Laser-based Treatment of the Aging Face for Skin Resurfacing: Ablative and Non-ablative Lasers

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CHAPTER SUMMARY

- Many aspects of dermatoheliosis 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 greater postoperative recovery.
- Non-ablative laser skin remodeling is a good alternative for patients who desire modest improvement of dermatoheliosis with a limited post-treatment recovery period.
- Fractionated laser systems provide the benefits of higher energy treatments with fewer side-effects and faster recovery than traditional lasers.
- Continued developments in laser technology will lead to greater efficacy with an improved safety profile.

INTRODUCTION

Dermatoheliosis, a term coined by the late Thomas B. Fitzpatrick, is the appearance of roughened surface texture, and variable degrees of dyspigmentation, telangiectasias, wrinkling, and skin laxity.[1,2] Clinically, dermatoheliosis is equivalent to photoaging and histopathologically is usually limited to the epidermis and upper papillary dermis. It is, therefore, amenable to treatment with a variety of ablative and non-ablative lasers and light sources.[3]

The armamentarium of laser technology available to treat dermatoheliosis is ever-expanding (Table 34.1) and other types of energy-based devices (see Chapter 41) are also capable of improving photoaging. 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.

ABLATIVE LASER SKIN RESURFACING

Laser resurfacing of photodamaged skin has been the gold standard for rejuvenation of photoaging facial skin for over 30 years. The early 1990s marked the start of this trend with the arrival of optimized CO_2 lasers, and in the past several years has shifted towards fractional resurfacing (both ablative and non-ablative) as described by Manstein and colleagues,[4] due to its faster recovery time and safer side-effect profile. Nonetheless, it provides an important historical framework for understanding cutaneous resurfacing and in a few instances, may be preferable over fractional resurfacing for certain dermatological conditions.

Proper patient selection

A focused history should be obtained prior to any resurfacing procedure. In particular, it is important to document if the patient has had any previous procedures or any contraindications to resurfacing. Ablative laser resurfacing may unmask hypopigmentation or fibrosis produced 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. Likewise, patients with a history of lifting procedures may have non-facial skin present on the face, and the aggressiveness of any resurfacing procedure needs to be tempered. Any past history of herpes labialis puts the patient at risk for disseminated herpes infection with laser resurfacing. A history of delayed wound healing, autoimmune disease or other immunologic deficiency may complicate the postoperative healing course. Additionally, patients with scleroderma, lupus erythematosus, and vitiligo may also exhibit worsening of their conditions after ablative skin resurfacing. Other dermatologic conditions such as psoriasis, verrucae, and molluscum contagiosum that may undergo koebnerization after ablative laser skin resurfacing should be identified on history. Medications that may impact resurfacing should be elicited during the initial consultation. Isotretinoin may potentially lead to an increased risk of postoperative hypertrophic scar formation due to its detrimental effect on wound healing and collagenesis. 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. Patients with a

Table 34.1 Lasers and light sources for skin rejuvenation

	Laser type	Wavelength (nm)
Ablative resurfacing	Carbon dioxide (pulsed)	10 600
	Erbium:YAG (pulsed)	2940
	YSGG (pulsed)	2790
	Fractionated	10 600, 2790 and 2940
Non-ablative remodeling	Pulsed-dye	585–595
	Nd:YAG (Q-switched; normal mode)	1064
	Nd:YAG, long-pulsed	1320
	Diode, long-pulsed	1450
	Erbium:glass	1540
	Intense pulsed light source	515–1200
Non-ablative	Fractional resurfacing	1550, 1540, 1320, 1440, 1927

Nd, neodymium; Q-switched, quality-switched; YAG, yttrium-aluminum-garnet; YSGG, yttrium-scandium-gallium-garnet.

propensity to scar or keloid will be at greater risk of scar formation after laser resurfacing, independent of the laser's selectivity and the operator's expertise. Patients with active acne or a history of acne may experience a flare with post-procedural occlusive wound care.

A physical exam of the area to be resurfaced must also be done prior to treatment. While a variety of dermatologic conditions are amenable to laser skin resurfacing, clinically suspicious growths, especially pigmented lesions, should be properly evaluated with a thorough physical exam and possibly clinicopathologic correlation prior to any cosmetic procedure. The patient's Fitzpatrick skin phototype should be noted as fairer skin type patients have a lower incidence of undesirable postoperative hyperpigmentation compared to patients with darker Fitzpatrick skin types.

Finally, it is critical that the patient have a realistic expectation of the procedure and the potential risks, benefits and side effects. Patients who believe that every wrinkle will be abolished with the ablative laser resurfacing procedure are not good treatment candidates. Furthermore, those who cannot physically or emotionally handle the prolonged postoperative course should also be dissuaded from pursuing ablative laser skin resurfacing procedures.

Preoperative preparation

Lasers, such as carbon dioxide (10 600 nm), the erbium:yttrium-scandium-gallium-garnet (Er:YSGG) and erbium:yttrium-aluminum-garnet (Er:YAG, 2940 nm), are selectively absorbed by water and act to ablate skin in a highly precise fashion. Vaporization of the epidermis and upper part of the dermis stimulates healing with de novo collagen and elastin formation, collagen contraction and resultant tighter and rejuvenated skin. While fully ablative resurfacing produces impressive results, the healing process normally takes weeks to months and is accompanied by a risk of scarring and pigmentary alteration. Thus, more so than for any other type of laser procedure, proper patient selection and consultation is paramount. The ideal patient for ablative cutaneous laser resurfacing is one with a Fitzpatrick skin phototype I or II, conditions that are amenable to ablative resurfacing, and realistic expectations of the resurfacing procedure and accompanying risks. For patients that are not ideal candidates or are unable to tolerate extended postoperative healing, the fractional ablative and non-ablative lasers offer a more facile recovery course, with the caveat of the possible need for multiple procedures.

There is no strong consensus regarding the topical preoperative agents for ablative laser skin resurfacing. The use of topical retinoic acid compounds, hydroquinone bleaching agents, or α-hydroxy acids for several weeks before ablative cutaneous resurfacing have been anecdotally advocated as a means of hastening recovery and decreasing the incidence of postinflammatory hyperpigmentation.[5] Investigators demonstrated that the preoperative use of topical tretinoin, hydroquinone, or glycolic acid had no effect on the incidence of postablative laser hyperpigmentation.[6] Likewise, due to the de-epithelialized and compromised skin barrier following ablative laser skin resurfacing, the concern for infection has led to many laser surgeons advocating the use of oral antibiotic prophylaxis. However, a controlled study demonstrated no significant change in the postlaser resurfacing infection rate in patients treated with prophylactic antibiotics.[7] Moreover, because laser resurfacing can trigger a herpes labialis outbreak, some believe that all patients, should receive prophylactic oral antivirals such as acyclovir, famciclovir, or valacyclovir starting 1 day prior to resurfacing and continuing for 6–10 days postoperatively.

Technical aspects

Carbon dioxide laser

The Ultrapulse 5000 (Lumenis Corp, Yokneam, Israel), was one of the first high-energy pulsed-laser systems, and emits individual carbon dioxide pulses (ranging from 600 μs to 1 ms) with peak energy densities of 500 mJ. The Silk-Touch (Lumenis Corp), 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 to 5 J/cm^2, which are the energy densities necessary for complete tissue vaporization.[8–11] 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, with an underlying zone of thermal damage ranging from 20 to 150 μm.[8,10,12–14]

The depth of tissue ablation is directly correlated with the number of passes performed and ideally is restricted to the epidermis and upper papillary dermis.[15] 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 deeper thermal injury with subsequent increased risk of scarring.[16,17] 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.[17] Removal of partially desiccated tissue by wiping and avoidance of pulse stacking is paramount to prevention of excessive thermal accumulation.[18]

Ideally, the goal of ablative laser skin resurfacing is to vaporize tissue to the papillary dermis. Containing ablation to this level decreases the risk for scarring and permanent pigmentary alteration. In selecting 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.[9,19] Areas with thinner skin (e.g., periorbital) require fewer laser passes, and laser resurfacing of non-facial areas (e.g., neck, chest) should be cautiously approached due to the relative paucity of pilosebaceous units in these areas.[19] However, safe resurfacing of the neck has been reported.[20] 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.[18]

The benefits of cutaneous ablative 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.[21–26] 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 dysplasia with normal, healthy epidermal cells from adjacent follicular adnexal structures.[8,13] 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.[27,28] Immediately after carbon dioxide laser treatment, an inflammatory wound healing response begins, with granulation tissue formation, neovascularization, and increased production of macrophages and fibroblasts.[13]

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 are also considered contraindications to carbon dioxide laser treatment because of the unpredictable tissue healing response and increased risk for scarring.[29,30]

Erbium:yttrium-aluminum-garnet laser

The 2940-nm Er:YAG laser can more precisely ablate water than the carbon dioxide laser due to its wavelength corresponding to the 3000-nm absorption peak of water.

The absorption coefficient of the Er:YAG is $12\,800$ cm^{-1} (compared with 800 cm^{-1} for the carbon dioxide laser), making it 12–18 times more efficiently absorbed by water-containing tissue than is the carbon dioxide laser.[31] The pulse duration (mean 250 ms) is also much shorter than the carbon dioxide laser, resulting in decreased thermal diffusion, less hemostasis, and increased intraoperative bleeding which often hampers deeper dermal treatment. Because of the limited ability of the Er:YAG laser to result in thermal injury, the amount of collagen contraction is also significantly lower (1–4%) compared with that observed with carbon dioxide laser irradiation.[5,32] Taken together, these characteristics lead to a direct linear relationship between fluence delivered and amount of tissue ablated of approximately 2–4 μm of tissue vaporization per J/cm^2 and much smaller collateral zones of thermal necrosis (~20–50 μm) are therefore produced.[31,33–35] Laser-induced ejection of desiccated tissue from the target site produces a distinctive popping sound. Manual removal of desiccated tissue is often unnecessary due to the limited thermal damage.

Fluences used for the short-pulsed Er:YAG laser commonly range from 5 to 15 J/cm^2, 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 and three to four times as many passes are needed with the short-pulsed Er:YAG laser to achieve similar depths of penetration as with a single pass of the carbon dioxide laser.[3,5] The need for multiple passes increases the likelihood of uneven tissue penetration in a treatment area. Deeper dermal lesions or areas of the face with extreme photodamage and extensive dermal elastosis may require upwards of nine or ten passes of the short-pulsed Er:YAG laser.[8,10,31]

Pinpoint bleeding caused by inadequate hemostasis and tissue color change with multiple Er:YAG passes can hinder adequate clinical assessment of wound depth. Treated areas whiten immediately after treatment and then the white color quickly fades. These factors render it far more difficult for the surgeon to determine treatment end-points and thus extensive knowledge of laser–tissue interaction is required.

Conditions amenable to 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 rapid recovery period. Re-epithelialization is completed within an average of 5.5 days, compared with 8.5 days for multiple-pass carbon dioxide laser procedures.[10,33] 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.[3,36] The major disadvantages of the short-pulsed Er:YAG laser are its limited ability to effect significant collagen shrinkage and its failure to induce new and continued collagen

formation postoperatively.[3,33,37] 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.

Erbium:yttrium-scandium-gallium-garnet (Er:YSGG) laser

The Er:YSGG laser emits at 2790 nm and lies between the CO_2 and Er:YAG laser water absorption spectra, and was thus hypothesized to harvest the benefits of both CO_2 and Er:YAG laser ablative resurfacing (i.e., milder thermal damage with faster recovery) with fewer of the drawbacks of each individual laser. Small studies[38,39] have demonstrated these claims but a direct head to head comparison of the Er:YSGG to the CO_2 or Er:YAG laser has yet to be performed. In our opinion, it remains a viable option for those seeking improvement of their dermatoheliosis without the prolonged downtime of ablative CO_2 resurfacing.

▶ Ablative fractional resurfacing (see Video 34.2)

While ablative resurfacing lasers remove tissue in a horizontal fashion, ablative fractional resurfacing devices drill vertically oriented columns into the skin and have the ability to achieve comparable clinical results while still keeping portions of epidermis intact, thereby allowing for quicker recovery and an improved safety profile. Fractional energy is delivered through microscopic zones of thermal injury, leading to coagulation necrosis and resultant new collagen ▶ formation (see Video 34.1). An annular pattern of coagulation occurs, with increasing fluences resulting in increasing treatment depths. This annular coagulation leads to collagen contraction and tissue shrinkage, which translates to improvement in laxity, appearance of pores, and scars. Improvement in textural abnormalities, dyschromias, and mild skin laxity can be achieved in as little as a single treatment (Fig. 34.1).

Several devices perform ablative fractional resurfacing.[40] The Fraxel repair (Reliant Technologies Inc, Mountain View, CA) system is the "first in class" fractionated carbon dioxide laser with a rolling handpiece that allows for treatment energies up to 70 mJ/cm². The ActiveFX (Lumenis Ltd, Yokneam, Israel) is another fractionated carbon dioxide device using a computerized pattern generator (UltraScan Encore CPG) with a 1.3 mm spot for moderate effects on tone, texture, and tightening with low downtime. DeepFX, another computerized pattern generator used with Ultra-Pulse Encore (Lumenis Ltd) carbon dioxide laser, delivers 0.1 mm diameter spots; therefore, it enables tightening of skin with deep wrinkles and scars more effectively than other methods of skin resurfacing. The ablation depth and the residual thermal damage depend on the energy density (micropulse laser energy up to 50 mJ) and the number of stacked pulses (up to five) used. With increasing parameters, the postoperative bleeding increases and the patient's downtime will be prolonged. The Lutronic® eCO₂™ (Lutronic Corporation, Goyang, S. Korea) dual mode CO_2 laser system enables users to ablate tissue with 0.12 mm or 0.3 mm diameter microbeams. Fully ablative resurfacing can be performed with a 1.0 mm tip. The scanned microbeams are delivered using Controlled Chaos Technology™ (CCT™), which is an algorithm to pseudo-randomly deliver each laser microbeam as far apart as possible from the previous one, in an effort to minimize thermal diffusion between ablative columns. Other devices include a fractionated 10 600-nm CO₂RE (Syneron-Candela, Wayland, MA), a 2790-nm fractionated Pearl laser (Cutera, Brisbane, CA), and a Lux 2940-nm fractional handpiece (Palomar Medical Technologies Inc, Burlington, MA), which can be attached to a pulsed light laser system utilizing erbium laser energy to deliver deep dermal ablative columns.

While ablative fractional devices allow for quicker recovery than traditional fully ablative devices, when compared with their non-ablative counterparts, downtime can be considerably longer, lasting on average 5–7 days. The procedure
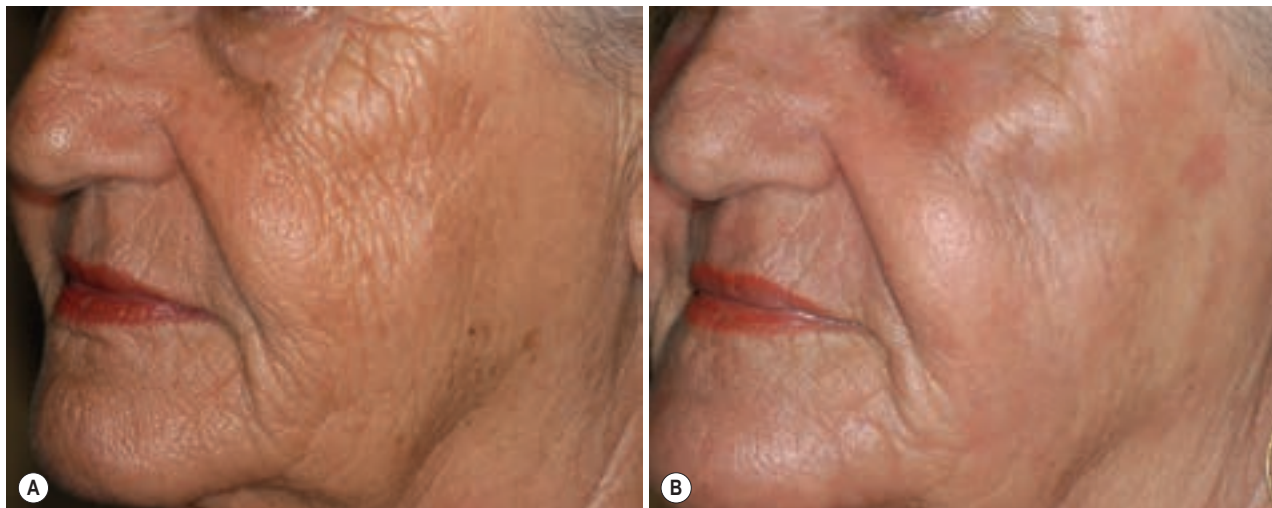

FIGURE 34.1 Resurfacing with a fractionated CO_2 laser (A) before and (B) several months after a single treatment.

is generally tolerated after topical anesthesia has been applied for 1 h and local nerve blocks are administered. If the patient is accompanied by a capable escort, an anxiolytic may be given. A forced air cooling system can be utilized to further minimize procedural pain. Most patients experience erythema, edema, and crusting which usually resolves within 7 days. Some patients experience hyperpigmentation, acneiform eruptions, or milia formation. Some laser surgeons advocate giving patients oral corticosteroids in the perioperative period to minimize associated edema. Antiviral and antibiotic prophylaxis should also be considered as part of the pre- and post-procedure care.

Results from a single treatment take 3–6 months to be fully realized. Most patients receive only one or two treatments, but selected patients with significant photodamage or acne scarring may require more. Several features of ablative fractional resurfacing represent true advances over traditional ablative lasers. While ablative fractional resurfacing can be performed safely on the neck and chest, hypertrophic scarring of the neck has been reported.[41] Unlike ablative resurfacing, hypopigmentation following ablative fractional resurfacing has not yet been reported and appears to be very rare.[42,43]

Optimizing outcomes

Side-effects associated with ablative 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 34.2). 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 traditional ablative procedures. The degree of erythema correlates directly with the depth of ablation and the number of laser passes performed.[3,44] It may also be aggravated by underlying rosacea or dermatitis. Postoperative erythema resolves spontaneously but may be reduced with the application of topical ascorbic acid which may serve to decrease the degree of inflammation.[45,46] Its use should be reserved until at least 4 weeks after the procedure in order to avoid irritation. Similarly, other topical agents such as retinoic acid derivatives, glycolic acid, and fragrance-containing or chemical-containing cosmetics and sunscreens should be strictly avoided in the early postoperative period until substantial healing has occurred.[3] Adequate preoperative patient evaluation and education are absolute essentials to avoid the pitfalls discussed below and optimize the clinical outcome.

Minor side-effects of laser resurfacing include milia formation and acne exacerbation, which may be caused by the use of occlusive dressings and ointments during the postoperative period, particularly in patients who are prone to acne.[16,19,42,47] 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.[26,42,47] Allergic and irritant dermatitis 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.[44,48]

Wound infections associated with ablative laser resurfacing include Staphylococcus, Pseudomonas, or cutaneous candidiasis and should be treated aggressively with an appropriate systemic antibiotic or antifungal agent.[49] However, the use of prophylactic antibiotics remains controversial.[7] The most common infectious complication is a reactivation of labial herpes simplex virus (HSV), which is most likely caused by the thermal tissue injury and epidermal disruption produced by the laser.[16,44] After carbon dioxide resurfacing, approximately 7% of patients develop a localized or disseminated form of HSV.[44] These infections develop within the first 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.[9] 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.[16,44] Although the risk of scarring has been significantly reduced with the newer pulsed systems (compared with the continuous wave lasers), inadvertent pulse stacking or scan overlapping, poor technique, 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.[19,50] Ultrapotent (class I) topical corticosteroid preparations should be applied to decrease the inflammatory response. A pulsed-dye laser (PDL) also can be used to improve the appearance and symptoms of laser-induced burn scars.[50]

Table 34.2 Side-effects and complications of ablative laser skin resurfacing

Expected side-effects	Complications		
	Mild	Moderate	Severe
Erythema	Extended erythema	Infection (bacterial, viral, fungal)	Hypopigmentation
Edema	Milia	Hyperpigmentation	Hypertrophic
Pruritus	Acne		scarring
	Contact dermatitis		Ectropion

Ectropion of the lower eyelid after periorbital laser skin resurfacing is rarely seen, but if encountered it usually requires surgical correction.[19] 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 eversion.

Hyperpigmentation is one of the more common side effects of cutaneous laser resurfacing and may be expected to some degree in all patients with darker skin tones.[19,44] The reaction is transient, but its resolution may 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.[5] 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 photochemotherapy to stimulate repigmentation has proven successful in some patients.[51,52]

Postoperative care

Meticulous wound care in the postprocedure period is vital to a successful outcome with ablative laser-resurfacing. Both open and closed wound care has been advocated by laser surgeons during re-epithelialization. Partial-thickness cutaneous wounds heal more efficiently and with a lower risk of scarring when maintained in a moist environment because the presence of a dry crust or scab impedes keratinocyte migration.[52] The "open" technique involves frequent application of thick healing ointment to the de-epithelialized skin surface, whereas occlusive or semiocclusive dressings are placed directly over the treated area in the "closed" technique. An advantage of the open technique is easy wound visualization, while with the closed technique, there is less patient involvement and possibly less postoperative pain.[53,54] However, additional expense and a higher risk of infection have also been associated with the use of closed dressings.[3,46,48] Concomitant use of ice-packs and anti-inflammatory medications has also been advocated by some laser surgeons.

Summary

Ablative laser skin resurfacing has revolutionized the approach to photodamaged facial skin. The advent of fractional ablative resurfacing has made the benefits of ablative resurfacing available to a greater range of patients and with an improved safety profile. Utilizing proper technique and treatment parameters, excellent clinical results can be obtained with any one or a combination of ablative laser systems. 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 RESURFACING *(see Video 34.3)*

Non-ablative rejuvenation refers to the series of techniques that were developed to treat aspects of aging without the downtime of ablative resurfacing.[55] The goal of non-ablative rejuvenation is to correct rhytides, telangiectasias, lentigines, and skin texture without the crusting, erythema, long recovery period and potential for infection/scarring that ablative resurfacing procedures come with. Lasers and light devices used for non-ablative treatment include the pulsed-dye laser (PDL), the 1320-nm Nd:YAG, the 1450-nm diode, and intense pulsed light (IPL). Non-ablative technology does not produce results of ablative carbon lasers, but many patients are willing to accept modest clinical improvement in exchange for fewer associated risks and downtime.

Preoperative preparation

Setting up realistic expectations for improvement is essential. Patients need to be aware that the results are not as dramatic as with traditional resurfacing. Patients who are good candidates are those with mild to moderate facial photodamage.

For patients with a strong history of herpes simplex infection, prophylactic oral antiviral medications can be considered when treating the perioral skin. The intense heat produced by the laser or light source can reactivate prior herpes simplex infection.

Technical aspects

Non-ablative lasers and light devices selectively target water, stimulate collagen production, and stimulate dermal remodeling without destroying the epidermis.[56] Devices that emit light within the infrared portion of the electromagnetic spectrum (1000–1500 nm) are weakly absorbed by superficial water-containing tissue, which allows for deeper tissue penetration. The epidermis is protected by cryogen spray or other cooling methods so that only the dermis reaches high temperatures.

Devices

Visible light lasers
Pulsed-dye laser

Pulsed-dye lasers (PDLs) have been used to treat facial rhytides. The induction of dermal collagen remodeling has been demonstrated with the 585-nm pulsed-dye laser to

treat hypertrophic scars and keloids.[57,58] Studies have also supported the ability of 585-nm and 595-nm PDLs to reduce mild facial rhytides with few side effects.[59] Zelickson and colleagues demonstrated that 90% (9/10) of the mild to moderate wrinkles and 40% (4/10) of the treated patients with moderate to severe wrinkles had clinically observable improvement in their sun-induced skin wrinkles after one treatment. Histologic examinations of the treated areas showed a superficial dermal band of well-organized elastin and collagen fibers replacing pre-treatment elastic tissue. There was also increased cellularity and mucin deposition that was consistent with dermal collagen remodeling. The most common side-effects of PDL treatment include mild edema, purpura, and transient post-inflammatory hyperpigmentation. Although increased extracellular matrix proteins and types I and III collagen and procollagen have been detected following PDL treatment, the exact mechanism for improving rhytides remains unknown.[60] One potential is that vascular endothelial cells damaged by the yellow laser light release mediators that stimulate fibroblasts to produce new collagen fibers.[61]

Intense pulsed light source

Intense pulsed light (IPL) has been shown to be successful for rejuvenation of photodamaged skin.[62] The IPL source emits a broad, continuous spectrum of light in the range of 515–1200 nm. The filters are used to eliminate shorter wavelengths depending on the clinical application since shorter filters favor heating of melanin and hemoglobin. There has been progress in the evaluation of specific microstructural changes induced by IPL application, including the induction of growth-phase fibroblasts and levels of extracellular matrix proteins.[63,64] An examination of microscopic changes induced by IPL in the treatment of poikiloderma of Civatte demonstrated homogenization of melanin distribution and an increase in non-fragmented elastic fibers.[65]

Weiss and associates investigated the long-term clinical results on the face, neck, and chest after 5 years using filtered flashlamp IPL.[66] They reported that the signs of photoaging including telangiectasias and mottled pigmentation of the face, neck, and chest, can be improved by IPL with a long-lasting result. Skin textural smoothing was an additional benefit observed long term, but was difficult to quantify. Bitter demonstrated subjective 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/cm^2).[67]

Mid-infrared lasers
1320-nm Nd:YAG laser

The 1320-nm neodymium:yttrium-aluminum-garnet (Nd:YAG) laser has been used for non-ablative skin rejuvenation.[68] The 1320-nm Nd:YAG laser handpiece 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. Typically, a series of three or more treatment sessions are scheduled at regular intervals (every 4 weeks) for a maximum mitigation of fine rhytides.[69] The treatments are well-tolerated and side-effects include transient erythema and edema.

El-Domyati and co-workers evaluated the clinical effects and the histological changes after Nd:YAG 1320-nm laser treatment of periocular wrinkles.[70] Six subjects (Fitzpatrick skin types III and IV) received six treatments at 2-week intervals. Subjects were photographed, and skin biopsies were obtained at baseline as well as 3 and 6 months after treatment. A noticeable clinical and histologic improvement was observed after Nd:YAG 1320-nm treatment. Collagen types I, III and VII, as well as newly synthesized collagen, together with tropoelastin showed a statistically significant increase in response to treatment, while the mean level of total elastin was significantly decreased after treatment.

1450-nm diode laser

The 1450-nm mid-infrared-wavelength diode laser (Smoothbeam, Candela, Wayland, MA) targets dermal water and penetrates the skin to an approximate depth of 500 nm (see Video 34.4). The 1450-nm mid-infrared-wavelength diode laser has peak powers in the 10–15 W range, with relatively long pulse durations of 150–250 ms. Goldberg and associates demonstrated the short-term efficacy of a 1450-nm diode laser for the treatment of mild to moderate facial rhytides, and 13 out of 20 patients had clinical improvement after 2–4 treatments.[71] Tanzi and colleagues treated 25 patients with mild to moderate perioral or periorbital rhytides with four consecutive 1450-nm diode laser treatments.[72] 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, which is a finding consistent with results obtained using other non-ablative laser systems. The treatments were well-tolerated with mild side effects including transient erythema, edema, and post-inflammatory hyperpigmentation.

NON-ABLATIVE FRACTIONAL RESURFACING

In 2004, the concept of fractional photothermolysis (FP) was developed at the Wellman Center for Photomedicine at Harvard Medical School and caused a massive paradigm shift with regards to both efficacy and safety.[4] Whereas traditional resurfacing treats the entirety of the skin, fractional photothermolysis treats only a percentage of the skin. This is apparent only when viewed microscopically, analogous to the pixilated appearance of seemingly confluent newspaper lettering on higher magnification. While the gold standard remains the traditional CO_2 laser, these devices have provided a modest but appreciable step

forward to achieving clinically significant results with much less downtime and fewer side-effects and complications.

Technical aspects

Non-ablative fractional resurfacing (NAFR) delivers narrow beams of high-energy light at a variety of wavelengths targeting tissue water. This results in small cylindrical columns of thermal damage, so-called "microthermal zones" (MTZs), distributed across the treatment area in a pixilated pattern. There is sufficient energy in the fractionated columns of the beam to induce thermal damage without spread to the adjacent tissue. Depending on the device, depths of up to 1.5 mm can be reached. These columns of thermal damage are surrounded by normal skin. The surrounding "skip areas" act as a nutritional and structural reservoir to provide the framework necessary for rapid healing. This concept of focal microscopic zones of treatment surrounded by islands of sparing is the fundamental unifying theme of all fractional devices and is essential for the improved safety profile and recovery time seen with these devices.

Histology of tissue immediately after treatment reveals clear zones of epidermal and dermal necrosis within the MTZ. Lactate dehydrogenase (LDH) staining for cell viability confirmed viability of tissue adjacent to the MTZs.[19] Epidermal debris termed microscopic epidermal necrotic debris (MEND) overlying the MTZ contains cellular components as well as melanin, which are gradually extruded over the course of 2 weeks. No histological or clinical evidence of persistence of the microthermal zones was present at 3 months. Despite visible necrosis of the epidermis and dermis in the MTZs, the stratum corneum remained histologically and functionally intact. Thus, rejuvenation with the prototype device was termed non-ablative.[4]

Immunohistochemical studies demonstrate neocollagenesis after NAFR with expression of markers such as heat shock proteins (47, 70, and 72), collagen III, proliferating cell nuclear antigen, and alpha-smooth muscle actin in treatment areas.[73] Heat shock protein 47, required for collagen remodeling and maturation, persists for nearly three months following treatment, suggesting ongoing collagen synthesis far after the immediate recovery phase.[73]

Devices

The prototype non-ablative fractionated device developed by Reliant Technologies (now Solta Medical Inc, Hayward, CA) was a 1550-nm erbium-fiber laser with an optical scanning handpiece, and is now known as Fraxel Re:Store. It is the device used in the initial studies, and is the most extensively evaluated device to date. At the time of this publication, the device is FDA approved for surgical scars, acne scars (Fig. 34.2), and photorejuvenation. It produces modest patient discomfort during treatment, and most patients may benefit from a topical anesthetic. Forced chilled air is always used as an adjunctive safety and anesthetic complement. The Re:Store device creates MTZs in the order of 100–200 μm in width and 500–1400 μm in depth. Energy levels are adjustable from 4–70 mJ/MTZ. The original device utilized a blue optical dye to ensure accurate analysis of the scanning speed, which has now become unnecessary with technological advancements. It is generally a well-tolerated procedure with erythema and edema routinely lasting 2–3 days after a standard treatment.

The Affirm (Cynosure, Westford, MA) differs from the Re:Store, in that it utilizes a 1440-nm laser operating through a complex array of lenses, known proprietarily as Combined Apex Pulse (CAP) technology. The Affirm is effective for similar conditions as with the Re:Store, and it is FDA approved for the treatment of periorbital and perioral rhytides. The addition of a 1320-nm wavelength "stacked" with the 1440-nm pulse appears to improve upon its efficacy.[74] The Affirm uses a stamping device to create zones of injury approximately 100 μm in width and 200–300 μm in depth. The procedure is generally well tolerated, with discomfort levels and postoperative erythema similar to other non-ablative fractional devices.

Operating on its Icon platform, Palomar Medical Technologies (Burlington, MA) employs non-ablative fractional technology with a 1540-nm wavelength. This platform allows the incorporation of various modalities such as IPL
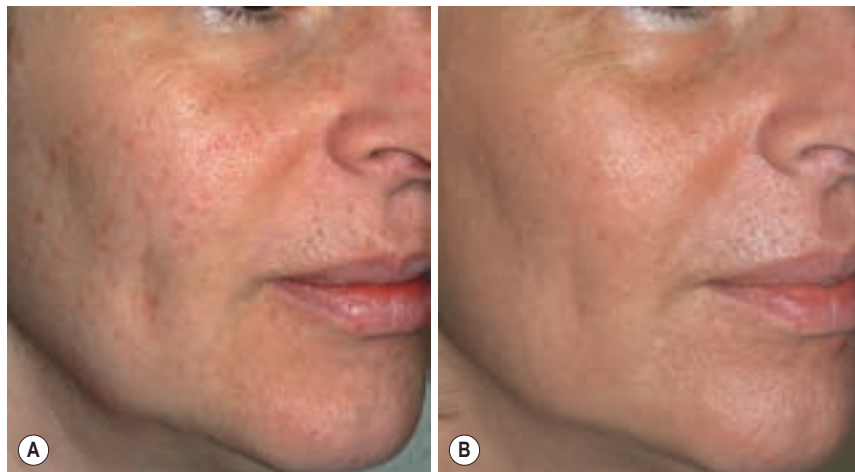

FIGURE 34.2 Acne scars (A) before and (B) several months after a series of 1550-nm non-ablative fractionated resurfacing.

or fractionated lasers to be attached to a single unit through the use of separate handpieces. The design is intended to add convenience and affordability, while enabling the physician to treat a variety of conditions. Currently, the standard 1 mm tip, the XF Microlens Optic, and the XD Microlens Optic can attach to the 1540-nm handpiece. The XF Microlens Optic uses a stamping mode while simultaneously delivering parallel cooling to the skin via a cooled sapphire window. The XD Microlens combines cooling and tissue compression to obtain greater depth of penetration with less injury to the epidermis.

The Thulium 1927-nm laser (Solta Medical) increased the versatility of fractionated devices. Given the strong absorption of water at this wavelength, the Thulium device has a non-linear depth to energy profile, unlike the 1550-nm non-ablative devices. Thus, the maximum depth of penetration of 202 μm is achieved at around 20 mJ per pulse.[75] At this energy, the dermal thermal injury profile is similar to a superficial CO_2 laser, the main advantage being that there is no epidermal loss with the Thulium, and thus no exudation or bleeding. With this minimal depth of penetration, one can effectively perform superficial treatments aimed primarily at targeting epidermal processes. In addition to applications for dermatoheliosis and dyschromia (Fig. 34.3), this device is quite effective at removing widespread actinic keratoses. Although the mechanism is not fully understood, focal injury can give rise to generalized improvement with all fractional devices, rather like lawn aeration will give rise to a uniform improvement in the appearance of the grass. This is a major advance both from a treatment and outcome point of view. Care should be taken to avoid using densities above 50%.

Another addition to NAFR is the Clear + Brilliant 1440-nm laser (Solta Medical) operating at 1440-nm wavelength with a low density (10%) and at a low energy (4–9 mJ). This device can reach a maximum depth of approximately 200 μm. These treatments should have minimal to no downtime, and the device has been marketed to be used on all skin types by non-physician providers.

Preoperative routine

Once patient selection with appropriate expectations and a thorough explanation of risks and benefits is complete, careful and consistent perioperative routine is crucial to avoid many of the potential pitfalls and complications associated with NAFR. While there is no set consensus for preoperative prophylaxis, general guidelines that we have found useful are presented below.

All patients who are having full face treatment should receive HSV prophylaxis using either acyclovir 400 mg orally three times daily or the often better-tolerated twice daily valacyclovir 500 mg orally, regardless of documented history of an outbreak. This therapy is initiated the day prior to the treatment procedure and continued for a total of 7 days. The patient should also be instructed that should they have an outbreak despite the prophylaxis, they should inform the physician so an appropriate treatment dose of antivirals can be prescribed. When the patient arrives on the day of the procedure, they are first instructed to cleanse their face thoroughly with soap and water. After the skin is dry, it is our practice to apply a topical anesthetic. Various formulations of topical anesthetics can be utilized including commercially available topical lidocaine formulations as well as compounded lidocaine and a combination of lidocaine and tetracaine designed for in-office use. After 1 h of application, the topical anesthesia is removed and the skin is wiped with alcohol to make certain that there is no residual anesthetic. Prior to initiating treatment, both the patient and provider should have appropriate eye protection rated for the specific wavelength of the device.
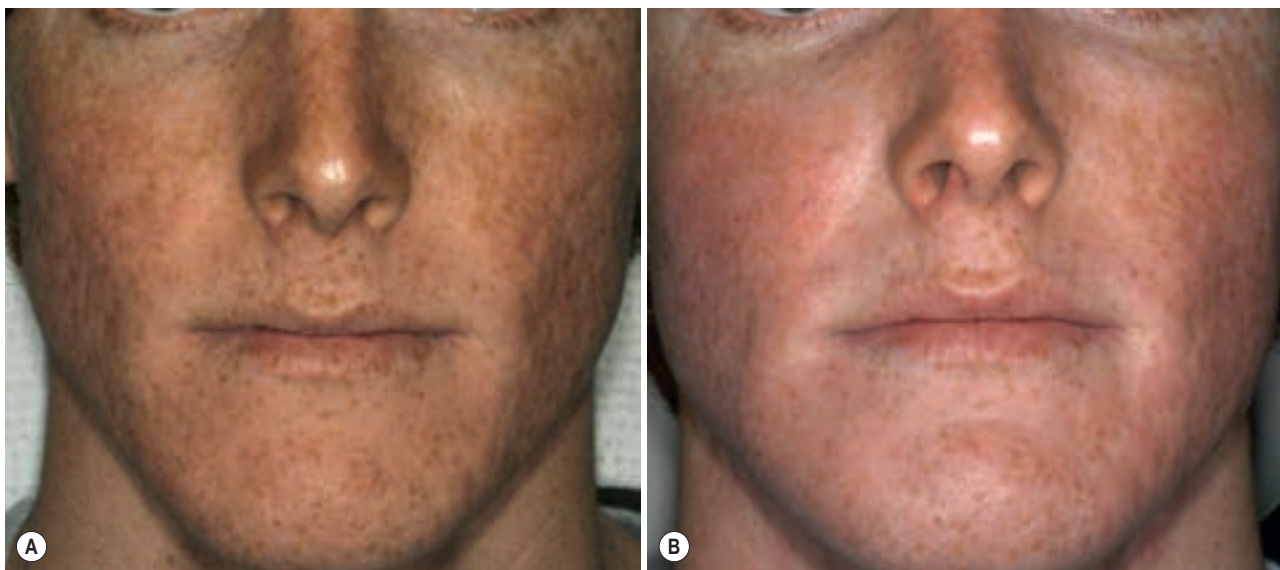

FIGURE 34.3 Lentigines (A) before and (B) several months after single non-ablative fractional treatment with a 1927-nm laser.

Adverse effects

In general, NAFR has fewer complications than traditional ablative lasers. Most complications can be easily managed and are self-limited. As with any side-effect, early identification and treatment will improve outcome. The most common infection after fractional laser skin resurfacing is related to the herpes simplex virus (HSV), with reported rates ranging from 0.3% to 2%.[76,77] The infection rates with traditional ablative laser resurfacing were much higher, with 2–7% of cases developing HSV reactivation.[78] As mentioned previously, antiviral prophylaxis should be administered to all patients, even those without a documented history, as many cases of reactivation have occurred in patients without evidence or remembrance of a prior clinical outbreak.[79]

The incidence of bacterial infection after NAFR appears extremely low with 0.1% of all treated cases documented to develop impetigo.[76]

The rates of acneiform eruptions are significantly lower (2–10%) with fractional skin resurfacing compared with traditional skin resurfacing.[76] It can be easily managed with a short course of oral tetracycline-based antibiotics. In the setting of future repeat treatments, antibiotics can be initiated prior to treatment to prevent future outbreaks. Milia can occur in up to 19% of treated patients and is likely related to occlusive moisturizers.[76] They often resolve without additional intervention. Non-comedogenic moisturizers may aid in reducing the incidence of milia.

For NAFR, prolonged erythema is defined as post-treatment redness that persists longer than four days.[79] It has been reported in less than 1% of patients treated with NAFR. Despite concerns for erythema, one should be reminded that erythema is the clinical end-point of fractional resurfacing and is an expected, transient side-effect. We should keep in mind that erythema is associated with wound healing and continued heat shock protein expression, indicating ongoing dermal remodeling.

It is well known that patients with darker skin phototypes (Fitzpatrick skin types III–VI) have a higher likelihood of developing post-inflammatory hyperpigmentation (PIH), which occurs following any inflammatory insult. In general, PIH occurs much less frequently with NAFR compared to traditional resurfacing. However, the incidence varies and depends on the system used, the parameters applied, and skin types treated. Incidences of up to 12% have been reported, even with low density and low energy levels.[80] Recently, a retrospective case series of 45 patients with darker skin phototypes (skin types III–V) found that 17% of patients undergoing NAFR for acne scarring developed some form of hyperpigmentation.[81] These figures included patients who were prescribed bleaching cream prior and/or after last treatment, and was considered low incidence by the authors. To minimize the risk, several strategies can be employed. First, patients should avoid sun exposure at least 2 weeks before and after treatment, and the application of a topical 4% hydroquinone prior to treatment and very early in the recovery phase can minimize risk of hyperpigmentation dramatically.

Hyperpigmentation has been more closely related to treatment densities rather than depth (energy), and reducing density based on skin phototype can also help minimize the incidence of pigmentary alterations. Finally, appropriate cooling will prevent excessive heating of the epidermis. Compared with traditional full face CO_2 laser resurfacing, delayed onset, permanent hypopigmentation related to NAFR has not been reported.

Postoperative management

Immediately after treatment, the patient should apply ice to alleviate discomfort and minimize edema. Following application of ice, the face should be gently cleansed. The patient is given explicit verbal and written care instructions. Ice packs can be applied as necessary and sleeping with the head elevated on two pillows may hasten resolution of post-treatment edema. While many authors debate the prudence of postoperative antibiotics and/or antifungals, given the low incidence of impetigo and candidiasis demonstrated to date, we do not routinely prescribe them. If the patient has a history of acne and has broken out after prior treatments, a course of twice daily tetracycline, such as doxycycline, is started at the time of the procedure and continued for 10 days total.

The patient should be instructed regarding the normal healing process. After the initial edema and erythema subsides, many may have subtle bronzing to their skin. Depending on the device and treatment parameters, they may also experience superficial desquamation, which might feel like sandpaper. Patients are advised to avoid exfoliating and to use gentle cleansers during the healing phase, which could last up to 2 weeks.

Optimizing outcomes

Rarely, postoperative hyperpigmentation can develop several weeks after non-ablative skin remodeling and is more likely to be experienced by patients with darker skin tones. Consideration is also given for darker skin types or in those who suffer from melasma. In these instances, a 4% hydroquinone cream can be initiated up to 2 weeks prior to treatment. It can be resumed as soon as the erythematous phase of the recovery has stopped and the patient can tolerate a topical application. Sun protection and avoidance remains standard for all patients postoperatively and cannot be stressed enough, especially in the setting of persistent erythema.

Summary

For those patients who desire a less aggressive approach to photorejuvenation than ablative laser skin resurfacing, non-ablative dermal remodelling is a great option for patients willing to accept modest clinical improvement for ease of treatment and a favorable side-effect profile.

Skin resurfacing has evolved drastically over recent years. Traditional fully ablative resurfacing procedures are less commonly performed in favor of fractionated ablative and non-ablative resurfacing. The availability of several ablative and non-ablative wavelengths allows the dermatologic surgeon to tailor a treatment to the specific concerns of a wide variety of patients interested in cutaneous resurfacing for both medical and cosmetic uses. Further advances in technology will continue to lead towards a wider range of treatment indications and greater efficacy and safety profiles.

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