Nonablation Resurfacing

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ABSTRACT

In expert hands, ablative laser resurfacing has a long history of excellent results in the treatment of photodamage-induced rhytids, depressed acne scars, and other signs of cutaneous aging. Over the last decade there have been a growing number of reports in the emerging area of nonablative resurfacing. Nonablative modalities provide less impressive clinical results for rhytid reduction but have shown particular promise for the treatment of scars and superficial dyschromias. It is also ideally suited for those patients seeking a minimally invasive, greatly reduced downtime procedure.

KEYWORDS: Nonablative resurfacing, photorejuvenation, facial resurfacing

Premature signs of skin aging have a genetic predisposition but are often greatly increased due to the combination of sun overexposure and tobacco abuse. Traditional methods of combating genetic and environmental influences include the judicious use of sunscreen, tobacco avoidance, α-hydroxy acids, retinoids, and chemical peels. More aggressive means for rejuvenation involve ablative skin resurfacing techniques, which yield epidermal and partial dermal regeneration.

The original modalities employed for the purpose of ablative rejuvenation were deep chemical peels and dermabrasion, both of which have a long history in aesthetic medicine. Over the last 15 years, carbon dioxide laser resurfacing has proven to be a precise and more efficient method of skin ablation. Although the clinical results are impressive, the recovery is prolonged and the risks are considerable. Today’s “cell phone society” patient has thus enthusiastically welcomed several minimal downtime, low-risk procedures that allow a timely return to their routine.

The concept of nonablative rejuvenation truly came alive in the early 1990s when anecdotal evidence emerged of an improvement in the appearance of actinically damaged skin surrounding blood vessels treated with a flashlamp pulsed-dye laser. Evaluation and biopsy examination revealed that the superficial epidermis and dermis in these areas not ablated were without significant injury. It was theorized that subthreshold injury to dermal structures could result in the stimulation of dermal collagen remodeling.

The unifying principle of nonablative rejuvenation is the induction of a controlled injury to dermal collagen while sparing the epidermis from undesired damage. As the targeted dermal collagen remodels under an ideally intact epidermis, the clinical appearance is that of smoother, tighter skin. Clinical studies involving the treatment of actinically damaged facial skin with a multitude of nonablative applications have followed.

Early established modalities for nonablative resurfacing were adapted from 585- to 595-nm pulsed-dye lasers (N-lite, ICN, Costa Mesa, CA), the 1064-nm, Q-switched neodymium:yttrium-aluminum-garnet (Nd:YAG) laser, the 1064-nm–long pulsed Nd:YAG laser (Laserscope, San Jose, CA), the 1320-nm Nd:YAG laser (CoolTouch Laser Corp., Auburn, CA), the 1450-nm diode laser (Smoothbeam, Candela, Wayland, MA), the 1540-nm Er:glass laser (Quantel, Paris), and Intense Pulsed Light (IPL) Source systems. More recently studied nonablative modalities of facial resurfacing include ultrasound (SmartSound, Sound Skin, Oswego,
IL; SkinMaster, Symedex LLC, Minneapolis MN) and radiofrequency devices (TheraCool, Thermage, Hayward, CA).

Light-based systems used for nonablative photon rejuvenation can be split into two primary categories: visible light and mid-infrared wavelength devices. Visible light devices such as the 532-nm (green) light, 585-nm (yellow) light, and IPL systems with cutoff filters bracketing the visible light spectrum are best suited to treat pigmented and vascular lesions. These wavelengths are strongly absorbed by oxyhemoglobin and melanin in the epidermis and superficial dermis. In theory the superficial vessels are injured, resulting in a leakage of wound-healing factors and fibroblast-stimulating factors indirectly stimulating collagen production. Mid-infrared wavelength devices at 980, 1064, 1320, 1450, and 1540 nm are coupled with cooling mechanisms that serve to protect the epidermis while simultaneously heating and stimulating collagen remodeling in the dermis. These mid-infrared wavelengths are absorbed primarily in water (intra- and extracellular) and can uniformly heat tissue independent of skin type.

Newer modalities for nonablative skin rejuvenation include radiofrequency devices and ultrasound, both of which involve mechanisms of generating controlled heat within the dermis and indirectly stimulating collagen remodeling. Unlike radiofrequency systems, ultrasound has the added theoretical benefit of sono-phoresis, which is speculated to drive topical products such as α-hydroxy acids deeper into the dermis.

Initial speculation about rhytid reduction with nonablative systems began quite serendipitously when it was noted that there was a decrease in the clinical appearance of rhytids while using a pulsed-dye laser for treatment of vascular periorbital lesions. Histological improvement of dermal collagen was also noted after treatment with the pulsed-dye laser. Using these findings, Zelickeon et al. evaluated the use of a 585-nm pulsed-dye laser in the treatment of facial rhytids and reported improvement. Kilmer et al. also reported improvement in treatment of rhytids. An endpoint of clinically visible purpura was again used for dosing. Although this does provide an easily reproduced endpoint for the clinician, it is an endpoint not tolerated by all patients.

Soon after the aforementioned was noted, reports of impressive clinical findings with use of a modified pulsed-dye laser (N-lite, ICN, Wales, UK) emerged. Bjerring and Heikendorff reported on efforts to quantify specific induction of increased skin collagen production. The authors applied a biochemical assay developed to monitor production of type III collagen after nonablative therapy. They report an increase in production rate of collagen III of 144%.6

IPL, a nonlaser light source, can be delivered at a variety of wavelengths (590 to 1200 nm). Filters permit the inclusion and exclusion of given wavelengths. With blockage of shorter wavelengths, deeper wavelengths can be absorbed in the dermis and yield nonablative dermal remodeling. Goldberg reported on five patients who underwent four sessions of IPL source therapy and from whom pretreatment and 6-month posttreatment biopsies were obtained. Their results indicated histological evidence of new upper papillary dermal collagen formation. The IPL has particular utility for the treatment of dyschromias and mottling.

Although these light-based devices have been well accepted by physicians and patients for treating vascular lesions, dyspigmentation, and rosacea, enthusiasm for its rhytid reduction effects in practice has been tempered as the clinical results have been disappointing for some patients and physicians. No clear-cut criteria for patient selection have yet been defined to identify those patients who might be best candidates for a nonablative approach to rejuvenation.

Mid- and infrared frequency lasers deposit non-specific heat into the dermis with the purpose of stimulating collagen remodeling. To protect the epidermis and upper dermis from injury, the hand pieces of these systems have been coupled with cooling devices. Although the mechanism postulated is different from that of visible light devices, studies have shown clinical results in rhytid reduction similar to those achieved with visible light devices. In one of the first nonablative resurfacing trials, a 1064-nm Q-switched Nd:YAG laser was studied for the treatment of periorial and periorbital rhytids. Eleven subjects with perioral and/or periorbital rhytids were evaluated using a Q-switched Nd:YAG laser at 5.5 J/cm². Three patients were reported to have improvements consistent with ablative resurfacing, three with improvement not equivalent to ablative remodeling, and two with no clinical improvement.

The first system specifically designed for the purpose of nonablative resurfacing was a 1320-nm Nd:YAG laser (Cool Touch). The goal of this system, similar to that of the previously described systems, is improvement of rhytids without the creation of an open wound. Studies have reported that this system is able to produce thermal stimulation of dermal fibroblasts within the papillary and mid-reticular dermis while concomitantly cooling the epidermis to protect it from undesired thermal injury.

In the initial study, Nelson et al. described treatment with one or more passes of a 1320-nm Nd:YAG laser on photodamaged skin. Laser energy was delivered through a 5-mm spot size with fluences up to 10 J/cm². At 2 months after treatment, 60% of periorbital facial rhytids were reported as mildly clinically improved. Histologically, there is replacement of the irregular collagen bands with organized new collagen fibrils. In a 1999 study, Kelly et al. reported the use of the 1320-nm wavelength Nd:YAG laser for the treatment of facial rhytids. They reported statistically significant findings
at 12 weeks.\textsuperscript{14} In another study of similar technology, Goldberg reported clinical improvement in 8 of 10 patients in the study.\textsuperscript{15}

Ross et al. reported a study with the Smoothbeam\textsuperscript{TM} 1450-nm diode laser system for the nonablative treatment of photoaged skin. The 1450-nm wavelength of this system is extremely well absorbed by water. Sixteen patients (14 periorbital, 2 perioral) with rhytids were treated with split-face treatments; half with four visits 3 weeks apart with the 1450-nm laser device and the contralateral side with cryogen cooling alone. The authors reported mild to moderate improvement in 12 of 16 patients on the treated side.\textsuperscript{16}

Dayan et al. reported on 34 patients serially treated with the long-pulsed, 1064-nm Nd:Yag laser in a nonablative fashion. Objectively defined significant reduction was noted at 4-month follow up in fine lines (10.7%), coarse wrinkles (11.9%), skin laxity (17.3%), and overall appearance (20%). The authors reported no adverse events or complications and an ability to treat a wide range of skin types (I to V; Fig. 1). In a parallel study laboratory evaluation of in vivo porcine skin treated in series (four treatments in 8 weeks) revealed significant increase in reticular dermal layer collagen content (5%, $p < 0.02$) at 12 weeks following the final treatment.\textsuperscript{17}

A new technology being evaluated for nonablative rejuvenation includes ultrasound. Ultrasound’s benefits are delivered via both thermal and nonthermal mechanisms. Ultrasound-generated heat has been shown to increase collagen tissue extensibility, alter blood flow, and increase enzymatic activity.\textsuperscript{18} Many of the benefits of ultrasound energy may also be attributed to its nonthermal mechanisms.

Ultrasound’s nonthermal mechanisms include acoustic streaming, sonophoresis, and cavitation. Rapid oscillation of tissue and fluid as a result of ultrasound energy promotes movement of fluid waves against cells. This is theorized to produce alterations of cellular membrane permeability and ion concentrations between the inner and outer cell wall,\textsuperscript{18} which may stimulate an intracellular cascade resulting in increased fibroblastic activity and collagen formation.\textsuperscript{19}

Sonophoresis is the notion that ultrasound can facilitate the passage of topical products through the skin’s hydrophobic barrier. Cavitation, the most novel of ultrasound mechanisms, involves the generation of gaseous bubbles in a medium.\textsuperscript{20} Mitragotri et al. found supporting evidence that ultrasound caused cavitation in the keratinocyte’s lipid bilayer resulting in structural disorder and permeability.\textsuperscript{20}

Evidence has been reported that the penetration of topically applied agents such as α- and β-hydroxy acids are dependent on the vehicle, concentration, and product pH.\textsuperscript{21} However, the product’s potency may be dependent on its ability to penetrate the epidermis. Recognizing an ultrasound-induced cavitation disruption of the epidermal lipid bilayer, it is theorized that a

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\caption{(A) Prior to nonablative resurfacing. (B) Following a series of nonablative laser treatments.}
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Topically applied agent followed by ultrasound treatment would allow for further penetration of the topical agent into the dermis where it can act more effectively to stimulate collagen. However, recent in vivo porcine skin studies performed at the University of Illinois treated with a topically placed α-hydroxy acid preparation followed by 10 passes with a low-frequency ultrasound device (SkinMaster) were unable to identify any effects on collagen and elastin content (S.H.D., unpublished data, 2003). It is nonetheless believed that other ultrasound devices of different configurations may yet show promise for nonablative rejuvenation. Further work needs to be undertaken regarding optimal ultrasound exposure time, intensity level, and the best topical agent.

Recent enthusiasm has been generated for a radiofrequency device that has been shown to "tighten skin" and offer a nonsurgical means in which to rejuvenate the periorbital area and elevate the brows (Fig. 2). The radiofrequency–designed hand piece is coupled with a contact cryogen cooling mechanism that provides pre-, post-, and parallel cooling to protect the epidermis and superficial dermis prior to, during, and after heat deposition. This novel mechanism allows for detailed designation of temperature in the dermis over a wider area (volumetric heating) than that which is achieved with nonablative light-based devices. Early results have been very promising, with over 80% of treated patients showing significant objective improvement in wrinkle severity and progressive improvement up to 6 months following a single treatment.22 Similar to other nonablative devices, results are subtle and gradual. However, unlike other nonablative measures, only one treatment seems required, which offers a more palatable option for patients.

Nonablative facial treatments are an attractive option for both the physician and the patient. Advantages to the aesthetic physician are that all of the devices discussed previously can be used in an office setting without difficulty. Most use a standard 110-V outlet and require few disposables. In general, these treatments can be performed with minimal patient discomfort.

Patient advantages include the immediate return to their routine. The devices we have discussed have a significant range in price. Some have other applications such as hair removal, vascular, and dyschromia treatment, which may offer a more cost-effective investment. Because such devices are still evolving and results are in their initial stage, the cosmetic surgeon must strongly consider all aspects of the risk/reward ratio before incorporating such procedures or pieces of equipment into their practices. Although the rhytid reduction results reported from studies on nonablative methods of facial rejuvenation are seductive, there is a subset of patients who are treated that either have no appreciable improvement or are disappointed with the limited results. Prognosticating factors determining outcome are lacking. This may be an overlooked part of the published reports.
but is a critical element to the success of these procedures in a clinical practice.

Nonablative resurfacing represents the newest approach to improving photodamaged skin and is best suited for those patients who have a limited willingness for downtime. Patients must be counseled and expectations managed but, with proper patient selection, patient satisfaction can be maximized.

REFERENCES

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