INTRODUCTION

Years of damaging UV light exposure manifests clinically as a sallow complexion with roughened surface texture, and variable degrees of dyspigmentation, telangiectasias, wrinkling, and skin laxity.\(^1\)\(^2\) Histologically, these extrinsic aging effects are usually limited to the epidermis and upper papillary dermis and are therefore amenable to treatment with a variety of ablative and non-ablative lasers and light-sources.\(^3\)

The armamentarium of lasers and light-based sources available to treat cutaneous photodamage is larger than ever before (Table 38.1). The most appropriate technique will depend upon the severity of photodamage and rhytides, the expertise of the laser surgeon, and the expectations and lifestyle of the individual patient.

Historical Vignette

Although dermatologic laser surgery is nearly four decades old, the field was revolutionized in 1983 when Anderson and Parrish elucidated the principles of selective photothermolysis.\(^4\) This basic theory of laser-tissue interaction explains how selective tissue destruction is possible. In order to effect precise thermal destruction of target tissue without unwanted conduction of heat to surrounding structures, the proper laser wavelength must be selected for preferential absorption by the intended tissue chromophore. Furthermore, the pulse duration of laser emission must be shorter than the thermal relaxation time of the target–thermal relaxation time (\(T_d\)) being defined as the amount of time necessary for the targeted structure to cool to one-half of its peak temperature immediately after laser irradiation. The delivered fluence (energy density) must also be sufficiently high to cause the desired degree of thermal injury to the skin. Thus, the laser wavelength, pulse duration, and fluence each must be carefully chosen to achieve maximal target ablation while minimizing surrounding tissue damage.

The first system developed for cutaneous laser resurfacing was the carbon dioxide laser, which was

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38 Laser Skin Resurfacing: Ablative and Non-ablative

Tina S Alster MD and Elizabeth L Tanzi MD

Summary box

- Many aspects of cutaneous photodamage are amenable to treatment with a variety of ablative and non-ablative lasers and light sources.
- Ablative laser skin resurfacing offers the most substantial clinical improvement; but is associated with several weeks of postoperative recovery.
- Severe side effects and complications after ablative laser skin resurfacing can be minimized by careful patient selection, proper surgical technique, and meticulous postoperative care.
- Non-ablative laser skin remodeling is a good alternative for patients who desire modest improvement of photodamaged skin without significant post-treatment recovery.
- Good candidates for non-ablative laser and light-source treatments are patients with mild-to-moderate photodamage and rhytides and realistic clinical expectations.
- With ongoing advancements in laser technology and techniques, more improved clinical outcomes with minimal postoperative recovery will be realized.

Table 38.1 Lasers and light sources for photorejuvenation

<table>
<thead>
<tr>
<th>Laser Type</th>
<th>Wavelength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ablative</td>
<td></td>
</tr>
<tr>
<td>Carbon dioxide (pulsed)</td>
<td>10 600 nm</td>
</tr>
<tr>
<td>Erbium:YAG (pulsed)</td>
<td>2490 nm</td>
</tr>
<tr>
<td>Non-ablative</td>
<td></td>
</tr>
<tr>
<td>Pulsed dye</td>
<td>585–595 nm</td>
</tr>
<tr>
<td>Nd:YAG (Q-switched; normal mode)</td>
<td>1064 nm</td>
</tr>
<tr>
<td>Nd:YAG, long-pulsed</td>
<td>1320 nm</td>
</tr>
<tr>
<td>Diode, long-pulsed</td>
<td>1450 nm</td>
</tr>
<tr>
<td>Erbium:glass</td>
<td>1540 nm</td>
</tr>
<tr>
<td>Intense pulsed light source</td>
<td>515–1200 nm</td>
</tr>
</tbody>
</table>

Nd, neodymium; Q-switched, quality-switched; YAG, yttrium-aluminum-garnet.
approved by the Food and Drug Administration (FDA) in 1996. The earliest systems were continuous-wave (CW) lasers, which were effective for gross lesions and destruction. However, these systems could not reliably ablate fine layers of tissue because of prolonged tissue dwell times and production of unacceptably high rates of scarring and pigmentation alteration. The unpredictable nature of these lasers prevented their widespread use in facial resurfacing procedures. With the subsequent development of high-energy, pulsed lasers it became possible to safely apply higher energy densities with exposure times that were shorter than the thermal relaxation time of water-containing tissue, thus lowering the risk of thermal injury to surrounding non-targeted structures.

The short-pulsed erbium:yttrium–aluminum–garnet (Er:YAG) laser was approved by the FDA in 1996 for cutaneous resurfacing. It was introduced as an alternative to carbon dioxide skin resurfacing in an attempt to minimize the recovery period and limit side effects while maintaining clinical benefit.

In an attempt to limit the prolonged postoperative recovery period associated with ablative laser skin resurfacing and in response to growing public interest in minimally-invasive treatment modalities, non-ablative laser and light source technology was developed. Rapid advances in this technology have produced several lasers and light-based sources capable of improving fine facial rhytides, dyspigmentation, and telangiectasia associated with cutaneous photodamage.

# ABSTRACT ASPECTS

## ABLATIVE LASER SKIN RESURFACING

### Preoperative preparation

The ideal patient for ablative cutaneous laser resurfacing is one with a fair complexion (skin phototype I or II), cutaneous lesions that are amenable to treatment with a resurfacing laser, and realistic expectations of the resurfacing procedure. Adequate preoperative patient evaluation and education are absolute essentials to avoid pitfalls and optimize the clinical outcome. Proper patient selection is paramount as ablative laser resurfacing can be complicated by a prolonged postoperative recovery period, pigmentary alterations, or unexpected scarring. The patient’s emotional ability to tolerate an extended convalescence is an important factor in determining the most appropriate choice of laser. Although carbon dioxide lasers or modulated Er:YAG lasers will produce the most dramatic results, some patients may be unable to tolerate the intensive recovery period. For patients unable or unwilling to tolerate extended postoperative healing, a short-pulsed Er:YAG laser or application of non-ablative laser procedures may be more suitable choices.

Currently, there is no consensus among laser experts regarding the most appropriate preoperative regimen for ablative laser skin resurfacing patients. The use of topical retinoic acid compounds, hydroquinone bleaching agents, or α-hydroxy acids for several weeks before ablative cutaneous resurfacing has been touted as a means of speeding recovery and decreasing the incidence of postinflammatory hyperpigmentation. Topical tretinoin enhances penetration of chemicals through the skin and has been shown to accelerate postoperative re-epithelialization after dermabraision or deep chemical peels. However, because ablative laser-induced wounds are intrinsically different from those created by physically destructive methods, laser skin penetration is not typically affected by the topical application of any of these medications. In addition, being that postinflammatory hyperpigmentation is relatively common after ablative cutaneous laser resurfacing, many laser surgeons originally believed that the prophylactic use of topical bleaching agents would reduce the incidence of this side effect, but investigators subsequently demonstrated that the preoperative use of topical tretinoin, hydroquinone, or glycolic acid had no effect on the incidence of postablative laser hyperpigmentation.

Due to the moist, de-epithelialized state of ablative laser-resurfaced skin and the possibility of bacterial contamination and overgrowth, many laser surgeons advocate oral antibiotic prophylaxis, however, this practice remains controversial due to the results of a controlled study that demonstrated no significant change in post-laser resurfacing infection rate in patients treated with prophylactic antibiotics.

### n TECHNICAL ASPECTS

#### Carbon dioxide laser

The Ultrapulse 5000 (Lumenis Corp, Yokeam, Israel), one of the first high-energy, pulsed-laser systems developed, emits individual carbon dioxide pulses (ranging 600 μs to 1 ms) with peak energy densities of 500 mJ, whereas the SilkTouch (Lumenis Corp, Yokeam, Israel), another high-energy pulsed laser system, is a continuous-wave carbon dioxide system with a microprocessor scanner that continuously moves the laser beam so that light does not dwell on any one area for more than 1 ms. The peak fluences delivered per pulse or scan range from 4–5 J/cm², which are the energy densities necessary for complete tissue vaporization.

Studies with these and other pulsed and scanned carbon dioxide laser systems have shown that after a typical skin resurfacing procedure, water-containing tissue is vaporized to a depth of approximately 20–60 μm, zone of thermal damage ranging from 20–150 μm.

The depth of ablation is directly correlated with the number of passes performed and usually is restricted to the epidermis and upper papillary dermis. However, stacking of laser pulses by treating an area with multiple passes in rapid succession or by using a high overlap setting on a scanning device leads to excessive thermal injury with subsequent increased risk of scarring. An ablative plateau is reached, with less effective tissue ablation and accumulation of thermal injury. This effect is most likely caused by reduced tissue water content after initial desiccation, resulting in less selective absorption of energy.

The complete removal of partially desiccated tissue and avoidance of pulse stacking is paramount to prevention of excessive thermal accumulation with any laser system.

The objective of ablative laser skin resurfacing is to vaporize tissue to the papillary dermis. Limiting the depth of penetration decreases the risk for scarring and permanent pigmentary alteration. When choosing treatment parameters, the surgeon must consider factors such as the anatomic...
location to be resurfaced, the skin phototype of the patient, and previous treatments delivered to the area. In general, areas with thinner skin (e.g. periorbital) require fewer laser passes and non-facial (e.g. neck, chest) laser resurfacing should be avoided due to the relative paucity of pilosebaceous units in these areas. To reduce the risk of excessive thermal injury, partially desiccated tissue should be removed manually with wet gauze after each laser pass to expose the underlying dermis.

The clinical and histologic benefits of cutaneous laser resurfacing are numerous. With the carbon dioxide laser, most studies have shown at least a 50% improvement over baseline in overall skin tone and wrinkle severity (Fig. 38.1a–b). The biggest advantages associated with carbon dioxide laser skin resurfacing are the excellent tissue contraction, hemostasis, prolonged neocollagenesis and collagen remodeling that it provides. Histologic examination of laser-treated skin demonstrates replacement of epidermal cellular atypia and dyplasia with normal, healthy epidermal cells from adjacent follicular adnexal structures. The most profound effects occur in the papillary dermis, where coagulation of disorganized masses of actinically induced elastotic material are replaced with normal compact collagen bundles arranged in parallel to the skin’s surface. Immediately after carbon dioxide laser treatment, a normal inflammatory response is initiated, with granulation tissue formation, neovascularization, and increased production of macrophages and fibroblasts.

Persistent collagen shrinkage and dermal remodeling are responsible for many of the continued clinical benefits observed after carbon dioxide resurfacing and are influenced by several factors. Thermal effects of laser irradiation of skin produce collagen fiber contraction at temperatures ranging from 55 °C to 62 °C through disruption of interpeptide bonds resulting in a conformational change to the collagen’s basic triple helical structure. The collagen molecule is thereby shortened to approximately one third of its normal length. The laser-induced shrinkage of collagen fibers may act as the contracted scaffold for neocollagenesis, leading to subsequent production of the newly shortened form. In turn, fibroblasts that migrate into laser wounds after resurfacing may up-regulate the expression of immune modulating factors that serve to enhance continued collagen shrinkage.

The carbon dioxide resurfacing laser is a most effective tool for improving photo-induced facial rhytides; however, dynamic rhytides are not as amenable to laser treatment. Many patients experience recurrence of movement-associated rhytides (particularly in the glabellar region) within 6–12 months postoperatively. Thus, cosmetic denervation with intramuscular injections of botulinum toxin type A is often used concomitantly with laser resurfacing to provide prolonged clinical improvement.

Absolute contraindications to carbon dioxide laser skin resurfacing include active bacterial, viral, or fungal infection or an inflammatory skin condition involving the skin areas to be treated. Isotretinoin use within the preceding 6–12-month period or history of keloids also are considered contraindications to carbon dioxide laser treatment because of the unpredictable tissue healing response and greater risk for scarring.

In an attempt to address many of the difficulties associated with the use of multiple-pass carbon dioxide laser skin resurfacing, refinements in surgical technique have been developed. In 1997, a minimally traumatic single-pass carbon dioxide laser resurfacing procedure was described that resulted in faster re-epithelialization and an improved side effect profile than reported after use of the multiple-pass technique. Rather than remove partially desiccated tissue (as is typical with multiple-pass procedures), the lased skin is left intact to serve as a biologic wound dressing. Additional laser passes can then be applied focally only in areas of more extensive involvement in order to limit unnecessary thermal and mechanical trauma to less involved skin. Subsequent reports have substantiated the improved side effect profile of this less aggressive procedure.

**Erbium:yttrium–aluminum–garnet laser**

The Er:YAG laser is a more precise ablative tool than the carbon dioxide laser and emits 2940 nm wavelength light that corresponds to the 3000 nm absorption peak of water. The absorption coefficient of the Er:YAG is 12 800 cm⁻¹.

![Figure 38.1 Perioral rhytides (A) before and (B) several months after carbon dioxide laser skin resurfacing.](image)
(compared with 800 cm−1 for the carbon dioxide laser), making it 12 to 18 times more efficiently absorbed by water-containing tissue than is the carbon dioxide laser. The pulse duration (mean 250 µs) is also much shorter than the carbon dioxide laser, resulting in decreased thermal diffusion, less effective hemostasis, and increased intraoperative bleeding which often hampers deeper dermal treatment. Because of limited thermal skin injury, the amount of collagen contraction is also reduced with Er:YAG treatment (1–4%) compared to that observed with carbon dioxide laser irradiation.

The erbium laser’s efficient rate of absorption, short exposure duration, and direct relationship between fluence delivered and amount of tissue ablated leads to 2–4 µm of tissue vaporization per J/cm², producing a shallow level of tissue ablation. Much narrower zones of thermal necrosis, averaging only 20–50 µm, are therefore produced. Laser-induced ejection of desiccated tissue from the target site produces a distinctive popping sound. Thermal energy is confined to the selected tissue, with minimal collateral thermal damage. Because little tissue necrosis is produced with each pass of the laser, manual removal of desiccated tissue is often unnecessary.

The short-pulsed erbium laser fluences used most often range from 5–15 J/cm², depending on the degree of photodamage and anatomic location. When lower fluences are used, it is often necessary to perform multiple passes to ablate the entire epidermis. The ablation depth with the short-pulsed Er:YAG does not diminish with successive passes, because the amount of thermal necrosis is minimal with each pass. It takes three to four times as many passes with the short-pulsed Er:YAG laser to achieve similar depths of penetration as with one pass of the carbon dioxide laser at typical treatment parameters. To ablate the entire epidermis with the short-pulsed Er:YAG laser at 5 J/cm², at least two or three passes must be used which increases the possibility of uneven tissue penetration. Deeper dermal lesions or areas of the face with extreme photodamage and extensive dermal elastosis may require up to nine or ten passes of the short-pulsed Er:YAG laser, whereas the carbon dioxide laser would effect similar levels of tissue ablation in two or three passes.

Pinpoint bleeding caused by inadequate hemostasis and tissue color change with multiple Er:YAG passes can impede adequate clinical assessment of wound depth. Irradiated areas whiten immediately after treatment and then quickly fade. These factors render it far more difficult for the surgeon to determine treatment endpoints and thus requires extensive knowledge of laser–tissue interaction.

Conditions amenable to short-pulsed Er:YAG laser resurfacing include superficial epidermal or dermal lesions, mild photodamage and subtle dyspigmentation. The major advantage of short-pulsed Er:YAG laser treatment is its shorter recovery period. Re-epithelialization is completed within an average of 5.5 days, compared with 8.5 days for multiple-pass carbon dioxide procedures. Postoperative pain and duration of erythema are reduced after short-pulsed Er:YAG laser resurfacing, with postoperative erythema resolving within 3–4 weeks. Because there is less thermal injury and trauma to the skin, the risk of pigmentary disturbance is also decreased, making the short-pulsed Er:YAG laser a good alternative in patients with darker skin phototypes.

The final clinical result is typically less impressive than that produced by carbon dioxide laser skin resurfacing for deeper rhytides. However, for mild photodamage, improvement of approximately 50% is typical (Fig. 38.2A–B). Although clinical and histologic effects are much less impressive than those produced with the carbon dioxide laser, short-pulsed Er:YAG laser skin resurfacing still affords modest improvement of photodamaged skin with a shorter recovery time.

To address the limitations of the short-pulsed Er:YAG laser, modulated Er:YAG lasers systems were developed to improve hemostasis and increase the amount of collagen shrinkage and remodeling effected. The Er:YAG-carbon dioxide hybrid laser system delivers both ablative Er:YAG and coagulative carbon dioxide laser pulses. The Er:YAG component generates fluences up to 28 J/cm² with a 350 µsec pulse duration, while excellent hemostasis is provided by the carbon dioxide component which can be

![Figure 38.2](https://example.com) Periorbital rhytides and infraorbital hyperpigmentation (A) before and (B) several months after erbium laser skin resurfacing.
programmed to deliver 1–100 msec pulses at 1–10 W power. Zones of thermal necrosis measuring as much as 50 µm have been observed depending on the treatment parameters used and significant increase in collagen thickness has been noted 3 months after four passes with this hybrid technology.\textsuperscript{51} Another modulated Er:YAG device is a dual-mode Er:YAG laser that emits a combination of short (200–300 µsec) pulses and long coagulative pulses to achieve tissue ablation depths of up to 200 µm per pass. The output from the two Er:YAG laser heads are combined into a single stream in a process called optical multiplexing.\textsuperscript{52} The desired depth of ablation and coagulation can be programmed by the laser surgeon into the touch-screen control panel. Several investigators have studied the histologic effects of dual-mode Er:YAG laser resurfacing and found a close correlation between the programmed and actual measured depths of ablation.\textsuperscript{53,54} The actual zones of thermal injury correlate well to the first pass with decreasing coagulative efficiency on subsequent passes. The variable-pulsed Er:YAG laser system delivers pulse durations ranging from 500 µsec to 10 msec. Shorter pulse durations are used for tissue ablation and longer pulses are used to effect coagulation and zones of thermal injury similar to the carbon dioxide laser.\textsuperscript{52,55}

Since the modulated Er:YAG lasers were developed to produce a greater thermal effect and tissue contraction than their short-pulsed predecessors, investigators compared collagen tightening induced by the carbon dioxide laser with that of the carbon dioxide–Er:YAG hybrid laser system.\textsuperscript{56} Intraoperative contraction of approximately 43% was produced after three passes of the carbon dioxide laser, compared with 12% contraction following Er:YAG irradiation. At 4 weeks, however, the carbon dioxide and Er:YAG laser treated sites were contracted to the same degree, highlighting the different mechanisms of tissue tightening observed after laser treatment. Immediate thermal-induced collagen tightening was the predominant response seen after carbon dioxide irradiation, whereas modulated Er:YAG laser resurfacing did not produce immediate intraoperative contraction but instead induced slow collagen tightening.\textsuperscript{52,56}

\section*{OPTIMIZING OUTCOMES}

\subsection*{Carbon dioxide laser skin resurfacing}

Side effects associated with carbon dioxide laser skin resurfacing vary and are related to the expertise of the laser surgeon, the body area treated, and the skin phototype of the patient (Table 38.2). Certain tissue reactions, such as erythema and edema, are expected in the immediate postoperative period and are not considered adverse events. Erythema can be intense and may persist for several months after the procedure. The degree of erythema correlates directly with the depth of ablation and the number of laser passes performed.\textsuperscript{3,57} It may also be aggravated by underlying rosacea or dermatitis. Postoperative erythema resolves spontaneously but can be reduced with the application of topical ascorbic acid which may serve to decrease the degree of inflammation.\textsuperscript{58,59} Its use should be reserved for at least 4 weeks after the procedure in order to avoid irritation. Similarly, other topical agents such as retinoic acid derivatives, glycolic acid, fragrance-containing or chemical-containing cosmetics and sunscreens should be strictly avoided in the early postoperative period until substantial healing has occurred.\textsuperscript{57}

Adequate preoperative patient evaluation and education are absolute essentials to avoid the pitfalls discussed below and optimize the clinical outcome.

Mild side effects of laser resurfacing include milia formation and acne exacerbation, which may be caused by the use of occlusive dressings and ointments used during the postoperative period, particularly in patients who are prone to acne.\textsuperscript{22,24,57,60} Milia and acne usually resolve spontaneously as healing progresses and the application of thick emollient creams and occlusive dressings ceases. Oral antibiotics may be prescribed for acne flares that do not respond to topical preparations.\textsuperscript{29,57,60} Contact allergies, irritant or allergic, can also develop from various topical medications, soaps, and moisturizers used postoperatively. Most of these reactions are irritant in nature due to decreased barrier function of the newly resurfaced skin.\textsuperscript{57,61}

Wound infections associated with ablative laser resurfacing include \textit{Staphylococcus}, \textit{Pseudomonas}, or cutaneous candidiasis and should be treated aggressively with an appropriate systemic antibiotic or antifungal agent.\textsuperscript{62} However, the use of prophylactic antibiotics remains controversial.\textsuperscript{14} The most common infectious complication is a reactivation of labial herpes simplex virus (HSV), most likely caused by the thermal tissue injury and epidermal disruption produced by the laser.\textsuperscript{25,57} Any patient undergoing full-face or perioral ablative resurfacing should receive antiviral prophylaxis, even if a history of HSV is denied. It is impossible to predict who will develop HSV reactivation, because a negative cold sore history is an unreliable method to determine risk, as many patients do not remember having had an outbreak or are asymptomatic HSV carriers. After carbon dioxide resurfacing, approximately 7% of patients develop a localized or disseminated form of HSV.\textsuperscript{57} These infections develop within the first

### Table 38.2 Side effects and complications of ablative laser skin resurfacing

<table>
<thead>
<tr>
<th>Expected Side Effects</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erythema</td>
<td>Extended erythema</td>
<td>Infection (bacterial, viral, fungal)</td>
<td>Hypopigmentation</td>
</tr>
<tr>
<td>Edema</td>
<td>Milia</td>
<td>Hyperpigmentation</td>
<td>Hypertrophic scarring</td>
</tr>
<tr>
<td>Pustules</td>
<td>Acne</td>
<td>Ectropion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Contact dermatitis</td>
<td></td>
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</tbody>
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postoperative week and can present as erosions without intact vesicles because of the denuded condition of newly lased skin. Even with appropriate prophylaxis, a herpetic outbreak still can occur in up to 10% of patients and must be treated aggressively.13 Oral antiviral agents, such as acyclovir, famciclovir, and valacyclovir are effective agents against HSV infection, although severe (disseminated) cases may require intravenous therapy. Patients should begin prophylaxis by the day of surgery and continue for 7–10 days postoperatively.

The most severe complications associated with ablative cutaneous laser resurfacing include hypertrophic scar and ectropion formation.22,57 Although the risk of scarring has been significantly reduced with the newer pulsed systems (compared to the continuous wave lasers), inadvertent pulse stacking or scan overlapping, as well as incomplete removal of desiccated tissue between laser passes can cause excessive thermal injury that could increase the development of fibrosis. Focal areas of bright erythema, with pruritus, particularly along the mandible, may signal impending scar formation.24,62 Ultrapotent (class I) topical corticosteroid preparations should be applied to decrease the inflammatory response. A pulsed dye laser also can be used to improve the appearance and symptoms of laser-induced burn scars.63

Ectropion of the lower eyelid after periorbital laser skin resurfacing is rarely seen but, if encountered, usually requires surgical correction.24 It is more likely to occur in patients who have had previous lower blepharoplasty or other surgical manipulation of the periorbital region. Preoperative examination is essential to determine eyelid laxity and skin elasticity. If the infraorbital skin does not return briskly to its normal resting position after a manual downward pull (snap test), then ablative laser resurfacing near the lower eyelid margin should be avoided. In general, lower fluences and fewer laser passes should be applied in the periorbital area to decrease the risk of lid evasion.

Hyperpigmentation is one of the more common side effects of cutaneous laser resurfacing and occurs to some degree in all patients with darker skin tones (Fig. 38.3).24,57 The reaction is transient, but its resolution can be hastened with the postoperative use of a variety of topical agents, including hydroquinone, retinoic, azelaic, and glycolic acid. Regular sunscreen use is also important during the healing process to prevent further skin darkening. The prophylactic use of these products preoperatively, however, has not been shown to decrease the incidence of post-treatment hyperpigmentation.13 Postoperative hypopigmentation is often not observed for several months and is particularly difficult because of its tendency to be intractable to treatment. The use of an excimer laser or topical phototochemotherapy to stimulate repigmentation has proven successful in some patients.64,65

**Erbium:YAG laser skin resurfacing**

Side effects and complications following Er:YAG laser resurfacing are similar to those observed after carbon dioxide laser skin resurfacing, although they differ in respect to duration, incidence, and severity.49,66,67 Although greater postoperative erythema is seen after modulated Er:YAG laser treatment than is usually produced with a short-pulsed Er:YAG system, the side effect profile and recovery period after modulated Er:YAG laser skin resurfacing remain more favorable than after multiple-pass carbon dioxide laser treatment. In an extended evaluation of 50 patients, investigators reported complete re-epithelialization in an average of 5 days after dual-mode Er:YAG laser skin resurfacing with only three patients having prolonged erythema beyond 4 weeks.67 In a split-face comparison of 16 patients after pulsed carbon dioxide and variable-pulsed Er:YAG laser skin resurfacing, other investigators reported decreased erythema, less edema, and faster healing on the Er:YAG laser-treated facial half.68

Postinflammatory hyperpigmentation is not uncommon after any cutaneous laser resurfacing procedure. While hyperpigmentation following modulated Er:YAG laser skin resurfacing (mean 10.4 weeks) can last longer than after treatment with a short-pulsed Er:YAG laser, it is not as persistent as that observed after multiple-pass carbon dioxide laser treatment (mean 16 weeks).67 However, when comparing the most current trends in ablative cutaneous laser resurfacing—single-pass carbon dioxide versus multiple-pass, long-pulsed Er:YAG laser skin resurfacing—postoperative healing times and complication profiles are comparable, even in patients with darker skin phototypes. In a retrospective review and analysis of 100 consecutive patients, Tanzi and Alster43 showed average time to re-epithelialization was 5.5 days with single-pass carbon dioxide and 5.1 days with long-pulsed Er:YAG laser resurfacing. Postoperative erythema was observed in all patients, lasting an average of 4.5 weeks after single-pass carbon dioxide laser treatment and 3.6 weeks after long-pulsed Er:YAG laser treatment. Hyperpigmentation was seen in 46% of patients treated with single-pass carbon dioxide and 42% of patients treated with the long-pulsed
Er:YAG laser (average duration 12.7 weeks and 11.4 weeks, respectively). Delayed-onset permanent hypopigmentation—a serious complication that has been observed several months after multiple-pass carbon dioxide laser skin resurfacing—has not yet been seen following single-pass treatment. To date, only three cases of hypopigmentation after modulated Er:YAG laser skin resurfacing have been reported. Since it is possible for hypopigmentation to present several years postoperatively, clinical studies are ongoing to determine its true incidence following either single-pass carbon dioxide or modulated Er:YAG laser skin resurfacing.

### POSTOPERATIVE CARE

Wound care during the immediate postoperative period is vital to the successful recovery of ablative laser-resurfaced skin. During the re-epithelialization process, an open- or closed-wound technique can be prescribed. Partial-thickness cutaneous wounds heal more efficiently and with a much reduced risk of scarring when maintained in a moist environment because the presence of a dry crust or scab impedes keratinocyte migration. Although there is consensus on this principle by laser surgeons, disagreement exists regarding the optimal dressing for the laser-ablated wound. The ‘open’ technique involves frequent application of thick healing ointment to the de-epithelialized skin surface; whereas occlusive or semi-occlusive dressings are placed directly on the lased skin in the ‘closed’ technique. While the open technique facilitates easy wound visualization, the closed technique requires less patient involvement and may also decrease postoperative pain. Proposed advantages of closed dressings include increased patient comfort, decreased erythema and edema, increased rate of re-epithelialization, and decreased patient involvement in wound management. On the other hand, additional expense and a higher risk of infection have been associated with the use of these dressings.

In addition to the prescribed wound care, ice pack application and anti-inflammatory medications should be used during this time. Furthermore, pain medication is particularly important for ablative laser-resurfaced patients during the first few postoperative days.

### PITFALLS AND THEIR MANAGEMENT

#### Proper patient selection

While a variety of epidermal and dermal signs of facial photodamage are amenable to laser skin resurfacing, suspicious growths should be biopsied for histologic examination prior to laser irradiation.

#### Has the patient ever had the areas treated before?

Ablative laser resurfacing may unmask hypopigmentation or fibrosis produce by prior dermabrasion, cryosurgery, or phenol peels. In addition, the presence of fibrosis may limit the vaporization potential of ablative lasers, thereby decreasing clinical efficacy. Patients who have had prior lower blepharoplasties (using an external approach) are at greater risk of ectropion formation after infraorbital ablative skin resurfacing.

What is the patient’s skin phototype?

Pale skin tones have a lower incidence of undesirable postoperative hyperpigmentation compared to patients with dark skin tones after ablative laser skin resurfacing.

Does the patient have a history of herpes labialis?

Reactivation and/or dissemination of prior herpes simplex infection can occur with laser resurfacing. The de-epithelialized skin is also particularly susceptible to primary inoculation by herpes simplex virus, therefore all patients should be treated with prophylactic antiviral medication prior to ablative laser skin resurfacing.

Does the patient have an autoimmune disease or other immunologic deficiency?

Because the postoperative course associated with ablative skin resurfacing is prolonged, intact immunologic function and collagen repair mechanisms are necessary to optimize the tissue-healing response. In addition to possible delayed wound healing, patients with scleroderma, lupus erythematosus, and vitiligo may also exhibit worsening of their conditions after ablative skin resurfacing.

Are there other dermatologic conditions present which could potentially spread after treatment?

Psoriasis, verrucae, and molluscum contagiosum are but a few conditions that could conceivably undergo Koebnerization after ablative laser skin resurfacing. Thus, the skin should be carefully inspected to rule out the presence of these other inflammatory or infectious cutaneous lesions so that the final clinical result is optimized.

Is the patient taking any medications that are contraindicated?

Concomitant isotretinoin use could potentially lead to an increased risk of postoperative hypertrophic scar formation due to its detrimental effect on wound healing and collagenogenesis. Because the alteration in healing is idiosyncratic, a safe interval between the use of oral retinoids and ablative laser skin resurfacing is difficult to calculate; however, most practitioners delay the treatment for at least 6–12 months after cessation of the drug.

Does the patient have a tendency to form hypertrophic scars or keloids?

Patients with a propensity to acne breakouts will be at greater risk of scar formation after laser resurfacing, independent of the laser’s selectivity and the operator’s expertise.

Is the patient prone to acne breakouts?

Complete control of acne eruptions should be obtained prior to ablative laser skin resurfacing with appropriate topical or systemic antibiotics. Occlusive ointments used in the immediate postoperative period may induce acne and complicate the postoperative course.
Does the patient have realistic expectations of the procedure and will he/she be compliant with postoperative instructions?

Patients who believe that every rhytide will be removed with the ablative laser resurfacing procedure are not good treatment candidates. Furthermore, those who can not physically or emotionally handle the prolonged postoperative course should also be dissuaded from pursuing ablative laser skin resurfacing procedures.

SUMMARY

Ablative laser skin resurfacing has revolutionized the approach to photodamaged facial skin. Technology and techniques continue to evolve, further enhancing the ability to achieve substantial clinical improvement of rhytides and dyspigmentation with reduced postoperative morbidity. Utilizing proper technique and treatment parameters, excellent clinical results can be obtained with any one or combination of carbon dioxide and Er:YAG laser systems available. Therefore, the best choice of laser ultimately depends on the operator’s expertise, clinical indication, and individual patient characteristics. Regardless of the type of ablative resurfacing laser used, the importance of careful postoperative follow-up cannot be overemphasized.

NON-ABLATIVE LASER SKIN REMODELING

Preoperative preparation

Proper patient selection is critical to the success of nonablative laser skin remodeling. Patients with mild-to-moderate facial photodamage with realistic expectations of treatment are the best candidates for non-ablative procedures. Patients seeking immediate improvement in photodamaged skin or those who desire a dramatic result may be less than satisfied with the overall clinical outcome. For patients with a strong history of herpes labialis, prophylactic oral antiviral medications should be considered when treating the perioral skin. Reactivation of prior herpes simplex infection can occur after nonablative laser skin remodeling due to the intense heat produced by the laser or light source.

Prior to nonablative laser procedures, sun exposure should be avoided, particularly when using longer-wavelength systems such as the pulsed dye laser or intense pulsed-light source. Unwanted absorption of irradiation by activated epidermal melanocytes can increase the risk of side effects, including crusting, blistering, and dyspigmentation.

TECHNICAL ASPECTS

Many of the nonablative laser systems currently in use emit light within the infrared portion of the electromagnetic spectrum (1000-1500 nm). At these wavelengths, absorption by superficial water-containing tissue is relatively weak, thereby effecting deeper tissue penetration. Since nonablative remodeling involves creation of a dermal wound without epidermal injury, all of these laser systems employ unique methods to ensure epidermal preservation during treatment. These methods typically include contact cooling hand-pieces or dynamic cryogen devices capable of delivering variable duration spray spurts either before, during, and/or after laser irradiation. Since laser beam penetration and dermal wounding must be targeted to the relatively superficial portion of the dermis, contact cooling devices that theoretically lead to excessive dermal cooling may affect the level or degree of energy deposition in the skin. As such, there remains no general consensus concerning which method of cooling is most efficacious during treatment.

In general, treatment of facial photodamage with nonablative technology does not produce results comparable to those of ablative carbon dioxide and Er:YAG lasers; however, many patients are willing to accept modest clinical improvement in exchange for fewer associated risks and shorter recovery times.

Pulsed dye laser

Clinical studies have demonstrated the ability of 585 nm and 595 nm pulsed dye laser (PDL) to reduce mild facial rhytides with few side effects. The most common side effects of PDL treatment include mild edema, purpura, and transient postinflammatory hyperpigmentation. Although increased extracellular matrix proteins and types I and III collagen and procollagen have been detected following PDL treatment, the exact mechanism whereby wrinkle improvement is effected remains unknown. One theory states that vascular endothelial cells damaged by the yellow laser light release mediators that stimulate fibroblasts to produce new collagen fibers.

Intense pulsed light source

Several investigators have shown successful rejuvenation of photodamaged skin after intense pulsed light (IPL) treatment. The IPL source emits a broad, continuous spectrum of light in the range of 515 nm to 1200 nm. Cut-off filters are used to eliminate shorter wavelengths depending on the clinical application, with shorter filters favoring heating of melanin and hemoglobin. Bitter showed improvement in wrinkling, skin coarseness, irregular pigmentation, pore size, and telangiectasia in the majority of 49 patients treated with a series of IPL treatments (fluences 30–50 J/cm²). In a retrospective review of 80 patients with skin phototypes I-IV, Weiss and colleagues reported signs of photoaging, including telangiectasias and mottled pigmentation of the face, neck, and chest, improved by a series of IPL treatments. While substantial clinical improvement of dyspigmentation and telangiectasia associated with cutaneous photodamage is often seen, neocollagenesis and dermal collagen remodeling with subsequent improvement in rhytides following IPL treatment has been more modest. The effect on dermal collagen is thought to be induced by heat diffusion from the vasculature with subsequent release of inflammatory mediators stimulated by vessel heating.
cooling. When skin surface temperatures are maintained at a dynamic cryogen spray apparatus used for epidermal photorejuvenation. Lee evaluated a combination tech-
and limited, including transient erythema, purpura, and of the class II rhytides. Side effects of treatment were mild size, and pulse duration 6–20 ns. At least slight
QS Nd:YAG laser at a fluence of 2.5 J/cm², 7 mm spot
a series of three monthly treatment sessions with a
dyspigmentation and telangiectasias.

Greater with KTP laser treatment than with long-pulsed groups treated with monotherapy, patient satisfaction was
both separately and combined, for non-invasive photo-
pulsed 532 nm potassium-titanyl-phosphate (KTP) laser,
reduction in 61 patients (242 sites) was conducted
Another study using the QS Nd:YAG laser for rhytide
improvement 24 weeks following treatment.

Side effects of treatment were mild, moderate, and severe rhytides using a 1320 nm Nd:YAG laser. Three treatments were delivered at 2-week intervals using fluences ranging 28–36 J/cm² with a 5 mm spot size. Cryogen spray cooling was applied in 20–40 ms
only, three patients demonstrated improvement. These three patients had also developed prolonged post-treatment erythema (lasting up to one month)—suggestion that the amount of dermal wounding (with subsequent collagen remodeling)
was directly related to the degree of cutaneous injury. Another study using the QS Nd:YAG laser for rhytide
reduction in 61 patients (242 sites) was conducted using a topical carbon solution for improved optical penetration of the 1064 nm light. Patients underwent
a series of three monthly treatment sessions with a QS Nd:YAG laser at a fluence of 2.5 J/cm², 7 mm spot
size, and pulse duration 6–20 ns. At least slight
improvement was seen in 97% of class I rhytides and 86% of the class II rhytides. Side effects of treatment were mild and limited, including transient erythema, purpura, and postinflammatory hyperpigmentation.

A long-pulsed Nd:YAG laser has also been used for photorejuvenation. Lee evaluated a combination tech-
nique using a long-pulsed 1064 Nd:YAG laser and long-
pulsed 532 nm potassium-titanyl-phosphate (KTP) laser, both separately and combined, for non-invasive photo-
rejuvenation in 150 patients, skin phototypes I through V. Patients treated with the combined laser approach showed at least 70% improvement in erythema and pigmentation and 30–40% improvement in fine rhytides. In the patient
patients with periocular rhytides received three consecutive laser treatments at bi-weekly intervals. Three 300 µs pulses were delivered at 100 Hz and fluence of 32 J/cm² with a 5-
mm spot size hand-piece. Epidermal protection was achieved application of a 20 ms cooling spray after a 10 ms preset delay. Patients were evaluated at 1 and 3 months after
treatment. Although four of the ten patients showed clinical improvement in rhytide severity by end-study, these findings
were not statistically significant. Similarly, the slight homogenization of collagen noted on histology at 1 and 3 months following treatment was not statistically significant and inconsistent with the clinical findings.

In another study, Kelly et al. treated 35 patients with mild, moderate, and severe rhytides using a 1320 nm Nd:YAG laser. Three treatments were delivered at 2-week intervals using fluences ranging 28–36 J/cm² with a 5 mm spot size. Cryogen spray cooling was applied in 20–40 ms
spurts with 10 ms delays. Patients were evaluated at 12 and 24 weeks following treatment with statistically significant improvement noted in all clinical grades after 12 weeks. Only the most severe rhytides; however, showed persistent improvement 24 weeks following treatment.

Goldberg devised two similar studies to examine the effectiveness of the 1320 nm Nd:YAG laser for the treatment of facial rhytides. In the first study, ten patients with skin types I–II and class I–II rhytides in the periorbital, perioral, and cheek areas were treated. Four treatments were administered over a 16-week period using fluences of 28–38 J/cm² with a 30% overlap and a 5 mm spot size. One or two laser passes were applied to achieve the treatment endpoint of mild erythema. Skin surface temperatures were limited to 40–48 °C using the aforementioned dynamic cooling spray in order to provide epidermal protection, whilst effecting dermal temperatures ranging 60–70 °C. Six months following treatment, two patients showed no clinical improvement, six showed 'some' improvement, and two showed 'substantial' improvement. This study emphasized several key points in non-ablative laser resurfacing. It suggested a thermal feedback sensor is best used intraoperatively with this technology in order for appropriate treatment fluences to be selected based upon the individual patient’s cutaneous temperature, thereby maximizing dermal temperatures that effectively lead to collagen reformation. Furthermore, longer follow-up periods are usually required to fully appreciate the effect of serial treatment sessions on dermal collagen stimulation.

In the second study, ten patients underwent full-face treatments with the 1320 nm Nd:YAG laser at 3–4-week intervals. As with the first study, treatment results were inconsistent—four patients showed no improvement, four showed some improvement, and two showed substantial improvement in facial rhytides and overall skin tone.

1320 nm Nd:YAG laser

A 1320 nm Nd:YAG laser was the first commercially available system marketed solely for the purpose of non-
ablative laser skin remodeling. The 1320 nm wavelength is associated with a high scattering coefficient that allows for dispersion of laser irradiation throughout the dermis. The latest model is capable of delivering energy densities up to 24 J/cm² with a pulse duration of 350 µs through a 10-mm spot size hand-piece. The 1320 nm Nd:YAG laser hand-piece contains three portals: the laser beam itself, a thermal feedback sensor that registers skin surface temperature, and a dynamic cryogen spray apparatus used for epidermal cooling. When skin surface temperatures are maintained at 40–45 °C dermal temperatures reach 60–65 °C during laser irradiation, thereby effecting collagen contraction and neocollagenesis. In order to prevent unwanted sequelae (e.g. blistering) from excessive heat production, it is imperative that epidermal temperatures be kept lower than 50 °C. A series of three or more treatment sessions are scheduled at regular intervals (typically once a month) for maximum mitigation of fine rhytides. Side effects of treatment are generally mild and include transient erythema and edema.

Menaker et al. reported effective rhytide reduction in an early study using a prototype 1320 nm Nd:YAG laser. Ten patients with periocular rhytides received three consecutive laser treatments at bi-weekly intervals. Three 300 µs pulses were delivered at 100 Hz and fluence of 32 J/cm² with a 5-
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Others also studied the 1320 nm Nd:YAG laser for treatment of facial rhytides in ten women. Full-face treatment was administered to three patients, whereas two patients had perioral treatment, and five patients received periorbital treatment. Laser fluences of 30–35 J/cm² were delivered in triple 300 µs pulses at a repetition rate of 100 Hz. Dynamic cryogen spray cooling was used with a 30 ms spurt and a 40 ms delay between cryogen spurt and laser irradiation. A thermal sensor was also used to maintain peak surface temperatures in the range of 42–45 °C in order to avoid excessive tissue heating. Treatments were administered twice a week over a period of 4 weeks, for a total of eight treatment sessions. Only two out of ten patients expressed satisfaction with their final result despite clinician evaluations showing significant improvement in five of ten patients and fair improvements in another three. Moreover, there was no correlation between histologic changes and the degree of subjective clinical improvement as judged by the patients.

A more recent study by Fatemi et al. demonstrated that the 1320 nm Nd:YAG laser produced mild subclinical epidermal injury that could potentially lead to enhanced skin texture and new papillary collagen synthesis by stimulation of cytokines and other inflammatory mediators. Thus, the long-term histologic improvement seen in photodamaged skin may not be based solely on direct laser heating of collagen, but by further stimulation of cytokine release by heating the superficial vasculature. In addition, the histologic findings suggested that multiple passes with fluence and cooling adjusted to a T_max of 45–48 °C can yield improved clinical results, as compared to those specimens in which epidermal temperatures above 45 °C were not achieved.

1450 nm diode

The 1450 nm mid-infrared wavelength diode laser targets dermal water and penetrates the skin to an approximate depth of 500 µm. This low-power laser system achieves peak powers in the 10–15 W range with relatively long pulse durations of 150–250 ms. Because of these long exposure times, epidermal cooling must be delivered in sequence during the application of laser energy in order to avoid excessive thermal build-up within the superficial layers of the skin.

Goldberg et al. reported on the effects of 1450 nm diode laser irradiation in 20 patients with class I-II rhytides. Two to four treatment sessions were delivered with 6 months follow-up evaluation. Patients were treated with laser and cryogen spray cooling on one facial half and cryogen spray cooling alone on the contralateral side. On the laser-treated facial halves, seven did not demonstrate any improvement, ten showed mild improvement, and three had moderate improvement. None of the sites treated with cryogen alone showed any improvement after 6 months. Side effects of treatment were mild and included transient erythema, edematous papules, and one case of postinflammatory hyperpigmentation persisting for 6 months. The authors concluded that the 1450 nm diode laser was effective for treatment of mild to moderately severe facial rhytides with minimal morbidity. Additionally, their study demonstrated that non-ablative laser treatment alone was responsible for the clinical improvements and that the non-specific injury induced by cryogen spray cooling could not effect the changes seen.

Hardaway and colleagues demonstrated statistically significant mean wrinkle improvement of 2.3 (range 0–4, with 4 representing severe wrinkling) at baseline to 1.8 at 6 months following a series of three 1450 nm diode laser treatments. They concluded that although the 1450 nm diode laser is capable of targeting dermal collagen and stimulating fibrosis, clinical improvement of rhytides was mild and did not correlate well with the degree of histologic change noted in previous studies.

In a controlled clinical and histologic study, Tanzi and Alster demonstrated improvement in mild to moderate perioral or periorbital rhytides in 25 patients treated with four consecutive 1450 nm diode laser treatments. Peak clinical improvement was seen 6 months after the series of laser treatments. The periorbital area was more responsive to laser treatment than the perioral area—a finding consistent with results obtained using other non-ablative laser systems (Fig. 38.4A–B). Side effects were limited to transient erythema, edema, and postinflammatory hyperpigmentation.
pigmentation. In a separate controlled study performed by the same group, 20 patients with transverse neck lines received three consecutive monthly treatments using a long-pulsed 1450 nm diode laser. Modest improvements in appearance and texture of the transverse neck lines was reported, as measured by blinded clinical assessments and through three-dimensional in vivo microtopography (PRIMOS Imaging System; GFMI, Germany). Mean fluences of 11.6 J/cm² were used with a 6 mm spot size and 50 msec total cryogen.

1540 nm Erbium:glass laser

The 1540 nm erbium-doped phosphate glass laser is another mid-infrared range laser that has also been used for amelioration of fine facial rhytides and atrophic facial scars. Similar to other infrared laser systems, the erbium:glass laser targets intracellular water and penetrates tissue to a depth of 0.4–2 mm. The 1540 nm wavelength has the least amount of melanin absorption compared with the 1320 nm and 1450 nm laser systems—a potential advantage of this system when treating tanned or darker-skinned patients. Mordon et al. studied the 1540 nm erbium:glass laser on hairless rat abdominal skin with pulse train irradiation (1.1 J, 3 Hz, 30 pulses) and varying cooling temperatures (+5 °C, 0 °C, −5 °C). Biopsies were obtained after 1, 3, and 7 days following treatment, and demonstrated fibroblast proliferation and new collagen synthesis as early as the third day. The authors concluded that this laser system held promise for treating facial rhytides because of its high water absorption and reduced scattering effect allowing light energy deposition to remain in the upper dermis where most solar elastosis is evident.

Ross et al. used the 1540 nm erbium:glass laser with a sapphire cooling hand-piece to treat the preauricular skin of nine patients. A 5 mm collimated beam was used to deliver fluences of 400–1200 mJ/cm². Epidermal necrosis and scar formation were noted at the highest pulse energies. Several key points were illustrated by this study; namely, that denatured collagen located deep in the dermis (more than 600 µm) is associated with granuloma formation, and that the peaks of heating and cooling with non-ablative laser remodeling are in proximity, by necessity, since maximum wrinkle reduction may be achieved by a zone of thermal remodeling that the peaks of heating and cooling with non-ablative laser procedures may take weeks to realize, thus concern and increase the overall satisfaction with treatment. Clinical improvements after a series of non-ablative skin remodeling and is more likely to be experienced by patients with darker skin tones. In some cases, investigators demonstrated an association of post-treatment hyperpigmentation with excess intraoperative epidermal cryogen cooling. Although always transient, topical bleaching agents and light glycolic acid peels can hasten the resolution of postinflammatory hyperpigmentation.

In the weeks following a series of non-ablative laser procedures, follow-up visits can help identify patient concerns and increase the overall satisfaction with treatment. Clinical improvements after a series of non-ablative laser procedures may take weeks to realize, thus reassurance by the laser surgeon regarding the patient’s progress can be particularly important.

POSTOPERATIVE CARE

Since the epidermis remains intact following non-ablative laser skin remodeling, postoperative care is minimal. Some patients experience mild erythema and edema lasting less than 24 hours.

PITFALLS AND THEIR MANAGEMENT

Is the amount of photodamage amenable to non-ablative laser skin remodeling?

Patients with mild-to-moderate facial photodamage are the best candidates for non-ablative procedures. Patients with
severe rhytides and skin laxity may be disappointed with the overall clinical outcome.

**Does the patient have a history of herpes labialis?**

Reactivation of prior herpes simplex infection can occur with perioral non-ablative laser skin remodeling due to the intense heat produced by the laser. Patients with a strong history of herpes simplex labialis may require prophylactic oral antiviral medication to avoid an outbreak.

**What is the patient’s skin phototype?**

Although the majority of current non-ablative systems used are within the mid-infrared range of the electromagnetic spectrum and not avidly absorbed by epidermal melanin, patients with darker skin phototypes may develop postinflammatory hyperpigmentation after non-ablative laser treatment. This temporary reaction most likely develops following inflammation created by concomitant cryogen-spray epidermal cooling.

**Does the patient have realistic expectations of non-ablative laser skin remodeling?**

Patients seeking immediate improvement after a single non-ablative treatment are not good candidates as clinical improvement occurs after multiple sequential treatment sessions (usually three to five) and is often delayed 3–6 months after the final non-ablative laser procedure. Moreover, patients seeking dramatic results following non-ablative laser skin techniques should be dissuaded from treatment as clinical improvement may be subtle.

### SUMMARY

For those patients who desire a less aggressive approach to photorejuvenation than ablative laser skin resurfacing, non-ablative dermal remodeling represents a viable alternative for patients willing to accept modest clinical improvement in exchange for ease of treatment and a favorable side-effect profile. Treatments are typically delivered at monthly intervals with final clinical results taking several months after laser irradiation to be realized. Although clinical outcomes with these non-ablative systems are not yet comparable with those of ablative carbon dioxide or Er:YAG lasers, they do improve overall skin texture, tone and elasticity—subjective findings often difficult to represent in photographs. None of the non-ablative laser systems has yet emerged as being clearly superior—each produces similar degrees of improvement in dermal pathology after multiple sessions at standard treatment parameters. With continued research efforts focused on non-ablative laser skin remodeling, it is possible that further refinements and advances in this technology will more closely approximate the effects of ablative laser treatment without its associated complications and risks.

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