

Successful Treatment of Acneiform Scarring With CO₂ Ablative Fractional Resurfacing

Anne M. Chapas, MD, Lori Brightman, MD, Sean Sukal, MD, Elizabeth Hale, MD, David Daniel, MD, Leonard J. Bernstein, MD, and Roy G. Geronemus, MD*

Laser & Skin Surgery Center of New York, New York, New York

Background: Acneiform scarring after severe episodes of acne is a common cosmetic concern, treatable by a variety of modalities with varying degrees of success. Ablative CO₂ laser resurfacing, while effective, is associated with an undesirable side effects profile, lengthy recovery period, and risk of infection as well as potential pigmentary alterations. Newer modalities using the principles of fractional photothermolysis (FP) create patterns of tiny microscopic wounds surrounded by undamaged tissue beneath the skin with an erbium-doped 1,550 nm laser. These devices produce more modest results in many cases than traditional carbon dioxide (CO₂) lasers but with fewer side effects and shorter recovery periods. A novel ablative 30 W CO₂ laser device uses a technique called ablative fractional resurfacing (AFR), combines CO₂ ablation with a FP system.

Methods: Thirteen subjects (skin types I–IV, aged 28–58 years) with moderate to severe acne scars underwent two or three treatments with the AFR device at 1–2 months intervals. Post-treatment erythema and edema as well as improvements in texture, atrophy, and overall satisfaction with appearance were graded on a quartile scale by subjects and investigators after each treatment and 1 and 3 months after the final treatment. Petechiae, oozing and crusting, dyschromia, and scarring were graded as present or absent 3 days, 1 week, 1 month, and 3 months following each treatment. A three-dimensional optical profiling system (Primos imaging) was used to generate a high resolution topographic representation of the acneiform scar in order to measure the depths of 10 scars from each cheek prior to the first treatment and 3 months after the last treatment.

Results: Post-treatment side effects were mild to moderate and transient, resolving rapidly within the study period. No delayed onset hypo-pigmentation or permanent scarring was observed. Quartile grading scores correlating to at least 26–50% improvements in texture, atrophy, and overall improvement were noted in all patients. Primos topographic analysis showed that all patients had quantifiable objective improvement in the depths of acneiform scars that ranged from 43% to 79.9% with a mean level of improvement of 66.8%.

Conclusion: Successfully combining ablative technology with FP, AFR treatments constitute a safe and effective treatment modality for acneiform scarring. *Lasers Surg. Med.* 40:381–386, 2008. © 2008 Wiley-Liss, Inc.

Key words: fractional resurfacing; acne scars; carbon dioxide

INTRODUCTION

Facial scarring resulting from severe acne in teen and early adult years is a common cosmetic concern. Acneiform scars are the result of compromised collagen production during the natural wound healing process, resulting in topographical depressions. Given the dermal pathology present with acne scarring, particularly in ice-pick scars, this condition can be difficult to treat effectively without utilizing treatment modalities capable of affecting dermal remodeling at least 1 mm below the skin surface. A variety of modalities have been employed to this end, including punch excision, dermabrasion, chemical peels and traditional ablative and nonablative laser treatments, each with varying degrees of success and side effects [1].

The carbon dioxide (CO₂) laser has been proven effective for a wide range of dermatologic conditions, including treatment of acne scars [1]. High-energy, short duration exposure to 10,600 nm CO₂ laser light vaporizes intra- and extracellular water, causing tissue ablation rapid enough to limit extraneous dermal injury and reduce the likelihood of additional scarring [1,2]. Removing the epidermis and dermis in this way stimulates wound remodeling with new collagen and elastin formation and subsequent improvement in atrophic scars.

Although significant clinical improvements can be made, traditional CO₂ laser ablation is not without risks. Patients undergoing CO₂ facial resurfacing can expect post-treatment erythema that lasts for weeks or even months, depending on the depth of ablation, so substantial downtime is to be expected. Edema, burning discomfort, milia and exacerbation of acne, oozing or crusting, and intermittent pruritis are among transient potential side effects. Significant complications such as infection, scarring or alterations in skin texture may occur. Increased likelihood of contact dermatitis to topical preparations is possible, as

*Correspondence to: Roy G. Geronemus, MD, Director, Laser & Skin Surgery Center of New York, 317 East 34th Street, New York, NY 10016. E-mail: rgeronemus@laserskinsurgery.com

Accepted 27 May 2008

Published online in Wiley InterScience
(www.interscience.wiley.com).

DOI 10.1002/lsm.20659

is post-inflammatory hyperpigmentation (PIH), especially in patients with darker skin phototypes [2]. Delayed-onset hypopigmentation is also a concern, particularly given that it is not transient and can markedly detract from overall clinical outcomes [3].

The introduction of fractional photothermolysis (FP) revolutionized laser surgery by delivering energy in a novel beam pattern [4]. Using a non-ablative erbium-doped 1,550 nm laser, full thickness columns of coagulation are created in a pixilated pattern (termed microthermal zones, or MTZs) just beneath the surface of the skin, leaving healthy skin between MTZs. The density and depth of MTZ may be adjusted in order to target the intended tissue in a precise manner. Because epidermal integrity is preserved and each wound is surrounded by healthy tissue, healing is rapid and recovery time dramatically reduced [5]. Though post-treatment erythema occurs in 100% of patients [4], the side effects profile for FP is minimal and includes a number of transitory events such as edema, dryness, pruritis, and bronzing [6].

FP is a well-tolerated and effective modality for an expanding variety of conditions such as photoaging, periorbital wrinkling, mild to moderate acne scarring, melasma, pigmented lesions, and poikiloderma of Civatte [4,7,8]. Patients generally require multiple treatments to achieve significant results; however even with multiple treatments, severe acne scarring is only minimally improved with nonablative energies. A novel ablative 30 W CO₂ laser investigational device (Fraxel re:pair laser prototype, Reliant Technologies, Inc., Mountain View, CA) uses a technique similar to FP, termed ablative fractional resurfacing (AFR). By depositing a pixilated pattern of microscopic ablative wounds surrounded by healthy tissue in a manner similar to that of FP [9], AFR combines the increased efficacy of ablative techniques with the safety and reduced downtime associated with FP. This is a prospective study to evaluate the efficacy of AFR in the treatment of patients with moderate to severe acne scarring.

METHODS

The subject population consisted of 15 enrolled subjects (skin types I–IV, aged 28–58 years) presenting with moderate to severe acne scars between December 2006 and January 2007, excluding on the basis of active infections, history of keloid scar formation, known allergies to lidocaine, recent Accutane use, smoking, pregnancy or cosmetic procedures in the treatment area within 12 months of enrollment. Each subject underwent two ($n = 5$) or three ($n = 10$) full-face treatments with the Fraxel re:pair prototype device at intervals of approximately 1–2 months.

Prophylactic valacyclovir hydrochloride (Valtrex, GlaxoSmithKline, Research Triangle Park, NC) and dicloxacillin were administered to all subjects pretreatment. Prior to treatment the area was washed with a gentle cleanser and water. The skin was then wiped with 70% alcohol pads and allowed to dry. A thick layer of 30% lidocaine gel was then spread evenly over the entire

treatment area with one hour allotted for penetration (wiped off before treatment), followed by facial nerve blocks (1% lidocaine plus epinephrine) given 15 minutes prior to treatment. Oxycodone hydrochloride plus acetaminophen (Percocet) and diazepam (Valium) were administered orally prior to treatment.

The fixed spot size was 120 μm for the Fraxel re:pair prototype device, with pulse energies of 20–100 mJ per pulse, densities of 100–400 MTZ/cm² per pass and total treatment densities of 200–1,200 MTZ/cm², depending on the treatment location. Treatment density was reduced by 33–66% in sensitive locations such as the nose and upper and lower eyelids. Specifically, three passes each were delivered to the neck, chin, lips, cheeks, and forehead, with two to three passes over the nose, two over the upper eyelid, and one over the lower eyelid. In addition, treatment energies were modulated such that maximum energies 70–100 mJ were used for the primary acne scar target regions, such as the cheeks, forehead and chin, while treatments on the eyelid were limited to the 20–30 mJ range.

Clinical improvement in texture, atrophy and overall satisfaction was graded on a quartile scale (0 = no improvement; 1 = <25% improvement; 2 = 26–50% improvement; 3 = 51–75% improvement; 4 = >75% improvement) evaluated at 1 and 3 months following final treatment by both patient and investigator. Objective measurement of skin texture was achieved with a three-dimensional optical profiling system (Primos imaging) that was used to generate a 30 mm \times 40 mm high resolution topographic representation of the acneiform scars. Images were obtained from each cheek in the areas of the most pronounced acneiform scarring pre-treatment and at 3 months following the last treatment. Analysis of these areas was done in standard fashion as previously described [10]. These images were used to analyze the changes in the acneiform scars over time. To accurately assess the degree of improvement, 10 scars from the cheeks of 10 different patients were isolated and analyzed to determine the cross-sectional area after the pre- and post-topographical image shells were aligned. A cross-sectional line graph across each scar, measured 10 points of depth to determine the mean change from baseline to post-treatment 3. From these 10 points, the mean change in baseline depth (μm) was determined and used to calculate the overall percentage change in each scar's depth. An example of this analysis is shown in Figure 1a,b.

Adverse effects during the recovery period (erythema, edema, petechiae, and oozing and crusting) were evaluated at days 3, 7, 30, and 90 after each laser treatment. Erythema and edema were graded on a five point scale (0 = none; 1 = trace; 2 = mild; 3 = moderate; 4 = severe), and petechiae and oozing and crusting were graded as present (yes) or absent (no). Side effects (dyschromia and scarring) were also evaluated at the same time points post-treatment. Additionally, dyschromia was graded on a five point scale (0 = none; 1 = trace; 2 = mild; 3 = moderate; 4 = severe), and scarring was graded as present (yes) or absent (no).

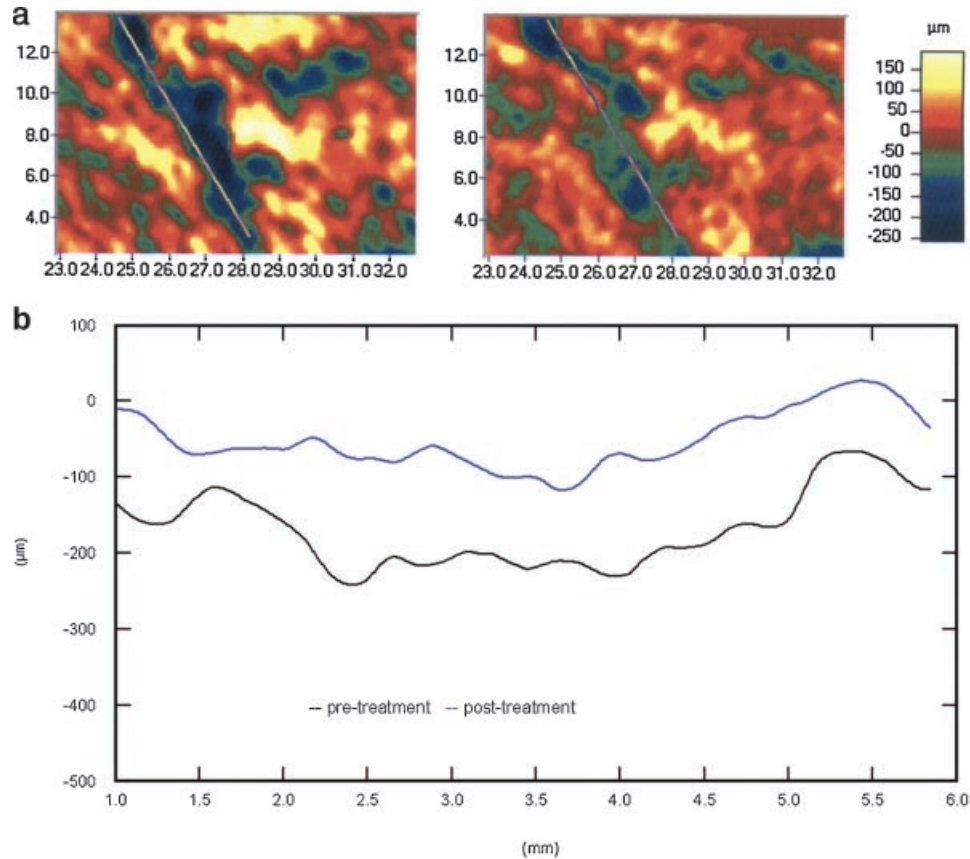


Fig. 1. **a**: Primos color coded topographic images obtained from the patient in Figure 2, shows that there is significant improvement in the deeper acneiform scars, this is represented by the lighter hue of blue (invagination) and the loss of red (evagination). **b**: Cross-sectional representation of line A drawn across scar in (a). Ten points along this graph were compared to generate the overall mean improvement in scar depth.

RESULTS

Safety

Thirteen subjects were followed to completion of the 3-month follow-up visit. Two subjects could not complete the protocol due to relocation during the observation period. Overall incidence and resolution of erythema, edema, and infection are graphically demonstrated in Table 1. Immediate erythema, present in 100% of patients, was graded as mild to moderate (mean 2.92), decreased to 1.7 by day 3 and to 1.3 by day 7 post-procedure and resolved to trace amounts (0.64 to -0.89) by 1 month after treatment. By 3 months post-treatment, only three patients showed erythema (one trace, two mild). Immediate post-treatment edema, present in all but one patient, was graded as mild to moderate (mean 2.85), diminished to 1.5 by day 3 post-treatment and resolved to trace amounts (1.0) after 7 days. There was no edema at 1 month post-treatment. Trace edema was evident in a single case at 3 months. Effects were consistent from treatment to treatment. It was observed that treatments became increasingly more tolerable throughout the treatment series, as evidenced by

reduced duration of post-treatment responses and re-epithelialization.

Immediate, transient post-treatment petechiae were observed in 53% of subjects ($n = 8$). All petechiae resolved by day 7 after the first and second treatments, and by day 3 after the third treatment. Immediate, transient post-treatment oozing and crusting were observed in 80% of subjects ($n = 12$). All oozing and crusting resolved by day 7 after the first and second treatments. After the third treatment, 2 patients experienced oozing and crusting 7 days after the treatment which resolved within the next 21 days. No oozing or crusting was evident at 3 months post-treatment. There was no incidence of permanent scarring.

There was no evidence of dyschromia following the first two treatments. Trace post-inflammatory hyperpigmentation developing after the third treatment and resolving completely by 3 months later, was seen in one subject. One case of trace and one case of mild post-inflammatory hyperpigmentation were observed at the 3-month follow up visit. Each subject who exhibited transient post-inflammatory hyperpigmentation was treated using a single pass technique at a setting of 300 MTZ/cm², as

TABLE 1. Post-Treatment Side Effects

	Erythema	Edema	Infection/scarring
Day 3 post-procedure	1.7	1.5	0
Day 7 post-procedure	1.3	1.0	0
1 month post-procedure	0.7	0	0
3 months post-procedure	0	0	0

Average values for erythema and edema on graded scale of 0–3; 0 = no erythema or edema, 1 = mild, 2 = moderate, 3 = severe.

opposed to a multiple pass approach for delivery of the same total density, as was used for other subjects. Neither immediate nor delayed hypopigmentation was observed during the 3 months following the last treatment. These patients have been followed in our office for up to 14 months without evidence of hypopigmentation.

Efficacy

Table 2 demonstrates subject and investigator gradings of texture, atrophy, and overall satisfaction with appearance at 1 and 3 months after the last treatment. As dermal remodeling progressed over the 1–3 months following the last treatments, improvement scores were also higher. Quartile grading scores correlating to a 26–50% improvement in texture were noted overall (means 2.27 and 2.39 for subjects and investigators, respectively), with consistent results from treatment to treatment. Scores correlating to a 26–50% improvement in atrophy were also noted (means 2.11 and 2.19) for subjects and investigators, respectively); <25% improvement was seen after treatment 1, rising to 26–50% improvement after subsequent treatments. Subjects and investigators recorded average overall quartile grading scores of 2.42 and 2.46, respectively, at 3 months following the last treatment, correlating to 26–50% consistent overall satisfaction with the improvements obtained. Figures 2 and 3 demonstrate improvement in atrophy and texture of cheek scarring 3 months after the last treatment.

Subjective observations of improvement correlated with objective measures of improvement using Primos topographical skin imaging. Three-dimensional topographical

images were taken from both cheeks in all 13 patients. The images were obtained at baseline (pre-treatment) and at 3 months after the last treatment. Figure 1, an example of the color coded topographic images obtained from the patient in Figure 2, shows that there is significant improvement in the deeper acneiform scars, this is represented by the lighter hue of blue (invagination) and the loss of red (evagination). To accurately quantitate the level of improvement, 10 scars were isolated from 10 different patients and mean percentage of improvement was determined as described in the methods section. Table 3 shows that the mean improvements in each scar depth ranged from 47.6% to 79.9%, with an overall mean of 66.8%.

DISCUSSION

This is the first study demonstrating the effectiveness of AFR treatments for moderate to severe acne scarring. Generally, subjects were treated three times at monthly intervals, initially at 30 mJ per pass and a density of 200 MTZ per pass, with three passes for most facial treatment areas.

Subjects and investigators both noted similar (26–50%) improvement in texture, atrophy, and overall improvement of scarring. Improved efficacy was likely due to deeper dermal penetration of energy that could not be achieved with traditional ablative devices without unseemly side effects. Despite our small sample size, trends in responses to various treatment energies were identified. Patients who were treated using higher energy levels (70–100 mJ) on deeper scars on the cheeks for the second and third

TABLE 2. Average Subject and Investigator Evaluations of Texture, Atrophy and Overall Satisfaction With Appearance Averages at 1 and 3 Months Post-Treatment

	1 month post-procedure patient assessment	1 month post-procedure investigator assessment	3 months post-procedure patient assessment	3 months post-procedure investigator assessment
Texture	1.75	1.92	2.27	2.39
Atrophy	1.42	1.75	2.11	2.19
Overall satisfaction	1.5	1.83	2.42	2.46

Subject and investigator quartile graded scale. Evaluations were based on a quartile scale as follows; 0 = 0% change, 1 = <25%, 2 = 26–50%, 3 = 51–75% and 4 = > 75%.



Fig. 2. Clinical image correlating to topographical primos image in Figure 1.

treatments received the highest improvement scores. All four of these subjects showed average overall improvement in the 51–75% range 3 months after their final treatment. Ex vivo studies with this device have shown tissue ablation and thermal effects as deep as 1 mm into the skin which may account for our success with severe scarring [11].

Objective topographical analysis of individual scars substantiated our clinical observations and showed that the median depths of scars are improved by 66.8%. All of the scars evaluated with Primos showed improvement in depth, even those with starting depths of 400 μm . This information should guide surgeons on the appropriate fluence levels in order to target these deeper scars. In addition, it allows us to predict how improvement in individual scar depths will translate to an overall global affect on a person's appearance.

Subjects were highly satisfied with the overall outcome, as well as with the reduced downtime and safety profile, with no delayed onset hypopigmentation or permanent scarring observed. Compared to conventional ablative CO₂ devices [3], the side effect profile is greatly improved, and as with FP, rapid re-epithelialization from the surrounding undamaged tissue is believed to be responsible for the comparatively rapid recovery and reduced downtime noted with AFR.

Pigmentation abnormalities following CO₂ resurfacing is always a concern. Alster and West [1] reported a 36% incidence of hyperpigmentation when using conventional CO₂ resurfacing. In a minority of patients, AFR treatment resulted in post-inflammatory hyperpigmentation. The high density parameters used in these treatments were likely a causative factor as high density nonablative FP



Fig. 3. Improvement in atrophy, texture and overall appearance 3 months after the 3rd treatment.

TABLE 3. Mean Percentage Change of Each Scar Was Used to Calculate Overall Mean Percentage Change

	Scar										Mean
	1	2	3	4	5	6	7	8	9	10	
% Overall change from baseline	47.6%	57.9%	76.7%	71.0%	43.3%	68.9%	73.7%	76.5%	79.9%	72.2%	66.8%

treatments have been associated with a greater incidence of hyperpigmentation in predisposed patients [12]. Delayed pigment abnormalities which have been reported with traditional CO₂ resurfacing were not observed in our patients following AFR treatment. Although these patients were only followed for 3 months in this protocol, our experience with this device to treat a variety of conditions over the last 18 months has produced no delayed pigmentary complications. Bernstein et al. [3] reported a 19.2% incidence of pigmentary change (predominantly hypopigmentation) following CO₂ resurfacing which correlated with prolonged erythema after treatment. The low incidence of pigmentary change seen in this study may be due to the spatial separation of thermal damage characteristic of AFR which results in rapid healing and a shortened period of post-operative erythema.

The treatment strategy in the protocol was based on previous experience with nonablative fractional resurfacing in the treatment of acne scars, where repetitive treatments were necessary for optimal results. In this study patient satisfaction increased with each treatment. Also, recovery after the second and third treatments were faster and better tolerated, possibly due to priming of the wound healing response by the first treatment. However, the optimum interval between successive treatments remains to be determined.

CONCLUSION

AFR using a CO₂ laser source represents a new treatment paradigm by offering the ability to ablate and resurface deep dermal tissue targets, without significant risk for adverse sequelae. The efficacy and favorable side effects profile for this technology, with low incidence of pigmentary changes, make it a viable alternative for the treatment of moderate to severe acneiform scarring. Depth of ablation appears to be the critical attribute of this modality for this indication. Future work would be beneficial, including longer follow-up periods for the assessment of possible late-emerging pigmentary changes. In addition, optimizing parameter selection for darker skin type patients needs further study.

ACKNOWLEDGMENTS

The authors would like to acknowledge the participation of Carol Janicik, RN.

DISCLOSURES

Roy Geronemus: Reliant Technologies-share-holder, investigator.

REFERENCES

1. Alster TS, West TB. Resurfacing of atrophic facial acne scars with a high-energy, pulsed carbon dioxide laser. *Dermatol Surg* 1996;22(2):151–154; discussion 154–155.
2. Nanni CA, Alster TS. Complications of carbon dioxide laser resurfacing. An evaluation of 500 patients. *Dermatol Surg* 1998;24(3):315–320.
3. Bernstein LJ, Kauvar AN, Grossman MC, Geronemus RG. The short- and long-term side effects of carbon dioxide laser resurfacing. *Dermatol Surg* 1997;23(7):519–525.
4. Geronemus RG. Fractional photothermolysis: Current and future applications. *Lasers Surg Med* 2006;38(3):169–176.
5. Manstein D, Herron GS, Sink RK, Tanner H, Anderson RR. Fractional photothermolysis: A new concept for cutaneous remodeling using microscopic patterns of thermal injury. *Lasers Surg Med* 2004;34(5):426–438.
6. Fisher GH, Geronemus RG. Short-term side effects of fractional photothermolysis. *Dermatol Surg* 2005;31(9 Pt 2):1245–1249; discussion 1249.
7. Behroozan DS, Goldberg LH, Dai T, Friedman PM. Fractional photothermolysis for the treatment of poikiloderma of civatte. *Dermatol Surg* 2006;32:298–301.
8. Alster TS, Tanzi EL, Lazarus M. The use of fractional laser photothermolysis for the treatment of atrophic scars. *Dermatol Surg* 2007;33(3):295–299.
9. Hantash BM, Bedi VP, Kapadia B, Rahman Z, Jiang K, Tanner H, Chan KF, Zachary CB. In vivo histological evaluation of a novel ablative fractional resurfacing device. *Lasers Surg Med* 2007;39(2):96–107.
10. Friedman PM, Ming JH, Skover GR, Payonk GS, Kimyai-Asadi A, Geronemus RG. Treatment of atrophic facial acne scars with the 1064-nm Q-switched Nd:YAG laser: Six-month follow-up study. *Arch Dermatol* 2004;140(11):1337–1341.
11. Hantash BM, Bedi VP, Chan KF, Zachary CB. Ex vivo histological characterization of a novel ablative fractional resurfacing device. *Lasers Surg Med* 2007;39(2):87–95.
12. Chan HH, Manstein D, Yu CS, Shek S, Kono T, Wei WI. The prevalence and risk factors of post-inflammatory hyperpigmentation after fractional resurfacing in Asians. *Lasers Surg Med* 2007;39(5):381–385.