The Safety of Laser Skin Resurfacing With the Microablative Carbon Dioxide Laser and Review of the Literature

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ABSTRACT

Objective: The aim of this study was to evaluate the incidence of adverse effects following laser skin resurfacing with the microablative carbon dioxide (CO_2) laser system (SmartXide DOT; DEKA, Calenzano, Italy).
Methods: A retrospective chart review was performed. Data was collected for DOT laser procedures performed at three clinical centers from 2008-2014.
Results: Of the 1,081 DOT laser procedures, there were 13 complications (1.3% of all cases), which included eleven cases of prolonged erythema and two cases of post-inflammatory hyperpigmentation. Of note, there were no cases of scarring.
Limitations: This was a retrospective chart review. Data was collected from laser case logs. However, all patients with complications were evaluated clinically by a physician.
Conclusion: Microablative fractional resurfacing with the DOT laser enables treatment of a diversity of skin conditions with short post-procedure recovery time and an extremely low incidence of adverse side effects.

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INTRODUCTION

Nonsurgical skin rejuvenation continues to be a major, evolving field in dermatology, especially as more patients seek aesthetic improvement for a variety of skin conditions including: photo-damage, wrinkles, acne scars, surgical scars, striae, and lentigines. In recent years, many devices have been developed for cutaneous laser resurfacing including fully ablative carbon dioxide (CO_2) lasers, nonablative lasers, fractional ablative lasers, and fractional nonablative lasers. Each treatment modality has its own risks and benefits. It is important for physicians to understand the safety profiles and potential complications associated with different laser devices.

Laser skin resurfacing was introduced in the 1990s with the CO_2 laser.[1-3] The CO_2 laser emits light at 10,600nm, and water is the target chromophore. A variety of CO_2 lasers have been utilized for cutaneous resurfacing ranging from high energy, pulsed and continuous wave lasers. These lasers provide excellent results for facial wrinkles, photo-damaged skin, and acne scars; however, there are several major disadvantages associated with the use of these laser devices including the inability to use these lasers on non-facial skin, the need for general anesthesia, 2-3 week post-operative recovery period, and significant risk of dyschromia and scarring. Additionally, commonly reported side-effects included prolonged post-treatment erythema, which persists for approximately 6-8 weeks, transient hyperpigmentation, and permanent hypopigmentation.

In an attempt to avoid the surgical morbidity associated with traditional CO_2 ablative resurfacing, nonablative lasers and other devices were developed. Nonablative lasers heat the dermis causing protein denaturation and thereby stimulating collagen synthesis and tissue remodeling.[4] Nonablative devices target the dermis and leave the epidermis intact unlike traditional CO_2 lasers that target both the epidermis and dermis. Many devices have been developed for nonablative dermal remodeling, including 1320nm, 1450nm, and 1540nm lasers; intense pulsed light; pulsed dye laser; radio- frequency devices; and ultrasound devices. Nonablative laser resurfacing is better tolerated than traditional CO_2 laser resurfacing as it leaves the epidermis intact, however, the final aesthetic results are not nearly as impressive.

As a result of the significant surgical morbidity associated with traditional, fully ablative CO_2 laser resurfacing and the suboptimal outcomes achieved with nonablative resurfacing devices, the concept of fractionated laser surgery was developed. Fractional photothermolysis (FP) was introduced by Manstein

and Anderson in 2004.[5] In FP, the laser thermally ablates microscopic columns of epidermal and/or dermal tissue at regularly spaced intervals. There is sufficient energy within the laser columns to induce local thermal damage without spreading to adjacent tissue. The intact, unaltered skin between the microscopic treatment zones (MTZs) allows for rapid healing by providing nutritional and structural support to the ablated tissue.

Initially, the lasers that were used to employ the concept of FP were devices in the near to mid infrared wavelength range (700nm-1000nm).[6] These devices are considered nonablative fractional lasers since they have minimal to no ablative effect on the epidermis. Rather, these lasers create MTZs within the dermis. Therefore, the treatment outcomes are not equivalent to resurfacing procedures that target both the epidermis and dermis. Consequently, the concept of FP was extended to ablative laser wavelengths produced by CO_2 (10,600nm) and Erbium:YAG (2,940nm) lasers.[7,8] There are now a number of fractional ablative lasers on the market including the microablative CO_2 laser system (SmartXide DOT; DEKA, Calenzano, Italy).

To our knowledge, there have been no publications in the medical literature reporting complications due to the microablative CO_2 laser system (DOT laser). In a preliminary study performed by Gotkin et al., the efficacy and safety of the DOT laser system was evaluated.[9] A total of 32 patients underwent a single resurfacing procedure using the DOT laser. Laser therapy was implemented to treat the following conditions: photo-damage, wrinkles, scars, striae, and lentigines. All 32 patients demonstrated significant clinical improvement following treatment. No patients demonstrated prolonged erythema, post-inflammatory hyperpigmentation, or scarring at three-month follow-up.

To further evaluate the safety of the DOT laser, we performed a large, retrospective review to assess the safety profile of this unique laser system.

METHODS

A retrospective review of medical records was performed. Data was collected for all DOT laser procedures performed from 2008-2014. The same DOT laser system (SmartXide DOT; DEKA, Calenzano, Italy) was used by all three physicians who participated in this study. Institutional review board approval was not required.

Prior to the laser procedure, patients applied a compounded topical anesthetic cream consisting of 20% benzocaine, 10% lidocaine, and 4% tetracaine (CMP BLT), compounded by TLC pharmacy (an eCompounding pharmacy). The CMP BLT cream was actively massaged into the skin area(s) being treated and then left on the skin for sixty minutes. During the laser procedure, the Zimmer Cryo Chiller was used to dispense cold air anesthesia. Immediately post-procedure, ice cold soaks were applied to the treatment site(s) for 15-20 minutes. Topical 1% hydrocortisone cream (Hanke) or 1%hydrocortisone ointment combined with Aquaphor Healing ointment (Gotkin and Sarnoff) was then applied to the treat-

FIGURE 1A. The 83-year old woman demonstrates dyschromia, laxity, and rhytides before undergoing DOT laser resurfacing. The entire face and upper neck were treated with 25 watts, 1800 millisecond pulse duration, and a spacing of 200 microns. The same laser settings were used for a second pass of the perioral area, cheek, and jawline.

FIGURE 1B. The same patient demonstrates marked reduction in dyschromia and laxity at 17 months following DOT laser resurfacing.

TABLE 1.

Laser Settings Utilized in Dot Laser Resurfacing Procedures

Investigator	Face				Neck			
	Power (watts)	Pitch Density (microns)	Dwell Time (millisec)	Passes	Power (watts)	Pitch Density (microns)	Dwell Time (millisec)	Passes
1	30	500	500	1-3	20	500	500	1
2	25-30	200-500	1800-2000	2-3	20	200-500	1000	1
3	20-30	200-500	1000-1500	1-3	20	400	1000	1

ed area(s) until re-epithelialization was complete; this was followed by broad spectrum sunscreen of 30 SPF or greater.

The following laser parameters were utilized by the three laser surgeons involved in the study (Table 1). For the face, Dr. C. William Hanke used the following settings: power of 30 watts, pitch density (distance between MTZs) of 500 microns, and dwell time (pulse duration) of 500 milliseconds. One to three passes were performed depending upon the severity of the pathology and patient tolerance for postoperative morbidity. For the neck, Dr. Hanke used the following settings: power of 20 watts, pitch density of 500 microns, dwell time of 500 milliseconds. When treating the neck, only one pass was performed without any overlap.

When treating skin regions on the face, Dr. Robert H. Gotkin used the following settings: power 25-30 watts, pitch density 200-500 microns, and dwell time 1800-2000 milliseconds. The settings varied based on the following factors: anatomic area being treated, age of the patient, Fitzpatrick skin type, degree of solar elastosis, treatment goals of the patient, and duration of downtime that the patient is willing to tolerate to accomplish the treatment goals. The number of passes depended on the degree of solar elastosis and patient tolerance. Usually the number of passes ranged from two to three. For the neck, Dr. Gotkin's preferred settings were: power of 20 watts, pitch density 200-500 microns; dwell time 1000 milliseconds. Only one pass was performed when treating skin on the neck.

Like Dr. Gotkin, Dr. Sarnoff also believes the settings cannot be defined in a "cookbook" approach. They will vary based upon all the factors listed above. In general, however, Dr. Sarnoff uses between 20-30 watts, a pitch density 200-500 microns, and a dwell time or pulse duration of 1000-1500 milliseconds on the face. Of note, there will be variation based on the anatomic area being treated (eg, periorbital vs. cheek vs. forehead). The neck is treated with less power, less pitch density (ie, greater distance between the dots), and shorter pulse durations. For deep perioral rhytides, Dr. Sarnoff uses 30W, 200 micron pitch, and 1700-2000 millisecond pulse duration. Drs. Gotkin and Sarnoff apply cold compresses immediately upon completion of the procedure. Patients are treated postoperatively with a combination of Aquaphor Healing ointment and 1% hydrocortisone ointment applied to the entire treated area. Scrupulous hand-washing is emphasized prior to wound care every 3-4 hours. Wound care consists of: removing the old ointment, cleansing the skin with a gentle cleanser (Pink Pearl, ABBE Cosmetics, Farmingdale, NY), and re-application of hydrocortisone ointment and Aquaphor Healing Ointment. Patients routinely are given a ten-day course of oral antibiotics and a ten-day course of oral anti-viral medication. Additionally, Drs. Gotkin and Sarnoff see their patients every other day to monitor the healing process, cleansing of the skin, and to identify and treat any potential complications early.

RESULTS

A total of 1,081 DOT laser procedures were performed from 2008-2014. The face and neck were the predominant body areas treated. The most common indication for treatment was photoaging.

Thirteen complications occurred in 1,081 DOT laser treatments (1.2% of all cases; Table 2). Two cases of post-inflammatory hyperpigmentation occurred, one involving the face, and the other involving the chest. Eleven patients experienced prolonged erythema (defined as erythema persisting for greater than 4 weeks following laser treatment). The body regions affected by prolonged erythema included the following; full face (1), neck (4), eyelids (1), nose (2), back (2), chest (1).

DISCUSSION

Microablative laser resurfacing with the DOT laser can be used to treat a variety of skin conditions including facial rhytides, skin discoloration due to sun-damage, surgical scars, and acne scars. Usually one can obtain considerable improvement in skin quality with one or two treatments (Figure 1). Some patients return for annual treatment to help maintain the skin quality.

As demonstrated by this retrospective chart review, the DOT laser has an excellent safety profile. Moreover, unlike traditional fully ablative CO_2 laser resurfacing, the DOT laser is a very well

TABLE 2.

Complications in Dot Laser Resurfacing Procedures		
Complication	Number (%)	Comment
Prolonged erythema > 4 weeks	11 (1%)	Face (1); Neck (4); Eyelids (1); Nose (2); Chest (1); Back (2)
Post-inflammatory hyper-pigmentation	2 (0.2%)	Face (1); Chest (1)
Permanent hypo-pigmentation	0	-
Scaring	0	-

tolerated procedure, especially with topical and cold air anesthesia.[10] As a result of the combination of cold air with topical anesthesia, the procedure causes minimal to no discomfort. Topical anesthesia is applied to the skin for one hour prior to the laser procedure. Additionally, the post-operative recovery time is significantly shorter compared to traditional fully ablative CO_2 skin resurfacing. Following DOT laser treatment, patients experience mild erythema, which resolves within 5-7 days. Moreover, most patients can resume use of makeup within 3-5 days post-procedure.

Complications of Traditional Fully Ablative CO_2 Laser Resurfacing

Although traditional fully ablative CO_2 resurfacing is an effective treatment modality for skin rejuvenation, it is associated with major complications. In particular, hypertrophic scarring of facial and non-facial skin is a well-documented complication of traditional, fully ablative CO_2 laser resurfacing.[11,12] Permanent and disfiguring scarring can result from excessive energy settings or as a consequence of post-operative viral, bacterial, and/or fungal infection. Less severe complications following laser treatment include prolonged erythema, post-inflammatory hyperpigmentation, and persistent hypopigmentation.

Complications of Fractional Resurfacing with Other CO_2 Laser Devices

Fractional resurfacing is associated with fewer complications compared to traditional fully ablative CO_2 laser resurfacing.[4] Minor complications, which usually resolve within 1-3 months, include prolonged erythema and post-inflammatory hyperpigmentation. Delayed, persistent hypopigmentation can be a minor or moderate complication depending on the severity of the hypopigmentation, as well as the percentage of body surface area affected. Hypertrophic scarring using fractional resurfacing has been reported more commonly on the neck and rarely on the face. Various fractional ablative lasers on the market (SmartXide DOT, Ultrapulse, Fraxel repair, etc.) have assorted published side effect profiles (Table 3).

Metelitsa et al. published a literature review regarding complications following fractional laser resurfacing. They reported prolonged erythema in over 12.5% of patients following fractional ablative laser treatments.[15-17] The frequency of post-inflammatory hyperpigmentation exhibits a wide range from 1% to 32%.[15,17-24]

Clementoni et al. reported their experience using random fractional ultrapulsed CO_2 resurfacing for photo-damaged skin on the face. A total of 312 patients were treated from 2006 to 2009. No long-term or serious complications were observed. Post-inflammatory hyperpigmentation was the most common complication, occurring in seventeen patients (5.64%). Prolonged erythema was observed in seven patients (2.24%) with a mean duration of 27.3 days. None of the patients developed scarring.[13]

Rahman et al. reported the effects of fractional deep dermal ablation using a 30 W, 10,600nm CO_2 laser system (Reliant Technologies Inc., Mountain View, CA). Thirty patients underwent laser resurfacing for the treatment of photo-damaged skin on the face. Of those thirty patients, 33% exhibited prolonged erythema and 20% exhibited post-inflammatory hyperpigmentation. Of note, there were no reports of scarring or persistent hypopigmentation.[19]

Although less frequent, scarring and functional impairment of anatomic structures, such as ectropion, are more serious complications that can potentially result from laser resurfacing procedures. Of note, there are several published reports of scarring following fractional laser treatments.[25,26]

In 2009. Avram et al. reported a series of five patients who developed scarring on the neck following fractional ablative CO_2 laser resurfacing. All five patients were treated with the same CO_2 laser device (Fraxel re:pair®, Reliant Technologies, Inc.). The hypertrophic scars were confirmed histopathologicically.[25]

Fitzpatrick et al. published a case series regarding the outcomes of neck resurfacing using the ultrapulsed CO_2 laser. Three of ten patients developed hypertrophic scarring. Four of ten patients developed permanent hypopigmentation.[14] Of particular note, the laser settings used on the neck were the same as those used for facial resurfacing.

Fife et al. reported four patients who developed scarring or ectropion from a series of 650 patients who underwent fractional CO_2 laser resurfacing. All four patients were women. One patient developed unilateral ectropion and scarring following fractional CO_2 laser treatment to the entire face. Two months af-

TABLE 3.

Complications in Fractional Ablative Resurfacing Procedures			
Author	Laser type	Area(s) treated	Complication
Metelitsa et al	Literature review of all fractional lasers	Face	12.5% prolonged erythema 1-32% post-inflammatory hyperpigmentation
Rahman et al	Prototype fractional CO2 laser device (Reliant Technologies Inc.)	Face	33% prolonged erythema 20% post inflammatory hyperpigmentation no reports of scarring or hypopigmentation
Clementoni et al	Ultrapulse CO2	Face	2.24% prolonged erythema 5.64% post inflammatory hyperpigmentation no reports of scarring
Fitzpatrick et al	Ultrapulse CO2	Neck	30% hypertrophic scarring 40% permanent hypopigmentation
Avram et al	Fraxel re:pair	Neck	Series of 5 patients with scarring on neck
Ross et al	Active FX fractionated CO2	Neck	Single case of persistent erythema and scarring

ter the laser procedure, the ectropion had completely resolved, but a small area of thickened skin remained along the medial lower eyelid. Another patient developed linear erosions on the right neck following fractional CO_2 laser to the face and neck. Bacterial and viral cultures were negative. The patient subsequently developed a thickened, 5cm x 1cm band-like scar on the right neck. The third patient was a woman who underwent fractional CO_2 laser treatment of the eyelids, face, and neck. On the third postoperative day, she exhibited yellow exudate and erythema on the neck. Bacterial cultures demonstrated methicillin-resistant *Staphylococcus aureus* (MRSA). The infection resolved following treatment with oral antibiotics. At the follow-up visit, the affected skin on the neck demonstrated irregular texture and linear streaking compatible with scarring. The final patient was a woman with melasma who underwent fractional CO_2 laser treatment of the neck. On post-operative day six, a patchy, soft eschar with yellow exudate developed within the treated area.[26] On postoperative day nineteen, a vertical, thickened area along the left lateral neck was consistent with a scar.

Ross et al. reported a single case of persistent erythema and scarring involving the neck in a 55-year-old Caucasian female who underwent AFR with an Active FX fractional CO_2 laser.[27] On post-procedure day nine, the patient was noted to have diffuse erythema of the neck, as well as linear ulcerations. Eight weeks post-procedure, she was noted to have linear, vertically oriented hypertrophic scars.

The scarring described in the reports could have been due to overly aggressive treatment, infection, or site-specific tissue characteristics. Repetitive or overlapping passes with the laser should be avoided since excessive heat accumulation can lead to thermal damage and subsequent scarring.[28] Non-facial skin, especially skin on the neck, is more vulnerable to thermal injury. Pilosebaceous units play an important role in wound healing and re-epithelialization following fractional ablative laser resurfacing.[29] The skin on the lower two-thirds of the neck has fewer pilosebaceous units compared to other body regions; hence, wound re-epithelialization is less efficient.[25] Additionally, the cutaneous vasculature is limited on the neck, which further impairs wound healing. Therefore, less aggressive laser settings should be used when treating the neck. Moreover, treating the lower neck is more problematic compared to the upper neck. Fife et al. recommend maximum treatment densities of 35% for the upper neck and 20% for the lower neck.[26]

Overall, the DOT laser shows a very low morbidity rate compared to published data on the other fractional CO_2 lasers (Table 3).

Procedural Recommendations for DOT Laser Resurfacing

Pre- and post-procedure instructions are critical as they can help reduce the risks of procedural complications. To help reduce the risk of prolonged erythema, patients should be advised to temporarily avoid using active, topical products (eg, salicylic acid, Vitamin C, retinoic acid, and glycolic acid) for 2 weeks prior to laser procedures as these ingredients increase skin sensitivity. Likewise, these active skincare products should not be restarted until 3-4 weeks post-laser treatment since the MTZs created by the laser enable increased absorption of topical products; this can result in increased skin irritation.

To reduce laser-induced melanocyte stimulation and subsequent post-inflammatory hyperpigmentation, laser resurfacing should be scheduled when patients do not have a tan. Additionally, to reduce the risks of prolonged erythema and post-inflammatory hyperpigmentation, patients should be counseled regarding the importance of daily sun protection following laser treatments. Several sources recommend that

patients avoid ultraviolet exposure two weeks prior to laser treatment, as well as two weeks after treatment.[15,16]

Herpes simplex infection, the most common infectious complication following laser resurfacing, affects up to 2% of patients.[17] Patients are at risk for herpes reactivation, especially when laser resurfacing is performed near the lips. To reduce the risk of herpes reactivation, patients should be prescribed prophylactic oral antiviral therapy.

When performing laser resurfacing, one should use different energy settings for different body regions. In regards to the head and neck, we recommend being cautious when treating the lower two-thirds of the neck since there is a decreased density of adnexal structures. Hence, this region of the neck is more susceptible to thermal injury and subsequent scarring. In contrast, the skin of the upper third of the neck is more similar to the skin of the face.

Limitations of Study

This was a retrospective chart review. Data was collected from laser case logs.

CONCLUSION

This is the first large-scale study to examine the safety profile of the microablative SmartXide DOT laser. Overall, the DOT laser is an extremely safe device that can be used to treat a variety of skin problems. A major benefit of this treatment modality is that it is a minimally invasive procedure that requires very short downtime and is well tolerated by patients, especially using a combination of topical and cold air anesthesia.

It is critical for dermatologists, plastic surgeons and other healthcare providers to be familiar with the safety profiles of different laser devices. Moreover, it is important to recognize and report complications associated with laser treatments to improve patient safety and improve our understanding regarding the limits and therapeutic efficacy of these devices.

DISCLOSURES

Drs. Hanke, Doerfler, and Gustafson have no conflicts of interest relevant to the topic. (Add Drs. Sarnoff and Gotkin.)

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