

Nonablative Acne Scar Reduction after a Series of Treatments with a Short-Pulsed 1,064-nm Neodymium:YAG Laser

GRAEME M. LIPPER, MD,*[†] AND MARITZA PEREZ, MD*^{†‡}

BACKGROUND Effective treatment of facial acne scarring presents a major challenge. Nonablative lasers and radiofrequency devices work by thermally stimulating dermal collagen remodeling, thereby softening acne scars in a minimally invasive fashion. One such laser, a 1,064-nm short-pulsed Nd:YAG, uses rapidly scanned low-energy infrared pulses to heat the dermis selectively through the normal dermal microvasculature.

OBJECTIVE In this pilot study, the safety and efficacy of a novel short-pulsed Nd:YAG laser were investigated for the treatment of moderate to severe facial acne scarring.

MATERIALS AND METHODS Nine of 10 enrolled patients with moderate to severe facial acne scarring received eight sequential 1,064-nm Nd:YAG treatments (laser parameters 14 J/cm², 0.3 milliseconds, 5-mm spot size, 7-Hz pulse rate, 2,000 pulses per side of face). Patients were graded for the presence and severity of three scar morphologies: superficial (rolling), medium-depth (boxcar), and deep (ice pick). Outcome measures included blinded evaluation of before and after photographs by three physician observers (scar severity score) and patient self-assessment.

RESULTS Acne scarring improved in 100% of the nine patients completing the study. Scar severity scores improved by a mean of 29.36% (95% confidence interval, 16.93%–41.79%; $p = .006$); 89% of patients noted greater than 10% scar improvement. No treatment-related adverse events were seen.

CONCLUSION Our findings support the use of a short-pulsed, low-fluence 1,064-nm Nd:YAG laser as a safe, effective treatment for facial acne scarring. Scar improvement was noted in all treated subjects with minimal discomfort and no downtime. This protocol appears to be most effective at reducing scar depth and softening scar contours.

A laser upgrade needed for the study was provided to the authors at a reduced price.

Effective treatment of facial acne scarring presents a major challenge, with current therapeutic modalities including punch or elliptical excision, ablative laser skin resurfacing [CO₂, erbium (Er):YAG], chemical peels, dermabrasion, subcision, and injection of filler substances such as colla-

gen, hyaluronic acid, and autologous fat grafts.¹ Given the varied morphology and depth of acne scars, which range from subtle atrophic “rolling” to deep “boxcar” and “ice-pick” lesions,² most cosmetic surgeons advocate a combination approach, tailoring the treatment to each subtype of le-

sion. Ice-pick scars, for instance, may require punch excision, whereas subtle rolling atrophic scars traditionally respond well to laser skin resurfacing using either carbon dioxide or Er:YAG systems.^{2–4} The best cosmetic results are often achieved when combining both punch excision and laser skin

*Advanced Dermcare, Danbury, Connecticut; [†]Department of Medicine, Danbury Hospital, Danbury, Connecticut; [‡]Department of Cosmetic Dermatology, St. Luke’s-Roosevelt Medical Center, New York, New York

resurfacing techniques.⁵ Unfortunately, many of the traditional surgical and ablative laser techniques used for the treatment of facial acne scarring present challenges of patient discomfort, morbidity, and significant downtime.

Nonablative lasers and intense pulsed light sources (IPLs) generate dermal heat through variable absorption of the three main dermal chromophores: water, oxyhemoglobin within dermal vasculature, and melanin-containing structures such as hair follicles. Their ability to alter dermal collagen structure is mediated, at least in part, by thermal induction of collagen neosynthesis and remodeling, as evidenced by posttreatment histology and increased dermal levels of collagen N-terminal propeptide (PIIINP), collagen types I and II, elastin, and collagenase (MMP-1).⁶ The concept of nonablative dermal remodeling was first described in the late 1990s, when Zelickson and colleagues⁷ noted the incidental softening of periocular rhytids in photodamaged skin treated for facial telangiectasia with a 585-nm flashlamp-pumped pulsed dye laser. Subsequent studies demonstrated improvement of atrophic facial scars treated with the pulsed dye laser using both purpuragenic⁸ and subpurpuric⁹ settings.

It is now known that a wide range of visible light^{8,9} and infrared lasers¹⁰⁻¹⁴ of variable wavelengths, pulse durations, and fluences can

all stimulate dermal collagen synthesis. Furthermore, radiofrequency-based heating of dermal collagen produces both immediate collagen tightening and increased expression of collagen type I messenger RNA.¹⁵ Most of these lasers (e.g., 1,320-nm Nd:YAG, 1,450-nm diode) and radiofrequency devices use cryogen or contact cooling to achieve selective dermal heating while sparing the epidermis. In contrast, a novel short-pulsed 1,064-nm infrared laser (Vantage, Cutera, Brisbane, CA) produces gradual dermal heating through cumulative absorption by oxyhemoglobin within the normal dermal microvasculature. The temporal and energy profile of this laser (0.2–0.5 milliseconds, 5–7 Hz, 13–18 J/cm²) facilitates diffusion of heat from the dermal microvasculature into the surrounding papillary and reticular dermis without inducing purpura or epidermal injury. In contrast to many current nonablative light and radiofrequency devices, treatment-associated discomfort is minimal, and no epidermal cooling is required.

The purpose of this pilot study was to evaluate the safety and efficacy of a manually scanned, short-pulsed 1,064-nm Nd:YAG laser (Vantage, Cutera) for the treatment of moderate to severe facial acne scarring. The primary study end point was treatment-blinded physician assessment of scar severity as measured by digital photographs taken before and 1 to 2 months after a complete

series of eight laser treatments. The secondary end point was patient assessment of treatment outcome, as measured by a follow-up phone survey or questionnaire.

Materials and Methods

Study Design and Study Population

This observational study evaluated patients receiving a series of laser treatments with a short-pulsed Nd:YAG laser for the treatment of moderate to severe facial acne scarring. Informed consent was obtained from each study participant, including maternal consent for one minor. This study was conducted in accordance with the principles of the Declaration of Helsinki, the International Conference on Harmonization Guidelines for Good Clinical Practice, and local regulatory requirements. Ten patients (7 male, 3 female; mean age 32 years, range 15–48 years) with Fitzpatrick skin phototypes I–V and mild to severe facial acne scarring were enrolled in the study, and 9 completed the study (Table 1); 1 male patient dropped out after two treatments for non-treatment-related reasons (scheduling conflict). Exclusion criteria included pregnancy, history of keloidal scarring, recurrent facial herpes simplex infection (more than six episodes per year), ongoing nodulocystic acne, isotretinoin use within 2 months of the study, or laser skin resurfacing or dermabrasion within 1 year of the

TABLE 1. Patient Characteristics

Age (Years)	Skin Phototypes	Baseline Acne Scar Severity Score
Mean, 32 Range, 15–48	I (3), II (3), III (2),* IV (1), V (1)	Mean, 109.6 Range, 23–206

*One patient with skin phototype III dropped out of the study after two treatments for non-treatment-related reasons.

study. With the exception of isotretinoin, patients were allowed to continue their topical or oral acne medications during the study. With the exception of 1 male patient who had received Er laser resurfacing for his acne scars 18 months before the study, no other patients had received prior treatment for their acne scars. All patients were treated by the same physician and prepped with a gentle non-alcohol-based cleanser to remove all makeup before each procedure. To reduce absorption by coarse facial hairs, male patients were required to shave before each treatment. Treatments were conducted with appropriate patient eye shielding at all times.

Patients were treated in two treatment zones: the left cheek, chin, and lateral temple and the right cheek, chin, and lateral temple. During each treatment, each zone received 2,000 pulses using the following laser parameters: 1,064-nm wavelength, 0.3 millisecond pulse duration, 14 J/cm², 7 Hz, 5-mm spot size. The treatment was administered by manually scanning the rapidly pulsed laser in an even, painting motion throughout the entire treatment zone. The laser handpiece was oriented perpendic-

ular to the skin at all times, at a distance of 1 to 2 cm. Throughout the treatment, patients were asked to give verbal feedback if any treated area became “too hot”; in this manner, patient feedback provided an additional safeguard against inducing unwanted epidermal injury. During the first 1,000 pulses of treatment, the entire treatment zone was evenly painted in a rapid, rhythmic fashion, inducing uniform mild erythema. This also induced mild analgesia, with all patients reporting that the sensation of heat dissipated within the first 1,000 pulses. During the second 2,000 pulses, the manual scanning rate was slowed, increasing the “dwell time” over areas of scarring while following patient feedback to avoid discomfort. No topical anesthetics or oral analgesics were administered before, during, or after the treatments, and no skin cooling was required. Patients received eight sequential treatments, each spaced 2 weeks apart.

Efficacy and Safety Evaluation

High-resolution digital photographs (Cybershot DSC-F717, Sony, New York, NY) were taken of each patient at baseline, and again 2 to 4 weeks after the final

treatment. All photographs were taken in a standardized manner (en face, 45° left, 45° right), without a flash, using fine resolution (5.0 megapixels) and macro-lens settings. Pre- and post-treatment photographs were assessed by three nontreating, blinded independent observers (board-certified dermatologists) using the following weighted scale: 3 points for deep, 2 points for shallow, and 1 point for superficial scars. For each patient, corresponding 10 × 10-cm² grids from before and after pictures were graded for overall acne severity in this manner. As a secondary outcome measure, patients were asked to assess their percentage of improvement using the following five-point scale: 0 = no or minimal improvement (0%–10%); 1 = slight improvement (11%–25%); 2 = moderate improvement (26%–50%); 3 = significant improvement (51%–75%); and 4 = marked improvement (> 75%). Patient global assessment was determined by phone interview or written questionnaire completed 1 to 2 months after the final treatment. Additional phone interview follow-up was obtained from five patients 6 to 12 months after their last treatment. Patients were also asked to rate overall treatment discomfort on a scale of 1 (none) to 4 (severe) and to report any treatment-associated adverse signs or symptoms.

Statistical Analysis

The primary outcome measure was change in scar severity score

(pre- vs. posttreatment) as assessed by three blinded evaluators evaluating pre- and posttreatment photos for each subject. Observers counted the number of each type of acne scar (rolling—least severe, boxcar—more severe, and ice pick—most severe) and then multiplied by its weighting factor (rolling = 1 × ; boxcar = 2 × ; ice pick = 3 ×), yielding the overall score. The difference of evaluation effect among the three evaluators was tested by one-way analysis of variance based on the mean percent change from before to after treatment. No statistically significant difference among the three evaluators was found ($p = .1195$), and these data were pooled together. The percent change from before to after treatment of overall scores was calculated. The mean, standard deviation, median, and range for before treatment, after treatment, and percent change were generat-

ed. The difference of mean percent change was tested using the Student's paired t test with a significance level of .05.

Results

Physician Assessment

Acne scarring improved in 100% of the nine patients completing the study (Table 2). Scar severity scores (baseline vs. 1–2 months after the final treatment) improved by a mean of 29.36% [95% confidence interval (CI), 16.93%–41.79%; $p = .006$]. Scar severity scores showed some interobserver variability; however, this was not statistically significant ($p = .1195$).

Patient Self-Assessment

Patients reported significant scar reduction at 1 to 2 months after the last laser treatment, with eight of nine patients (89%) reporting subjective scar improvement in

the range of 10% to 50%. One patient with severe baseline scarring (mean scar severity score, 108) noted scar improvement of less than 10%. All patients reported being satisfied with their treatment results, and all stated that they would undergo treatment again. Two patients (both female) noted that their acne scars were “shallower” and easier to conceal with makeup after treatment. Five of nine patients were available for additional follow-up (range, 6–12 months after the last laser treatment), and all confirmed the persistence of moderate scar improvement (26%–50%).

Adverse Events

Treatments were well tolerated, with overall treatment discomfort rated at 0 (“none”) or 1 (“minimal”) by eight of nine patients. One patient (skin phototype III)

TABLE 2. Reduction in Mean Scar Severity Scores*

Subject	Mean Scar Severity Score		
	Before Treatment	After Treatment	% Change
1	39.0	21.3	-45.30
2	206.3	140.7	-31.83
3	34.3	18.3	-46.60
4	97.3	76.3	-21.58
5	196.7	141.3	-28.14
6	99.0	87.7	-11.45
7	183.0	154.0	-15.85
8	108.0	97.3	-9.88
9	23.0	10.7	-53.62
Mean	109.6	83.1	-29.36
Standard deviation	71.36	56.19	
Median	99.0	87.7	

*Pooled data analysis of scar severity scores ($N = 9$). Subjects showed a mean improvement of 29.36%, with individual percent improvements ranging from 9.88% to 46.60%. There was a statistically significant difference from pretreatment to posttreatment scores ($p = .006$; 95% CI, -16.93% to -41.79%).



Figure 1. Representative photographs of acne scar improvement taken before (A and C) and after (B and D) treatment with a short-pulsed 1,064-nm Nd:YAG laser. Photos were taken 2 to 4 weeks after the last treatment. Improvement is noted in scar contours, depth, and erythema.

noted grade 3 (“moderate”) discomfort during his initial treatment, which reduced to minimal discomfort for all subsequent treatments. Treatment-induced erythema was characterized by all subjects as being both mild and transient, with no subjects reporting erythema persisting for more than 2 hours after treatment. No patients reported blistering, scarring, purpura, crusting, persistent swelling, pain, or other adverse events, and none noted flaring of their acne after treatment. Of note, two patients (both female) reported apparent im-

provement of their inflammatory acne, although this was not quantified. Of the five patients available for additional follow-up (6–12 months after their last treatment), none reported delayed-onset changes in skin pigmentation, erythema, worsening of acne, or increased skin sensitivity (Figure 1).

Discussion

Although clinicians have a potent arsenal of treatments for active inflammatory and cystic acne vulgaris, the scarring residue of

acne remains difficult to treat. When severe, acne scarring can be emotionally debilitating, leading to poor self-image and, in some cases, exacerbating clinical depression.¹⁶ Acne scars vary in morphology and depth, ranging from superficial rolling atrophic scars to deep ice-pick and boxcar lesions extending into the deep reticular dermis and, in some cases, into the subcutis. Consequently, the most effective treatment plans employ a combination of approaches including punch and elliptical excision for deep scars; subcutaneous incisionless surgery (subcision) and/or filler substances for tethered or rolling scars;² and chemical, mechanical, or laser resurfacing for the epidermal and superficial dermal ablation of shallow scars. Ablative treatments for acne scarring such as carbon dioxide (CO₂), Er, and CO₂:Er-blended lasers work by thermally stimulating collagen neosynthesis while stripping away varying depths of epidermis and dermis. Unfortunately, by compromising the epidermal barrier, these modalities necessitate up to 2 weeks of patient downtime for epidermal recovery, with associated adverse events including patient pain, persistent erythema, transient hyper- or hypopigmentation, milium formation, dermatitis, and more severe complications (i.e., infection, keloid or hypertrophic scar formation, permanent hypopigmentation).

In contrast, a wide range of visible and infrared laser, IPL, and radiofrequency devices are capable of thermally inducing dermal collagen neosynthesis while sparing the epidermis. How these nonablative devices work to remodel the dermis remains the subject of active research, but photothermal (or electrothermal) injury is likely the major stimulus. Sublethal heating of vascular endothelial cells and fibroblasts is thought to initiate a cascade of dermal remodeling through the induction of cytokines (e.g., platelet-derived growth factor) and enzymes (collagenase) involved in the normal wound healing process.^{17,18} When thermal injury is limited to the dermis, the desired effect of stimulating dermal collagen production and remodeling can be accomplished while avoiding the unwanted consequences of epidermal injury such as infection, pain, and erythema.

Many nonablative lasers (e.g., 1,320-nm Nd:YAG, 1,450-nm diode), IPLs, and radiofrequency devices require cryogen or contact cooling to achieve selective dermal heating without epidermal injury. In contrast, a novel short-pulsed 1,064-nm infrared laser (Vantage, Cutera) produces gradual dermal heating through cumulative absorption by oxyhemoglobin within the dermal microvasculature. The temporal profile of this laser (0.2–0.5 milliseconds) closely approximates the thermal relaxation time of small, normal dermal capillaries

(approximately 0.1 milliseconds), providing gradual, selective dermal heating when rapidly scanned over a target area of skin. In contrast, the pulse profile of long-pulsed Nd:YAG lasers (10–50 + milliseconds) yields thermal confinement within larger structures such as reticular leg veins and hair follicles, while the Q-switched (QS) 1,064-nm Nd:YAG (4–6 nanoseconds) produces megawatt bursts of energy within subcellular structures such as melanosomes and tattoo particles, resulting in both photothermal and photoacoustic effects.

Our findings support the use of a short-pulsed, low-fluence 1,064-nm Nd:YAG laser as a safe, effective treatment for facial acne scarring. Scar improvement was noted in all treated subjects with minimal discomfort and no downtime. Acne scarring improved in 100% of the nine patients completing the study. Our treatment protocol of eight sequential treatments, spaced 2 weeks apart, yielded significant objective and subjective scar improvement in all treated subjects with minimal treatment-associated discomfort and no downtime. Scar severity scores improved by a mean of 29.36% (95% CI, 16.93%–41.79%; $p = .006$), and 89% of patients reported subjective scar improvement of at least 10%. No treatment-related adverse events were observed. Consistent with results from other nonablative laser and radiofrequency modalities, this short-

pulsed 1,064-nm Nd:YAG treatment appears to be most effective at reducing scar depth and softening scar contours and least effective at treating scars with a deeper, ice-pick morphology.

Our results are in good agreement with those reported by other investigators using a range of nonablative laser technologies to treat acne scarring.^{13,14,19,20} Rogachefsky and colleagues¹⁹ reported significant mean acne scar reduction in 12 subjects (10 female, 2 male; ages 35–59 years; Fitzpatrick skin types I–III) treated with a 1,320-nm Nd:YAG laser in three monthly sessions. Investigators measured scar improvement at 6-month follow-up that was especially evident for atrophic acne scars—a finding that we also noted. Although Rogachefsky and colleagues noted no complications at 6-month follow-up, they made no mention of procedure-associated pain, which is anecdotally significant. Both the 1,320-nm Nd:YAG and the short-pulsed 1,064-nm Nd:YAG are infrared lasers with low melanin absorption, however, the latter also targets a minor peak of oxyhemoglobin absorption and might be expected to have significant photothermal effects on tissue microvasculature. The lasers also have markedly different pulse profiles: the 1,320-nm Nd:YAG delivers a 50-millisecond macropulse consisting of six 300-microsecond trains, whereas the short-pulsed 1,064-nm YAG delivers 300-microsecond pulses at a rate of

7 Hz. Differences in treatment depth of penetration should also be considered, since Rogachefsky and coworkers used a 10-mm spot size in contrast to the 5-mm spot size used in our study; the latter would be expected to yield more superficial dermal heating, although such differences depend on multiple variables and would need to be objectively quantified.

In another comparable study, Friedman and colleagues²⁰ reported similar improvement in acne scarring (31.6% at 3-month follow-up) after a series of five treatments with a QS 1,064-nm Nd:YAG laser (Medlite IV, Continuum, Santa Clara, CA). This study enrolled 11 patients (8 women, 3 men; ages 28–50 years; skin phototypes I–III) and quantified acne scar improvement using a white-light, noncontacting optical profiler [phaseshift rapid in vivo measurement of skin (PRIMOS); GF Messtechnik, Tetlow, Germany]. Investigators noted an 8.9% improvement in roughness analysis 1 month after the third treatment session, and this continued to improve to 31.6% 3 months after the fifth treatment session—results that are comparable to our 29.36% improvement in scar severity score noted 1 to 2 months after our eighth treatment. Friedman and coworkers²⁰ reported that their treatments were well tolerated, causing only mild erythema and pinpoint petechial hemorrhage, while our treatment protocol produced only a mild heating

sensation with no instances of petechial hemorrhage, blistering, or pain. As noted above, the QS 1,064-nm Nd:YAG and short-pulsed 1,064-nm Nd:YAG differ drastically in temporal profile, with the former delivering energy within a pulse duration that is approximately 100,000 times shorter than the latter. Consequently, the QS YAG induces rapid target chromophore heating with high peak temperatures, both photothermal and photoacoustic effects, microvascular rupture, and petechial hemorrhage, while the short-pulsed Nd:YAG induces gradual heating of microvasculature without vessel rupture. In contrast to the short-pulsed 1,064-nm Nd:YAG, the QS 1,064-nm Nd:YAG is also more likely to cause unwanted hypopigmentation in darker skin phototypes, since nanosecond 1,064-nm laser pulses can destroy melanocytes, even at relatively low fluences. Although Friedman and colleagues²⁰ noted no dyspigmentation or scarring in their study population, they only treated patients with skin phototypes I to III and used a low average fluence (3.4 J/cm²). In our study, we noted no short-term or long-term dyspigmentation and treated patients with skin phototypes IV (*N* = 1) and V (*N* = 1).

One limitation of our study is the relatively short follow-up period of 1 to 2 months after the final treatment session, because optimal improvement may only be evident after 6 to 12 months of

follow-up.¹⁹ Such a shortcoming, however, would be expected to underestimate the final treatment result, which was subjectively noted to be at least 25% acne scar improvement by the five subjects available for longer-term follow-up (6–12 months after their last treatment session). Of note, none of these individuals reported delayed-onset adverse events such as dyspigmentation, acne flaring, or persistent erythema, and all expressed satisfaction with their results. Because our treatment protocol of eight sequential bi-monthly treatments was based on anecdotal experience, optimal parameters, treatment intervals, and numbers for the short-pulsed 1,064-nm YAG have yet to be determined. It should also be noted that our protocol differed from comparable studies both in treatment length (16 weeks) and in number (eight sessions). In this context, our primary outcome measure (scar severity score) was taken 10 to 14 weeks after the fifth treatment—a follow-up period comparable to one of the end points used by Friedman and colleagues²⁰ (12 weeks after the fifth treatment).

Study results of nonablative dermal remodeling have traditionally been limited by small sample size, lack of controls, and lack of objective measurement. We attempted to control for observer bias by using a blinded observer format and a standardized scale to quantify the severity of acne scarring (scar severity score). Al-

though scar severity scores showed some interobserver variability, this was not statistically significant ($p = .1195$). Nevertheless, there are other arguably superior methods for objectively analyzing scar improvement. As noted above, Friedman and colleagues and others have used a three-dimensional topographical imaging technique, The PRIMOS imaging system, to generate three-dimensional virtual models of the skin surface at variable time points, allowing investigators to compare surface microtopography in an objective, quantifiable manner.^{20,21} In a small pilot study, the PRIMOS system confirmed a modest improvement in facial acne scars treated with either the 1,450-nm diode or the 1,320-nm Nd:YAG laser.¹³ Such attempts to quantify subtle differences in skin topography provide an objective means for gauging the clinical efficacy of competing nonablative acne scarring treatments.

One can also try to quantify the efficacy of nonablative devices using histologic and biochemical markers, although the former option may be limited in the case of acne scarring due to the intrinsic variability of scarred, chronically inflamed skin. Recently, Orringer and coworkers²² characterized the sequence of biological changes seen after CO₂ laser resurfacing, confirming that dermal remodeling occurs through a well-organized, reproducible wound healing response. This process includes

increased production of type I and type III procollagen mRNA, peaking 3 weeks after CO₂ laser skin resurfacing and remaining elevated for at least 6 months. Orringer and colleagues hypothesized that such biochemical markers can also be measured in nonablative procedures designed to improve photodamaged skin, providing an objective measure of treatment efficacy. In this context, Schmults and associates²³ recently performed an ultrastructural analysis of photodamaged facial skin treated with the microsecond-pulsed 1,064-nm Nd:YAG laser used in our study.²³ Using similar treatment parameters to ours (fluence 13 J/cm², pulse duration 0.3 milliseconds, spot size 5 mm, administered at 7 Hz in a rapid painting motion), they observed a decrease in collagen fiber diameter in the papillary dermis of photodamaged skin ($N = 9$), demonstrable as early as 1 month after a series of three treatment sessions. This change was consistent with the increased deposition of thin-caliber procollagen and type III collagen seen during an early wound healing response.

In conclusion, our results support the use of a short-pulsed, low-fluence 1,064-nm Nd:YAG laser as a safe, effective treatment for facial acne scarring. Scar improvement was noted in all treated subjects with minimal discomfort and no downtime. This protocol appears to be most effective at reducing scar depth

and softening scar contours, although the optimal treatment protocol (i.e., number of treatments, frequency, and parameters) has yet to be determined. Strengths of this technology include minimal treatment-associated discomfort (without anesthesia), ease of administration, total absence of downtime, and an excellent safety profile even when used on darker skin phototypes. Future studies of this short-pulsed 1,064-nm Nd:YAG laser for the treatment of acne scarring should address long-term clinical improvement, biochemical markers of efficacy, and optimal treatment parameters.

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Address correspondence and reprint requests to: Graeme M. Lipper, MD, Advanced Dermcare, 25 Tamarack Avenue, Danbury, CT 06811, or e-mail: cglipper@aol.com.