

Cutaneous Laser Surgery in Darker Skin Phototypes

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Effective laser surgery in patients with darker skin phototypes can be achieved despite a greater inherent risk of side effects. Although the incidence of undesirable postoperative sequelae has decreased with the development of advanced laser technology and individualized treatment parameters, the risks may never be eliminated completely. Therefore, thorough patient preoperative preparation and education regarding the risks of cutaneous laser surgery will remain an essential aspect of treatment in patients with darker skin tones. As more refined laser techniques evolve, the ability to safely and effectively treat these patients will continue to improve.

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Safe and effective cutaneous laser surgery in patients with darker skin phototypes presents laser surgeons with a challenge that is being encountered more frequently as the United States population increases and becomes more ethnically diverse. US population statistics reveal dramatically changing demographics during the past decade. Between 1990 and 2000, Hispanic and Asian populations accounted for 40% of the total growth of the US population, African American populations for 12%, and non-Hispanic Caucasian populations for slightly more than 2%.¹ In 2000, the total number of individuals in the United States with skin of color was approximately 85 million.¹

Despite the increased demand by Hispanic, Asian, and African American patients for dermatologic laser surgery, the majority of the current literature remains devoted to examining laser procedures performed on individuals with fair skin tones (skin phototypes I–II), and protocols primarily have been defined on the basis of the more extensive clinical experience encountered through treating these patients.

Due to melanin's wide absorption spectrum, which ranges from 250 to 1200 nm, melanin can be targeted specifically by all visible light and near-infrared dermatologic lasers currently in use. Non-specific laser energy absorption by relatively large quantities of melanin in the basal layer of the epidermis in dark complexions can increase unintended nonspecific thermal damage and lead to a higher risk of side effects including permanent dyspigmentation, textural changes, focal atrophy, and scarring. Furthermore, competitive absorption by epidermal melanin substantially decreases the total amount of energy reaching dermal lesions, rendering it more difficult to achieve the degree of tissue destruction necessary to achieve the desired clinical result. Treatment parameters, therefore, must be considered carefully when performing laser surgery on patients with darker skin tones.

Although often difficult, effective laser therapy in patients with dark pigmentation can be achieved²⁻⁷ because the absorption coefficient of melanin decreases exponentially as wavelengths increase. Illustrating this principle, epidermal melanin absorbs approximately 4 times as much energy when exposed to the 694-nm ruby laser than when irradiated by the 1064-nm beam generated by the Nd:YAG laser, thus allowing greater penetration of the longer wavelength.⁸ Therefore, lasers generating wavelengths that are less efficiently absorbed by endogenous melanin can provide a

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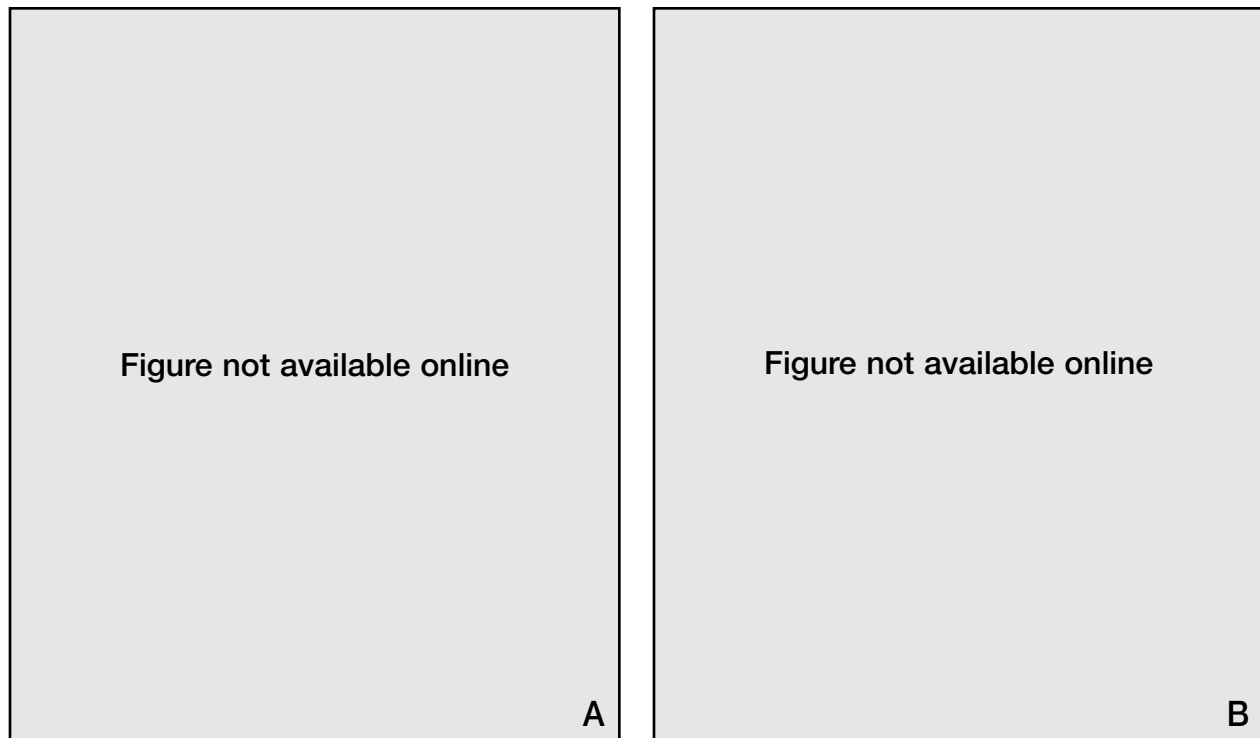


Figure 1. Nevus of Ota on the left nose and eyelid before (A) and 2 months following the fifth Q-switched 755-nm alexandrite laser treatment (B).

greater margin of safety while still allowing the laser surgeon to achieve satisfactory results.

When establishing a treatment protocol for an individual patient, the laser power level is at least as important as the laser wavelength chosen when treating darker skin because highly melanized skin absorbs electromagnetic energy much more efficiently than fair skin. For example, phototype VI skin may absorb as much as 40% more energy when irradiated with a visible light laser than phototypes I or II skin when fluence levels and exposure duration remain constant.⁹ Thus, it is best to initially employ conservative power settings (the minimal threshold fluences necessary to produce the desired tissue effect in a given individual as determined through irradiation test spots) to minimize the extent of collateral tissue damage. Clearly, a prudent approach to treatment is preferable to incurring the risk of irreparable tissue damage resulting from excessive thermal injury, even though a prudent approach may necessitate multiple laser treatments to achieve maximal clinical results.¹⁰

Pigment-Specific Lasers

Pigment-specific laser technology generates green (510 nm, 532 nm), red (694 nm), or near-infrared (755 nm, 800 nm, 1064 nm) light to selectively tar-

get intracellular melanosomes or tattoo pigment. Pigment-specific lasers also are used to eradicate unwanted hair by destroying follicular structures in which melanin is heavily concentrated.

Q-switched laser systems generating nano-second (ns) pulses that are significantly shorter than the 10- to 100-ns thermal relaxation time of melanosomes represent the safest means for treating pigmented lesions in darkly pigmented skin. Q-switched laser systems currently available include the 532-nm frequency-doubled Nd:YAG, 694-nm ruby, 755-nm alexandrite, and 1064-nm Nd:YAG lasers. Melanin absorbs energy throughout this range of wavelengths; however, the absorption peak of melanin lies within the UV range, with decreased absorption capacity at the longest wavelengths. Hence, the far-infrared wavelengths generated by the alexandrite and Nd:YAG laser systems are absorbed less efficiently by epidermal melanin, which limits the extent of unwanted thermal injury to nontargeted tissues of the epidermis and upper papillary dermis. Consequently, this allows for deeper dermal penetration, making the effective treatment of pigmented dermal lesions and hair follicles possible. Whether targeting superficial epidermal lesions such as lentigines, ephelides, café au lait macules, or lesions with a

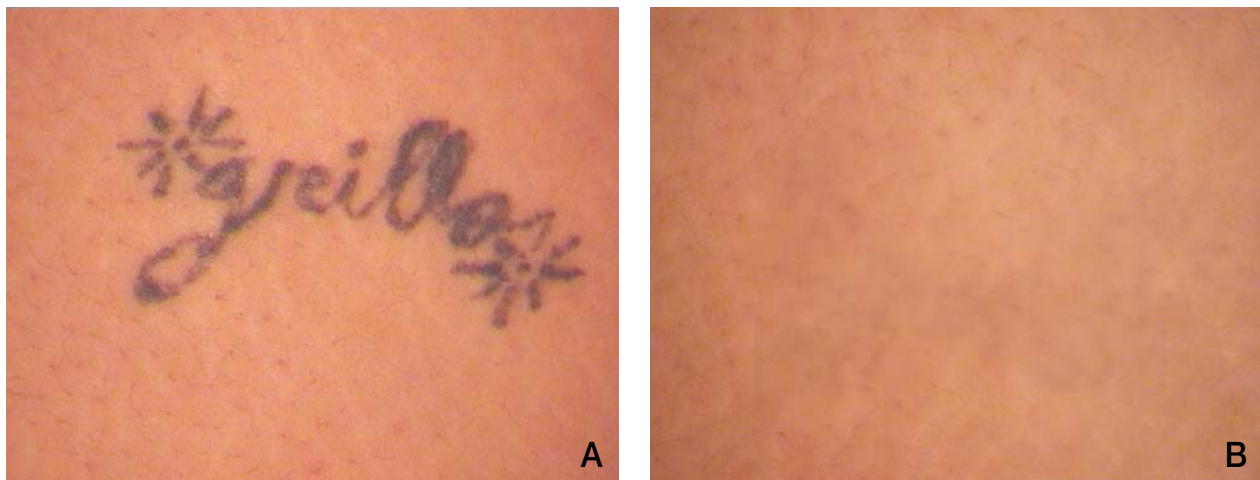


Figure 2. Professionally applied blue-black tattoo before (A) and after 8 Q-switched 1064-nm Nd:YAG laser treatments (B).

deep dermal component such as nevus of Ota, melanocytic nevi, or nevus spilus, treatment should be initiated at threshold fluences (the minimum fluence necessary to produce immediate lesional whitening, signaling the destruction of intracellular melanosomes). If the clinical threshold is exceeded, epidermal exfoliation and pinpoint bleeding ensues, resulting in blistering, possible temporary or permanent hypopigmentation, and rarely, skin textural changes or scarring.^{8,10}

Of the pigmented lesions that disproportionately affect ethnic groups with darker skin phototypes, nevi of Ota have proved especially amenable to treatment with Q-switched ruby, alexandrite, and Nd:YAG lasers.¹¹⁻¹⁵ Of these systems, the alexandrite laser appears to offer distinct advantages over other modalities. The longer wavelength of the alexandrite laser produces less epidermal damage and hypopigmentation than the ruby laser; what's more, it requires lower fluences than the Nd:YAG and produces less tissue splatter intraoperatively (Figure 1).^{13,15} In a small percentage of treated patients, recurrence of pigment may be seen despite initial successful Q-switched laser therapy.^{16,17}

Hori's macules, also known as acquired bilateral nevus of Ota-like macules, are characterized clinically as bilateral, confluent, or reticulate blue-brown or slate-grey dyspigmentation most commonly involving the malar region in Asian patients.^{18,19} Compared with nevus of Ota, Hori's macules develop in adulthood, are bilateral, and do not involve mucosa. Improvement of Hori's macules has been documented after treatment with Q-switched ruby,²⁰ Q-switched alexandrite,²¹ or Q-switched Nd:YAG^{22,23} lasers. Transient postin-

flammatory hyperpigmentation occurs after laser treatment in most patients despite the pretreatment use of topical hydroquinones.²³

Laser technology has greatly enhanced the ability to remove unwanted tattoo pigment. Because multiple pigments may be present in a tattoo, effective treatment can require the use of several wavelengths throughout the visible and near-infrared spectrum. Tattoos can respond unpredictably to laser treatment not only because their chemical compositions are highly variable but also because they can be placed in the deep dermis. Treatment is more difficult and unpredictable in patients with darker skin phototypes due to the presence of significant amounts of epidermal melanin that absorbs the laser energy. As described previously, lasers that generate energy characterized by longer wavelengths cause less collateral epidermal damage and penetrate more deeply, affording a safer and usually more effective form of treatment.²⁴ Although the Q-switched 694-nm ruby laser is highly effective in removing black and blue tattoo pigments, its wavelength is strongly absorbed by epidermal melanin and its potential for inducing long-term dyspigmentation or other untoward side effects is relatively high in patients with darker skin tones. Thus, either the Q-switched 1064-nm Nd:YAG or 755-nm alexandrite laser would be a better choice for treating black and blue tattoo pigments in darker skin because their energy is less well absorbed by epidermal melanin (Figure 2).²⁴⁻²⁷ Epidermal ablation with a resurfacing laser may enhance the safety and effectiveness of tattoo removal in patients with darker skin phototypes by eliminating the problem of competitive melanin absorption.²⁵

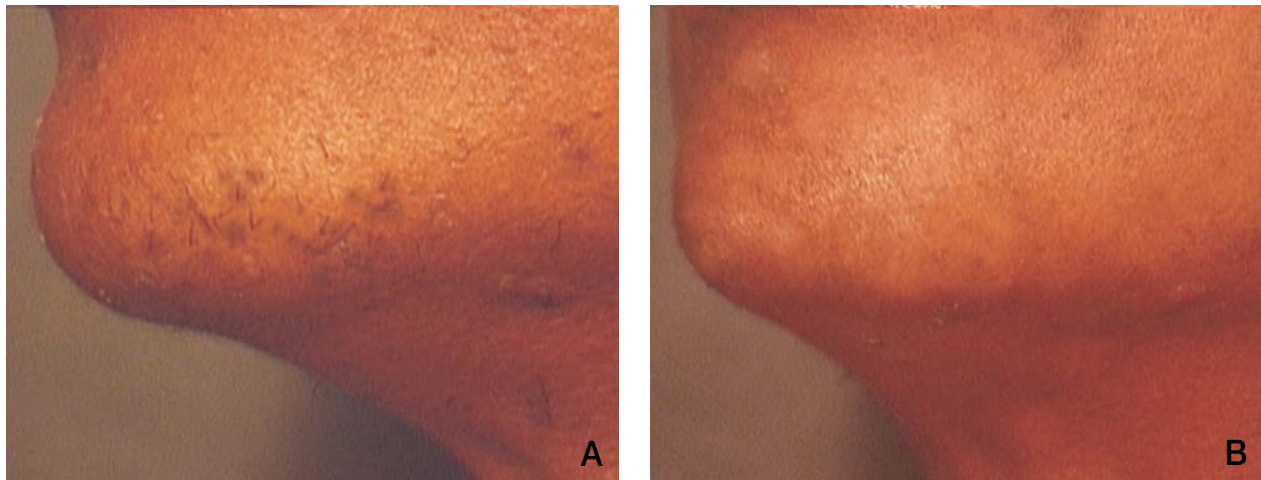


Figure 3. Coarse, pigmented terminal hair on the chin prior to (A) and 6 months after 3 consecutive monthly long-pulsed 1064-nm Nd:YAG laser treatments (B).

Photoepilation continues to gain popularity with cutaneous laser surgeons and the public alike. In a retrospective study of 900 patients, Nanni and Alster²⁸ concluded that skin type has a direct impact on the risk of side effects of laser-assisted hair removal. Recently, the combination of longer wavelengths, active epidermal cooling, and extended pulse durations provided by the most advanced laser technology has reduced the side effects following laser-assisted hair removal in patients with darker skin tones.²⁸⁻³⁵ Several pigment-specific laser systems with relatively long (millisecond) pulse durations have demonstrated safety and efficacy in more darkly pigmented patients. These laser systems include the 755-nm alexandrite,³⁰⁻³³ 810-nm diode,^{32,33} and 1064-nm Nd:YAG.^{34,35} Intense pulsed light treatment of hirsutism in patients with darker skin tones also may be possible; however, studies have been limited.³⁶ Alster and colleagues³⁵ demonstrated significant long-term hair reduction after a series of 3 monthly long-pulsed 1064-nm Nd:YAG laser treatments in 20 women with skin phototypes IV to VI. (Figure 3). Adverse effects were limited to transient pigmentary alteration without fibrosis or scarring. Pseudofolliculitis barbae, a condition with a high incidence in the African American population, also has been shown to respond favorably to laser-assisted hair removal with either a long-pulsed diode³⁷⁻³⁹ or Nd:YAG⁴⁰ laser with minimal untoward sequelae.

Vascular-Specific Lasers

Vascular-specific laser systems include a wide array of Q-switched, pulsed, and quasi-continuous-wave

lasers generating green or yellow light with wavelengths ranging from 532 to 600 nm. Because 577 nm represents a major absorption peak of oxyhemoglobin, the 585-nm pulsed dye laser has proved to be the most vascular-specific laser. For the treatment of port-wine stains, hemangiomas, and facial telangiectasias, the 585-nm pulsed dye laser has garnered the best clinical track record for both effectiveness and safety, regardless of patient skin phototype. This system also has proven effective in the treatment of hypertrophic scars and keloids, which occur more frequently among individuals with darker skin tones (Figure 4).⁴¹ Transient postinflammatory hyperpigmentation is the most common side effect of pulsed dye laser treatment of port-wine stains in pigmented skin.⁴² Hyperpigmentation usually resolves spontaneously within 2 to 3 months, as does transient hypopigmentation. Permanent hypopigmentation and scarring are rare. The side effect profiles for the frequency-doubled Nd:YAG and potassium-titanyl-phosphate lasers are similar, but side effects resulting from nonspecific epidermal injury in patients with darker skin generally are more common.^{43,44} Investigators found that although the 578-nm copper vapor laser could improve port-wine stains in patients with skin phototypes III-IV, a significant degree of epidermal injury resulted from laser treatment.^{2,3}

In 1998, long-pulsed (millisecond) 1064-nm lasers were introduced in an effort to target violaceous leg telangiectasia and large-caliber subcutaneous reticular veins.⁴⁵ The benefit of this wavelength is the deep penetration of its energy due to relatively low absorption by melanin, thus effecting

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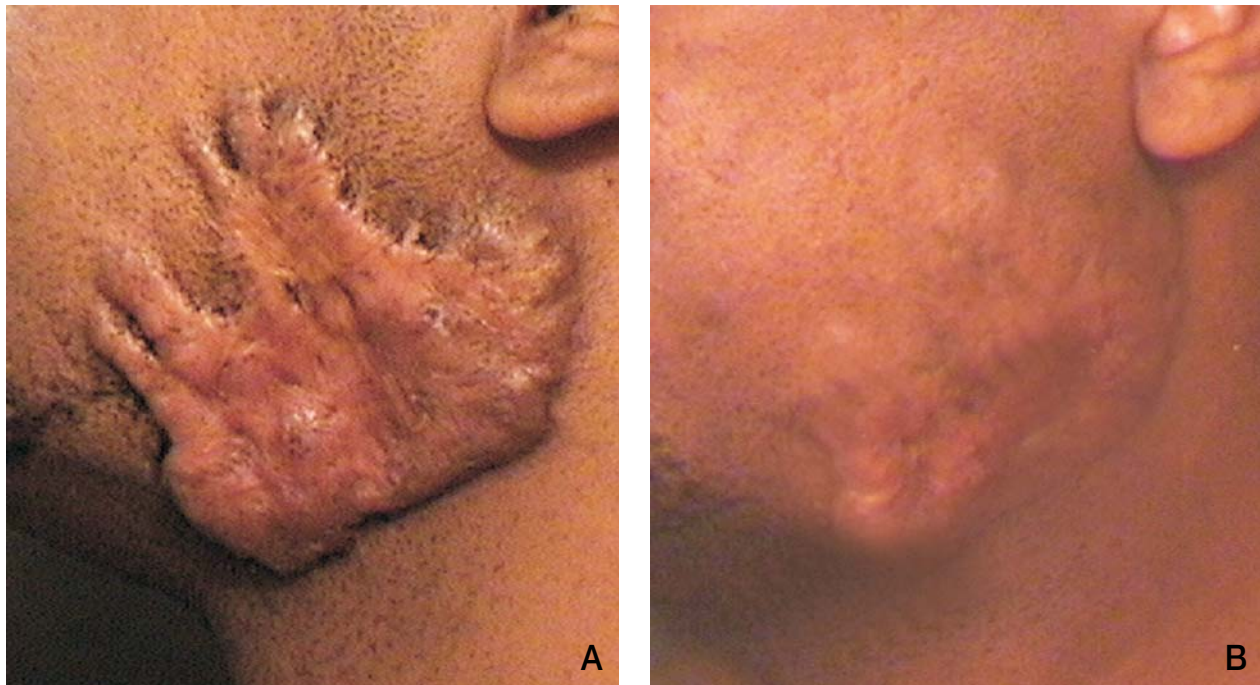


Figure 4. Keloid scar on the cheek and mandible unresponsive to intralesional corticosteroids (A). The same scar after several bimonthly 585-nm pulsed dye laser treatments (B).

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safe treatment in patients with darker skin tones. These millisecond-domain 1064-nm lasers may offer a viable future treatment option for vascular birthmarks in patients with darker skin phototypes.⁴⁶

Ablative and Nonablative Laser Skin Resurfacing

Cutaneous laser resurfacing can provide an effective means for improving the appearance of diffuse dyschromia, photoinduced rhytides, and atrophic scarring in patients with darker skin phototypes. Several reports document the long-term safety of high-energy pulsed and scanned carbon dioxide lasers and short- and long-pulsed Er:YAG lasers for the treatment of more darkly pigmented patients.⁴⁷⁻⁵¹ Although the degree of cosmetic improvement possible following ablative laser skin resurfacing in patients with skin phototypes I and II may not be attainable in patients with darker skin tones, studies report a high rate of satisfaction in this population.^{4,5} Preoperative skin preparation and meticulous postoperative care are essential for success when treating patients with darker skin phototypes. Effective patient education and comprehensive information about the most commonly experienced side effects, especially postinflammatory hyperpigmentation, is crucial in the management of patients with darker skin tones. Transient hyperpigmentation is the

most commonly experienced side effect after a patient undergoes laser skin resurfacing (affecting approximately one third of all patients); however, the incidence rises to 68% to 100% among patients with skin phototypes greater than type III (Figure 5).^{49,51}

Of particular importance for individuals with darker complexions, especially those living in regions where UV radiation is most intense, is the strict avoidance of excessive sun exposure and the consistent use of broad-spectrum sunblock both before and after laser treatment. Ideally, individuals with darker complexions should follow strict pretreatment regimens that include consistent sunscreen use for longer periods than is necessary for those with fair skin tones. Use of a sunscreen with a sun protective factor of ≥ 30 should be initiated at least 3 to 4 months before surgery and reinstated as soon as possible postoperatively.⁵² Although presurgical topical treatments cannot obviate the risk of postinflammatory hyperpigmentation in patients with darker skin phototypes, some of these treatments may enhance the eventual postoperative results. Investigators have found that, contrary to the assumptions of many clinicians, pretreatment with hydroquinone, tretinoin, or glycolic acid does not decrease the incidence of hyperpigmentation following ablative laser resurfacing in any skin phototype.⁵³ However, pretreatment with retinoic acid does appear to speed

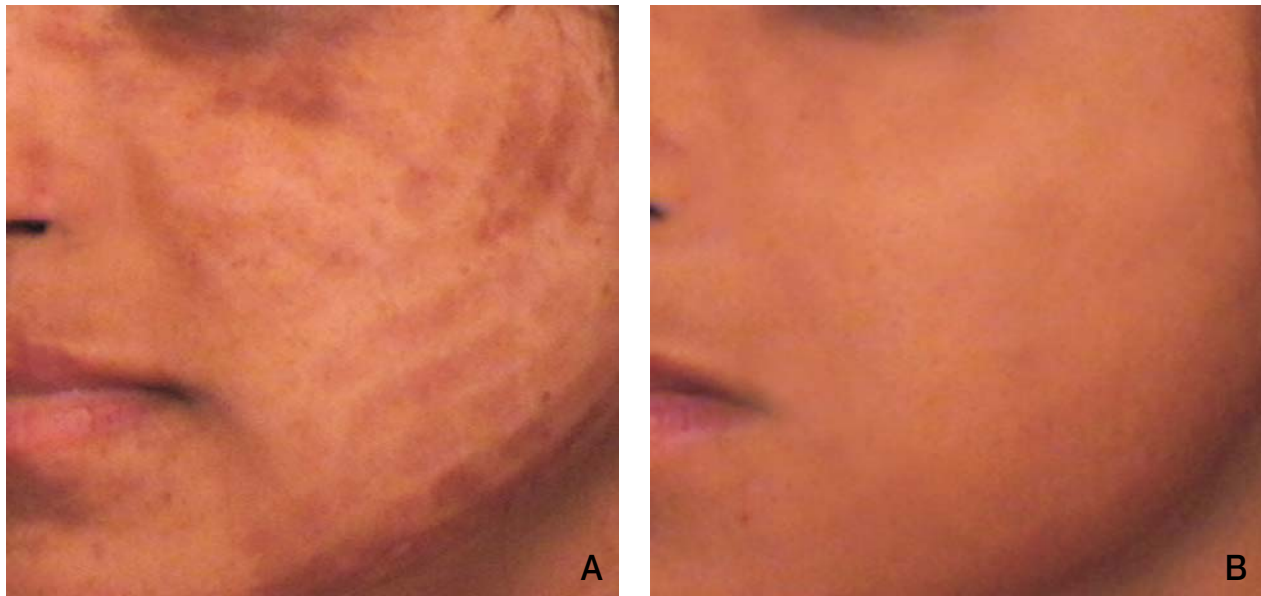


Figure 5. Postinflammatory hyperpigmentation of the face seen 4 weeks after carbon dioxide laser skin resurfacing (A) and 3 months after daily use of topical retinoic acids and hydroquinone and biweekly glycolic acid peels (B).

reepithelialization rates; also, it can reduce rates of melanin production after being reinstated after the initial stage of healing is completed and the skin has regained its tolerance.^{54,55} Thus, even if retinoic acid does not decrease the actual incidence of posttreatment hyperpigmentation, it still may reduce its severity and duration, factors of critical importance for patients with darker skin tones.

Newer dermal collagen remodeling options, including nonablative lasers, may prove to be a more satisfactory compromise between efficacy and safety in patients with darker skin tones. A cooling device protects the epidermis, while laser energy is absorbed in the upper dermis. Although nonablative lasers have not yet accrued a long history of clinical use in patients with darker complexions, it is reasonable to anticipate that nonablative lasers may offer benefit to patients who desire clinical improvement with decreased risk of postoperative dyspigmentation. Future studies are warranted to evaluate the safety and efficacy of these lasers for patients with skin characterized by a relatively high melanin content.

Conclusion

When performing any type of cutaneous laser surgery on darkly pigmented skin, a higher risk of side effects exists. The likelihood of these sequelae will decrease as more advanced surgical parameters are developed; however, these risks will probably never be eliminated completely. Consequently,

thorough patient education regarding the risks of cutaneous laser therapy will remain an essential part of therapy when treating patients with darker skin tones. Careful preparation and counseling are essential parts of treatment because some degree of postoperative dyspigmentation is likely. The dangers of excessive sun exposure and the benefits from the consistent application of broad-spectrum sunblock should be stressed. As more refined laser techniques evolve, the ability of cutaneous laser surgeons to safely and effectively treat more patients with dark pigmentation will continue to improve.

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