Devices for Rejuvenation of the Aging Face

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Over the last 30 years, there has been a substantial increase in the number of ablative and nonablative devices that can be used to treat the signs of skin aging. Some devices have found new indications or new technology to refine older indications. In this article, we review the ablative and nonablative devices that are currently available for photorejuvenation of the aging face.

Cosmet Dermatol. 2012;25:412-418.

In the field of cosmetic dermatology, there are a variety of options to reverse the physical signs of aging. Many of these options include treatment with devices that induce remodeling of the dermis and epidermis, resulting in a more youthful appearance (Table). In the 1980s, the continuous wave CO_2 laser was introduced with impressive results in reversing the signs of aging but also was associated with a high potential for side effects and substantial downtime. Since then, many new devices have been made available to laser surgeons that offer varying degrees of facial rejuvenation with fewer side effects and less downtime. In this article, we review the ablative and nonablative devices that are currently available for photorejuvenation of the aging face.

ABLATIVE RESURFACING

CO_2 and Erbium:Yttrium-Aluminum-Garnet Lasers

Prior to the development of the continuous wave CO_2 laser in the 1980s, dermabrasion and deep chemical peels were the only tools available to the dermatologist for treatment of deep static rhytides. The development of the continuous wave CO_2 laser allowed ablation of the dermis but was associated with high rates of unwanted side effects, such as scarring and dyspigmentation. Patients also experienced substantial downtime (approximately 2 weeks) following the procedure. Because of the need for more controlled ablation with less severe side effects, the erbium:yttrium-aluminum-garnet (Er:YAG) laser as well as the high-energy superpulsed and scanning CO_2 lasers were developed for cutaneous use. These newer devices help control the excess thermal injury that previously had led to unwanted side effects. The Er:YAG laser offers modes of variable long- and short-pulse durations to promote more controlled ablation. Later, Manstein et al[1] introduced the concept of fractional photothermolysis, which produces columns of treated tissue surrounded by noninjured tissue, collectively known as microscopic treatment zones, in a process that allows the untreated tissue to act as a reservoir for cells to heal the treated tissue more quickly. Many manufacturers have incorporated this fractional photothermolysis technology into both ablative (and nonablative) lasers, and the practitioner can now choose from fractionated ablative lasers in a myriad of spot sizes, shapes, and depths of ablation. Other advantages of fractional ablative therapy include faster reepithelialization, less swelling, less erythema, and the option to treat multiple areas such as the neck, hands, and chest.[2]

Although the Er:YAG laser allows for more precise ablation, the cosmetic results achieved with the CO_2 laser are similar and perhaps better according to reports from the few known head-to-head studies.[3,4] Both lasers produce their effects by varying degrees of ablation followed by reepithelialization, neocollagenesis, and wound contracture. The superior results observed in CO_2 resurfacing

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The authors report no conflicts of interest in relation to this article.
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Photorejuvenation Devices

Device/Therapy	Light Source	Mechanism	Uses
Ablative lasers	10,600-nm CO_2 laser, 2940-nm Er:YAG laser	Energy is absorbed by water as the chromophore, which results in tissue destruction and subsequent remodeling	Mild to severe rhytides, dyspigmentation, solar elastosis, actinic cheilitis, vascular changes, scars
Vascular lasers[a]	532-nm KTP laser, 585- or 595-nm PDL	Energy is absorbed by hemoglobin as the chromophore, decreasing telangiectasia and vascular photodamage	Erythema, telangiectasia, vascular malformations, erythematous and hypertrophic scars
Near-infrared lasers	1064-nm Nd:YAG	Mainly vascular improvement (targeting hemoglobin) but also some mild collagen heating and subsequent new collagen formation	Erythema, deeper telangiectasia, mild rhytides
Mid-infrared lasers	1320-nm Nd:YAG, 1450-nm diode laser, 1540-nm erbium glass laser, fractionated 1550-nm erbium fiber laser	Collagen heating causing subsequent remodeling and neocollagenesis, fractionated treatment allows faster healing but may require more passes	Mild to moderate rhytides, skin laxity, mild scars
IPL	500- to 1200-nm noncoherent flashlamp-pumped light source, cutoff filters allow elimination of shorter wavelengths	Wide range of wavelengths covers a variety of chromophores, treating multiple components of photoaging	Fine rhytides, telangiectasia, pigmented lesions, poikiloderma, scar modification
PDT	Multiple light sources can be used to activate topical photosensitizers 5-ALA and MAL: blue light (417 nm), red light (630 nm), and PDL	PpIX is activated by the light source and releases reactive oxygen species, causing an inflammatory response	Actinic keratoses, photoaging
LED	Emits a narrow band of electromagnetic radiation, measured in milliwatts, ranging from UV to visible and infrared wavelengths	Unknown, but theories point to an intracellular nonthermal effect mediated by mitochondrial cytochrome light absorption yielding increased fibroblast activity	Redness, fine lines and wrinkles, acne, inflammation
Radiofrequency	Monopolar, bipolar, or tripolar devices create an electrical field that runs through the skin	Resistance of tissue results in heat production, which denatures collagen and stimulates new collagen production	Skin laxity, photodamage, rhytides
Ultrasound devices	Intense focused ultrasound waves transfer energy into the skin, resulting in heat	Dermal and subcutaneous heating result in collagen and tissue remodeling	Rhytides, skin laxity

Abbreviations: Er:YAG, erbium:yttrium-aluminum-garnet; KTP, potassium titanyl phosphate; PDL, pulsed dye laser; IPL, intense pulsed light; PDT, photodynamic therapy; ALA, aminolevulinic acid; MAL, methyl aminolevulinate; PpIX, protoporphyrin IX; LED, light-emitting diode.
[a]Vascular lasers are not discussed in this article.

likely are a result of extra thermal damage, which leads to greater remodeling in comparison to the Er:YAG laser[4-6]; however, the clinician can compensate by performing more passes with the Er:YAG laser.[4]

Patient selection depends on many factors. Patients with Fitzpatrick skin types I to IV are ideal candidates. For cosmetic resurfacing, the dermatologist primarily will treat only the face when using scanning or pulsed CO_2 lasers. Treatment of the neck and chest areas with a scanning CO_2 laser should only be performed by experienced laser surgeons using caution and lower energy levels. A decreased proclivity to scarring with the Er:YAG and fractional therapy allows the dermatologist to treat areas such as the neck, hands, and chest with less risk for scarring.[2] Contraindications to ablative therapy include a history of keloids, collagen vascular disease, and recent surgical face-lifts or blepharoplasties, as well as a reduced number of adnexa (ie, from radiation dermatitis, morphea) to serve as a reservoir for cutaneous stem cells. Relative contraindications include diseases that can koebnerize such as psoriasis and vitiligo. Clinicians generally wait 6 months to 1 year after the patient has finished an oral isotretinoin regimen before treating with ablative therapy.[7] Treatment during pregnancy is not recommended, though most practitioners do not order a pregnancy test. The standard of care is to place the patient on antivirals, regardless of history of herpetic infections, and to consider antibiotics if the patient is prone to cutaneous bacterial infections. Prophylactic treatment begins 1 day before treatment and continues until 5 days postprocedure for fractionated or Er:YAG laser therapy and for 10 to 14 days after continuous wave or long-pulsed CO_2 therapy. Physicians also have prescribed oral corticosteroids to help with edema, topical tretinoin before treatments to speed postprocedure healing, and systemic antifungals to prevent candidiasis.[7-9]

Options for anesthesia range from topical agents for focal areas to nerve blocks with concomitant peripheral infiltration of lidocaine for full-face ablative therapy. We also use an additional combination of oral anxiolytics and narcotic pain medications when performing full-face resurfacing.

There is no standard technique for treatment with ablative lasers because every machine varies, and techniques for the short-pulsed Er:YAG laser will differ from the scanning CO_2 laser. The clinician usually will make multiple passes that overlap to provide the best cosmetic outcome. Because the Er:YAG laser has a shorter depth of penetration, more passes often are required to achieve results that are comparable to the CO_2 laser.[10]

Postoperative treatment consists of immediate application of petrolatum ointment or other bio-occlusive. Application of emollients should be continued until reepithelialization occurs, while bio-occlusive dressings are only used for the first few days secondary to increased rates of infection with prolonged use.[11] Following the procedure, the patient should adhere to strict sun protection measures, which should be continued for several months until erythema resolves to minimize the chances of hyperpigmentation. An acneiform eruption may occur due to the occlusive dressings and petrolatum and typically resolves on cessation.

Long-term complications consist of hypopimentation, hyperpigmentation, and scarring. Hyperpigmentation is most commonly reported in darker skin types and is treated with bleaching agents, topical tretinoin, and sun protection.[12] Scarring is the result of excessive thermal damage. High fluences, multiple passes, and more overlap may provide greater cosmetic results but also may cause greater thermal damage and potential scarring.

The Er:YAG and fractionated ablative lasers are safer than the nonfractionated CO_2 lasers to use on the face (Figure 1), neck, chest, and hands for treatment of photodamaged skin, as they are associated with a lower scarring risk. Long-pulsed and scanning CO_2 lasers will still produce the most dramatic results in treating deep facial rhytides but with increased side effects and downtime. Fractional ablative photothermolysis can improve healing time and safety of both the Er:YAG and CO_2 lasers without severely compromising cosmetic results.

NONABLATIVE RESURFACING

Following the success of ablative resurfacing devices, nonablative devices were designed to improve the appearance of aging skin without the downtime or risk for side effects that were associated with ablative laser treatments. Many nonablative devices have been developed over the years, including vascular lasers, near-infrared lasers, and mid-infrared lasers[13-16]; other nonlaser modalities for rejuvenation of aging skin include intense pulsed light (IPL), photodynamic therapy (PDT), light-emitting diode, radiofrequency, and ultrasound devices.

Infrared Lasers

Infrared lasers promote collagen heating and subsequent remodeling. Although the results are not as dramatic as treatment with ablative lasers, improvement has been documented with little to no downtime and a substantially lower risk for scarring and dyspigmentation (Figure 2).[17]

Technique for infrared lasers varies from device to device, but overall, each treatment requires 1 to 3 passes. Topical anesthesia can be administered to lessen associated pain. The skin should be heated to 40°C to 45°C, which corresponds to a dermal temperature of approximately 60°C to 65°C. Epidermal cooling also should be

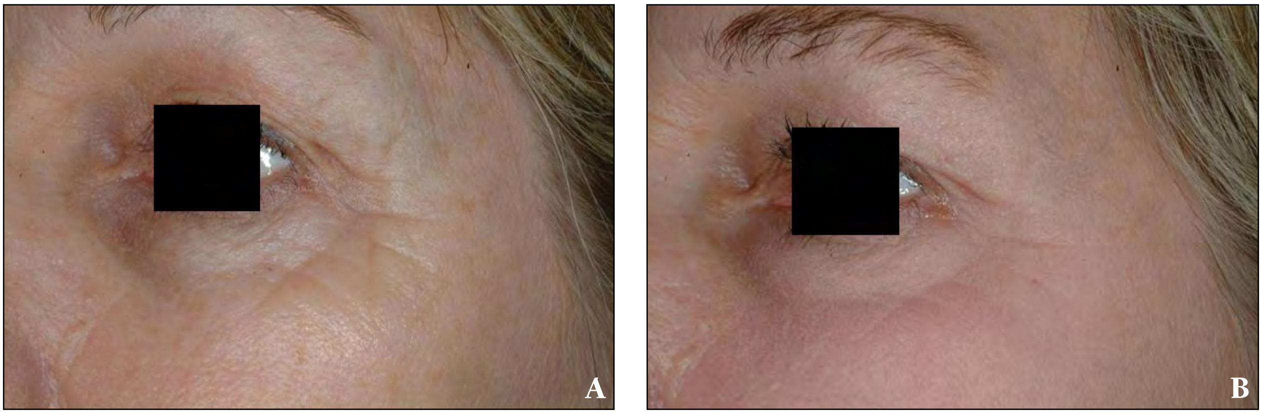

Figure 1. Patient before (A) and 6 months after treatment with fractionated CO_2 laser (B). Photographs courtesy of Mary P. Lupo, MD, New Orleans, Louisiana.

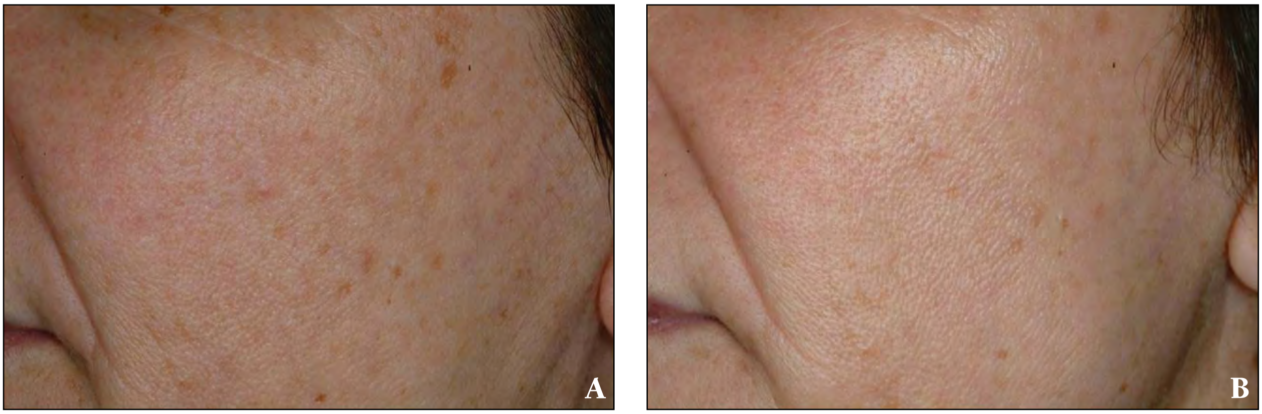

Figure 2. Patient before (A) and 3 months after treatment with a fractionated infrared 1550-nm erbium fiber laser (Fraxel, Solta Medical, Inc)(B). Photographs courtesy of Mary P. Lupo, MD, New Orleans, Louisiana.

used to prevent burning. The clinical end point should be mild erythema and/or edema. Insufficient energy delivery will not produce any results, and multiple treatments are necessary at regular intervals (ie, at least 3 treatments at monthly intervals) for visible results.[18]

Intense Pulsed Light

Intense pulsed light is a light-based technology used for nonablative skin rejuvenation. Intense pulsed light is emitted from a noncoherent flashlamp-pumped source, which has a broad-spectrum emission range from 500 to 1200 nm. This spectrum of radiation covers a wide range of chromophores and thus targets signs of photoaging such as fine rhytides, telangiectasia, and pigmented lesions. Cutoff filters allow for elimination of shorter wavelengths and concurrent emission of yellow, red, and infrared light waves, which serves to treat the multiple components of photoaging.[19,20]

Intense pulsed light systems benefit from their relative ease of use; large spot sizes, which allow larger areas to be covered in a shorter amount of time; and versatility in their ability to treat a variety of photodamaged targets. There also is little to no downtime associated with treatment. Although topical anesthesia can be administered, it is not required in most patients. Side effects include erythema and mild swelling, and a few patients have reported mild bruising or crusting due to superficial breakdown. Current efficacious strategies include double pulsing with short delays between pulses and thin gel technique (using a thin layer of ultrasound gel between handpiece and skin) for clearance of telangiectasia and lentigines with little downtime. Patients undergo a series of 4 to 6 treatments during which consistent incremental progress is achieved.[21,22] Pathology specimens from treated areas in patients who underwent IPL demonstrated new collagen formation in the papillary dermis.[23] Although IPL can yield mild to moderate improvement in fine rhytides, the most dramatic benefits are seen in the improvement of dyspigmentation and vascular changes (Figure 3), which promotes overall photorejuvenation effects.[24-28]

Intense pulsed light has become a first-line treatment for many practitioners in patients with signs of mild to moderate photoaging. Although it is not the best treatment of rhytides, dyspigmentation, or vascular changes associated with aging, the fact that IPL treats all of these cosmetic deficiencies makes it a useful tool for improving the overall signs of aging. As a testament to the wide acceptance of IPL, there are more than 10 different manufacturers of various IPL systems, with more than 10,000 devices sold from 1995 to 2005.[22]

Photodynamic Therapy

In dermatology, PDT involves the application of a topical photosensitizer, which is selectively absorbed into target tissue after an incubation period. This process is followed by activation of the photosensitizer via visible light, most commonly blue (417 nm) or red (630 nm) light in the presence of ambient oxygen. The activation reaction generates reactive oxygen species, which oxidize tissue proteins, lipids, and nucleic acids, selectively destroying the target tissue.[29,30]

The most commonly used PDT photosensitizer in the United States is 5-aminolevulinic acid, and the US Food and Drug Administration also recently approved 5-methyl aminolevulinate. On application, these agents are selectively concentrated in actinically damaged skin and sebaceous glands. Both agents are precursors of protoporphyrin IX (PpIX), which is a potent photosensitizer.[31] The maximum absorption of PpIX is at 410, 630, and 690 nm. When PpIX is exposed to light, the production of cytotoxic reactive oxygen species induces an inflammatory response.[32,33]

Aminolevulinic acid–PDT using IPL or pulsed dye laser is an efficacious photorejuvenation modality.[34] In these studies,[34,35] aminolevulinic acid was applied 30 to 120 minutes prior to exposure to the respective light sources. Possible side effects include erythema and crusting, but overall they are minimal. Photodynamic therapy is indicated by the US Food and Drug Administration for the treatment of actinic keratoses, but beneficial effects also have been demonstrated when used adjunctively to treat cosmetic photoaging.

Light-Emitting Diode

Light-emitting diode can be classified as a nonablative skin rejuvenation modality and uses nonthermal technology to modulate cellular activity with light. Light-emitting diode devices emit a narrow band of electromagnetic radiation, measured in milliwatts, that ranges from UV to visible and infrared wavelengths. They provide a small but significant improvement in fine lines and redness through an unknown mechanism.[32,35-37]

Figure 3. Patient before (A) and 3 months after treatment with intense pulsed light (B). Photographs courtesy of Mary P. Lupo, MD, New Orleans, Louisiana.

Radiofrequency Devices

Radiofrequency devices work by generating an electrical field that runs through the dermis and subcutaneous tissue and changes polarity millions of times per second. The tissue's resistance to the electrical flow results in heat energy that promotes collagen remodeling (Figure 4).[38-41] Monopolar, bipolar, and even tripolar radiofrequency devices are available. Monopolar devices have 1 electrode with a grounding plate. Bipolar and tripolar devices have multiple electrodes that allow for more evenly distributed energy. Increasing the number of electrodes decreases the depth of the effects, but the electrodes may be spaced further apart to increase depth. These devices often are combined with other light sources or lasers.

Multiple treatments at regular intervals are necessary for results. Multiple passes with larger tips at each treatment result in more controlled results, but the exact technique varies from device to device. Technique has evolved from fewer passes with higher energy levels to more passes with lower energy settings, resulting in more predictable outcomes with fewer side effects. Topical anesthesia can be administered to alleviate patient discomfort, but often it is not necessary. Side effects mostly include erythema and edema, but a few cases of burns and scarring also have been reported[39-42]; these side effects can be better controlled through correct usage of the devices.

Ultrasound Devices

Intense focused ultrasound is another way to use energy to transfer heat into the dermis and subcutaneous tissue, allowing controlled thermal coagulative points that result in collagen heating and remodeling. Although studies are limited, they have been successful in showing improvement of rhytides and laxity in preauricular, neck, cheek, and chin areas in most but not all treated patients.[42-44]

Prior to treatment, topical or injected anesthesia should be administered. Multiple passes are made with different probes that treat at different depths. Slight erythema and edema can be expected with treatment[42-45]; otherwise, few side effects have been reported.

CONCLUSION

Many devices are available for the rejuvenation of aging skin. In choosing a procedure, it is important to determine which therapy is most appropriate for the patient. Possible outcomes and side effects must be discussed with the patient who also should be educated prior to the procedure regarding his/her expectations. The risk for side effects and downtime are crucial in procedure selection.

The last 30 years have resulted in an explosion of options when choosing devices to combat aging. Over time, many devices have found new indications and new technology that allow their older indications to be refined. Likely, over time many of the newer devices will continue to be honed to produce greater results while reducing risks for patients.

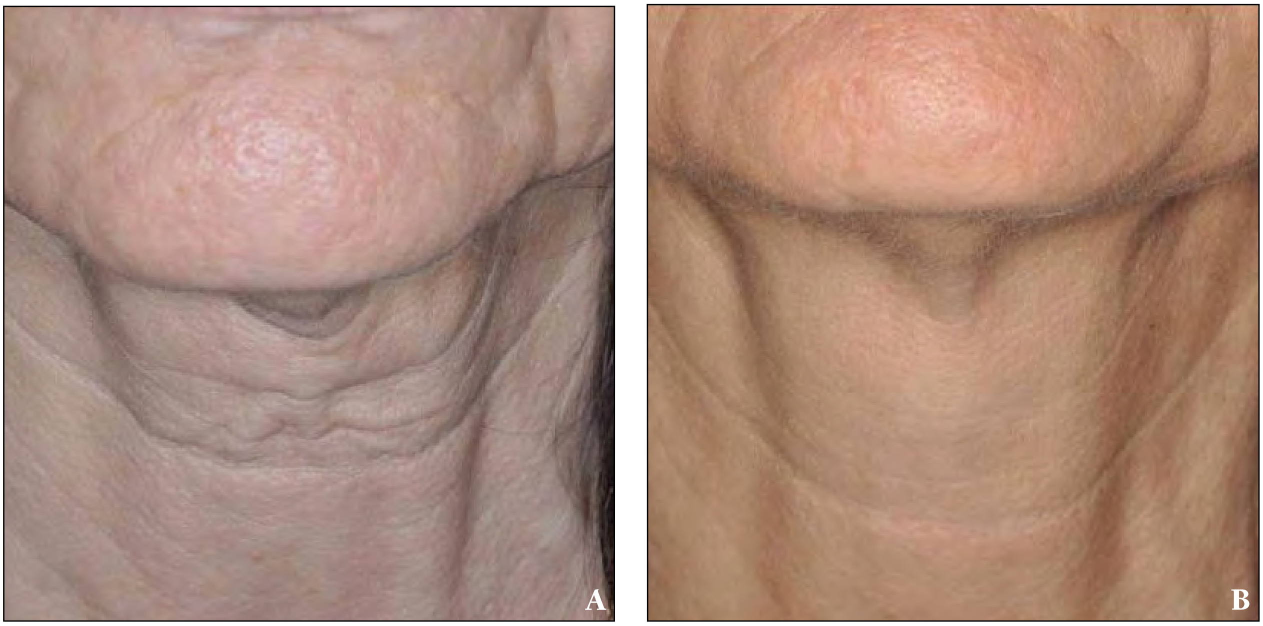

Figure 4. Patient before (A) and after 4 monthly treatments with the Exilis radiofrequency device (BTL Industries)(B). Photographs courtesy of Mary P. Lupo, MD, New Orleans, Louisiana.

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