

Analysis of Hyperpigmentation and Hypopigmentation After Er:YAG Laser Skin Resurfacing

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Background and Objectives: Pigmentary disorders—such as hyperpigmentation and hypopigmentation, are devastating complications of erbium:yttrium-aluminum-garnet (Er:YAG) laser resurfacing. This study was undertaken to assess the clinical and histopathologic features of hyperpigmentation and hypopigmentation following Er:YAG laser resurfacing, especially in darker skin.

Study Design/Materials and Methods: One hundred and ninety patients (skin phototypes III and above), treated with Er:YAG lasers—short-pulsed and modulated (variable-pulsed and dual-mode) Er:YAG lasers—for skin resurfacing were recruited. The clinical features of hyperpigmentation and hypopigmentation were evaluated retrospectively using medical charts and serial photographs. For histopathologic examinations, skin biopsies were performed in three patients at hyperpigmentation sites and in four patients at hypopigmentation sites.

Results: Hyperpigmentation was observed in 38.4% of the patients. Mean onset and duration were 3.5 and 7.2 weeks, and then it has faded away within 16 weeks in 93.2% of cases. Hypopigmentation was observed in 13.7% of the patients; its mean onset was 2 months after treatment, and it faded within 1 year in 85% of cases. The incidences and mean durations of these side effects were more intense and longer in patients treated with short-pulsed, variable-pulsed, and dual-mode Er:YAG lasers, in increasing order. In terms of histopathologic examinations, melanin amounts in the epidermal basal layer were observed to vary.

Conclusions: Hyperpigmentation and hypopigmentation are frequent complications of Er:YAG laser resurfacing. Long pulse duration-induced thermal damage seems to be the most important factor in terms of the induction of pigmentary disorders. *Lasers Surg. Med.* 36:47–51, 2005. © 2005 Wiley-Liss, Inc.

Key words: Er:YAG laser resurfacing; hyperpigmentation; hypopigmentation

INTRODUCTION

In the last two decades, laser skin resurfacing using carbon dioxide (CO₂) or erbium:yttrium-aluminum-garnet (Er:YAG) lasers has been widely used to facial rhytides, photodamaged skin, and various scars, such as acne, smallpox and chicken pox scar [1–3]. Although the resurfacing of facial skin using these lasers is known to be effective and

safe for the treatment of these cosmetic disabilities, many complications have been reported, including erythema, hyperpigmentation, hypopigmentation, keloidal or atrophic scar, acne flare-up, pruritus, wound infection, and milia [4–6]. Of these pigmentary disorders, hyperpigmentation is one of the most common, whereas hypopigmentation is relatively rare [4–9]. These pigmentary disorders may be quite conspicuous and can be a source of considerable anxiety and embarrassment for patients. However, relatively few studies have described the clinical features, and the pathophysiologies of hyperpigmentation and hypopigmentation following Er:YAG laser resurfacing, especially in darker skin.

MATERIALS AND METHODS

One hundred and ninety patients (91 males and 99 females) with facial acne scars and smallpox scars were recruited for this study. All patients had Fitzpatrick skin phototypes III to V. Short-pulsed Er:YAG laser (DermaTM 20; ESC Medical Systems, Haifa, Israel), variable-pulsed Er:YAG laser (CO3, Cynosure, MA), and dual-mode Er:YAG laser (Contour, Sciton Laser Corp, Palo Alto, CA) were used for the facial skin resurfacings. Ninety-seven patients were treated with a 350 microsecond short-pulsed Er:YAG laser, using a 2 mm spot-sized handpiece at a setting of 12.5–15 J/cm². The laser was delivered with 4–5 passes. Fifty-two patients were treated with a variable-pulsed Er:YAG laser, with 4–5 passes at 5 Hz using a 5 mm spot-sized handpiece at a setting of 7.0–7.5 J/cm² with a 7 millisecond pulse duration. Forty-one patients were treated with a dual-mode Er:YAG laser using a 4 mm spot-sized scanner. Initially 1–2 pulses of 350 microsecond ablation mode at 17.5 J/cm² were delivered to remove the entire epidermis. This was followed by 2–3 pulses of 350 microsecond ablation mode at 17.5 J/cm² and 8 millisecond coagulation mode at 3.15 J/cm² for further ablation and for a controlled thermal effect. A final pulse of 350 microsecond ablation mode at 17.5 J/cm² was used to

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remove necrotic tissue. Following the laser treatment, all patients were managed using the occlusive dressing technique with polyurethane foam. After the laser operation, acyclovir (200 mg, five times a day) and tosylflouxacin (150 mg, three times a day) for oral prophylaxis and oral prednisolone (10 mg, three times a day) for the prevention of severe postoperative edema, were prescribed for 4–5 days. Seven days after operation, the wound dressings were removed. Forty patients with hyperpigmentation were treated with 4% hydroquinone cream on the lesion daily at night until the entire lesion disappeared; the other 33 patients were untreated. Patients with hypopigmentation did not receive any treatment. Initial clinical photographs were taken before the laser treatment and follow-up photographs were taken for 12 months at 2–4 week intervals. The incidences, onset times, and the durations of hyperpigmentation or hypopigmentation, and the efficacy of 4% hydroquinone cream on hyperpigmentation caused by laser resurfacing were evaluated throughout using medical charts and photographs by three independent investigators. The Student's *t*-test was used to evaluate the efficacy of the hydroquinone treatment. For histopathologic examinations, skin biopsies were performed in three patients at hyperpigmentation sites and in four patients at hypopigmentation sites with informed consents. Specimens were embedded in paraffin blocks for hematoxylin and eosin, and Fontana-Masson staining.

RESULTS

Hyperpigmentation was observed in 73 of the 190 patients (38.4%) (Fig. 1). Twenty-four were males and 59 females, their ages ranged from 20 to 54 years (mean age, 32.6 years). Hyperpigmentation was observed in 24 patients (24.7%) treated with short-pulsed Er:YAG laser, 22 patients (42.3%) treated with variable-pulsed Er:YAG laser, and in 27 patients (65.9%) treated with dual-mode Er:YAG laser (Table 1). Hyperpigmentation appeared within 8 weeks in all cases (Table 2), with a mean onset time of 3.5 weeks after treatment. In 87.7% of the hyperpigmentation cases, it disappeared within 12 weeks (Table 3), but in one patient, it persisted for more than 1 year. Mean duration was 6.5 weeks in the short-pulsed Er:YAG laser group, 7.6 weeks in the modulated Er:YAG laser group (comprising both variable-pulsed and dual-mode Er:YAG laser), and 7.2 weeks for all hyperpigmentation cases (Table 4). It lasted for 6.5 weeks in patients treated with 4% hydroquinone cream (40 patients, 54.8%), and for 8.0 weeks in patients not treated (33 patients, 45.2%). This difference was not statistically significant (Student's *t*-test, $P = 0.185$). Staining with hematoxylin and eosin, and Fontana-Masson stains showed no variations in the number of melanocytes, but increased amounts of melanin in the epidermis, particularly in the basal layer (Fig. 2A,B).

Hypopigmentation was observed in 26 patients (13.7%) (Fig. 3), 13 males and 13 females of mean age of 29.2 years (range 19–58 years). Hypopigmentation was observed in 8 patients (8.0%) treated with short-pulsed Er:YAG laser, 8 patients (15.3%) treated with variable-pulsed Er:YAG



Fig. 1. Four weeks after Er:YAG laser resurfacing. Extensive hyperpigmentation was observed in the treatment area—forehead, cheeks, and chin.

laser, and in 10 patients (24.4%) treated with dual-mode Er:YAG laser (Table 1), and it appeared within 6 months in all cases (Table 5) with a mean onset time of 2 months after treatment. Hypopigmentation disappeared within 12 months in 85% of the cases (Table 6), with a mean duration of 4.4 months in the short-pulsed Er:YAG laser group, 5.5 months in the modulated Er:YAG laser group, and a mean of 5.1 months in total (Table 4). Hematoxylin and eosin, and Fontana-Masson stainings showed reductions in epidermal melanin content, but no variations in the number of basal epidermal melanocytes (Fig. 4A,B).

DISCUSSION

Since 1988, the resurfacing with CO₂ or Er:YAG lasers has been widely used to treat facial wrinkles, photoda-

TABLE 1. Incidences of Hyperpigmentation and Hypopigmentation by Laser Type

Er:YAG laser type	Hyperpigmentation [n (%)]	Hypopigmentation [n (%)]
Short-pulsed	24/97 ^a (24.7)	8/97 ^a (8.0)
Variable-pulsed	22/52 ^a (42.3)	8/52 ^a (15.3)
Dual-mode	27/41 ^a (65.9)	10/41 ^a (24.4)
Total	73/190 (38.4)	26/190 (13.7)

^aNumber of patients treated with each type of laser.

TABLE 2. Onset Time of Hyperpigmentation After Laser Resurfacing

Onset time (weeks)	Number (%)
≤4	63 (86)
4–8	10 (14)
Total	73 (100)

aged skin, acne scars, smallpox scars, chicken pox scars, seborrheic keratoses, and pigmented nevi [1–3]. Recently, three types of Er:YAG laser—short-pulsed, variable-pulsed, and dual-mode—have been used for skin resurfacing. The variable-pulsed Er:YAG laser delivers short pulses for ablation and long pulses to induce thermal damage, whereas the dual-mode Er:YAG laser has short ablative pulses of high fluence and long coagulative pulses of low fluence. One of the advantages of the dual-mode Er:YAG laser is that high energy can be delivered rapidly and uniformly using a scanner. Compared with the short-pulsed Er:YAG laser, modulated Er:YAG lasers (variable-pulsed and dual-mode Er:YAG lasers) can produce significant thermal effects [8–12]. Frequent complications of Er:YAG laser resurfacing are erythema, hyperpigmentation, acne flare-up, and pruritus [4,8]. However, most of these complications are temporary and mild [4,7,8].

The actual pathogenesis of the postinflammatory hyperpigmentation and hypopigmentation are unknown. It has been speculated that normal biologic phenomena, especially the reactions of inflammatory cells, epidermal cells, and melanocytes are likely to play a role [13], and that this type of microenvironment can be induced by thermal damage caused during laser resurfacing. Dark pigmented individuals are particularly prone to postinflammatory hyperpigmentation. Ruiz-Esparza et al. suggested that prolonged and intense erythema correlate with prolonged tissue inflammation, with resultant pigmentary disturbances in dark-skinned patients [14]. However, only limited data is available in the clinical features of hypopigmentation following Er:YAG laser resurfacing. Weinstein reported that hypopigmentation appears more frequently in patients with a lighter skin tone, and is caused by a diminution of skin luminescence, which is more common in Fitzpatrick skin types I and II, because of a reduction in amount of reflected light [4]. Bernstein et al. reported that hypopigmentation is due to the removal of photodamaged skin [15]. They also reported that this phenomenon appeared to be caused by the difference

TABLE 3. Duration of Hyperpigmentation

Duration (weeks)	Number (%)
≤4	32 (43.8)
4–8	24 (32.9)
8–12	8 (11.0)
12–16	4 (5.5)
> 16	5 (6.8)
Total	73 (100)

TABLE 4. Mean Durations of Hyperpigmentation and Hypopigmentation for Short-Pulsed, Variable-Pulsed, and Dual-Mode Er:YAG Lasers

	Hyperpigmentation (weeks)	Hypopigmentation (months)
Short-pulsed	6.5	4.4
Variable-pulsed	7.3	5.3
Dual-mode	7.8	5.7
Total	7.2	5.1

^aMean durations of hyperpigmentation and hypopigmentation by modulated (variable-pulsed and dual-mode) Er:YAG lasers.

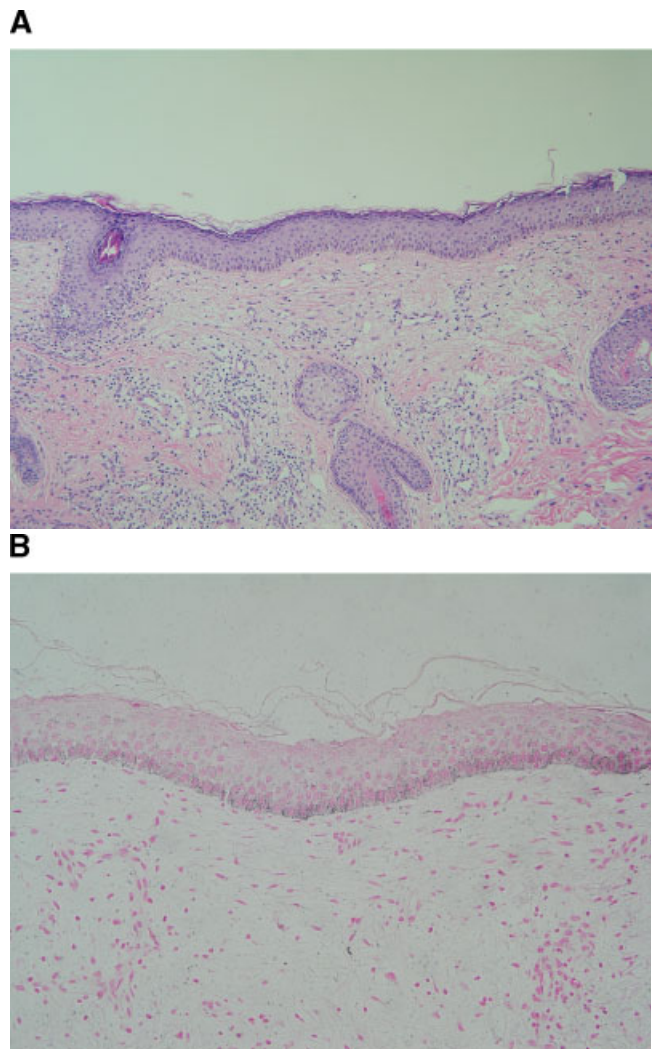


Fig. 2. Histopathologic findings of hyperpigmentation, 4 weeks after Er:YAG laser resurfacing. **A:** Mild perivascular inflammatory cell infiltration and superficial dermal fibrosis were noted. No significant change was observed in terms of the number of melanocytes (H&E stain, ×100). **B:** Post-treatment skin biopsy revealed increased melanin levels in the epidermal basal layer (Fontana-Masson stain, ×200).



Fig. 3. Two months after Er:YAG laser resurfacing. Well-demarcated, prominent hypopigmentation was observed in the treatment area.

between photodamaged skin and new unexposed skin, and described this effect as pseudo-hypopigmentation. Histopathologically, we observed quantitative changes in amount of melanin in the epidermal basal layer for hyperpigmented and hypopigmented skins without a change in the number of melanocytes. These findings indicate that laser resurfacing may have some influences on the complex microenvironment of keratinocytes, melanocytes, and collagen fibers, and that hypopigmentation after Er:YAG laser resurfacing is not a pseudo-hypopigmentation but a true though transient hypopigmentation caused by an altered microenvironment which results a melanin reduction in the epidermis.

TABLE 5. Onset Time of Hypopigmentation After Laser Resurfacing

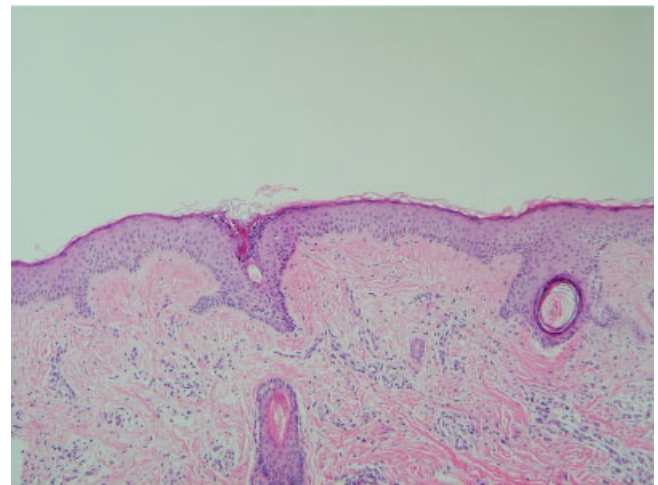
Onset time (month)	Number (%)
1st	12 (46)
2nd	5 (19)
3rd	3 (11.5)
4th	3 (11.5)
5th	2 (8)
6th	1 (4)
Total	26 (100)

TABLE 6. Duration of Hypopigmentation

Duration (months)	Number (%)
≤6	20 (77)
7–12	2 (8)
> 12	4 (15)
Total	26 (100)

Both hyperpigmentation and hypopigmentation were observed most frequently in patients treated with the dual-mode Er:YAG laser, and this was followed by the variable-pulsed Er:YAG laser and the short-pulsed Er:YAG laser in decreasing order. The duration of hyperpigmentation was

A



B

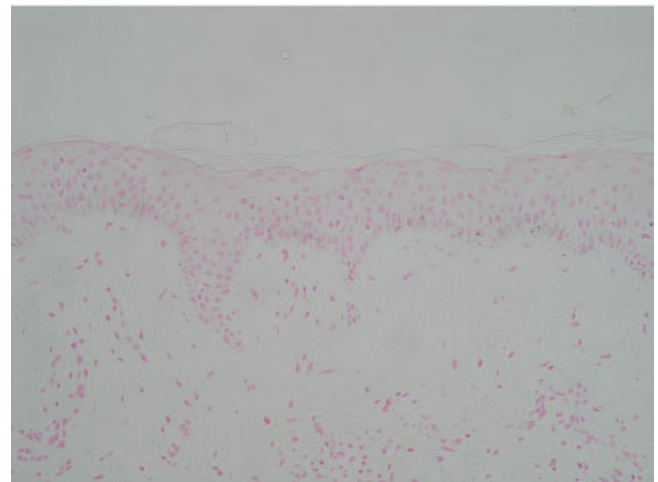


Fig. 4. Histopathologic findings of hypopigmentation, 2 months after Er:YAG laser resurfacing. **A:** Mild perivascular inflammatory cell infiltration and superficial dermal fibrosis were noted. There was no change in the number of basal melanocytes (H&E stain, $\times 100$). **B:** Post-treatment biopsy revealed sparse epidermal melanin (Fontana-Masson stain, $\times 200$).

longer for modulated Er:YAG lasers than for short-pulsed Er:YAG laser, and this result was consistent with the findings of other studies [7,8,16–18]. The incidences of these side effects in the variable-pulsed and the dual-mode Er:YAG laser resurfacing groups were equivalent to or higher than previously reported incidences following CO₂ laser resurfacing. Thermal damage of modulated Er:YAG laser resurfacing to the surrounding tissues, including melanocytes, appears to match that of CO₂ laser resurfacing. In addition, the use of a scanner in dual mode Er:YAG laser resurfacing may induce a change in pigmentation more frequently than the use of a handpiece, as was reported by Ross et al. and Manuskatti et al. [19,20].

Generally, hyperpigmentation after Er:YAG laser resurfacing developed about 1 month after treatment, and lasted for 2–3 months [4,8,18,21]. However, darker skinned patients showed a higher risk of occurrence and a longer duration of postinflammatory hyperpigmentation following laser resurfacing in the mid- to far-infrared range. Goldman reported that treatment with bleaching agents, such as hydroquinone, would cause hyperpigmentation after laser resurfacing to fade faster [21]. However, our study indicates that the duration of hyperpigmentation did not differ significantly between hydroquinone treated and untreated patients. Further well-controlled, double-blind studies are required to evaluate the efficacy of hydroquinone for hyperpigmentation after laser resurfacing. It has been reported that hypopigmentation becomes evident 6 months after laser resurfacing and never recovers spontaneously without treatment, and that it may even prove fatal [15,22,23]. In our study, hypopigmentation appeared earlier, and faded within 1 year without treatment in most cases. This may be because hypopigmentation can be detected readily in darker skinned patients, because of skin contrast differences, in addition, a darker skin has a tendency to tan more easily.

In conclusion, hyperpigmentation and hypopigmentation are frequent, usually temporary complications of Er:YAG laser resurfacing, and skin phototype and the amount of thermal damage caused during long-pulse laser treatment seem to be the important factors in terms of their incidence and duration.

REFERENCES

- Papadavid E, Katsambas A. Lasers for facial rejuvenation: A review. *Dermatol Surg* 2003;42:480–487.
- Ratner D, Tse Y, Marchell N, Goldman MP, Fitzpatrick RE, Fader DJ. Cutaneous laser resurfacing. *J Am Acad Dermatol* 1999;41:365–389.
- Walsh JT Jr, Flotte TJ, Anderson RR, Deutsch TF. Pulsed CO₂ laser tissue ablation: Effect of tissue type and pulse duration on thermal damage. *Lasers Surg Med* 1988;8:108–118.
- Weinstein C. Erbium laser resurfacing: Current concepts. *Plast Reconstr Surg* 1999;103:602–616.
- Nanni CA, Alster TS. Complications of cutaneous laser surgery: A review. *Dermatol Surg* 1998;24:209–219.
- Lowe NJ, Lask G, Griffin ME, Maxwell A, Lowe P, Quilada F. Skin resurfacing with the Ultrapulse carbon dioxide laser. Observations on 100 patients. *Dermatol Surg* 1995;21:1025–1029.
- Tanzi EL, Alster TS. Side effects and complications of variable-pulsed erbium:yttrium-aluminum-garnet laser skin resurfacing: Extended experience with 50 patients. *Plast Reconstr Surg* 2003;111:1524–1529.
- Jeong JT, Park JH, Kye YC. Resurfacing of pitted facial acne scars using Er:YAG laser with ablation and coagulation mode. *Aesthetic Plast Surg* 2003;27:130–134.
- Zachary CB. Modulating the Er:YAG laser. *Lasers Surg Med* 2000;26:223–226.
- Anderson RR. Lasers in dermatology—A critical update. *J Dermatol* 2000;27:700–705.
- Tanzi EL, Alster TS. Single-pass carbon dioxide versus multiple-pass Er:YAG laser skin resurfacing: A comparison of postoperative wound healing and side-effects rates. *Dermatol Surg* 2003;29:80–84.
- Trelles MA, Mordon S, Benitez V, Levy JL. Er:YAG laser resurfacing using combined ablation and coagulation modes. *Dermatol Surg* 2001;27:727–734.
- Halter RM, Nootheti PK. Ethnic skin disorder overview. *J Am Acad Dermatol* 2003;48:143–148.
- Ruiz-Esparza J, Lupton JR. Laser resurfacing of darkly pigmented patients. *Dermatol Clin* 2002;20:113–121.
- Bernstein LJ, Kauvar AN, Grossman MC, Geronemus RG. The short- and long-term side effects of carbon dioxide laser resurfacing. *Dermatol Surg* 1997;23:519–525.
- Kwon SD, Kye YC. Treatment of scars with a pulsed Er:YAG laser. *J Cutan Laser Ther* 2000;2:27–31.
- Jeong JT, Kye YC. Resurfacing of pitted facial acne scars with a long-pulsed Er:YAG laser. *Dermatol Surg* 2001;27:107–110.
- Bass LS. Erbium:YAG laser skin resurfacing: Preliminary clinical evaluation. *Ann Plast Surg*. 1998;40:328–334.
- Ross EV, Grossman NC, Duke D, Grevelink JM. Long-term results after CO₂ laser skin resurfacing: A comparison of scanned and pulsed systems. *J Am Acad Dermatol* 1997;37:709–718.
- Manuskatti W, Fitzpatrick RE, Goldman MP. Long-term effectiveness and side effects of carbon dioxide laser resurfacing for photoaged facial skin. *J Am Acad Dermatol* 1999;40:401–411.
- Goldman MP. The use of hydroquinone with facial laser resurfacing. *J Cutan Laser Ther* 2000;2:73–77.
- Laws RA, Finley EM, McCollough ML, Grabski WJ. Alabaster skin after carbon dioxide laser resurfacing with histologic correlation. *Dermatol Surg* 1998;24:633–636.
- Grimes PE, Bhawan J, Kim J, Chiu M, Lask G. Laser resurfacing-induced hypopigmentation: Histologic alterations and repigmentation with topical photochemotherapy. *Dermatol Surg* 2001;27:515–520.