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Review of non-invasive and minimally invasive skin tightening techniques

Fat reduction treatments have advanced rapidly over the past decade, but this is only half of the story. Fat reduction can sometimes lead to excess skin, which can be troublesome and concerning for patients. For this reason, skin-tightening modalities have been growing with the rise of body contouring. In this article, Sam Ghani explores the options for non-invasive and minimally-invasive skin tightening techniques, which can be the final step in achieving a patient's body goals

In recent years, there has been a huge rise in the demand for non-invasive treatments for skin tightening. For many years the gold standard for addressing loose or excess skin has been in the surgical domain, in the form of skin removal treatments, such as face lifts, arm lifts, neck lifts and abdominoplasty. Although the results of such procedures are impressive, they are associated with significant morbidity, as well as a long downtime and significant expense. Furthermore, these procedures work by removing excess skin and pulling the residual skin over the same area, which results in the skin appearing to be more taut. However, the skin quality itself is essentially unaltered by this process. With a shift towards non-invasive treatments for aesthetic enhancements, there has been a strong drive towards the development and successful implementation of technologies that can deliver comparable skin tightening effects without the complications of surgery.

The need for skin tightening technologies

The ageing process results in a cumulative depletion of collagen and elastin, as well as loosening of fibrous septae. These factors combine to increase skin laxity. This is particularly worsened by the effects of photoageing on the face. Large fluctuations in weight and the after-effects of pregnancy result in increased skin laxity around the abdomen, thighs and arms. Hormonal surges heighten the effects of this with the development of cellulite (fibrodysplasia) around the thighs and buttocks.

In 1997, Hayashi et al published a landmark study in which they described the histological changes affecting collagen fibrils when exposed to temperatures reaching around 65°C (Hayashi et al, 1997). They found that heat resulted in shrinkage and denaturation, followed by de novo synthesis, remodelling and regeneration. More recently, this process has been further evaluated (Lolis and Goldberg, 2012). Heat exposure to the dermal and subdermal layers of the skin results in denaturation of collagen and disruption of the fibrous septae present in the subdermal layer. This subsequently results in neocollagenesis, shrinkage of the fibrous septae, and thickening of the adjacent epidermis. The net result of this is an increase in collagen, reduction in elastin and shortening of the fibrous septae, producing a significant skin tightening effect (Lolis and Goldberg, 2012). Hence treatment modalities able to specifically target this region of the skin with focused heat energy can result in skin tightening effects. Although not as significant as surgery, the effects can nevertheless be effective (Lolis and Goldberg, 2012) and appreciated by those patients seeking a non-invasive alternative with a shorter downtime and reduced morbidity.

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The ideal treatment option

The ideal non-invasive or minimally invasive skin-tightening treatment should be able to specifically target heat energy at the dermal and subdermal layers of the skin in the region of concern, leaving other structures in tact and unaffected. Over the last decade, there has been an explosion in a variety of technologies claiming to be able to offer exactly this. This review summarises the different skin tightening modalities available ,with a brief evaluation of the published literature.

Non-invasive approaches to skin tightening can be broadly divided into ablative and non-ablative technologies. In addition, it is important to note that not all modalities are suitable for all areas. The majority of energy-based devices are focused on providing skin tightening effects to the face—specifically the forehead and cheeks. Few treatments have demonstrable benefits in skin tightening for the rest of the body, including the neck, abdomen, arms and thighs.

Ablative approaches

Fractional and non-fractional ablative lasers

Ablative approaches to skin tightening involve the delivery of energy to all layers of the skin, resulting in vapourisation of the epidermis and resultant heating of the dermal and subdermal layers. Ablative approaches that have demonstrated a clear im-

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Ablative approaches to skin tightening have demonstrated positive results, but are associated with significant patient downtime

provement in skin laxity include ablative lasers (fractional and non-fractional). Although not as invasive as surgery, ablative skin tightening treatments are still associated with significant downtime for the patient. They are painful procedures that can also be associated with significant morbidity. Fitzpatrick et al conducted a comparative study using a CO2 ablative laser and Erbium-Yag laser (Fitzpatrick et al, 2000). They demonstrated an average skin tightening of 43% and 42% respectively, which reduced to 34% and 36% at 6 months post treatment. They identified less dramatic results with fractionated carbon dioxide lasers in their clinical practice over the same period of time; however, this was not included as part of the study. However, there were significantly more side effects noted with non-fractionated approaches, including increased recovery time, increased bruising and higher pain scores (Fitzpatrick et al, 2000).

Plasma technology

As with invasive surgery, there has been a shift away from ablative non fractional lasers. The recent popularisation of plasma technology has yielded a unique, essentially fractionated ablative skin tightening technique that has been shown to be particularly effective on delicate areas of the face, for example the upper and lower eyelids. De Goursac published the findings of a retrospective review of 35 patients who received a non-surgical blepharoplasty for periorbital rejuvenation using a device known as Jett Plasma (De Goursac, 2018). Plasma is considered the fourth state of matter, which is created by adding energy to a gas.

The Jett Plasma is a handheld device that passes a direct current through air to result in a beam of energy that is precise and has a beam width of less than 0.1 mm. De Goursac treated the periorbital region of 38 patients with a mean age of 48 years with the Jett Plasma device using her own previously published protocol (De Goursac, 2018). De Goursac managed to achieve a significant improvement in the drooping of the upper eyelid in the majority of patients documenting an average lift of 2 mm, with few side effects (De Goursac, 2018).

Plasma pen

Proponents of the plasma pen have suggested that the same technique can be used for skin tightening applications on any part of the body, including the abdomen, arms and neck. In the author's opinion, this is probably not the case, as there is very limited energy delivery to the dermal and subdermal regions, with likely no effect on the subdermal fibrous septae, irrespective of the number of 'dots' placed. In addition, the force of vectors required to deliver effective skin tightening in the abdomen and thigh areas are likely to require large amounts of energy delivery that cannot be generated using the plasma pen. The procedure is also extremely tedious and time consuming over larger areas.

Non-ablative skin tightening

Radiofrequency

Non-ablative skin tightening modalities can be broadly divided into radiofrequency devices and ultrasound-based devices. Radiofrequency has been around for more than a decade and has a number of variations in terms of energy delivery and efficacy. Radiofrequency is based upon delivery of an electric current through charged particles flowing through a tissue of specific impedance (resistance). Energy output is thermal in origin and is dependent on the amount of current delivered, the length of time of delivery of this current, as well as the impedance (Lolis and Goldberg, 2012). Radiofrequency devices can be monopolar, bipolar or unipolar.

Monopolar radiofrequency devices consist of an electrode and a grounding pad attached to the patient. Some devices have a built in cooling spray around the electrode to prevent superficial heat damage and deliver heat specifically to the dermis initiating the processes of collagen denaturation, disruption of fibrous septae followed by neocollagenesis and shrinkage of fibrous septae. The electrodes disperse their energy in a uniform manner thanks to capacitance coupling. Exact temperatures vary across devices, but in general, the dermis heats up to around 65–75°C with the epidermis maintained at around 35–45° C thanks to the built-in cooling spray.

Zelickson et al examined punch biopsy samples of abdominal skin treated with monopolar radiofrequency (Thermacool, Thermage) immediately after treatment and at intervals of 3 weeks and 8 weeks (Zelickson et al, 2004). At 8 weeks, the authors identified collagen fibrils with a greater diameter, shortening of collagen fibres and an overall increase in collagen. El-Domyati et al replicated these results in the face through biopsy samples taken immediately after facial treatment with a monopolar radiofrequency device, as well as 3 months later (El-Domyati et al, 2011). Similarly, there was evidence of increased collagen formation, as well as a thickened epidermis (El-Domyati et al, 2011). Objective skin tightening effects of these histological changes were demonstrated through brow elevation achieved at intervals following forehead treatment with Thermacool. Recorded complications included short-term erythema and oedema, as well pain and discomfort during the procedure. Indeed, it was clearly noted that as the energy per pass increased, there was increased pain (El-Domyati et al, 2011).

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Some devices have a built-in cooling function which helps to prevent superficial heat damage to the patient

Bipolar radiofrequency consists of two electrodes placed close to each other with an electric current passing between them. There is no grounding plate, and a cooling spray is not required. Bipolar radiofrequency results in heat energy that penetrates to a lower depth as compared with monopolar radiofrequency (El-Domyati et al, 2011). Indeed, the depth of penetration can be derived from half the distance between the electrodes (El-Domyati et al, 2011). However, there is better distribution of the energy, as well as less pain (El-Domyati et al, 2011).

Bipolar radiofrequency is sometimes combined with other forms of light energy, such as intense pulsed light (IPL). The net effect of this is that tissues are pre-treated with the light-based modality, resulting in photothermolysis and a reduction in tissue impedance. Subsequently, there is better absorption of the bipolar radiofrequency energy and hence improved effect (El-Domyati et al, 2011).

Sadick et al published the results of 188 patients treated with the Aurora (Syneron) system (bipolar radiofrequency), and demonstrated a skin laxity improvement of 62.9% (Sadick et al, 2005). Further histological analysis revealed an increase in epidermal thickness alongside a reduction in elastin and increase in collagen. One of the most well-known bipolar radiofrequency devices on the market is the VelaSmooth device (Syneron Candela), incorporating electro-optical synergy (ELOS) technology—a combination of infra-red light and bipolar radiofrequency energy with vacuum cups between the electrodes. This system was developed for the treatment of fibrodysplasia (cellulite). Khan et al (2010) demonstrated a statistically significant decrease in thigh circumference at 4 weeks post VelaSmooth treatment, alongside at least 50% improvement in cellulite at 8 weeks (Khan et al, 2010). A noticeable skin tightening effect was also recorded. Syneron Candela has now launched the VelaShape—a high power device (with 50 W of radiofrequency compared with VelaSmooth's 20 W), which claims to enable quicker treatments and results.

Further innovation of radiofrequency-based devices has come in the form of fractionated bipolar devices incorporating a microneedle-type probe. Following treatment, columns of heat energy-treated tissue are separated by unaffected columns of tissue that are considered to act as a break between treated areas, as well as a reservoir of cells that promote and accelerate wound healing. This is a similar concept to fractionated ablative and non-ablative laser devices.

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Ultrasound-based devices have lipolytic, as well as skin tightening, effects

Ultrasound

Ultrasound-based devices have developed alongside radiofrequency. Ultrasound based energy devices have a lipolytic effect, as well as a skin tightening effect, and this is dependent upon their depth of action. High intensity focused ultrasound (HIFU) and microfocused ultrasound (MFU) deliver thermal energy to the dermis and subdermal layers, resulting in a skin tightening effect. When delivered to depths below the subdermal layer and within the adipocytes themselves, they have a lipolytic effect and can result in fat reduction (Pritzker et al, 2014).

One example of a HIFU device, the Liposonix system (Valeant Pharmaceuticals), operates at a frequency of 2 MHz, delivering 1000 W/cm² amounting to 100 J/cm² of energy, resulting in heating to 55°C (Sklar et al, 2014). HIFU is specifically adept at fat reduction and results in fat necrosis with sparing of surrounding tissues treating to a depth of 1.3 cm (Sadick, 2016). With HIFU specifically, the mode of action is that the ultrasound is delivered to a focal point, which determines the depth of action, and therefore the outcome. The user therefore needs to have a thorough understanding of the anatomy of the treatment site to ensure that the energy is delivered to the appropriate depth by altering the focal point. Training is therefore essential.

MFU is more commonly used in skin tightening (MacGregor and Tanzi, 2013). MFU delivers thermal energy to a depth of 5 mm, resulting in temperatures of around 60°C and has been US Food and Drug Administration (FDA) approved as a skin tightening technique for the face, neck and décolletage. Ultrasound is delivered in short pulses and at a higher frequency in MFU treatment, amounting to 0.5–10 J/cm² of energy to the more superficial dermal subdermal interface, as well as the fibrous septae (Sklar et al, 2014). One variation of MFU is MFU-V, in which visual ultrasound screening is combined with MFU to provide the user with visualisation of the subcutaneous structures to a depth of 8 mm.

Ulthera (Merz) is a MFU device that was specifically developed for skin tightening and lifting of submental tissues and the neck region. It has received FDA approval for this. Ulthera is able to target down to the superficial musculoaponeurotic system (SMAS) layer and creates a 1 mm zone of coagulation. White et al (2007) first demonstrated the formation of discrete and reproducible zones of thermal injury and collagen denaturation in the SMAS using the Ulthera device (White et al, 2007). They used two frequency settings of 9.5 MHz and 4.4 MHz at a fixed focal depth of 4.5 mm with an energy setting ranging from 0.5–8.0 J/cm². They also identified that the higher the energy setting, the greater the degree of shrinkage; however, this had to be offset against increased amount of pain (White et al, 2007). Alam et al reported the results of Ulthera use in 35 patients (Alam et al, 2010). They reported an average brow elevation of 1.7 mm to 1.9 mm (comparable to reported results with monopolar and bipolar radiofrequency energy devices).

Saket et al (2017) conducted a retrospective review of 22 women, aged between 35 and 65 years of age, who received HIFU treatment to the face and neck for improved lift and skin tightening (Saket et al, 2017). They objectively assessed results using a specific skin laxity measuring tool and demonstrated an average improvement in skin laxity of 58–60%. This was alongside relatively few side effects (Saket et al, 2017). However, this modality causes fat loss and therefore should be used in caution on faces where volume loss is already contributing to an ageing effect. In this situation, fat reduction can cause further volume loss that is not necessarily compensated for by the relative improvement in skin laxity, giving a worse overall appearance. For this reason, effective patient selection is crucial.

New developments in skin tightening: combination treatment modalities

The vast majority of skin tightening treatments developed to date have focused on addressing the effects of skin laxity with ageing on the face and submental and neck regions. Recent further advances in radiofrequency and ultrasound technologies have yielded combination treatment modalities that have been developed to address skin laxity, excess stubborn fatty deposits and fibrodysplasia (cellulite) over other regions of the body. Little data have been published regarding resultant skin tightening effects, although there are a multitude of claims in the market. However, with the evolution of technology, there has been a shift away from the non-invasive transcutaneous approach of non-ablative radiofrequency and HIFU/MFU technologies for addressing skin laxity of the face, towards minimally-invasive subdermal radiofrequency energy for addressing skin laxity on the neck, arms, abdomen, back and thighs.

Wu et al (2016) published the results of a prospective trial consisting of 12 subjects, aged between 18 and 65 years, who were treated for skin laxity in posterior aspect of the arms using a thermistor-controlled subsurface monopolar radiofrequency device (Wu et al, 2016). This device consisted of a monopolar radiofrequency probe that is inserted subdermally through a small incision in the skin. Epidermal temperature is continuously monitored via an external infra-red camera to protect the patient against superficial burns. The procedure was performed using 100 ml of tumescent anaesthesia in each arm and subsurface temperature set at 60°C. All patients reported significant improvement in skin laxity under the arms, and this concurred with expert investigator photographic evaluation (Wu et al, 2016).

Similar devices have been developed by Inmode called BodyTite and FaceTite. These devices are based on radiofrequency technology and consist of a bipolar radiofrequency probe that is inserted subdermally and is connected to an external arm that continuously assesses surface temperature. Radiofrequency energy is delivered via a subcutaneous cannula, therefore this treatment option is considered to be more invasive. This technology has been available in one form or another for approximately 10 years, during which time it has been refined and the cannulas have been improved. These skin tightening applications are becoming more popular in the US; however, there are only a handful of providers currently operating in the UK.

J-Plasma, developed by Bovie Medical and incorporated into the Renuvion device, is a further innovation on the existing subdermal radiofrequency devices. J-Plasma is a plasma device that delivers an electric current through flowing helium and combines this with radiofrequency energy. This has resulted in the development of an ablative energy beam device that is controlled and consistent in its energy delivery footprint. Heat delivered at the source does not exceed 85°C and, when used subdermally, physician reports on DocMatter suggest external epidermal temperatures that do not exceed 40°C, irrespective of the number of passes applied. In the author's experience,

Figure 1: Female patient before (left) and 4 months after treatment with JPlasma skin tightening procedure

the results of treatment subdermally to the neck, arms and abdomen have produced preliminary results very comparable to more invasive surgical skin lift procedures (*Figure 1*). Renuvion are in the process of conducting a multicentre retrospective review of treatment outcomes.

Training and safety

Training and ensuring safety for the patient are of paramount importance when providing any form of aesthetic treatment. Energy-based devices command respect and it is of the utmost importance that adequate training and certification is achieved by the intended operator prior to offering these treatments to their clients. Transcutaneous ultrasound and the majority of radiofrequency devices available require a certain degree of training, normally provided by the manufacturer, and adherence to manufacturer-approved treatment protocols is required. In the case of minimally-invasive surgical approaches to skin tightening—ThermiTight (Thermi) and J-Plasma (Renuvion)—the learning curve is much steeper and hands on training from an approved trainer is essential. There are currently no approved trainers for J-Plasma in the UK. The skill set required for offering J-Plasma consists of basic liposuction techniques, including tumescent anaesthesia followed by an understanding of the intricacies of the J-plasma head units and energy levels recommended by established J-Plazty operators, as well as the manufacturer.

Conclusion

In conclusion, there has been a massive drive in the development of skin tightening technologies over the last decade. The preference has been to adhere to non-invasive, non-ablative energy-based technologies that can deliver heat to the deep dermal and subdermal layers of the skin, specifically initiating collagen denaturation, neocollagenesis and disruption of the fibrous septae, triggering their shrinkage. The most popular energy technologies are radiofrequency and HIFU/MFU. The results of both appear to be similar, but are still behind the final results of definitive surgery.

Few studies have compared the effects of different technologies, and further research is needed to elucidate their efficacy in comparison to oneother. The majority of focus has been on skin tightening of the face, but with the ever-increasing popularity of liposculpting and an awareness of skin laxity in other parts of the body, the demand for non-invasive and minimally-invasive approaches for skin tightening of the neck, arms and abdomen will continue to increase. The development of subdermal radiofrequency probes for minimally-invasive skin tightening procedures will push the boundaries even further, especially with the exciting results that have been achieved with combination devices.

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