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Radiofrequency: An Update on Latest Innovations

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ABSTRACT

As the aging population in our society continues to grow, new technologies and procedures promising a more youthful appearance are continuously sought. The utilization of radiofrequency technology remains a novel method for the treatment of many aesthetic and medical dermatological indications. Innovative applications are constantly identified, expanding treatment options for various patient concerns including aging of the hands, cellulite, non-invasive lipolysis, and postpartum skin laxity. Non-invasive treatments are ideal for busy patients seeking minimal recovery time and so called lunch-time procedures. Furthermore, new developments in treatment devices enhance efficacy while decreasing patient discomfort.

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INTRODUCTION

As the aging population in our society continues to increase, many people are seeking technologies and treatments to help achieve a more youthful appearance. This, coupled with the general population's busy lifestyle, is leading towards a desire for procedures with minimal side effects and little to no recovery time. Of the skin rejuvenation modalities, radiofrequency (RF) has emerged as a safe and effective treatment for a broad range of aesthetic and medical indications.[1-4]

Radiofrequency emits focused electromagnetic waves which meets resistance within the tissue, generating heat.[5] This thermal energy affects collagen's triple helix structure, subsequently breaking the intramolecular hydrogen bonds resulting in immediate collagen contracture and subsequent neocollagenesis within the dermis without disrupting the epidermis.[6-8] This results in further collagen tightening and an overall increase in collagen content.[9] A study by el-Domyanti et al[10] shows that RF further decreases elastotic material in the upper dermis and induces reorientation of elastic fibers within the papillary and upper reticular dermis. Unabsorbed by melanin, RF is chromophore independent allowing it to be safely used for all skin types.[11] RF is associated with few complications and adverse effects while allowing a quick recovery time.[12-14]

RF devices vary based on the number of electrodes, dividing them into unipolar, bipolar and multipolar devices. Unipolar devices have a single electrode with a grounding pad. The highest concentration of electrical energy, and consequently heat, remains near the tip of the electrode and decreases distally.[15] This type of device results in the deepest tissue penetration resulting in the highest efficacy,[5] though it is accompanied with significant discomfort[16,17] Unipolar devices have shown significant improvements in skin tightening and laxity, rhytids, brow elevation and both active and scarring acne lesions.[9,10,13,16,18-21] Furthermore, the use of a mobile device for the delivery of unipolar radiofrequency in a split face study has shown a trend toward improvement of rhytides and laxity of facial skin.[55]

Bipolar devices consist of two electrodes, without a grounding pad, emitting a fast, alternating current.[15] The controlled energy distribution decreases the discomfort associated with older devices.[22-24] The main limitation of this device is that the treated area is limited to the volume between the two electrodes[25] with the depth of penetration being approximately half the distance between the two electrodes.[26]

Lastly, multipolar devices work similarly to the bipolar ones but consist of three or more electrodes. One electrode maintains a positive charge while the others carry negative charges. Electrodes alternate between positive and negative charges to avoid overheating.[15] These devices allow a larger volume to be heated with less discomfort, although only superficial areas are treated.[23,24]

Popular approaches to radiofrequency therapy involve combining treatment modalities allowing for enhanced efficacy and reduced adverse effects. Several devices have been combined with RF including broadband light, lasers, ultrasound, pulsed electro-magnetic fields, and vacuum devices. Combining differing mechanisms of action leads to complimentary effects.

New Indications

A myriad of studies have been conducted expanding indications for the use of radiofrequency devices and discovering the underlying mechanisms resulting in their efficacy. Identifying

the mechanisms involved in exhibiting results allows clinicians to identify new uses. One such identified use, which has shown promising results in daily practice, is for postpartum skin laxity. RF induced skin tightening would be efficacious for this particular indication. This tightening and lifting effect on skin results from the preferential heating of collagen-based fibrous septa leading to contraction of subcutaneous tissue.[1,27]

Another indication, although lacking significant clinical studies, is the treatment of aging hands. Based on the author's personal clinical experience, RF improves the aesthetic appearance of the dorsal surface of the hands. RF reduces skin laxity and increases dermal collagen, which is believed to reduce the visibility of superficial veins in the hand.[6,7,28,29] A novel, first-of-its-kind, study utilizing three treatments of unipolar RF at two week intervals resulted in 50% visual improvement based on an improvement of at least one point on the Global Aesthetic Improvement Scale.[30]

Acne vulgaris is the most common skin disease in the United States[31] and efficacious treatments, particularly for recalcitrant acne lesions, are in great demand. This has led to the study of RF treatments for their effectiveness in treating both active acne lesions and residual scarring. RF is hypothesized to inhibit sebaceous gland activity by heating the sebaceous glands, which leads to an increased metabolic state of the gland in turn resulting in its shrinkage. The subsequent reduction of sebum production and decrease in P. acnes, thus improves the patient's skin condition.[8,9] It may help with acne scarring based on its ability to promote neocollagenesis within the dermis. Sadick et al[32] treated acne scars with 1-3 treatments one month apart with a phase-controlled multisource RF device and found a significant reduction of scar depth four weeks following the last treatment. Using a unipolar device, Ruiz-Esparza et al[9] treated 222 patients with moderate to severe active cystic scarring acne. A 75% reduction of active lesions was seen in 92% of patients. Initial results were visible one month following 1-3 treatment sessions with the full effect being seen four months following treatment. Similarly, a reduction in lesion count was seen in another study consisting of 32 patients with moderate inflammatory acne.[8]

Cellulite, a common aesthetic concern among patients may also be improved utilizing RF treatments. Theoretically, the higher electric conductivity of septa compared with adipose tissue allows electric charge to flow through septa preferentially. This results in a change in configuration of the septa, targeting adipocytes for thermal injury.[15] Unipolar RF has been used to treat grade III and IV cellulite on the upper thigh in 30 patients.[33,55,56] A total of six treatments were performed at two week intervals. A significant decrease in the appearance of cellulite resulted in a mean decrease in thigh circumference of 2.45 centimeters (cm). Dermal fibrosis, reported on histology, results in long lasting effects. Sadick et al[34] noted improvements in the appearance of cellulite in 100% of patients, whereas Alster et al[35] noted clinical improvement in 90% of treated patients.

The high impedance of subcutaneous adipose generates greater amounts of energy, allowing RF to induce irreversible thermal damage to adipocytes.[1,26,36] This is the mechanism behind RF's use for non-invasive lipolysis. In fact, RF penetrates deeper than other modalities such as laser therapy, along with providing

better skin and subcutaneous tissue contraction following a loss in adipose tissue.[37-39] Unipolar RF long pulse delivery systems penetrate to a depth up to 3 cm and heat the subcutaneous fat layer in a uniform distribution. Heating the adipose tissue up to 45 °C for 3 minutes triggers apoptosis. Furthermore, it increases basal metabolic rate and macrophage activity 4-8 weeks following treatment. This thermal damage also increases triglyceride release and vascular perfusion leading to increased oxygen content and lipid turnover. Devices combined with mechanical manipulation further enhance circulation as well as lymphatic drainage contributing to fat cell turnover.

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Novel Technologies

Although RF devices already have a reputation for their efficacy coinciding with minimal downtime and side effects, improvements continue to be made to minimize discomfort and improve patient satisfaction. New tips have integrated a cooling system with digitally pulsed RF delivery. This allows the RF to be interrupted by cooling bursts, reducing discomfort. Hand pieces also vibrate which is hypothesized to inhibit pain impulses based on the Gate Control Theory of Pain Mitigation.[40] Continuous vibration activates the large alpha nerve fibers which activate inhibitory neurons, blocking the impulse propagation of small pain fibers. Furthermore, tips may apply a low voltage electrical current termed Transcutaneous Electrical Nerve Stimulation (TENS). This current is delivered to the skin via electrodes placed near the source of pain. Electrically stimulated nerves then send signals to the thalamus and cortex also altering normal pain perception. Together this vibration and TENS is part of the Comfort Pulse Technology. Along with decreasing discomfort, newer tips use less energy to reach maximum temperature and reach this temperature faster. Selected hand pieces contain sensors, which continually monitor temperature and pressure. These devices shut off automatically if the hand piece is not in full contact with the skin. This feature prevents RF “arcing”, which feels to the patient like static shock.[41]

adjustA new, non-invasive RF device incorporates RF with low-frequency pulsed electromagnetic fields (PEMF). This combined technology is referred to as $(MP)^2$, which stands for “Multi Polar Magnetic Pulse”. Although originally used to facilitate bone healing following fracture,[42] PEMF was described to stimulate dermal fibroblasts and collagen production by Murray and Farndale.[43] RF and PEMF have different mechanisms of action and target different elements within the skin and therefore, their combination has several benefits. RF contracts and remodels collagen by heating the dermis. The non-thermal mechanism of PEMF induces collagen neosynthesis by releasing fibroblast growth factor-2 (FGF-2).[5] Additionally, PEMF stimulates angiogenesis, which facilitate healing following the thermal injury induced by RF.[44] This synergistic effect is optimized when simultaneously emitted from the same electrode.[45] This combination device has received FDA clearance for non-invasive treatment of facial wrinkles and rhytides and Health Canada clearance for temporary reduction of cellulite and skin tightening. In a study outlined by Krueger et al,[5] 31 subjects with facial wrinkles received 10 treatments. The results of this study showed a significant decrease in wrinkles and an improvement in elasticity in 97% of the subjects 3 months after the last treatment. The treatment was rated to be free of pain by 100% of the subjects. No unexpected adverse side effects were reported during the study, however the investigators noted post-treatment edema, which only lasted for 10-30 minutes. In a similar study performed by Lee et al,[45] 10 Korean patients underwent 8 treatment sessions with this device over the course of 6 weeks. The results showed improvements in skin laxity, nasolabial folds, and facial contours. Improved skin texture was noted in 90% of the subjects. The participants in this study also rated their level of pain during the treatment to be very low. The results of both studies indicate that the $(MP)^2$ technology provides a safe, effective and painless treatment for the reduction of wrinkles and rejuvenation of aged skin. Further advancements have been made to this technology to add the beneficial effects of adjustable pulsed suction. This allows for the added benefit of enhanced energy penetration, lymphatic drainage and improved circulation. This newer technology is supposed to be effective in reducing thigh circumference, improving cellulite, skin tightening and wrinkle reduction.

Sublative RF is a new, minimally invasive way of delivering RF thermal energy. These devices contain a microneedle electrode array, delivering thermal injury directly to reticular dermis and creating ablative micro-spots within the skin.[8] This is believed to lead to faster healing by leaving damaged tissue surrounded by healthy tissue. Furthermore, by directly heating the reticular dermis, adverse effects such as post-inflammatory hyperpigmentation are avoided.[11] Some devices even insulate the proximal half of each microneedle, protecting the epidermis and papillary dermis.[46] This sparing of the epidermis and adnexal structures also aids in rapid healing.

Fractional RF results in a dry microablation which, similar to sublative RF, leaves remaining, unaffected healthy tissue in place in between ablative pulses also contributing to rapid healing.[32] This decreases downtime and risk of side effects, such as infection, by leaving the skin intact in comparison with traditional ablative resurfacing devices which leave open wounds. Aside from minimizing side effects and downtime, fractional RF has been shown to significantly increase reticular dermal volume and hyaluronic acid and elastin content 10 weeks following treatment[22,47-49] Fractional RF has shown efficacy against facial skin laxity, which correlated with this resulting neoelastogenesis[22,50] Additionally, anti-senescent pathways involving sirtuins have also shown to be up-regulated by fractional RF.[51] Aside from its efficacy on skin laxity and improvement of wrinkles, overall skin textural improvements suggest an induced anti-aging effect on the epidermal layer.[22]

As seen with other ablative and sublative devices, disrupting the epidermal barrier assists in the penetration of topically applied substances. These devices provide a direct route for transdermal delivery of large hydrophilic molecules such as growth factors, peptides and cytokines. These topically applied substances are being used for anti-aging effects and enhance the efficacy of RF treatments alone. The efficacy of this RF-assisted delivery was demonstrated in a study applying a stem cell conditioned medium (SCM) consisting of growth factors and cytokines following RF treatment.[11] A sublative RF device was used, consisting of non-insulated microneedle electrodes in order to decrease bleeding. Following RF treatment and SCM application, proteins from the cultured medium were demonstrated in both the epidermis and dermis. Greater improvements of wrinkles as well as overall skin appearance was seen with the combined treatment compared to sublative RF alone. As RF induces a wound and partially denatures collagen, it is intuitive that adding growth factors and cytokines involved in the healing process will enhance healing, although further studies are required.

DISCUSSION

Although RF has been found to be very well tolerated, it is not without its own risk of adverse effects (Table 1). Transient erythema and edema as well as post-operative discomfort may be present, but can be reduced with the use of cold compresses.[46] Application of cold compresses may also help prevent ecchymoses, which also can be reduced with lidocaine and epinephrine injection prior to treatment. Single pass treatments with maximum energy are associated with increased patient discomfort and can be improved with multiple passes of lower energy, which also correlates with increased efficacy of collagen denaturation and skin tightening.[7,27] Likewise, lower temperatures seem to be safer and more comfortable for patients.[5,52] As discussed, original unipolar devices have been associated with increased adverse effects, however adjustments have been made to allow for more tolerable procedures including increased heating efficiency, vibrating hand pieces, and redesigned tips concentrating heat to the center rather than the periphery.[53]

TABLE 1.

Summary of Studies Utilizing RF Devices

Device Type	Pain	Anesthetic	Treatments	Passes	Adverse Effects
Unipolar	Mild-moderate	None	3; 2 week intervals	2	None reported.
Unipolar	Not reported	Topical 5% lidocaine cream 1 hour prior	1-3; 4 week intervals	Not reported	None.
Unipolar	Not reported	None	6; 2 week intervals	3	Not reported.
RF + Infrared Light + Vacuum	Minimal discomfort	None	Twice weekly for 4 or 8 weeks	Not reported	Temporary swelling, local crusting which resolved within 72 hours.
Bipolar RF + Infrared Light + Mechanical Manipulation	Minimal-none	None	Twice weekly for 4 weeks	4-6	Transient erythema & bruising.
Phase Controlled Multi-Source	Not reported	Topical 2.5% lidocaine/2.5% prilocaine cream 30 minutes prior	1-3; 4 week intervals	2 pulses	Erythema resolved within hours. Micro-crusts developed within 1-2 days and resolved within 5-7 days.
RF +Pulsed Electromagnetic Field	None	None	10		Mild post-treatment edema, self-resolving in <30 minutes
RF + Pulsed Electromagnetic Field	Minimal	None	8 over the Course of 6 weeks		Slight facial Erythema

Histological studies have demonstrated molecular results of RF treatments, including immediate collagen shortening and increased collagen expression[7,54] as well as increased epidermal thickness.[10] However, more studies are required to verify these results and clarify RF's effect on the epidermis.

Statements have been made attempting to identify ideal protocols for RF treatments, however optimal programs for initial treatment and maintenance programs remain unknown. Subsequent treatments may result in longer-lasting results as immediate results diminish over the first week, but reappear over 1-6 months if the treatment course is completed. 53 In particular, discrepancies exist between the number of treatments and intervals between treatments. It would be ideal to develop a maximum efficacy protocol for each indication for RF treatment.

CONCLUSION

RF is a novel technique to achieve improvement in many different medical and aesthetic conditions. New indications continue to emerge such as postpartum skin laxity, acne scarring and cellulite treatments, which have shown clinical efficacy in daily practice. Updated vibrating hand pieces and those that deliver pulsed RF maintain efficacy while improving patient satisfaction. By leaving the epidermis intact, patients enjoy less side effects and shorter recovery periods.[46] Furthermore, RF is safe and appropriate for all skin types and does not require wound care.[1]

DISCLOSURES

The authors have not disclosed any conflict of interest.

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