Percutaneous Radiofrequency Technologies for the Lower Face and Neck

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KEYWORDS

• Radiofrequency • Percutaneous • Subdermal • Cervical rejuvenation • ThermiTight • FaceTite • Inmode • Thermi

KEY POINTS

- The neck contour contributes significantly to overall facial aesthetics; the aging neck frequently displays subcutaneous and subplatysmal fat, which blunts the cervicomental angle.
- Stigma of surgery, fear of morbidity, and increased time in the public eye has led patients to desire less invasive treatments, earlier in life, with less morbidity and downtime.
- Percutaneous radiofrequency technologies safely and effectively ablate subcutaneous fat and tighten skin by delivering energy directly into the subdermal space.
- In select patients, percutaneous radiofrequency treatment yields a 30% to 40% contraction at 6 months and 40% to 50% at 1 year.
- Percutaneous radiofrequency treatment is a one-time, no sutures, no scalpels, no surgery procedure performed in the office under local anesthesia with long-lasting effects and minimal downtime.

Video content accompanies this article at http://www.facialplastic.theclinics.com.

INTRODUCTION

In aesthetic medicine, the gold standard for treatment of skin laxity is surgical excision. Yet in recent years, stigma of surgery, fear of morbidity, and increased time in the public eye via social media has led many patients to desire less invasive treatments, earlier in life, with less morbidity and downtime. With respect to facial aesthetics, the neck subunit often ages earlier and more noticeably than others and is one of the most common motivations for patients to present for rejuvenation options.

Controlled disruption and subsequent remodeling of dermal and subdermal collagen is the underlying mechanism of nonsurgical skin rejuvenation. In the neck, the hypodermis contains a complex collagen network involving the papillary and reticular dermis, fibroseptal network intermixed with subcutaneous fat, and underlying fibrous fascia. These deeper tissue layers act in concert with the more superficial dermal skin layers to create the skin's tone, quality, and durability. In addition to ptotic skin, the aging neck frequently displays subcutaneous and subplatysmal fat, which blunts the cervicomental angle and contributes to an

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aged aesthetic. Traditionally, noninvasive cervical rejuvenation has been accomplished via chemical ablation, light- or laser-based technologies, ultrasonic energy, or transcutaneous radiofrequency (RF) devices. Although each of these technologies has their indications and merits, their results are either modest skin tightening requiring multiple procedures that often fail to meet patients' expectations, or significant skin tightening at the risk of excessive morbidity. These technologies also fail to address subdermal adipose tissue, which limits their effectiveness in many patients presenting for rejuvenation. Liposuction has been used for many years in the minimally invasive setting to remove submental fat; however, many patients presenting for neck rejuvenation have poor skin tone that fails to recoil and fill the dead space after fat removal, resulting in an overall unfavorable aesthetic outcome.

Recently, percutaneous RF technologies have been introduced to simultaneously ablate subcutaneous fat and tighten the overlying skin.[1–5] These technologies safely and effectively apply energy directly into the subdermal space, targeting the upper dermal collagen network, the deeper fascial layer, and fibrofatty septum, which anchors the dermis to the deep fascia. Significant skin tightening and fat reduction have been reported with these technologies, beyond that which is currently achievable with other minimally invasive energy-based technologies.

This article focuses on percutaneous, subdermal RF devices, highlighting the physiology of skin tightening, the overall energy-based skin tightening landscape that led to the development of these technologies, the procedural steps to using these technologies, and a discussion of their indications and results.

GENERAL STATISTICS

In the annual Plastic Surgery Statistics report published by the American Society of Plastic Surgery, 1.8 million surgical cosmetic procedures and 15.7 million minimally invasive cosmetic procedures were performed in 2017. Among the surgical procedures, liposuction (including treatments to body and neck) ranked number 2 at nearly 250,000 treatments, a 5% increase from the previous year. Facial and neck rejuvenation accounted for the majority of minimally invasive procedures, with 2 of the 5 most popular treatments being procedures aimed skin tightening (chemical peel and microdermabrasion), combining for 2.1 million treatments performed.[6] This trend of increasing demand for minimally invasive skin tightening and fat reduction is also evident in the dermatologic surgery domain.

According to the 2018 American Society for Dermatology Surgery consumer survey on cosmetic and dermatologic procedures, 70% of 3252 respondents reported considering various aesthetic procedures, up from 52% in 2014. Seventy-three percent of respondents were concerned by excess fat under the chin and neck, and the same percentage with skin texture, discoloration, or both. Fifty-seven percent of respondents were considering procedures to tighten skin or smooth wrinkles using ultrasound, laser, light, or RF treatments.[7]

ANATOMY

The contour of the neck contributes significantly to overall facial aesthetics. A youthful neck is characterized by an acute cervicomental angle with a firm and well-defined jawline. The skin is smooth without dyschromia, rhytids, or platysmal banding. Submandibular glands are tightly bound beneath the mandibular border, and jowling is absent anteriorly (**Fig. 1**). In contrast, the aged/aging neck is characterized by submental adiposity with blunting of the cervicomental angle, platysmal banding, and ptotic dyspigmented skin with vertical and horizontal rhytids. The epidermis is thickened, there is an accumulation of elastotic collagen whorls, decreased dermal thickness, and in many cases, subplatysmal fat accompanies subdermal adiposity (**Fig. 2**).[8]

Youthful Neck

- Acute cervicomental angle[8]
- A firm, well-defined jawline
- Skin is smooth and devoid of horizontal or vertical neck lines
- Smooth and even platysma without banding
- Without visible submandibular glands or jowling
- Skin that is bright and even in color with minimal melanin or vascular lesions

Aging Neck

- Blunted, obtuse cervicomental angle[8]
- Poorly defined jawline with jowling
- Skin is rough with dyschromia and telangiectasia
- Thickened epidermis and decreased dermal thickness
- Decrease in collagen, elastin, and ground substances, with an accumulation of elastotic collage whorls in the deep dermis
- Atrophy of the platysma muscle with banding
- Accumulation of subplatysmal and subcutaneous fat in the submentum

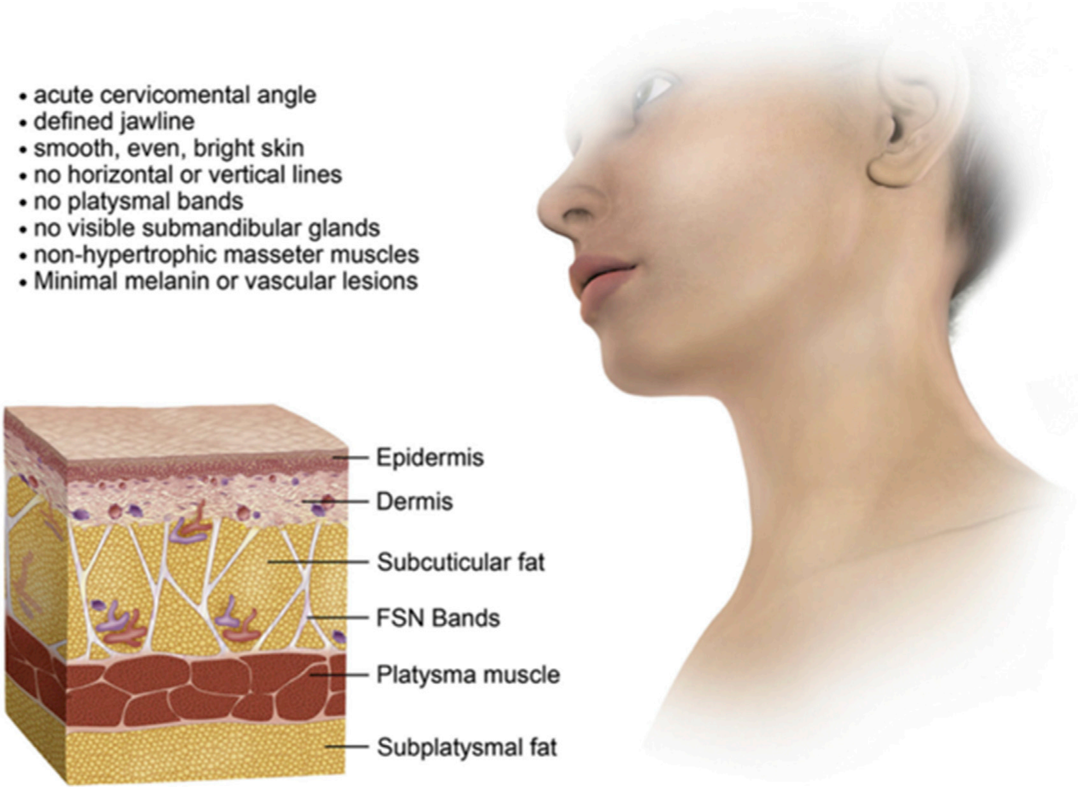

Fig. 1. The ideal youthful neck. (*From* Mulholland RS. Nonexcisional, minimally invasive rejuvenation of the neck. Clin Plast Surg 2014;41(1):12; with permission.)

Cervical subcutaneous fat

A wide variation in the presentation of aging exists with respect to the cervical subcutaneous layer. Subcutaneous and supraplastysmal fat is found in the deep subdermis, superficial to the platysma muscle and is generally distributed between suprahyoid and infrahyoid compartments. Some patients with aging necks have little fat between the deep dermis and the platysma, whereas others display an extensive amount. Regardless, even modest amounts of subcutaneous cervical fat create an obtuse cervicomental angle and distract from a youthful appearance.

In conjunction with the increase in obesity worldwide, a variety of techniques have been developed over the past 30 years to treat submental and cervical adiposity. Conventional body liposuction is performed in the deep adipose layer, which limits the potential for postoperative contour deformities and dermal damage.[9] Superficial, subcutaneous liposuction was first described in the mid 1980s,[10] and, since then, numerous modifications, devices, and techniques have been developed.[9] Shortly after introduction, superficial suction-assisted liposuction (SAL) was adapted from body contouring for use in the neck to treat subcutaneous, preplatysmal adiposity.[8]

SAL is based on mechanical disruption of adipose tissue by suction. The cannula moves manually through the subcutaneous space and disrupts the adipose cells, while the suction aspirates small clusters of adipose through openings in the cannula.[3] Although the tumescent technique[11] developed in the late 1980s dramatically improved the postoperative recovery profile and safety, liposuction was still prone to significant postoperative edema, ecchymosis, and pain.

Documented skin contraction after SAL is minimal, ranging between the 6% and 10% at 1 year postoperatively, largely depending on the patient's inherent skin elasticity. Although this level of skin contraction can occasionally produce satisfactory results in select patients, the majority of patients with preplatysmal adiposity substantial enough to cause blunting of the cervicomental angle also have poor skin tone that will not contract and fill the dead space after SAL, resulting in an unfavorable cosmetic outcome. Furthermore, despite the multitude of advanced techniques and devices, SAL in the superficial subcutaneous fat plane is still prone to contour irregularities and skin ischemia.[9,12]

Energy based liposuction technologies were subsequently introduced, including ultrasound-assisted lipolysis and laser-assisted lipolysis

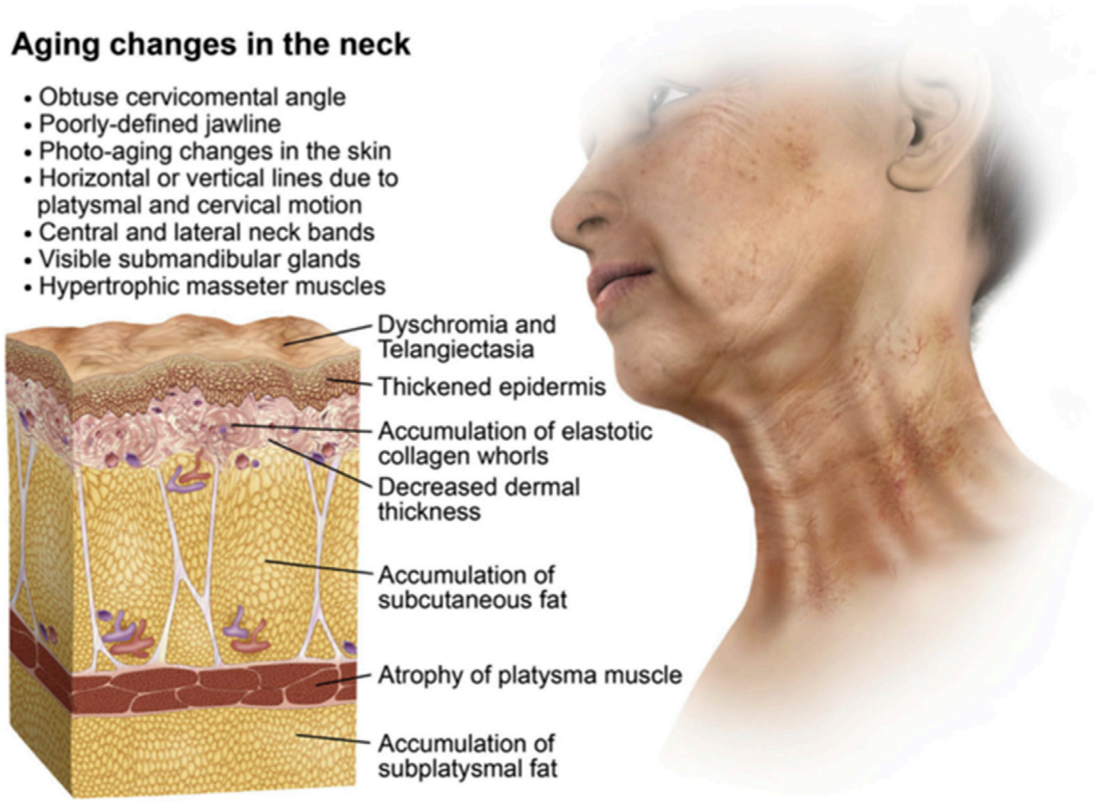

Fig. 2. The aging neck. (*From* Mulholland RS. Nonexcisional, minimally invasive rejuvenation of the neck. Clin Plast Surg 2014;41(1):13; with permission.)

(LAL), which resulted in less bleeding and bruising and enhanced recovery times versus SAL, although skin tightening was only modestly improved.[3,13–18]

CERVICAL SKIN TIGHTENING

The goal of all noninvasive skin tightening devices is to heat and remodel dermal and subcutaneous collagenous networks while avoiding collateral damage to unintended tissues.[19] Collagen consists of polymers held together by hydrogen bonds. The strength of collagen is directly proportional to the degree of hydrogen bond cross-linking.[20] Chemical or thermal energy delivered to collagen results in its denaturation, while the heat-stable intramolecular cross-links are preserved.[21] After this energy is applied, collagen fibrils ultimately undergo contraction and remodeling, which results in increased fibril size and strength.[2] Furthermore, thermal injury also results in the activation of wound-healing pathways, including recruitment of fibroblasts, which lay down new collagen leading to neocollagenesis[22]—whereby new collagen fills in surface imperfections, resulting in more youthful appearing skin.[23]

Cervical Collagenous Network

- Dermis, both papillary and reticular
- Fascia, consisting of a thick layer of connective tissue located between the platysma and skin
- Fibrous septum (fibroseptal network or fibrofatty septum), consisting of thin layers of connective tissue separating lobules of fat and connecting the dermis with the fascia
- Reticular fibers, a framework of single collagen fibers encasing fat cells

By convention, the more ablative (or destructive) the technology, the greater potential for skin tightening. In older chemical ablation techniques, colloquially known as "chemical peels," topical agents applied to the skin created a chemical dissolution and coagulation of dermal proteins. The wound healing that followed over the next several weeks resulted in neocollagenesis, elastin production, and overall skin tightening.[8] Often, these techniques were difficult to control and results were either too subtle for patient satisfaction or too intense and resulted in burns. With the aim of more precisely controlling the depth to which heat was applied, laser resurfacing technologies, including carbon dioxide and erbium YAG lasers were developed for facial rejuvenation.[13,24–26] In a photothermolytic process, photons from these lasers interacted with dermal water resulting in ablative coagulative disruption of dermal collagen triple helices. An immediate skin tightening ensued, followed by a secondary tightening effect over the next 6 months owing to neocollagenesis and production of elastin and ground substances.[13] Although these technologies provided significant rhytid reduction and superficial skin tightening, they regularly led to an unacceptable degree of postprocedure erythema, swelling, and downtime.[8]

In an attempt to reproduce the results of ablative lasers while reducing downtime and complications, nonablative laser and light technologies were developed. These devices work by photons interacting with a dermal chromophore, such as melanin or hemoglobin.[13] The downtime and recovery from these nonablative technologies was far more tolerable than full ablative lasers, but multiple treatments were often required and the long-term results often fell short of patient expectation.[13,27–29] Additionally, because these technologies rely on interaction with dermal chromophores, they were often unpredictable when used on patients with higher Fitzpatrick skin types and had the potential for long-term complications such as demarcation, pigmentation irregularities, and scarring.[30,31] This limitation sparked the development of skin tightening technologies that were nonablative, did not rely on chromophore interaction, and produced significant skin tightening while minimizing downtime and postoperative edema.

Each type of collagen has an optimal temperature at which remodeling is induced while avoiding destruction.[4] RF energy interaction with collagen has been studied in cornea, joint cartilage, and vascular tissue, and the threshold for collagen denaturation depends on the tissue wherein it resides. This ranges from approximately 60°C to 80°C.[19] RF-based devices produce heating through the application of an electromagnetic current instead of interaction with a chromophore. As electrons shift polarity and move within the targeted tissue, heating is produced through tissue resistance according to Ohms law.[13] The depth of heating depends on several factors, including the tissue's impedance and the frequency of the current.[19]

Early RF devices emitted energy at the skin surface using electrode arrays, which required energy to pass through the epidermis to heat the underlying dermis. This represented an inherent safety limitation, because the threshold temperature for an epidermal burn is roughly 48°C, which is significantly lower than the optimal temperature for dermal collagen contraction, roughly 60°C to 65°C.[19] As a result, aggressive skin cooling and multiple short duration treatments were required. Surface temperature thresholds also limited the depth to which electrothermal energy could penetrate into the dermis, because increasing the RF power (and thereby depth) would necessarily increase the heat delivered to the skin surface.

To circumvent these issues, transcutaneous (or microneedle) RF technologies were developed that delivered energy directly into the dermis, bypassing the epidermal–dermal junction. In this technique, a fractionated tip or array of needles is inserted in the skin, each with parallel rows of bipolar electrodes, creating closed circuits among the pins. The density of the pins and amount of energy controls the intensity of ablation. The pattern of dermal injury is minimal at the epidermis, and increases in size as the RF energy descends to deeper layers of the dermis. This technique results in a lower potential for skin surface injury while allowing for higher temperatures to be delivered to dermal collagen. Additionally, because these RF technologies do not depend on interaction with chromophores to create heat, they deliver a more even and widespread energy distribution that is safe on all skin types without risk for hyperpigmentation.[32,33]

Microneedle RF technologies safely and successfully produce modest skin tightening and rhytid reduction by heating the papillary and reticular dermis.[13,34–37] RF energy has also been shown to decrease elastotic material in the upper dermis and induce reorientation of elastic fibers within the papillary and upper reticular dermis.[38] Nevertheless, treating conditions resulting from skin laxity, jowling, and platysmal banding requires heating of deeper subdermis that cannot be achieved by RF microneedle technologies alone.[22,39] The dermis and underlying hypodermis create a complex collagen network involving the papillary and reticular dermal layers, fatty, fibrous septi, and underlying fascial layers, all of which act in concert with the more superficial dermal skin layers to create the skin's tone, quality, and durability. Unfortunately, transcutaneous microneedle RF technologies are unable to deliver consistent and measurable heat to the deeper hypodermal layers and their effect is limited to dermal collagenous tissue.[2] Furthermore, subcutaneous, preplatysmal adiposity cannot be addressed with microneedle technologies, which limits their effectiveness in many patients presenting for rejuvenation.

DEVELOPMENT OF SUBDERMAL ENERGY DELIVERY DEVICES

Recently, subdermal energy delivery technologies have been introduced which simultaneously ablate subcutaneous fat, as well as tighten the overlying skin.

Subdermal Laser-Assisted Lipolysis

Since the first multicenter study of LAL,[40] the technique has been updated and advanced by multiple groups of investigators, including the development of devices that introduce laser energy directly into subdermal tissue using fiberoptic lasers.[13,16,41–43] Histologic analysis after these techniques showed coagulation of small blood vessels, rupture of adipocytes, reorganization of the reticular dermis, and coagulation of collagen in fat tissue. A growing base of evidence has since shown that subdermal LAL can induce moderate tissue skin contraction without ablation of the epidermal–dermal junction, as well as a decrease in subcutaneous fat volume.[44]

The physics, quantification, and safety of subdermal thermal energy delivery was later defined by DiBernardo and colleagues[45] in an investigation of subdermal LAL using fiberoptic 1064 nm, 1320 nm, and multiplex lasers (Smart Lipo, Cynosure Inc., Westford, MA). DiBernardo and associates showed that administering laser energy directly into the subdermal space (5 mm below the skin surface) and heating the subdermis to 50°C to 55°C resulted in a nonablative, coagulative disruption of the deep reticular collagen fibers.[45] DiBernardo and coworkers also found that heating the subdermis to 50°C to 55°C correlated with epidermal temperatures between 40°C to 42°C, and that epidermal and dermal injuries typically occurred when surface temperatures increased beyond 47°C.

Subsequently, the same authors released a preliminary report on skin shrinkage and increased elasticity as a result of multiwavelength LAL,[46] followed by a randomized, blinded, split abdomen study showing that LAL induced greater mean skin shrinkage and tightening versus SAL alone at one and 3 months after treatment.[47] Furthermore, LAL allowed for a small diameter cannula, which permitted treatment to superficial areas such as the face and neck where it is difficult to remove fat and where irregularities are common after treatment.

Nevertheless, relatively slow treatment speeds, poor control of uniform heating, and a risk profile of burns limited the usefulness of LAL, and inspired further development of alternative energy-based lipolysis devices.

Radiofrequency-Assisted Liposuction/Lipolysis

In 2009, Paul and Mulholland[3] introduced RF-assisted liposuction/lipolysis (RFAL), a novel method for body contouring using a bipolar subdermal (percutaneous) RF device (BodyTite system, Invasix Ltd, Yokneam, Israel). The BodyTite system consists of a bipolar handpiece that includes a subcutaneous RF delivery probe to treat the septofascial and fasciocutaneous structures of the subdermis, and an external electrode that glides along the skin surface, functioning as the bipolar return electrode and as a transepidermal nonfractionated RF energy delivery system for the papillary and reticular dermis.[3] The investigators examined 40 lipoplasty zones in 20 patients, comparing the effectiveness and safety profile of RFAL to LAL (Smart Lipo, Cynosure Inc.) and standard power-assisted liposuction. LAL demonstrated relatively poor surface temperature uniformity, wherein epidermal hot spots of up to 47°C were noted during treatment while a significant part of the thermal zone was cold, below 35°C. This condition led to either early cessation of treatment resulting in lack of uniform heating, poor skin contraction, inconsistent results, or created a high risk for burns if additional energy was applied. In contrast, the temperature, impedance, and power controls of the BodyTite device enabled sustained RF delivery at subnecrotic thermal levels that were reached more quickly than with LAL. The result was twice the heating uniformity as LAL and facilitated longer treatment times at critical target temperatures. Other advantages over LAL included strong defragmentation of fat cells and coagulation of blood vessels in the treated zone, decreasing bleeding and bruising, significant tissue contraction, and retraction of the entire subcutaneous fibrous and dermal matrix.[3]

In a follow-up study, Paul and colleagues[4] presented results from a series of patients undergoing RFAL for body contouring and proposed the mechanism for RFAL by comparing the threshold temperature and contraction levels of 3 different types of ex vivo collagenous tissues, namely, adipose tissue with septal and reticular connective tissue, dermis, and fascia. The strongest contraction response was observed in adipose tissue containing septal connective tissue and reticular collagen fibers encasing fat cells. The contraction temperature threshold was the highest for dermis at 81.9°C, while the septa with adipose tissue and dermis contracted at 61.5°C and 69.4°C, respectively. These results reaffirmed that only transcutaneous, subdermal delivery of RF could heat the fascia and septa to necessarily high enough temperatures while avoiding epidermal burns. Patients demonstrated statistically significantly greater tissue tightening than reported with other energy-based liposuction technologies and the overall area contraction was more substantial than linear contraction. Because the dermis was not routinely heated to defined threshold temperatures during treatment, the investigators confirmed that skin tightening and elasticity change after RFAL was not the result of dermal collagen contraction, but instead is the result of subdermal tissue contraction of vertical and oblique fibrous adipose matrices[4] (**Fig. 3**).

The principles of body contouring with RFAL, developed by Paul and Mulholland, were then applied face and neck using a newer, smaller bipolar RF device (FaceTite, Invasix Ltd).[48] Forty-two patients with face and neck skin laxity were treated with the FaceTite hand piece powered by the BodyTite platform using more conservative temperature thresholds than with body RFAL (38°C–40°C vs 40°C–42°C for body RFAL). The result was clinically significant tightening and lifting of the brow, lower lid, cheek, and neck beginning at 3 to 4 weeks and continuing over 6 months. Punch biopsies were taken immediately after treatment, revealing localized coagulative necrosis of subcutaneous fat, collagen, and fibrous tissue coagulation at the dermis–fat junction and restructuring of the reticular dermis without disruption the fasciocutaneous blood supply. No complications were reported, including no hyperpigmentation in patients with Fitzpatrick skin types IV or V.

Subdermal monopolar radiofrequency

The preliminary success of the FaceTite system soon invited new competitive technologies into the percutaneous RF landscape. Prior work by Royo de la Torre and colleagues[49] showed that variability in tissue density and conductivity in the subdermis can quickly and unpredictably increase subdermal temperatures during transcutaneous RF, resulting in pain or burns. With these data in mind, Key introduced the concept of thermistor-controlled percutaneous RF using a monopolar subdermal RF system that included novel real-time subdermal and epidermal temperature monitoring systems (ThermiTight, ThermiAesthetics, Southlake, TX).[2] During the preliminary investigation in 18 patients, the investigators reported a weak linear dependence between subdermal and epidermal temperatures, similar to the results of Royo de la Torre and colleagues.[49] As such, the monopolar ThermiTight device was developed to

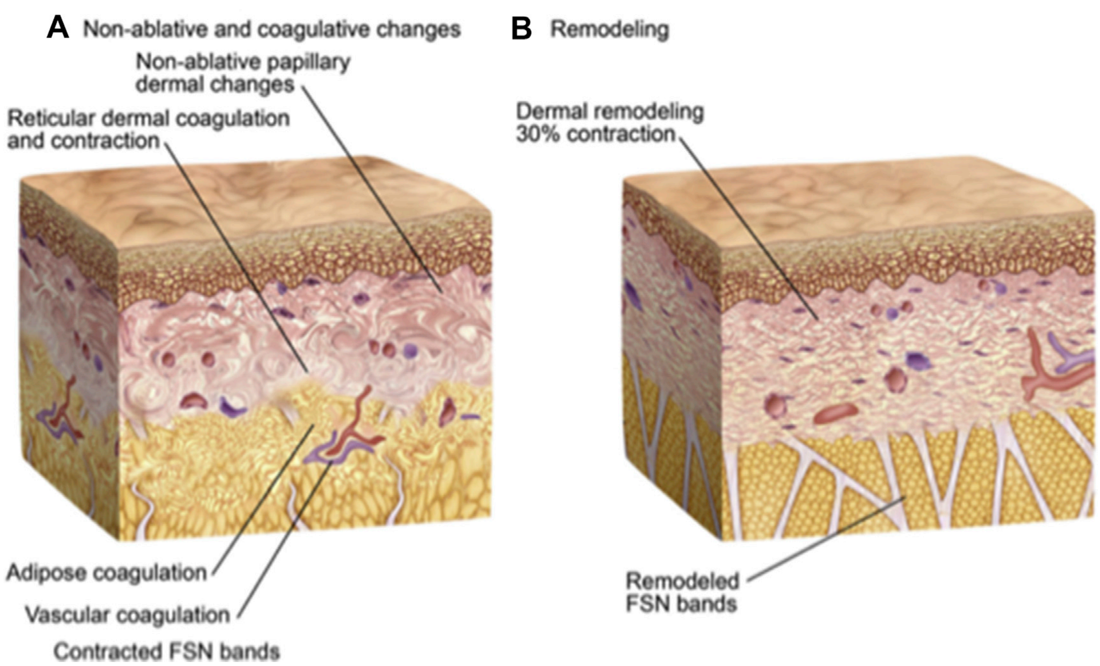

Fig. 3. Effects after FaceTite. (*A*) Immediate changes to the dermis and subdermis following percuatneous radiofrequency treatment. (*B*) Collagen remodeling in months following percutaneous radiofrequency treatment.FSN, Fibroseptal network. (*From* Mulholland RS. Nonexcisional, minimally invasive rejuvenation of the neck. Clin Plast Surg 2014;41(1):23; with permission.)

include a thermistor, which is a temperature sensing element at the distal tip of the treatment probe that detects changes in resistance when exposed to small temperature changes. The thermistor constantly modulates the RF output current during treatment, allowing for precise and consistent subdermal temperatures to be reached for longer durations without the development of hot spots or burns. Mean and median subdermal temperatures were 55.4°C and 55°C, respectively. The ThermiTight system was integrated with a forward looking infrared (FLIR) camera that continuously monitors epidermal temperatures of during treatment and displays them for the physician to view. The FLIR temperature readings were compared with a standard external handheld infrared laser thermometer, which found a significant difference in readings, thus supporting the use of the FLIR camera. FLIR monitors the entire field, not just 1 spot. No complications were reported in any of the patients.

The clinical usefulness of the ThermiTight system was then evaluated in 35 patients undergoing treatment of submental and jowl skin laxity.[2] Subsurface temperature settings were set between 50°C and 60°C and the clinical endpoint for a particular treatment site was defined at an epidermal temperature of 42°C. Two blinded reviewers graded patient photographs at baseline and 30 days postoperatively on a 4-point skin laxity scale. Seventy-four percent of patients demonstrated clinical improvements in skin laxity, with a mean change of −0.78/4.00 ($P < .001$). Mild erythema was noted in some patients that lasted less than 12 hours and no complications were reported.

DEVICES

As of this writing, only 2 percutaneous RF devices have been cleared by the US Food and Drug Administration for face and neck treatment—the ThermiTight (ThermiAesthetics) and FaceTite (InMode Corporation, Toronto, Canada).

The FaceTite system consists of a solid, silicon-coated, 1.8-mm diameter, 13-cm long, RF-emitting probe with a bullet-shaped plastic tip connected to a console containing the RF card, electronics, and a central processing unit with graphical user interface (**Fig. 4**). In this bipolar system, the RF current flows unidirectionally from the internal/subdermal probe out to the external electrode, which glides along the epidermal surface in tandem with the RF-emitting internal electrode. The external electrode contains a series of sensors that relay information to the console and CPU, including high and low soft tissue impedance sensors and epidermal contact and thermal sensors. The epidermal temperature is monitored and sampled 10 times per millisecond and the RF energy is turned off

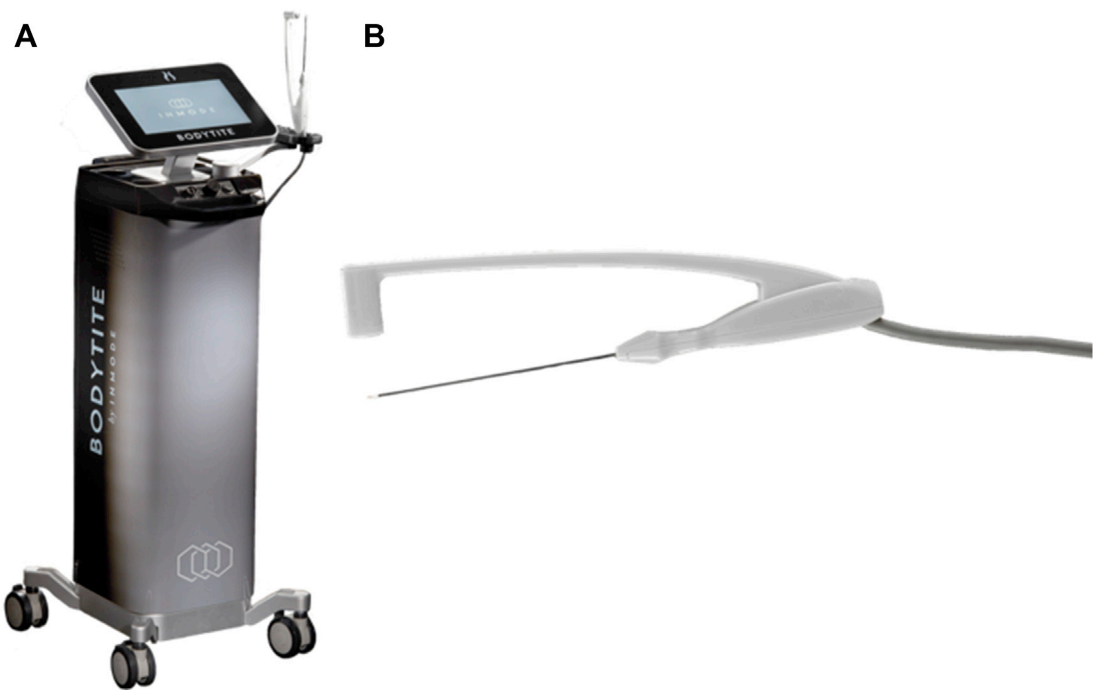

Fig. 4. (*A*) FaceTite (BodyTite) Platform. (*B*) FaceTite handpiece. (*Courtesy of* InMode Corporation, Toronto, Canada.)

when the selected therapeutic end point is achieved and turned on when epidermis decreases to 0.1°C below the target epidermal temperature. The platform gives audio feedback in the form of bell signals when the temperature is within 2°C of goal temperature and when goal temperature has been reached.

The ThermiTight system consists of solid, blunt, 18-G monopolar subdermal RF emitting probes that vary in length from 5 to 20 cm long from handpiece to distal tip (**Fig. 5**). The handpiece is connected to the Thermi console, where the subdermal temperature treatment goal is set by the user. This monopolar device produces 3-dimensional volumetric heating as the current flows from the handpiece to the grounding pad, which is placed on the patient. The energy confinement at 50°C is limited to roughly a 3-mm radius from the treatment probe tip. Safety features include the treatment probe thermistor (described in detail elsewhere in this article), as well as constant epidermal temperature monitoring via a FLIR camera system.

PROCEDURE DESCRIPTION

The patient is placed in a seated position with the lower face and neck exposed. Informed consent is obtained and pretreatment photos are taken. A wheal of lidocaine, 1%, with epinephrine 1:100,000 is raised bilaterally underneath each earlobe and in the central submental crease. A 16-G needle is then used to create 3 pilot hole openings in the skin at the site of prior lidocaine injection, piercing through the dermis and entering the subcutaneous tissue. The lower face and neck are then sterilely prepped and draped. Tumescent anesthesia (10 mL lidocaine, 1%; 1.5 mL sodium bicarbonate, 8.4%; and 0.4 mL epinephrine 1:1000 in 100 mL 0.9% normal saline) is then introduced through the 3 previously made needle openings using a tumescent fluid infusion cannula. Typically, 80 to 100 mL of tumescent is used to treat the entire lower face and neck with approximately 20 mL injected per neck treatment area (eg, left neck, left jowl, right neck, right jowl, and central neck/submentum). Tumescent fluid is

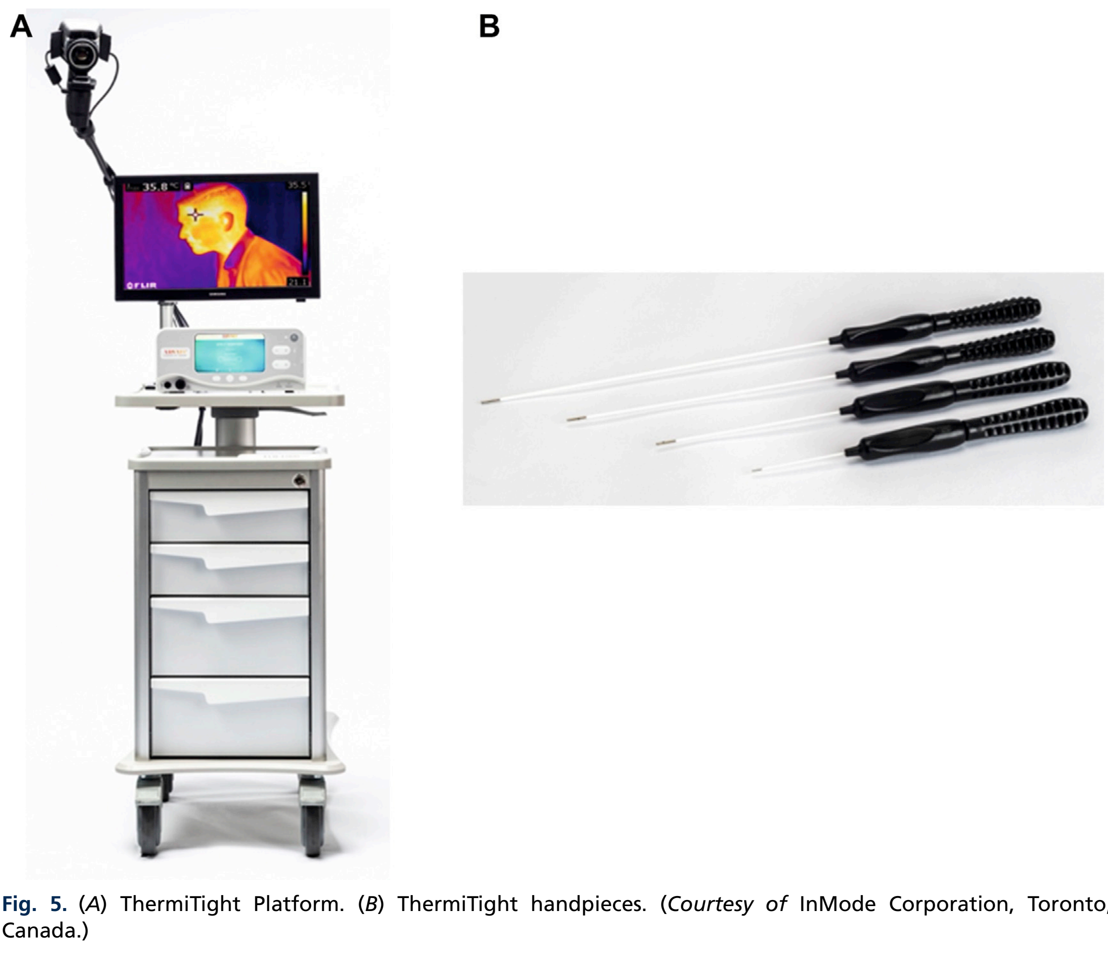

Fig. 5. (*A*) ThermiTight Platform. (*B*) ThermiTight handpieces. (*Courtesy of* InMode Corporation, Toronto, Canada.)

a critical component to the procedure. The water in the tumescent fluid aids in good RF conductivity, provides adequate clearance within the subcutaneous fat space required for the instrument to travel, and provides a secondary source of heat transfer heat after the application of the RF energy has been completed. Additionally, when using the FaceTite system, the turgor of the overlying soft tissues provided by the tumescent fluid ensure satisfactory coupling of the external probe to the skin.[50]

In general, both the ThermiTight and FaceTite procedures have been proven safe and well-tolerated in office settings under local anesthesia. Some patients and physicians prefer the use of selective nerve blocks or general anesthesia, particularly if additional surgical or minimally invasive procedures are to be combined with percutaneous RF treatments. Oral analgesia in the form of benzodiazepines are also commonly used. Once adequate anesthesia is obtained, the RF probe is inserted into the left infraauricular pilot hole and advanced/retracted subcutaneously at alternating angles to create subcutaneous tunnels through which the probe will travel when the RF energy is initiated. The RF probe is then inserted along the inferior mandibular border completely to its hub and the device energy is activated. The probe is withdrawn 1 cm at a time, delivering energy for approximately 5 seconds in each spot before being withdrawn each additional centimeter. Next, the probe is fanned across the left neck by inserting the probe and then applying the energy as the probe is continuously withdrawn. Once the left neck is completed, the left jowl area is next treated. It is important to apply the probe immediately subcutaneous in this area and not dive deeper into the jowl fat because the terminal branches of the marginal mandibular branch of the facial nerve are in close proximity. Some users have advocated for mapping of the marginal mandibular nerve preoperatively with a transcutaneous nerve stimulator; however, this step has not been necessary in these authors' experience. Once the left jowl area is completed, the right neck, right jowl, and central/submental areas are then treated in sequence.

Treatment time is approximately 7 to 10 minutes per lateral neck area, 1 to 2 minutes per jowl area, and 3 to 5 minutes in the central neck zone. In general, a treatment zone surface area of 3 cm^2 is treated every 2 minutes, with total treatment times between 25 and 38 minutes yielding optimal results.[51] It is important to understand, however, that subdermal and epidermal surface temperatures, not time, define the treatment durations within each area. Usually, epidermal temperature limit is set between 38°C and 42°C, whereas the subdermal temperature goal is set between 50°C and 65°C depending on the user and the treatment area.

The techniques for ThermiTight (Video 1) and FaceTite (Video 2) are essentially the same, with the addition of ultrasound gel being applied to the skin when using the FaceTite device to decrease friction from the external receiving electrode (see Video 2). Once the procedure is completed, a microliposuction cannula is used to aspirate any liquefied fat from the treatment areas because this can increase postprocedure irritation and/or inflammation if left in situ. This measure is generally recommended if more than 20 mL of liquefied fat is expected to be aspirated. A single 6-0 fast-absorbing gut suture is used to close the port holes if liposuction was performed; otherwise, they are allowed to heal by secondary intention. The patient is discharged with a neck compression garment to be worn for 24 to 48 hours, then nightly for 1 week. In the authors' experience, postprocedural opiate pain medications have not been required and pain is well-controlled with over-the-counter analgesics.

DISCUSSION

As of 2011, a person is turning 60 year old every 10 seconds. In 2011, one-fourth of the US population is between 42 and 60 years old, representing nearly 100 million people with skin laxity who may benefit aesthetically from an excisional surgical procedure.[52] Nevertheless, fewer than 180,000 excisional surgeries on the face and neck were performed in the United States in 2017, indicating that only 1% to 2% of patients with cervical skin laxity actually present for an excisional procedure.[8] Since the early 2000s, there has been an explosion of new minimally invasive and noninvasive skin tightening technologies in the United States and internationally. Many aging patients today are willing to accept less significant results with fewer complications and shorter recovery versus more effective invasive surgical procedures. Additionally, the age at which patients present for rejuvenation continues to decrease, with 49% of cosmetic procedures in the United States being performed on patients 20 to 54 years old.[6] The average millennial will take 25,000 selfies in their lifetime and are more aware of their appearance to the world than any preceding generation.[50] In these increasingly younger and more savvy populations, surgical neck rejuvenation has been stagnant or decreasing in recent years, with 2000 fewer neck lifts performed in 2017 than 2016 (a 4% decrease). In the same time frame, minimally invasive fat reduction and skin tightening, including in the neck, has increased by 7% and 9%, respectively, with nearly 700,000 combined procedures performed in 2017. It is, therefore, of critical importance for plastic surgeons to keep abreast of and master the wide variety of alternatives to excisional procedures to treat the lower face and neck.

Percutaneous RF technologies deliver significantly higher power with greater energy transfer efficiency than LAL or other energy systems. In percutaneous RF systems, optimal temperatures are delivered to the whole volume of treated tissue, not only the superficial subdermal layer, and can heat deep adipose and subcutaneous tissue to much higher temperatures without compromising skin safety.[4] Histologic analysis immediately after treatment with percutaneous RF reveals coagulative necrosis of the subdermal fat layer and the deep reticular dermis, as well as nonablative coagulation of the papillary dermis. Coagulation of small blood vessels in the hypodermis is also evident, which may decrease postoperative ecchymosis.[50] Skin biopsies at 12 months after the procedure show normal dermal architecture with healthy collagen and elastin fibers in the deep reticular dermis and no evidence of scar tissue or abnormal collagen fibers.[4]

Published results from percutaneous RF treatments have generally shown up to a 25% area contraction at 6 months and 35% to 60% achieved at 1 year, statistically significantly higher than results reported with other energy emitting liposuction or skin tightening technologies.[4,8,13,46,50,53] This level of skin contraction is often considered a successful aesthetic outcome in patients who might otherwise have required an excisional procedure. The success of these procedures also increases the potential patient population who may not have skin laxity severe enough to warrant a standard excisional operation, but will likely have a poor aesthetic outcome with liposuction alone owing to deficient elasticity of the overlying skin.[50] The authors refer to these patients as "tweeners"—patients whose cervical rejuvenation mandates a treatment that falls in between that an excisional procedure and of noninvasive skin resurfacing with or without liposuction. Results at 6 months for a typical patient treated with FaceTite are shown (**Fig. 6**).

The national mean physicians fee for a surgical face/neck lift is $7448, whereas the average fee for noninvasive fat reduction is $1481 and $2060 for nonsurgical skin tightening. In contrast, the average physicians fee for one ThermiTight or FaceTite treatment between is $3000 and $4500.[54] Although the majority of percutaneous RF treatments are one-time only procedures, providing these treatments can enhance a surgeon's downstream operative volume, because some of these patients will ultimately require excisional procedures and a trusting relationship has already been established between the surgeon and patient. This finding is supported by recent data indicating approximately 45% of patients who underwent cosmetic procedures in 2017 had undergone prior cosmetic procedures, either surgical, noninvasive, or minimally invasive.[6] The senior author often discounts an excisional procedure for patients who have previously undergone percutaneous RF treatment in his practice. The results of percutaneous RF treatments can also be enhanced by providing additional nonsurgical procedures, such as RF microneedling, neuromodulators, dermal fillers, or laser/chemical skin resurfacing. Some surgeons have also advocated using percutaneous RF devices to undermine skin flaps of the neck and lower face as part of rhytidectomy,[3,8] whereas others may offer these treatments to patients after rhytidectomy to maintain skin tightening results. Early publications with ThermiTight studied the effect on facial nerve ablation for treatment glabellar frown lines and platysmal banding, although the practical applications never developed for these indications.

African Americans and Hispanics underwent 1.6 million and 1.9 million cosmetic procedures in 2017, respectively, a 17% and 16% increase, respectively, from the year prior. This increase is in contrast with an 8% increase among Caucasians, who underwent 12.3 million procedures. Because percutaneous RF treatments are chromophore independent, they are safe and effective in patients with darker skin tones, and this characteristic represents an opportunity to provide energy-based skin tightening for these populations who are increasingly seeking cosmetic cervicofacial rejuvenation.

Most patients seeking treatment for cervical rejuvenation are between 45 and 55 years old, roughly 60% of whom are considered by treating physicians to be suitable candidates for treatment with percutaneous RF technology.[51] In recent expert consensus panel and physician surveys on percutaneous temperature-controlled RF treatments, nearly 90% agreed that procedures with these devices in appropriate patients can safely and effectively achieve skin tightening and fat reduction of the submental tissue and jowls. In these patients, 95% of physicians agreed that percutaneous RF treatments deliver comprehensive skin tightening and 85% agreed skin tightening continues to be evident 6 months after a single treatment.[51]

Fig. 6. (*A*, *C*) A 48-year-old woman with cervical submental adiposity, blunting of the jaw line and cervicomental angle, mild jowling, and mild skin ptosis. (*B*, *D*) Six months after FaceTite procedure to the lower face and neck.

Although standardized treatment parameters, temperature protocols, contraindications, and preoperative and postoperative analgesic regimens are still being developed, a best practices treatment algorithm has been published for subdermal monopolar radiofrequency with ThermiTight (**Box 1**).

Patient selection is critical to achieving optimal outcomes with percutaneous RF treatments. Unsuitable candidates include women during pregnancy; patients with collagen vascular diseases, autoimmune diseases, or acute infections; patients with cochlear and neurostimulator implants; and patients with morbid conditions that could make them unsuitable for the procedure. For patients with an external pacemaker, implantable defibrillator, or monitoring equipment, an attending cardiologist should be consulted before undertaking the procedure. All implanted devices should be evaluated for contraindications from the manufacturer. In addition, patients with preplatysmal adiposity and skin laxity must be distinguished

Box 1
Best practices guidelines for scalable multifunction RF with ThermiTight

- Candidates for scalable multifunction RF
  - Mild to moderate skin laxity.
  - Fat reduction of the submentum, lateral neck, mandibular border, and jowl lateral to the nasolabial fold.
- Preparation
  - Clean the area of insertion with 4% chlorhexidine solution or betadine.
  - Administer diluted lidocaine solution via the subdermal cannula using a double Klein Solution (ie, 0.2% concentration).
  - Optional: Map the marginal mandibular nerve using a peripheral nerve stimulator.
- Procedure
  - Divide the neck into 3 zones, namely, the paramedian, right, and left lateral zones.
  - Insert the electrode fully.
  - Avoid skin contact with the hub.
  - Wait for the actual temperature to reach the set temperature. Subsurface temperature target is set between 55°C and 56°C and epidermal temperature is not to exceed 46°C.
  - Monitor the epidermal temperature with the external infrared FLIR camera throughout the procedure.
  - Slowly withdraw the electrode approximately 0.5 to 1.0 cm per second.
  - Keep the actual temperature within 3°C to 5°C of the set temperature.
  - Repeat liner strokes in a fanning manner until the area has been treated, reaching the clinical end points with each stroke.
- Clinical end point
  - The skin temperature should reach between 42°C and 46°C over the entire area treated.
  - The entire area must be a uniform color (yellow-white color on the infrared monitor); use the FLIR default color scheme.
  - The actual temperature and set temperature should remain within 3° of each other throughout the entire procedure.
- Preventing complications
  - Avoid tenting the skin.
  - Avoid catching the dermis with the cannula.
  - Avoid end-hitting distal skin with the tip of the cannula.
  - Monitor the skin temperature and cool with saline-soaked swabs for skin heated to more than 46°C.

Data from Kinney BM, Andriessen A, DiBernardo BE, et al. Use of a controlled subdermal radio frequency thermistor for treating the aging neck: Consensus recommendations. J Cosmet Laser Ther 2017;19(8):444–50.

from those significant subplatysmal fat, which also compromises the appearance of a youthful neck, but is more difficult to treat without an excisional procedure, and will not respond as ideally to percutaneous RF treatments. Reported thermal injuries are in the 1% range, with most occurring within the first 10 to 15 cases.[3,50] Nevertheless, when a percutaneous RF treatment does result in a burn, it is by definition full thickness, and often will require surgical excision and management.

SUMMARY

Percutaneous RF technologies have recently been introduced to safely and effectively ablate subcutaneous fat and tighten skin by delivering energy directly into the subdermal space, targeting the upper dermal collagen network, the deeper fascial layer, and fibrofatty septum. Ideal candidates for percutaneous RF treatments have early jowling or jaw line blunting, mild to moderate marionette lines, early neck tissue laxity, or minimal to moderate submental adiposity. These patients are considered by the authors as tweeners, whose cervical rejuvenation mandates a treatment that falls in between that of an excisional procedure and of noninvasive skin resurfacing with or without liposuction. In these patients, a 30% to 40% area contraction at 6 months and 40% to 50% at 1 year is common after treatment and is statistically significantly higher than results reported with other energy emitting liposuction or skin tightening technologies. Percutaneous RF treatments are marketed to patients as a one-time no sutures, no scalpels, no surgery procedure performed in the office under local anesthesia with long-lasting effects and minimal downtime. Percutaneous RF treatments can drive practice volume by recruiting patients who may not have otherwise presented for cervical rejuvenation owing to fear of surgery and because some patients treated with these technologies will ultimately present for excisional procedures later in life. Additionally, percutaneous RF treatments can be combined with additional skin resurfacing procedures such as RF microneedling or CO_2 laser, or with neuromodulators and/or dermal fillers. Percutaneous RF is also chromophore independent, which allows for safe and effective treatment of patients with darker skin types, who are increasingly seeking cosmetic cervicofacial rejuvenation.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at https://doi.org/10.1016/j.fsc.2019.03.003.

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