

Radiofrequency in Clinical Dermatology

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With the increasing interest in anti-aging, the demand for less invasive, non-surgical treatments has increased as well. Radiofrequency (RF) uses electric current instead of optical sources like laser and uses the energy generated from the current to generate heat inside the dermis. The heat, as a result, triggers dermal remodeling to give its anti-aging effects. RF treatment has been used in the field of cosmetic dermatology to improve skin laxities, wrinkles, acne scars, cellulite, and striae distensae since early 2000s, and many a number of previous studies have been published using various medical devices. Based on the layout of the electrodes, the RF treatment comes in two different types, namely the monopolar type and the bipolar type. Recently, the fractional type RF technology has been introduced and used widely. The outcomes so far show that the RF treatment is effective for treating aging skin and scar treatment in mild to moderate degrees of severity. It is one of the effective and safe treatment option and has the advantage of the patient being able to go back to their normal lives faster. In this review, we will examine the fundamental working mechanism of the RF technology and summarize the profound study results in the field.

Key words

Radiofrequency; Rejuvenation

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INTRODUCTION

As the interest and demands for cosmetic treatments increase, the tendency of the rejuvenation treatment, which mainly depended on the surgical treatments in the past, is shifting toward less invasive, more effective treatments which allow faster recovery to normal lives. In line with such a tendency, the radiofrequency (RF) treatment is gaining more attention these days. Unlike the laser treatment, the RF treatment uses a new, nonablative technology utilizing electric current for skin rejuvenation. RF gives focal dermal heat damages on the dermis, which results in less damage on the epidermis, reduction in the adverse events, and faster recovery to normal lives. There is a variety of RF technology devices, including monopolar, bipolar, and fractional RFs. In this review, we will summarize and compare the most representative studies in the field of RF technology.

HISTORY

RF energy has been in use with various medical devices. Bovies, which are still widely used in the operation rooms, are one of the most profound examples of RF electrocautery device. In dermatology, RF technology was first introduced for nonablative skin rejuvenation after FDA approved RF treatment for facial wrinkle reductions in early 2000s. And then RF devices were approved for off-face treatments in 2006.¹

RF TECHNOLOGY

RF devices generate an electric current within an electromagnetic field of 3 kHz-300 MHz frequency.¹⁻³ Once the current reaches the tissue, the current meet the unique resistance of the tissue, which is called the impedance. When the current goes through a tissue with electric resistance, heat is generated, as the electric energy is converted to heat energy.⁴ Such an energy discharge amount can be calculated using the following formula;

$$\text{Energy (J)} = I^2 \times z \times t,$$

Here, I = current, z = impedance, t = time (seconds).

Therefore, it could be said that the amount of the generated energy depends on the energy that flows on the impedance of the target tissue. The subcutaneous fat layer or other places of high resistance can generate a larger amount of energy, thus making it possible for the

heat to penetrate even deeper layers. While diffraction, absorption, and scatters cause the loss of a part of energy generated by a laser or other optical devices, RF energy is free from the influence of diffraction, absorption by the chromophores, or other tissue interactions, which, therefore, give no influences on to the epidermal melanin. For this reason it could be used for any skin types, and it is possible to control the depth of the energy's infiltration.²⁻⁴

The contraindications of RF treatment include the patients with implantable medical devices, such as a pacemaker or a defibrillator. Those with collagen vascular diseases or autoimmune diseases are also contraindicated. In addition, caution is required when using RF treatments for patients who are under radioactive treatment or recurring herpes infections.^{5,6}

RF devices come in two different types according to the configurations of electrode, which are the monopolar type and the bipolar type. The monopolar type uses a single electrode tip, which delivers energy to the space between the electrode and the grounding plate. The bipolar type passes electrical current between the two electrodes applied to the skin. The bipolar type penetrates a smaller volume of tissues, and this allows it to work even less energy compared to the monopolar type. The depth of heating depends on the size and geometry of the treatment tip. For the bipolar type, the depth is half of the distance between the two electrodes. This gives the monopolar type of being able to penetrate deeper, but the bipolar type is still superior in terms of the pain it causes.

MONOPOLAR RF

One of the most representative devices of the monopolar type, the Thermacool system (Thermacool, Thermage, Inc., Hayward, CA) emits an RF energy of 6 MHz, which is delivered onto the skin through a disposable electrode tip. For this type of devices, cryogen is used as the cooling module. Fitzpartrick et al.⁷ conducted a large-scale clinical study using the monopolar RF technology and proved its efficacy in treating the periorbital wrinkles. In that study, 86 subjects were treated once with the device, and 83.2% of the treated patients showed grade 1 or higher improvement of the periorbital wrinkles. In addition, 61.5% of the patients showed an eyebrow lift of 0.5 mm or higher in a photographic assessment. As a result of this study, US FDA approved the use of Thermage on the upper face wrinkles in 2002, and the entire face in 2004.

In addition to facial rejuvenation, it could be used for improvement of the acne or acne scars. The most repre-



sentative treatment mechanism of this technology for these conditions can be the restoration of the activities of sebaceous glands and the recovery of collagen in the dermis. In a clinical study with 22 patients, where 1 to 3 treatment sessions were given to the patients using 65-103 J/cm² of energy, 92% of the patients showed 75% or more reduction of the number of acne lesions, while 9% of them showed 25-50% reduction in lesion counts. In addition to the lesions of acnes, some patients also showed improvements of the acne scars.⁸

The treatment mechanism of the monopolar RF is to generate heat to cause two different effects on collagen. Firstly, the heat disintegrates the hydrogen bonds to change the triple helix structures, resulting in a contraction of collagen. Secondly, the gradual contraction along with wound healing process causes regeneration of collagen. Such changes take place of a period of 2 to 6 months in a slow pace, resulting in a thicker layer of regenerated dermis.^{9,10}

Two aspects should be considered when determining which is better between treating in a single session with a higher energy or using less energy over a number of sessions. The first aspect is the 'effect', and the other is the 'side effect' of the treatment. In earlier days, using a higher amount of energy concentrated in a single session was more popular. The biggest problem with this approach was the pain it caused. Further studies afterwards revealed that applying a lower amount of energy over a number of sessions was more helpful for collagen denaturation and the improvement of the skin elasticity. Since then, bigger tips started to be used for the treatment, and the recent trend seems to apply less energy over a number of sessions.¹³

According to the studies of long-term treatment effects of the monopolar RF technology by Suh et al.,¹¹ in which 8 patients were followed-up for a period of 6 to 7 years, they received 4 sessions of the treatment in average without using any other rejuvenation treatments. The severity of the wrinkles, based on Glogau's wrinkle classification system, maintained the improved status without worsening after treatment. 75% of the patients were satisfied with the results, and 25% of the patients were highly satisfied. In the preceding studies, the patients in their 30s to 40s appeared to maintain the best effects, and the maintained effects reduced as the patients grew older. However, in the long-term follow-up study, patients of all ages, including those in their 60s, maintained the effects of the treatment desirably.^{11,12}

The authors of the study concluded that, in consideration of the preceding findings that lower-energy/high

passes approach was better in terms of the effects of the treatment and the stability of the patients, recommended multiple treatment sessions with approximately 1 year intervals and a higher number of passes in each session.¹¹

The most representative of such studies are summarized in Table 1.

BIPOLAR RF

The biggest difference between the bipolar type and the monopolar type is the 'configuration.' While the monopolar type uses only one electrode placed on the skin and requires a grounding electrode on the other side, the bipolar type RF requires two electrodes to contact the skin and the current to flow from one electrode to another. The electric current, for this reason, could go as deep as half the distance between the two electrodes. The major limitation of this configuration is the depth of penetration. The monopolar device achieves high penetration of the emitted current, which serves as its main advantage and also its major drawback, which is associated with pain. The bipolar configuration is not as penetrating but provides more-controlled distribution of energy and less pain. In order to maximize the benefits of the bipolar RF, the electro-optical synergy (ELOS) technology where the light and laser are used together could be applied, or the FACES technology (functional aspiration controlled electrothermal stimulation) could be used, where vacuum is used to maximize the depth of penetration.^{4,19,20}

The basic mechanism of treatment is similar to that of the monopolar type, where the emitted energy causes the contraction of the collagen in dermis, the inflammatory process, and the contraction of the fibrous septa.

Table 1 shows a summary of various studies using the bipolar RF technology.

In the ELOS system, which was developed by Syneron (Syneron Medical Ltd., Yokneam, Israel), the IPL, diode laser, or other light energy could be used to pre-heat the target tissue through photothermolysis and to lower the impedance of the tissue and, as a result, making it easier for the RF energy to penetrate the tissues. In addition, the optical components can be used for a direct reaction with fibroblasts, blood vessels, and the pigments in the epidermis. Some of the most well-known examples of ELOS technology include Aurora SR, which uses both of RF and IPL technology, Polaris WR, which combines RF with 900 nm diode laser, VelaSmooth which combines RF and infrared light of 700-2,000 nm with a suction system.¹²⁻²⁷ Furthermore, each of the combined hand

Table 1. Major studies of radiofrequency in cosmetic dermatology

Author	Year	Indication	RF device	Parameters	Result	Comments	RF type
Fitzpatrick et al. ⁷	2003	Periorbital wrinkles (n=86)	Thermage ThermoCool TC system (Hayward, CA, USA)	52-220 J delivered through the 1 cm ² treatment tip surface	Improvement of at least 1 point of Fitzpatrick wrinkle score in 83.2% of treated areas		Monopolar
Ruiz-Esparza et al. ⁸	2003	Facial wrinkles and laxity (n=15)	Thermage ThermoCool TC system (Hayward, CA, USA)	5 patients: 0.25 cm bipolar electrode, 0.201-0.395 amps 8 patients: "window frame" bipolar electrode, 0.201-0.395 amps 2 patients: 1 cm monopolar electrode, 52 J/cm ² , 0.447 amps	Cheek contour improvement: 50% or more for 60% of patients Mandibular line improvement: 50% or more for 27% of patients Marionette lines improvement: 50% or more for 65% of patients 96% of the patients showed some clinical improvement		Monopolar
Finzi et al. ¹³	2004	Facial and neck laxity (n=25)	Thermage ThermoCool TC system (Hayward, CA, USA)	73-85 J/cm ² , 1 cm tip, one pass to the entire face and neck initially 68-85 J/cm ² , three passes to the forehead		The multipass vector (impave) treatment	Monopolar
Nahm et al. ¹⁴	2004	Eyebrow lifting (n=10)	Thermage ThermoCool TC system (Hayward, CA, USA)	134 J/cm ² to the forehead 115 J/cm ² to the temple and cheeks 97 J/cm ² to the jaw line and inferior postauricular surface	All patients displayed gradual improvement throughout the 3 months on the treatment side of the face		Monopolar
Fritz et al. ¹⁵	2004	Mild to moderate laxity of face (n=20)	Thermage ThermoCool TC system (Hayward, CA, USA)	85-135 J/cm ² , 1 cm tip, single pass	Two RF treatments yielded significantly better improvement than a single treatment.	Compare single RF treatment vs. 2 treatments with 1 month interval	Monopolar
Bassieis et al. ¹⁶	2004	Upper face rejuvenation and brow elevation (n=24)	Thermage ThermoCool TC system (Hayward, CA, USA)	330 W, 6 MHz, 1 cm ² tip	Compared to the control group, the posttreatment measurements were improved		Monopolar
Kushikara et al. ¹⁷	2005	Facial wrinkles and laxity (n=85)	Thermage ThermoCool TC system (Hayward, CA, USA)	74-124 J/cm ² , 1 cm ² hand piece (corresponding to the system treatment level 12-15, average numbers of shots were 68 for each cheeks)	The overall objective improvement rates (50% or more) at 3 months post-treatment for the jowls, marionette lines and nasolabial folds, and other facial wrinkles were 78.0%, 69.5%, and 73.8%, respectively, and 89.0%, 89.0%, and 83.8 %, at the 6-month evaluation.		Monopolar
Friedman et al. ¹⁸	2007	Facial wrinkles and laxity (n=16)	Accent system (Alma Lasers, Ltd., Caesarea, Israel)	The treatment protocol was divided into two phases Phase I: 120 W × 20 seconds (1.6 kJ) per pass for the unipolar and 60 W × 20 seconds (1.0 kJ) per pass for the bipolar handpieces, respectively. One pass Phase II: 100 W × 20 seconds (2.4 kJ) per pass for the unipolar and 50 W × 20 seconds (1.2 kJ) per pass for the bipolar, respectively. One pass	The Accent system is an effective and safe modality for the improvement of age-related rhytides and lax skin.		Unipolar + bipolar

RF, radiofrequency; vs, versus; IR, infrared; IPL, intense pulsed light; FL, fractional laser; MTZ, microthermal zone; FRM, fractional radiofrequency microneedle; MRF, microneedle radiofrequency.

Table 1. Continued

Author	Year	Indication	RF device	Parameters	Result	Comments	RF type
Gold et al. ²⁰	2007	Wrinkles and elastosis (n=46)	An investigational prototype (Lumenis, Inc., Santa Clara, CA)	2 to 8 W, 2 seconds per pulse, one to three passes, eight sessions	Significant improvement in the skin's appearance and texture was observed during the treatment course and continued to increase during the follow-up period.	Functional Aspiration Controlled Electrothermal Stimulation (FACES) technology	Bipolar
Sadick et al. ²⁵	2004	Cellulite of skin irregularity on the thighs of buttocks (n=35)	Velasmoth (Syneron Medical Ltd. Yokneam, Israel)	7, 14 or 20 J/cm ² (RF), 5, 10 or 15 J/cm ³ (IR light) and vacuum level of 200 mbar, twice weekly for 4 or 8 weeks	70% of all patients showed a reduction after 4 weeks of treatment. 100% of all patients showed some level of improvement in skin texture and cellulitis.	The device is a combination of RF, IR light and mechanical suction-based massage device	Bipolar
Alster et al. ²⁶	2005	Moderate bilateral thigh and buttock cellulite (n=20)	Velasmoth (Syneron Medical, Ontario, Canada)	20 W (RF), 20 W (IR light), and vacuum level of 200 millibar, four to six passes, twice a week over a one-month period.	90% of patients noticed overall clinical improvement	The device is a combination of RF, IR light and mechanical suction-based massage device	Bipolar
Sadick et al. ²²	2005	Facial wrinkle (n=23)	Polaris™ WR (Syneron, Yokneam, Israel)	One full pass over the entire face and neck and three passes over the wrinkled areas -Initial: 80 J/cm ² (RF) and 30 J/cm ² (optical), one pass -Subsequent passes: 90-100 J/cm ² (RF) and 40-50 J/cm ² (optical)	At 6 months, more than half of the patients had at least a 50% improvement in wrinkling.	The device is a combination of bipolar RF and optical energy.	Bipolar
Doshi et al. ²³	2005	Facial rhytides, skin laxity (n=20)	Polaris™ WR (Syneron, Inc., Israel)	Optical (diode): 32-40 J/cm ² , mean 36.4 J/cm ² , RF: 50-85 J/cm ² , mean 67.4 J/cm ² , three treatments at 3-week intervals	Modest improvement in majority of patients	The device is a combination of bipolar RF and optical energy.	Bipolar
Hammes et al. ²⁴	2006	Perioral and periorbital wrinkles (n=24)	Polaris™ WR (Syneron, Inc., Israel)	26-30 J/cm ² (Optical) and 70-90 J/cm ² (RF), six sessions, 4-week intervals, two passes.	58% of the subjects reported medium or notable wrinkle reduction	The device is a combination of bipolar RF and optical energy.	Bipolar
Prieto et al. ²¹	2005	Acne vulgaris (n=32)	Aurora AC® (Syneron, Medical Ltd. Yokneam, Israel)	Optical (400-980 nm IPL): 6-10 J/cm ² , RF: 15-20 J/cm ² , twice weekly for 4 weeks	Mean lesion count was reduced by 47%	☑	Bipolar
Yu et al. ²⁷	2007	Facial laxity and periorbital rhytides (n=19)	ReFirme ST Applicator (Syneron Medical Ltd.)	700-2,000 nm, 10 W/cm ² (IR) and 70-120 J/cm ² (RF) three sessions, 3-week intervals	At 3 months after the last treatment, 89.5% of the subjects reported moderate to significant subjective improvement in skin laxity of cheek, jaw, periorbital area.	The device is a combination of bipolar RF and optical energy.	Bipolar
Kim et al. ²⁸	2011	Dyschromia, rhytides and skin laxity (n=11)	SRA + Refirm ST + Matrix IR system (Syneron Medical Ltd. Yokneam, Israel)	SRA: IPL (470-980 nm) 16-18 J/cm ² + RF 20-22 J/cm ² , Refirm ST: IR (700-2,000 nm), + RF 100-120 J/cm ² (RF), Matrix IR: diode (915 nm) 50-60 mJ/cm ² + RF 80-90 J/cm ² , Four sessions, 3-week intervals	All patients showed statistically significant reduction in photoaging global score.	Combination treatment of bipolar RF and optical energy	Bipolar

RF, radiofrequency; vs, versus; IR, infrared; IPL, intense pulsed light; FL, fractional laser; MTZ, microthermal zone; FRM, fractional radiofrequency microneedle; MRF, microneedle radiofrequency.

Table 1. Continued

Author	Year	Indication	RF device	Parameters	Result	Comments	RF type
Seo et al. ⁴²	2012	Wrinkles, widened pores (n=25)	ScarLet™ (Viol, Sungnam, Korea)	Single pass, three sessions. The treatment parameters were determined based on the specific anatomical location.	56% of patients had achieved more than 50% improvement in overall appearance.	Fractionated microneedle system	Bipolar fractional
Shin et al. ⁴³	2012	Mild to moderate acne (n=20)	Mosaic eCO ₂ ™ (Lutronic Co) or ScarLet™ (Viol, Sungnam, Korea)	CO ₂ FL: 80 mJ, density of 100 spots/cm ² , two passes MRF: intensity of 8, density of 25 MTZ/cm ² , depth of 1.5-2.5 mm	MRF device and CO ₂ FL can be used for acne vulgaris patients and MRF device is more convenient than CO ₂ FL because of its short downtime.	Split face comparison of a fractional microneedle RF and fractional CO ₂ FL in acne patients	Bipolar fractional
Cho et al. ³⁴	2012	Acne scars and large facial pores (n=30)	FRM device (INTRACel; Jeisys, Seoul, Korea)	1.5-mm needle at a power of 500 W (maximum power 700 W), two sessions	Eight weeks after two sessions of FRM treatment, the grade of acne scars improved in 22 patients (73.3%), did not change in seven (23.3%), and became aggravated in one (3.3%).	Fractionated microneedle system	Bipolar fractional
Kim et al. ³⁵	2013	Periorbital wrinkles (n=11)	RFXEL (Medipark, Gyeonggi-do, Korea)	0.4s duration, energy level of 20, three sessions	A consistent and progressive significant improvement in Fitzpatrick Wrinkle Classification System scores	Fractionated microneedle system	Bipolar fractional
Lee et al. ³⁷	2011	Wrinkles, dyspigmentation, widened pores (n=26)	Matrix RF system (Syneron Medical Ltd. Yokneam, Israel)	The treatment parameters were determined based on the severity of the preexisting skin conditions, distribution of lesions, specific anatomical location	Fractional RF treatments produced moderate (26-50%) and incremental improvements in each category of physician evaluation.	☑	Bipolar fractional
Peterson et al. ³⁸	2011	Acne scars (n=15)	Matrix IR + Matrix RF (Matrix eLaser, Syneron-Candela, Irvine, CA, USA)	Three sessions, every 4 to 6 weeks, single pass Matrix IR: 60-70 J/cm ² (IR) and 80-100 J/cm ² (RF), two passes, Matrix RF: 19-25 J/cm ² , single pass (program C)	A 72.3 % decrease was observed on the acne scar scale.	Novel device with a hand-piece combining optical and RF energies along with a fractionated RF handpiece	Bipolar fractional
Bloom et al. ³⁹	2012	Mild to moderate photo-damage, skin laxity, fine lines, and wrinkling (n=25)	eMatrix (Syneron-Candela, Irvine, CA, USA)	40-50 mJ/cm ² , 144 pin high-density, three sessions, 1 month interval	A statistically significant improvement in rhytides, dyschromias and texture was noted.	☑	Bipolar fractional
Yeung et al. ⁴⁰	2012	Acne scars (n=24)	Matrix IR + Matrix RF system (Syneron Medical Ltd. Yokneam, Israel)	Matrix IR: 50-70 J/cm ² (IR) and 70-100 J/cm ² (RF), Spot size 5 mm x 5 mm, Matrix RF: 50-62 mJ/pin, spot size 12 mm x 12 mm 4-week intervals, up to sessions.	Modest but statistically significant improvement was noted in acne scars, with the mean grade decreased by 29%, and 52% were rated with at least moderate objective global improvement at 3 months.	The device is a combination of bipolar RF and optical energy.	Bipolar fractional

RF, radiofrequency; vs, versus; IR, infrared; IPL, intense pulsed light; FL, fractional laser; MTZ, microthermal zone; FRM, fractional radiofrequency microneedle; MRF, microneedle radiofrequency.

pieces could be selected and operated on a basic platform of single RF device according to the physician's choice. With using three handpieces in a serial order (RF + IPL, RF + infrared light, RF + diode laser), we previously achieved the improvement of superficial dyschromia, erythema and wrinkles in a single treatment. The measurements proved that the melanin index (MI) and erythema index (EI) decreased, and the cutometer measurements also showed an improvement of the elasticity of the skin.²⁸

The devices using FACES technology (Aluma System Lumenis, Inc., Santa Clara, CA) is composed of an RF generator, handpiece, and tips with two horizontal electrodes. This device creates a vacuum by means of suction. In a study with 46 patients who received treatments over 5 sessions in 1 to 2 weeks' intervals showed statistically significant improvements in terms of the facial wrinkles and the skin elasticity. They also showed 50% improvements in the treatment of striae distensae.^{20,29}

The most representative of the studies using bipolar RF are summarized in Table 1.

FRACTIONAL RF

The fractional RF technology is a newly developed form of RF treatment, which is divided in two different types in the mode of energy delivery. One of them is an RF system using a microneedle, while the other is a system which is represented by the Matrix RF, using the bipolar RF to trigger a partial epidermal ablation. In a study using Renesis (Prmavea Medical, Inc. Ferment, CA), the generation of the controlled RF thermal zone (RFTZs) was confirmed. The advantage of this system is that, it can deliver the fractional RF energy using a microneedle with protection of the adnexal structures.³⁰

In a study that evaluated the histological changes after fractional RF treatment, it was shown that molecular changes up to 10 weeks after the treatment, consecutive inflammatory reactions were observed starting from day 2 after treatment, which triggered the wound healing process and RFTZs were replaced by new collagen as a result of the heat shock protein generation. Then, neocollagenesis occurred to result in dermal remodeling.³¹

Based on several studies, it could be concluded that the fractional microneedle RF technology was effective in treating wrinkles and the scars of acne.³²⁻³⁵

Matrix RF system (Syneron Medical, Ltd) is an RF treatment equipment that aligns the multielectrode pins in a pair to induce partial epidermal ablation. The nonhomogenous thermal wounds on the skin are directly

delivered to the reticular dermis, while other areas than the target area are maintained intact, resulting in faster recovery from the wounds. The histological finding confirmed that the demarcated zones, which were identified by ablation, coagulation, necrosis, and subnecrosis, were generated to 450 μ m in depth. Along with that, higher energy and a low coverage rate resulted in good clinical outcomes while causing less pain to the patients.³⁶

In a study with Asian population, the technology showed good clinical results on wrinkles, skin texture, or pores without post-inflammatory hyperpigmentation. In addition, the technology was also effective against acne or acne scars.³⁷⁻⁴⁰ In the study by the author, clinical improvements were observed after 4 sessions in terms of the depressed scars and enlarged pores. In that study, all of MI, EI, and cutometer measurements showed significant improvements after treatment. In addition, histological observations showed that procollagen I, III, and elastin increased after treatment, causing less hindrance in daily lives due to shorter downtime caused by erythema or crust and less pain (unpublished data).

CONCLUSION

The development in RF technology for skin rejuvenation allowed a large variety of non-surgical anti-aging treatment. Up until now, RF treatments have been used for skin laxity, rhytides, acne vulgaris, scar, and cellulites. Most of the results of the treatments were positive, but the groups with the best chance of the positive results were the patients who showed the early signs of aging with mild to moderate degrees. In the meantime, the patients with profound skin fold or laxity required more invasive treatments or combined treatments. For this reason, treatments of these days usually combine other treatments, such as laser, botulinum toxin, or fillers, etc., to achieve the maximum effects with the minimum downtime. The RF will remain as the promising alternative treatment for ablative and nonablative laser and light based treatments. Further studies would be necessary to identify the ideal treatment parameters (energy level and the number of passes) and the treatment intervals, in a comparative study between different types of RF technologies and on new indications, as well.

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