New Facial Rejuvenation Techniques

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The popularity of cutaneous laser resurfacing has soared in recent years. For optimal clinical improvement, patients have been limited to the carbon dioxide and erbium:yttrium aluminum garnet lasers. With these systems, tissue can effectively be ablated to induce collagen shrinkage and remodeling that result in an improved clinical appearance. The prolonged recovery periods associated with traditional cutaneous laser resurfacing have sparked an immense interest in devices that rejuvenate the skin while minimizing adverse effects. Both physicians and patients seem willing to accept more gradual improvement if it is associated with fewer complications such as prolonged erythema or delayed-onset hypopigmentation. The following review discusses the newest devices in development or currently available for skin rejuvenation.

THERAPIES FOR rejuvenating photo-aged skin have evolved from chemical peeling and manual dermasanding or dermabrasion to high-energy, short-pulsed laser systems. With each method, the goal is the removal of the epidermis and variable wounding of the dermis, which will allow re-epithelialization, new collagen formation, and ultimately, clinical improvement in texture, color, and wrinkling. Although each method has its place and is still frequently employed, acceptable results can be elusive. Chemical peels have a certain unpredictability; dermabrasion is a very technique-dependent procedure that can result in pigment changes and scarring even in skilled hands. Even the more precise and reproducible modes of tissue removal such as the carbon dioxide (CO_2) and erbium: yttrium aluminum garnet (Er:YAG) lasers can produce the same adverse effects and complications associated with all resurfacing procedures, including prolonged erythema, edema, milia formation, irritant dermatitis, infectious complications, hyperpigmentation, and delayed hypopigmentation.[1-6]

Use of the established rejuvenating laser systems can achieve remarkable results but may be intimidating to the novice or less surgically oriented practitioner. Several new rejuvenation techniques are becoming available that may eventually become a regular part of everyday cosmetic practice. Indeed, they will probably be less invasive and more operator-friendly, and may reduce re-epithelialization times and posttreatment erythema. Radiofrequency resurfacing, focal or selective dermal heating by reverse thermal gradient nonabrasive radio frequency resurfacing, microdermabrasion, intense pulsed light, and the long-pulse 1,320 nm and 1,540 nm neodymium:YAG, nonablative Er:YAG, and pulsed dye lasers are among the latest alternatives to ablative cutaneous resurfacing.

COBLATION: RADIOFREQUENCY RESURFACING

A new bipolar, multielectrode device, the Coblation System (ArthroCare Corp, Sunnyvale, CA), has been introduced as an alternative to laser skin resurfacing. The system was initially used in arthroscopic surgery to ablate damaged meniscus, ligament, and articular cartilage. The controlled tissue injury seen in cartilage suggested the device might work for cutaneous resurfacing.[7] Because of structural differences in dermal and articular collagen, the device has different tissue effects in skin but has been successfully used for photo-rejuvenation.

The configuration of the device is straightforward and the unit itself is the size of a videocassette recorder. The stylet, or probe, is a small hand-held device that requires firm pressure while being moved across the cutaneous surface, optimally at a rate of 1.0 to 1.5 cm/sec. An intravenous solution setup is required for the normal saline-conductive medium, and the drip provides continuous wetting of the skin at approximately 3 drops per second. The multielectrode system permits precise ablation of soft tissue, minimizing damage to surrounding soft tissues. Electrical en-

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1085-5629/00/1904-0003$10.00/0

doi:10.1053/sder.2000.18362

ergy is delivered on application of the device to the skin, passing through a saline conductive medium to the tissue and then returning via the receptive "collecting" electrode located to the side of the handpiece. An alternative conductive medium, namely saline gel, might be more user-friendly. Tissue ablation is the localized disruption of molecular bonds by means of the application of sodium plasma energy. While this kinetic energy might play an important local role, the mere application of localized heat may also induce a split at the dermoepidermal junction. Traditional electrosurgery uses high-radiofrequency (RF) energy within a single electrode, generating temperatures greater than 400°C. Temperatures generated with Coblation are much lower, approximately 70°C to 100°C. An additive cooling effect from the chilled saline irrigant further limits residual thermal collagen damage.

This difference can be seen with the naked eye. Traditional electrosurgery causes obvious desiccation and shrinkage with char formation, and RF resurfacing causes a very localized heat (plasma) damage manifested by immediate epidermal slough. Collagen shrinkage is not physically seen during RF resurfacing although it probably occurs. Collagen contraction occurs at temperatures of 60°C to 65°C. One of the reasons that tissue shrinkage is not visible is that desiccation of tissue does not occur in this very moist environment. Histologically, Coblation causes epidermal separation and minor upper-dermal thermal damage, whereas traditional electrosurgery results in a more marked injury characterized by epidermal ablation and upper-dermal homogenization due to coagulation necrosis. In articular cartilage, residual thermal collagen damage has been found to be 100 μm after Coblation therapy.[7] The end result is volumetric tissue removal with simultaneous hemostasis and minimal surrounding tissue damage. As has already been alluded to, this method of tissue removal, with its relatively controlled heat generation, is termed cold ablation or "coblation." This admittedly charming name is a misnomer since the process is neither cold nor truly ablative, but coblation is certainly colder than traditional RF desiccation.

Two preclinical studies with coblation using ex vivo tissue samples (fresh arm skin and standing cones excised during Mohs surgery) found that residual thermal collagen damage is limited to the upper dermis and follicular infundibulum.[8,9] Tissue was treated with a variable number of passes and power settings. For a given number of passes (1 to 3 in both studies) a correlation existed between depth of injury and number of passes. There was not a correlation between zone of residual thermal collagen damage and voltage setting. That is, for a given number of passes, the zone of injury remained consistent with increasing voltage applied. Depth of injury after 3 passes in Tope's study measured 80 to 97 μm at the highest voltage used.[8] The average depth of ablation plus residual thermal collagen damage for all passes and power levels was 114.1 μm in Burns' protocol, confining injury to the upper papillary dermis.[9] A comparable number of passes with pulsed CO_2 laser systems can produce 120 to 150 μm of residual thermal collagen damage.[10]

Initial feasibility studies evaluated this electrosurgical device for scar revision. Number of passes (up to 25) and power levels varied depending on degree of skin surface irregularity; both investigators and patients scored all 6 scars as improved. Adverse effects were mild and consisted of erythema, hypopigmentation, and a single hypertrophic scar.[9] In phase I trials, 17 patients underwent resurfacing of periorbital rhytids, with some cases of transient hyperpigmentation. Overall, patients were satisfied and all patients volunteered for phase II.

A multicenter phase II prospective study evaluating the safety and efficacy of the Coblation system for facial rhytids has recently been completed.[11] Ninety-five patients, Fitzpatrick skin types I-III, were treated for periorbital and perioral rhytids. Subjects underwent from 1 to 3 passes, depending on the severity of wrinkling, with voltages set at 125 V or greater. The average age of the patients was 52 years. A total of 75 periorbital and 50 perioral sites were evaluated by patients, investigators, and an independent panel. Primary endpoints were degree of wrinkle improvement and cosmetic improvement at 6 months. Adverse effects, time until re-epithelialization, and resolution of pain were also determined during the same period.

Rapid healing was seen after the procedure, with full epithelialization by day 28 for all patients; 50% had experienced full re-epithelialization by day 14. Resolution of edema, erythema, hyperpigmentation, hypopigmentation, and pain

was relatively rapid. Edema, present in 60% to 70% of areas during week 1, was present in less than 1% at month 3. Erythema was noted to be 100% at day 2, 30% at month 3, and 4% at month 6, when it became mild in nature. Hyperpigmentation was first noted on day 28 and was more frequent in the periorbital region at 26%, versus 4% for the perioral regionl. Patients with darker skin types had a greater incidence of hyperpigmentation. Of the 3 cases of hypopigmentation, 2 persisted at 6 months followup.

Adverse events were uncommon. Pruritis, eczema, and irritant dermatitis were seen in 2 patients (2%) each. Five instances of hypertrophic scarring were noted, 4 periorbital and a single perioral site. All periorbital scars treated with topical or intralesional corticosteroids resolved; the single patient with perioral scarring declined treatment because of a satisfactory cosmetic outcome.

All evaluators determined an improvement in wrinkle score for both anatomic sites. The improvement was judged as greatest by patients, followed by investigators and then panelists. Improvement correlated with the severity of wrinkling at baseline. Cosmetic appearance, based on a scale of 0 to 10, was likewise judged as improved by all evaluators, with greatest improvement noted by patients. The effects both of an increased number of passes and of increased voltage were separately evaluated. An improvement in wrinkles was seen with each. Specifically, patients receiving 3 passes were judged to have greater mean improvement than those who received fewer than 3, and patients receiving more than 125 V were similarly felt to have improved more than patients treated at 125 V.

In summary, the investigators found the procedure to be safe and effective. There was a trend toward greater improvement in class II and III wrinkles compared with class I wrinkles. RF resurfacing is appropriate for resurfacing isolated cosmetic units in patients with mild to moderate photo damage, and has the advantage of a quicker recovery period than ablative laser resurfacing. The device received Food and Drug Administration approval in March 2000.

SUBSURFACE/NONABLATIVE RESURFACING

The desire to avoid prolonged healing times required by the open wounds associated with traditional resurfacing led to the development of subsurface approaches to facial rejuvenation. Because epidermal ablation is not requisite for induction of a dermal wound–healing response, the goal is to bypass this layer, thus reducing both acute problems such as epidermal blistering and shortening wound healing times. Although clinical improvement may be more gradual and less dramatic, patients are generally spared lengthy recovery times. Multiple lasers and devices are being introduced that use this approach. The careful choice of wavelength and fluence and, often, the use of cooling devices, serve to create focal thermal damage within the dermis. The creation of a dermal wound without epidermal ablation forms the basis of subsurface or nonablative resurfacing.

Cooling systems in particular have been rapidly developed and incorporated into nonablative laser devices. The efficacy of skin cooling was first described with the first argon laser treatment of port-wine stains; decreased scarring was seen with pretreatment chilling of the skin with ice.[12] For example, high fluences with the Nd:YAG, are necessary for inducing localized dermal injury and may be safely used with efficient epidermal cooling. The underlying target, which is not cooled, is still capable of reaching the thermal threshold necessary for collagen contraction. In clinical practice, skin cooling is achieved through handpieces that either concurrently cool the skin or provide a short cryogen burst immediately before the laser pulse.[13] The depth of cooling is determined by the temperature of the cryogen and contact time with the skin.

Q-Switched 1,064 nm and 532 nm Nd:YAG

One of the first studies in subsurface remodeling was performed with the 1,064-nm Q-switched Nd:YAG laser.[14] The primary chromophore of the 1,064-nm wavelength is pigment and it is only weakly absorbed by water. However, the Q-switched 1,064-nm Nd:YAG laser provides the desired depth of penetration for subsurface remodeling, and the nanosecond range pulse duration limits thermal damage secondary to heat diffusion. In an early study, 11 patients with perioral or periorbital class I or II rhytids were evaluated. Results of unilateral ablative resurfacing using the CO_2 laser were compared with results of the contralateral Q-switched 1,064-nm Nd:YAG laser

treatment in each patient. All patients improved in the CO_2 laser treated areas and 9 of 11 patients had improvement with the Nd:YAG laser. While prolonged erythema among CO_2 treated patients was universal, only 3 of 11 patients treated with the Nd:YAG laser had erythema 1 month later. Interestingly, these same 3 patients had comparable improvements to CO_2-treated areas. The remainder had less or no improvement with the Nd:YAG treatment. Complete re-epithelialization with the Nd:YAG laser treatment occurred at 3 to 5 days, compared with 6 to 11 days required for re-epithelialization of areas subjected to ablative treatment.

Carbon Solutions with the Nd:YAG Laser

Topical carbon–assisted solutions have been used with the Q-switched 1,064-nm and 532-nm wavelengths to enhance laser absorption. The carbon solution absorbs the 532-nm wavelength, and to a lesser extent, the 1,064-nm wavelength. The 1,064-nm Q-switched Nd:YAG at low energy fluence has been used in combination with a topical carbon solution for perioral and periorbital photodamage.[15] At 8 months, 61 patients with 242 sites had a mildly beneficial effect in improving skin elasticity and reducing rhytids. The majority of adverse effects consisted of mild, brief erythema. There was no epidermal ablation seen with the low energy fluences administered.

Other proponents of topical carbon solutions have inspired controversy by showing "predictable thermal effects" using the Q-switched frequency-doubled 532-nm Nd:YAG laser.[16] The theory is that reproducible coagulation depths can be obtained by converting laser light to heat via the carbon solution, with subsequent heat transfer to tissue. The carbon solution prepared for this study formed a film that prevented penetration beyond the stratum corneum. A direct correlation between pulse duration and depth of dermal coagulation was found in experiments performed on rats. In contrast to the 1,064-nm wavelength at low energy fluence, epidermal ablation at the 532-nm wavelength was seen with all pulse durations. The use of carbon solution in this protocol is based on "standardization of skin thermal damage by controlling the heat source." The authors conclude that the Nd:YAG at the 532-nm wavelength, in conjunction with a carbon-assisted solution and proper laser exposure times, should be tested for resurfacing selected cosmetic units.

Recently, the use of a carbon lotion for nonablative therapy using the Q-switched 1,064-nm Nd:YAG laser has been tested for its effects on rhytids and dyschromias.[17] Twelve patients, 2 from each skin type, fair and dark, were treated at weekly intervals for a total of 4 sessions. Before the laser treatment, the skin was treated with a carbon lotion. While skin types I-III reported only a day or less of erythema and mild stinging, skin types IV-VI reported 0.5 to 1.5 days of purpura, blistering, and crusting. Both skin types showed an average improvement of 25% in rhytids, but dyschromias improved more markedly in darker skinned individuals—35% improvement, compared with 20% improvement in lighter-skinned subjects. Two cases of transient hypopigmentation in type VI skin necessitated reduction in the treatment fluence near the end of the treatment series. The idea of a carbon-assisted solution seems counterintuitive, as the carbon functions to increase heat absorption in the higher layers of the skin. This produces an "ablative" effect made evident by the blistering and crusting seen particularly in darker skin types, even at low fluences. Carbon solution in conjunction with the Nd:YAG laser remains experimental.

1,320-nm Long Pulse Nd:YAG

The 1,320-nm longpulse Nd:YAG laser (CoolTouch system; Laser Aesthetics, Auburn, CA) has been introduced for nonablative skin resurfacing. The depth of heat generated by the long-pulse 1,320-nm laser is selectively controlled through the use of an epidermal cooling system, which is activated immediately before the delivery of the laser energy. The CoolTouch delivers high-energy fluences of approximately 25 to 35 J/cm^2. The pulse width is 200 μs and is delivered in triple pulses. A penetration depth of about 200 μm can be reached with these parameters. The system handpiece combines a cooling cryogen spray, laser beam, and thermal feedback sensor. To preserve the epidermis, a cryogen burst of 20 to 40 ms, with a delay of 30 to 50 ms, is released before a 20-μs laser pulse. The unique thermal sensor provides negative feedback if epidermal temperatures do not remain in the range of 44°C to 48°C, inducing longer cooling spray times.

Since the major component of the epidermis

and papillary dermis is water, it seems to follow that the 1,064- and 532-nm wavelengths are not ideal wavelengths for resurfacing. The main chromophore of the 532-nm wavelength is hemoglobin; the 1,064-nm laser targets pigment, although there is weak absorption by water. The advantage of the 1,320-nm wavelength is that the primary chromophore is water. This unique wavelength easily penetrates into the upper dermis, where most of its energy is absorbed by tissue water. Initial studies with the 1,320-nm Nd:YAG laser compared laser irradiation with and without coolant of the skin of both animals (pigs) and humans. Selective thermal injury to the papillary and upper reticular dermis was achieved with the addition of cryogen spray cooling, using fluences of 20 to 36 J/cm^2. Without the coolant, the same energy fluences produced dermal injury as well as epidermal blistering and necrosis.[18] A subsequent clinical study by the same investigator revealed improvement in rhytids 2 months after treatment, without persistent erythema or pigmentary changes.

Histologic evaluation was performed in 10 subjects with class I-III rhytids after 4 monthly treatments with the 1,320-nm Nd:YAG laser.[19] Dynamic cryogen cooling of the epidermis was applied for 30 ms with a delay time of 40 ms before laser pulsing. Peak measured epidermal temperatures ranged from 40°C to 48°C. While 2 of 10 subjects showed no improvement clinically, 8 patients had some or substantial improvement. At 1 month, 6 of 10 subjects showed some histologic evidence of new dermal collagen formation, and all 10 patients had histologic evidence of new dermal collagen formation after 6 months. No blistering was noted, and final evaluation at 6 months revealed no erythema, pigmentary changes, or scarring in any individual.

Early results from an ongoing trial with the long-pulse 1,320-nm Nd:YAG laser have been published by Lask et al.[20] Twenty patients with mild to severe photo-damage were treated in the periorbital region and evaluated for side effects and clinical improvement. Single treatments were administered. Low radiant exposures were used to assess whether these treatments were sufficient for inducing synthesis of new collagen. Preoperatively, treatment areas were anesthetized with EMLA cream (Astra USA, Inc, Westborough, MA). The coolant provided an additional anesthetic effect. Overall, the patients said the procedure was mildly painful. One patient described the pain as severe, possibly (according to the investigators) because of inadequate anesthetic. All patients had some degree of erythema immediately after treatment. Additionally, 2 patients had edema and 1 had small blisters. Another 3 patients reported left-sided blisters only; these were believed to be due to excess cryogen cooling from a damaged handpiece. At 1 month after treatment, 3 of 19 patients had persistent adverse effects with 1 small bump, 1 case of hypopigmentation, and 1 case of hyperpigmentation. Short-term clinical follow up at 1 month in 18 of 20 patients has shown mild (0% to 25%) improvement in wrinkles in 72% of subjects and moderate (26% to 50%) improvement in another 28%, as rated by the investigators. All patients felt improved to some degree.

In another trial using the long-pulse 1,320-nm Nd:YAG, 35 patients were given 3 nonablative laser treatments performed sequentially at 2-week intervals.[21] Seventy periorbital treatment sites showed statistically significant improvement after 6 months in severe rhytids only. Interim analysis at 12 weeks showed improvement in the mild to moderate groups, possibly secondary to edema. Patients received topical EMLA anesthetic and described the procedure as only mildly uncomfortable. Four patients reported small superficial blisters. The subsequent postinflammatory hyperpigmentation resolved with hydroquinone in all cases. Additionally, 2 permanent "barely perceptible" pinpoint pitted scars developed. The authors suggested that optimization of treatment parameters would improve results.

In contrast, Menaker et al[22] recently reported improvement in only 4 of 10 subjects treated in the periorbital and perioral regions. Pitted scarring was seen in 3 patients at the 3-month follow-up period. However, the thermal feedback sensor was not used in this study, resulting in perhaps minimal response in some cases or overtreatment and scarring in others.

Ruiz-Esparza[23] evaluated the 1,320-nm Nd:YAG laser for full-face photorejuvenation. He treated 24 volunteers with varying degrees of photo damage at fluences below the threshold of pain. His technique requires the laser to be in the continuous mode, using the handpiece in a sweeping motion over the whole face. Treatments lasted 1 to 2 minutes. No cooling device was used.

An average of 28 treatments on a twice-weekly schedule for 3 consecutive months were administered to each subject. Five patients underwent biopsy testing before and after treatment. Although changes were mild to very mild, treatments were painless, and post-treatment erythema and edema did not occur. Subjective increases in "skin turgor" and "skin clarity and glow" were noted in 17 and 19 patients, respectively. The wrinkle improvement seen in 14 patients continued at the termination of the study at 6 months. Histologic changes were observed in all 5 specimens after 6 months; collagen appeared more homogenous and condensed, and dermal thickness increased. In this protocol, the advantage of having no down time may be offset by the frequent and large number of treatments necessary.

1540-nm Nd:YAG

Nonablative skin remodeling using a 1,540-nm laser with contact cooling was introduced in France.[24] The 1,540-nm wavelength offers better absorption by water, less scattering, and decreased melanin absorption than 1,064-nm or 1320-nm wavelengths. Again, cooling protects the epidermal layer. In this clinical and histologic study, male hairless rats were tested. Different energy fluences, using a single 3-ms pulse or pulse train irradiation and different cooling temperatures (−5°C, 0°C, +5°C), were evaluated. The rats were examined at 1, 3, and 7 days after the procedure. The clinical effects varied with both dose and cooling temperature. At all cooling temperatures, single-pulse irradiation led to epidermal injury, whereas pulse-train irradiation showed epidermal preservation and the confinement of thermal damage to the dermis. Histologically, new collagen synthesis marked by fibroblast proliferation was detected in the lower dermis at day 3 and in the upper dermis at day 7. Clinical evaluations of use of the contact cooling device and pulse-train irradiation on humans continue.

Intense Pulsed Light

Recently, a flash lamp that emits noncollimated, noncoherent light, or intense pulsed light (IPL) has been shown to induce mild improvement in rhytids without epidermal ablation. IPL treatments for skin rejuvenation are known by alternate names such as PhotoDerm (ESC Medical, Inc, Needham, MA). IPL is filtered and broadband; the emitted wavelengths can range from 550 to 1,200 nm, in the visible to near infrared spectrum. A filter is used to selectively block and define wavelengths below a certain threshold. The device is useful for a variety of skin lesions, including port-wine stains, telangiectasias, lentigines, and unwanted hair. Vascular lesions, for example, are effectively treated within the 550- to 570-nm range, while the longer wavelengths are probably superior for skin rejuvenation. Like wavelength, pulse width can be varied extensively, and double and triple pulsing is typically used. The IPL contact crystal is a large rectangular shape that permits a large surface area to be treated, compensating for the slow repetition rates. Although a cooling device is not incorporated into the system, epidermal cooling or topical anesthetic may be electively used.

IPL has been evaluated for subsurface remodeling of isolated cosmetic units as well as full-face rejuvenation. In a full-face testing protocol, 30 patients underwent 5 serial IPL treatments at 3-week intervals using a 550-nm cut-off filter and double pulsing.[25] Patients were given topical EMLA or Elamax (Ferndale Laboratories, Ferndale, MI) before the treatment sessions. The investigators were specifically aiming for subpurpuric parameters to speed up recovery. Both patients and physicians assessed results using pretreatment and post-treatment photographs. For the 150 treatments, a 2% incidence of purpura and swelling was documented, resulting in a 1- to 3-day recovery period. Erythema was commonly seen, but was resolved within hours. No scarring was reported. Clinical results were modest, with 49% of patients reporting a 75% or greater overall improvement in their skin's appearance. Seventy-three percent of patients reported a 25% or greater improvement in fine wrinkles, while 36% reported a 50% or greater improvement in fine wrinkles. Interestingly, 79% of patients reported a 50% improvement in their pore size. The investigators noted some benefit in all patients, from smoother texture to reduction in telangiectasias and improved pigmentation. Continued improvement was seen at the 6-month follow-up. Compared with pretreatment biopsies, post-treatment biopsies showed normalization of pigment, reduction of inflammation and telangiectasias, and new collagen formation. The investigators stress that,

with this protocol, a minimum of 5 treatments are necessary to produce visible results.

A comparison study between the subsurface remodeling efficacy of IPL and the long-pulse 1,064-nm Nd:YAG was reported by Goldberg.[26] Ten subjects with mild to moderate photo-damage were each subjected to 3 sets of parameters. Lateral canthal and temple (or crow's feet) regions were divided into upper and lower segments for a total of 4 treatment areas per patient. One segment received IPL using a 590-nm filter, another segment received IPL using a 755-nm filter, and a third segment was treated with the long-pulse 1,064-nm Nd:YAG laser. The final segment served as a control. Triple-millisecond pulses were used with both the IPL and Nd:YAG laser treatments. Each subject received up to 5 treatment sessions. All subjects were evaluated for clinical improvement as well as adverse effects. Erythema was seen in 6 of 10 patients treated at 590-nm, in 4 of 10 patients treated at 755-nm, and in no patients receiving the 1,064-nm laser. Similarly, blistering was seen in 6 of 10 patients who received IPL treatments at 590-nm as opposed to only 1 in 10 patients each who had been treated with the IPL at 755-nm and the 1,064-nm Nd:YAG laser. The investigators speculated that the high-energy fluences used were the probable cause of blistering. Furthermore, efficient epidermal absorption of the 590-nm wavelength may explain the greater erythema and blistering with this filter. At 6 months, no pigmentary alteration was seen, nor was any scarring or erythema evident. Improvement was graded on a scale from 0 to 10. Overall, patients graded their results similarly for all 3 treatments, with an average improvement of 4 in 10. The investigators rated improvement more conservatively than patients and in some cases saw no improvement.

Recent studies by Zelickson and Kist[27] seem to support the use of IPL for dermal matrix remodeling by citing an increase in various extracellular proteins in the papillary dermis.[27] Six weeks after treatment, the biopsies of 2 patients with moderate photo damage showed increases in collagen I, collagen III, elastin, procollagen, and hyaluronate receptors after a single IPL treatment. One of the 2 patients also exhibited an increase in collagenase, indicative of dynamic remodeling within the dermis. Ultimately, this dermal remodeling translates into clinical improvement.

Pulsed Dye Laser

Other nonablative lasers such as the pulsed dye laser (PDL) have an ability to improve rhytids. The PDL delivers yellow light that is well absorbed by hemoglobin. A possible role for the PDL in the treatment of rhytids has been suggested by the apparent dermal collagen changes that accompany improvement in hypertrophic scars and striae distensae.[28,29] Acne scarring, in particular, was noted to be significantly improved with 1 to 2 PDL treatments in a study by Alster.[30]

In a small pilot study, Kilmer and Chotzen[31] evaluated the PDL for the treatment of rhytids. Five female patients with mild wrinkling were administered single PDL treatments to the left lateral periorbital region and graded for improvement. Two of the 5 patients had a greater than 50% improvement in wrinkling, and 3 of 5 patients had a greater than 75% improvement at 6 and 12 weeks. All patients elected to have contralateral treatment in spite of postoperative purpura.

An expanded study by Zelickson et al[32] tested the effectiveness of the pulsed dye laser in treating sun-induced wrinkling of isolated cosmetic units. Twenty patients were treated, half with mild to moderate wrinkling, and the remainder with moderate to severe rhytids. Single PDL treatments were administered. Side effects included purpura and swelling in all subjects, which lasted from 1 to 2 weeks. Two subjects had postinflammatory hyperpigmentation. At 6 months, more than half of the patients showed clinical improvement with a single PDL treatment. Ninety percent of the patients with mild to moderate wrinkling and 40% of the patients with moderate to severe wrinkling had clinically observable improvement. Several patients monitored for 14 months showed progression of their wrinkling. Thirteen patients underwent pretreatment and 12-week post-treatment biopsies. Histologic examination of the treated areas showed an increased amount of normal staining in elastic and collagen fibers in the superficial dermis, with increased cellularity and mucin deposition.

The effect of the PDL on dermal matrix proteins, studied by Zelickson and Kist, supports the collagen remodeling concept.[27] In the same protocol, examining the effects of PDL on dermal collagenesis, 5 patients with moderate photo damage were administered a single PDL treatment.

Biopsies 6 weeks aftertreatment showed increases in collagen I, collagen III, collagenase, and elastin in 86% of specimens. Procollagen was increased in 71% of specimens, and 57% showed an increase in hyaluronate receptor. These increases are indicative of a reparative response and illustrate that dermal remodeling is not specific to 1 wavelength, as similar changes were induced with intense pulsed light.

Erbium:YAG

Since the advent of the Er:YAG laser, clinicians have been given a new way to perform laser abrasion with potentially fewer adverse effects. The peak absorption of water is 3,000 nm. The Er:YAG laser, at 2,940 nm, absorbs water 15 times more efficiently than the CO_2 laser, resulting in a very precise ablation of tissue.[33,34] Traditionally, the Er:YAG laser is used for ablative resurfacing and has an ablation threshold of approximately 1.5 to 2.5 J/cm^2.

The application of the Er:YAG laser to nonablative resurfacing has been investigated by Kelley et al.[35] In animal studies, cryogen-spray cooling was used in combination with subablative fluences to achieve selective dermal remodeling with the Er:YAG laser. Multiple laser pulses were rapidly administered to Spraque-Dawley rats, and histologic sections were examined for epidermal injury and dermal coagulation. Evaluation of specimens at 1 hour showed epidermal preservation with only "minimal damage" and dermal coagulation to a depth of greater than 100 μm. Hypercellularity and compact collagen were found in subsequent biopsy specimens at 4 and 8 weeks. Although not tested in humans, this procedure offers yet another potential form of subsurface remodeling, with preservation of the epidermis through the use of low fluences and cryogen-spray cooling.

Reverse Thermal Gradient Nonablative RF Resurfacing

The nonablative lasers tested to date require multiple treatment sessions to achieve gradual, visible improvement. A new device that can produce immediate collagen contraction with a single treatment has been tested in animals. The Thermage nonablative RF device (Howard, CA) uses RF energy with simultaneous contact cooling for epidermal preservation. A cryogen sprayed onto a contact cooling plate ensures epidermal cooling before, during, and after energy delivery. The handpiece delivers RF energy to a 1-cm^2 area.

Although long-term data are not available, the new nonablative RF device was recently evaluated for its effects on skin contraction in animals.[36] A total of 12 guinea pigs and 216 treatment sites (1-cm^2 grids) were studied. Three different power settings were tested: 70 J, 85 J, and 100 J. Initial skin contraction was measured with hand calipers. In 13 instances, significant local blanching occurred. In each case, this progressed to scabbing over a 3- to 4-day period after treatment. Within 2 weeks all scabbing had resolved, although erythema persisted. One month after treatment, only 1 case of erythema remained. The investigators established a correlation between the amount of energy applied and the amount of skin tightening immediately after treatment. With high-power settings, contraction ranged from 6.9% to 9.1%. For the medium-power settings, skin contraction averaged 5.1% to 5.7%. The lowest setting produced 1.7% to 2.8% skin contraction. Histology indicated preservation of the epidermis in 94% of the treated specimens; the remaining 6% of the treated grids demonstrated significant epidermal injury. These results in skin contraction suggest that immediate collagen denaturation occurs with the nonablative RF system. Characteristically, denaturation is followed by a period of neocollagenesis. When the final data are analyzed, the study will determine whether the initial skin tightening is maintained over time. The low rate of epidermal ablation in guinea pig skin suggests a comparable safety profile in human skin.

OTHER RESURFACING SYSTEMS

Microdermabrasion

Aluminum oxide crystal microdermabrasion, developed in 1985, uses a double system of projection and suction within a flexible tube in order to achieve superficial wounding of the skin. Crystals are projected against the skin via a handpiece that directly contacts the cutaneous surface. A second circuit aspirates the crystals and debris bringing about superficial epidermal detachment and, subsequently, an increased blood flow to the area. With the tip of the handpiece perpendicular to the skin surface, a linear sweeping or rotary movement about a central point permits treatment of

the desired area. Depth of the abrasion depends on pressure and duration of contact. Surface area may vary, but a single session for the face lasts 15 to 30 minutes. In general, abrasion is limited to the epidermis, but superficial dermal abrasion may be desirable in the treatment of rhytids and scars.

The advantages of microdermabrasion are numerous, including simplicity of use, safety, and comfort to the patient. These make it a very popular procedure. Patients rarely require local anesthesia, usually none at all, and need no preoperative medications. The ejection of debris and blood, a hazard with traditional dermabrasion or laserabrasion, is eliminated by the aspiration system of the device. Inconvenience to the patient is minimal; after the procedure, an emollient cream to treat desquamation may be all that is necessary. Erythema is mild and transient and is often perceived as beneficial by the patient. Short-lived edema, often perceived as beneficial by the patient, is less often experienced. After the procedure, a normal appearance quickly returns, and benefits last several weeks. Treatments are performed at 1- to 2-week intervals, usually as a series of 6 treatments. If dermal abrasion is done, treatment intervals are accordingly increased.

The potential hazards associated with aluminum oxide crystals are minimal. Aluminum oxide is chemically inert, and granuloma formation in the skin does not occur. The conjunctival congestion and punctate keratopathy discussed by Lu et al[37] are easily avoided through the use of protective eyewear. The suggestion that aluminum is involved in the pathogenesis of Alzheimer's disease[38,39] appears unfounded, as this would require the introduction of aluminum into the tissues of the body, a phenomenon that does not occur with microdermabrasion. Airborne particles may be inhaled but are effectively cleared by the respiratory epithelium.[40] There is some concern about nasal congestion but it does not seem problematic.

Large, controlled studies using microdermabrasion are lacking, but one group assessed its effectiveness on various types of facial scarring.[41] Patients received a variable number of treatments at 1 to 2 week intervals, and sessions were terminated when sufficient improvement was appreciated. Forty-one patients completed the treatment with good to excellent clinical improvement in scarring, including 16 cases of acne scars, 18 traumatic scars, 3 cases of surgical scars, 1 burn scar, 2 cases of chicken pox scars, and 1 angiofibroma. Mean frequencies of treatments were 15.19 for acne scars, 4 in cases with traumatic and surgical scars, and 5.5 in patients with chicken pox scars. Abraded skin healed 3 to 5 days after each session; no significant side effects were seen. Postinflammatory hyperpigmentation was mild and transient when present. There was progressive increase in erythema with repeated treatments. A single patient, after 26 treatments, underwent biopsy, which showed slight fibrotic changes in the upper dermis.

Ambulatory microdermabrasion has more limited clinical indications than laser resurfacing. Ablation is superficial so that deep acne scars and rhytids are not amenable to this therapy. For fine wrinkling, concomitant topical therapy with fruit acids or Retin-A (Ortho Pharmaceutical, Inc, Raritan, NJ) aids in maintaining an improved appearance. Likewise, in the treatment of acne, microdermabrasion is used as an adjuvant to systemic and topical therapy, perhaps aiding the absorption of topical medications. Fine wrinkling, thin actinic and seborrheic keratoses, comedones, solar lentigines, soft and elevated scars, and textural irregularities may respond to serial treatments.

CONCLUSION

Surgical alternatives to Er:YAG and CO_2 laser resurfacing are rapidly expanding. Although the CO_2 laser and the newer variable pulse duration Er:YAG laser remain the gold standards for rejuvenating photo-damaged skin, their use for resurfacing is accompanied by a lengthy and often painful postoperative recovery period. As with the traditional resurfacing lasers, the goal for new rejuvenating systems is collagen contraction and remodeling, but the treatment principles and results are sometimes vastly different. For nonablative resurfacing, the ability to selectively confine thermal injury to the papillary and upper reticular dermis results in reduced patient discomfort, fewer complications, and less down-time. Patient demand for these devices will become greater as nonablative systems are refined and prove capable of producing predictable, consistent results. Ideally, this clinical improvement should be maintained over time.

The Visage electrosurgical system (ArthoCare Corp) is a form of ablative resurfacing that can induce collagen contraction and remodeling by

using sodium plasma energy to disrupt molecular bonds. It is useful for the treatment of isolated cosmetic units and requires a single procedure. Clinical results and recovery times are comparable to those of the Er:YAG laser. Re-epithelialization occurs within 1 week and erythema typically resolves within a month. While scarring has been known to occur with this system, the lack of dose dependency offers a safety net, and ablation depths typically plateau after several passes.

The nonablative resurfacing devices provide even shorter recovery periods by sparing the epidermis from ablation. Q-switched Nd:YAG laser treatments may achieve dermal remodeling, but their use has been superseded by the long-wavelength 1,320-nm Nd:YAG. There are few proponents of using carbon solutions in conjunction with the Nd:YAG for resurfacing purposes.

The CoolTouch 1,320-nm Nd:YAG, which incorporates a cooling device into the system, is currently available for photo-rejuvenation. Three to 6 monthly treatments can produce modest, incremental improvement. Side effects, if they occur, consist of mild erythema and edema. Scarring has not been reported with the model currently commercially available. Because of the lack of epidermal ablation, dyschromias and surface irregularities such as actinic keratoses require adjuvant treatment.

IPL sources need further investigation to optimize treatment parameters. Clinically, modest improvement in rhytids can be achieved. Increases in extracellular matrix proteins provide evidence for a dermal wounding response, and neocollagenesis is supported histologically. Purpura may complicate treatment if low fluences are not used, making multiple procedures necessary to achieve a visible effect.

PDL systems have long been plagued by post-treatment purpura. Newer models such as the V-Beam (Candela, MA) offer promise for reducing or eliminating this cosmetically unacceptable adverse effect through the use of cooling devices, longer wavelengths, and longer pulse widths. The proposed mechanism for the reparative response with the PDL may differ from that of other forms of nonablative rejuvenation. Whereas other methods seem to rely on thermally-induced injury as a direct result of laser energy absorption by collagen, the PDL may rely on destruction of vascular structures that would lead to tissue ischemia and influence the dermal extracellular matrix. Alternatively, the direct conduction of heat to perivascular structures, including collagen, may induce a remodeling response.

Perhaps with the exception of microdermabrasion, the systems described herein are all capable of altering the collagen network. While clinical results with these systems may be modest, physicians are now afforded greater flexibility in treating patients who are intolerant of the temporal, physical, and psychological demands associated with recovery from traditional laserabrasion. An even greater number of techniques available for facial rejuvenation will follow. For example, in a recent trial, low-level laser therapy resulted in significant reduction in acne lesions and scarring.[42] The hypothetical dermal collagen changes that accompany improvement in scarring suggest expanded use of low-level laser therapy for the treatment of rhytids.

Several of these technologies require further analysis. Results of early testing of the nonablative Er:YAG laser, the nonablative RF resurfacing device, and the 1,540-nm glass:YAG laser show that each has an effect on neocollagen formation, but the long-term effects as well as their role in human neocollagen formation have yet to be elucidated.

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