Facial Plastic Surgery & Aesthetic Medicine
Volume 24, Supplement 1, 2022
© American Academy of Facial Plastic and Reconstructive Surgery, Inc.
DOI: 10.1089/fpsam.2022.0226

Facial Plastic Surgery & Aesthetic Medicine

Open camera or QR reader and scan code to access this article and other resources online.

SPECIAL COMMUNICATION

Transcutaneous Radiofrequency Microneedling in the Facial Plastic Surgeon's Practice: A Review

Isabelle Magro, MD,[1] Amit Kochhar, MD,[2] Demetri Arnaoutakis, MD,[3] and Kian Karimi, MD, FACS[4,*]

Abstract

Importance: Minimally invasive methods for skin rejuvenation are in high demand. A diverse array of minimally invasive devices has been developed for aesthetical purposes and should be considered to help patients achieve their goals.

Observations: Radiofrequency (RF) microneedling is a safe and effective intervention for treatment of various aesthetical and dermatological conditions in all skin types. This review highlights Morpheus8 (InMode, Inc., Irvine, CA) and what differentiates it from other similar devices.

Conclusions and Relevance: RF microneedling addresses aesthetical and dermatological concerns for a diverse variety of patients in whom surgical intervention may not be desired. Morpheus8 has unique technological properties and advances that make it the preferred device for many practices.

Downloaded by 72.142.106.178 from www.liebertpub.com at 09/14/22. For personal use only.

Background and History

The demand for noninvasive and minimally invasive methods for skin rejuvenation has increased steadily over the past few decades.[1] In facial aesthetics, several nonsurgical technologies have been developed to meet this growing need.[2] Lasers, chemical peels, and dermabrasion emerged to facilitate skin resurfacing, whereas therapies such as cryolipolysis and deoxycholic acid were developed to remodel adipose tissue. However, there have been limited applications for reduction of skin laxity. Laser technology was initially adopted to achieve this goal; however, the energy and subsequent heat required to obtain the desired skin tightening resulted in damage to the epidermis and complications such as burns and irreversible pigmentation changes.

This is particularly problematic in darker pigmented skin types, thus limiting the use of lasers for this purpose.[3] An alternative from lasers for skin tightening was high-frequency ultrasound. However, its efficacy was also limited and it is associated with significant procedural pain and discomfort.[4,5]

Radiofrequency (RF) technology has been used for over a century across medical specialties for many purposes, including electrocautery, cardiac ablation, surgical oncology, and orthopedics.[2,6] RF has also been found to stimulate collagen remodeling and was first approved for cosmetic use in the early 2000s for the treatment of facial wrinkles and rhytids.[2] Over the subsequent decades, RF has evolved with the development of various modalities and combination therapies.[7] More recently,

[1]Department of Otolaryngology, Head and Neck Surgery, Keck Medicine of USC, University of Southern California, Los Angeles, California, USA.
[2]Pacific Neuroscience Institute, Providence St. Johns Medical Center, Santa Monica, California, USA.
[3]Department of Otolaryngology, Division of Facial Plastic Surgery, University of South Florida, Tampa, Florida, USA.
[4]Rejuva Medical Aesthetics, Los Angeles, California, USA.

*Address correspondence to: Kian Karimi, MD, FACS, Rejuva Medical Aesthetics, 11645 Wilshire Boulevard, Suite 605, Los Angeles, CA 90025, USA, Email: kiankarimi@gmail.com

the technology has been combined with nonenergy-based devices such as microneedling to improve skin rejuvenating outcomes by enhancing dermal, subdermal, and adipose heating while further minimizing epidermal heating and its complications.[7,8]

Devices that combine both RF with microneedling to target the dermal layer include Fractora (InMode, Irvine, CA) and Profound (Candela Medical, Marlborough, MA). Morpheus8 (InMode) that targets the subdermal and adipose layers was introduced in August 2020.[8] This article highlights Morpheus8 and what differentiates it from other devices.

Technological Overview

RF is an oscillating electrical current that induces collisions between charged molecules, which generate thermal energy. The amount of thermal energy produced is proportional to the impedance of the tissue through which it is delivered and the duration of administration as dictated by Ohm's law: Energy (J) = current^2 × resistance × time.[9,10] Impedance of the tissue is determined by several variables including water and electrolyte composition, collagen content, and temperature.[11] RF energy has a uniquely electrothermal effect rather than a selective photothermal effect like lasers, which target specific chromophores. Therefore, RF energy can be used in all skin types regardless of pigmentation, whereas lasers should be used with caution in patients with darker skin.[5,7,12]

RF therapy can target different tissues including the skin, soft tissue, and adipose tissue. The depth of penetration is inversely proportional to the frequency of the current applied to the treatment area.[13] Energy applied to the skin and soft tissue by RF technology induces contraction through two mechanisms. Immediate tissue contraction is secondary to cleavage of hydrogen bonds in the collagen triple helix, which shorten and thicken collagen fibrils. Delayed tissue contraction results from inflammation that triggers a wound healing cascade leading to neoangiogenesis, neocollagenesis, and elastic reorganization over 3–4 months.[14] RF energy applied to adipose tissue is remodeled through fat necrosis.[15]

Treatment with RF energy aims to optimally heat the dermal collagen while protecting the epidermis from injury.[7,15] Optimal collagen contraction occurs when dermal temperatures reach 65°C to 70°C when coagulation and collagen denaturing occur. However, epidermal temperatures must remain <42°C to 45°C as epidermal burns occur at 44°C.[16,17] Various methods are used to minimize epidermal injury while administering adequate temperatures to the treatment area. These include constant motion of the handpiece and superficial cooling.

Different types of RF energy can be used to customize treatment for a particular area. Types of RF energy include monopolar, bipolar, and multipolar modes. Monopolar RF consists of one emitting electrode within the operator's handpiece that transmits to a grounding pad placed distally on the patient's body. Bipolar RF consists of two emitting electrodes that are adjacent to one another within the operator's handpiece. Although monopolar RF has a greater depth of penetration than bipolar RF, bipolar RF has a more localized distribution of energy with less associated discomfort than the monopolar RF.[2,7]

Multipolar RF consists of multiple emitting electrodes that facilitate both deep and superficial penetration of energy.[1] RF energy can also be delivered as bulk or fractional heating. In bulk heating, the epidermis, dermis, and fibroseptal network and adnexa are all heated simultaneously though at different temperatures. In contrast in fractional heating, treated areas are interspersed with untreated areas, which allows for more rapid healing and decreased downtime.[7]

Nonenergy-based devices such as microneedling can also be used for skin tightening and adipose remodeling while preserving the epidermis. Microneedling uses microneedles to penetrate the dermis at varying depths leading to local inflammation that stimulates wound healing through the release of growth factors including TFG-alpha, TFG-beta, VEGF, and PDGF, which induce neocollagenesis, neoelastogenesis, and angiogenesis.[1,18,19]

RF combined with microneedling further enhances skin tightening and adipose remodeling by delivering energy through microneedles at a desired predetermined depth. The precision of energy delivery optimizes dermal, subdermal, and adipose heating and minimizes epidermal damage to facilitate contraction of the dermis, subdermis, and surrounding connective tissue and can induce coagulation of fat.[1] The treatment can be customized for each patient by adjusting the penetration depth and energy settings. Morpheus8 was examined to look at perfusion and lymphatic changes after treatment and was found to not negatively affect either property, thus inferring it to be safe in combination with surgical procedures[20]

Indications and Contraindications

RF microneedling has numerous indications in facial aesthetics, including skin rejuvenation, acne scars, melasma, hair thinning, and dermatological conditions such as acne vulgaris and rosasea.[21] RF microneedling for skin rejuvenation is most suitable in younger patients who have evidence of aging that does not warrant surgical intervention, in patients who have undergone surgical intervention who have recurrent signs of aging, or as an adjunct procedure after surgery in select patients.[1] RF microneedling may also be used on various parts of the body to treat cellulite, striae, and axillary hyperhidrosis.[21]

Contraindications to RF with microneedling include collagen vascular disorders, active infection, immunocompromised state, pregnancy, and poor wound healing.

Downloaded by 72.142.106.178 from www.liebertpub.com at 09/14/22. For personal use only.

Table 1. Summary of settings based on skin types+device tip for area

Skin type	*No. of passes*	*Treatment areas*	*Depth of penetration (mm)*	*RF energy level (kW)*	*Device tip*
I–III	1–3	Bony areas, periorbital, forehead, chin	2	15–35	12-coated and 24-coated
IV–VI	1–2	Bony areas, periorbital, forehead, chin	2	15–25	12-coated and 24-coated
I–III	3	Soft tissue, neck	1–3	15–40	24-coated
IV–VI	3	Soft tissue, neck	1–3	15–30	24-coated
I–III	2–3	Body areas	1–4	25–45	24-coated
IV–VI	2–3	Body areas	2–4	20–30	24-coated

RF, radiofrequency.

Though not a contraindication for treatment, a history of herpes simplex virus should be elicited and patients should be started on valacyclovir before treatment.[1]

Techniques

There are several RF microneedling devices available with varying characteristics. Devices have varying number of needles that range from 10 to 126. Depth of penetration is adjustable ranging from 1 to 2 mm for treatments in the face and from 3 to 4 mm for treatment of body areas.[1,7] Needle length ranges from 0.25 to 4.5 mm and should be selected accounting for an additional 1 mm zone of heat effect during treatment. Needles can also be insulated or noninsulated.

Theoretically, insulated needles minimize heat dissipation at the epidermal layer and may be more likely than protect against epidermal injury than noninsulated needles, which generate a thermal zone throughout the entire length of the electrode. For this reason, noninsulated needles may be more likely to cause postinflammatory hyperpigmentation, blistering, and scarring in darker skin types, though studies have not substantiated this hypothesis.[7,21]

RF energy delivered may range from 5 to 62 kW and can be administered in a cycle, fixed, or repetition mode.[1] Cycle mode entails penetration and retraction of the needles from the skin with every pulse, which is preferred in sensitive and small areas like the periorbital region. Fixed mode entails penetration of the needles with the ability to administer multiple pulses before retraction. Repetition mode allows multiple pulses to be delivered at a predetermined pulse repetition rate. Stacking of pulses should be avoided in areas with thin skin or overlying bone.[1]

RF energy should be adjusted according to the thickness of the skin and the pigmentation of the skin. Energy levels should be administered at reduced levels when treating areas with thin skin or underlying bone. Though RF microneedling can be used in all skin types, the energy administered should be started at a lower level (15 kW or lower) in darker skin types and gradually increased over the treatment course (maximum of 40 kW over soft tissue and 25 kW over bone).[1] When administering the treatment, the handpiece should be moved over the selected area with ~50% overlap with each administration.

Energy delivered, number of sessions, weeks between session, and days of downtime vary based on the treatment area. Postprocedure pain and thermal recovery of the treated areas are proportional to energy delivered and should be taken into consideration when selecting the mode of anesthesia. Preprocedure anesthesia often involves topical anesthetics applied 45 to 60 min before the treatment though can also involve local anesthesia and nerve blocks for more extensive treatments. The use of adjunctive analgesics such as a 50/50 combination of inhaled nitrous oxide and oxygen has been extremely useful in the senior author's practice.

Postprocedure treatment should include immediate cooling of the skin to reduce discomfort, erythema, and

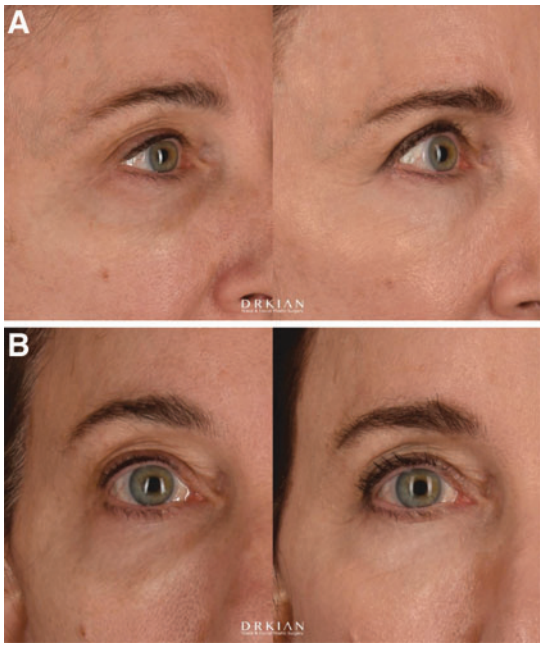

Fig. 1. Facial skin tightening before and after three treatments of Morpheus8. **(A, B)** Before treatment, 1 year after three Morpheus8 treatments. Treatment settings: Morpheus8 under eyes, tip: 24-coated. Energy level: 35, depth: 2 mm, pulse rate: 1, rep: 30 PPS, total pulses: 60. PPS, pulse per second; rep, repetitions.

Downloaded by 72.142.106.178 from www.liebertpub.com at 09/14/22. For personal use only.

edema. Patients should apply a topical with antibiotic properties (i.e., Alastin Skin Nectar, HealMD), or antibiotic ointment to the treated area for 1 to 3 days after the procedure while the microneedle puncture sites heal. Patients should refrain from applying any other topical agents for this time period.

Clinical Applications

In the senior author's practice (K.K.), Morpheus8 has been utilized to treat >1000 patients for various indications. Although a newer handpiece that penetrates up to 8 mm has been released, the author focuses this section on the original handpiece that has tips that penetrate from 0.5 mm to 4 mm of depth. A summary of setting ranges based on skin type is given in Table 1.

As discussed previously, the demand for ''skin tightening'' is at an all-time high. Morpheus8 has been useful in our practice to help patients achieve this through either a one-time procedure or a series of procedures, spaced 6 to 8 weeks apart (Figs. 1–3).

Morpheus8 can be used on procedure-naïve skin or as an adjuvant treatment after a surgical procedure. In our practice, Morpheus8 has been utilized as a ''rescue'' to skin laxity that was not corrected or improved with rhytidectomy alone—after all, rhytidectomy and other facial surgical procedures simply reposition skin and soft tissue but do not actually increase the concentration of elastin or enhance tightening of collagen fibers (Figs. 2 and 4).

Morpheus8 is an excellent modality to improve face and neck rhytids. Settings, depth, and frequency of treatments will vary on patient skin types, expectations, and tolerance for ''downtime.''

Other clinical uses of Morpheus8 as a stand-alone modality include improvement of acne scars, treatment of malar bags and festoons, reduction of excess adipose in the nasolabial, submental, and jowl compartment, and improvement of body cellulite. An improvement of festoons is demonstrated after two treatments (Fig. 3).

In combination with RF-assisted lipolysis such as FaceTite and AccuTite, Morpheus8 is always utilized

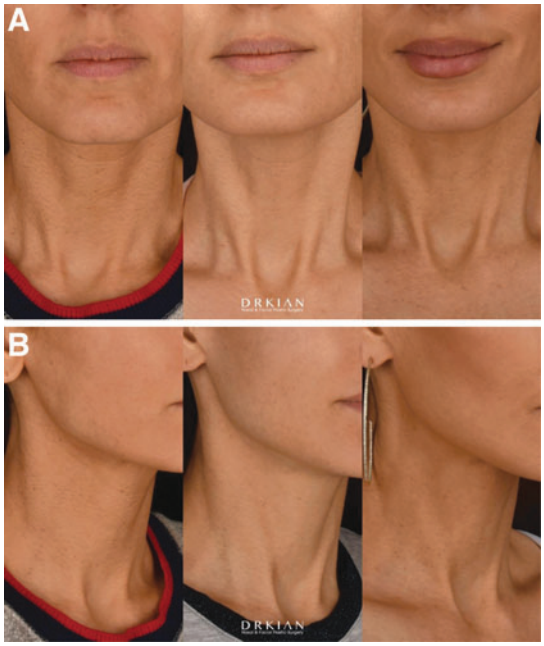

Fig. 2. Postface and neck lift+Morpheus8 for skin laxity improvement. **(A, B)** Before surgical "micro" neck lift procedure, 2 years and 2 months after surgical "micro" neck lift procedure, 1 year after EmbraceRF. Treatment settings: AccuTite: internal heat: 65°C, external heat: 40°C, time: 120 s, energy: 0.2 kJ/side, total: 4 kJ delivered. Morpheus8: depth: body 4 mm, energy: 30, mode: fixed, rep: 1.0 PPS, double-stack "poof": 6 pulses per side, 12 pulses total, right NLF: 6 pulses.

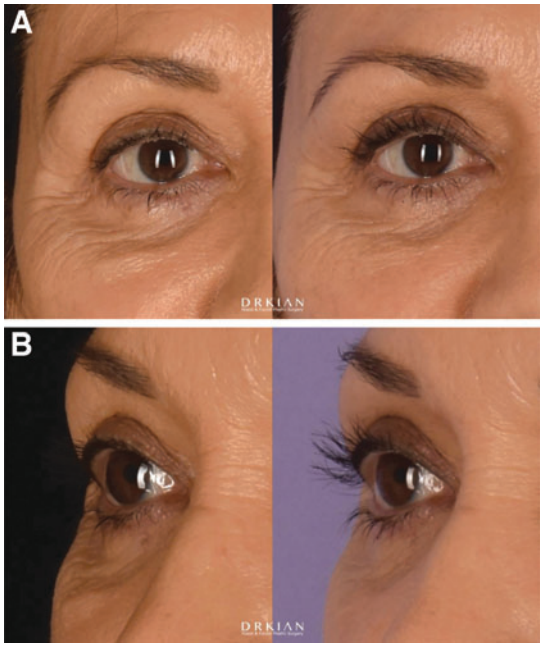

Fig. 3. Morpheus8 for malar bags improvement. **(A, B)** Before treatment, after one Fractora treatment and two Morpheus8 treatments. Treatment 1: Fractora, Tip: 24-Coated, Energy Level: 15, Pulse Rate: 1.0, Total Pulse: 8. Treatment 2: Morpheus8, Depth: Face, Energy Level: 25, Rep: 0.5PPS, Total Pulses: 8. Treatment 3: Morpheus8, Depth: Face, Energy Level: 25, Rep: 1.0PPS, Total Pulses: 11.

Downloaded by 72.142.106.178 from www.liebertpub.com at 09/14/22. For personal use only.

Fig. 4. Facelift with perioral Morpheus8. **(A)** Before lower face and neck lifting procedure with Morpheus8, 5 weeks after lower face and neck lifting procedure with Morpheus8. **(B)** Before (left) and 5 weeks (right) after lower face and neck lifting procedure with perioral Microneedling RF treatment. Treatment 1: morpheus8, tip: 24-coated, energy level: 25, rep: 2 PPS, total pulse: 125. Treatment 2: Morpheus8, tip: 24-coated, energy level: 25, rep: 2 PPS, total pulses: 320. Treatment 3: Morpheus8, tip: 24-coated, energy level: 25, rep: 2 PPS, total pulses: 248. Treatment 4: Morpheus8, tip: 24-coated, energy level: 25, rep: 3 PPS, total pulses: 248.

Fig. 5. Fat reduction (nasolabial folds, submental, jowl region). **(A, B)** Before treatment, 2 months after AccuTite/EmbraceRF treatment. Treatment settings: external: 39°C, internal: 65°C, time: 120 s, Joules: submentum 0.5 kJ, nasolabial folds 0.3 kJ/side.

simultaneously to either tighten skin, reduce the subcutaneous fat layer, or both (Figs. 5–7 shows two great EmbraceRF results—one male and one female).

Results and Complications

Multiple studies have shown the safety and efficacy of RF microneedling for various indications. Tan et al. performed a review of the literature to evaluate the safety and efficacy of RF microneedling as compared with other energy-based devices. The authors identified 42 higher quality studies: 14 studies for skin rejuvenation, 7 for acne scars, 6 for acne vulgaris, 5 each for striae and axillary hyperhidrosis, 2 for melasma, and 1 each for cellulite, genetic alopecia, and rosacea). These studies illustrated efficacy of RF microneedling for the aforementioned indications.[21]

Studies evaluating RF microneedling for skin rejuvenation have shown 20 to 60% mean improvement in facial rhytids, skin laxity, and textural roughness after one to three treatment sessions.[22–28] The earliest observed effects were noted at 1 month with the largest improvement at 3 months and persisting until 7 months.[28] A small study examining treatment of periorbital rhytids found that botulinum toxin A was more effective with a more rapid onset and shorter downtime than RF microneedling.[29] However, RF microneedling had a longer lasting effect with continued improvement 6 months after treatment.[29]

A study examining the optimal settings for RF microneedling concluded that a targeted dermal temperature of 67°C with a duration of 3 to 4 s was most effective.[30] Studies also showed less clinical improvements with temperatures of 69.5°C, which caused partial denaturing of the collagen.[26,30] The optimal depth of treatment for RF microneedling was 1.3 to 2 mm to target the reticular dermis.[31]

Lasers including erbium-doped yttrium aluminum garnet (Er:Yag) and CO_2 fractional ablative lasers can also be used in skin rejuvenation. A large study comparing laser and RF microneedling found that the Er:Yag fractional ablative laser was more effective in treating periorbital rhytids, but RF microneedling was more effective

Downloaded by 72.142.106.178 from www.liebertpub.com at 09/14/22. For personal use only.

Downloaded by 72.142.106.178 from www.liebertpub.com at 09/14/22. For personal use only.

Fig. 6. EmbraceRF male results. **(A, B)** Before treatment, 1 year and 5 months after microliposuction and EmbraceRF treatments. Treatment 1: EmbraceRF—FaceTite: internal: 65, external: 39, time: 120 s, joules: submandibular 1.3 kJ per side, superior neck 1.3 kJ per side, submentum 3 kJ. Morpheus8: first pass: lower third: 41 pulses per side. submental+ submandible: 50 pulses per side, depth: 4 mm, mode: cycle, energy: 25, rep: single. Second pass: lower third, submental and submandible: 85 pulses, depth: 3 mm, mode: cycle, energy: 25, rep: single. Treatment 2: Morpheus8 (24 pin)—submentum: 4 mm/35 J/3 mm/30 J/2 mm/20 J on cycle/1.0 PPS; total number pulses = 165. Treatment 3: Morpheus8 (24 pin)—Submentum: 4 mm/35 J/3 mm/30 J/2 mm/25 J/1 mm/20 J on cycle/1.0 PPS; total number pulses = 178. Cheeks: 3 mm/30 J, 2 mm/25 J, 1 mm/20 J. Treatment 4: Morpheus8 (24 pin)—submentum/jawline, tip: 4 mm, energy: 35 energy, pulse rate: single cycle, pulses: 44. Submentum/jawline—first pass: tip: 3 mm, energy: 30, pulse rate: single cycle, pulses: 47. Submentum/jawline—second pass: tip: 3 mm, energy: 30, pulse rate: single cycle, pulses (no.): 37.

Fig. 7. EmbraceRF female results. Before treatment, 2 months after EmbraceRF and MicroLiposuction treatment. FaceTite settings: internal: 40, external: 60, time: 120 s, joules: 3.3 kJ to submentum. Morpheus8 treatment settings: Area 1: energy: 30, 24 pin, 4.0 mm, mode: fixed, number of pulses: 66, repetition: 1.5. Area 2: energy: 30, 24 pin, 3.0 mm, mode: fixed, number of pulses: 40, repetition: 1.5. Area 3: energy: 25, 24 pin, 2.0 mm, mode: fixed, number of pulses: 50, repetition: 1.5.

for the treatment of nasolabial, perioral, jawline, and neck rhytids.[32] This finding was attributed to the difference in skin thickness. Whereas the Er:Yag fractional laser allows broader more superficial microthermal zones of injury in the upper face where the skin is thinner, RF microneedling creates deeper microthermal zones of injury in the lower face where the skin is thicker.[32]

Though surgical facelift is the gold standard treatment for skin laxity, the procedure requires significant downtime with the risk of adverse events including postoperative scaring, which may require further scar management.[33] Though less effective than surgical facelift in providing skin rejuvenation, RF microneedling provides noticeable improvements without the associated risks of surgery and can be used in combination with surgical rhytidectomy (Fig. 4A, B).

Studies have also shown that RF with microneedling is effective in treating acne scars.[34–37] A study found that RF microneedling was equally as effective as erbium-doped glass (Er:Glass) in treating acne scars, but that RF microneedling was less painful, had less downtime, and fewer complications particularly in darker skinned individuals.[38] Studies have also shown that RF microneedling can be used in combination with laser therapy such as Er:Glass, CO_2 Fractionated ablative laser, and noninvasive fractional bipolar radiofrequency for superior results to laser therapy alone.[39–41]

RF microneedling is also effective in managing acne vulgaris, a common chronic skin disease involving blockage and/or inflammation of pilosebaceous units.[34,35] Studies suggest that RF microneedling may yield better outcomes than diode nonablative fractional lasers[42] and cause less complications such as postinflammatory hyperpigmentation and erythema compared with CO_2 fractional lasers.[43] Studies have also shown promising

results in treating rosacea,[44] melasma,[45,46] and male-pattern androgenetic alopecia[47] with RF microneedling, though more high-quality studies are needed to further support these uses. Outside of the head and neck, RF microneedling has also shown to have promising outcomes when used to treat striae and cellulite in the abdomen and lower body.[21]

RF microneedling is well tolerated and safe in all skin types. The most common side effects are pain, erythema, purpura, and edema, which resolve on average within 5 days. The most common complications include postinflammatory hyperpigmentation and erythema, which often resolve with photoprotection.[21] Less common complications include prolonged swelling, hardened areas, and neuropraxia. Dayan et al. (2019) examined the outcomes of Morpheus8 in 247 patients and found that prolonged swelling of >6 weeks occurred in 4.8% of patients, hardened area for >12 weeks occurred in 3.2% of patients, and neuropraxia occurred in 1.2% of patients.[1] All of these complications resolved without intervention. Rare complications include burns and seromas, which are reported in <1% of patients.[2]

Conclusions

RF microneedling is an effective and safe minimally invasive treatment for various facial aesthetical and dermatological conditions. This technology promotes skin contraction and adipose remodeling while preventing epidermal injury in all skin types. RF microneedling can be used in diverse patients to address aesthetical and dermatological concerns that often do not warrant the risks and complications associated with traditional surgical techniques.

Morephus8 has been revolutionary in the arena of RF microneedling devices due to the extensive number of studies demonstrating its efficacy and safety as a standalone procedure or in simultaneous or sequential combination with nonsurgical and surgical interventions. In the senior author's practice, it is utilized nearly daily for the myriad of indications discussed in this article with extremely high patient and practitioner satisfaction.

Author Disclosure Statement

K.K. and D.A. were consultants for InMode. For all other authors, no competing financial interests exist.

Funding Information

No funding was received in the preparation of this work.

References

1. Dayan E, Chia C, Burns AJ, et al. Adjustable depth fractional radiofrequency combined with bipolar radiofrequency: a minimally invasive combination treatment for skin laxity. *Aesthetic Surg J.* 2019;39(Supplement 3):S112–S119.
2. Dayan E, Burns AJ, Rohrich RJ, et al. The use of radiofrequency in aesthetic surgery. *Plast Reconstr Surg Glob Open.* 2020;8(8):e2861.
3. Atiyeh BS, Dibo SA. Nonsurgical nonablative treatment of aging skin: radiofrequency technologies between aggressive marketing and evidence-based efficacy. *Aesthetic Plast Surg.* 2009;33:283–294.
4. Fisher GH, Jacobson LG, Bernstein LJ, et al. Nonablative radiofrequency treatment of facial laxity. *Dermatol Surg.* 2005;31(s3):1237–1241.
5. Greene RM, Green JB. Skin tightening technologies. *Facial Plast Surg.* 2014;30(1):62–67.
6. Miniaci A, Codsi MJ. Thermal capsulorrhaphy for the treatment of shoulder instability. *Am J Sports Med.* 2006;34(8):1356–1363.
7. Weiner SF. Radiofrequency microneedling. *Facial Plast Surg Clin North Am.* 2019;27(3):291–303.
8. Mulholland RS. Internal and external radiofrequency assisted lipocoagulation (RFAL) in the control of soft tissue contraction during liposuction: part 2 "outside in" RFAL thermal tissue tightening. In: Enhanced Liposuction—New Perspectives and Techniques. Duncan DI, ed. London: IntechOpen; 2021. https://www.intechopen.com/chapters/76342 doi: 10.5772/intechopen.97378. Accessed August 16, 2022
9. Alster TS, Lupton JR. Nonablative cutaneous remodeling using radiofrequency devices. *Clin Dermatol.* 2007;25(5):487–491.
10. Belenky I, Margulis A, Elman M, et al. Exploring channeling optimized radiofrequency energy: a review of radiofrequency history and applications in esthetic fields. *Adv Ther.* 2012;29(3):249–266.
11. Schepps JL, Foster KR. The UHF and microwave dielectric properties of normal and tumour tissues: variation in dielectric properties with tissue water content. *Phys Med Biol.* 1980;25(6):1149–1159.
12. Battle EF, Battle S. Clinical evaluation of safety and efficacy of fractional radiofrequency facial treatment of skin type VI patients. *J Drugs Dermatol.* 2018;17(11):1169–1172.
13. Beasley KL, Weiss RA. Radiofrequency in cosmetic dermatology. *Dermatol Clin.* 2014;32(1):79–90.
14. 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):204–209.
15. Lawrence WT. Nonsurgical face lift. *Plast Reconstr Surg.* 2006;118(2):541–545.
16. Hayashi K, Thabit G, 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):107–112.
17. Clementoni MT, Munavalli GS. Fractional high intensity focused radiofrequency in the treatment of mild to Moderate laxity of the lower face and neck: a pilot study. *Lasers Surg Med.* 2016;48(5):461–470.
18. Fritz K, Salavastru C. Ways of noninvasive facial skin tightening and fat reduction. *Facial Plast Surg.* 2016;32(3):276–278.
19. Issa MCA, De Britto Pereira Kassuga LE, Chevrand NS, et al. Transepidermal retinoic acid delivery using ablative fractional radiofrequency associated with acoustic pressure ultrasound for stretch marks treatment. *Lasers Surg Med.* 2013;45(2):81–88.
20. Dayan E, Theodorou S, Rohrich RJ, et al. Aesthetic applications of radiofrequency: lymphatic and perfusion assessment. *Plast Reconstr Surg Glob Open.* 2020;8(10):e3193.
21. Tan MG, Jo CE, Chapas A, et al. Radiofrequency microneedling: a comprehensive and critical review. *Dermatol Surg.* 2021;47(6):755–761.
22. Kim JK, Roh MR, Park GH, et al. Fractionated microneedle radiofrequency for the treatment of periorbital wrinkles. *J Dermatol.* 2013;40(3):172–176.
23. Lee SJ, Kim JI, Yang YJ, et al. Treatment of periorbital wrinkles with a novel fractional radiofrequency microneedle system in dark-skinned patients. *Dermatol Surg.* 2015;41(5):615–622.
24. Kwon SH, Choi JY, Ahn GY, et al. The efficacy and safety of microneedle monopolar radiofrequency for the treatment of periorbital wrinkles. *J Dermatolog Treat.* 2021;32(4):460–464.
25. Gold M, Taylor M, Rothaus K, et al. Non-insulated smooth motion, microneedles RF fractional treatment for wrinkle reduction and lifting of the lower face: international study. *Lasers Surg Med.* 2016;48(8):727–733.
26. Alexiades-Armenakas M, Newman J, Willey 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(2):263–273.
27. Zhang M, Fang J, Wu Q, et al. A prospective study of the safety and efficacy of a microneedle fractional radiofrequency system for global facial photoaging in Chinese patients. *Dermatol Surg.* 2018; 44(7):964–970.
28. Liu TM, Sun YM, Tang ZY, et al. Microneedle fractional radiofrequency treatment of facial photoageing as assessed in a split-face model. *Clin Exp Dermatol.* 2019;44(4):E96–E102.

Downloaded by 72.142.106.178 from www.liebertpub.com at 09/14/22. For personal use only.

29. Jeon IK, Chang SE, Park GH, et al. Comparison of microneedle fractional radiofrequency therapy with intradermal botulinum toxin a injection for periorbital rejuvenation. *Dermatology*. 2014;227(4):367–372.
30. Alexiades M, Berube D. Randomized, blinded, 3-arm clinical trial assessing optimal temperature and duration for treatment with minimally invasive fractional radiofrequency. *Dermatol Surg.* 2015;41(5):623–632.
31. Lu W, Wu P, Zhang Z, et al. Curative effects of microneedle fractional radiofrequency system on skin laxity in Asian patients: a prospective, double-blind, randomized, controlled face-split study. *J Cosmet Laser Ther.* 2017;19(2):83–88.
32. Serdar ZA, Tatlıparmak A. Comparison of efficacy and safety of fractional radiofrequency and fractional Er:YAG laser in facial and neck wrinkles: six-year experience with 333 patients. *Dermatol Ther*. 2019;32(5):e13054.
33. 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.
34. Hellman J. Long term follow-up results of a fractional radio frequency ablative treatment of acne vulgaris and related acne scars. *J Cosmet Dermatological Sci Appl.* 2016;6(3):100–104.
35. Hellman J. Retrospective study of the use of a fractional radio frequency ablative device in the treatment of acne vulgaris and related acne scars. *J Cosmet Dermatological Sci Appl*. 2015;5(4):311–316.
36. Faghihi G, Poostiyan N, Asilian A, et al. Efficacy of fractionated microneedle radiofrequency with and without adding subcision for the treatment of atrophic facial acne scars: a randomized split-face clinical study. *J Cosmet Dermatol*. 2017;16(2):223–229.
37. 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):1219–1225.
38. Chae WS, Seong JY, Jung HN, et al. Comparative study on efficacy and safety of 1550 nm Er: glass fractional laser and fractional radiofrequency microneedle device for facial atrophic acne scar. *J Cosmet Dermatol*. 2015;14(2):100–106.
39. Kwon HH, Park HY, Choi SC, Bae Y, Jung JY, Park GH. Combined fractional treatment of acne scars involving non-ablative 1,550-nm erbium-glass laser and micro-needling radiofrequency: a 16-week prospective, randomized split-face study. *Acta Derm Venereol.* 2017. doi:10.2340/00015555-2701
40. Tatlıparmak A, Aksoy B, Shishehgarkhaneh LR, et al. Use of combined fractional carbon dioxide laser and fractional microneedle radiofrequency for the treatment of acne scars: a retrospective analysis of 1-month treatment outcome on scar severity and patient satisfaction. *J Cosmet Dermatol.* 2020;19(1):115–121.
41. Park JY, Lee EG, Yoon MS, et al. The efficacy and safety of combined microneedle fractional radiofrequency and sublative fractional radiofrequency for acne scars in Asian skin. *J Cosmet Dermatol*. 2016;15(2):102–107.
42. Kwon HH, Park HY, Choi SC, et al. Novel device-based acne treatments: comparison of a 1450-nm diode laser and microneedling radiofrequency on mild-to-moderate acne vulgaris and seborrhoea in Korean patients through a 20-week prospective, randomized, split-face study. *J Eur Acad Dermatol Venereol.* 2018;32(4):639–644.
43. Shin JU, Lee SH, Jung JY, et al. A split-face comparison of a fractional microneedle radiofrequency device and fractional carbon dioxide laser therapy in acne patients. *J Cosmet Laser Ther.* 2012;14(5):212–217.
44. Park SY, Kwon HH, Yoon JY, et al. Clinical and histologic effects of fractional microneedling radiofrequency treatment on Rosacea. *Dermatol Surg.* 2016;42(12):1362–1369.
45. Jung JW, Kim WO, Jung HR, et al. A face-split study to evaluate the effects of microneedle radiofrequency with Q-switched Nd:YAG laser for the treatment of melasma. *Ann Dermatol.* 2019;31(2):133–138.
46. Kwon HH, Choi SC, Jung JY, et al. Combined treatment of melasma involving low-fluence Q-switched Nd:YAG laser and fractional microneedling radiofrequency. *J Dermatolog Treat*. 2019; 30(4):352–356.
47. Yu AJ, Luo YJ, Xu XG, et al. A pilot split-scalp study of combined fractional radiofrequency microneedling and 5% topical minoxidil in treating male pattern hair loss. *Clin Exp Dermatol.* 2018;43(7):775–781.

Downloaded by 72.142.106.178 from www.liebertpub.com at 09/14/22. For personal use only.