Recent advances in technology have provided laser surgeons with new options for cutaneous laser resurfacing. Despite its popularity, there is limited information on the short-term and long-term side effects and complications of variable-pulsed erbium:yttrium-aluminum-garnet (erbium:YAG) laser skin resurfacing. The purpose of this study was to prospectively evaluate postoperative wound healing, side effects, and complications of multiple-pass, variable-pulsed erbium:YAG laser skin resurfacing for facial photodamage, rhytides, and atrophic scarring. Fifty consecutive patients with facial photodamage, rhytides, or atrophic scarring were treated with a variable-pulsed erbium:YAG laser. Side effects and complications relating to postoperative healing, erythema, and pigmentary changes were tabulated. Patients were evaluated at postoperative days 3 through 7 and at 1, 3, 6, and 12 months after laser skin resurfacing. The average time for reepithelialization was 5.1 days. Prolonged erythema (>1 month) was observed in three patients (6 percent). Transient hyperpigmentation occurred in 20 patients (40 percent), with an average duration of 10.4 weeks. No cases of hypopigmentation or scarring were seen. In summary, a variable-pulsed erbium:YAG laser can safely be used for the treatment of facial photodamage, rhytides, and atrophic scarring. Although more postoperative erythema is seen after variable-pulsed erbium:YAG laser treatment than usual, the potential for delayed-onset permanent hypopigmentation may be seen in as many as 20 percent of patients following multiple-pass carbon dioxide laser treatment. In response to these disadvantages, other laser systems were developed in an attempt to limit the prolonged recovery period and potentially high morbidity of these procedures. The short-pulsed erbium:YAG laser was approved for cutaneous laser resurfacing by the Food and Drug Administration in 1996. The 2940-nm wavelength emitted by the erbium:
YAG laser corresponds to the peak absorption coefficient of water and is absorbed 12 to 18 times more effectively by superficial, water-containing cutaneous tissue than the 10,600-nm wavelength of the carbon dioxide laser.\textsuperscript{21} Short-pulsed (250 \textmu sec) erbium:YAG lasers reliably ablate 5 to 15 \textmu m of tissue per pass at a fluence of 5 J/cm\textsuperscript{2}, producing a residual zone of thermal damage not exceeding 15 \textmu m.\textsuperscript{22,23} These findings are in contrast to the changes observed after carbon dioxide cutaneous laser resurfacing, which produces 20 to 60 \textmu m of tissue ablation and up to 150 \textmu m of residual thermal damage per pass. As a result of precise tissue ablation and a limited zone of thermal damage, short-pulsed erbium:YAG laser treatment results in faster reepithelialization and an improved side-effect profile compared with carbon dioxide cutaneous laser skin resurfacing.\textsuperscript{24–27} Because of these advantages, it was initially postulated that the short-pulsed erbium:YAG laser system would completely replace the carbon dioxide laser as a resurfacing tool; however, this initial enthusiasm was tempered by poor intraoperative hemostasis and the system’s limited ability to effect significant collagen shrinkage.\textsuperscript{8,22}

To address these limitations, modulated erbium:YAG laser systems were developed to improve hemostasis and increase the amount of collagen shrinkage. With extended pulse durations up to 500 \textmu sec, variable-pulsed erbium:YAG laser systems combine tissue ablation with induction of dermal collagenization by means of controlled thermal injury.\textsuperscript{28} Despite the increasing popularity of variable-pulsed erbium:YAG laser skin resurfacing treatments, there is limited information documenting the short-term and long-term side effects and complications of this procedure. The objective of this study was to prospectively evaluate postoperative wound healing, side effects, and complications of multiple-pass, variable-pulsed erbium:YAG laser skin resurfacing for the treatment of facial photodamage, rhytides, and atrophic scarring.

**Materials and Methods**

Fifty consecutive patients (47 female and three male, aged 21 to 71 years, skin phototypes I through V) with moderate-to-severe facial photodamage, rhytides, or atrophic scars were included in the study. Five patients (10 percent) reported dermabrasion to the involved areas more than 3 years before study initiation. Eleven patients (22 percent) had received collagen injections in the remote past. Three patients (6 percent) had undergone a full face lift more than 5 years before the study. Two patients (4 percent) had undergone full-face carbon dioxide laser skin resurfacing 6 years previously, and one patient (2 percent) had received a phenol peel more than 5 years before the study.

Each patient received laser treatment in an outpatient surgical facility by a single surgeon (T.S.A.) with a dual-mode sequential ablation/coagulation pulsed erbium:YAG laser (Contour; Sciton, Palo Alto, Calif.). Cutaneous 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 laser was calibrated to 90-\textmu m ablation (22.5 J/cm\textsuperscript{2}) and 50-\textmu m coagulation using a square scanning handpiece with 50 percent overlap to vaporize the epidermis in a single pass over the entire face. An additional one to two regional passes were delivered using identical laser settings to treat residual rhytides or scars. Laser scans were placed adjacent to one another without overlapping, thereby preventing char formation. Partially desiccated skin was thoroughly removed with saline-soaked gauze between each laser pass, producing skin with a clean, pale-pink hue with minimal to no bleeding. The partially desiccated tissue remaining from the final laser pass was left intact to serve as a biological wound dressing.

Immediately after treatment, Aquaphor ointment (Beiersdorf, Inc., Wilton, Conn.) 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 application of Aquaphor and a cooling mask (SkinVestment, Inc., Washington, D.C.). A 10-day course of prophylactic antiviral treatment (valacyclovir 500 mg two times per day) was prescribed beginning on the day of surgery. Patients were observed closely during the first postoperative week, during which time any residual coagulated debris was gently loosened and/or removed with cool compresses. All patients were able to apply camouflage makeup within 7 to 10 days postoperatively.

The patients were evaluated daily during postoperative days 3 through 7, and at 1, 3, 6, and 12 months after laser skin resurfacing. The presence and duration of side effects and com-
Complications were recorded at each postoperative patient visit (Fig. 1). If prolonged erythema or hyperpigmentation was noted, the patient was evaluated every 2 weeks until its complete resolution. Daily use of topical 5% glycolic acid (M.D. Forte; Herald Pharmacal, Inc., Colonial Heights, Va.), and/or 0.1% N-furfuryladenine (Kinerase; ICN Pharmaceuticals, Aurora, Ohio), and/or kojic acid/lactic acid mix (KojiLac-C; Young Pharmaceuticals, Wethersfield, Conn.) was prescribed for patients with hyperpigmentation, as were biweekly to monthly 30% glycolic acid peels that were performed in-office until the dyspigmentation was corrected (Fig. 2).

RESULTS

The average time to reepithelialization (defined by the absence of serous discharge and the presence of new skin) was 5.1 days. Post-

![Fig. 1. (Above, left) Photodamaged skin before laser skin resurfacing. (Above, right) Three days after variable-pulsed erbium: YAG laser treatment, superficial bacterial infection was suspected and confirmed with cultures. (Below, left) Mild erythema without evidence of residual infection was seen after 1 week on oral antibiotics. (Below, right) Prolonged clinical improvement was noted 12 months postoperatively.](image-url)
Fig. 2. (Above, left) Moderate atrophic scarring on the cheeks of a man with skin phototype IV. (Above, right) Complete reepithelialization and mild erythema was noted 1 week after variable-pulsed erbium:YAG laser treatment. (Below, left) Hyperpigmentation evident at 1 month postoperatively resolved with the use of topical bleaching creams and light glycolic acid peels by the third postoperative month (below, right).

Discussion

Laser skin resurfacing has become one of the most popular techniques for the treatment of cutaneous photodamage, rhytides, and atrophic scars. Although previous reports have documented the efficacy of modulated erbium:YAG laser skin resurfacing for these indications, limited data exist concerning the frequency, severity, and duration of side effects and complications associated with its use.

The immediate postoperative recovery period and incidence of prolonged erythema are

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<th>TABLE I</th>
<th>Side Effects of Variable-Pulsed Er:YAG Laser Treatment</th>
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<td>Prolonged Erythema</td>
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<td>I</td>
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<td>II</td>
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*Er:YAG, erbium:yttrium-argon-garnet.*
more favorable with variable-pulsed erbium:YAG laser treatment than with cutaneous carbon dioxide laser resurfacing. Prolonged erythema occurs in a significantly large number of patients following multiple-pass carbon dioxide laser skin resurfacing. In the present study of 50 patients treated with a variable-pulsed erbium:YAG laser, reepithelialization was complete in an average of 5 days, and only three (6 percent) cases of prolonged erythema were seen. In a split-face comparison of 16 patients following pulsed carbon dioxide and variable-pulsed erbium:YAG laser skin resurfacing, Rostan et al. reported decreased erythema, less edema, and faster healing on the side treated with the erbium:YAG laser.

Postinflammatory hyperpigmentation is not uncommon following cutaneous laser resurfacing. Jeong and Kye documented hyperpigmentation in eight of 35 patients (23 percent, skin phototypes III through V) treated with a variable-pulsed erbium:YAG laser for pitted acne scars. Similarly, 40 percent of our patients—predominantly those with darker skin tones—developed hyperpigmentation. All cases of hyperpigmentation responded completely to a combination of light chemical peels and topical bleaching creams. Although hyperpigmentation following variable-pulsed erbium:YAG laser skin resurfacing can last longer than that seen after treatment with a short-pulsed erbium:YAG laser, it is not as persistent as that observed after multiple-pass carbon dioxide laser skin resurfacing (average: variable-pulsed erbium:YAG laser, 10.4 weeks; carbon dioxide laser, 16 weeks).

Delayed-onset, permanent hypopigmentation is a serious complication of any type of laser skin resurfacing procedure and often takes several months to develop. To date, there have been only three published cases of hypopigmentation as a consequence of variable-pulsed erbium:YAG laser treatment. Although hypopigmentation was not observed in our study population at the 1-year follow-up evaluation, additional confirming studies are warranted to assess its true incidence.

In conclusion, variable-pulsed erbium:YAG laser skin resurfacing is relatively safe for facial photodamage, rhytides, and atrophic scarring. The variable-pulsed erbium:YAG laser offers several advantages over short-pulsed erbium:YAG laser systems, including improved intraoperative hemostasis and visibility and enhanced clinical outcomes. Although the reepithelialization process and the persistence of postoperative erythema after variable-pulsed erbium:YAG laser resurfacing are more prolonged than those seen following short-pulsed erbium:YAG treatment, the overall side-effect profile and recovery period are more favorable than after multiple-pass carbon dioxide laser resurfacing. In addition, and of particular importance in the treatment of patients with darker skin tones, the postinflammatory hyperpigmentation seen with variable-pulsed erbium:YAG laser skin resurfacing is less persistent than that observed after treatment with the carbon dioxide laser.

Tina S. Alster, M.D.
Washington Institute of Dermatologic Laser Surgery
2311 M Street, N.W., Suite 200
Washington, D.C. 20037
talster@skinlaser.com

REFERENCES

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