Microneedling: a new approach for treating textural abnormalities and scars

Sara Hogan, MD, MHS;[1] Mara Weinstein Velez, MD;[2] and Omer Ibrahim, MD[3]

Abstract

Microneedling is a minimally invasive procedure wherein small holes are created across the stratum corneum while keeping the epidermis partially intact. This produces microchannels that increase skin permeability and simultaneously stimulate growth factor release. Since the epidermis is retained, microneedling has less risk of infection, postinflammatory hyperpigmentation, and scarring compared to other resurfacing modalities. This is a review of the literature on microneedling in the treatment of textural abnormalities, specifically rhytides, scars, and striae.

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Microneedling is a minimally invasive procedure in which small holes are created across the stratum corneum while keeping the epidermis partially intact. This creates microchannels that increase skin permeability and simultaneously stimulate growth factor release as these microscopic perforations heal. A growing amount of evidence supports the utility of microneedling in the treatment for an expanding number of dermatologic conditions including photoaging, dyspigmentation, and laxity. In the following article, we review the medical literature on microneedling in the treatment of textural abnormalities, specifically rhytides, scars, and striae.

History of microneedling

Microneedling was first described in 1995 by Orentreich and Orentreich who at that time termed it "subsicion."[1] In the vertical application of subscision, a needle was inserted at 90 degrees to disrupt muscle attachments of the superficial musculoaponeurotic system, and in turn, soften rhytides. They postulated that this "controlled trauma" initiated wound healing and connective tissue formation to augment depressed skin areas.[1] The following year Fernandes tunneled a 15-gauge needle parallel to the skin surface to treat perioral rhytides, calling this method "percutaneous collagen induction," for which he theorized that intentional scarring of the dermis would build up underlying connective tissue.[2] Although treated areas improved, patient bruising was significant and hard nodules were noted. Fernandes subsequently designed a matrix of sharp needles that would evenly penetrate skin from the epidermis to the reticular dermis—the prototype for the microneedling roller. In 1997, Camirand and Doucet published findings of improvement in texture and color of scars treated with a tattoo gun, in a process they called "needle abrasion." They developed this technique after noting improvement of hypopigmented scars of rhytidectomy patients who were treated the previous year with flesh-colored ink tattooing.[3] They posited that trephination by the tattoo gun alone was responsible for a mechanical realignment of collagen fibers.[2,3]

Mechanism of microneedling

The mechanism by which microneedling exerted its effects was elucidated when Fernandes later expanded his study of percutaneous collagen induction. He document its mechanism of action via the 3 phases: (1) inflammation, (2) proliferation, and (3) remodeling (Figure 1).[4] The inflammatory phase occurs shortly after microneedles penetrate the epidermis and superficial dermis, causing localized damage to superficial blood vessels and collagen bundles, and the release of platelets and neutrophils.[4,5] Within hours, barrier properties of the epidermis are recovered via secretion of lamellar bodies and lipid synthesis.[6] Epidermal microchannels rapidly heal by transepidermal migration of keratinocytes; however, longer needles with wider cross-sectional areas and occlusion can retard this process up to 40 hours.[6,7]

In the proliferative phase, occurring about 5 days after treatment, neutrophils are replaced with monocytes. These monocytes transform into macrophages that together with platelets release growth factors (eg, TGF-ß1, TGF-ß3, platelet-derived growth factor, connective tissue activating protein III). [4,5] Microneedling in mouse models was found after 2 weeks to upregulate gene expression of all 3 forms of TGF-ß, especially TGF-ß3 (a suppressor of scar formation) and TGF-ß2, and to a lesser extent TGF-ß1; at 8 weeks, TGF-ß2 was significantly downregulated, while especially TGF-ß3 remained upregulated.[8] Also during this phase keratinocytes start to reestablish the basement membrane by increasing laminin and collagen production, and a fibronectin matrix forms to align with fibroblasts and provide a scaffold for collagen deposition.[4,5]

The remodeling phase can last from 8 months to 1 year. After 12 weeks, immunohistochemical assays of both human skin and animal models treated with microneedling demonstrate a statistically significant increase in epidermal thickness, development of rete ridges, and neoformation of collagens I, III, and IV.[4,9,10] These new collagen fibers are evenly spaced, unlike those seen with scars.[9] Collagen III is the primary type of collagen present in early wound healing, and is gradually replaced by collagen I over time with changes in dermal structure. At 3 months, one study of histological staining demonstrated a decrease in dermal elastin, which was interpreted by authors as a reorganization of aberrant fibers or even a decrease in solar elastosis.[11] In contrast to normal wound healing where scar tissue is formed with limited normal tissue regeneration, it is thought that the controlled trauma of microneedling minimizes environmental stresses (eg, infection, air,

[1]Cleveland Clinic Foundation, Cleveland, Ohio.
[2]Schweiger Dermatology Group, New York City, New York.
[3]Skincare Physicians, Chestnut Hill, Massachusetts. Dr Ibrahim is now with Chicago Cosmetic Surgery and Dermatology, Chicago, Illinois.
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Correspondence: Sara Hogan; sara.hogan@gmail.com

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ultraviolet radiation, mechanical tension) to maximize tissue regeneration.[12] The ultimate result of treatment is tightening of skin laxity, smoothing of scars, and improvement of wrinkles. These effects can last for 5 to 7 years.[4]

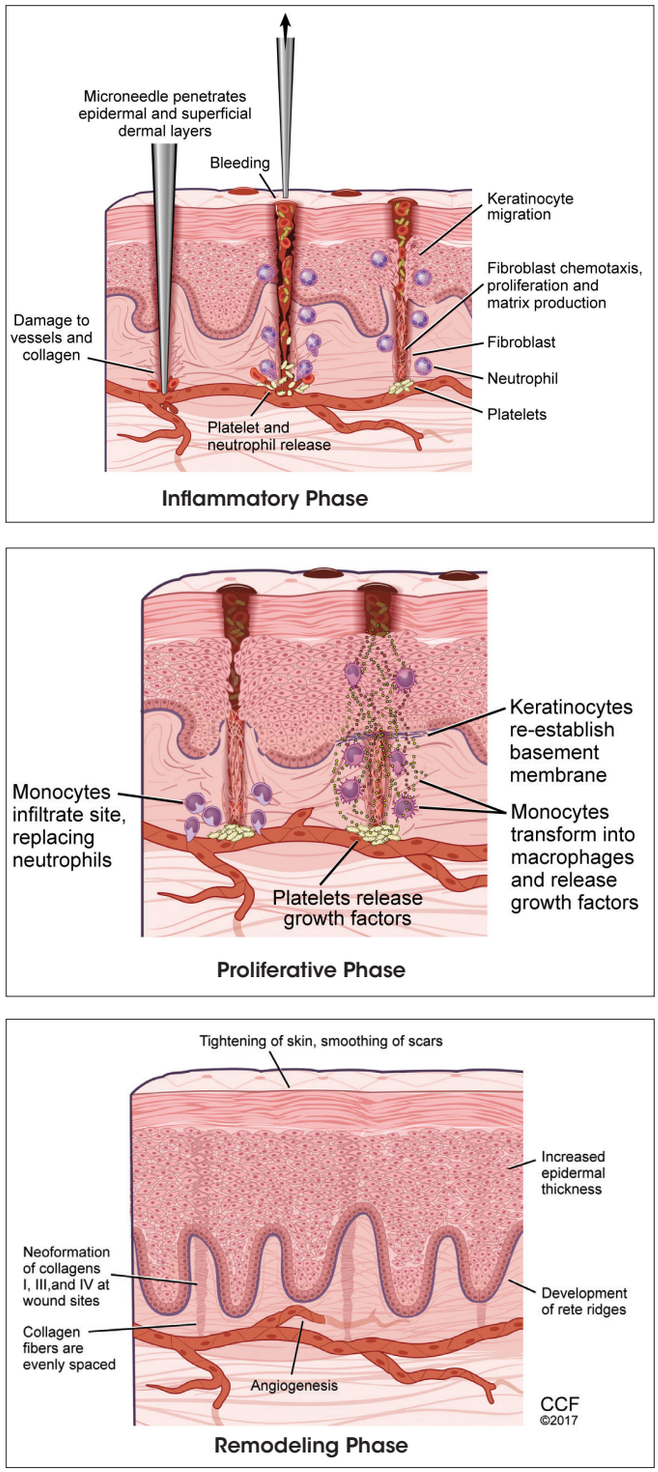

FIGURE 1. Overview of the mechanism of action of microneedling. Illustration by Dave Schumick, BS, CMI. Reprinted with the permission of the Cleveland Clinic Center for Medical Art & Photography © 2017. All rights reserved.

Microneedling devices

Microneedles may be solid or hollow. The first microneedles were composed of silicone, but are now made of a range of materials, including metals (eg, titanium, nickel), glass, polymers and sugars.[13] There is great variety in needle geometries, arrangement, number, cross-sectional area, and length. The 2 most common types of handheld microneedling devices for dermatologic use are rollers and stampers or pens. Microneedling rollers are composed of a drum-shaped rolling barrel device with fine, protruding needles in evenly spaced in rows. These are rolled across target areas of skin. Microneedling pens consist of an array of needles extending from the end of a handpiece, oftentimes with an underlying piston, and are applied in a gliding or stamping manner over the skin. Depending on the device, microneedle applicators are either reusable for personal use or disposable for individual procedures. Rollers and pens may be manual or motorized, powered by batteries or electrical sources. In automated microneedling devices, speeds are adjustable. Needles can penetrate the skin up to 100 times per second with piston stroke frequency ranging from 10 Hz to 90 Hz, resulting in up to 1000 microchannels created per second at high settings. Devices are available with different needle lengths that can be adjusted with a dial, ranging from 0.25 mm to 3 mm (Figure 2).

Fractional microneedling radiofrequency (MRF) combines the fixed spacing and depth of microneedles with the energy of radiofrequency. Insulated needles penetrate the skin and transmit RF energy directly to the dermis while minimizing epidermal damage. This heating of dermal structure incites tissue remodeling by stimulating both stem cells in skin appendages and epidermal stem cells between bridging areas. Similar treatment indications exist for traditional microneedling and MRF, but at present there are no controlled studies comparing the 2 modalities.

How is microneedling performed?

Microneedling can be applied to a myriad of locations on the body. The depth of microneedles to treat different areas varies by facial subunit and body location, but specific depths have not been studied. The location of the tip of the needle and the depth of penetration appear to be key in obtaining optimal treatment results. The insertion force of microneedles is low enough to allow for successful insertion by hand without significant pressure.[6] In a study of 11 patients with traumatic and atrophic acne scars treated with microneedling at 1.5 mm depth, histological specimens obtained at baseline and 6 to 8 weeks after 1 treatment showed elastin fibers only at 1 depth of 0.6 mm, not deeper or in the epidermis.[14] The authors speculated that roller device geometry and shape determined the depth of needle penetration, not pressure; for example, a round microneedle roller with 1.5 mm needles arranged at 15 degrees would penetrate the skin at 1.2 mm.[14] Sasaki more recently examined the penetration depth of 6 different needle lengths on an electronic microneedle via histological measurements (taken from the epidermis to deepest level of microchannels) and found that depths correlated closely up to 1.0 mm of needle length; greater variability, however, was noted with longer needles from 1.5 mm to 2.5 mm.[15]

Clinical studies detailing exact treatment parameters are limited but in a typical microneedling treatment, target areas are pretreated for 30 to 60 minutes with a topical anesthetic. Early developers of microneedling shared the opinion that daily pretreatment for 1

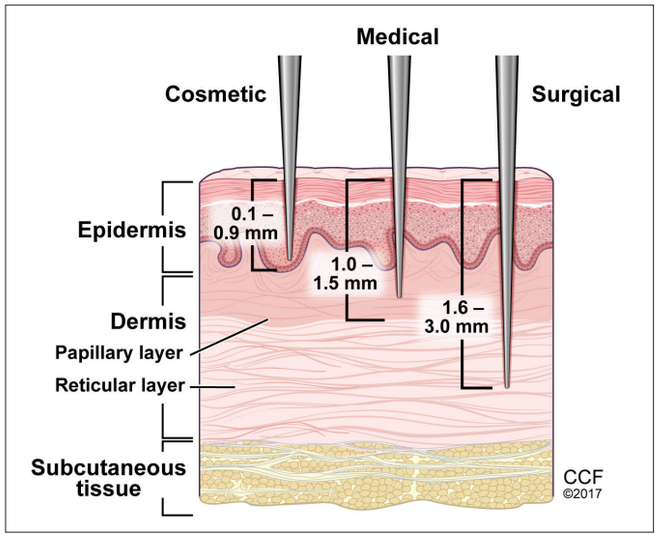

FIGURE 2. Microneedle depth schematic. Illustration by Dave Schumick, BS, CMI. Reprinted with the permission of the Cleveland Clinic Center for Medical Art & Photography © 2017. All rights reserved.

month with topical Vitamin A (eg, retinyl palmitate) and Vitamin C (eg, ascorbyl tetraisopalmitate) was necessary to maximize initial collagen production and maintain the homeostasis between collagenesis and collagenolysis.[8,9,19,20] Vitamin A was thought to control the release of TGF-ß1 as retinoic acid favors the development of a lattice-like collagen network, while vitamin C was necessary for collagenesis.[5,16] Practitioners currently vary with their practices regarding pretreatment, with some recommending cessation of retinoids 1 week prior to treatment.

Once treatment areas are anesthetized, a glide agent (eg, hyaluronic acid, platelet-rich plasma, serum, etc) is applied. The skin is stretched as the microneedling device is then passed over in different directions (horizontal, vertical and diagonal) anywhere from 4 to 10 times, depending on the body location. Overtreatment is less likely than with other ablative resurfacing treatments, as microneedles repeatedly rolled over an area are more likely to slip into existing holes than create new perforations.[4]

The treatment endpoint is pinpoint bleeding or petichiae. It should be noted that the procedure does carry risk of potential exposure to blood-borne pathogens through provider exposure to blood. Microneedling penetrates into the superficial reticular dermis, largely avoiding nerve bundles, hence why the process is not associated with much pain.[13]

After treatment, areas are cleansed with a saline solution. Patients may experience slight edema, which resolves in 24 hours. Mild erythema may be noted up to 5 days postprocedure.[16] Dryness, pinpoint crust formation, and peeling may also be noted. Patients should be advised of photoprotection for up to 7 days after treatment. Total treatment time is less than 20 minutes and postprocedure downtime is minimal, making microneedling a highly desirable office procedure.

At present microneedling rollers and pens are a US Food and Drug Administration (FDA) Class I devices, considered to be low risk and subject to the least regulatory control. Due to the growing popularity of microneedling and home devices available for purchase, however, the FDA at the time of this writing has a Class II approval for pending.

The risks and pitfalls of microneedling

Before embarking on offering microneedling to patients, the practitioner must select the appropriate patient and the appropriate device, and must possess a realistic knowledge of risks and expectations. Contraindications to microneedling include collagen vascular disease, the presence of verruca or cutaneous malignancy (microneedles in theory could spread viral-infected or neoplastic cells), active skin infection, and a predisposition to keloid formation. Complications of microneedling include bruising (most noted over facial bony prominences), infection, reactivation of herpes simplex labialis, and rarely scar formation.

In one case report, a patient treated for varicella and acne scars with microneedling at 2.0 mm depth developed facial papules in a horizontal and vertical linear pattern similar to a tram track.[18] The authors counseled that strong pressure with a large needle device on bony areas of the face could increase risk of such a complication. The following year, the same group reported the case of a patient treated with a roller microneedle at 1.5 mm who developed a "rail track appearance," who was later found to have positive patch testing to nickel at 48 hours.[19] It is therefore prudent to obtain a history of any allergic hypersensitivity to metals prior to microneedling. "Tram tracking" has also been reported in patients treated with MRF.[20]

Another case series reported complications in patients treated with Vitamin C serum during microneedling: 1 patient developed erythema nodosum and a systemic hypersensitivity reaction, while another developed erythematous nodules in treated areas and was later found to have positive patch testing to the serum (but not individual serum ingredients).[21] Caution therefore should be used in the application of topical products not designed specifically for intradermal injection during microneedling treatment.

Compared to other ablative resurfacing modalities, microneedling has a decreased risk of infection, photosensitivity, and postinflammatory hyper- or hypopigmentation because it does not deliver heat to the skin (Table).[17] Fractional photothermolysis involves the application of multiple beams of pixilated light to produce minimal thermal zones. The thermal damage incurred during this procedure initiates a biological signaling cascade with increased expression of heat shock proteins, which then upregulate TGF-β. Ablative devices remove some degree of tissue (ie, vaporization) and create a surrounding zone of coagulated tissue, which also initiates the wound-healing cascade. Microarrays of mouse skin treated with microneedling found increased expression IL-10 (a pigmentation suppressor factor) and decreased expression of melanocortin-1 receptor for up to 2 weeks after treatment.[12] Mechanically, microneedling exerts little effect on melanocytes in the epidermis and at the dermal-epidermal junction, and epidermal preservation allows for the procedure to be repeated multiple times until satisfactory outcomes are achieved.[20] Thus, microneedling is a favorable alternative resurfacing treatment in patients with higher Fitzpatrick skin types. [2,20] Fabbrocini and colleagues examined the efficacy of microneedling in 3 groups stratified by Fitzpatrick skin type using global assessment and computer analysis of patient photographs. In addition to a statistically significant reduction in acne severity compared

TABLE Medical microneedling devices

Device Name	Manufacturer	Manual or Motorized	Needle Number	Needle Length	Needle Size	FDA Status
Gliding Stamper						
Aquagold Fine Touch™	Aquavit Pharmaceuticals, New York, NY, USA	Motorized	20	0.6 mm	18G	Registered
Collagen P.I.N.™	Induction Therapies, SD, USA	Motorized	12 or 36	0-2.75mm 0-3 mm	12-32G 30-36G	Registered
COSMOPen™	CosmoFrance Inc, Miami, FL, USA	Motorized	12	0.25-2.5 mm	32G	Registered
Cytopen®	Emage Medical, Charlotte, NC, USA	Motorized	12	0.25-2.5 mm	32G	Registered
eDermastamp™	Dermaroller GmbH, Wolfenbuttel, Lower Saxony, Germany	Motorized	6	0-1.5 mm		Registered
Dermapen®3D	Equipmed, Sydney, Australia	Motorized	12	0-2.5 mm	33G	Registered
Rejuvapen®	Refine USA, LLC, Jacksonville Beach, FL, USA	Motorized	9	0.2-2.5 mm	33G	Registered
SkinPen®	Bellus Medical, Dallas, TX USA	Motorized	12	0.25-2.5 mm	32G	Registered
Fractional Radiofrequency Stamper						
Fractora™	Invasix, Lake Forest, CA USA	Bipolar Motorized	20 or 60	2.5 mm	32G, Insulated and non-insulated	Cleared
Infini™	Lutronic, Fremont, CA USA	Bipolar Motorized	49	0.5-3.5 mm	34G, Insulated	Cleared
INTRAcel™	Jeisys Medical, Seoul, South Korea	Bipolar Motorized	49	0.5-2 mm	32G, Insulated	Cleared
Intensif™	EndyMed, New York, NY, USA	3DEEP Motorized	25	0.5-5 mm	Non-insulated	Cleared
Profound	Syneron, Irvine, CA	Bipolar Motorized	10	6 mm	Insulated	Cleared
Vivace	Aesthetics Biomedical Phoenix, AZ, USA	Bipolar Motorized	36	0.5-3.5 mm	30G, Insulated and non-insulated	Cleared

Abbreviations: FDA, U.S. Food and Drug Administration; G, gauge.

Adapted from Bonati L, Epstein G, Strugar T. Microneedling in All Skin Types: A Review. *J Drugs Dermatol.* 2017;16(4):308-331

to baseline across all skin types, they found that posttreatment erythema was more often experienced by fair skin types, and resolved in all groups in 24 to 48 hours.[22] Taking this observation one step further, a 2015 study of 22 patients with recalcitrant melasma unresponsive to topical lightening and sunscreen that were treated with microneedling at 1.5 mm needle length alone resulted in clinical improvement of hyperpigmentation, with all patients reporting satisfaction with results.[23] Two recent comprehensive reviews on microneedling studies in skin of color with acne scars concluded that microneedling is safe in patients with higher Fitzpatrick skin types, with few instances of postinflammatory hyperpigmentation and scarring.[20,24]

Microneedling and scars

Microneedling has been studied extensively in the treatment of atrophic acne scars. Fabbrocini treated acne scar patients with a microneedling roller and after only 2 sessions over 8 weeks, noted reduction of acne scar severity in all patients, with transient erythema and edema as the only side effect.[25] Another study of moderate to severe acne scar patients treated with a microneedling roller 1.5 mm in length found that 94% of patients achieved a reduction in scarring severity by 1 or 2 grades on the Goodman and Baron's Global Qualitative Acne Scarring System and 72.2% showed a marked response to treatment.[26] Patients with the most severe (grade 4), however, had less impressive response. Additionally,

TABLE Medical microneedling devices (continued)

Device Name	Manufacturer	Manual or Motorized	Needle Number	Needle Length	Needle Size	FDA Status
Stamper						
Cosmetic Focus-CIT™	Environ SkinCare, Cape Town, South Africa	Manual	14	1mm	30G	
Dermastamp®	Dermaroller GmbH, Wolfenbuttel, Lower Saxony, Germany	Manual	12	2 mm		Registered
Eclipse MicroPen™	Eclipse Aesthetics, LLC, TX, USA	Motorized	12	0-2 mm	32G	Registered
Hand Roller						
Cosmetic Roll-CIT™	Environ SkinCare, Cape Town, South Africa	Manual	260	0.2mm	30G	
Dermafrac™	Genesis Biosystems, Lewisville, TX, USA	Motorized	180	0.25-0.5 mm	25G	Registered
Dermaroller MC4, MC⁹	Dermaroller GmbH, Wolfenbuttel, Lower Saxony, Germany	Manual	MC4: 72 MC9: 162	0.2-2.5 mm		Registered

Abbreviations: FDA, U.S. Food and Drug Administration; G, gauge.
Adapted from Bonati L, Epstein G, Strugar T. Microneedling in All Skin Types: A Review. *J Drugs Dermatol.* 2017;16(4):308-331

5 patients developed postinflammatory hyperpigmentation and 2 developed tram-track scarring, which was attributed to pressure while needling.[26] Alam et al performed the first split-face, placebo-controlled randomized clinical trial of microneedling in a variety of acne scars. Patients who received 3 microneedling treatments at a depth of 2.0 mm separated by 2 weeks were found to have significantly lower mean acne scores in the treatment group compared with baseline, and a mean 41% improvement in patient perception of overall scar appearance on the treated side.[27]

Patients with higher Fitzpatrick skin types who received MRF found improvement of at least 1 scar grade on the Goodman and Barron's Global Qualitative Acne Scarring System in 57.9% patients after 1 month, and in 100% of patients after 3 months.[28] A coincidental improvement in skin dyspigmentation among 47.4% of patients was also noted and thought to be due to destruction of "dropped" dermal melanosomes and enhanced dermal remodeling.[28] A retrospective photographic analysis of 31 patients treated with MRF for facial atrophic acne scarring demonstrated that after 4 treatment sessions at 6-week intervals, a substantial improvement (58%) was noted in the appearance of all acne scars per the Goodman and Barron's scale.[29] The device was set to multiple needle depths, creating layers of the electrothermal coagulation at different layers of the dermis and presumably leading to treatment at several layers of scarring.[29] Another study of MRF in moderate-to- severe atrophic and rolling acne scars had patients treated at 1.5 mm length for 3 times at 1 month intervals. At 6 months, the majority demonstrated clinical improvement at 6 months as assessed by blinded reviewers and patient perception.[30] As seen with roller microneedle studies, atrophic and rolling acne scars responded better to treatment than ice-pick and hypertrophic scars.

Several studies have examined microneedling in relation to other treatments for acne scarring. In patients with box-type atrophic acne scars and postinflammatory hyperpigmentation, microneedling with a roller alone was compared to microneedling with 35% glycolic acid alternated every 3 weeks. After 5 sessions, a statistically significant decrease in the severity of superficial and moderate acne scars was observed (62% improvement) in the combined treatment group as determined by the Echelle d'Evaluation clinique des Cicatrices d'acne classification, as well as improvement of hyperpigmentation. The authors concluded that glycolic acid serves to promote new collagen formation initiated by microneedling.[31] In a comparison study of microneedling with a roller at 1.5 mm depth and 100% trichloroacetic acid (TCA) chemical reconstruction of skin scars (CROSS) administered in 4 treatments in 4-week intervals, both groups experienced an improvement of scar severity by clinical observation, though statistical significance between treatments was not reached.[32] The authors determined that microneedling should be recommended for rolling acne scars and 100% TCA CROSS should be recommend for ice-pick scars to address lesion depth.[32] In a randomized control trial by the same authors, atrophic acne scar patients received either 4 sessions of microneedling with a roller with 20% TCA or 1 session of a phenol peel.[33] Acne scar severity significantly improved in 69.4% of those in the microneedling and TCA group, and 75.1% in the phenol peel group, with the most significant improvement seen among rolled scars, which the authors ascribed to neocollagenesis displacing dermal tethering.[33] Yet another clinical trial compared the efficacy of a microneedle roller alternated with either 20% TCA or 1540 nm nonablative fractional laser in 1 group and a combination of the 2 modalities in another group in the treatment of atrophic acne

scars. Acne scar improvement was statistically significant in all groups, but most notable in the combination group and for rolling type scars. It was hypothesized that microneedles facilitated deeper penetration of 20% TCA into the skin, bypassing epidermal damage to stimulate collagen formation and elastin normalization.[34]

At least 3 studies examined microneedling with subscision. Garg showed in an uncontrolled trial that severe acne scars treated with subsicion then alternated with roller microneedling and 15% TCA peel resulted in 64% of severe acne scar patients moving to "moderate" scarring, and 22% of moderate acne patients moving to complete resolution after 3 months of treatment.[35] Gadkari and colleagues performed full face subcision, followed by either roller microneedling at 2.5 mm or cryoroller on half of a face on 30 patients with mild to severe acne scarring. Assessment with a grading scale showed 57% improvement in the subcision and cryoroller side compared to 40% improvement in the subscision and roller microneedle side, with only transient erythema and edema noted.[36] Hassan et al randomized patients to receive either roller microneedling alone at 2 mm or roller microneedling with subsicion every month for 3 months, and efficacy was seen in 100% of the combination group compared to 77% who received only microneedling.[37]

An evaluator-blinded randomized clinical trial of nonablative erbium laser 1340 nm compared to microneedling at 2 mm alone for the treatment of atrophic acne scars found that all patients noted improvement after the second treatment session, and that both groups showed clinical and statistical improvement in the degree of scars. Posttreatment erythema lasted longer with the laser-treated group (2-3 days compared to 1 day) and 13.6% of laser patients developed postinflammatory hyperpigmentation, compared to none in the microneedling group.[38] Osman recently compared the safety and efficacy of ablative fractional Erbium-Doped Yttrium Aluminum Garnet (Er:YAG) 2940 nm to microneedling pen at 2 mm in atrophic acne scars in a randomized split-face trial. At the end of the study period, significant improvement was seen clinically and increased dermal collagen was demonstrated on histopathology in both treatment groups. The Er:YAG-treated side showed significantly better results than microneedling pen (70% vs 30%) and was associated with lower pain scores.[39]

The use of microneedling in active inflammatory acne is less known. A few studies have shown decreased number of acne lesions with treatment by MRF. This is thought to be secondary to a sebosuppressive effect of thermal energy.[40-42]

Microneedling and burn scars

With regard to burn scars, mouse models have shown that microneedling for 4 weeks results in an increase in collagen III, and by 8 weeks increases mean epidermal thickness by up to 140 %.[9,43] These results are more pronounced with repeated treatments. This is supported in vivo by histological examination of tissue from patients with mature—defined as present for over 23 months—second-degree burns who received microneedling treatment, which showed epidermal thickening, and normalization of dermal collagen and elastin up to 12 months postoperatively.[44]

Microneedling and wrinkles, laxity, and skin texture

In a recent comprehensive review of microneedling, only 4 studies were listed on microneedling and skin rejuvenation and none of these studies were designed against lasers.[45] Fabbrocini and colleagues treated neck laxity with roller microneedling and noted improvement in 90% of patients using global assessment, silicone rubber impressions (29% decrease in skin irregularities), and ultrasound images (24% reduction in depth of rhytides) after only 2 treatments.[46] A similar study of perioral rhytides using a microneedling pen demonstrated a mean 2.3 times reduction in wrinkle severity by global assessment and a 33% decrease in skin irregularity by silicone microimpresssions.[47] Fabbrocini et al performed a split-face study of microneedling alone compared to microneedling and platelet-rich plasma (PRP), which showed decreased scar severity grade on both sides of the face, but more significant improvement on the side treated with combination therapy.[52] In a more recent study, 50 patients with acne scarring were treated with full face roller microneedling, and then administered topical (glide) and intradermal PRP on one side of the face and intralesional distilled water on the other side. Results showed a 62% improvement in the Goodman's scale on the PRP-treated side, compared to 45% on the microneedling and water side.[53] Furthermore, El-Domyati demonstrated improvements in "wrinkly" periorbital and forehead skin appearance and texture via photographs and skin biopsies in 65% of patients with Glogau class II-III rhytides after 3 treatments with a roller microneedle.[11] It is the authors' experience that the microneedling pen is a safe and effective treatment for skin rejuvenation, specifically perioral rhytides (Figure 3).

More research has been performed on the use of microneedling radiofrequency (MRF) in rhytides. Cho treated acne scars and enlarged facial pores in 30 patients with a 49-electrode MRF device and found improvement by global assessment in 73% of patients after only treatment session.[48] Clementoni et al conducted a study of 33 patients treated with MRF for mild to moderate laxity of the lower face and neck (excluding the upper lip) which confirmed on histology well-demarcated areas of coagulation in the dermis that spared the epidermis, and demonstrated moderate to high improvement of skin laxity and facial rhytides in 82% of patients on global assessment.[49] Patients treated with MRF experienced mild edema and erythema at needle-insertion sites, both of which resolved within days of treatment.[49,50] Seo and colleagues performed a split-face trial of MRF alone compared to MRF with a stem cell serum and found improvement based on global assessment that was more pronounced with combined treatment, which was supported on histology with a corresponding increase in dermal collagen.[51]

The rationale of the use of microneedling in the treatment of striae distensae centers around the conceptualization of striae as dermal scars. Ryu et al treated 30 patients with moderate to severe striae with roller microneedling for 3 months. At the end of the study, histological evaluation of biopsies showed large numbers of thick collagen fibers and marked to excellent improvement was noted in 43.8% of patient.[54] Park and colleagues conducted a study comparing efficacy of MRF alone, fractional CO_2 laser alone and combined MRF and fractional CO_2 laser in patients with striae. The combination groups had a mean improvement score of 3.4 compared to 2.2 in the fractional CO_2 and 1.8 in the MRF groups, and histology demonstrated thickening of epidermis, and increase in both dermal collagen and elastin by the study's end.[55]

Microneedling and drug delivery

Microneedling has also been evaluated as a means for transdermal drug delivery in the treatment of a variety of conditions.[12,13]

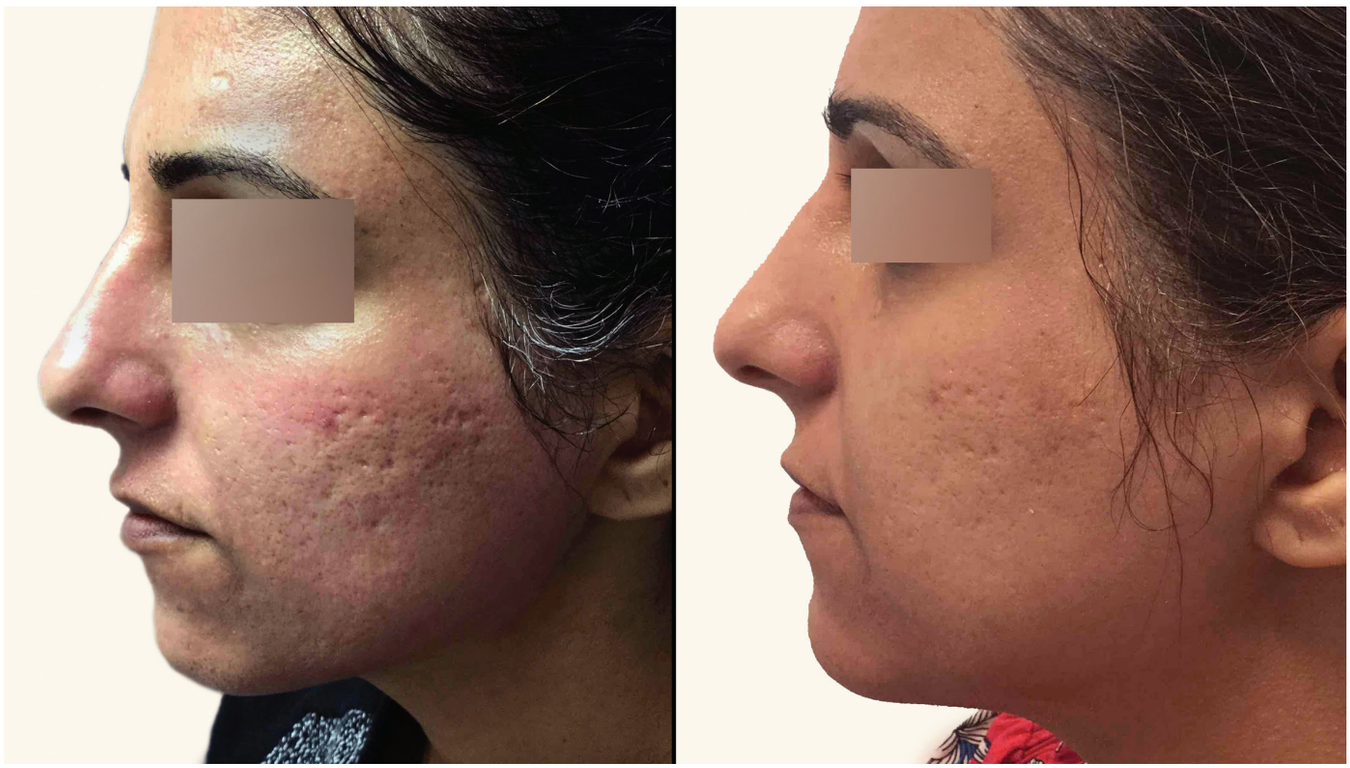

FIGURE 3. Patient treated with microneedling for acne scars at baseline (left) and after 2 treatments (right)

Microneedles can be used for transdermal delivery via coating or encapsulating a solid needle with a drug, creating microchannels with a solid needle through which a drug can diffuse, or topical application of a drug followed by multiple hollow needle punctures.[6] Serrano demonstrated with Fontana Masson stains that microneedles widen the hair infundibulum, allowing for the enhanced movement of compounds inside deeper hair structures, peaking after 60 to 90 minutes.[56] Sasaki measured pigmented particles on histology and fluorescein-labeled platelets on confocal microscopy to visualize the optimal time for topical application of a medication after a microneedling channel was placed, and determined the most favorable time to be between 5 and 30 minutes.[15]

In dermatology practice, there are numerous applications of microneedling as a means of drug delivery. El-Fakahany and colleagues performed a split-face study on 15 patients with atrophic acne scars where 1 side was pretreated with microneedling pen at 0.5 mm followed by application of topical anesthetic and the other side only received topical anesthetic. The full face was then treated with microneedling at a depth of 2.5 mm. The pretreated side was notably more comfortable during the full-face microneedling.[57]

A split-face trial of microneedling with Vitamin C versus platelet-rich plasma suggested that microchannels potentiate the natural wound healing cascade due to the presence of the patient's growth factors juxtaposed with growth factors released by wounding.[58] Another study comparing microneedling plus intradermal injection of PRP, microneedling plus 100% TCA CROSS and microneedling plus the combination of both PRP and TCA, in the treatment of atrophic acne scars did not find any statistically significant difference in therapeutic response among the 3 groups. However, authors found a trend towards greater improvement with combined therapy. They concluded that improved PRP absorption via microneedling and platelet release of growth factors improved wound healing.[59]

A study comparing the efficacy of tranexamic acid administration in melasma by either microinjection or microneedling found at 11 months improvement score was 44.4% in the microneedling group compared to 35.7% improvement in the microinjection group, suggesting better and more even penetration.[60] Microneedling has also been used in treatment of refractory warts at a depth of 2 mm to aid in administration of topical bleomycin with minimal pain and no necrosis.[61] Transdermal bleomycin administration has also been documented by topical application followed by hollow needle puncture into hypertrophic scars.[62]

For hair loss disorders, microneedling has been demonstrated to induce new hair growth in androgenetic alopecia patients—both as a monotherapy and in combination with minoxidil—after 8 to 10 sessions.[63] In female AGA patients, microneedling used in conjunction with a growth factor solution resulted in increased mean hair shaft density after 2 weeks, which was maintained through 6 weeks of follow-up.[64] A study of microneedling in alopecia areata patients showed increased triamcinolone absorption without steroid-induced atrophy (thought to be countered by collagen induction) and hair regrowth after 3 sessions.[65]

Microneedle rollers have been documented to aid in the absorption of aminolevulinic acid (ALA) prior to photodynamic therapy, allowing for greater activity of ALA and likely contributing to observed clinical improvement in photoaging.[66] Torezan et al later performed a split-face study where patients received methyl ami-

nolevulinate (MAL) after curettage or MAL with microneedling at 1.5 mm. They found that though actinic keratoses clearance was similar between treatment applications, facial erythema and coarse wrinkles improved more on the side treated with microneedling.[67]

Conclusion

In summary, microneedling is a fractional resurfacing treatment that retains the majority of the epidermis, which decreases recovery time and decreases the risk of adverse effects such as infection, dyspigmentation and scarring. The existing literature suggests that microneedling is an effective treatment for textural abnormalities of the skin by releasing growth factors, increasing epidermal thickness and spurring collagen synthesis. These benefits can last up to 12 months after microneedling treatment, though it remains unclear if more treatment sessions are needed for better efficacy. Importantly, microneedling acts synergistically with other treatments for textural abnormalities, such as subscision, chemical peels, fractional ablative laser, and platelet-rich plasma. Compared to available treatment modalities for skin resurfacing, microneedling is less expensive and requires less recovery time, but does require more treatments for notable results. Microchannels created by microneedling also allow for the passage of cosmeceuticals and topical medications into the dermis, for which there are numerous potential dermatological applications.

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