

Lasers in Dermatology

An Overview of Types and Indications

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Abstract

Advances in laser technology have been so marked over the past two decades that successful eradication of many cutaneous pathologies and congenital defects, including vascular and pigmented lesions, tattoos, scars, and unwanted hair, can now be fully realized. Because of the relative ease with which many of these lesions can be removed, coupled with a low incidence of adverse postoperative sequelae, demand for laser surgery has increased substantially. In this review, the currently available laser systems with cutaneous application are outlined, with special reference to recent advancements and modifications in laser technology that have greatly expanded the laser surgeon's armamentarium and improved upon overall treatment efficacy.

1. Laser Principles

The word laser is an acronym for Light Amplification by the Stimulated Emission of Radiation. It was with Einstein's quantum theory formulated in the early 1900s, that the concept of stimulated light emission was born. This theory argued that a photon of light energy could stimulate the emission of another photon upon collision of excited molecules that then return to

their stable resting states. A cutaneous application for this theory was not evident until 1959 when Maiman^[1] used monochromatic 694nm ruby light to develop the first laser. In 1963, dermatologist Dr Leon Goldman initiated ruby laser treatment of a variety of cutaneous pathologies, thus pioneering the use of lasers on human skin.^[2] The argon and carbon dioxide (CO₂) lasers were subsequently developed in 1964 and rapidly became the focus of cutaneous laser research for the next two decades. The argon laser emits

blue-green 488/514nm light and was used primarily to treat benign vascular proliferations. Although this laser could effectively lighten most port-wine stains and hemangiomas, there was an unacceptably high rate of hypertrophic scar formation.^[3] The CO₂ laser, emitting infrared light at 10 600nm, was used for tissue vaporization and destruction of various epidermal and dermal lesions. Unfortunately, this continuous-wave (CW) laser also produced high incidences of hypertrophic scarring and pigmentary alteration due to prolonged exposure (and burning) of the skin to laser light energy.^[4,5]

Since the early 1980s, with the elucidation of the principles of selective photothermolysis by Anderson and Parrish,^[6] laser technology has become so refined and has gained such popularity among medical professionals across a wide range of specialties, that it is now considered a first-line treatment for many congenital and acquired cutaneous conditions. Anderson and Parrish's theory revolutionized the field of cutaneous laser surgery, describing how controlled destruction of targeted lesional tissue was possible without significant thermal damage to surrounding normal structures. First, a proper wavelength which is absorbed preferentially by the intended tissue target (chromophore) should be selected. Secondly, in order to limit the amount of thermal energy deposited within the skin, the exposure duration of the tissue to light (pulse duration) must be shorter than the target or chromophore's thermal relaxation time – defined as the time required for the targeted site to cool to one-half of its peak temperature immediately after laser irradiation. Finally, the energy density (or fluence) delivered by the laser must be sufficiently high so as to destroy the target within the allotted time. Therefore, based upon these principles, laser parameters (e.g. wavelength, pulse duration, fluence) can be tailored for specific cutaneous applications to effect maximal target destruction with minimal collateral thermal damage.

Laser light has several unique properties that account for its therapeutic activity. The first property, monochromaticity, implies that the emitted light is of a single, discrete wavelength determined by the lasing medium (e.g. solid, liquid, gas) in the optical cavity through which the light is passed. The wavelength of laser light permits selective absorption of energy by certain chromophores within the skin (e.g. hemoglobin, melanin, tattoo ink). Coherence, the second property, refers to laser light traveling in phase with respect to both time and space. Lastly, collimation of laser light indicates emission of a narrow intense beam of light in parallel fashion in order to achieve its propagation across long distances without light divergence. Collimated light can therefore be focused into small spot sizes allowing for site-specific destruction.

2. Laser Types

CW mode lasers, exemplified by the CW CO₂, and older argon units, emit a constant beam of light with long exposure durations which result in non-selective tissue injury. Quasi-CW mode lasers including the potassium titanyl phosphate (KTP), copper vapor, copper bromide, krypton, and argon-pumped tunable dye lasers, shutter the CW beam into short segments, producing interrupted emissions of constant energy. The pulsed laser systems emit high-energy laser light within ultra short pulse durations with relatively long intervening time periods between each pulse (0.1 to 1 second). These laser systems may be either long-pulsed, such as the pulsed dye laser with pulse durations ranging from 450 to 1500 μ sec, or short-pulsed (50 to 100 nsec), such as the quality(Q)-switched ruby, alexandrite, or neodymium:yttrium-aluminum-garnet (Nd:YAG) lasers. The Q-switched lasers have photo-optical shutters that permit release of stored energy within the laser cavity in short high energy bursts, delivering power outputs as high as 10⁹W. The pulsed laser systems are better adapted for treating skin lesions according to the principles of selective photothermolysis since the thermal relaxation times of most cutaneous chromophores are very short. Since cutaneous lasers have different clinical applications based upon their specific wavelengths and pulse durations, choice of laser should be based upon the target's individual absorptive characteristics (table I).

3. Pigment Lasers

3.1 Quality (Q)-Switched Ruby Laser (694nm)

The Q-switched ruby laser (QSRL) emits short pulsed (20 nsec to 40 nsec) red light within the visible portion of the electromagnetic spectrum. Because melanin is selectively targeted at 694nm, the QSRL can be used to eradicate a variety of epidermal and dermal pigmented lesions.^[7-19] Longer pulsed, normal-mode ruby lasers have been shown to be useful for hair epilation and some congenital nevi.^[20-24]

Superficial (epidermal) pigmented lesions such as solar lentigines and ephelides can be significantly lightened or completely eradicated within 1 to 2 QSRL treatments,^[13] whereas deeper (dermal) pigmented lesions such as nevus of Ota, blue nevi, and melanocytic nevi usually require more treatment sessions to achieve similar clinical fading.^[17-19] Laser treatment of mixed-type (epidermal/dermal) pigmented lesions such as café-au-lait macules, Becker's nevus, and nevus spilus are more difficult to eradicate and have a higher rate of recurrence than do purely epidermal or dermal lesions.

Immediately after ruby laser irradiation, an ash-white tissue response with edema is evident, lasting approximately 30 to 60

Table I. Types of laser and their cutaneous application

Laser type	Wavelength	Cutaneous application
Copper vapor/bromide (quasi-CW)	510nm 578nm	Pigment Vascular lesions
Pulsed dye	510nm 585nm	Superficial pigment, red/yellow/orange tattoos Vascular lesions, warts, hypertrophic scars, striae
Potassium titanyl phosphate (KTP)	532nm	Pigmented/vascular lesions
Neodymium:yttrium-aluminium-garnet (Nd:YAG) [frequency-doubled]	532nm	Superficial pigment, red/orange/yellow tattoos
Tunable dye argon (quasi-CW)	577/585nm	Vascular lesions
Ruby	694nm	
Q-switched		Pigment, blue/black/green tattoos
Normal mode		Hair
Alexandrite	755nm	
Q-switched		Pigment, blue/black/green tattoos
Long-pulsed		Hair
Nd:YAG	1064nm	
Q-switched		Pigment, blue-black tattoos
Long-pulsed		Hair (darker skin phototypes)
Nd:YAG	1320nm	Nonablative skin resurfacing
Erbium:YAG (pulsed)	2940nm	Skin resurfacing, epidermal lesions
Carbon dioxide (CO ₂)[CW]	10 600nm	Actinic cheilitis, verrucae, rhinophyma
CO ₂ (high-energy, pulsed)	10 600nm	Skin resurfacing, epidermal/dermal lesions

CW = continuous wave; **Q-switched** = quality-switched.

minutes after treatment. Cutaneous healing is complete within 7 to 14 days. Because melanin absorbs QSRL energy so strongly, transient postinflammatory pigmentary alteration of treated skin may result. Hypo- or hyperpigmentation may persist for several months after the procedure. Fortunately, permanent depigmentation and other untoward effects such as hypertrophic scarring are rare.

3.2 Q-Switched Alexandrite Laser (755nm)

The Q-switched alexandrite laser can also selectively remove epidermal and dermal pigmentation. The alexandrite emits red light at 755nm with pulse durations ranging 50 nsec to 100 nsec. Like the QSRL, the alexandrite laser is an ideal system for the treatment of deeper lesions such as intradermal nevi and nevus of Ota (fig. 1).^[16,25-27] Its slightly longer wavelength (compared to the QSRL) is responsible for decreased absorption by epidermal melanin, leading to reduced risk of post-treatment hypopigmentation. Long-pulsed (2 to 40 msec) alexandrite lasers have also recently been developed for hair epilation. These lasers target follicular melanin and induce long term permanent reduction in hair follicle density.^[20]

3.3 Q-Switched Neodymium:Yttrium-Aluminum-Garnet (Nd:YAG) Laser (1064nm and 532nm)

The neodymium:yttrium-aluminum-garnet (Nd:YAG) laser emits infrared light at 1064nm and, when frequency-doubled by passing the laser light beam through a potassium diphosphate crystal, the wavelength is halved so that 532nm green light is produced. Q-switched Nd:YAG lasers at either 532nm or 1064nm have pulse durations ranging from 5 nsec to 20 nsec. At a wavelength of 532nm, superficial epidermal melanin is effectively destroyed thereby making the frequency-doubled Nd:YAG laser system most useful in the removal of solar lentigines and ephelides.^[28,29] However, concomitant absorption of 532nm light by oxyhemoglobin within the superficial dermis is a risk with this system, and frank purpura from superficial capillary destruction lasting up to 10 to 14 days may result. The 1064nm QS Nd:YAG laser penetrates the skin much more deeply and is therefore a more effective tool for dermal pigmentation. In addition, it is an ideal system for the treatment of pigmented lesions in patients with darker skin phototypes since there is negligible interaction with epidermal melanin, thereby reducing the risk of postoperative pigmentary alteration. While QS Nd:YAG lasers have been used for hair removal, their effectiveness was lower than long-pulsed red and infrared systems. Recently, long-pulsed (up to 50 msec) 1064nm

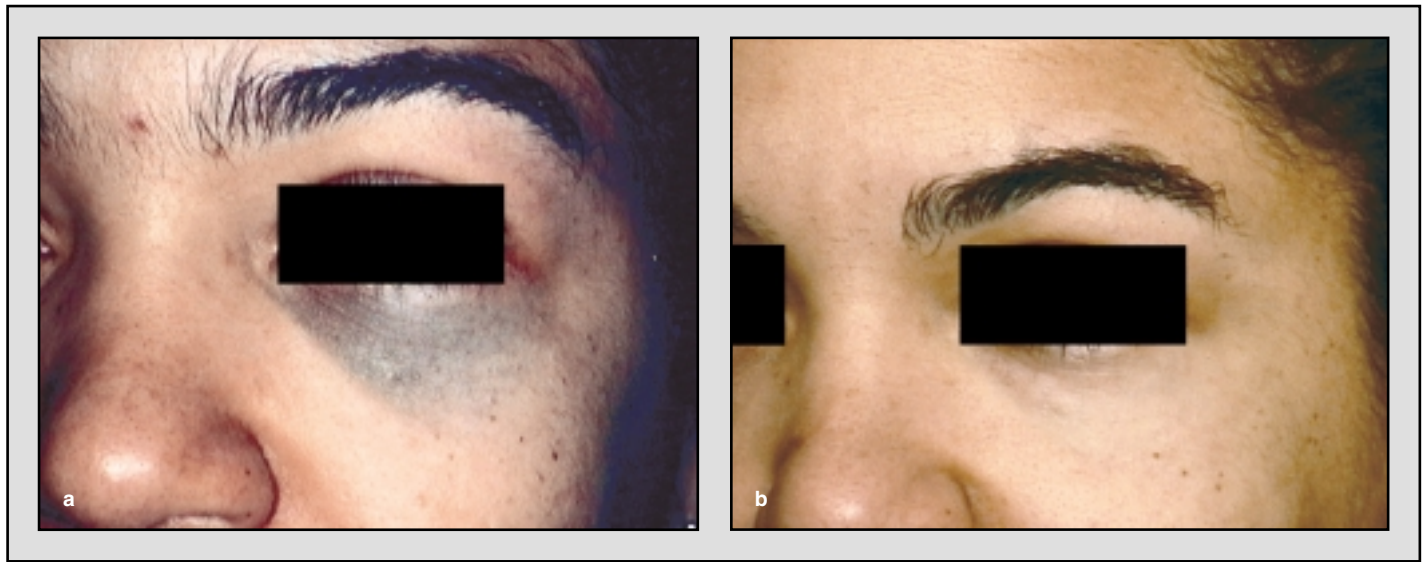


Fig. 1. Nevus of Ota involving the infraorbital region with dermal and scleral pigmentation before (a) and after (b) 6 consecutive Q-switched alexandrite (755nm) laser treatments at bi-monthly time intervals.

Nd:YAG systems have been developed which have proven useful in removing hair even in individuals with dark skin tones (a problem when using shorter wavelength lasers with greater epidermal interaction).^[30]

3.4 Pigmented Lesion Dye Laser (510nm)

The pigmented lesion dye laser (PLDL) is a 510nm green light laser that is not commonly used today, but is ideally suited for treating epidermal pigmentation.^[31-34] Superficial pigmented lesions such as solar lentigines, ephelides, and café-au-lait macules have successfully been eradicated with this system. Whereas only 1 or 2 treatments are typically needed to treat lentigines and ephelides, café-au-lait macules are more resistant to therapy, often requiring several treatment sessions (6 or more). An ash-gray discoloration and thin crust develop after laser treatment, resolving within 1 to 2 weeks. Like the 532nm Nd:YAG, laser energy absorption by oxyhemoglobin at the 510nm wavelength is possible resulting in transient purpura.

3.5 Copper Vapor Laser (578nm)

The copper vapor laser simultaneously emits 510nm green light and 578nm yellow light. Vascular lesions (e.g. port-wine stains, telangiectasias, venous malformations) are treated with the yellow light, whereas the green light is used for superficial pigment removal (lentigines, ephelides).^[35-38] The continuous wave copper vapor laser beam is mechanically shuttered in order to limit thermal destruction to the intended target. However, because of its 'quasi-

continuous wave' nature, incidences of hypertrophic scarring and permanent pigmentary alteration may be higher when compared with the Q-switched mode lasers which can more effectively heat targeted tissue by their ability to emit high energy pulses.

4. Tattoo Lasers

Early methods of tattoo removal including dermabrasion, excision, salabrasion, chemical peels, electrocautery, and cryotherapy, were destructive and non-selective, often resulting in hypertrophic scarring and permanent pigmentary alteration. These techniques have largely been abandoned for treatment of tattoos subsequent to the development of pigment-specific cutaneous lasers.

Laser tattoo removal was pioneered by Goldman in the early 1960s when he experimented with ruby (694nm) and argon (488 to 514nm) lasers, and later, CO₂ lasers for this purpose.^[2,39,40] Unfortunately, these early continuous wave lasers were all associated with high rates of hypertrophic scarring since excessive amounts of thermal energy were deposited within the tissue during treatment. The argon laser's shorter wavelength also resulted in significant energy absorption by both hemoglobin and melanin, contributing to the additional risk of hypopigmentation.^[41] With CO₂ laser coagulation of water-containing tissue, cutaneous tattoo pigment was removed by non-selective thermal damage and through transepidermal elimination during the healing process, both processes leading to unwanted postoperative skin texture changes.^[42]

By the early 1990s, high-energy, pulsed pigment-specific lasers were developed which were capable of selectively destroying cutaneous tattoo pigment without significant collateral tissue damage. These Q-switched red and infrared lasers can emit high energy densities with ultra short (nanosecond) pulse durations to effect pigment destruction. Tattoo ink particles are shattered by the laser light and removed from the area by phagocytosis and lymphatic transportation.

For optimal pigment removal, the choice of laser is based upon the absorption spectra of the various ink colors present within the tattoo. Because black pigment absorbs red and infrared light so well, any one of the three most common Q-switched lasers – 694nm ruby, 755nm alexandrite, and 1064nm Nd:YAG can be used.^[43-55] These lasers are relatively equivalent in their ability to remove darkly pigmented tattoos with average treatment fluences ranging from 6 to 8 J/cm². The ash-white tissue response observed immediately after laser irradiation signifies that sufficient, but not excessive, laser energy has been used. The 1064nm QS Nd:YAG laser may be a safer alternative when treating patients with dark skin because its longer wavelength has minimal interaction with epidermal pigment.^[56,57] Blue and green inks absorb best in

the 600 to 800nm range, rendering either the ruby or alexandrite lasers appropriate for treatment. Yellow, orange, and red tattoos do not absorb red and infrared wavelengths, but rather green light, making the frequency-doubled 532nm Nd:YAG or 510nm pulsed dye lasers the best choice (fig. 2). Usually, only 2 to 4 treatment sessions are necessary to achieve significant clearing of these ink colors.

Professional tattoos are more resistant to therapy and require numerous (8 to 10) treatment sessions because the tattoo ink is located deep within the dermis, the pigment particles are densely packed, and they are often comprised of multicolored dyes. Amateur tattoos, on the other hand, usually require fewer laser treatments (average 4 to 6) due to the fact that only carbon-based inks are used which are typically more sparsely and superficially placed in the skin.

In general, treatment of tattoos with Q-switched lasers is well tolerated with a low incidence of adverse sequelae. Transient hypopigmentation is more common following treatment with the QSRL since its shorter wavelength is partially absorbed by epidermal melanin, but could potentially occur with any of these pigment-specific laser systems.^[42,51] Transient hyperpigmentation



Fig. 2. Multicolored professional tattoo before (a) and after (b) 8 treatments at bi-monthly intervals with a Q-switched alexandrite (755nm) laser for the black and blue inks. Only 3 treatments with a frequency-doubled neodymium:yttrium-aluminium-garnet (Nd:YAG) [532nm] laser were needed to remove the yellow and red tattoo inks.

may also occur, especially when treating darker skin phototypes, but can be treated with topical bleaching agents and broad-spectrum sunscreens. If a patient is prone to the development of postoperative hyperpigmentation, then treatment intervals may need to be extended beyond the usual 6 to 8 weeks in order to permit sufficient time for healing. A systemic allergic or localized granulomatous tissue reaction to tattoo ink particle antigens is another possible complication of laser tattoo removal.^[58] Tattoo ink darkening may occur following treatment of an iron or titanium oxide-containing flesh-tone, white, rust, or red colored tattoo with a Q-switched laser.^[59] Upon laser irradiation of these types of cosmetic tattoos, reduction of ferric oxide to ferrous oxide occurs, the latter being black and insoluble. Although this reaction can be permanent, continued treatment with a pigment-specific Q-switched laser system or vaporization with a CO₂ laser can serve to eventually lighten the unwanted pigment.^[43,60]

5. Vascular Lasers

Vascular-specific laser systems target intravascular oxyhemoglobin in order to effect destruction of various congenital and acquired vascular lesions. Since peak absorption of light by oxyhemoglobin occurs within the yellow portion of the electromagnetic spectrum, flashlamp-pumped pulsed dye (585nm), argon-pumped tunable dye (577, 585nm), KTP (532nm), copper vapor/bromide (578nm), and krypton (568nm) lasers are most commonly used. For most vascular lesions, lasers with pulse durations shorter than 1 msec are best in order to prevent overheating of small to medium caliber blood vessels. Purpura (bruising) is common after treatment due to extravasation of red blood cells from targeted blood vessels upon irradiation.

Quasi-CW mode lasers with longer pulse durations are more suitable for treatment of larger caliber vessels and do not produce significant postoperative purpura.

5.1 Quasi-Continuous Wave Mode Lasers

The argon-pumped tunable dye laser (APTDL) at 577 to 585nm, the KTP laser at 532nm, the copper bromide and copper vapor lasers at 578nm, and the krypton laser at 568nm are CW mode lasers that can be mechanically shuttered to deliver pulses as short as 20 msec for treatment of facial telangiectasias.^[37,61-67] While several of these laser systems have also been used to treat other vascular lesions such as port-wine stains, their 'quasi-CW' nature are often associated with higher incidences of hypertrophic scarring and textural changes.^[64,67] In addition, compared with the pulsed dye laser (see section 5.2), additional laser treatment sessions are typically needed (3 to 4, rather than 1 to 2) in order to achieve vessel clearance.

5.2 Flashlamp-Pumped Pulsed Dye Laser (585nm)

The 585nm flashlamp-pumped pulsed dye laser also targets intravascular oxyhemoglobin and is considered the laser of choice for most benign congenital and acquired vascular lesions because of its superior clinical efficacy and low risk profile. It has been used to successfully treat port-wine stains, superficial hemangiomas, telangiectasias, diffuse facial erythema, pyogenic granulomas, erythematous striae, and hypertrophic scars.^[68-75] With an extended pulse duration of 1.5 msec and large spot size, this laser system is able to effect relatively deep tissue penetration while maintaining its vascular specificity.

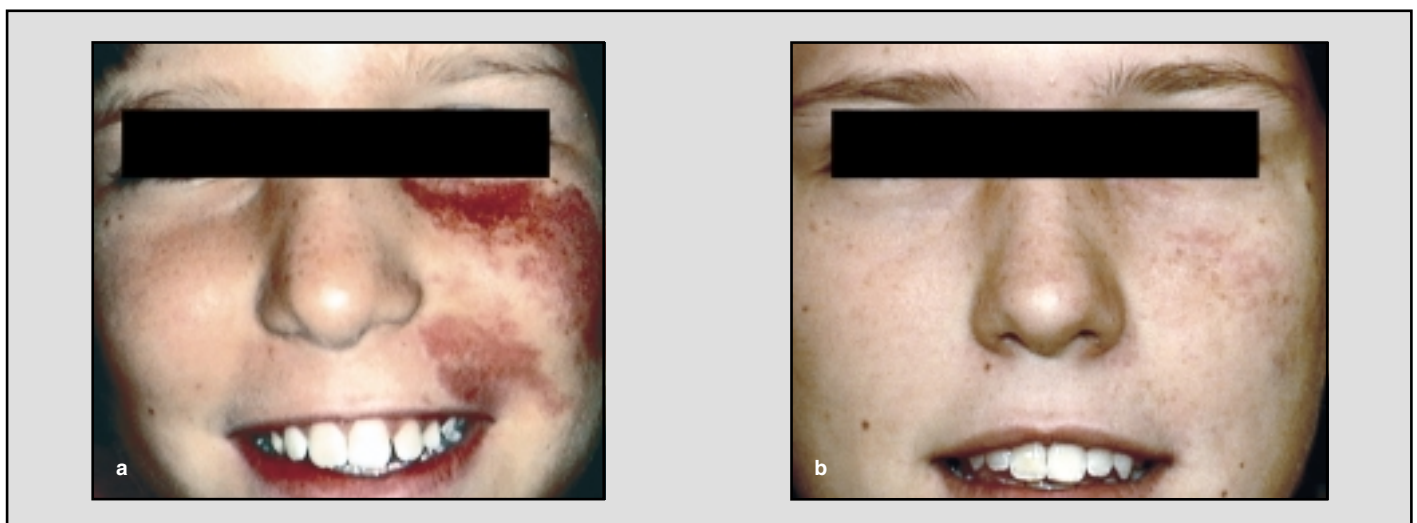


Fig. 3. Facial port-wine stain before (a) and after (b) 9 consecutive 585nm pulsed dye laser treatments at bi-monthly time intervals.

Fading of port-wine stains by 80% or more is observed after 8 to 10 treatments, whereas fewer sessions are typically necessary to improve hemangiomas, telangiectasias, and hypertrophic scars (fig. 3). For resistant cases, the use of a longer (595nm) wavelength and pulse duration (3 msec) provides deeper tissue penetration and additional vessel coagulation, resulting in improved lesional clearance.

Adverse effects of treatment with the pulsed dye laser often include postoperative edema and purpura, whereas vesiculation and crusting are rarely seen. Transient pigmentary alteration is more common in darker skinned patients because of laser interaction with epidermal melanin. The use of a dynamic cooling device during laser treatment protects the epidermis from potential overheating, permitting higher treatment fluences to be safely applied to the skin and reducing the risk of dyspigmentation. The fact that the pulsed dye laser has such a good adverse effect profile, coupled with the fact that it is the most efficacious modality available for benign vascular lesions and scars, make it a most useful tool in any laser practice.

5.3 Intense Pulsed Noncoherent Light

An intense pulsed light (IPL) source emits noncoherent light within the 500nm to 1200nm portion of the electromagnetic spectrum to treat a variety of vascular lesions including facial telangiectasias and port-wine stains.^[77-81] Filters are used to eliminate shorter wavelengths, thereby concentrating light energy so that improved dermal penetration is achieved. Light is delivered as a series of single, double, or triple pulse sequences with pulse durations of 2 to 25 msec and delays between pulses ranging another 10 to 500 msec.

Lesions with smaller caliber vessels are best treated with low cutoff filters (515nm or 550nm), while lesions with larger vessels respond best to longer wavelengths (high cutoff filters of 570nm and 590nm are used). Because shorter wavelength light also interacts more readily with epidermal melanin, the lower cutoff filters should only be used in fair-skinned patients. With longer pulse durations (up to 50 msec), the IPL source can slowly heat more deeply situated dermal vessels, thus improving treatment efficacy and lowering the risk of postoperative purpura and hyperpigmentation. Larger caliber vessels respond well to these treatments since high energy densities can be delivered via trains of pulses with relatively long delays between each pulse (40 to 60 msec). This has been termed additive heating and accounts for this system's efficiency in treating large vessels of the legs and deeper vessels within thick port-wine stains and hemangiomas.^[82,83]

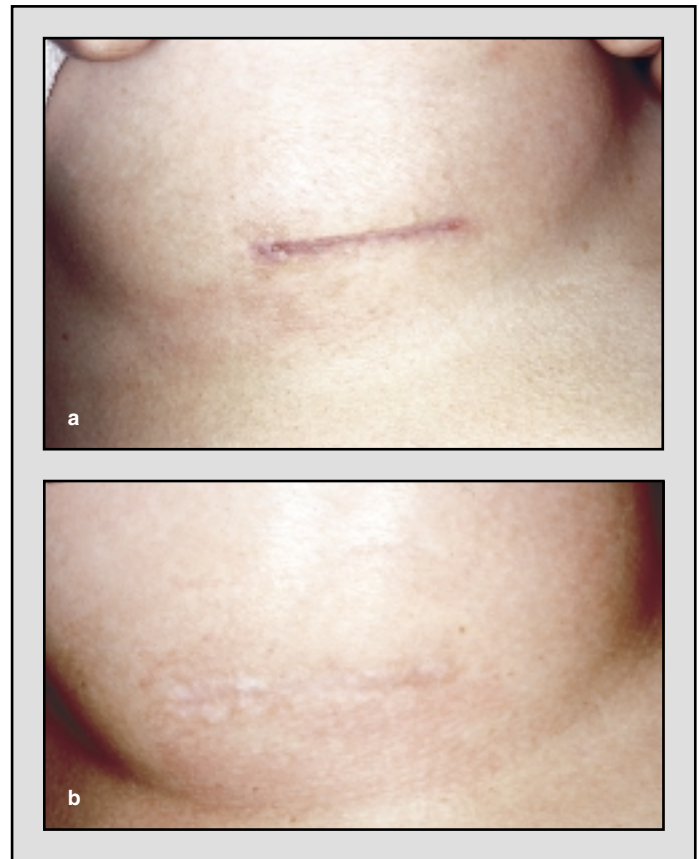


Fig. 4. Hypertrophic surgical scar on the breast before (a) and after (b) 2 treatments with a 585nm pulsed dye laser.

6. Lasers for Hypertrophic Scars and Keloids

Hypertrophic scars and keloids develop as an abnormal response to cutaneous injury and are characterized histologically by an overabundance of collagen. By definition, keloids project beyond the confines of the initial injury and do not regress with time, whereas hypertrophic scars are raised, firm scars limited in location to the site of injury and may spontaneously regress. These types of scars are notoriously difficult to eradicate and have a high rate of recurrence after traditional modes of treatment, including dermabrasion, excision, skin grafting, radiotherapy, and intralesional corticosteroids.^[84,85]

The 585nm pulsed dye laser is now considered to be first-line treatment for hypertrophic scars and keloids, being used with great success to reduce scar erythema and improve scar texture and pliability (fig. 4).^[86-97] It is also effective in reducing scar-associated symptoms such as pruritus or dysesthesia. Two or more laser sessions at 6- to 8-week time intervals yields substantial improvement in hypertrophic scars and keloids, although keloids may also require adjunctive corticosteroids or excision. Ablative

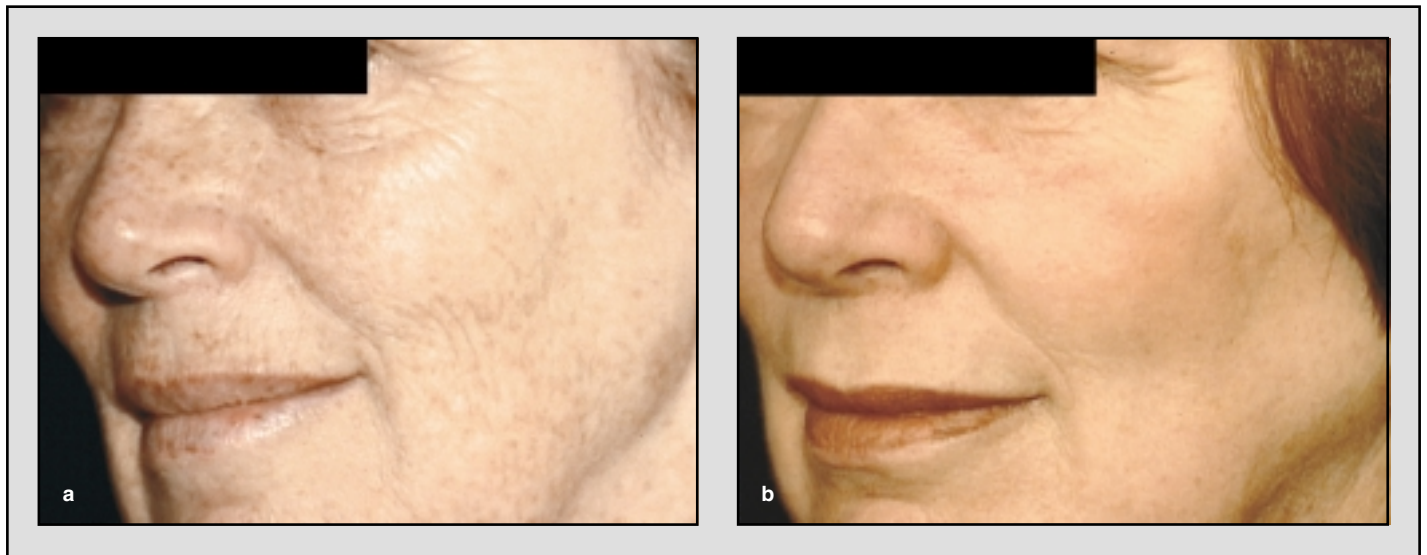


Fig. 5. Photodamaged facial skin with solar lentigines and rhytides before (a) and 1 year after (b) full face carbon dioxide laser resurfacing.

laser procedures (sections 8.1 and 8.2) are not advocated due to the risk of scar recurrence or worsening. Adverse effects of treatment with a pulsed dye laser include transient purpura and hyper- or hypopigmentation that resolve spontaneously.

7. Lasers for Epidermal and Dermal Lesions

A variety of epidermal and dermal growths including seborrheic keratoses, verrucae vulgaris,^[98,99] condyloma acuminatum,^[100-102] sebaceous gland hyperplasia, xanthelasma,^[103] rhinophyma,^[104] trichoepitheliomas,^[105] syringomas, actinic cheilitis,^[106-108] superficial basal cell carcinomas,^[109] and squamous cells *in situ*,^[110-111] can be effectively vaporized with a high-energy, pulsed CO₂ laser. Verrucae and condyloma acuminata have also been treated with 585nm pulsed dye laser irradiation,^[112-115] whereby coagulation of congested 'feeder' blood vessels occurs, leading to a diminution of their nutritional supply and eventual lesional regression.

8. Cutaneous Resurfacing Lasers

8.1 Pulsed Carbon Dioxide Lasers (10 600nm)

The pulsed or scanned CO₂ laser is considered the gold standard for cutaneous laser resurfacing, by which all other methods of facial rejuvenation are compared. Since the mid-1990s, when this laser came into widespread use, the field of cutaneous laser resurfacing has been revolutionized. It is most effective in ameliorating severely photodamaged facial skin, photoinduced facial rhytides, dyschromias, and atrophic scars through the delivery of high energy pulses in order to achieve tissue vaporization without

excessive thermal necrosis of residual skin.^[116-122] While the entire epidermis is eliminated after one CO₂ laser 'pass', additional laser passes are needed to effect collagen shrinkage and remodeling. This dermal remodeling is what accounts for most of the long term benefits observed in texture and appearance (both clinically and histologically) in CO₂ laser-treated skin. Overall skin tone, scar depth, and rhytide severity improves at least by 50% after treatment (fig. 5).^[116-122]

Potential adverse effects and complications associated with CO₂ laser resurfacing include prolonged erythema, acne or milia formation, wound infections, postinflammatory hyperpigmentation, delayed hypopigmentation, herpes simplex virus reactivation, hypertrophic scarring, and ectropion formation.^[125-128] Although the most dramatic improvement in actinically damaged and scarred skin is seen, CO₂ laser resurfacing also is associated with the highest and most prolonged postoperative morbidity rates. For these reasons, new laser systems have been developed in an attempt to emulate some of the beneficial effects of the CO₂ laser while limiting its adverse effect profile.

8.2 Erbium:YAG Lasers (2940nm)

The short-pulsed erbium:YAG (Er:YAG) laser produces modest improvement in photodamaged skin with less pronounced adverse effects compared with the CO₂ laser.^[116,129-134] With a shorter wavelength and a higher absorption coefficient in water-containing tissue, Er:YAG laser energy can much more efficiently produce fine, accurate tissue ablation.^[129] A photomechanical (rather than photothermal) tissue effect results, with Er:YAG

energy largely ejected as desiccated tissue with each laser pulse. Because residual thermal damage is so minimal, little vascular coagulation is effected, leading to inefficient hemostasis.^[129,131]

In addition, the limited thermal effect produced by Er:YAG laser irradiation results in less collagen contraction and remodeling, thereby accounting for the modest clinical results observed when compared with those of the CO₂ laser. Most recently, long-pulsed erbium lasers have become available that offer improved hemostasis, enhanced collagen shrinkage, and superior clinical efficacy compared with the short-pulsed Er:YAG systems. As an added bonus, the long-pulsed Er:YAG lasers do not produce such prolonged and severe adverse effects as those seen with CO₂ resurfacing. The Er:YAG laser system is therefore an ideal treatment modality for patients with mild facial photodamage, rhytides, and atrophic scars. The main advantage of treatment with this system is its shorter and generally less severe recovery period.^[116,133,134]

8.3 Nonablative Laser Resurfacing

Nonablative laser resurfacing is one of the newest trends to improve mild to moderate photodamage, rhytides, and scars.^[135,136] The use of relatively long pulse durations (up to 200 msec) and epidermal cooling (either contact or spray cooling) during irradiation of the skin provides selective dermal heating, whilst preventing epithelial injury and the development of a postoperative wound. Thus, these nonablative systems avoid most of the complications associated with traditional ablative lasers. On the other hand, nonablative laser resurfacing produces only mild clinical improvement in treated skin, but may be ideal for treatment of isolated cosmetic units (smaller areas of the face such as the perioral or periorbital areas) or in patients who do not desire or cannot tolerate a

prolonged convalescence (fig. 6). Typically, a series of 3 to 5 treatment sessions at monthly intervals are required for optimal results. Adverse effects of treatment are minimal and include mild erythema and edema that usually resolve within a few hours after treatment. Final cosmetic outcome from a series of treatments may not be evident for several months due to prolonged neocollagenesis. Because the epidermis is not affected by nonablative laser treatment, any patient with dyspigmentation should also pursue a good topical skin care regimen, chemical peels, or microdermabrasion. Nonablative laser resurfacing thus may best be used in conjunction with other methods of facial rejuvenation or as part of a maintenance skin program.

9. New Trends

Dynamic cooling devices minimize epidermal injury by limiting the amount of thermal energy deposited within the upper layers of skin during laser treatment.^[137,138] Epidermal cooling permits the safe use of higher fluences (to maximize lesional response) with reduced risk of unwanted superficial injury. This is particularly useful in the treatment of patients with dark skin tones, when the presence of increased superficial pigment often leads to a higher rate of postoperative pigmentary alteration. Another advantage of cooling is that treatment-associated pain is reduced.

Laser treatment of lower extremity telangiectasias remains limited, as sclerotherapy continues to be the gold standard for leg vein treatment. Lasers are largely reserved for those patients with a contraindication to sclerotherapy, for those who are needle-phobic, or for those with small, tortuous veins that are too small to inject. For now, lasers largely serve an adjunct role to sclerotherapy with improved results noted when the two methods

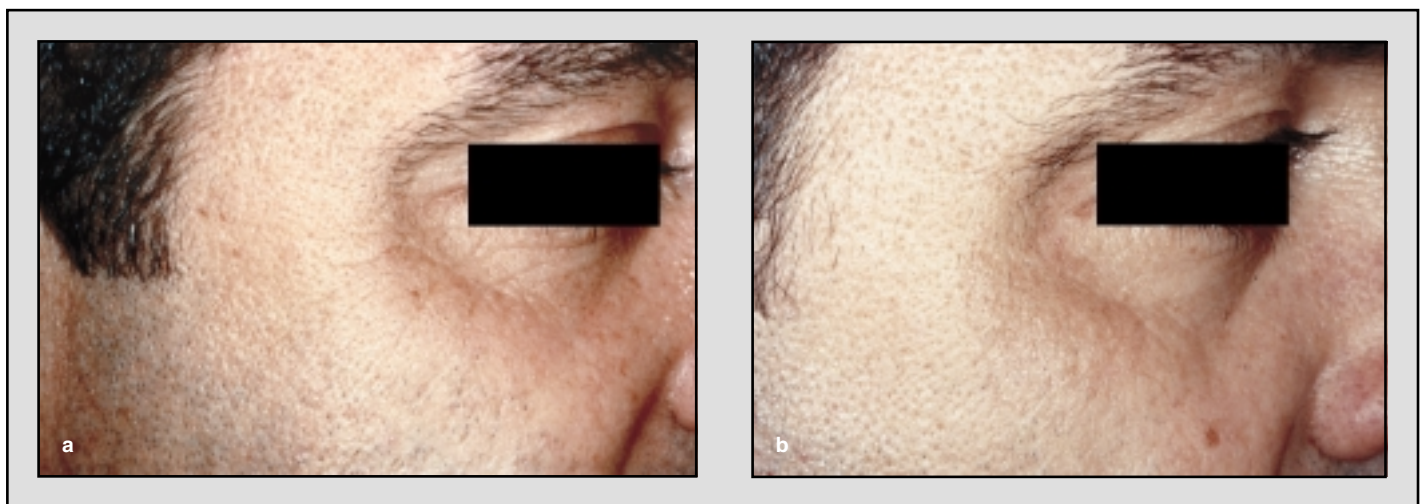


Fig. 6. Periorbital rhytides before (a) and 6 months after (b) 3 consecutive monthly treatments with a nonablative 1320nm neodymium:yttrium-aluminium-garnet (Nd:YAG) laser ('CoolTouch').

are used together. Recent progress also includes using lasers with longer wavelengths and pulse durations in order to improve penetration and heating of the larger caliber vessels.^[139]

Laser-assisted hair removal has also been refined over the last few years. Normal-mode or long-pulsed (millisecond pulse duration) ruby, alexandrite, diode, or Nd:YAG lasers effectively target follicular melanin, producing significant injury to the hair shaft. The safe treatment of darker skinned individuals remains a major concern, making either the Nd:YAG or diode lasers a better treatment choice since their longer wavelengths interact less vigorously with superficial melanin.^[30,140]

Recent advances in cutaneous laser resurfacing have been marked. Although the CO₂ and Er:YAG lasers are still widely used and nonablative laser resurfacing is taking hold, several new treatments have emerged that reproduce some of the important benefits of these traditional systems while improving their adverse effect profiles. Electrosurgical coblation is the newest skin resurfacing technique that involves a bipolar electrical device that disrupts the molecular bonds within treated skin, effectively leading to re-epithelialization and collagen remodeling without a prolonged postoperative recovery period.^[141,143]

While these new trends and recent discoveries are encouraging, further long term studies are needed before their true value can be determined. No doubt, in the next several years, the dermatologic laser surgery field will again undergo significant changes leading to further growth.

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