

FRACTIONAL CARBON DIOXIDE LASER RESURFACING

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The sophisticated lasers used today might seem unimaginable to Dr. Leon Goldman who first studied laser-cutaneous interactions in the 1960's¹. In 1983, Anderson and Parrish fundamentally changed our usage of lasers with the ground-breaking concept of photothermolysis via pulsed radiation². During the 1990's, the ability to apply high energy with short pulse durations made what is now termed "traditional" CO₂ very popular. Never before had a device been able to produce such changes in the appearance and function of skin. Many physicians consider the fully ablative traditional CO₂ laser to be the gold standard. Certainly, no other device can achieve the same results. Those results, however, come with side effects such as prolonged erythema and delayed hypopigmentation for some patients. Dr. Jeffrey Dover believes that today there are few instances where traditionally ablative CO₂ laser resurfacing is indicated (personal communication, January 2012).

In 2004, Manstein, et al developed a technique of creating thermal injury to skin in a fractional pattern in an attempt to achieve similar results while maintaining an acceptable side effect profile³. Following initial development of non-ablative fractional lasers, fractional CO₂ lasers entered the market in hopes of delivering even better results.

The benefits of CO₂ laser resurfacing are undeniable, whether fully ablative or fractional. The mechanisms by which such improvement is achieved have been the subject of much debate⁴. Although fully ablative traditional and fractional CO₂ lasers have distinctive characteristics, much of the research on fully ablative CO₂ resurfacing is applicable to fractional resurfacing⁵. All CO₂ lasers have a wavelength of 10,600 nm, heavily absorbed by water. To achieve ablation without excessive thermal damage, a

fluence of 5 J/cm² must be delivered within a pulse duration of < 1ms, the generally agreed upon thermal relaxation time of skin.

The denaturation temperature of collagen is conventionally stated to be 66.8 °C, although this varies ⁴. Once denatured by laser-generated heat, collagen rapidly contracts as fibers shrink to 1/3 of their length ⁶. The shrinkage of collagen is the primary mechanism of skin tightening although vaporization of intracellular water and ablation contribute as well. Next, a wound healing phase is initiated characterized by extremely high levels of collagenases (matrix metalloproteinases) which degrade the fragmented collagenous matrix ⁷. Rapid reconstitution of the epidermis from adjacent epidermal cells contrasts with healing after traditional resurfacing in which new epidermis is derived from cells that migrate from adnexal structures. A prolonged period of dermal neocollagenesis of up to at least 6 months follows ⁸.

Although tissue ablation certainly plays a role in effectiveness, the depth of deep rhytides exceeds the depth of ablation ^{9,10}. Residual thermal damage represents the true depth of injury and the primary factor leading to effectiveness ⁴. Residual thermal damage is increased with higher fluence ^{11,12} while increased density results in greater depth of ablation.

As with any cosmetic procedure, patient selection is important. Realistic expectations and a thorough understanding of the procedure and especially post-operative care are crucial. Although most patients require only one treatment, patients should be prepared for the possibility that more than one treatment may be necessary for best results. Contraindications to treatment include active cutaneous infection, diseases that inhibit healing such as scleroderma and a history of any diseases that koebnerize such as

vitiligo and psoriasis. Recent isotretinoin therapy or a history of radiation at the treatment site demands caution and non-aggressive parameters.

Regardless of history, all patients receive pre-operative antiviral prophylaxis with valacyclovir 500 mg BID beginning one day pre-operatively and continued for 10 days. Most laser surgeons also prescribe an antibiotic such as cefadroxil, dicloxacillin, doxycycline or ciprofloxin during the same time period ¹³. Others believe that antibiotics for Gram + organisms only promote Gram – infection. Fluconazole 200 mg is given on the day of surgery. Prophylactic facial cleansing with chlorhexidine BID for 3 days pre-operatively may further decrease the incidence of post-operative infection. Some surgeons prescribe intranasal mupirocin pre-operatively. Preconditioning the skin with tretinoin in an attempt to speed healing and reduce the incidence of post-operative milia and acne is of questionable benefit and promotes increased post-operative erythema ^{14, 15, 16, 17, 18}.

Fractional resurfacing begins with appropriate laser precautions and sedation of choice. While general or tumescent anesthesia may be used, the liberal application of topical anesthesia 1 – 2 hours before surgery is usually adequate. Kilmer believes that a hydrophilic topical anesthetic such as EMLA (eutectic mixture of lidocaine and prilocaine, Astra Zeneca) may alter the response to the laser ensuring fewer side effects ¹⁹. Because the primary target of CO₂ lasers is water, this makes intuitive sense. However, Naouri, et al believe the water content of topical anesthetics irrelevant ²⁰. Certainly, topical anesthesia should have very little effect on a narrow, deep ablative beam such as with Deep FX. Whether more superficial resurfacing such as Active FX is affected by topical anesthesia is open to debate. In addition to topical anesthesia, forced cold air provided by a Zimmer Cooler (LaserMed, Monroe, CT) or similar device is helpful.

Currently, there are a number of excellent fractional CO₂ devices on the market ²¹. This discussion will be limited to the specifics of using the Lumenis Ultrapulse Encore fractional CO₂ laser for photoaging and scarring of the face and neck. Two delivery devices offer dual depth ablation, Active FX and Deep FX, via separate handpieces. The Active FX handpiece has a collimated 1.3 mm spot size delivered in a non-sequential array (Cool Scan mode) to minimize thermal damage. Available energy varies from 2 mJ (150 mJ/cm²) to 225 mJ (169 J/cm²). Power settings range from 1 watt (4.4 Hz) to 60 watts (600 Hz). A computer pattern generator delivers 7 patterns in 9 different size options and 9 density options. It is the ability to alter the density that distinguishes fractional lasers from traditionally fully ablative ones. For density settings 1 – 3 with the square pattern, density varies between 55% and 82%. Densities 4 – 9 are fully ablative (100%) although the depth is much less than with traditional CO₂ lasers.

Active FX creates a shallow, broad ablative crater that can extend into superficial papillary dermis. One or 2 passes are commonly used. Typical energy settings for facial skin range from 100 - 125 mJ . Density settings from 2 – 4 are typical but may be increased for difficult cases such as acne scarring. Periorbital skin treatment parameters range from 60 - 90 mJ, density 2 - 3. Treatment of neck, chest and extremities is possible at reduced settings such as 70 – 80 mJ, density 1 – 2. Opinion varies regarding whether to debride between laser passes for traditional resurfacing ^{22, 23, 24, 25}. For fractional resurfacing it is not necessary.

For deep rhytides, scarring and for maximum collagen regeneration, Deep FX is used initially or exclusively. The Deep FX handpiece produces a more narrow, noncollimated beam at .12 mm with 4 pattern and 6 size options. One pulse or 2 stacked pulses can be used. Power ranges up to 600 Hz with a single pulse and to 300 Hz with double pulsing. Energy settings between 2.5mJ and 50 mJ are available. At 2.5 mJ, the ablation depth is quite shallow, approximately 76 μ which extends through the epidermis and possibly to superficial papillary dermis depending on site. Although the depth can be increased to 1600 μ or more, these settings are much too powerful to be clinically appropriate.

An energy setting between 15 -22.5 mJ is typical for the face. At 22.5 mJ ablation extends to approximately 675 μ which correlates with deep dermis (depending on skin thickness), encompassing most cases of solar elastosis. Density settings of 5 – 25% are available. This translates for a square scan area of 10 x 10 mm, from 196 spots at density 5% to 841 spots at 25%. Deep FX at aggressive settings can punch all of the way through eyelid skin. Safe settings for skin within the boney orbit include settings from 8 – 10 mJ and density 5 – 15%. Settings of 8 -10 mJ, density 5-15% are appropriate for off of the face sites such as neck, chest and extremities. The author uses one pulse only for all applications except scarring for which double pulsing is sometimes used.

Oni, et al documented that, on facial skin, a single pulse at 15 mJ extended to an average 416 μ which correlates with mid-dermis²⁶. Interestingly, double pulsing at 15 mJ was histologically equivalent to a single pulse at 30 mJ, extending 881 μ and 854 μ , respectively (deep reticular dermis). The relevance of this in terms of clinical outcome has

yet to be determined. Little data exists in the peer-reviewed literature regarding how best to combine Active FX with Deep FX.

Because the precise boundaries of the scanned imprints on the skin can be difficult to see, skip areas or, worse, pulse stacking can occur with Deep FX resurfacing. Because treated skin will turn red or urticate several minutes after treatment, untreated areas can be recognized and treated. If Active FX treatment is planned following Deep FX, areas missed with Deep FX will blend in.

Meticulous post-operative care is absolutely crucial to avoid infection and scarring. Cold soaks of white vinegar 1 tsp to 1 cup water or aluminum acetate (Domeboro, Bayer HealthCare, Morristown, New Jersey) soaks reduce erythema, edema and provide antisepsis. The skin should be kept moist with white petrolatum or Aquaphor (Beiersdorf, Wilton, CT). Other topicals are strongly discouraged. The concept of promoting rapid healing via use of autologous platelet-rich plasma has recently been introduced ²⁷.

Occlusive dressings such as Silon II (Bio Med Sciences, Inc, Allentown, Pa) have been shown to speed healing, reduce inflammation and possibly improve results following traditional resurfacing ^{4, 28, 29}. The dressings are cumbersome and not necessary for most fractional resurfacing. The author still uses Silon II with aggressive treatments for severe acne scarring. Reepithelialization usually takes 3 – 6 days. At that point a light moisturizer and sunscreen may be used. Mild to moderate erythema persists for several weeks. Topical vitamin C can be used to encourage neocollagenesis and reduce erythema ^{30, 31}.

Efficacy can be difficult to assess because histologic changes do not always correlate with changes in appearance. Moreover, changes in appearance are difficult to quantify and subjective for both patient and physician. Virtually all patients show at least modest

improvement (Figure 1). In general, thin skin responds better than thick. Young skin is capable of producing more collagen than old skin. Rahman found moderate or better improvement in 83% of patients³². Ortiz documented 50 – 75% improvement at 3 months with 25 – 50% improvement long term³³. Improvement of eyelid rhytides by 53% has been documented as well³⁴.

Acne scarring is more difficult to treat and realistic expectations should be stressed during the consultation. After 2 – 3 treatments for acne scarring, 26 – 50% improvement in texture and atrophy has been noted³⁵. The same study documented 68% improvement in the depth of scars as measured by the Primos three-dimensional optical system. Ice pick-type scars should undergo punch excisions prior to laser therapy (Figure 2). Box car-type scarring responds well (Figure 3). Most challenging to treat are rolling scars (Figure 4). These patients may benefit from a supra-SMAS facelift first. This stretches the skin, thereby effacing some of the rolling depressions. The increased tension placed on fibroblasts may enhance subsequent collagen formation⁷. Laser settings for rolling scars should be aggressive and many patients will require more than one treatment. Regardless of the etiology of scarring, thin scars respond better than thick ones (Figure 5).

Fractional CO₂ resurfacing represents one of the most useful devices produced by 50 years of research into laser-cutaneous interactions. Patients can expect excellent results with few complications. Additional research will further improve our ability to provide the best of care for our patients.

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FIGURES

Figure 1. 66 year old female (A) Before and (B) after Active FX resurfacing and transconjunctival lower blepharoplasty. Active FX settings - 2 passes, 100 mJ, 60 watts, pattern 1, size 9, density 6; periorbital areas - 2 passes, 80 mJ, 45 watts, pattern 5, size 6, density 4 and density 3; feathering with handpiece held tangentially - 80 mJ, 45 watts, pattern 1, size 9, density 3.

Figure 2. Combination ice pick and box car-type scarring. (A) Before and (B) after punch excisions followed by 2 passes of Active FX at 125 mJ, density 6. Periorbital areas – 1 pass Active FX at 80 mJ, density 3.

Figure 3. Box car-type acne scarring. (A) Before and (B) after fractional resurfacing. One pass of Deep FX at 22.5 mJ, 10% density, 1 pulse, followed by Active FX at 125 mJ, density 5. Periorbital areas – 1 pass Active FX at 80 mJ, density 2.

Figure 4. Rolling scars. (A) Before and (B) after treatment, showing only modest improvement despite aggressive settings. Punch excisions were followed by both Deep FX and Active FX. Deep FX – 125 mJ, density 20%, 2 pulses to most severely affected areas. Active FX – 1 pass at 125 mJ, density 7 to entire face except periorbital areas – 80 mJ, density 4. Silon II was placed as a wound dressing for 3 days to speed healing and reduce inflammation.

Figure 5. Facelift scar. (A) Before and (B) after fractional resurfacing. Two passes of Active FX at 90 mJ, density 4.