Advances in Cosmetic Surgery 1 (2018) 109–115
ADVANCES IN COSMETIC SURGERY

# Radiofrequency with Microneedling

**Omer Ibrahim, MD[a,*], Girish S. Munavalli, MD, MHS[b], Jeffrey S. Dover, MD, FRCPC[c]**
[a]Chicago Cosmetic Surgery and Dermatology, 20 West Kinzie Street, Suite 1130, Chicago, IL 60654, USA; [b]Dermatology, Laser, and Vein Specialists of the Carolinas, 1918 Randolph Road, Suite 550, Charlotte, NC 28207, USA; [c]SkinCare Physicians, 1244 Boylston Street, Suite 103, Chestnut Hill, MA 02467, USA

**KEYWORDS**
• Radiofrequency • Microneedling • Laxity • Wrinkles • Scars

**KEY POINTS**
- Skin laxity occurs as a result of intrinsic, or chronologic, aging, as well as extrinsic aging, including UV light exposure, pollution, and smoking.
- Radiofrequency delivers heat to the dermis, resulting in controlled collagen denaturation, dermal shrinkage, and neocollagenesis.
- When coupled with microneedling, radiofrequency devices elicit the wound-healing response and deliver larger amounts of heat deeper into the dermis, resulting in greater collagen remodeling.
- Radiofrequency with microneedling is effective and safe in improving skin laxity and texture; however, proper patient selection is paramount to treatment success.

## INTRODUCTION

A common complaint of patients seeking rejuvenating procedures is the sagging appearance of the skin, or skin laxity. Skin laxity occurs through a combination of both intrinsic and extrinsic aging processes. Intrinsic, or chronologic, aging results in skin wrinkling, atrophy, and loss of subcutaneous fat, and bone resorption. Extrinsic, or external, factors such as damaging UV light, pollution, and smoking, also contribute to the aging process [1]. Collagen, mainly types I and III, represents approximately 75% of the dry weight of the dermis and 20% to 30% of its volume [2]. Fibroblasts generate new collagen, whereas matrix metalloproteinases (MMPs) degrade it, along with elastin. UV radiation and other intrinsic and extrinsic sources of reactive oxygen species upregulate the production of MMPs, resulting in accelerated skin aging [3]. Elastin comprises 4% of the dry weight of the dermis and gives the skin its mechanical strength and ability to resist deformation, or elasticity [4]. Intrinsic aging causes atrophy of elastin fibers, whereas extrinsic aging such as UV light exposure causes a disorganization in the elastic fiber network, resulting in solar elastosis [5]. The vital role of elastin in maintaining the structure of the extracellular matrix is well established; even the slightest decrease in the number of elastin fibers results in significant changes in skin elasticity and strength, as is evident in conditions like cutis laxa [6–8].

The gold standard for correcting skin laxity and achieving tightening is surgical correction, such as rhytidectomy. Although consistently and uniformly effective, surgical procedures can be invasive, risky, costly, and inappropriate for some patients. As such, the demand for less invasive treatment modalities has

*Corresponding author, *E-mail address:* oibrahim@chicagodermatology.com

https://doi.org/10.1016/j.yacs.2018.03.001
2542-4327/18/ 

increased along with a concomitant flourishing in the field of energy-based tightening, especially radiofrequency (RF). In this review, the authors first discuss the mechanisms of noninvasive skin tightening and rejuvenation overall. They then specifically discuss the histologic cutaneous changes induced by both RF and microneedling. Next, they highlight the clinical evidence behind fractional radiofrequency (FRF) and radiofrequency with microneedling (RFM) in improving skin laxity and texture. Finally, they outline the procedural details of RFM.

## MECHANISMS OF SKIN TIGHTENING AND DERMAL REJUVENATION

A central mechanism by which cutaneous remodeling and skin tightening occurs in response to thermal energy is the resultant structural change in the collagen polymer. When a certain amount of heat is delivered to collagen, the structured collagen triple helix denatures into a disorganized coil pattern. Orthopedic studies evaluating joint capsular collagen have demonstrated the histologic effects on collagen from thermal energy [9]. The reportedly ideal temperature of 65°C for collagen shrinkage is derived from experiments examining the effect of heating on joint capsular tissue [10,11]. Investigators demonstrated that the threshold for shrinkage of bovine knee capsules was between 60°C and 62°C, the same temperature range at which collagen denaturation was noted on light microscopy of the specimens [11]. Hayashi and colleagues [10] found that temperatures greater than 65°C induce tissue shrinkage, and contraction progressed up to a temperature 80°C. Therefore it is evident that collagen contraction depends on both temperature and duration of heating.

When heated, the hydrogen bonds, crosslinks between lysine and hydroxylysine, and disulfide bridges within the collagen triple helix are broken and the helix unwinds into a haphazard coil [10,12–15]. Because of the heat-stable intermolecular crosslinks within the new collagen configuration, the coil maintains its shape, leading to increased tension within the collagen as the structure shrinks and thickens [13,16]. Investigators have shown then even with rehydration of heated tissue the tightening effect is still maintained, demonstrating that tightening is not due solely to dehydrating tissue [17].

Thermal injury and superficial ablation of the skin trigger the wound healing response, thereby explaining the cutaneous rejuvenating effects these interventions have on the skin. The stages of wound healing include 3 phases: inflammation, proliferation, and remodeling. During the inflammatory phase initiated by neutrophils and macrophages, fibroblast proliferation, type III collagen production, and keratinocyte proliferation are seen [18,19]. In the second week, during the proliferative phase, fibroblasts differentiate into myofibroblasts and cause tissue contraction of up to 40% [20]. Finally, during the remodeling period, after the third week, the overall collagen content of the dermis increases [18].

## CUTANEOUS RESPONSE TO RADIOFREQUENCY

RF uses electromagnetic wave frequencies to generate an electric field within tissue to cause heating [21]. The amount of energy delivered to tissue is proportional to the current, time, and resistance within the tissue, also known as impedance. Tissue impedance is the main variable in the amount of heat delivered by the generated electric current. The mechanisms by which RF devices produce skin tightening are volumetric heating of the dermal structures, such as collagen and fascia, and induction of the wound healing response [22].

In one orthopedic study, RF was shown to cause tissue shrinkage in the femoropatellar joint capsule of adult sheep by collagen fibril shortening [23]. Zelickson and colleagues [24] demonstrated collagen fibril contraction and increased procollagen type I expression in bovine tendons and human skin similar to findings after treatment with ablative lasers. Another study demonstrated thickening of collagen in facial skin treated with RF [25]. As discussed, optimal treatment parameters depend on temperature as well as duration of treatment.

Few studies have evaluated the wound healing response after RF. Hantash and colleagues [26] studied the wound healing response of abdominal skin at various time points after treatment with an FRF device. Neocollagenesis, neoelastogenesis, increased cellularity, and de novo hyaluronic acid were observed.

## CUTANEOUS RESPONSE TO MICRONEEDLING

The effects of microneedling on the skin were elucidated by Fernandes [27] in his study of percutaneous collagen induction. The study demonstrated that microneedling exerted its effects via the initiation of the wound healing response. The inflammatory phase ensues shortly after microneedles penetrate the epidermis and superficial dermis, causing focal damage to superficial blood vessels and collagen bundles, and the release of platelets and neutrophils [27,28]. Within a few hours, epidermal microchannels rapidly heal by transepidermal migration of keratinocytes; however, needles with wider cross-sectional areas and occlusion can retard this process up to 40 hours [29,30].

The proliferative phase follows the inflammatory phase 5 to 7 days later, during which neutrophils are replaced with monocytes. These monocytes transform into macrophages that together with platelets release a cascade of growth factors [27,28]. Studies have shown that microneedling in mouse models upregulates expression of all 3 forms of transforming growth factor-β (TGF-β), especially TGF-β (a suppressor of scar formation) [31]. In addition, keratinocytes begin 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 [27,28].

The remodeling phase can last from 8 months to 1 year. After 12 weeks, human and animal skin models treated with microneedling demonstrate significant increases in epidermal thickness and neoformation of collagens I, III, and IV [27,32,33]. Furthermore, the new collagen fibers are evenly spaced, unlike those seen with scars [32]. Collagen I gradually replaces collagen III, the primary type of collagen present in early wound healing. One study of histologic staining demonstrated a decrease in dermal elastin at 3 months, which was interpreted by investigators as a reorganization of aberrant fibers or even a decrease in solar elastosis [34]. The ultimate desired result of microneedling is tightening of skin laxity, smoothing of scars and irregularities, and improvement of wrinkles. These effects can last for 5 to 7 years [27].

## FRACTIONAL RADIOFREQUENCY: THE EVIDENCE

Given the ability of microneedling and RF to improve skin laxity and texture as single modalities, the combination of these technologies promised deeper delivery of thermal energy and greater improvement in laxity as well as skin texture. The concept of fractionation has classically been applied to lasers, particularly resurfacing lasers such as the carbon dioxide laser. However, recently fractionation has been applied to RF as well. As discussed, RF uses electric current to produce thermal energy as it passes through tissue and meets resistance. FRF devices transmit current through electrodes in contact with the skin or via arrays of paired microneedles that penetrate the skin. These devices form closed circuits of bipolar current [35]. The devices, equipped with electrodes, produce a pyramid-shaped pattern of thermal energy, with the smaller peak of the pyramid at the epidermis and the broader base of the pyramid deeper within the dermis [36]. The pyramidal pattern of heating results in large, yet safe, volumes of dermal heat delivery with minimal epidermal damage. Investigators have shown that less than 5% of the cutaneous surface is disrupted with one pass of the device [36]. The high temperatures at the level of the epidermis lead to focal, controlled epidermal ablation, while the dermis undergoes bulk heating and coagulative damage [36,37]. The intensity of the treatment and degree and depth of dermal heating can be tailored by adjusting the parameters such as energy level and coverage [37].

FRF has been successfully used for skin rejuvenation [36]. FRF can lead to improvements in skin laxity, texture, and wrinkles. Hruza and colleagues [37] showed that nearly 90% of patients exhibited improvements in skin tightness, smoothness, and wrinkling after 3 treatments, with approximately half of patients achieving an improvement of 40% or greater. Periorbital areas demonstrated the most improvement, whereas perioral sites showed the least improvement after treatment [37]. Because there is little epidermal disruption, FRF is generally not used for superficial pigment alteration [36]. However, studies have shown improvement in dyschromias and skin clarity [36,37].

Depending on patients' goals, most investigators recommend a series of 3 to 6 treatments to obtain optimal rejuvenation and patient satisfaction [36,37]. Maintenance of improvement can be achieved by undergoing an additional treatment every 3 to 4 months. Anecdotally, some clinicians use higher energies and densities in patients with lighter skin types and in older patients with increased baseline damage, while using lower energies and coverage in darker skin types [36,37]. In addition, when treating focal areas, there is less risk of sharp lines of demarcation between treated areas and nontreated areas, as has been noted with other energy-based fractional devices [36].

For acne scarring, 3 to 4 treatment sessions with FRF led to a moderate improvement of 25% to 75% [38]. Numerous reports on the effectiveness of FRF for acne scarring also demonstrated its safety in darker skin types with a relatively low risk of postinflammatory pigmentary alteration [39–41]. Although certainly effective for acne scarring, there is a dearth of head-to-head trials comparing FRF to more well-established treatments, such as ablative fractional lasers. Therefore, although FRF may not replace resurfacing lasers in the treatment of acne scarring, it may prove a useful adjunctive treatment modality.

FRF has also shown promise in the treatment of nonacne scarring. In an uncontrolled study of 95 patients with nonhypertrophic burn scars, investigators demonstrated significant improvements in cosmesis after 3 to 5 sessions at varying time intervals. There were improvements in the scar color, thickness, and pliability; however, no significant improvement was noted in vascularity, pain, or itch [42].

## RADIOFREQUENCY WITH MICRONEEDLING: THE EVIDENCE

The effects of FRF on scarring and skin rejuvenation can be augmented by the use of RFM (Fig. 1). RFM devices contain either insulated microneedles that produce small spherical thermal injury zones with coagulative damage around the tip of the needle or noninsulated microneedles that produce larger cylindrical thermal injury zones with coagulative damage spanning the dermis [43]. The needles can be adjusted to reach depths ranging from 0.5 to 3.5 mm [44]. As discussed, the trauma of the microneedles alone initiates the wound healing response and an ensuing cascade of growth factors, leading to collagen production and deposition in the upper dermis [45].

Many studies have demonstrated the efficacy of microneedling alone in the treatment of acne scars as well as other scar types [46–49]. Three studies investigated the efficacy of RFM in the treatment of acne scars in 91 patients (Fitzpatrick skin types III–V) and consistently reported moderate improvement in scar appearance after treatment [44,50,51]. Ice pick and boxcar acne scars respond more readily than rolling scars [52]. Overall, RFM appears to offer a more dramatic improvement in acne scarring than bipolar RF alone.

The role of RFM in skin tightening and rejuvenation has also been investigated. Six months after a single microneedle fractionated bipolar RF treatment, patients exhibited a 25.6% improvement in facial rhytides and a 24.1% improvement in facial and neck laxity [53]. Other studies have substantiated these findings [43,54]. For skin tightening, devices with noninsulated microneedles produce more effective skin tightening than the earlier, fully insulated microneedles, due to the deeper delivery of heat with each treatment [43].

Expected reactions associated with FRF and RFM include transient pain, redness, swelling, and mild superficial crusting that resolve within 3 to 5 days [38,49,51]. Transient postprocedure track marks have been reported after RFM (6%) [44]. Reported rates of postinflammatory hyperpigmentation are low (<3%) [39,41,51,55].

## PATIENT SELECTION

As with any procedure or device treatment, proper selection of patients is of the utmost importance for maximizing outcomes. For the 2 most frequently documented indications for RFM treatment, acne scarring and skin laxity, particularly of the lower face and neck, proper selection can be the difference between treatment success and failure.

Improvement in acne scarring is a function of the dermal collagen remodeling that occurs following treatment. The capability of delivering heat directly to all levels of the dermis, while avoiding the potential complications of overheating the epidermis, is tailor made

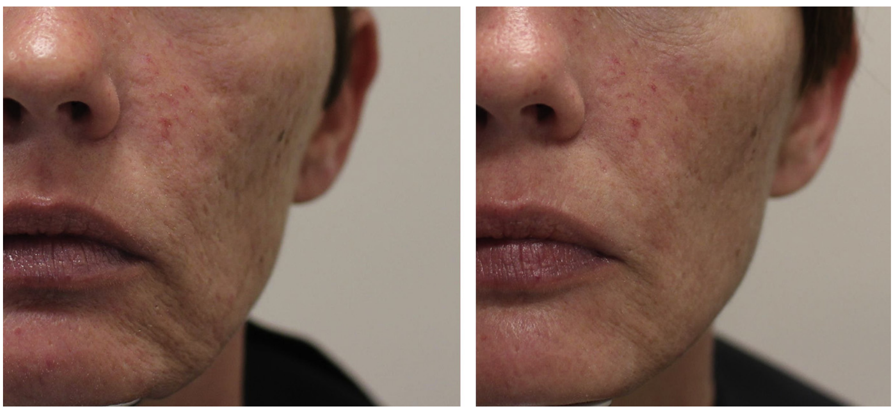

FIG. 1 Patient demonstrating significant improvements in lower facial laxity and skin texture after 3 treatments with RFM with insulated needles.

to the treatment of acne scarring with all skin types. During the initial consultation, the type of lesions should be carefully noted. Depressed distensible and boxcar scarring morphology seems to respond best from the authors' experience. These lesions are rooted in dermal contour deformity due to volumetric loss secondary to inflammatory sequelae of papular and nodulocystic acne. Focal neocollagenesis in the mid and upper dermis can revolumize the affected dermis and improve the depressed appearance of these types of scars. Depending on the age of the scars, concurrent erythema and pigmentation may also be present. RFM typically does not improve these issues; as such, the patient should be made aware that other modalities, including treatment with vascular or pigment lasers, can be used for more global improvement, once the depressed component of the scar has been treated. Ice pick and hypopigmented scarring are 2 other types of scarring that can occur from acne. These types of scars typically do not respond well to treatment with RFM and are more amenable to other options, such as trichloroacetic acid and laser resurfacing.

Mild to moderate skin laxity, particularly of the lower face and neck, is another primary indication for RFM treatment. Again, patient selection is critical, because RFM is not usually effective for severe laxity. Some generalities can be made during the consultation: thinner skin seems to respond better than thicker, sebaceous skin and mild to moderate laxity is more responsive than severe skin laxity. Laxity and rhytides of the lower face (perioral, mid cheeks, jawline, neck) have been shown to respond readily, most likely due to their more "volume-depleted" nature and evolution from bone or fat loss in the face. Rhytides of the lower face contrast with those of the upper face (periocular and forehead rhytides), where dynamic muscle movement is more responsible for the formation of upper facial lines and wrinkles. One historically difficult area to treat, which has proven to be quite responsive to RFM in these authors' hands, is the concentrically shaped laugh or accordion lines of the mid cheeks. With multiple RFM treatments, enough dermal collagen and elastin rebuilds, improving the appearance of these lines long term, while not leaving any noticeable demarcation between the treated area and the rest of the cheek cosmetic subunit.

## RADIOFREQUENCY WITH MICRONEEDLING: THE PROCEDURE

The procedure starts by obtaining adequate local regional anesthesia of the treatment area. Local anesthesia can be accomplished in numerous ways, including topical, local, or tumescent anesthesia, in order of least to most invasive. The authors have evolved their technique over time from using more tumescent anesthesia and local nerve blocks to delivering more precision local anesthesia to the exact level of microneedle penetration and energy deposition, using a 3- to 5-needle array with 0.4- to 0.5-mm needles (Mesoram, Munchen, Germany). Following anesthesia, a single- to multi-pass regimen is used, with settings that vary the depth of needle penetration matching the depth of the lesion. For example, some RFM devices allow for energy deposition at 0.1- to 0.5-mm increments, so that the dermis of an acne-scarred patient can be treated at levels of 2.5 mm, 2 mm, and 1.5 mm in multiple passes. The incremental layering of heat allows for thermal injury in a zone in and around the depth of the acne scar, thereby presumably maximizing volumetric enhancement. For laxity or rhytides, the intervals may change to 3.5 mm, 2.5 mm, and 2 mm to effect more thermal injury deeper in the mid to deep dermis.

Postoperative care centers on the use of bland emollients (creams or ointments) to decrease transepidermal water loss and accelerate healing. Healing tends to be rapid because of the fractional nature of these treatments as well as the lack of need for reepithelialization (the epidermis is relatively spared). Bruising and/or edema can be present within 1 to 2 days of the procedure, but is typically self-limited.

## SUMMARY

Skin laxity occurs as a result of intrinsic, or chronologic, aging, as well as extrinsic aging, including UV light exposure, pollution, and smoking. RF delivers heat to the dermis, resulting in controlled collagen denaturation, dermal shrinkage, and neocollagenesis. When coupled with microneedling, RF devices elicit the wound-healing response in response to microneedling and deliver larger amounts of heat deeper into the dermis, resulting in greater collagen remodeling. RFM devices are effective and safe in improving skin laxity and texture; however, proper patient selection is paramount to treatment success.

## REFERENCES

[1] Naylor EC, Watson RE, Sherratt MJ. Molecular aspects of skin ageing. Maturitas 2011;69(3):249–56.
[2] Bolognia J, Jorizzo JL, Schaffer JV. Dermatology. 3rd edition. Philadelphia: Elsevier Saunders; 2012.
[3] Kammeyer A, Luiten RM. Oxidation events and skin ageing. Ageing Res Rev 2015;21:16–29.

[4] Naouri M, Atlan M, Perrodeau E, et al. Skin tightening induced by fractional CO(2) laser treatment: quantified assessment of variations in mechanical properties of the skin. J Cosmet Dermatol 2012;11(3):201–6.
[5] Heinz A, Huertas AC, Schrader CU, et al. Elastins from patients with Williams-Beuren syndrome and healthy individuals differ on the molecular level. Am J Med Genet A 2016;170(7):1832–42.
[6] Malfait F, Francomano C, Byers P, et al. The 2017 international classification of the Ehlers-Danlos syndromes. Am J Med Genet C Semin Med Genet 2017;175(1):8–26.
[7] Zweers MC, van Vlijmen-Willems IM, van Kuppevelt TH, et al. Deficiency of tenascin-X causes abnormalities in dermal elastic fiber morphology. J Invest Dermatol 2004;122(4):885–91.
[8] Halper J, Kjaer M. Basic components of connective tissues and extracellular matrix: elastin, fibrillin, fibulins, fibrinogen, fibronectin, laminin, tenascins and thrombospondins. Adv Exp Med Biol 2014;802:31–47.
[9] Arnoczky SP, Aksan A. Thermal modification of connective tissues: basic science considerations and clinical implications. J Am Acad Orthop Surg 2000;8(5):305–13.
[10] Hayashi K, Thabit G 3rd, Massa KL, et al. The effect of thermal heating on the length and histologic properties of the glenohumeral joint capsule. Am J Sports Med 1997;25(1):107–12.
[11] Naseef GS 3rd, Foster TE, Trauner K, et al. The thermal properties of bovine joint capsule. The basic science of laser- and radiofrequency-induced capsular shrinkage. Am J Sports Med 1997;25(5):670–4.
[12] Bozec L, Odlyha M. Thermal denaturation studies of collagen by microthermal analysis and atomic force microscopy. Biophys J 2011;101(1):228–36.
[13] Ross EV, McKinlay JR, Anderson RR. Why does carbon dioxide resurfacing work? A review. Arch Dermatol 1999; 135(4):444–54.
[14] Flory PJ, Garrett RR. Phase transitions in collagen and gelatin systems. J Am Chem Soc 1958;80:4836–45.
[15] Allain JC, Le Lous M, Cohen S, et al. Isometric tensions developed during the hydrothermal swelling of rat skin. Connect Tissue Res 1980;7(3):127–33.
[16] Sadick N. Tissue tightening technologies: fact or fiction. Aesthet Surg J 2008;28(2):180–8.
[17] Gardner ES, Reinisch L, Stricklin GP, et al. In vitro changes in non-facial human skin following CO2 laser resurfacing: a comparison study. Lasers Surg Med 1996; 19(4):379–87.
[18] Ross EV, Yashar SS, Naseef GS, et al. A pilot study of in vivo immediate tissue contraction with CO2 skin laser resurfacing in a live farm pig. Dermatol Surg 1999; 25(11):851–6.
[19] Orringer JS, Rittie L, Hamilton T, et al. Intraepidermal erbium:YAG laser resurfacing: impact on the dermal matrix. J Am Acad Dermatol 2011;64(1):119–28.
[20] Seckel BR, Younai S, Wang KK. Skin tightening effects of the ultrapulse CO2 laser. Plast Reconstr Surg 1998; 102(3):872–7.
[21] Levy AS, Grant RT, Rothaus KO. Radiofrequency physics for minimally invasive aesthetic surgery. Clin Plast Surg 2016;43(3):551–6.
[22] Dierickx CC. The role of deep heating for noninvasive skin rejuvenation. Lasers Surg Med 2006;38(9):799–807.
[23] Lopez MJ, Hayashi K, Fanton GS, et al. The effect of radiofrequency energy on the ultrastructure of joint capsular collagen. Arthroscopy 1998;14(5):495–501.
[24] Zelickson BD, Kist D, Bernstein E, et al. Histological and ultrastructural evaluation of the effects of a radiofrequency-based nonablative dermal remodeling device: a pilot study. Arch Dermatol 2004;140(2):204–9.
[25] Kist D, Burns AJ, Sanner R, et al. Ultrastructural evaluation of multiple pass low energy versus single pass high energy radio-frequency treatment. Lasers Surg Med 2006;38(2):150–4.
[26] Hantash BM, Ubeid AA, Chang H, et al. Bipolar fractional radiofrequency treatment induces neoelastogenesis and neocollagenesis. Lasers Surg Med 2009;41(1):1–9.
[27] Fernandes D. Minimally invasive percutaneous collagen induction. Oral Maxillofac Surg Clin North Am 2005; 17:51–63.
[28] Tejero-Trujeque R. Understanding the final stages of wound contraction. J Wound Care 2001;10(7):259–64.
[29] Gupta J, Gill HS, Andrews SN, et al. Kinetics of skin resealing after insertion of microneedles in human subjects. J Control Release 2011;154(2):148–55.
[30] Kalluri H, Banga AK. Formation and closure of microchannels in skin following microporation. Pharm Res 2011;28(1):82–94.
[31] Aust MC, Reimers K, Gohritz A, et al. Percutaneous collagen induction. Scarless skin rejuvenation: fact or fiction? Clin Exp Dermatol 2010;35(4):437–9.
[32] Zeitter S, Sikora Z, Jahn S, et al. Microneedling: matching the results of medical needling and repetitive treatments to maximize potential for skin regeneration. Burns 2014. https://doi.org/10.1016/j.burns.2013.12.008.
[33] El-Domyati M, Barakat M, Awad S, et al. Microneedling therapy for atrophic acne scars: an objective evaluation. J Clin Aesthet Dermatol 2015;8(7):36–42.
[34] El-Domyati M, Barakat M, Awad S, et al. Multiple microneedling sessions for minimally invasive facial rejuvenation: an objective assessment. Int J Dermatol 2015. https://doi.org/10.1111/ijd.12761.
[35] Lolis MS, Goldberg DJ. Radiofrequency in cosmetic dermatology: a review. Dermatol Surg 2012;38:1765–76.
[36] Brightman L, Goldman MP, Taub AF. Sublative rejuvenation: experience with a new fractional radiofrequency system for skin rejuvenation and repair. J Drugs Dermatol 2009;8(11):S9–13.
[37] Hruza G, Taub AF, Collier SL, et al. Skin rejuvenation and wrinkle reduction using a fractional radiofrequency system. J Drugs Dermatol 2009;8(3):259–65.
[38] Simmons BJ, Griffith RD, Falto-Aizpurua LA, et al. Use of radiofrequency in cosmetic dermatology: focus on nonablative treatment of acne scars. Clin Cosmet Investig Dermatol 2014;7:335–9.

[39] Qin X, Li H, Jian X, et al. Evaluation of the efficacy and safety of fractional bipolar radiofrequency with high-energy strategy for treatment of acne scars in Chinese. J Cosmet Laser Ther 2015;17(5):237–45.
[40] Phothong W, Wanitphakdeedecha R, Sathaworawong A, et al. High versus moderate energy use of bipolar fractional radiofrequency in the treatment of acne scars: a split-face double-blinded randomized control trial pilot study. Lasers Med Sci 2016;31(2):229–34.
[41] Kaminaka C, Uede M, Matsunaka H, et al. Clinical studies of the treatment of facial atrophic acne scars and acne with a bipolar fractional radiofrequency system. J Dermatol 2015;42(6):580–7.
[42] Wang S, Mi J, Li Q, et al. Fractional microplasma radiofrequency technology for non-hypertrophic post-burn scars in Asians: a prospective study of 95 patients. Lasers Surg Med 2017;49(6):563–9.
[43] Tanaka Y. Long-term three-dimensional volumetric assessment of skin tightening using a sharply tapered non-insulated microneedle radiofrequency applicator with novel fractionated pulse mode in Asians. Lasers Surg Med 2015;47:626–33.
[44] Chandrashekar BS, Sriram R, Mysore R, et al. Evaluation of microneedling fractional radiofrequency device for treatment of acne scars. J Cutan Aesthet Surg 2014;7(2):93–7.
[45] Doddaballapur S. Microneedling with dermaroller. J Cutan Aesthet Surg 2009;2(2):110–1.
[46] Dogra S, Yadav S, Sarangal R. Microneedling for acne scars in Asian skin type: an effective low cost treatment modality. J Cosmet Dermatol 2014;13(3):180–7.
[47] Cachafeiro T, Escobar G, Maldonado G, et al. Comparison of nonablative fractional erbium laser 1,340 nm and microneedling for the treatment of atrophic acne scars: a randomized clinical trial. Dermatol Surg 2016;42(2):232–41.
[48] Alam M, Han S, Pongprutthipan M, et al. Efficacy of a needling device for the treatment of acne scars: a randomized clinical trial. JAMA Dermatol 2014;150(8):844–9.
[49] Schwarz M, Laaff H. A prospective controlled assessment of microneedling with the Dermaroller device. Plast Reconstr Surg 2011;127(6):146e–8e.
[50] Cho SI, Chung BY, Choi MG, et al. Evaluation of the clinical efficacy of fractional radiofrequency microneedle treatment in acne scars and large facial pores. Dermatol Surg 2012;38(7 Pt 1):1017–24.
[51] Vejjabhinanta V, Wanitphakdeedecha R, Limtanyakul P, et al. The efficacy in treatment of facial atrophic acne scars in Asians with a fractional radiofrequency microneedle system. J Eur Acad Dermatol Venereol 2014;28(9):1219–25.
[52] Min S, Park SY, Yoon JY, et al. Comparison of fractional microneedling radiofrequency and bipolar radiofrequency on acne and acne scar and investigation of mechanism: comparative randomized controlled clinical trial. Arch Dermatol Res 2015;307:897–904.
[53] Alexiades-Armenakas M, Newman J, Wiley A, et al. Prospective multicenter clinical trial of a minimally invasive temperature-controlled bipolar fractional radiofrequency system for rhytid and laxity treatment. Dermatol Surg 2013;39:263–73.
[54] Alexiades-Armenakas M, Rosenberg D, Renton B, et al. Blinded, randomized, quantitative grading comparison of minimally invasive, fractional radiofrequency and surgical face-lift to treat skin laxity. Arch Dermatol 2010;146(4):396–405.
[55] Man J, Goldberg DJ. Safety and efficacy of fractional bipolar radiofrequency treatment in Fitzpatrick skin types V–VI. J Cosmet Laser Ther 2012;87(6):179–83.