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Laser treatment of darker skin tones: a practical approach

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During the past decade, as cutaneous laser surgery has evolved into an accepted therapy for an extraordinarily wide array of skin pathologies, the patient population has not only soared in numbers but has also become more ethnically diverse. In particular, demand has risen dramatically among Asians, Hispanics, and African Americans, the majority of whom exhibit Fitzpatrick class III–VI phototypes. Yet most of the current literature remains devoted to examining laser procedures performed on individuals with fair complexions (phototypes I–III), and treatment protocols have largely been defined on the basis of the more extensive clinical experience that has accumulated surrounding these patients. Because of the growing popularity of laser surgery in countries where native skin tones are darker, where a high degree of ethnic diversity is the norm, and/or where sun exposure is constant, more studies are clearly needed in order to establish more highly refined parameters for treating skin characterized by a relatively high melanin content, to determine relative rates of postoperative pigmentary alteration in patients with darker complexions and/or mixed ethnic backgrounds, and to develop more effective treatments for pathologies that are more prevalent in darker ethnic groups (e.g., melasma, nevus of Ota, postinflammatory hyperpigmentation).

The clinical reports that have recently begun to emerge from such locales as Korea, Japan, Brazil, Mexico, and parts of the United States where the local population includes a large proportion of individuals of Asian, African, Native American, and/or Hispanic ancestry indicate that we still have much to learn in order to provide these patients with laser treatment that is both reliably effective and safe. Nonetheless, certain general principles governing approaches to treating patients with darker skin tones and diverse ethnic ancestry are beginning to become clear. Among these individuals, the most common cutaneous disorders amenable to laser treatment are often associated with excessive sun exposure and include melasma, photoinduced rhytides, and solar lentigines. Other conditions that frequently present for treatment include vascular or pigmented birthmarks, tattoos, and telangiectasias. Special preoperative, intraoperative and postoperative measures must be taken when performing laser treatment on patients with darker skin tones who manifest any of these pathologies in order to decrease the risk of postoperative complications. Among the most common adverse sequelae are transient or permanent pigmentary alterations, especially postinflammatory hyperpigmentation; these conditions are statistically far more likely to occur in this population than among ethnically homogeneous individuals with lighter phototypes. For example, although transient hyperpigmentation is the most common side effect observed after laser resurfacing, becoming clinically apparent in approximately one-third of all patients, the incidence increases to virtually 100% among individuals with the darkest complexions (1). Further, clinical experience in ethnically diverse areas such as Brazil and the United States is beginning to suggest that even patients who clinically appear to have fair complexions may follow this postoperative pattern if their genetic background includes ancestors with darker phototypes. Inevitably any form of postoperative dyspigmentation becomes more conspicuous and difficult to ameliorate the darker an individual's natural skin tone; hence such conditions often prove more psychologically stressful for these patients as well.

The wide absorption spectrum of melanin, which extends from the ultraviolet, through the visible, and into the near-infrared portions of the electromagnetic spectrum between approximately 250 and 1200 nm, means that this endogenous chromophore can potentially compromise the tissue specificity of almost every dermatologic laser in current use, including all pigment-specific and vascular-specific modalities, which generate visible light wavelengths, as well as near-infrared lasers targeting intracellular and extracellular water. Unintended damage to nontargeted healthy tissues, particularly the basal layer of the epidermis where melanin is normally concentrated and immediately adjacent regions of the upper papillary dermis, and diminished energy deposition in targeted lesional tissues are the results of competitive melanin absorption. These phenomena cannot be completely avoided when treating darker phototypes. And moreover, the darker a given patient's complexion, the greater becomes the possibility that serious postoperative complications arising from collateral tissue injury will occur and that sufficient damage to deeply involved lesional processes will not be achieved. Thus treatment parameters must be carefully and individually modulated in direct response to the actual amount of melanin present when performing laser surgery on patients with darker phototypes.

A case report describing the unsuccessful treatment of a black patient (class VI phototype) presenting with a port-wine stain makes these difficulties dramatically clear (2). Irradiation with a 585 nm pulsed dye laser produced extensive epidermal necrosis and only minimal vascular damage in the lesional site, despite this laser's well-documented ability to cause highly selective vascular injury as deeply as 1.2 mm below the dermoepidermal junction while sparing the epidermis in patients with lighter phototypes. The treatment did not result in any discernible improvement in the ectatic blood vessels making up the lesion, and the patient continued to exhibit persistent postinflammatory hyperpigmentation and marked textural changes throughout the 8-month follow-up period.

However, although to some extent inevitable, less than fully specific energy absorption does not represent an insurmountable barrier to laser treatment of darker phototypes since the absorption coefficient of melanin decreases exponentially as wavelengths increase. (Melanin's maximal absorption peaks lie in the ultraviolet range.) Illustrating this principle, epidermal melanin absorbs approximately four times as much energy when irradiated by the 694 nm beam of a ruby laser as when exposed to the 1064 nm light generated by the Nd:YAG laser, hence the far greater penetration depth of the latter. Thus whenever a range of laser options that can effectively treat a specific condition exists—as is the case, for example, when removing unwanted hair or treating many vascular and pigmented lesions—modalities generating wavelengths that are less efficiently absorbed by endogenous melanin can often provide a greater margin of safety while still allowing the surgeon to achieve satisfactory results, especially when treating more deeply involved processes. Moreover, when treating vascular lesions, the surgeon can also take advantage of the fact that epidermal melanin absorbs less energy when wavelengths are close to 542 nm or 577 nm, two of the main absorption peaks of oxyhemoglobin: at or near these wavelengths, strong absorption by blood decreases the total amount of energy available for melanin absorption (3).

Other intraoperative factors—power level and, to a slightly lesser extent, exposure duration—are at least as important as the laser wavelength chosen when irradiating darker skin and can be precisely modulated by the surgeon in order to take the ability of highly melanized skin to absorb energy more efficiently into account. As Anderson (4) has pointed out, the lightest skin phototypes transmit 50% or more of the energy of visible light wavelengths, while phototype class VI skin transmits less than 20%. (However, above 1200 nm, in the mid- to far-infrared portions of the spectrum, transmission rates are roughly equivalent for all phototypes since water is the absorbing chromophore.) This means that phototype class VI skin may absorb as much as 40% more energy when irradiated by a visible light laser than does class I or II skin when fluence levels and exposure durations remain constant. Therefore, with all pigment-specific and vascular-specific modalities, lower fluences and shorter exposure times can produce tissue injuries in darker skin equivalent to or even exceeding those achieved with higher fluences and longer exposures in fairer skin. This general principle has been borne out by the work of Korean investigators studying the effects of the 577 nm copper vapor laser on port-wine stains in Korean patients (phototypes III–V) (5). They observed that the threshold for lesional whitening ranged from 6 to 8 J/cm^2 for this group of patients, a finding which stands in sharp contrast to the fluence levels—ranging from 17 to 28 J/cm^2—known to be required in order to achieve equivalent effects in patients with class I or II complexions (6).

Consequently, irradiating test spots should be considered whenever laser surgery is performed on individuals with phototypes darker than class III, since a heightened degree of energy absorption will take place during treatment. Although not absolutely infallible, test sites can assist the surgeon in avoiding excessive energy deposition in cutaneous tissues and in determining the minimal fluences necessary to produce the desired effects in a given individual. Because unusually extensive collateral damage to healthy tissues in highly melanized skin—damage that can led to quite serious and often irreparable complications including permanent hypopigmentation or scarring—can easily occur when higher fluences are employed, it is generally best to err on the conservative side when treating these patients. Important too is the fact that individuals with darker skin tones have a statistically greater risk of developing hypertrophic scars or keloids after any form of cutaneous trauma (7). Multiple treatments may always be performed in order to achieve an optimal degree of lesional clearance, but excessive irradiation cannot be corrected. In fact, and more so than for patients with fair complexions, laser therapy involving multiple, carefully modulated treatment sessions as a norm may represent the most prudent course of treatment for patients with dark skin tones. Exposure durations likewise must be scrupulously controlled intraoperatively, since any increase will inevitably result in the formation of a more extensive zone of collateral thermal damage: nonoverlapping pulses should always be used during treatment and inadvertent pulse stacking strictly avoided. In general, visible light lasers equipped with Q-switched technology, which allows these systems to generate ultrashort pulses in the nanosecond range, offer a safer treatment option when treating pigmented lesions in darker phototypes than do systems requiring longer exposure times, whether pulsed or quasi-continuous wave. Of the far-infrared CO_2 laser systems currently available, the short-pulsed systems that generate pulses shorter than 1 msec, and thus cause less residual thermal damage than do scanned systems, may also afford a greater margin of safety for patients with darker skin, although good results have been achieved with scanned systems as well when other intraoperative measures have been taken to limit the depth of ablation and the degree of cumulative dermal heating (8–12). While competitive absorption by epidermal melanin is not as significant an intraoperative factor during ablative resurfacing with mid- to far-infrared lasers since these modalities target intra- and extracellular water, relatively conservative treatment parameters still appear to lessen the risk of extreme forms of postoperative dyschromia in patients with darker complexions.

Thorough preoperative skin preparation and scrupulous postoperative care are also crucial for success when treating patients with darker phototypes. Of prime importance for individuals with darker complexions, especially those living in regions where ultraviolet radiation is most intense, are the strict avoidance of excessive sun exposure and the consistent use of full-spectrum sunscreens both before and after laser surgery. While surgeons should always avoid treating tanned skin regardless of a given patient's phototype, this precaution is especially essential when treating patients who have inherently higher rates of melanin production. Ideally individuals with darker skin tones should follow strict pretreatment regimens that include consistent sunscreen use for longer periods than is necessary for those with fairer skin tones—that is, for 6 weeks at minimum, and more optimally for 3–4 months—in order to lessen the risk of postoperative hyperpigmentation (13,14). Some presurgical topical treatments may also enhance the ultimate postoperative results in patients with darker skin tones, although these cannot obviate the risk of posttraumatic hyperpigmentation. Recent reports have indicated that, contrary to the assumptions of many clinicians, pretreatment with hydroquinone, tretinoin, or glycolic acid does not decrease the incidence of hyperpigmentation after laser resurfacing, no matter the patient's phototype (15,16). But pretreatment with retinoic acid does appear to speed reepithelialization rates, and it can also reduce rates of melanin production after being reinstituted after the initial stage of healing is completed and the skin has regained tolerance (17,18). Thus, even if it does not reduce the actual incidence of posttreatment hyperpigmentation, retinoic acid may still lessen its severity and duration, factors of critical importance for patients with darker skin, as well as enhancing patient satisfaction by decreasing the duration of the most acutely morbid phase of the postoperative period (15–18).

Along with the use of retinoic acid to ameliorate this form of dyschromia, other special postoperative measures should be taken when caring for patients with darker phototypes. Topical application of L-ascorbic acid can reduce the duration of erythema and thereby may somewhat reduce the overall risk of postinflammatory hyperpigmentation, since skin that remains persistently erythematous after laser resurfacing remains likely to hyperpigment when exposed to ultraviolet (UV) light (19). Any form of dermatitis, whether caused by an irritant or allergic reaction, should be addressed promptly and aggressively, as should any bacterial or viral infections, since these complications may retard healing and may also be more likely to lead to scarring in patients with darker complexions and a greater tendency to develop hypertrophic scars or keloids. And since darker phototypes have an inherently greater tendency to develop such scars than do phototypes I and II, these patients must be monitored more vigilantly throughout the healing period and prompt measures taken whenever induration or incipient scarring becomes clinically apparent. The most expeditious and effective form of treatment for hypertrophic scarring and keloid formation is 585 nm pulsed dye laser irradiation, although other forms of treatment such as intralesional corticosteroid injections may also be beneficial (20,21).

Postinflammatory hyperpigmentation usually becomes apparent within 1 month after laser surgery and may last for 3–6 months in any phototype; however, for patients with darker complexions, the duration can be much longer and the level of discoloration more extreme. In addition to tretinoin, hydroquinone can be used both as a prophylactic measure once reepithelialization is complete and as a means of lessening its severity and duration. At-home applications of alpha-hydroxy acid creams and/or light trichloroacetic acid (TCA) or alpha-hydroxy acid (AHA) peels performed in the office can enhance the effects of hydroquinone and retinoic acid, as well as hasten the clearing of hyperpigmented macules by increasing the rate of epidermal cell turnover.

In contrast to postoperative hyperpigmentation, hypopigmentation does not usually become evident until 6 months or more after laser resurfacing. It may result from excessive injury to follicular melanocytes if excessive tissue trauma is induced, or it may represent an “unmasking” of already hypopigmented sites previously traumatized by dermabrasion, chemical peels, accidents, or inflammation. All candidates for laser resurfacing who have darker complexions should be thoroughly educated regarding the risks of delayed hypopigmentation since the condition seems to be permanent and will appear more cosmetically conspicuous in individuals with darker skin tones. Thus those who have undergone other forms of cutaneous resurfacing (e.g., dermabrasion, chemical peel) or have otherwise experienced significant cutaneous trauma should be approached with some reservation. Hypopigmentation can also become immediately apparent after irradiation with melanin- or vascular-specific lasers, although in this context it usually proves to be transient. However, if relatively high treatment energies are used and excessive tissue injury results, such cases of hypopigmentation can last much longer and can perhaps become permanent. This risk is made evident in a report by surgeons employing a 694 nm ruby laser at fairly high power settings to remove dark epidermal nevi in two Japanese patients with unusually dark complexions; the irradiated sites remained hypopigmented more than 2 years after surgery (22).

The foregoing considerations are generally applicable to any form of cutaneous laser surgery performed on patients with darker skin tones. In addition, many special considerations apply specifically to the treatment of pigmented lesions, vascular lesions, and generalized manifestations of photodamage and/or atrophic scarring, as well as laser-assisted hair removal, tattoo removal, or pathologies such as melasma and nevus of Ota that are more prevalent in darker ethnic groups.

Pigment-specific lasers

Pigment-specific laser technology with lasers generating green (510, 532 nm), red (694 nm), or near-infrared (755, 1064 nm) light centers around the selective destruction of intracellular melanosomes that predominate in pigmented skin lesions. Quality- or Q-switched laser systems that generate ultrashort pulses have generally been proven safer with a lower side effect profile than have continuous wave or quasi-continuous wave lasers, especially for patients with darker skin tones. The pulse durations of today’s Q-switched systems—the 532 nm frequency-doubled Nd:YAG, the 694 nm ruby, the 755 nm alexandrite, and the 1064 nm Nd:YAG lasers—are shorter than the thermal relaxation time of melanosomes, estimated to be between 10 and 100 nsec, and as a result, they are capable of inducing far more highly selective tissue damage that can laser systems with longer exposure times (23).

Systems generating shorter wavelengths require lower fluences to induce damage in pigmented cells than do longer wavelength lasers since the absorption coefficient of melanin varies inversely with wavelength (Fig. 1). Moreover, due to less efficient epidermal melanin absorption, the longer wavelengths of Q-switched red and near-infrared lasers penetrate more deeply and can affect lesions involving a deep dermal component (e.g., nevus of Ota, melanocytic nevi) (Fig. 2). The shorter wavelength of the green light generated by the Q-switched frequency-doubled Nd:YAG laser (532 nm), however, is so strongly absorbed by epidermal melanin that its penetration depth is far more limited and is effective only in eradicating superficial lesions (e.g., lentigines, ephelides, Becker's nevi, café-au-lait macules). Regardless of what system is used, pigment-specific laser treatment should be initiated at the threshold fluence which causes an immediate tissue-whitening effect: this optical phenomenon signals appropriate energy deposition in the melanosome with light scattering secondary to thermally and photoacoustically induced destruction of the organelle. If the clinical threshold is exceeded, epidermal exfoliation and pinpoint bleeding ensue, resulting in blistering, possible temporary or permanent hypopigmentation, and perhaps even skin textural changes or scarring. If, on the other hand, subthreshold fluences are employed, the resulting injury may stimulate melanocyte activity, contributing to postoperative hyperpigmentation and an apparent worsening of the existing lesion. This result is often seen after pigment-specific laser treatment of melasma and café-au-lait macules (24).

Of the pigmented lesions that disporportionately affect patients belonging to ethnic groups

Fig. 1. Solar lentigines on the cheek of a woman with skin type III (A) before and (B) after one treatment with a 532 nm Nd:YAG laser at 1.5 J/cm^2.

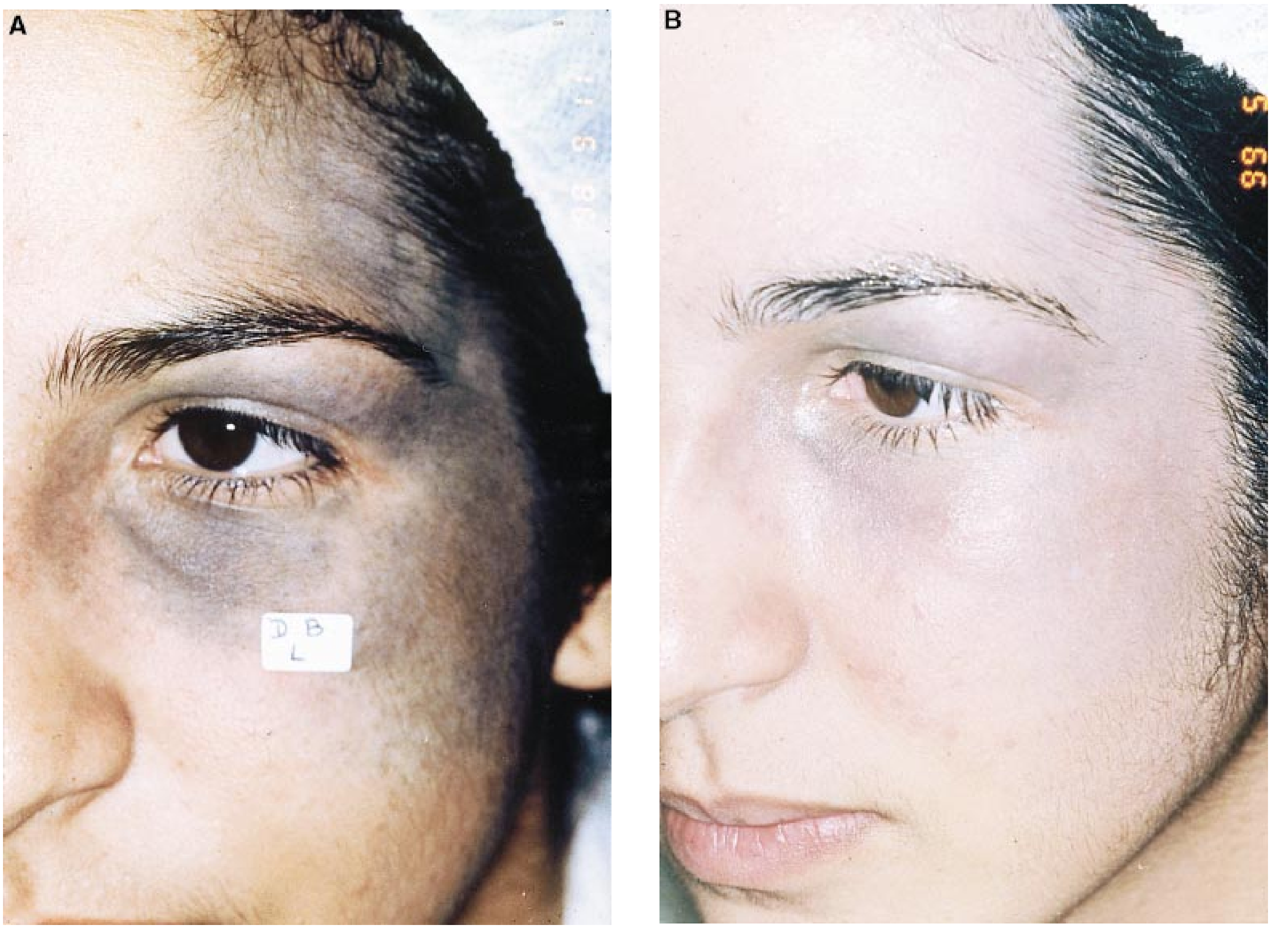

Fig. 2. Nevus of Ota involving the first and second branches of the left trigeminal nerve with cutaneous and scleral pigmentation (A) before and (B) after three sessions with a 755 nm Q-switched alexandrite laser at 6.0 J/cm^2.

with darker phototypes, nevus of Ota has proved to be highly responsive to treatment with pigment-specific lasers, while melasma, unfortunately, has not. Nevi of Ota, most prevalent among Asians, are unilateral oculodermal lesions that are usually located in facial areas innervated by the first and second branches of the trigeminal nerve: the periocular areas, temple, and cheek. Q-switched ruby, alexandrite, and Nd:YAG lasers are all capable of destroying the lesion, but the 755 nm alexandrite lasers offers distinct advantages over other modalities. Most importantly, due to its longer wavelength, its energy is less well absorbed by epidermal melanin than is ruby laser light, substantially reducing the likelihood of long-term pigmentary alterations which are sometimes observed after ruby laser treatment. Second, since effective therapy with the alexandrite laser can be achieved with lower fluences than those required with the Nd:YAG laser, less intraoperative tissue spatter occurs (25).

No pigment-specific laser modality has been shown to provide fully satisfactory treatment for melasma, a disorder most prevalent among individuals with type IV–VI complexions, especially Hispanic women living in tropical areas where exposure to intense UV light is perpetual (26–28). Melasma is an extraordinarily difficult disorder to resolve because its etiology is multifactorial: hormonal factors, excessive UV exposure, and genetic predisposition are among the causes most often cited as responsible for the condition. It appears as a scattering of lightly or darkly hyperpigmented macules over the centrofacial, malar, and mandibular regions; involvement may be limited to the epidermis or extend deeply into the dermis. Its response to irradiation with any pigment-specific laser is highly unpredictable: a virtual lack of response, worsening of the dyschromia, and recurrence are the too-frequent outcomes, especially among patients with darker complexions (24,29). Moreover, side effects arising from

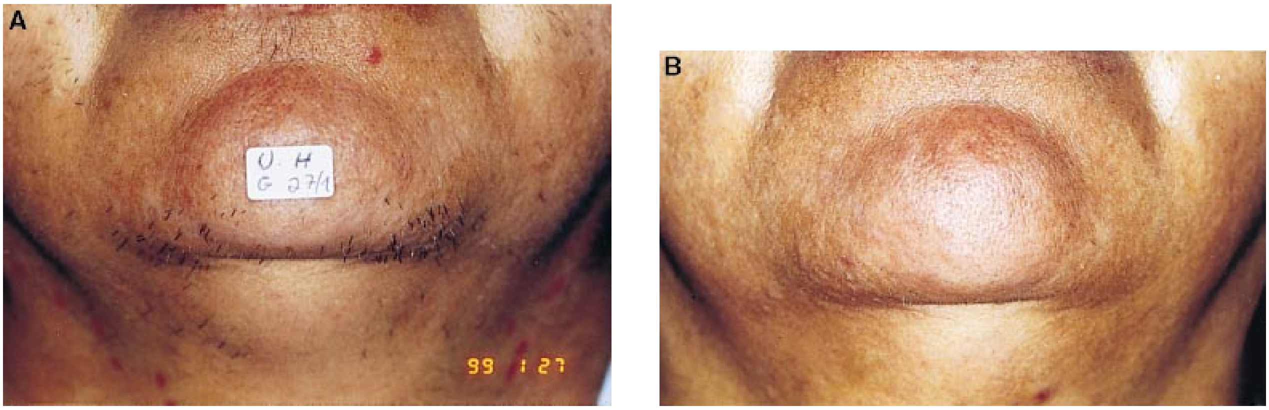

Fig. 3. **(A) Dark terminal hair growth on the chin of a woman with type III skin. (B) After three treatment sessions with an 800 nm long-pulsed diode laser, noticeable hair reduction is seen.**

excessive thermal damage to the epidermis are not uncommon, including focal atrophy, hypertrophic scarring, and permanent hypopigmentation. Recently, however, it has been reported that recalcitrant melasma unresponsive to topical tretinoin and chemical therapy may prove responsive to resurfacing treatment with the Er:YAG laser (30). The 2940 nm Er:YAG laser cleanly ablates epidermal tissue while producing a minimal zone of residual thermal damage, usually on the order of 3–5 µm. This high degree of tissue specificity affords a greater margin of safety when treating melasma than can be provided by any pigment-specific modality, substantially decreasing the likelihood of serious long-term side effects.

Pigment-specific lasers that penetrate cutaneous tissue deeply enough to target melanin located within the hair shaft and follicle are also used for the removal of unwanted hair (Fig. 3). The ideal patient for laser-assisted hair removal is a fair individual (phototypes I–II) with dark hair, since a greater proportion of laser energy will be preferentially absorbed by the comparatively heavily melanized follicular unit. Such specificity, of course, cannot be achieved in individuals with darker complexions. Of the laser-assisted hair removal systems currently available, those generating longer wavelengths (e.g., 694 nm ruby, 755 nm alexandrite, 800 nm diode) and accompanied by passive or active means for cooling and protecting the epidermis induce fewer side effects among darker phototypes (31). Q-switched 1064 nm Nd:YAG laser irradiation (SoftLight), whether or not employed in conjunction with the application of a topical carbon solution which acts as an exogenous chromophore, has demonstrated the lowest incidence of side effects caused by nonspecific epidermal melanin absorption since its wavelength is more weakly absorbed by melanin than any other laser-assisted hair-removal modality currently available (32). Unfortunately, how-

Fig. 4. Hypopigmentation seen following long-pulsed diode laser irradiation of unwanted inguinal hairs in a patient with type III skin and a tan.

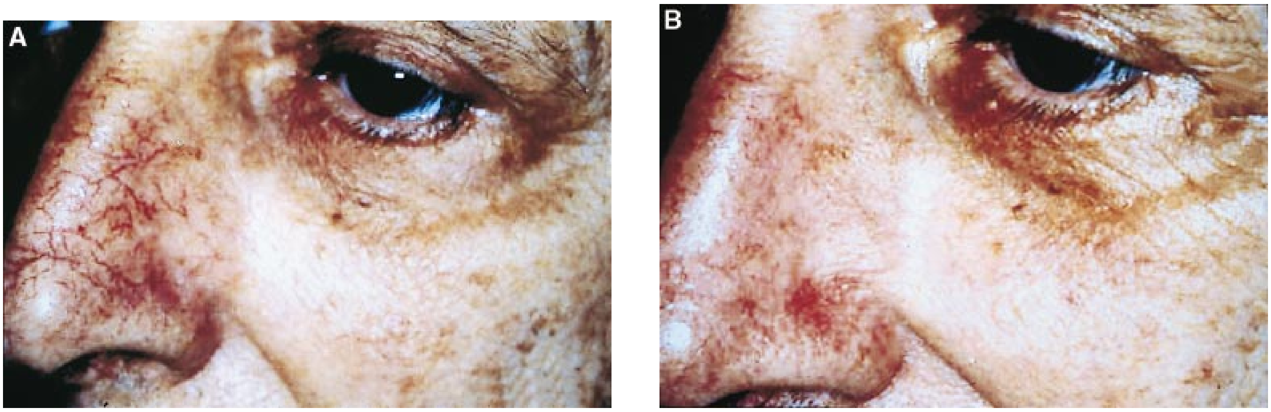

Fig. 5. **Facial telangiectasias (A) before and (B) after two treatments with a 532 nm long-pulsed Nd:YAG laser at 9.5 J/cm^2.**

ever, its clinical efficacy for hair removal is the least impressive due to the short pulse durations and its inability to adequately heat the follicular unit. Initial reports of long-pulsed Nd:YAG laser irradiation, however, have been encouraging in terms of hair removal and limited side effects in patients with darker skin tones, as the other long-pulsed lasers can lead to pigmentary alteration in darker or tanned skin tones (Fig. 4).

Vascular-specific lasers

Vascular-specific modalities include a wide array of quasi-continuous wave, pulsed, and Q-switched yellow and green light lasers generating light with wavelengths ranging from 532 to 590 nm. Since 577 nm represents a major absorption peak of oxyhemoglobin, the most highly vascular specific of these modalities has proved to be the 585 nm flashlamp-pumped pulsed dye laser. The Q-switched frequency-doubled Nd:YAG and the quasi-continuous wave KTP lasers generate 532 nm light, which is close to a secondary oxyhemoglobin absorption peak at 542 nm. Although epidermal melanin absorbs energy throughout the green and yellow portions of the spectrum, its rate of absorption—and hence the potential for excessive thermal damage to nontargeted tissues—is greatly reduced at wavelengths where competitive absorption by oxyhemoglobin is particularly strong (3,29) (Fig. 5).

For the treatment of port-wine stains, hemangiomas, and facial telangiectasias, the longer wavelength (585 nm) flashlamp-pumped pulsed dye laser (PDL) has garnered the best clinical track record for both effectiveness and safety, regardless of patient phototype. This laser has also proved effective in treating hypertrophic scars and keloids, aberrant healing responses which occur more frequently among individuals with darker complexions (Fig. 6). Few serious side ef-

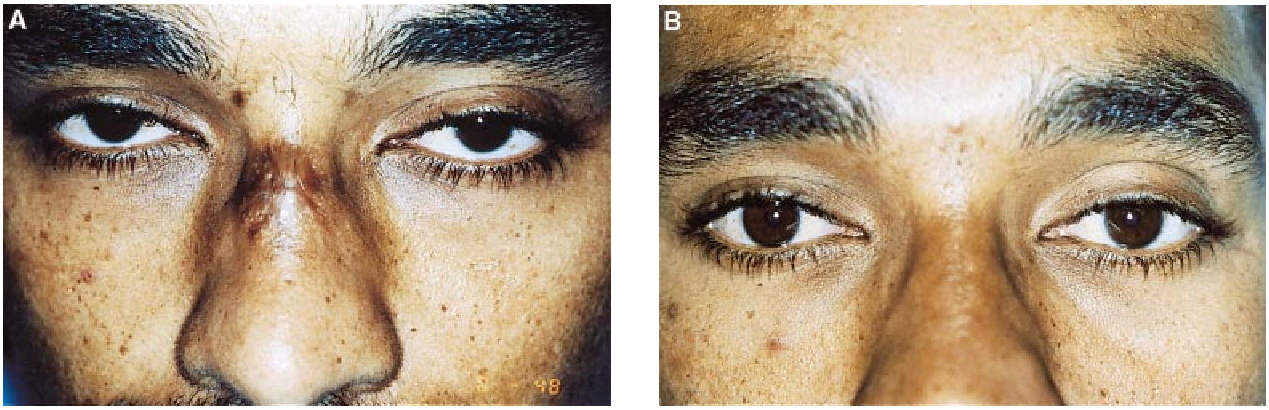

Fig. 6. **Hypertrophic scar on the nose of a patient with type IV skin (A) before and (B) after three sessions with a 585 nm pulsed dye laser at 6.5 J/cm^2 using a 7 mm spot size.**

Fig. 7. Professional tattoo with black and blue inks on the arm of a 30-year-old man (A) before and (B) after eight treatments with a 1064 nm Q-switched Nd:YAG laser at 5.5 J/cm^2.

fects occur after pulsed dye laser irradiation. Transient posttreatment hyperpigmentation can occur and is, of course, observed more frequently among individuals with darker complexions. Most often, it resolves within 3–6 months, as does transient hypopigmentation. Permanent hypopigmentation and scarring are extremely rare. The side-effect profiles for the frequency-doubled Nd:YAG and KTP lasers are similar, but side effects resulting from nonspecific epidermal damage in darker phototypes are generally more common (33), as is true with other quasi-continuous wave lasers (e.g., copper vapor). For example, according to the reports of Korean investigators, while the 578 nm copper vapor laser can improve port-wine stains in patients with class III–V phototypes, a significant degree of epidermal damage also results from treatment with this laser (5,6). As with pigment-specific laser treatment, treatment with vascular-specific modalities should be initiated at threshold fluences, and energy densities should be increased only with caution when treating darker phototypes: an immediate purpuric response signals the threshold for lesional damage after irradiation with the flashlamp-pumped pulsed dye laser; immediate vessel blanching indicates threshold response with either the KTP or frequency-doubled Nd:YAG lasers.

Tattoo lasers

Because of the multiplicity of pigments that can appear in tattoos, effective treatment can require the use of wavelengths throughout the visible and near-infrared portions of the electromagnetic spectrum by the full range of Q-switched pigment-specific lasers. Whether professional, amateur, cosmetic, or traumatically induced, tattoos respond unpredictably to laser irradiation, not only because their chemical compositions and energy absorption are highly variable, but also

Fig. 8. **(A) Traumatic tattoo on the face of a 37-year-old man after a fall on asphalt. (B) After four sessions with a 755 nm Q-switched alexandrite laser at 6.0–7.0 J/cm^2, clearing of tattoo ink is evident.**

because they almost always involve a deep dermal component. In individuals with darker complexions, treatment is rendered more difficult and unpredictable because of the presence of increased amounts of epidermal melanin. In general, as when treating other isolated lesions with pigment-specific or vascular-specific modalities, systems 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. Illustrating this principle, although the Q-switched ruby laser has long been known to provide highly effective treatment of black and dark blue tattoo pigments, its 694 nm wavelength is strongly absorbed by epidermal melanin, and its potential for inducing long-term pigmentary changes or other untoward side effects in darker phototypes is relatively high. A better choice for treating blue and black tattoo pigments in darker skin is the Q-switched Nd:YAG laser, since its energy is weakly absorbed by epidermal melanin (34) (Fig. 7). The frequency-doubled Nd:YAG laser (532 nm) can also provide effective treatment for red, yellow, and orange pigments, whereas the relatively long infrared wavelength of the Q-switched alexandrite (755 nm) laser offers a relatively safe way of destroying black, blue, and green tattoo pigments in darker phototypes (Fig. 8). Finally, when treating tattoos in patients with darker skin tones, epidermal ablation with a resurfacing laser eliminates the problem of competitive melanin absorption, and may enhance the safety and effectiveness of tattoo removal in patients with darker phototypes (34).

Resurfacing lasers

Cutaneous laser resurfacing can provide a safe and satisfactorily effective means for improving the appearance of diffuse dyschromia, photoin-

Fig. 9. **Atrophic acne scars in a patient with type IV skin (A) before and (B) after full-face CO_2 laser resurfacing (three passes, 300 mJ energy, 60 W power, CPG density 6).**

duced rhytides or other manifestations of excessive UV light exposure, and atrophic scarring in patients with darker phototypes (Figs. 9 and 10). However, because of the risk factors associated with aggressive therapy, the same degree of optimal clinical improvement attainable in patients with phototypes I and II generally cannot be achieved in individuals with darker complexions. Chief among these risks are permanent hypopigmentation and hypertrophic scarring or keloid formation. Transient postinflammatory hyperpigmentation is an almost inevitable side effect following laser resurfacing of patients with darker skin phototypes (Fig. 11), but the far more serious risks of scarring and permanent dyspigmentation can largely be mitigated by following conservative treatment parameters in order to limit the degree of collateral thermal damage: lower energy settings should be used, fewer passes performed, and depths of ablation limited when treating these patients. Both the Er:YAG and the comparatively shorter-pulsed CO_2 (e.g., TruPulse) lasers produce less extensive tissue trauma than other pulsed and scanned CO_2 resurfacing systems, thereby providing the surgeon with an inherently greater margin of safety. Yet most CO_2 resurfacing lasers can provide safe and effective treatment provided that other intraoperative measures are taken to limit the extent of collateral tissue damage (9,11,12).

This greater margin of safety, however, does exact its price, since maximal collagen shrinkage

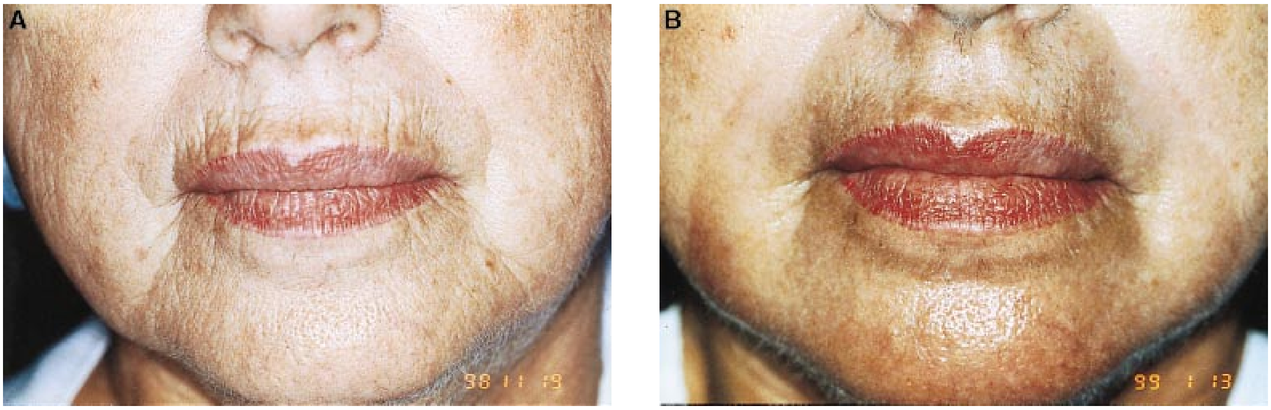

Fig. 10. Perioral rhytides in a female with skin phototype III (A) before and (B) after CO_2 laser resurfacing (three to four passes, 300 mJ energy, 60 W power, CPG density 6).

depends on the creation of a relatively extensive zone of residual thermal damage in the upper papillary dermis. Collagen tightening is essential for maximal cosmetic improvement of rhytides and atrophic scars, as studies comparing the cosmetic results attainable from various Er:YAG and CO_2 resurfacing modalities have demonstrated (35,36). The primary challenge involved in performing laser resurfacing on patients with phototypes III–VI involves balancing the two equally important goals of minimizing risks and maximizing cosmetic improvement when treating each individual patient.

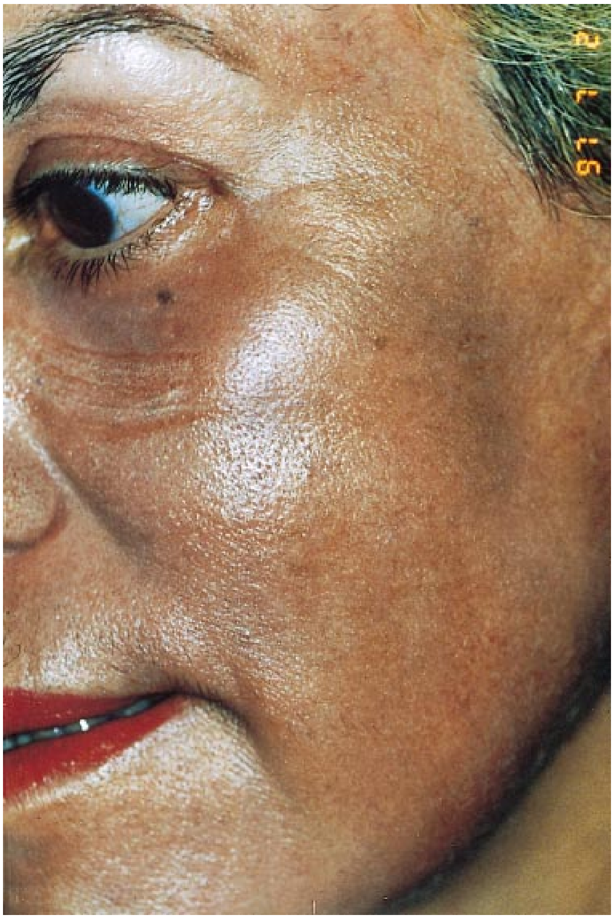

Fig. 11. Postinflammatory hyperpigmentation seen in a patient with type III skin 1 month after full-face CO_2 laser resurfacing.

In conclusion, when performing any form of cutaneous laser surgery on patients with darker skin tones, a palpably higher risk of more extreme forms of transient or permanent postoperative pigmentary disturbance exists, as does a higher risk of changes in skin texture, hypertrophic scarring, or keloid formation, than when treating paler skin phototypes (I or II). The likelihood of these sequelae will lessen as more refined surgical techniques are developed, but these risks cannot be fully obviated, at least not for the foreseeable future. Consequently, thorough patient education regarding the risks of cutaneous laser therapy will remain an essential part of therapy when treating individuals with darker complexions. Careful psychological preparation and counseling will also remain essential parts of treatment, since some degree of postoperative dyschromia will almost certainly continue to be experienced by most members of this population. The dangers of excessive sun exposure and the benefits derived from consistently applying full-spectrum sunscreens should be stressed when treating individuals with darker phototypes. Lastly, expedient physician recognition of and intervention for adverse sequelae will limit long-term detriment to the patient.

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