 mg daily for 1–2 weeks). Other regimens may include topical antifungals or antibiotic creams.

Contact dermatitis is another complication that can occur and is typically caused by the use of moisturizer, antibiotic ointment, or makeup. If mild to moderate, then a strong steroid cream is recommended, and if severe, systematic oral steroids should be used.[63,64] Synechia, hypopigmentation, hypertrophic scarring, scleral show (mostly in patients with a history of blepharoplasty), ectropion, and laser injury to the globe are among other potential complications.

CASE STUDIES

The following are the case descriptions performed by a senior author.

PERIORAL CO_2

Case 1 (**Fig. 3**): A case of perioral CO_2 laser skin resurfacing in a 68-year-old female. Pre and postprocedure photos were taken 1 year apart. The Luxar Novapulse CO_2 laser was used to resurface the perioral region in a painting pattern with 25% overlap. The first pass was performed in the E8 mode at 6 W. A second pass was made under the same settings and the papillary dermis was identified. A third pass was made in the E8 mode at 4 W. The final pass was taken over the vermilion border to allow for resurfacing of the vermilion mucosa. Eschar was removed between passes with saline-soaked gauze.

Fig. 3. Preprocedure photos of a 68-year-old female (*A–C*). One-year postperioral Skin resurfacing with Lumenis Ultrapulse CO_2 (*D–F*).

Case 2 (**Fig. 4**): Another case of perioral CO_2 laser skin resurfacing in a 63-year-old female that shows significant improvement of perioral fine rhytids. The Luxar Novapulse CO_2 laser was used to resurface the perioral region in a painting pattern with 25% overlap. The first pass was performed in the E8 mode at 6 W. A second pass was made under the same settings and a papillary dermis was identified. A third pass over the lips whereby the perioral rhytids were most concentrated was made in the E8 mode at 4 W. That final pass was taken over the vermilion border to allow for resurfacing of the vermilion mucosa. Eschar was removed between passes with saline-soaked gauze. Postprocedural photos were taken 1 year after the laser resurfacing.

FULL-FACE CO_2

Case 4 (**Fig. 5**): This case represents concurrent treatment with full-face CO_2 laser resurfacing and facelift in a 62-year-old female. The Lumenis Ultrapulse CO_2 laser was used. The Deep FX handpiece was used to treat the perioral face at the following settings: 25 mJ, density 5%. The remainder of the face (except those areas within the bony orbit) was treated at the following settings: 10 mJ, density 5%. Then, the Active FX handpiece was affixed to the device and the first pass was performed on the lower eyelids and skin contained within the orbital rims (excluding the hair-bearing brow) at the following settings: 80 mJ, 45W, density 4, pattern 5, size 6. A second pass was made. The remaining facial skin (excluding the skin flaps) was treated at the following settings: 100 mJ, 60W, density 1, pattern 1, size 9. The second pass was made in a direction orthogonal to the first, in a similar painting pattern. The facelift skin flaps were then treated with a single pass at 80 mJ, 45W, density 4, pattern 5, size 6. Blending/feathering of the treatment area was performed along the jawline with the handpiece held tangentially to the skin: 80 mJ, 45W, density 3, pattern 1, size 9. The postoperative photo was

Fig. 4. Photos of a 63-year-old female with perioral fine rhytids (*A*, *C*). One-year postperioral Skin resurfacing with Lumenis Ultrapulse CO_2 (*B*, *D*).

Fig. 5. Concurrent treatment with full-face CO_2 laser resurfacing and facelift in a 62-year-old female. Preoperative photo (*A*). Six-weeks postoperative photo (*B*).

Fig. 6. Concurrent full-face CO_2 laser resurfacing and facelift in a 59-year-old female. Preoperative photos (*A–C*). One-year postoperative photos (*D–F*).

taken 6 weeks after the procedures showing complete resolution of erythema by 6 weeks.

Case 5 (**Fig. 6**): Another case of concurrent treatment with full-face CO_2 laser resurfacing and facelift in a 59-year-old female. The Lumenis Ultrapulse CO_2 laser with the Deep FX handpiece attached was used to treat the perioral region with the following settings: 25 mJ, density 5%, 50% overlap. A single pass was made. The remainder of the face (except for that skin contained within the orbital rims) was treated at the following settings: 20 mJ, density 5%, 50% overlap. A single pass was made. Eschar was removed with saline-soaked gauze. The Active FX handpiece was then affixed to the laser and used to resurface the facial skin (except for the skin within the confines of the orbital rims) at the following settings: 100 mJ, 60W, pattern 1, size 9, density 6. Two passes were made in vertical and horizontal painting patterns. Eschar was removed with saline-soaked gauze. For the skin within the confines of the orbital rims, a single pass was made at the following settings: 80 mJ, 40W, pattern 5, size 6, density 4. The postoperative photos were taken 1 year after the procedures.

Case 6 (**Fig. 7**): 70-year-old female status post concurrent full-face CO_2 laser resurfacing and facelift. Preop and postop photos were taken one year apart. At the completion of the facelift, the Lumenis Ultrapulse CO_2 laser was then brought into the field and the Active FX handpiece was attached. The first pass was performed on the lower eyelids (80 mJ, density 3, 45W). A second pass was made under the same settings. The central face including the forehead, nose, medial cheeks, and perioral region was then treated with three passes total (identical settings). The skin

Fig. 7. Concurrent full-face CO_2 laser resurfacing and facelift in a 70-year-old female. Preoperative photos (*A–C*). One-year postoperative photos (*D–F*).

flaps were then treated with two passes in orthogonal painting patterns.

Case 7 (**Fig. 8**): In this case, a concurrent treatment of neck lift and full-face CO_2 laser resurfacing was performed in a 75-year-old female. Following the neck lift, the Lumenis Ultrapulse CO_2 laser was then brought into the field and the Active FX handpiece was attached. The first pass was performed on the lower eyelids (60 mJ, density 5, 45W). A second pass was made under the same settings. The central face including the forehead, nose, medial cheeks, and perioral region was then treated with three passes (identical settings). The skin flaps were then treated with two passes at 50 mJ, density 4, 45W. Postprocedure photos were taken at 1 year.

Case 8 (**Fig. 9**): This case shows impressive results (1-year postprocedure), in a 60-year-old female who underwent stand-alone full-face CO_2 skin resurfacing. The Lumenis Ultrapulse CO2 laser with the Deep FX handpiece attached was used to treat the perioral region with the following settings: 25 mJ, density 5%, 50% overlap. A single pass was made. The remainder of the face (except for that skin contained within the orbital rims) was treated at the following settings: 20 mJ, density 5%, 50% overlap. A single pass was made. Eschar was removed with saline-soaked gauze. The Active FX handpiece was then affixed to the laser and used to resurface the facial skin (except for the skin within the confines of the orbital rims) at the following settings: 100 mJ, 60W, pattern 1, size 9, density 6. Two nonoverlapping passes were made in vertical and horizontal painting patterns. Eschar was removed with saline-soaked gauze. For the skin within the confines of the orbital rims, a single pass was made at the following settings: 80 mJ, 40W, pattern 5, size 6, density 4.

Fig. 8. Concurrent full-face CO_2 laser resurfacing and neck lift in a 75-year-old female. Preoperative photos (*A*, *C*). One-year postoperative photos (*B*, *D*).

Fig. 9. Full-face CO_2 skin resurfacing in a 60-year-old female. Preprocedure photos (*A*, *C*). One-year postprocedure photos (*B*, *D*).

SUMMARY

Although many different technologies/techniques exist for facial and neck skin rejuvenation, fractionated CO_2 laser allows for significant skin tightening, reduction in rhytid burden, high patient satisfaction, and a manageable side effect/complication profile. This has been proven to be safe and effective in concurrent treatment with other aging face procedures such as rhytidectomy and endoscopic browlift. The optimal results are dependent on the operator's technique and experience and cannot be replaced by the use of laser technology.

CLINICS CARE POINTS

- The ideal candidates for laser skin resurfacing are patients with Fitzpatrick skin types I-II but

Fitzpatrick type III can also be considered for laser resurfacing (albeit less aggressively).

- In the senior author's practice, all patients are started on valacyclovir, fluconazole, and cephalexin one day prior to their treatment to decrease the potential risk of post-procedural herpetic, fungal, and bacterial infections but these treatments are controversial.
- Concurrent CO_2 laser resurfacing with other aging face procedures such as rhytidectomy should be considered as it has proven to be safe and can yield excellent results.
- The immediate endpoint in superficial CO_2 laser resurfacing is the removal of the epidermal layer of the skin and exposure of the papillary dermis that clinically is distinguishable with yellowing of the wound bed and pinpoint bleeding.

DISCLOSURE

The authors have no personal or financial conflicts of interest to disclose.

REFERENCES

1. Kitzmiller WJ, Visscher M, Page DA, et al. A controlled evaluation of dermabrasion versus CO2 laser resurfacing for the treatment of perioral wrinkles. Plast Reconstr Surg 2000;106(6):1366–72 [discussion: 1373-1364].
2. Reed JT, Joseph AK, Bridenstine JB. Treatment of periorbital wrinkles. A comparison of the SilkTouch carbon dioxide laser with a medium-depth chemical peel. Dermatol Surg 1997;23(8):643–8.
3. Altshuler GB, Anderson RR, Manstein D, et al. Extended theory of selective photothermolysis. Lasers Surg Med 2001;29(5):416–32.
4. Ross EV, Miller C, Meehan K, et al. One-pass CO2 versus multiple-pass Er:YAG laser resurfacing in the treatment of rhytides: a comparison side-by-side study of pulsed CO2 and Er:YAG lasers. Dermatol Surg 2001;27(8):709–15.
5. Hohenleutner S, Hohenleutner U, Landthaler M. Comparison of erbium: YAG and carbon dioxide laser for the treatment of facial rhytides. Arch Dermatol 1999;135(11):1416–7.
6. van Hillegersberg R. Fundamentals of laser surgery. Eur J Sur 1997;163(1):3–12.
7. Guttenberg SA, Emery RW 3rd. Laser physics and tissue interaction. Oral Maxill Surg Clin North Am 2004;16(2):143–7.
8. Gregory RO. Laser physics and physiology. Clin Plast Surg 1998;25(1):89–93.
9. Riggs K, Keller M, Humphreys TR. Ablative laser resurfacing: high-energy pulsed carbon dioxide and erbium:yttrium-aluminum-garnet. Clin Dermatol 2007;25(5):462–73.
10. Herd RM, Dover JS, Arndt KA. Basic laser principles. Dermatol Clin 1997;15(3):355–72.
11. Fisher JC. Basic biophysical principles of resurfacing of human skin by means of the carbon dioxide laser. J Clin Laser Med Surg 1996;14(4):193–210.
12. Polanyi TG. Physics of surgery with lasers. Clin Chest Med 1985;6(2):179–202.
13. Gillis TM, Strong MS. Surgical lasers and soft tissue interactions. Otolaryngol Clin North Am 1983;16(4):775–84.
14. Janda P, Sroka R, Mundweil B, et al. Comparison of thermal tissue effects induced by contact application of fiber guided laser systems. Lasers Surg Med 2003;33(2):93–101.
15. Absten GT. Physics of light and lasers. Obstet Gynecol Clin North Am 1991;18(3):407–27.
16. Reinisch L. Laser physics and tissue interactions. Otolaryngol Clin North Am 1996;29(6):893–914.
17. Ratz JL. Laser physics. Clin Dermatol 1995;13(1):11–20.
18. Moy RL, Bucalo B, Lee MH, et al. Skin resurfacing of facial rhytides and scars with the 90-microsecond short pulse CO2 laser. Comparison to the 900-microsecond dwell time CO2 lasers and clinical experience. Dermatol Surg 1998;24(12):1390–6.
19. Xu XG, Gao XH, Li YH, et al. Ultrapulse-mode versus superpulse-mode fractional carbon dioxide laser on normal back skin. Dermatol Surg 2013;39(7):1047–55.
20. Luo YJ, Xu XG, Wu Y, et al. Split-face comparison of ultrapulse-mode and superpulse-mode fractionated carbon dioxide lasers on photoaged skin. J Drugs Dermatol : JDD 2012;11(11):1310–4.
21. Trelles MA, Rigau J, Mellor TK, et al. A clinical and histological comparison of flashscanning versus pulsed technology in carbon dioxide laser facial skin resurfacing. Dermatol Surg 1998;24(1):43–9.
22. Orringer JS, Sachs DL, Shao Y, et al. Direct quantitative comparison of molecular responses in photodamaged human skin to fractionated and fully ablative carbon dioxide laser resurfacing. Dermatol Surg 2012;38(10):1668–77.
23. Sherry SD, Miles BA, Finn RA. Long-term efficacy of carbon dioxide laser resurfacing for facial actinic keratosis. J Oral Maxill Surg 2007;65(6):1135–9.
24. Borges J, Araújo L, Cuzzi T, et al. Fractional Laser Resurfacing Treats Photoaging by Promoting Neocollegenesis and Cutaneous Edema. J Clin Aesthet Dermatol 2020;13(1):22–7.
25. Baker DC. Lateral SMASectomy, plication and short scar facelifts: indications and techniques. Clin Plast Surg 2008;35(4):533–50, vi.

26. Glogau RG, Matarasso SL. Chemical face peeling: patient and peeling agent selection. Facial Plast Surg : FPS 1995;11(1):1–8.
27. Fitzpatrick TB. The validity and practicality of sun-reactive skin types I through VI. Arch Dermatol 1988;124(6):869–71.
28. Alexis AF. Lasers and light-based therapies in ethnic skin: treatment options and recommendations for Fitzpatrick skin types V and VI. Br J Dermatol 2013;169(Suppl 3):91–7.
29. Alster T, Hirsch R. Single-pass CO2 laser skin resurfacing of light and dark skin: extended experience with 52 patients. J Cosmet Laser Ther 2003;5(1):39–42.
30. Hamilton MM, Kao R. Recognizing and managing complications in laser resurfacing, chemical peels, and dermabrasion. Facial Plast Surg Clin North Am 2020;28(4):493–501.
31. Hunzeker CM, Weiss ET, Geronemus RG. Fractionated CO2 laser resurfacing: our experience with more than 2000 treatments. Aesthet Surg J 2009; 29(4):317–22.
32. Krupa Shankar D, Chakravarthi M, Shilpakar R. Carbon dioxide laser guidelines. J Cutan Aesthet Surg 2009;2(2):72–80.
33. Alexiades-Armenakas MR, Dover JS, Arndt KA. The spectrum of laser skin resurfacing: nonablative, fractional, and ablative laser resurfacing. J Am Acad Dermatol 2008;58(5):719–37 [quiz: 738-740].
34. Manuskiatti W, Fitzpatrick RE, Goldman MP. Long-term effectiveness and side effects of carbon dioxide laser resurfacing for photoaged facial skin. J Am Acad Dermatol 1999;40(3):401–11.
35. Campbell TM, Goldman MP. Adverse events of fractionated carbon dioxide laser: review of 373 treatments. Dermatol Surg 2010;36(11):1645–50.
36. Sriprachya-Anunt S, Fitzpatrick RE, Goldman MP, et al. Infections complicating pulsed carbon dioxide laser resurfacing for photoaged facial skin. Dermatol Surg 1997;23(7):527–35 [discussion: 535-526].
37. Manuskiatti W, Fitzpatrick RE, Goldman MP, et al. Prophylactic antibiotics in patients undergoing laser resurfacing of the skin. J Am Acad Dermatol 1999; 40(1):77–84.
38. Gaspar Z, Vinciullo C, Elliott T. Antibiotic prophylaxis for full-face laser resurfacing: is it necessary? Arch Dermatol 2001;137(3):313–5.
39. Alster TS, Lupton JR. Prevention and treatment of side effects and complications of cutaneous laser resurfacing. Plast Reconstr Surg 2002;109(1): 308–16 [discussion: 317-308].
40. Goldman MP. The use of hydroquinone with facial laser resurfacing. J Cutan Laser Ther 2000;2(2): 73–7.
41. Wong ITY, Richer V. Prophylaxis of post-inflammatory hyperpigmentation from energy-based device treatments: a review [Formula: see text]. J Cutan Med Surg 2021;25(1):77–86.
42. Kilmer SL, Chotzen V, Zelickson BD, et al. Full-face laser resurfacing using a supplemented topical anesthesia protocol. Arch Dermatol 2003;139(10): 1279–83.
43. Bjerring P, Andersen PH, Arendt-Nielsen L. Vascular response of human skin after analgesia with EMLA cream. Br J Anaesth 1989;63(6):655–60.
44. Naouri M, Atlan M, Perrodeau E, et al. High-resolution ultrasound imaging to demonstrate and predict efficacy of carbon dioxide fractional resurfacing laser treatment. Dermatol Surg 2011;37(5):596–603.
45. Altshuler GB, Zenzie HH, Erofeev AV, et al. Contact cooling of the skin. Phys Med Biol 1999;44(4): 1003–23.
46. Kelly KM, Nelson JS, Lask GP, et al. Cryogen spray cooling in combination with nonablative laser treatment of facial rhytides. Arch Dermatol 1999;135(6): 691–4.
47. Rohrich RJ, Gyimesi IM, Clark P, et al. CO2 laser safety considerations in facial skin resurfacing. Plast Reconstr Surg 1997;100(5):1285–90.
48. Wald D, Michelow BJ, Guyuron B, et al. Fire hazards and CO2 laser resurfacing. Plast Reconstr Surg 1998;101(1):185–8.
49. Hirshman CA, Smith J. Indirect ignitioin of the endotracheal tube during carbon dioxide laser surgery. Arch Otolaryngol 1980;106(10):639–41.
50. Fader DJ, Ratner D. Principles of CO2/erbium laser safety. Dermatol Surg 2000;26(3):235–9.
51. Kotlus BS. Dual-depth fractional carbon dioxide laser resurfacing for periocular rhytidosis. Dermatol Surg 2010;36(5):623–8.
52. Ramsdell WM. Fractional carbon dioxide laser resurfacing. Semin Plast Surg 2012;26(3):125–30.
53. Baker TJ. Chemical face peeling and rhytidectomy. A combined approach for facial rejuvenation. Plast Reconstr Surg Transplant Bull 1962;29:199–207.
54. Guyuron B, Michelow B, Schmelzer R, et al. Delayed healing of rhytidectomy flap resurfaced with CO2 laser. Plast Reconstr Surg 1998;101(3):816–9.
55. Park GC, Wiseman JB, Hayes DK. The evaluation of rhytidectomy flap healing after CO2 laser resurfacing in a pig model. Otolaryngol Head Neck Surg 2001;125(6):590–2.
56. Wright EJ, Struck SK. Facelift combined with simultaneous fractional laser resurfacing: Outcomes and complications. J Plast Reconstr Aesthet Surg 2015; 68(10):1332–7.
57. Truswell WHt. Combining fractional carbon-dioxide laser resurfacing with face-lift surgery. Facial Plast Surg Clin North Am 2012;20(2):201–13, vi.
58. Ramirez OM, Pozner JN. Laser resurfacing as an adjunct to endoforehead lift, endofacelift, and biplanar facelift. Ann Plast Surg 1997;38(4):315–21 [discussion: 321-312].
59. Koch BB, Perkins SW. Simultaneous rhytidectomy and full-face carbon dioxide laser resurfacing: a

case series and meta-analysis. Arch Facial Plast Surg 2002;4(4):227–33.
60. Li D, Lin SB, Cheng B. Complications and posttreatment care following invasive laser skin resurfacing: a review. J Cosmet Laser Ther 2018;20(3):168–78.
61. Fulton JE Jr. Complications of laser resurfacing. Methods of prevention and management. Dermatol Surg 1998;24(1):91–9.
62. Hirschmann JV. Antimicrobial prophylaxis in dermatology. Semin Cutan Med Surg 2000;19(1):2–9.
63. Nanni CA, Alster TS. Complications of cutaneous laser surgery. A Review Dermatol Surg 1998;24(2):209–19.
64. Franck P, Henderson PW, Rothaus KO. Basics of lasers: history, physics, and clinical Applications. Clin Plast Surg 2016;43(3):505–13.