Single-Pass Carbon Dioxide Versus Multiple-Pass Er:YAG Laser Skin Resurfacing: A Comparison of Postoperative Wound Healing and Side-Effect Rates

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BACKGROUND. **Ablative laser skin resurfacing with carbon dioxide (CO_2) and erbium:yttrium-aluminum-garnet (Er:YAG) lasers has been popularized in recent years and their side effects individually reported. No prior study, however, has directly compared the relative healing times and complications rates between the two different systems.**

OBJECTIVE. **To evaluate and compare postoperative wound healing and short- and long-term side effects of single-pass CO_2 and multiple-pass, long-pulsed Er:YAG laser skin resurfacing for the treatment of facial photodamage and atrophic scars.**

METHODS. **A retrospective chart review and analysis of sequential clinical photographs were performed in 100 consecutive patients who underwent laser skin resurfacing with single-pass CO_2 (Ultrapulse 5000; Coherent, Palo Alto, CA, N = 50) or multiple-pass, long-pulsed Er:YAG laser resurfacing (Contour; Sciton, Palo Alto, CA, N = 50). All laser procedures were performed by a single operator for the amelioration of facial rhytides or atrophic scars. The rate of re-epithelialization, duration of erythema, and presence of complications were tabulated.**

RESULTS. **The average time to re-epithelialization was 5.5 days with single-pass CO_2 and 5.1 days with long-pulsed Er:YAG laser resurfacing. Postoperative erythema was observed in all patients, lasting an average of 4.5 weeks after single-pass CO_2 laser treatment and 3.6 weeks after long-pulsed Er:YAG laser treatment. Hyperpigmentation was seen in 46% of the patients treated with single-pass CO_2 and 42% of the patients treated with the long-pulsed Er:YAG laser (average duration of 12.7 and 11.4 weeks, respectively). No incidences of hypopigmentation or scarring were observed.**

CONCLUSION. **Skin resurfacing with single-pass CO_2 or multiple-pass long-pulsed Er:YAG laser techniques yielded comparable postoperative healing times and complication profiles.**

E.L. TANZI, MD, AND T.S. ALSTER, MD HAVE INDICATED NO SIGNIFICANT INTEREST WITH COMMERCIAL SUPPORTERS.

LASER SKIN resurfacing is an effective treatment option for many patients with cutaneous photodamage, wrinkles, and acne scarring.[1–4] Based on the principles of selective photothermolysis,[5] ablative resurfacing lasers target and effectively vaporize water-containing tissue. Collagen shrinkage and remodeling are initiated by controlled thermal injury to the dermis.[6–8]

Several laser systems are currently available for cutaneous laser resurfacing, including high-energy pulsed and scanned carbon dioxide (CO_2) and erbium:yttrium-aluminum-garnet (Er:YAG) lasers. Although excellent improvement of photodamaged skin, rhytides, and atrophic scars can be achieved after multiple pass treatment technique with these laser systems,[1,3,9–15] an extended recovery period and, in some cases of CO_2 laser resurfacing, prolonged erythema have diminished the enthusiasm for multipass CO_2 procedures.[16,17] Moreover, delayed-onset permanent hypopigmentation has been shown to occur in upward 20% of those treated with multiple-pass CO_2 laser skin resurfacing.[17,18] In response to these disadvantages, refinements in the CO_2 surgical technique and Er:YAG laser technology have been developed.

In 1997, a minimally traumatic single-pass CO_2 laser resurfacing procedure was described that resulted in faster re-epithelialization and an improved side-effect profile than typically observed after use of the multiple-pass technique.[19] After application of the CO_2 laser scans, partially desiccated skin is left intact (rather than removed as is typical with multipass procedures) to serve as a biologic wound dressing. Additional passes with the CO_2 laser may be performed focally in areas of more extensive involvement to limit unnecessary thermal and mechanical trauma to less involved skin. Subsequent reports have substantiated the improved side-effect profile of this less aggressive procedure.[20,21]

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In addition to the development of minimally traumatic CO_2 laser techniques, the search for alternative methods of cutaneous resurfacing led to the development of the Er:YAG laser. At a wavelength of 2940 nm, the Er:YAG laser corresponds to the peak absorption coefficient of water and is absorbed 12 to 18 times more efficiently by cutaneous water-containing tissue than is the 10,600-nm wavelength of the CO_2 laser.[22] At a fluence of 5 J/cm^2, a typical short-pulsed (250 μs) Er:YAG laser reliably ablates 10 to 20 μm of tissue per pass, producing a residual zone of thermal injury not exceeding 15 μm.[4,23] In contrast, CO_2 laser skin resurfacing produces 20 to 60 μm of tissue ablation and up to 150 μm of residual thermal injury per pass. As a result of the minimal thermal injury induced by short-pulsed Er:YAG laser resurfacing, faster re-epithelialization and an improved side effect profile are effected (as compared with CO_2 laser skin resurfacing).[24–26] On the other hand, minimal thermal injury in the dermis provides insufficient vascular coagulation (resulting in poor intraoperative hemostasis) and reduced collagen contraction and remodeling (resulting in less impressive clinical results).[4,23]

To address the limitations associated with short-pulsed Er:YAG laser skin resurfacing, modulated (variable-pulsed) Er:YAG laser systems have been developed to improve intraoperative hemostasis and induce collagen remodeling. Modulated Er:YAG laser systems allow precise control of ablation while increasing the ability to induce collagen formation and achieve hemostasis through increased thermal injury.[18]

Although the previously described single-pass CO_2 and modulated Er:YAG laser skin resurfacing techniques for facial photodamage, rhytides, and atrophic scarring have gained popularity among cutaneous laser surgeons, long-term studies comparing their relative side effects and complications have not been performed. Therefore, the objective of this study was to evaluate and compare postoperative wound healing and side-effect profiles of these two techniques for the treatment of photodamage and atrophic scarring.

Methods

A retrospective chart review and analysis of digital photography was performed in 50 consecutive patients (49 females and 1 male; mean age, 51; skin phototypes I–V) who received single-pass CO_2 laser resurfacing (Ultrapulse 5000; Lumenis Laser Corp., Santa Clara, CA) and 50 consecutive patients (47 females and 3 males; mean age, 47; skin phototypes I–V) who received multiple-pass, long-pulsed Er:YAG laser (Contour; Sciton Laser Corp., Palo Alto, CA) resurfacing (Table 1).

All laser procedures were performed by a single surgeon (T.S.A.) over a 2-year period for the indication of photodamage, rhytides, or atrophic scarring on the face. Anesthesia was obtained with regional nerve blocks using 1% lidocaine with 1:200,000 epinephrine. For full-face procedures, intravenous anesthesia was administered by a certified nurse anesthetist using a combination of propofol, midazolam, fentanyl, and ketamine.

The CO_2 laser was calibrated to 300-mJ energy and 60-W power through an 8-mm square scanning handpiece, and the entire face was treated with adjacent nonoverlapping laser scans in a single laser pass at CPG density 5. The 3-mm collimated handpiece was used at 300- to 500-mJ energy and 5- to 7-W power to refine treatment edges. Partially desiccated tissue remained intact to serve as a biologic wound dressing.

Er:YAG laser resurfacing was performed in dual mode (sequential ablation/coagulation) after being calibrated to 90-μm ablation (22.5 J/cm^2) with 50% spot overlap and 50-μm coagulation. A square scanning handpiece was used to vaporize the epidermis in a single pass over the entire face. An additional one to two regional passes were delivered to the involved areas using identical laser settings. Laser scans were placed in an adjacent nonoverlapping manner, carefully removing all partially desiccated skin with saline-soaked gauze between each laser pass. The partially desiccated tissue remaining from the final laser pass was left intact as a biologic wound dressing. The laser-irradiated skin showed a clean, pale pink hue with minimal to no bleeding.

Immediately after laser treatment, Aquaphor ointment (Beirsdorf Inc., Wilton, CT) was applied to the irradiated skin. Each patient was instructed to perform gentle facial rinses with dilute acetic acid soaks several times daily, followed by an application of ointment

Table 1. Patient Characteristics

Procedure	*Female*	*Male*	*Mean Age (Year)*	*SPT I*	*SPT II*	*SPT III*	*SPT IV*	*SPT V*
One pass CO_2	49	1	51	13	26	6	4	1
Multipass Er:YAG	47	3	47	20	16	7	5	2

Abbreviation: SPT, skin phototype.

and a cooling masque (SkinVestment Inc., Washington, DC). A 10-day course of prophylactic antiviral treatment (valacyclovir 500 mg twice daily) was initiated on the morning of surgery. Patients were followed closely during the first postoperative week, during which time any residual coagulated debris was gently removed with cool water and dilute acetic acid compresses. All patients were able to apply camouflage make-up within 7 to 10 days postoperatively.

Patients were formally evaluated by a physician on postoperative days 3 through 7, and at 1, 3, 6, and 12 months after the procedure. If prolonged erythema or hyperpigmentation was noted, the patient was evaluated every 2 weeks until complete resolution. The incidence, severity, and duration of side effects and complications were recorded at each postoperative patient visit. Patient satisfaction surveys (poor, fair, good, or excellent results) were obtained 12 months after the procedure.

Results

The average time to re-epithelialization was 5.5 days (range, 5–7 days) with single-pass CO_2 and 5.1 days (range, 5–8 days) with long-pulsed Er:YAG laser resurfacing (Table 2).

Postoperative erythema was observed in all patients, lasting an average of 4.5 weeks (range, 3–12 weeks) after single-pass CO_2 laser treatment and 3.6 weeks (range, 3–14 weeks) after long-pulsed Er:YAG laser treatment. Hyperpigmentation was seen in 46% of patients treated with single-pass CO_2 and 42% of patients treated with the long-pulsed Er:YAG laser (average duration of 12.7 and 11.4 weeks, respectively) (Figures 1A,B and 2A,B). The majority of patients experiencing postinflammatory hyperpigmentation had darker skin tones (skin phototypes III–V); however, nearly 40% of patients with skin phototype II also hyperpigmented.

Mild acne occurred in 12 patients (5 after CO_2 and 7 after Er:YAG) during the first postoperative week, presumably because of the use of occlusive ointment. All cases of acne responded without recurrence to oral minocycline (75 mg twice daily for 1 week). Seven patients (three after CO_2 and four after Er:YAG) developed transient milia requiring no intervention. Dermatitis was noted in five patients (one after CO_2 and four after Er:YAG) and responded to mild topical corticosteroid cream. No cases of herpetic or fungal infections were encountered; however, nine patients (four after CO_2 and five after Er:YAG) experienced localized superficial bacterial infections that fully resolved with oral ciprofloxacin (500 mg twice daily for 5 days). No hypopigmentation or hypertrophic scarring was observed in any study patient throughout the 12-month study period. Patient satisfaction surveys revealed good to excellent ratings in 85% of the patients after Er:YAG laser skin resurfacing and in 87% of the patients after single-pass CO_2 laser treatment.

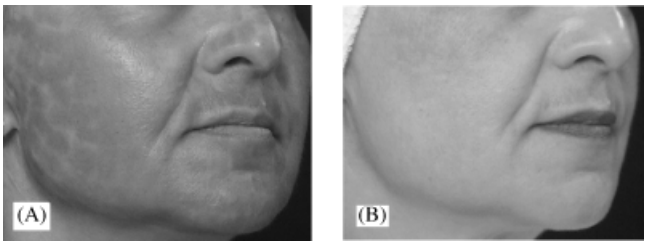

Figure 1. (A) Hyperpigmentation seen 4 weeks after single-pass CO_2 laser treatment in a patient with skin phototype III. (B) Hyperpigmentation resolved 13 weeks postoperatively.

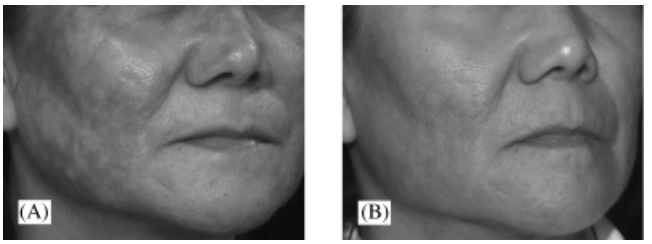

Figure 2. (A) Hyperpigmentation observed 3 weeks after multipass Er:YAG laser resurfacing (skin phototype III). (B) Complete normalization of skin pigmentation 11 weeks postoperatively.

Discussion

Although the demand for ablative laser skin resurfacing procedures has been in recent decline because of

Table 2. Postoperative Healing Time and Side Effect/Complication Rates

Procedure	*N*	*Reepithelialization Time (Average Duration in Days)*	*Erythema (Average Duration in Weeks)*	*Hyperpigmentation (Incidence; Average Duration in Weeks)*	*Hypopigmentation*	*Acne*	*Milia*	*Dermatitis*	*Infection*	*Scar*
One-pass CO_2	50	5.5	4.5	23 (46%; 12.7)	0	5 (10%)	3 (6%)	1 (2%)	4 (8%)	0
Multipass Er:YAG	50	5.1	3.6	21 (42%; 11.4)	0	7 (14%)	4 (8%)	4 (8%)	5 (10%)	0

the development of nonablative laser technology and concerns regarding postoperative morbidity, few modalities can rival the impressive clinical results that ablative lasers can achieve.[6,26] Less invasive CO_2 laser resurfacing techniques and Er:YAG laser technology have been developed to reduce the postoperative morbidity associated with traditional multiple-pass CO_2 laser resurfacing. Although these techniques have gained widespread acceptance among cutaneous laser surgeons, studies comparing their long-term side effects and complications are limited.

Ruiz-Esparza and Gomez[20] evaluated 15 patients after one-pass CO_2 laser skin resurfacing for a follow-up period of 18 months. All patients were re-epithelialized by 7 days, and continued clinical improvement of rhytides was observed throughout the length of the study. No cases of scarring or persistent dyspigmentation were reported. Ross et al.[27] evaluated 13 patients over a 6-month period following single-pass CO_2 laser resurfacing on one side of the face and multiple-pass, short-pulsed Er:YAG laser resurfacing on the contralateral side. Their histologic results demonstrated that when CO_2 and Er:YAG lasers produce equal levels of thermal destruction, equivalent healing and clinical improvement are effected.

Delayed-onset permanent hypopigmentation—a serious complication that has been observed several months after multiple-pass CO_2 laser skin resurfacing—has not yet been seen following single-pass treatment. Although no incidences of hypopigmentation occurred in this study population at the 1-year follow-up evaluation, the frequency of hypopigmentation following modulated Er:YAG laser skin resurfacing remains unknown. To date, only three cases of hypopigmentation following modulated Er:YAG laser skin resurfacing have been reported.[18,28,29] Because it is possible for hypopigmentation to present several years postoperatively, additional studies are necessary to assess its true incidence after either single-pass CO_2 or modulated Er:YAG laser skin resurfacing.

Conclusion

Single-pass CO_2 laser resurfacing has a comparable postoperative period and complication profile to that of multiple-pass, long-pulsed Er:YAG laser resurfacing, even in patients with dark skin tones. Thus, the CO_2 laser can still be employed when invasive skin resurfacing is indicated, effecting relatively few side effects and complications (compared with multipass CO_2 procedures). Reliable comparisons of clinical improvement between modalities in a retrospective review are tenuous at best as digital photography was not standardized for all of the patients studied. As such, a comparison of clinical improvement between the two systems was not reported herein. The high degree of patient satisfaction reported after treatment with each of the two systems, however, indicates an equivocal clinical effect. Clearly, additional long-term comparison studies between one-pass CO_2 and modulated Er:YAG laser skin resurfacing are warranted to delineate fully the advantages and disadvantages of each technique. Continued research and advances in ablative technology should further enhance the ability to achieve minimal-risk wrinkle or scar effacement.

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