Three-Dimensional Rejuvenation of the Photoaged Body

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Because of the multilayered pathophysiology of photoaging, a 1-dimensional approach targeting only a single skin layer is destined to fail. The treatment should address all affected skin layers in a multidimensional approach. Combining superficial and dermal procedures along with fillers for volume augmentation is the key to addressing these issues.

The 3-dimensional photoaging rejuvenation concept focuses on 3 types of rejuvenation corresponding to different skin layers. For each type, various scientifically proven procedures are available. However, combining the right techniques is sometimes difficult, as improvements in established modalities and new developments are continuously evolving. *Cosmet Dermatol.* 2011;24:381-387.

Photoaging is the premature aging of the skin caused by chronic UV exposure, particularly by UVA (320–400 nm) but also by UVB (290–320 nm) exposure. The clinical signs are discoloration, elastosis, deep wrinkles, and laxity, as well as inflammation and vascular lesions,[1] often accompanied by skin roughness and enlarged pores.[2] Furthermore, there also is a loss of volume attributable to lipoatrophy through transcriptional regulation of lipogenic enzymes triggered by UV radiation.[3] These factors together give photoaged skin its typical uneven and leathery appearance. In addition to the face, the most affected areas are the neck, décolletage, shoulders, forearms, and hands. Photoaging of the whole body is common in tanning bed users and sun worshippers.

Because of the multilayered pathophysiology of photoaging, a 1-dimensional approach targeting only a single skin layer is destined to fail. For a successful and satisfying outcome for the patient, the treatment needs to address all affected skin layers in a multidimensional approach. Combining superficial and dermal procedures along with fillers for volume augmentation is the key to addressing these issues. Although superficial treatments focus on discoloration and rough skin, dermal treatments focus on wrinkles, laxity, and vascular lesions. The deep dermal and subcutaneous approach is to tighten skin and replenish volume loss. For maximal safety and minimal

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downtime, rejuvenation approaches to the photoaged body should be nonablative, which corresponds to patients' expectations about the new natural look.[4]

The 3-dimensional photoaging rejuvenation concept focuses on 3 types of rejuvenation corresponding to different skin layers. The goals of type 1 rejuvenation are optimization of epidermal turnover and uniform chromophore distribution. Type 2 rejuvenation is deeper and targets decreased collagen, disorganized glycosaminoglycans and elastin, and superficial rhytides. Rejuvenation type 3 is deepest and targets deep dermal collagen disorders and skin laxity as well as loss and redistribution of subdermal fat. For each of these rejuvenation goals, various scientifically proven procedures are available. However, combining the right techniques is sometimes difficult, as improvements in established modalities and new developments are continuously evolving.

TYPE 1 REJUVENATION: EPIDERMAL TURNOVER AND UNIFORM CHROMOPHORE DISTRIBUTION

Treatment modalities for type 1 rejuvenation can be divided into superficial peeling systems and nonablative systems. Although both groups target pigment irregularities, peeling systems have a slight advantage in improving skin texture and radiance, whereas nonablative systems can additionally improve vascular conditions such as erythema or telangiectasia.

Superficial Peeling Systems

Superficial chemical peels affect the epidermis and dermal-epidermal interface; they can be used in nearly all skin types.[5] They decrease corneocyte adhesion and can increase dermal collagen.[6,7] Regeneration can be expected within 3 to 5 days. Common agents for superficial peels today include hydroxy acids, such as glycolic acid; salicylic acid; β-lipohydroxy acid; or tretinoin.[8] In a concentration of 10% to 20%, trichloroacetic acid also can be used for superficial peels.

Microdermabrasion is a minimally invasive procedure that relies on an abrasive component and a vacuum component. Most systems use a handpiece embedded with a coarse inert crystal that is applied to the skin surface.[9] Even though the ablation affects only the stratum corneum, a study by Karimipour et al[10] demonstrated increased type 1 collagen deposition in the upper dermis after a single treatment. Clinical evidence is given for the improvement of skin texture, fine wrinkles, and dyspigmentation.[11,12]

A new modality for superficial ablation is laser micropeeling. Based on a variable-pulse erbium:YAG (Er:YAG) laser with a wavelength of 2950 nm, tissue is vaporized up to 50 µm. Benefits of this modality are its tolerability under topical anesthesia, limited downtime, and high patient satisfaction with just a single procedure.[13] Studies showed a reduction in dyschromia and low postprocedure erythema,[14] but the results were not superior to intense pulsed light (IPL).[15]

Nonablative Systems

Short-pulsed lasers and IPL devices can be used for nonablative therapy of pigment irregularities and vascular conditions. Both modalities are based on the absorption of photons by chromophores leading to photothermolysis of the target structure. Because of the wide absorption spectrum of melanin (500–1100 nm), several laser systems with a pulse width in the nanosecond range are effective in the removal of pigmented lesions, including the pulsed dye laser (595 and 607 nm)[16,17]; the Q-switched ruby laser (694 nm)[18]; the Q-switched alexandrite laser (755 nm)[19]; and the Q-switched Nd:YAG laser (1064 nm),[20] which can be frequency doubled to produce visible green light with a wavelength of 532 nm.[21] Intense pulsed light with its wavelength spectrum of 500 to 1200 nm also targets melanin well. Because of the longer pulse durations in the millisecond range, a darkening and sloughing of the treated spots often is seen after treatments and makes IPL only second best for the treatment of pigmented lesions.[22]

Oxyhemoglobin has an optimal absorption range of 577 to 660 nm and needs a higher pulse duration than melanin.[23] Good evidence has been shown for the treatment of smaller superficial vessels, often seen in telangiectasia[24] or poikiloderma,[25,26] with microsecond pulsed dye lasers. For the treatment of larger deeper vessels containing more deoxyhemoglobin, longer wavelengths around 940 nm are needed. Because these vessels absorb light of the near-infrared spectrum, they are best treated with Er:YAG lasers.[27] Intense pulsed light with its wide spectrum (410–1400 nm) and millisecond pulse has been proven to treat small, more superficial vessels,[26] as well as deeper bigger vessels.[28]

TYPE 2 REJUVENATION: DERMAL FIBER NETWORK

The second type of rejuvenation primarily targets the fiber network of the papillary dermis to improve decreased collagen as well as glycosaminoglycans and disorganized elastin. Light-based systems with wavelengths in the infrared spectrum and radiofrequency (RF) devices are particularly suitable to reach this deeper layer with only partial or without epidermal ablation, accompanied by a short downtime. Good results can be expected with 1064-nm Nd:YAG lasers using high-power micropulses,

high repetition, and large spot size to obtain bulk heating. Multiple clinical studies employing this method have demonstrated mild but reproducible improvement in rhytides with histologic evidence of neocollagenesis after treatment.[29,30] For the treatment of photoaged skin with the fractional 1550-nm Er:YAG laser, clinical evidence is given for the treatment of wrinkles and dyschromia at the neck, décolletage,[31] and hands (Figure 1).[32] A new fractional dual-wavelength laser combining 1550-nm Er:YAG and 1927-nm thulium:YAG fibers promises even better results for the treatment of nonfacial photodamage.[33] The 1927-nm wavelength has a higher absorption coefficient for water than the 1550-nm wavelength, accompanied by a greater ability to target epidermal processes such as dyspigmentation and dyschromia.

In addition to its superficial effects on photoaged skin, IPL also affects the collagen in the upper dermis. Analysis showed that after a single IPL treatment, collagen was increased, elastin content was decreased, and elastin fiber arrangement was improved.[34] These histologic findings correlate with the clinical improvements seen in one other study.[35] The combination of IPL with RF leads to a synergistic effect, resulting in further improvement of wrinkles and skin texture accompanied by a reduction of skin laxity.[36] The energy of the light source preheats the target through selective tissue absorption, resulting in lowered impedance and providing a preferential conductive pathway for RF.

TYPE 3 REJUVENATION: DEEP RHYTIDES, SKIN LAXITY, AND VOLUME LOSS

The targets of type 3 rejuvenation are missing and disorganized collagen fibers in the deep dermis as well as subcutaneous volume loss due to UV-triggered lipoatrophy.

Rhytides and Skin Laxity

Several different platforms are in clinical use for the treatment of skin laxity. They can be separated into light-based systems such as lasers and broad-spectrum light sources, systems based on ultrasound or RF, and platforms combining different approaches.

Light-Based Systems—Light-based systems for the treatment of deep wrinkles and skin laxity need wavelengths that are strongly absorbed by tissue water. Particularly suitable lasers are the CO_2 (10,600 nm),

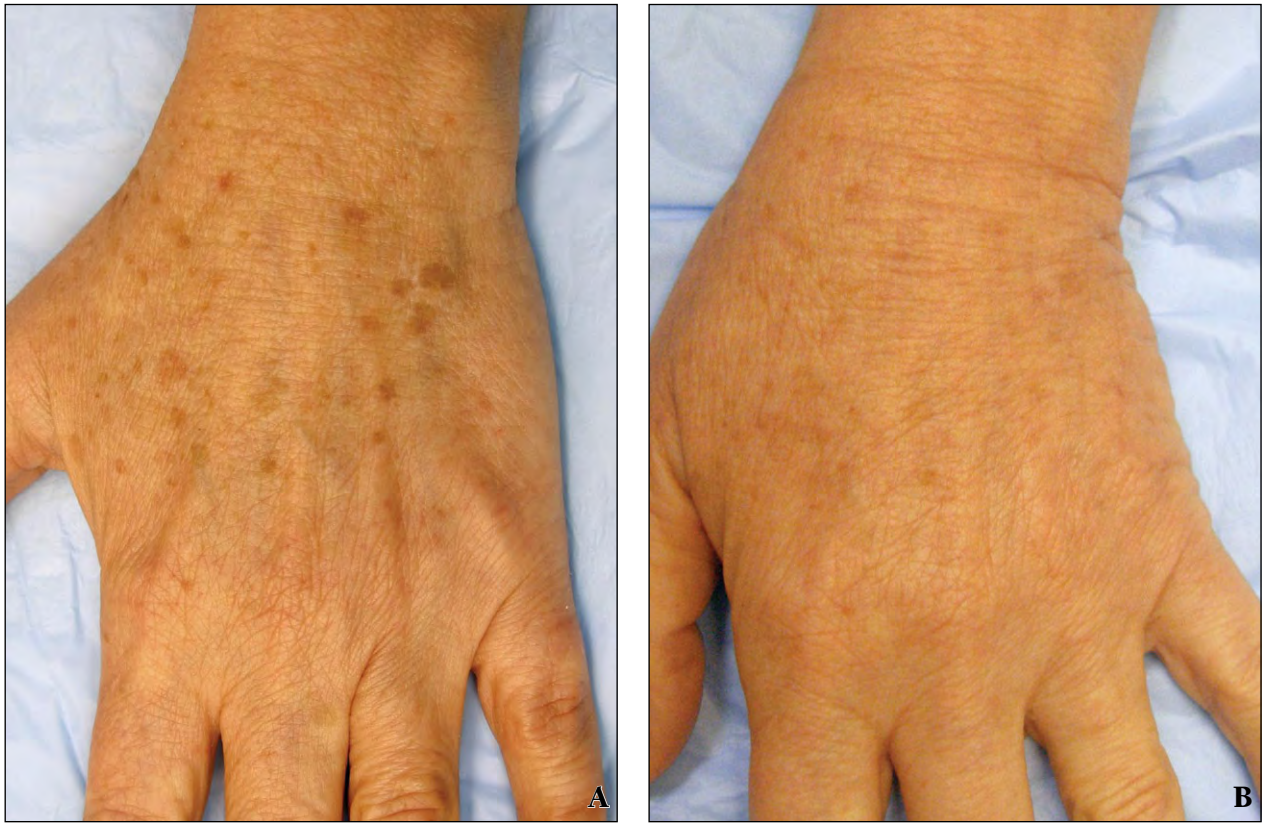

Figure 1. Photoaged skin on the left hand before (A) and after 2 treatments with the fractional 1550-nm erbium:YAG laser (B).

the 2790 nm erbium:yittrium scandium gallium garnet (Er:YSGG), or the 2940 nm Er:YAG. They can penetrate deep into the dermis independently from hemoglobin and melanin. Depending on pulse duration, fluence, and number of passes, they provide the ability to thermally ablate controlled layers of tissue with accuracy. Although CO_2 lasers are still the gold standard for skin rejuvenation, Er:YAG and Er:YSGG lasers offer a more precise ablative quality with minimal thermal damage to the surrounding tissues, resulting in less severe side effects and faster overall healing times.[37] Because of the prolonged recovery time and substantial risk for postoperative hyperpigmentation and hypopigmentation, scars, and other complications of ablative laser rejuvenation, fractional microablative resurfacing has become more important.

In contrast to ablative skin resurfacing in which a confluent uniform patch of dermal injury is induced, fractional resurfacing thermally ablates microscopic columns of epidermal and dermal tissue in regularly spaced arrays over a fraction of the skin surface. After a 48- to 72-hour phase of acute thermal damage, a phase of reepithelialization and repair starts, which is mediated by the adjacent columns of intact tissue. In this 30-day phase, the areas of thermally ablated tissue are repopulated by fibroblast-derived neocollagenesis and epidermal stem cell reproduction.[38] Because of the combination of ablation, coagulation, and deep dermal heating, the advantages of microablative fractional rejuvenation are collagen neosynthesis, tissue shrinkage, and enhanced collagen tightening.[39]

Another light-based system for treating the photoaged body is an infrared light source with a broad spectrum of 1100 to 1800 nm. It works by heating the dermis to achieve shrinkage and neogenesis of collagen fibers. Several clinical studies shows distinct reduction of skin laxity in facial and nonfacial photoaged skin.[40-42] A histologic study by Tanaka et al[43] show an increase in collagen and elastin levels up to 90 days after radiation. For the treatment of the photoaged body, fluences of 37 to 47 J/cm^2 with 2 to 4 passes are common.

Ultrasound Systems—An alternative to light-based systems is the use of intense ultrasound. This platform works by selective thermal coagulative change within the focal region of the beam while leaving the remaining regions unaffected.[44] The heating of the tissue is caused by friction developed between the molecules due to the vibration induced by the ultrasound waves. The system creates approximately 1-mm^3 zones of dermal coagulation at 3- to 4.5-mm depths depending on different probes with 4 to 7 MHz. The same transducer that delivers the focused heat to the dermis also is used to get a sonographic image of the skin to target the right depth, which is unique to this platform. Intense ultrasound is histologically[45-47] and clinically[48] proven to coagulate collagen and thereby tighten the facial and nonfacial skin. It is a safe and nonablative system with very little discomfort. Side effects are mild to moderate erythema immediately following treatment and, more rarely, elevated white linear striations.[48]

Radiofrequency Devices—Radiofrequency devices are another nonablative treatment modality for UV-induced skin laxity of the body. Radiofrequency devices produce a current that is passed through the skin, thereby causing heat from tissue resistance. The heating causes direct collagen contraction and immediate skin tightening.[49,50] Subsequent remodeling, reorientation of collagen bundles, and formation of new collagen due to wound healing is achieved over months after the treatment.[49,51] Several technologies currently on the market vary based on the number of electrodes. Unipolar systems have 1 electrode and a grounding pad, which is placed beneath the body. As the current passes from the electrode to the grounding pad, the penetration is deep and a high temperature develops near the electrode, requiring intense epidermal cooling.[52] In clinical studies, unipolar RF proved effective in the treatment of skin laxity and rhytides.[53,54] Known complications are discomfort, persistent erythema, nodularity/panniculitis, burns, and dermal adhesions.

Bipolar RF systems have 2 electrodes at a fixed distance with the current passing from 1 electrode to the other. The main advantage is the controlled distribution of the current inside the tissue, as the depth of penetration is half the distance between the electrodes.[52] Even if the depth of penetration is superficial, active cooling is necessary to prevent epidermal burns. The clinical indications and effects achieved are similar to unipolar RF[55] but with a lower risk profile and less discomfort. A recent development is a multifrequency bipolar system, which combines the frequencies 0.8, 1.7, and 2.4 MHz to target specific tissue depths. The clinical evaluation for this new platform is underway but not yet published.

Multipolar devices have 3 to 6 electrodes controlled by 1 to 3 RF generators. Although their penetration is superficial, they have deep dermal volumetric heating and no cooling is needed. Furthermore, they are less painful than unipolar or bipolar systems.[56] Their efficacy and tolerance in skin tightening and stimulation of collagen neosynthesis is shown in several studies.[57,58] A further stage is the combination of multipolar RF and magnetic pulses. Although RF increases collagen and elastin synthesis, the magnetic pulse field should increase the production of fibroblast growth factor β2.[59] The benefits of this platform are lower overall energy, increased safety, and no need for pretreatment preparation and topical cooling agents.

Volume Loss

After focusing on rough skin, discoloration, vascular lesions, wrinkles, and skin laxity, the last important step in 3-dimensional rejuvenation is to augment volume loss. Volume loss due to photoaging affects the hands, but the décolletage should be mentioned too, as the treatment of rhytides could improve the overall appearance. Most qualified for this approach are fillers such as hyaluronic acid and autologous fat injection treatments with poly-L-lactic acid and calcium hydroxylapatite (CaHA).

Poly-L-lactic acid is a biocompatible, biodegradable, immunologically inert, semipermanent soft tissue filler that stimulates local fibroblasts to promote neocollagenesis.[60] It is placed into the reticular dermis and subcutaneous tissue planes and lasts up to 2 years or more. Its efficacy in the treatment of nonfacial photoaging has been shown for the hands,[61] neck,[62] and chest. Adverse events for poly-L-lactic acid (eg, ecchymoses, edema, pain, pruritus, inflammation, nodules, hematomas) are not uncommon and have been reported with an incidence of 8.5% (11/130) for the face, hands, chest, or thighs.[63]

Because synthetic CaHA is identical in chemical composition to the inorganic constituent of teeth and bone, it is nonantigenic, nonirritating, and nontoxic. The particles have a diameter of 25 to 45 µm and are blended in a gel that contains water, glycerin, and sodium carboxymethylcellulose.[64] After injection, the CaHA particles are fixed in place with thin connective tissue without reaction in surrounding tissue, evidence of migration, or evidence of heterotopic bone growth.[64] After 18 months, the microspheres begin to degrade into metabolites consisting of calcium and phosphate ions. Besides the use for facial augmentation, CaHA is particularly suitable for the treatment of volume loss in the hands, as it produces a smooth and natural-looking result (Figure 2).[65] Studies showed good results with only some temporary swelling as a side effect.[66,67]

CONCLUSION

Three-dimensional rejuvenation of the photoaged body is an emerging area of aesthetic dermatology. The concept of specific approaches to achieve 3 different types of

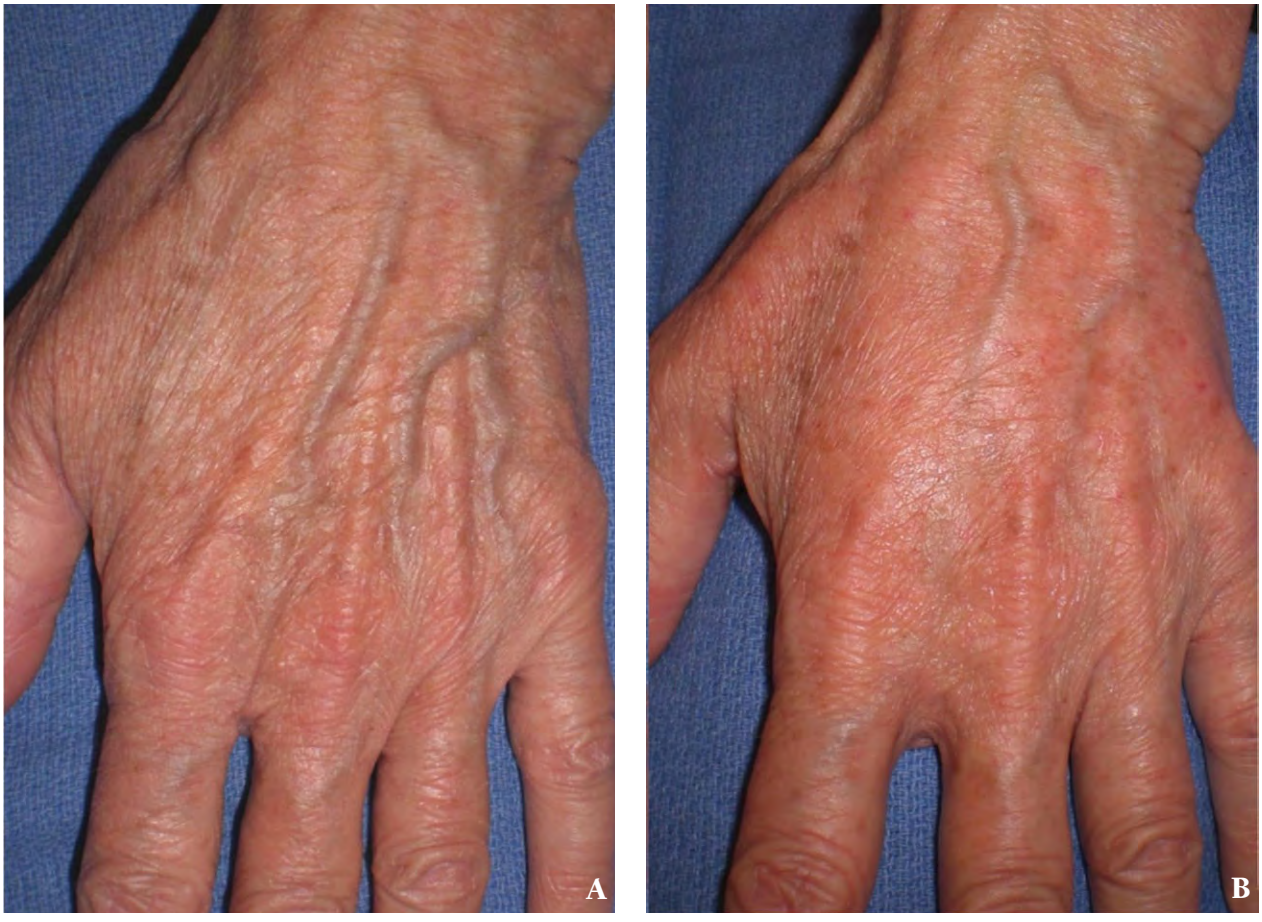

Figure 2. Volume loss on the left hand before (A) and after injection of calcium hydroxylapatite (B).

rejuvenation gives a precise tool to the attending physician. Combining physical modalities with dedicated fillers to treat discolorations, elastosis, deep wrinkles, and laxity, as well as inflammation and vascular lesions, leads to enhanced clinical results and greater patient satisfaction.

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