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Multi-Center Clinical Study and Review of Fractional Ablative CO_2 Laser Resurfacing for the Treatment of Rhytides, Photoaging, Scars and Striae

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ABSTRACT

Laser skin resurfacing has shifted over the past two decades from standard ablative resurfacing to non-ablative resurfacing and most recently, to fractional laser resurfacing. In this most recent category, fractional non-ablative lasers were first introduced followed by fractional ablative lasers, which offer an improved balance between safety and efficacy. In the current article, a review of fractional ablative resurfacing is presented alongside the results from a multi-center clinical study employing the fractional carbon dioxide (CO_2) laser (SmartXide DOT, DEKA) for the treatment of rhytides, photoaging, scars and striae distensae.

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INTRODUCTION

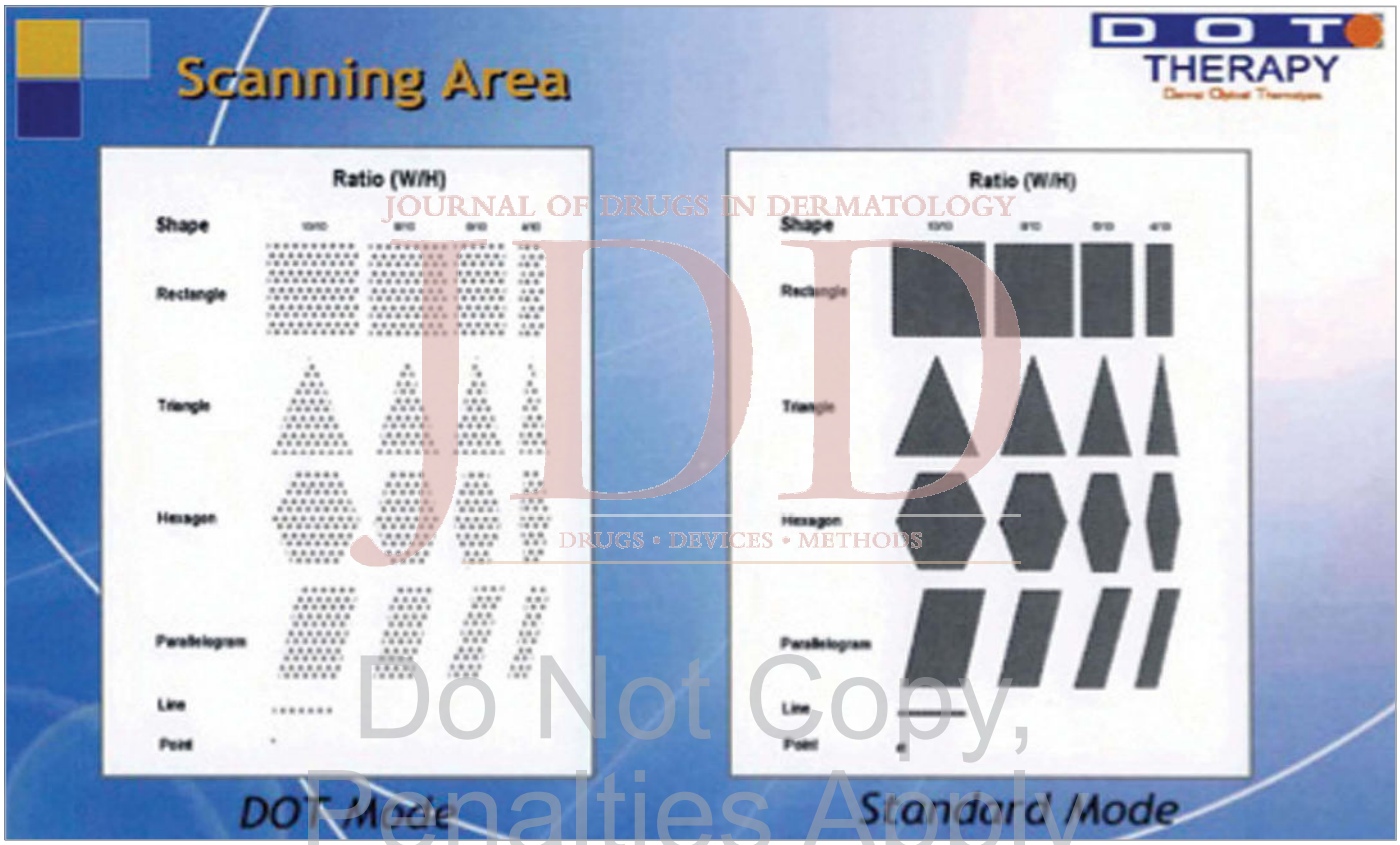
While highly effective in reducing rhytides, photoaging and acne scarring, standard ablative laser resurfacing was associated with significant side effects and complications.[1] In an effort to improve patient safety, non-ablative laser resurfacing emerged, which while safe, proved much less effective.[1] In a more balanced approach, fractional laser resurfacing was developed over the past several years in an effort to combine the efficacy of standard laser resurfacing with the safety of non-ablative modalities.[2] Although the first fractional laser device was non-ablative, producing microscopic columns of thermal injury in the epidermis and upper dermis, it pioneered a novel concept in lasers which has been quickly applied to fractional ablative laser resurfacing.

In fractional ablative laser resurfacing, ablative wavelengths including carbon dioxide (CO_2) (10,600 nm), erbium(Er): YAG (2940 nm) and the relatively novel yttrium aluminum garnet (YSGG) (2790 nm) lasers are delivered in a microscopic array to ablate microscopic columns of epidermis and dermis, with intervening zones of untreated tissue.[1] The key adjustable laser parameters of power, pitch, dwell time and spot density determine the percent surface area, penetration depth and clinical recovery time and efficacy. An additional unique feature of the fractional CO_2 device presented here (SmartXide DOT, Deka) is the multi-faceted adjustability of the size and shape of the treatment area. Fractional CO_2 laser resurfacing is an important advance to the laser field, striking a balance between safety and efficacy in the treatment of rhytides, photoaging and scars.

Fractional CO_2 Laser Resurfacing

In light of the fact that fractional non-ablative resurfacing yielded minimal to modest efficacy per treatment and required multiple treatments, fractional ablative lasers offered promise of higher efficacy in fewer treatments. Instead of creating microscopic columns of thermal injury, fractional ablative resurfacing generates microscopic columns of ablated tissue extending from the epidermis into the dermis. This approach increased efficacy closer to that of standard ablative resurfacing, but without the side effects and complications of the latter. The clinical results following a single treatment are more significant as compared to fractional non-ablative laser resurfacing, but the procedure is associated with comparatively more discomfort, post-operative erythema and recovery time.

> Laser skin resurfacing has advanced tremendously with the introduction of fractional laser resurfacing, particularly fractional ablative skin resurfacing. Among the fractional ablative lasers, the fractional CO_2 has demonstrated great utility in the treatment of rhytides, photoaging and scarring.



Types of Fractional Ablative Lasers

Ablative laser wavelengths work by being rapidly and efficiently absorbed by tissue water, resulting in very rapid heating and vaporization of cells. The three ablative wavelengths in use for fractional ablative laser resurfacing are: 10,600 nm emitted by the CO_2 laser, 2,940 nm emitted by the Er:YAG laser and 2,790 nm emitted by the yttrium: sapphire; garnet (YSGG) laser. The differences among the three ablative wavelengths in their absorption coefficients determine the relative degree of ablation versus thermal injury. The Er:YAG laser wavelength is absorbed with a very high coefficient by water such that cells vaporize immediately without thermal injury. The absence of collateral thermal injury is the reason the Er:YAG laser fails to achieve adequate peri-operative hemostasis.[1] The absorption coefficient for the wavelength emitted by the YSGG laser is lower than that of Er: YAG, such that it generates relatively less ablation but with some thermal injury which maintains better hemostasis. Finally, the CO_2 laser wavelength has a much lower absorption coefficient for water such that a significant amount of collateral thermal injury occurs, maintaining excellent hemostasis, but with a relatively higher risk of causing excessive thermal injury.[1] In standard ablative laser resurfacing comparative studies, higher clinical efficacy has been reported with CO_2 as compared to Er:YAG when controlling for energy delivery and penetration depth, suggesting the possibility that the thermal injury generated by the CO_2 laser may induce greater neocollagenesis.[1,4-6]

TABLE 1.

Key Parameters of Fractional Ablative Laser Resurfacing

Parameter	Range	Clinical Impact
Power or Fluence	5-100 mJ/ microbeam	Directly proportional to penetration depth and collateral thermal injury, if any
Microspot Diameter	125 – 1250 microns	Inversely proportional to penetration depth
Dwell Time	Up to 1 ms	Directly proportional to thermal injury
Microspot Spacing	Variable or Fixed	Inversely proportional to density of treated skin and peri-operative discomfort

Technological Properties

A number of different fractional ablative CO_2 technologies are available to date. All CO_2 devices deliver 10,600 nm wavelength.

TABLE 2.

Multi-Center Clinical Grading Results and Prameters for Fractional CO_2 Laser Treatment of Rhytides, Scars and Striae[10]

Grading Scale	Descriptive Parameter	Categories of Skin Aging and Photodamage			
		Rhytides	Laxity	Elastosis	Dyschromia
0	none	none	none	none	none
1	mild	wrinkles in motion, few, superficial	localized to nasolabial (nl) folds	early, minimal yellow hue	few (1-3) discrete small (<5 mm) lentigines
1.5	mild	wrinkles in motion, multiple, superficial	localized, nl and early melolabial (ml) folds	yellow hue or early, localized periorbital (po) elastotic beads (eb)	several (3-6), discrete small lentigines
2	moderate	wrinkles at rest, few, localized, superficial	localized, nl/ml folds, early jowls, early submental/ submandibular (sm)	yellow hue, localized po eb	multiple (7-10), small lentigines
2.5	moderate	wrinkles at rest, multiple, localized, superficial	localized, prominent nl/ ml folds, jowels and sm	yellow hue, po and malar eb	multiple, small and few large lentigines
3	advanced	wrinkles at rest, multiple, forehead, periorbital and perioral sites, superficial	prominent nl/ml folds, jowls and sm	yellow hue, eb involving po, malar and other sites	many (10-20) small and large lentigines
3.5	advanced	wrinkles at rest, multiple, generalized, superficial; few, deep	deep nl/ml folds, prominent jowls and sm, prominent neck strands	deep yellow hue, extensive eb with little uninvolved skin	Numerous (>20) or multiple large with little uninvolved skin
4	severe	wrinkles throughout, numerous, extensively distributed, deep	marked nl/ml folds, jowls and sm, neck redundancy and strands	deep yellow hue, eb throughout, comedones	numerous, extensive, no uninvolved skin

Most fractional CO_2 devices employ an optical scanner to scan a very small laser spot across the skin, such as in the case of the SmartXide DOT, while others use a stamping method of delivery where an array of laser spots are "stamped" on the skin through a micro lens array. The diameter of each microbeam differs, examples being 125 μ (e.g., Lumenis Deep Fx); 300 μ (e.g., SmartXide DOT); and 1.25 mm (e.g., Active Fx). Smaller microspot sizes correlate with greater penetration depths of the microbeam. The density of the microlesions differs among devices and is adjustable for several of them, extending from 5% surface area coverage to 100% depending upon the device. For the SmartXide DOT, the surface area adjusts from 5-100%. The energy output differs among the devices and is often represented as mJ or Watts per microbeam. As the energy output per microbeam increases, the penetration depth increases for a given microspot size. The SmartXide DOT generates power output of up to 30 W. The penetration depth of the microlesions varies from 300 μ to as much as 1.6 mm depending upon the device. For the SmartXide DOT, the penetration depth is up to 400 μ for single pulse and up to 1 mm for stacked pulses. The pulse duration is adjustable and plays a role in the degree of thermal damage that is induced.

Key Parameters

There are four key parameters that determine the intensity of fractional ablative laser resurfacing treatment (Table 1). Their adjustment with each device determines the extent of surface area to be treated, the penetration depth of the microbeam, the

TABLE 2. CONT'D.

Categories of Skin Aging and Photodamage		
Erythema-Telangiectasia (T-T)	**Keratoses**	**Texture**
none	none	none
pink E or few T, localized to single site	few	subtle irregularity
pink E or several T localized to 2 sites	several	mild irregularity in few areas
red E or multiple T localized to 2 sites	multiple, small	rough in few, localized sites
red E or multiple T, localized to 3 sites	multiple, large	rough in several, localized areas
violaceous E or many T, multiple sites	many	rough in multiple, localized sites
Violaceous E, numerous T little uninvolved skin	little uninvolved skin	mostly rough, little uninvolved skin
deep, violaceous E, numerous T throughout	no uninvolved skin	rough throughout

TABLE 3.

Sample Parameters According to Indication and Recovery Time for SmartXide DOT				
Sample Indication	**W**	**Dot spacing**	**Dwell time**	**Recovery time**
Lentigines photoaging	20	500	700	3 days
Moderate rhytides	25	650	850	5 days
Deep rhytides	30	800	>1000	7 days

FIGURE 1. Fractional CO_2 laser resurfacing for the treatment of rhytides and photoaging. The baseline and post-treatment photographs of a subject treated at site number one (MAA) are shown, with demonstrable improvements in rhytides, dyspigmentation and vascularity, and a milder improvement in skin laxity.

diameter of the microlesion and the degree of ablation vs. thermal injury that is induced. The precise manipulation of these four parameters in turn pre-determines the number of days of healing time required by the patient, which represents an important practical advantage. The first parameter is the power (Wattage), which is the energy delivery per microbeam. This varies from 5-100 mJ/microbeam per device (Table 1). As the power output is increased, the penetration depth for a set microdiameter in-

TABLE 4.

Multi-Center Clinical Grading Results and Prameters for Fractional CO_2 Laser Treatment of Rhytides, Scars and Striae

Site	Pre	Post	Change	# of Treatments	W	Spacing	Dwell	Passes
1. MAA Rhytides	3	2	1	4	17	750	700	1
	3	2.25	0.75	2	20	700	1000	1
	3.25	2.5	0.75	5	17	700	700	3
	4	3.5	0.5	5	15	750	800	2
	2.5	2	0.5	4	20	650	800	1
	2	1.5	0.5	1	17	750	700	1
	3.5	2.5	1	3	20	700	800	1
	2	1.5	0.5	3	20	500	100	1
	2	1.75	0.25	2	17	500	750	1
	3	2	1	2	15	750	800	1
Mean SD	2.83	2.15	0.68	3.10	17.80	675.00	715.00	1.30
	0.69	0.59	0.26	1.37	2.04	97.89	233.39	0.67
1. MAA Scars		mod	2	1	17	650	700	1
		mod	2	2	17	500	750	1
		mod	2	7	16	700	600	1
		adv	3	3	20	500	800	1
Mean SD			2.25	3.25	17.50	587.50	712.50	1
			0.50	2.63	1.73	103.08	85.39	0
1. MAA Striae		adv	3	3	15	750	600	1
		no	0	3	15	700	600	1
		mod	2	3	14	750	600	1
		no	0	4	14	750	600	1
		no	0	3	14	700	600	1
Mean SD			1.00	3.20	14.40	730.00	600.00	1
			1.41	0.45	0.55	27.39	0.00	0
2. RG/DS	2.00	1.50	0.50	1	30	200	1700	1
	2.00	1.50	0.50	1	25	500	1500	1
	4.00	1.50	2.50	1	30	200	1700	2
	3.00	1.00	2.00	1	30	200	2000	1
	3.00	1.50	1.50	1	30	300	1500	2
	3.00	1.50	1.50	1	30	200	1200	1
	3.50	2.00	1.50	1	30	200	1500	1
	3.00	2.00	1.00	1	25	400	1500	1
	4.00	1.50	2.50	1	30	200	2000	1
	4.00	1.50	2.50	1	30	200	1500	1
	2.00	1.00	1.00	1	25	500	1000	1
	4.00	1.50	2.50	1	30	200	2000	2
Mean SD	3.13	1.50	1.63	1	28.75	275	1591.67	1.25
	0.80	0.30	0.77	0.00	2.26	121.54	311.76	0.45
3. NS	2	1	1	2	25	400	300	1.5
	3	2	1	2	25	600	1500	1.5
	2	2	0	1	25	400	400	1.5
	2	1.5	0.5	2	25	600	800	2
	1.5	1	0.5	2	25	400	250	1
	2	2	0	2	25	400	400	2
	1.5	1	0.5	2	25	500	1200	1
	1.5	1.5	0	2	25	600	1600	2
	2	2	0	2	25	400	600	1
	1	1	0	2	25	400	400	2
	1.5	1	0.5	2	25	600	1400	1.5
	1.5	1.5	0	4	25	1000	350	1.5
	2	1.1	0.9	4	25	700	1300	1
	2.5	1.5	1	2	25	400	400	1
Mean SD	1.86	1.44	0.42	2.21	25.00	528.57	778.57	1.46
	0.50	0.43	0.42	0.80	0.00	172.89	506.01	0.41

Key: Grading scale of rhytides (see Table 2).
Grading scale of improvement for scars and striae: 0=no improvement; 1=minimal improvement; 2=moderate improvement; 3=advanced improvement; 4=complete resolution of scar or striae.

FIGURE 2. Acne scars treated with fractional CO_2 laser resurfacing. Significant reduction of acne scars is shown in this subject treated at site number one (MAA).

FIGURE 3. Fractional CO_2 laser resurfacing for the treatment of striae distensae. The clinical outcomes in the treatment of this condition were variable and inconsistent. Shown here is one case where improvement was noted.

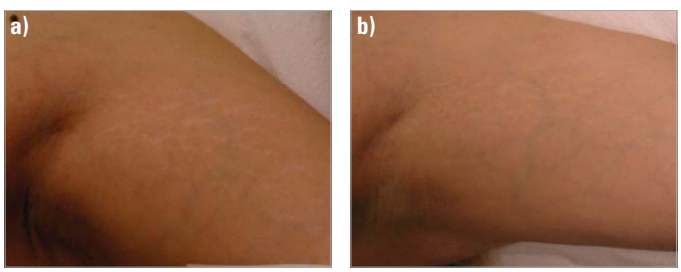


TABLE 5.

Severity Grading			
Site	**Pre**	**Post**	**Change**
MAA	3	2	1
	3	2.25	0.75
	3.25	2.5	0.75
	4	3.5	0.5
	2.5	2	0.5
	2	1.5	0.5
	3.5	2.5	1
	2	1.5	0.5
	2	1.75	0.25
	3	2	1
Mean SD	2.83	2.15	0.68
	0.69	0.59	0.26
MAA Scars		mod	2
		mod	2
		mod	2
		adv	3
Mean SD			2.25
			0.50
MAA Striae		adv	3
		no	0
		mod	2
		no	0
		no	0
Mean SD			1.00
			1.41
Got/Sarnoff	2.00	1.50	0.50
	2.00	1.50	0.50
	4.00	1.50	2.50
	3.00	1.00	2.00
	3.00	1.50	1.50
	3.00	1.50	1.50
	3.50	2.00	1.50
	3.00	2.00	1.00
	4.00	1.50	2.50
	4.00	1.50	2.50
	2.00	1.00	1.00
	4.00	1.50	2.50
Mean SD	3.13	1.50	1.63
	0.80	0.30	0.77
NS	2	1	1
	3	2	1
	2	2	0
	2	1.5	0.5
	1.5	1	0.5
	2	2	0
	1.5	1	0.5
	1.5	1.5	0
	2	2	0
	1	1	0
	1.5	1	0.5
	1.5	1.5	0
	2	1.1	0.9
	2	1.5	1
Mean SD	1.86	1.44	0.42
	0.50	0.43	0.42

creases proportionately. The second parameter is the pitch or microspot spacing. The smaller the pitch or spacing, the greater the density or surface area of skin treated. Some devices have adjustable pitch, such as the SmartXide DOT, whereas others are fixed. The dwell time or pulse duration of each micropulse correlates with the degree of thermal injury. Finally, the microbeam diameter, which is fixed for each device nevertheless varies significantly among devices and plays an important role in penetration depth (Table 1).

The relative influences of laser power output and dwell time (pulse duration) are shown in Figure 1. As power output is increased, the penetration depth of the ablative microcolumn is increased. As dwell time or pulse duration is increased, the degree of collateral thermal injury that is incurred increases. In order to achieve adequate hemostasis and possibly induce greater neocollagenesis, a combination of both ablative and thermal injury may be the ideal.

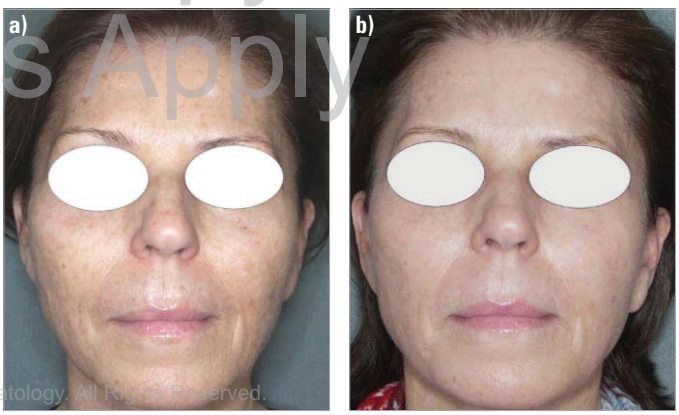
The effects of microspot diameter on penetration depth are significant. At a set energy level, a small microspot diameter results in far greater depth of ablation; a large diameter results in very superficial ablative depth. For example, one of the smallest microspot diameters among fractional CO_2 devices is 0.135 μ (Fraxel Repair, Solta), which achieves a reported penetration depth of 1.6 mm.[7] In contrast, the largest microspot diameter for a fractional CO_2 laser is 1.25 mm (Active Fx, Lumenis), which correlates with a penetration depth of only 80-100 microns. The SmartXide DOT contains a 300 μ microspot diameter with a penetration depth of 400 μ per pulse.

Microspot density is an important parameter adjustable in many fractional ablative devices and which determines the amount of surface area that is treated. The microspot density is equivalent to the treated area divided by the total surface area. It is the inverse of the microspot pitch or spacing. The smaller one adjusts the pitch or spacing, the higher the density of microlesions and the surface area that is treated. As the pitch or microspot spacing is increased, the density of treated skin decreases and this correlates with decreased patient discomfort and faster recovery time.

The fractional CO_2 device presented here possesses adjustable scanning spot size and shape (e.g., SmartXide DOT, Deka). This device is able to scan various shapes, including rectangles, triangles, hexagons, parallelograms and so on. The sizes and ratios of each shape are also adjustable. The significant advantages of this flexibility include the precise treatment of acne scars and striae. It has been shown that additional passes confined to the acne scars augment clinical improvement of the scars, much in the manner that trichloroacetic acid placement within acne scars has been shown to yield improvement through neocollagenesis. In the case of striae distensae, it is desirable to treat the affected areas, while leaving normal flanking skin untreated. Finally, the adjustable shapes allow for precise treatment of cosmetic areas, such as accurate coverage along the mandible and periorbital regions. For example, one may employ large rectangles for coverage of the majority of the face followed by triangles to fill in the gaps to create a precise line across the jaw.

FIGURE 4. Fractional CO_2 laser resurfacing for the treatment of rhytides and photoaging. A significant improvement was noted in this case, which was treated at site number two employing more aggressive parameters.

FIGURE 5. Fractional CO_2 laser resurfacing for the treatment of rhytides and photoaging. A clinical outcome from clinical site number three (NS).



Clinical Findings

Side Effects

Immediately following a pulse with fractional CO_2, white micromacules appear on the skin surface. These white microlesions slowly become erythematous macules. The post-operative erythema tends to become more prominent in the subsequent 1-3 days, depending upon the parameters employed. If low power

output is employed, erythema may be mild and resolve within one day; at high power settings and dwell times, erythema may be pronounced with accompanying edema for up to seven days or more. While treatments typically result in post-operative erythema, in some instances peri- and post-procedural crusting may be observed. Erythema severity and duration is reproducibly determined by the power, dot spacing and dwell time. A representative set of parameters and recovery times are shown in Table 3.

Clinical Outcomes

Clinical outcomes from fractional CO_2 laser resurfacing depend upon the aforementioned key parameters (Table 1), pass counts, treatment numbers and baseline grade severity (Table 2). Patients of higher baseline grade severity require more aggressive parameters, passes and treatment numbers. Final clinical outcome is observed at the 12 month timepoint, following the timecourse of neocollagenesis detailed in the literature. Gradual progressive improvement in rhytides and all categories of photoaging (see Table 2 and Figure 1) is typically observed, reaching a plateau at 12 months. While a modest reduction in skin laxity may be observed (see Figure 1), this beneficial clinical outcome is less consistent and may be secondary to the degree of collateral thermal injury, a direct result of dwell time, though this has not been directly tested.

Adverse Events

While the frequency of adverse events is much lower than that of standard ablative resurfacing, pre-medication with antivirals as prophylaxis against herpes simplex virus is necessary. It is important to monitor for post-treatment infections and advise patients to contact the physician if redness, pain, or oozing should manifest, though the incidence of this is far lower than with standard ablative resurfacing. In clinical trials and published reports, several cases of dyspigmentation and hypertrophic scarring have been observed, particularly on the neck and in instances where multiple passes were administered at aggressive settings.

Post-operative erythema in a dot pattern may persist for weeks or months following fractional ablative resurfacing. In addition, it is important to emphasize that while the side effect and complication rates are much lower than those of standard ablative resurfacing, fractional ablative resurfacing is not without side effects, recovery and the very small risk of pigment and textural changes, particularly when the energy output or pass counts are high. It is important to emphasize that prolonged erythema and potential textural changes including hypopigmented scarring increase with increasing power, dwell time and pitch. For the novice, it is advisable to commence with conservative settings and to avoid high-risk anatomic sites such as the neck and chest.

Fractional CO_2 laser resurfacing is safer than traditional CO_2 laser skin resurfacing; however, it is not without side effects and the potential for complications. Avoid aggressive, overlapping scans, more than two passes, or too high energy, all of which may lead to pigmentary and textural alteration. In addition, multiple passes with a fractional CO_2 device can cause charring or a brown discoloration to the skin, which increases the risk of scarring.

Post-procedural dermatitis, including allergic contact dermatitis to wound dressings, are known complications; they should be part of the post-operative instructions to the patients and should be treated with topical corticosteroids. Post-operative acneiform eruptions, either due to the thermal effect or occlusive hydrophobic wound dressings, must also be monitored. In this instance, switching to a non-occlusive cream based dressing and commencing a gentle acne preparation will speed resolution.

Histological Findings

A comparison of the histological findings immediately post-treatment with each of the three sets of parameters with fractional CO_2 laser demonstrates their relative penetration depths. The YSGG with a 300 micron spot size when applied at 160 J/cm^2 (half-maximum output) and 3 ms pulse duration results in a 600-800 micron ablative depth, 60 microns of coagulation at the bottom margin, with 40-50 microns of coagulation flanking each lateral edge. In contrast, the fractional CO_2 (SmartXide DOT) with a 300 micron microspot size at 20 W and a 1 ms dwell time results in a 300 micron ablative depth when three stacked pulses are administered, with 250 microns of thermal coagulation at lateral and deep margins.[7]

Histological evaluation of fractional CO_2 laser resurfacing demonstrates the direct correlation between energy output and ablative depth of penetration. The ablative penetration depth immediately following treatment with a fractional CO_2 device emitting a 135 micron microspot diameter ranged from 100 microns to 1.6 mm as the fluence was increased.[8] The wound healing that ensues during the first thirty days following treatment with fractional ablative CO_2 laser demonstrates granulation tissue at one to three days followed by progressive neocollagenesis, dermal remodeling and MMP upregulation to 30 days post-treatment.[9] Neocollagenesis continues for several months post-treatment, as has been demonstrated for standard ablative CO_2 laser resurfacing.[1]

Multi-Center Clinical Trial

A multi-center clinical study was performed with a fractional CO_2 device, the SmartXide DOT (Deka), evaluating its safety and efficacy in the treatment of rhytides, photoaging, acne scars and striae distensae. The study was conducted at three clinical testing centers and enrolled a total of 52 subjects.

PATIENTS AND METHODS

Patient Enrollment

A multi-center clinical study with the SmartXide DOT fractional CO_2 device was conducted under institutional review board approval (Essex IRB). Use with the DOT Scanner is FDA approved with 510(k) number K072159 for ablative skin resurfacing. Three clinical sites were included. A total of 52 subjects were enrolled, 22 (MAA), 20 (DS, RG) and 20 (NS). Inclusion criteria consisted of: male or female subjects between the ages of 30 and 75 years old; Fitzpatrick skin types I–VI; subjects demonstrating one of the following clinical disorders: rhytides (minimum baseline grade 2 on comprehensive grading scale, Table 2), photoaging (minimum grade 2), acne scars on the face, or striae distensae on the face, neck, décolletage, arms, or hands, or present with scars (traumatic, or acne), or striae; subjects refrained from using cosmeceutical or topical agents, such as retinoids, during the course of the study, except as directed by the study investigators. Exclusion criteria consisted of: subjects with localized or systemic infections; subjects with a history of any cosmetic treatment for six months prior to study treatment; subjects with a history of keloid scar formation, compromised wound healing ability or systemic disease; subjects who were immunocompromised; subjects with a history of gold therapy; subjects with a history of use of topical steroids or retinoids on the treatment area within three months of enrollment; subjects who were pregnant or lactating and women of childbearing age used an acceptable form of birth control (i.e., oral contraceptives, IUD, contraceptive implant, barrier methods with spermicide or abstinence) during the course of the study unless they are post-menopausal or surgically sterilized; subjects with any eye disorder which would preclude use of internal eye shields during treatment procedures; subjects with allergies to antiviral medications; subjects allergic to Benzocaine, Lidocaine, Tetracaine or epinephrine.

Treatment Protocol

Pre-treatment with anti-viral medication using famcyclovir 250 mg po bid was commenced in patients receiving facial treatments starting one day prior to the treatment and continuing to post-op day five. On the day of treatment, patients receiving facial treatments were anesthetized using topical anesthetic cream (4% lidocaine, 4% tetracaine, EMLA) for one hour prior to treatment. Cold air employing a Zimmer cooling technique was administered concomitant to each laser pulse for additional pain control. Immediately following treatment of a cosmetic area, cold compresses using gauze soaked in ice water were applied. Following treatment, Aquaphor ointment was applied to the treatment area and patients were instructed as to wound care, cleansing and petrolatum application.

Subjects received one to five treatments at monthly intervals based on physician assessment. Treatment parameters were determined by physician discretion and ranged from 5-30 W, 200-2,000 μs dwell time and 200-2,000 μm DOT pitch. From three subjects per center, skin biopsies (3 mm) for histological evaluation were taken at the following intervals: immediately post-treatment, three, seven, 14, 30 and 90 days post-treatment. Subjects received one to five treatments with the SmartXide DOT fractional CO_2 device at 15-30 W, 500-800 μ dot spacing, and dwell times ranging from 500-1,000 ms. The parameters employed for each clinical disorder differed and representative parameters are shown in Table 3.

Clinical Assessments

Patients were digitally photographed at baseline, one and three months at two study sites (DS/RG, NS) and to a final follow-up interval of six and 12 months at one study site (MAA). Clinical severity of rhytides and photoaging were graded employing a validated Comprehensive Grading Scale of Rhytides, Laxity and Photoaging (Table 2).[10,11] Clinical assessments of acne scars and striae distensae were confined to the determination of efficacy vs. no efficacy. The level of improvement, if any, was determined at final follow up as improvement or no improvement with no quantitative determination of extent of efficacy for acne scars or striae distensae. Quantitative assessments of level of efficacy were determined for rhytides and photoaging as described previously.[1,10,11]

RESULTS

Patient Demographics

Patients ranged in age from 35 to 65, mean 58 (SD 5). 47 females and five males were included in the study. 32 were in the rhytide/photoaging group, 15 in the acne scarring group and five in the striae distensae group. The number of subjects and treatment numbers at each study site are shown in Tables 2-4.

Clinical Outcomes

In Figures 1-5, clinical outcomes from the SmartXide DOT fractional CO_2 device are shown. Significant improvement in rhytides, photoaging, and acne scars are typically observed following fractional CO_2 therapy, improving gradually over a 6-12 month period. The results in clinical outcomes for the treatment of striae distensae were variable and inconsistent.

The parameters applied per subject and quantitative grading results employing the validated grading scale for rhytides and photoaging for all study sites are shown in Tables 4-5. The mean baseline grades, grade improvement in rhytides and photoaging, dosing and parameters differed among the three investigator sites. At the first site (MAA), the mean baseline rhytides and photoaging score was 2.83 (+/- SD 0.69) and the mean final follow-up score was 2.15 (SD +/- 0.59) with final follow up at 12 months. The mean grade difference was 0.68 (+/- SD 0.26) on the 4-point grading scale following a mean of 3.10 (+/- SD 1.37) treatments (Table 5). At site number two (RG/DS), the mean baseline grade was 3.13 (+/- SD 0.80); the mean follow-up grade was 1.50 (SD 0.30) following a mean of one treatment;

and the mean grade difference were 1.63 (+/- SD 0.77). At site number three (NS), the mean baseline grade was 1.86 (+/- SD 0.50); mean follow up grade was 1.44 (+/- SD 0.43); and mean grade difference was 0.42 (+/- SD 0.42) following a mean of 2.21 (+/- SD 0.80) treatments.

These differences in grade improvements correlated with dosing parameters such as power, dot spacing, dwell time and pass numbers. At treatment site number one, the mean power employed was approximately 18 W (+/- SD 2), mean dot spacing was 675 (+/- SD 98) microns, mean dwell time was 715 (+/- SD 233) microseconds, and mean pass number was 1.30 (+/- SD 0.67). At investigator site number two, the mean power employed was approximately 29 W (+/- SD 2.3), mean dot spacing was 275 microns (+/- SD 122), mean dwell time was 1592 microseconds (+/- SD 312) and mean pass count was 1.25 (+/- SD 0.45). At the third investigator site, the mean power employed was 25 W (+/- SD 0), mean dot spacing was 530 (+/- 173) microns, mean dwell time was 780 (+/- SD 506) microseconds, and mean pass count was 1.5 (+/- SD 0.4).

Clinical outcomes among acne scarring patients were consistently graded as moderate improvement on a 4-point improvement grading scale, where grades were 0=no improvement; 1=minimal improvement; 2=moderate improvement; 3=advanced improvement; 4=complete resolution of scars or striae. The mean grade improvement for scars was moderate at 2.25 (SD +/- 0.5). The mean grade improvement for striae was minimal at grade 1.00 (SD +/- 1.41) (Table 5).

Safety

Pain and discomfort were minimal during the course of treatment. No cases of infection, dyspigmentation or scarring were observed during the course of the study.

DISCUSSION

The results of this multi-center clinical study for the treatment of rhytides, photoaging, scars and striae with a fractional CO_2 device (SmartXide DOT) demonstrated excellent efficacy per treatment in rhytides and photoaging with an excellent safety profile. Efficacy was more moderate for the treatment of scars, requiring multiple treatment sessions. The data were inconclusive regarding the treatment of striae distensae following a series of treatments, with some patients demonstrating a significant improvement while others showed no change from baseline.

The grade improvements in rhytides and photoaging among the three study centers appeared to correlate with the dosing parameters employed. There was a direct correlation between the power employed, pitch (1/spacing), dwell time and pass counts. The investigator sites where power output was confined to the 20-25 W range, dot spacing to 500 µm and above and dwell times of under 800 µs, yielded more modest grade improvements of approximately 0.5 grade on the 4-point grading scale of rhytides and laxity (see Table 5). In contrast, the investigator sites where more aggressive parameters were employed of power output of 25-30 W, with spacing of 200 and dwell times in excess of 1 ms yielded significantly higher grade improvements, with an average grade improvement of 1.6 on the 4-point grading scale. This is logical and expected, given that as the power output increases, dot spacing decreases and dwell time augments, the degree of surface area coverage and depth of penetration and thermal injury approach that of standard CO_2 resurfacing. Another possible explanation for these findings is that the average baseline grades differed among the sites, with the sites demonstrating more modest grade improvements evincing lower baseline rhytide and photoaging grades. In contrast, the site with the larger grade improvement demonstrated a higher baseline grade. This explanation is unlikely as many studies have suggested that subjects with more advanced rhytides and laxity have demonstrated less responsiveness to laser resurfacing. Thus, it is likely that the larger grade improvements observed in the current study are due to the more aggressive parameters employed.

The clinical outcome in scars was consistently graded moderate in efficacy, with a 2.25 grade improvement on a 4-point grade improvement scale (see Results and Table 4). In contrast, striae alba were inconsistently responsive to treatment, with a mean grade improvement of 1.00, corresponding to minimal improvement. Of import, several striae subjects demonstrated no improvement to fractional CO_2 resurfacing treatment, whereas a subset evinced moderate-advanced improvement. Given the inconsistency and unpredictability of this result, the data presented here do not support the application of fractional CO_2 resurfacing for this condition.

Important drawbacks in comparing the efficacy rates among the investigator sites include the differences in baseline rhytide and photoaging grades among the sites. The subjects at site number two showed a mean baseline grade of 3.13 as opposed to 1.86 at site number three. This is the likely rationale for the more aggressive dosing parameters employed at the former site and may have contributed to the higher grade-level improvements reported at that site.

CONCLUSION

Laser skin resurfacing has advanced tremendously with the introduction of fractional laser resurfacing, particularly fractional ablative skin resurfacing. Among the fractional ablative lasers, the fractional CO_2 has demonstrated great utility in the treatment of rhytides, photoaging and scarring. Among the fractional CO_2 devices, the SmartXide DOT demonstrates versatility

in its scanned areas allowing for practical advantages in the treatment of cosmetic areas and specific lesions, such as acne scars. While differences exist in the microspot diameters and penetration depths of the different devices, we are beginning to understand the significance of these differences and software to augment penetration depth at larger microspot sizes.

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DISCLOSURES

The authors have no conflicts of interest to disclose.

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