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The New Age of Noninvasive Facial Rejuvenation

Rebecca Kleinerman, MD,[*,†] Daniel B. Eisen, MD,[‡] Suzanne L. Kilmer, MD,[§] and Omar A. Ibrahimi, MD, PhD[‖,¶]

The techniques of noninvasive facial rejuvenation are forever being redefined and improved. This article will review historical as well as present approaches to resurfacing, discussing the nonablative tools that can complement resurfacing procedures. Current thoughts on the pre- and postoperative care of resurfacing patients are also considered.
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As laser surgeons, we continuously refine our interventions to reduce the effects of the aging process. Facial rejuvenation sets the goals of texturally improving the skin, tightening laxity, and achieving uniformity of color. Treating the aging face requires a multifaceted plan. Laser resurfacing is often the central strategy, as it addresses both the intrinsic and extrinsic components of aging. Other laser, radiofrequency, and light-based techniques are able to complement our basic resurfacing tools. Using principles of selective photothermolysis,[1] we can target specific aspects of photoaging as well as work toward a more global pattern of rejuvenation. This review will discuss historical aspects and current ideas in laser resurfacing, including the pre- and postoperative management of resurfacing patients, combination treatments, and advances in the nonablative modalities used adjunctively to combat the components of aging.

History

Traditional resurfacing with the carbon dioxide (CO_2) laser (10,600 nm) enjoyed popularity in the 1990s.[2] Newer CO_2 lasers were able to operate in a pulsed fashion and vaporize superficial layers of skin with minimal conduction of heat, reducing collateral damage to the surrounding tissue.[2,3] This allowed for collagen contraction and deposition, with excellent long-term correction of photoaging.[4-6] Hence, the CO_2 laser came to be regarded as the criterion standard for resurfacing. However, fully ablative CO_2 laser treatment was associated with recovery periods lasting 2 or more weeks, the possibility of long-lasting erythema, and significant risks of infection, scarring, and pigmentary change.[7-10] The erbium:yttrium aluminum garnet (Er:YAG) laser (2940 nm), with a greater water absorption coefficient, created a more superficial pattern of ablation than the CO_2 laser without the coagulation effect, resulting in reduced downtime.[11] This shorter recovery period, however, came at the expense of decreased fibroplasia and less improvement, although equivalency was demonstrated with a larger number of passes.[12-14] Alterations of the pulse width of the Er:YAG laser eventually led to results that more closely approximated the CO_2 laser but did not, in fact, parallel them.[15] Subsequently, other means of treatment were developed to rejuvenate the skin while minimizing the length of recovery and potential side effects of ablation.

Nonablative rejuvenation, a term first applied to treatment parameters with the 585-nm pulsed-dye laser,[16] now refers to the series of techniques that were developed to treat aspects of aging without the downtime of ablative resurfacing. The goal of nonablative rejuvenation is to correct rhytides, telangiectases, lentigines, prominent pores, and sebaceous overgrowth without the crusting, oozing, erythema, lengthy recovery period, and the potential for infection and/or scarring of the ablative resurfacing procedures. Lasers used for nonablative treatment included the Q-switched neodymium:yttrium-aluminum-garnet (Nd:YAG), the long-pulsed 1064-nm Nd:YAG, the 1320-nm Nd:YAG, and the 1450-nm diode. Additionally, intense pulsed light (IPL) sources, low-intensity light sources (light-emitting diodes), and radiofrequency devices are considered nonablative.[17] Although not touted

*Department of Dermatology, Mt. Sinai School of Medicine, New York, NY.
†Schweiger Dermatology, New York, NY.
‡Department of Dermatology, University of California Davis, Sacramento, CA.
§Laser and Skin Surgery Center of Northern California, Sacramento, CA.
‖Connecticut Skin Institute, Stamford, CT.
¶Wellman Center for Photomedicine, Harvard Medical School, Massachusetts General Hospital, Boston, MA.
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Correspondence: Omar A. Ibrahimi, MD, PhD, Connecticut Skin Institute, 999 Summer Street, Stamford, CT 06905. E-mail: omar.ibrahimi@gmail.com

for "resurfacing" in the same sense as ablation, each of these nonablative adjunctive treatments has been proven to achieve specific goals, that is, the elimination of pigment, telangiectasia, sebaceous hyperplasia, and/or generalized tissue remodeling.

The novel principle of applying fractionation to laser energy was first developed by scientists at the Wellman Center for Photomedicine in 2004 with a 1550-nm infrared spectrum wavelength.[18] By creating subepidermal microscopic zones of injury with intervening portions of untreated skin, the group demonstrated that skin tightening occurred, pigmentation associated with photoaging was improved by transepidermal elimination, and there was decreased effacement of rete ridges with increased mucin deposition.[18] These changes conduce to a youthful appearance. This brought forth a new means of resurfacing that was regarded as "nonablative" or "microablative" because the epidermis, and notably the stratum corneum, remained largely intact throughout treatment.[19] Nonablative fractional resurfacing (NAFR) was applied to rejuvenation promptly and globally, as it minimized patients' recovery and discomfort while allowing for significant and easily interpreted results. Prototypes were created with random scanning as well as stamping patterns of fractional injury.[20] With NAFR, many of the components of photoaging (eg, red and brown pigment, poikiloderma) were cleared, and textural improvement was achieved (Fig. 1). Experts recommended a series of 4-6 treatments at 1-4-week intervals for optimal results. Furthermore, NAFR was applicable to all skin types, as it was theoretically less risky than the ablative resurfacing techniques of the 1990s. By decreasing the density of the microthermal zones of injury, the risk of postinflammatory pigmentary alteration in darker skin types was substantially reduced.[21]

Fractionation has since been applied to ablative modalities. Ablative fractional resurfacing (AFR) was introduced in 2007, with technological advances allowing for fractionation of the CO_2 laser beam.[22] Setting the goals of maximal correction and minimal recuperation time, fractionally ablative CO_2 lasers were able to provide another efficacious alternative to fully ablative procedures. A recent study quantified the regenerative effects of fractional versus fully ablative CO_2 resurfacing, indicating that fractionally ablative lasers produced approximately 40%-50% of the type 1 collagen induction of the fully ablative lasers.[23] The safety of fractional ablative CO_2 resurfacing has been studied, and one group asserted that in >2000 treatments, there were no cases of scarring or hypopigmentation observed.[24] However, reports of overwhelmingly safe and effective therapies unsupported by rigorous methodology should not be relied on to assume a lack of complications. Others have reported cases of scarring on the eyelid leading to ectropion, and at least 8 patients developed scarring after treatment on the neck.[25,26] The incidence of complications does, however, appear to be low. Investigation into the long-term results of this technology found that correction of scarring and photodamage was maintained at 1- and 2-year follow-up visits.[27,28] Although fully ablative resurfacing is still the gold standard, authors have suggested that the risk/benefit profile makes fractional ablative resurfacing (Fig. 2) an attractive option.[29]

Current Thoughts: Preoperative Assessment

Preoperative questions and preparations focused on the patient's skin type, chief concerns, and tolerance for recovery time can help prepare for a successful outcome. A 1998 survey of dermatologic and plastic surgeons determined that there was great variability in the pre- and postoperative regimens of laser surgeons.[30] For patients with Fitzpatrick skin types III and higher, there is some debate over whether a preoperative regimen of topical hydroquinone or other skin lightening agents is necessary to minimize postresurfacing hyperpigmentation. Although it is the practice of many to pretreat with several weeks of topical hydroquinone, West and Alster[31] demonstrated that glycolic acid cream, hydroquinone, and tretinoin creams before CO_2 resurfacing did not significantly effect the incidence of postoperative hyperpigmentation. The authors postulated that when the epidermal barrier is reformed, it is repopulated with follicular melanocytes, which are not affected by the topical therapy.[31] It should be noted, nevertheless, that this study was performed with a fully ablative resurfacing laser. It is unclear whether the same conclusions may be drawn with fractional resurfacing, both nonablative and ablative, which maintains islands of unaffected epidermis. Clinicians must individually weigh the risks and benefits of a course of pretreatment. Furthermore, it may be prudent to avoid resurfacing on recently sun-exposed/tanned skin, as preclinical studies have indicated a higher risk of complications with both pre- and postoperative ultraviolet light exposure.[32]

Similarly, pretreatment for laser resurfacing with tretinoin has also proved controversial. Several early studies in the dermabrasion/chemical peel literature documented more rapid re-epithelialization of partial thickness wounds and fewer milia after these procedures.[33,34] Orringer et al[35] examined the practice of a 3-week course of pretreatment in conjunction with fully ablative CO_2 resurfacing, and did not find any measurable differences in re-epithelialization or erythema of treated skin in comparison with controls. Again, the applicability of these data to fractionated procedures is unknown.

A limited patient history regarding scarring, vitiligo, koebnerizing conditions, orofacial herpes, and other infections can help individualize treatment. Antiviral prophylaxis has been shown to decrease the incidence of herpetic outbreaks postoperatively in patients with and without a history of orofacial herpes.[36,37] Antibiotic/antifungal prophylaxis may be considered when the resurfacing area is large or the patient has a history of infection.[38]

Furthermore, pretreatment with topical anesthetic agents may be useful not only for adequate pain control but also for skin hydration. This regimen has been associated with a low rate of postoperative hypopigmentation and scarring when used with fully ablative resurfacing.[39]

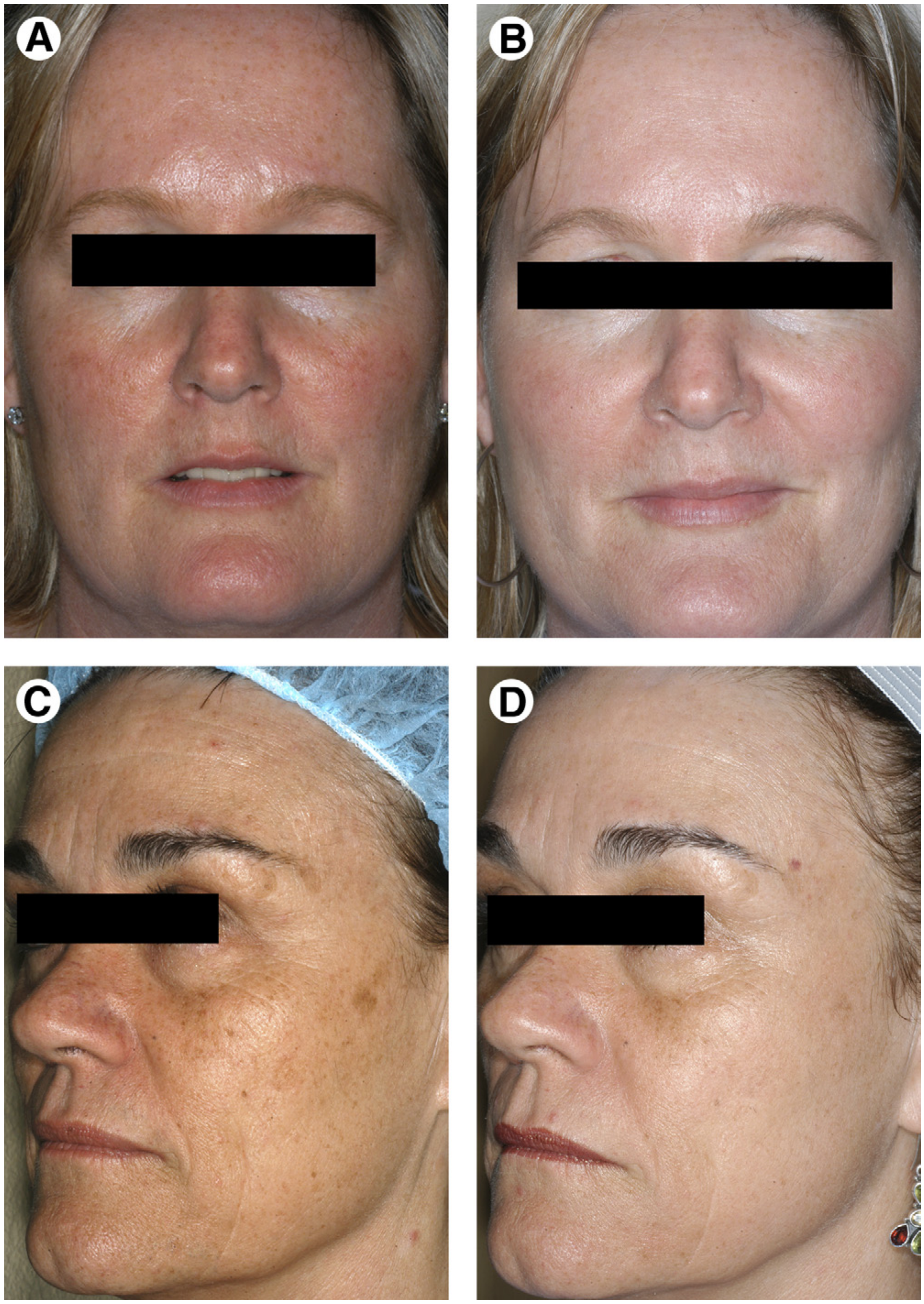

Figure 1 Nonablative fractional resurfacing can result in the improvement of photoaging. (**A**) Patient before treatment. (**B**) Two months after single treatment with nonablative fractional resurfacing. (**C**) Patient before treatment. (**D**) Three months after 3 nonablative fractional resurfacing treatments sessions at monthly intervals.

Current Thoughts: Treatment

Mounting evidence supports the benefits of fractionated resurfacing, both nonablative and ablative. In 2009, a novel wavelength of infrared light (1927 nm) was added to the 1550-nm nonablative fractional prototype (Solta Medical, Hayward, CA). This wavelength, with superficial penetration and a greater absorption coefficient for water than the 1550-nm wavelength, increases the ability to target epidermal pigment, and has been used with success for melasma and the elimination of superficial brown pigmentation induced by photoexposure.[40,41] This and other "combination" lasers allow the user to accentuate certain components of treatment and aim for specific end points while continuing to sidestep the pitfalls of ablation.[42]

With these advances in fractional nonablative technology, the question may be asked: Is there any measure of equivalence with multiple treatments to a single fractional ablative session? Can a patient avoid the downtime of an ablative treatment by scheduling a set number of fractional nonabla-

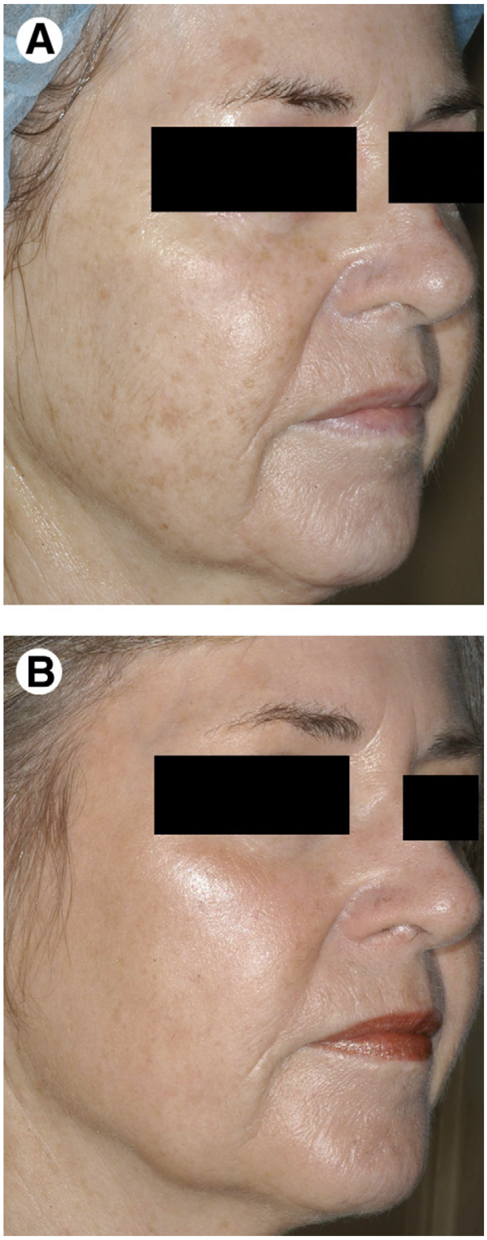

Figure 2 Ablative fractional resurfacing also results in the rapid improvement of photoaging with a single treatment. (**A**) Patient before treatment. (**B**) Three months after a single treatment with ablative fractional resurfacing.

tive procedures, and if so, what is the optimal time frame for these procedures? Data to clarify this question are sparse. Weiss et al[43] attempted to quantitate the improvement of 1 NAFR and 1 fractional ablative CO_2 treatment session for rhytides, showing a quartile improvement of ¼ versus ¾ in the periocular region by blinded photographic assessment. It is not clear whether these data can be extrapolated to indicate that 1 AFR is the equivalent of 3 NAFR procedures. Both AFR and NAFR typically require multiple treatment sessions, and both report positive outcomes.

In addition to current resurfacing modalities, recent progress has been made in the adaptation of nonablative lasers to treatments for which they may not have been initially conceived. A 2002 study demonstrated that the long-pulsed alexandrite laser, originally intended for hair removal and further used in the treatment of hypertrophic vascular malformations, was effective at treating lentigines in light-skinned patients.[44] Despite the nanosecond thermal relaxation time for melanosomes, longer pulses of the 755-wavelength laser, on the order of 3-40 ms, were able to effectively treat aberrant pigment as well.[45] Building on this, case reports suggested that the long-pulsed alexandrite could be used for darker phototypes.[46] A recent analysis compared the Q-switched alexandrite laser with the long-pulsed alexandrite laser for the treatment of lentigines in Asian patients.[47] The long-pulsed alexandrite was shown to safely and effectively treat lentigines in darker skin types with a lower risk of postinflammatory change than its Q-switched counterpart.[47] The authors attributed the higher incidence of postinflammatory change in the Q-switched alexandrite arm to the photomechanical effect typical of Q-switched lasers, which causes inflammation in the surrounding tissue and subsequent pigmentation.[47] Hence, the long-pulsed alexandrite has established itself as an important player in the removal of pigmented lesions in light and darker skin types.

Similarly, the long-pulsed dye laser (LPDL), intended for vascular treatment, has good absorption by melanin and was studied for lentigines with a compression handpiece.[48] By placing the glass-tipped handpiece firmly on the skin surface, as in diascopy, investigators were able to press blood out of the superficial vasculature and allow the 595-nm wavelength of the LPDL to target melanin rather than hemoglobin. Approximately 83% of lentigines in an Asian test population, without hyperpigmentation, hypopigmentation, or scarring, were cleared after 1 treatment.[48] Additionally, the LPDL seemed to deliver results with a lower incidence of side effects than the standard Q-switched ruby laser that was used for comparison.[48] By the same principle, the LPDL has been used to achieve clearance of dermatosis papulosa nigra in conjunction with compression of the area with a glass microscope slide, achieving comparable results with more traditional treatment modalities.[49]

Conversely, investigators have studied the application of the variable long-pulse alexandrite laser to the treatment of facial telangiectasia, a domain dominated by use of the LPDL.[50] Treating patients with Fitzpatrick skin types I or II, the authors determined that they could effectively reduce small and moderately sized telangiectasia by 48% in one treatment with minimal side effects.[50] The authors point out that adequate surface cooling is imperative, as fluences to achieve vessel clearance may exceed that which can lead to epidermal damage.[50]

Finally, our understanding of the use of IPLs has grown significantly in recent years. 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.[51,52] An examination of microscopic changes induced by IPL in the treatment of poikiloderma of Civatte demonstrated homogenization of melanin distribution and an increase in nonfragmented elastic fibers.[53] Clinically, evidence has accumulated to support the safety and efficacy of combination treatments for photoaging, including IPL and NAFR.[54] Kearney et al[54] determined that IPL performed immediately before NAFR synergistically improved outcomes, as assessed by blinded investigators 4 weeks after treatment, with only a marginal increase in downtime. A 2011 comparison study also established that the IPL is a viable alternative to the LPDL in the treatment of facial vessels.[55]

Current Thoughts: Postoperative Care

Work has been done to summarize and highlight the utility of topical therapy in enhancing the efficacy of laser treatment. The role of antioxidant therapy in the healing process is still ill-defined. Early investigations in ablative resurfacing suggested that aqueous vitamin C, applied after re-epithelialization, may decrease the risk of postlaser erythema after ablative resurfacing.[56] A recent article showed that a topical vitamin C formulation, when applied immediately after fractional CO_2 treatment, was able to decrease transepidermal water loss and restore skin pH to baseline levels more quickly than controls, although the authors did not note any difference in pigmentation or erythema.[57] Further work is needed to create an evidence-based protocol for antioxidant application after laser therapy.

Studies have compared the use of ointments and topical oil-in-water emulsions for postlaser care, with some variability in results. One such investigation favored a semiocclusive ointment preparation also containing barrier lipids and humectants over the topical oil-in-water emulsion after fractional CO_2 laser for perioral rhytides.[58] Another suggested that the emulsion was superior to white petrolatum in achieving re-epithelialization after erbium laser treatment.[59] Some dermatologic surgeons apply a beta-glucan ointment preparation after fractional ablative procedures, as studies have correlated beta-glucan, which has antibacterial and antineoplastic properties, with improved wound-healing ability, although the use of beta-glucan in laser care has not been yet evaluated.[60] Other laser surgeons prefer closed posttreatment dressings to open methods of posttreatment care, and there is some work to show that a hydrogel mask achieves quicker re-epithelialization and decreases morbidity associated with open techniques.[61] As with preoperative regimens, there is great variability in the current approach to postlaser care.

Conclusions

As technologies multiply, experience is gained in procedural efficacy, safety, and efficiency. We have seen the addition of ultrasonography for skin tightening, and newer versions of radiofrequency and infrared devices designed to minimize pain, treat face and body, and maximize results.[62,63] New indications are being found for older lasers, and therapeutic parameters are being established. The use of growth factors in postlaser care is currently being investigated.[64-66] Although there has been a shift toward fractionated resurfacing techniques in the name of safety, the fully ablative CO_2 laser remains the gold standard.

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