

REVIEW ARTICLE

Review of non-invasive body contouring devices for fat reduction, skin tightening and muscle definition

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ABSTRACT

Non-invasive body contouring is a rapidly growing field in cosmetic dermatology. Non-invasive contouring devices improve the body's appearance through the removal of excess adipose tissue, particularly in areas in which fat persists despite optimal diet and exercise routine. The technology can also be used for skin tightening. This article reviews the five FDA-approved non-invasive body contouring modalities: cryolipolysis, laser, high-intensity focused electromagnetic field, radiofrequency and high-intensity focused ultrasound. These devices have emerged as a popular alternative to surgical body contouring due to their efficacy, favourable safety profile, minimal recovery time and reduced cost. Although they do not achieve the same results as liposuction, they are an attractive alternative for patients who do not want the risks or costs associated with surgery. When used appropriately and correctly, these devices have demonstrated excellent clinical efficacy and safety.

Key words: body contouring, fat reduction, lipolysis, liposuction, skin tightening.

In recent years, non-invasive body contouring has emerged as an increasingly popular and growing area of cosmetic medicine. The increasing pressure to meet the standards of idealised body figures and a desire for optimal

health have rendered these novel treatments a valued adjunct to lifestyle measures such as diet and exercise.

Body contouring is defined as modification of the body's appearance through changes in size or shape. Fat reduction, a key component of body contouring, was previously only available through liposuction. However, liposuction requires some form of anaesthesia and is typically associated with a variety of surgical risks and significant downtime. These undesirable features have led to a shift in demand for effective, non-invasive treatments with a lower price point and reduced risks. Despite these advantages, expectations are lower than with liposuction, particularly in patients with higher BMI.¹ Moreover, the lipolytic responsiveness of adipose tissue has been found to be inversely proportional to an individual's BMI.

A number of different treatment options are now available, which allow for customised therapy that is tailored to the patient's personal preferences, body goals and body type. Currently, FDA-approved devices include cryolipolysis, laser, high-intensity focused electromagnetic field (HIFEM), radiofrequency (RF) and high-intensity focused ultrasound (HIFU). Studies of these modalities have demonstrated their clinical efficacy and safety for subcutaneous fat reduction and/or skin tightening (Table 1).

CRYOLIPOLYSIS BODY SCULPTING

Cryolipolysis is a popular non-invasive body contouring procedure that is moderately effective and generally well-tolerated. It uses controlled cooling to specifically target areas of adipose tissue whilst preserving surrounding structures such as the overlying skin, muscles and nerves.^{2,5}

The most commonly used cryolipolysis device, Coolsculpt[®] (ZELTIQ Aesthetics, Inc., Pleasanton, CA, USA), first received FDA clearance for fat reduction in the flank area in 2010. Since this time, cryolipolysis has been approved for several other body areas, including the abdomen, flank, thighs, buttocks, submental area, bra fat, back fat and, less commonly, the upper arms.⁴

A vacuum is used to suction adipose tissue into an applicator cup in which the fat is frozen between two cooling panels. The cold-initiated damage triggers panniculitis,

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Table 1 Comparison of modalities for body contouring

	Fat reduction	Skin tightening	Muscle hypertrophy and tone	Downtime	Level of evidence
Cryolipolysis	++	0	0	0	IV
Laser	+ / ++	0	0	0	II
HIFEM	++	0	++	0	IV
RF	+	++	0	0	IV
HIFU	+	++	0	0	II
Liposuction	++++	+	0	+++	IV

HIFEM, high-intensity focused electromagnetic technology; HIFU, high-intensity focused ultrasound; RF, radiofrequency.

which selectively induces apoptosis of the adipocytes without damaging surrounding tissues. The destroyed fat is then cleared by macrophages. This inflammatory process peaks at 2 weeks, but lasts for approximately 3 months and is accompanied by a progressive decline in fat thickness.^{3,5}

During the procedure, patients may experience tingling, stinging and aching associated with the intense cold. These unpleasant sensations tend to subside after 5–10 min as the area numbs. The device may also induce pulling and pinching sensations of the skin. After a cryolipolysis session, patients should expect some mild temporary bruising, swelling and sensory changes that usually resolve within days or weeks.^{4,6} A small number of patients may complain of mild-to-moderate pain that subsides within a few days.⁷ There are no reports of permanent skin or sensory disturbances, and other adverse effects are minimal.^{3,4,6,7} Rarely, patients may develop a hardened, tender area of localised adipose tissue known as paradoxical adipose hyperplasia 2–3 months after treatment.^{8,9} In some cases, it may require liposuction, although in others it may resolve spontaneously.

A typical treatment session applies controlled cooling at -10°C for 35–60 min; multiple sessions are recommended to optimise aesthetic results.⁵ Overall duration of the treatment is tailored to the needs of the patient and depends on the number of areas treated per visit and total number of sessions.

Results may first be noticed 3 weeks after starting treatment, but improvements may continue for up to 6 months. In patients with an ideal body weight, typically 1–3 treatment sessions are required at least 2 months apart for optimal results. Clinical studies investigating this modality have documented significant patient satisfaction, which is largely attributable to minimal discomfort during treatment, limited side effects and substantial fat reduction.^{3,10} A significant advantage of cryolipolysis is that results are permanent as demonstrated by long-term follow-up data. However, patients should be aware that results are still not as dramatic as liposuction.

The best candidates for this procedure are those with soft, discrete bulges of fat in localised areas that can be adequately pulled away from the body into the device. This poses a challenge when attempting to use cryolipolysis for the arms. Cryolipolysis is not recommended in patients who are obese, have amorphous fat, have had previous abdominal hernia surgery or suffer from cold-induced metabolic disorders.

Cryolipolysis may be used in conjunction with non-contact body contouring devices such as ultrasound and radiofrequency. Combination therapy helps maximise treatment efficacy by destroying more adipose cells and increasing overall fat reduction, and may also assist with skin tightening.

Possible leakage of fat contents from the apoptosed adipocytes raised concerns that serum lipid levels may become elevated and liver function may be compromised. Subsequent studies demonstrated no effect of cryolipolysis treatment on serum lipid levels or liver panel tests.^{11,12}

LASER BODY CONTOURING

Laser therapy is a relatively new, efficacious and safe option for patients seeking modest non-invasive body contouring. Two types of device currently exist. These devices are particularly useful for non-pinchable areas of adipose tissue such as the outer thighs or slimmer abdomens.

The older version, low-level laser therapy, was FDA-cleared in 2010 for fat reduction in the abdomen, back, thigh and submental area. Low-level laser therapy uses a 635 nm wavelength to create temporary microscopic openings within the cell membrane of adipocytes, allowing lipids to leak out. This does not, however, induce the apoptosis seen with other non-invasive body contouring modalities.¹⁰ The lack of adipocyte cell death led to concerns regarding the permanency of low-level laser therapy-induced fat reduction.¹⁵

A 1060-nm diode laser has recently been developed that seeks to reduce adipose tissue through a thermally induced inflammatory process that is reminiscent of cryotherapy (SculpSure[®]; Cynosure, Westford, MA, USA). Fifteen minutes of prolonged hyperthermic exposure selectively raises adipose tissue temperature to between 42 and 47°C. This disrupts the cell membrane integrity to a degree that triggers apoptosis, after which the destroyed cells are eventually cleared from the interstitial space.^{14,15} The specificity of the 1060 nm wavelength combined with the device's contact cooling system ensures preservation of the overlying skin and adnexae during treatment.¹⁶

Despite the leakage of fat associated with both lasers, there are no documented reports of changes in serum lipid levels associated with treatment.^{15,15}

Low-level laser therapy sessions typically last up to 30 min. The 1060-nm laser treatments are slightly shorter, lasting between 20 and 25 min. Less than 20 min is

insufficient to produce adequate results, and longer than 25 min increases the risk of dermal injury and the formation of subcutaneous nodules.¹⁶

Both the low-level laser therapy and 1060-nm laser have a favourable safety profile with no serious adverse effects reported. Treatment with the 1060-nm laser is associated with mild-to-moderate pain, as the degree of tissue heating is gradually raised according to the patient's tolerance levels to maximise results.¹⁶ Mild tenderness is the most commonly reported side effect of treatment. There are no reports of skin burns, scarring or pigmentation changes. Swelling, tenderness and induration may occur in some cases, but these undesirable outcomes typically resolve spontaneously within 1–3 weeks.¹⁶ Results are best seen after 3 months, but improvements may be seen in half this time.^{16,17} However, treatments have varying degrees of effectiveness, and anywhere from 2 to 12 sessions, are typically necessary for desired results, performed ideally 6–8 weeks apart. As with the other non-invasive devices, results are subtle compared with liposuction.

Laser treatment should be avoided in patients with a scar or tattoo at the treatment site, pregnant women and those with an abdominal hernia or implanted metal.

MAGNETIC RESONANCE CONTOURING

Magnetic resonance contouring with high-intensity focused electromagnetic technology (HIFEM) is the latest advancement for non-invasive body contouring. Magnetic stimulation has previously been used as an effective treatment for a variety of medical conditions, most commonly neuropsychiatric, musculoskeletal and urogynaecological disorders.^{18–20} Unlike other currently available non-invasive fat reduction therapies, magnetic resonance may also help improve muscle thickness, strength and tone.

High-intensity focused electromagnetic field received FDA approval in 2018 for contouring of the buttocks and abdomen. The treatment uses electromagnetic energy to stimulate supramaximal muscle contractions of approximately 20 000 pulses within one 30-min session.^{21,22} The physiological mechanism behind both the adipose and muscular benefits is incompletely understood; however, current data suggest that these contractions trigger intensive lipolysis within fat cells, which releases a large volume of free-fatty acids that damage surrounding adipose tissue.²⁵ Apoptosis ensues following adipocyte injury, as evidenced by the 91.7% increase in the apoptotic index of 120 histological samples.²¹ This yields a desirable reduction in fat.

The stress of rapid nerve firing and muscle fibre contractions also leads to compensatory muscle thickening. Recent studies have demonstrated a gradual increase in muscle thickness and strength over the course of 6 months; however, further investigation of the long-term sustainability of muscular changes is warranted.²¹ Another unique muscular benefit of HIFEM body contouring is a reduction in the distance between the large abdominal muscles. This outcome was observed in 91% of patients,

regardless of whether diastasis recti was clinically present.²²

Treatment involves at least four 30-min sessions spread evenly over the course of 2 weeks. Following this, one treatment every 3–6 months is recommended to maintain results. The strength of contractions can be adjusted from 0 to 100% with the Emsculpt® (BTL Industries, Inc., New York, NY, USA) device and is increased to the highest level tolerated by the patient to yield optimal effects. Stimulation intensities of 90 to 100% are commonly reached and sustained by a majority of patients.^{21,22} The treatment is described as comfortable by most patients; however, some individuals report sensations of painful, gripping muscle contractions or brief electric shocks.

Complications following treatment with HIFEM are minimal, as transient, mild muscle soreness was the only side effect noted in a minority of patients.²¹

Subtle skin changes may be appreciated after one or two sessions, but considerable improvements should not be expected until at least 4 weeks after the last treatment. Three clinical trials found that HIFEM treatment significantly reduced patients' abdominal waist circumference, adipose tissue thickness, muscle thickness and diastasis recti.^{21,22} Jacob and Paskova²² reported a 92% patient satisfaction with abdominal appearance 3 months after completing treatment. Another study demonstrated HIFEM's ability to lift and tone the gluteal muscles; this leads to a significant improvement in buttocks appearance that was associated with a high degree of patient satisfaction.²⁴ These data, although promising, have been derived from studies with a maximum 6-month follow-up period. As such, the sustainability of abdominal and gluteal changes and long-term adverse outcomes is unclear.

Consensus regarding the ideal candidate for HIFEM non-invasive body contouring is lacking. The efficacy of treatment may be less significant in patients with a higher BMI, which may be attributed to impaired muscle contraction intensity due to increased distance between the magnetic coil and the target tissue.²¹ Another study, however, found no such correlation.²² The ideal candidate may, therefore, be one with a low or medium BMI and less than 2.5 cm of subcutaneous fat that can be pinched between two fingers.^{22,25} Patients who fall outside of this demographic are still likely to see appreciable results. Again, results with this device are likely to be inferior to liposuction even in the best candidates. Contraindications for treatment with HIFEM include pregnancy and patients with metal or electronic implants.

RADIOFREQUENCY SKIN TIGHTENING AND BODY CONTOURING

Radiofrequency devices primarily cause skin tightening and can also cause mild fat reduction. Thermage® (Solta Medical, Pleasanton, CA, USA), the most commonly used radiofrequency device, was FDA-approved in 2002 for primarily tightening of skin but also fat reduction in a variety of locations, most commonly the face, abdomen, thighs and buttocks.^{25,26}

Based on the principle of volumetric heating and the varied impedance of different skin layers, radiofrequency energy is used to generate heat that selectively targets the collagen-rich tissue layers to contract and denature collagen fibres, which results in immediate skin improvement. Long-term skin rejuvenation occurs secondary to stimulation of fibroblasts, which fuels gradual growth of new collagen and elastic fibres.²⁷ The thermal injury also induces apoptosis of adipocytes, which is responsible for the fat reduction component of the treatment.

Radiofrequency devices may have up to three settings: unipolar, monopolar and bipolar. The unipolar type is more difficult to control and more likely to cause deep tissue damage. Alternatively, the multipolar type allows for more uniform wavelength penetration, which yields superior skin contouring. It is, therefore, preferred by many practitioners. Low-to-medium BMI and significant skin laxity are two features used to identify favourable candidates.

Since Thermage[®], many other radiofrequency devices have also emerged. Vanquish[®] (BTL Industries, Boston, MA, USA) is a monopolar radiofrequency device that has been developed primarily for fat reduction in the midsection including abdomen, back and flanks, and can cover very large treatment areas at one time through the unique use of extendable paddles. Patients who seek fat reduction in these sites may also benefit from truSculpt[®] (Cutera, Brisbane, CA, USA), another monopolar system with differently sized handpieces with maximal flexibility to target both large and smaller hard-to-reach treatment areas.

The Venus Legacy[®] (Venus Concept, Toronto, ON, Canada) device combines multipolar radiofrequency with pulsed electromagnetic fields to tighten skin and/or reduce adipose tissue depending on the applicator used. Pulsed electromagnetic fields is a non-thermal mechanism emitted through the applicator's electrodes to promote angiogenesis and growth factor release, resulting in increased collagen formation.

Radiofrequency sessions typically involve heating an area between 43 and 45°C over 20–30 min followed by air-cooling of the epidermis with the device's built-in cryogen spray which creates a reverse thermal gradient. This cooling process is critical to protect the skin from complications such as burns, infections, scarring and pigment changes.

Patients may experience mild heat-related pain during treatment. After sessions, most patients will experience transient, mild erythema and swelling that typically resolves within 24 h.²⁸ Less common adverse effects reported include facial tenderness, temporary dysesthesia, subcutaneous nodule formation and fat atrophy; these risks are minimised with high-pass treatment methods and use of bipolar settings.²⁹ Close monitoring of the skin appearance during treatment sessions is critical to identify any signs of epidermal injury. Some devices offer an additional safety feature in which a built-in temperature sensor helps to prevent burn-related superficial skin damage.

Numerous clinical trials have demonstrated this modality's efficacy in primarily tightening the skin and, to a

lesser extent, reducing fat.^{30–32} Some studies have reported improvement with skin tightening after a single treatment,³⁰ but in clinical practice, multiple treatments are needed, and gradual improvement is seen over the following 2–6 months. Permanency of these effects is still unknown; however, clinical studies demonstrated that 71–97% of patients were satisfied with the body improvements.

ULTRASOUND SKIN TIGHTENING AND BODY CONTOURING

Ultrasound devices for body contouring have been uniquely designed for skin tightening and mild fat reduction using acoustic energy.^{33,34} They are broadly classified into two categories: high-frequency and low-frequency devices.

There are several different high frequency ultrasound devices that have garnered FDA approval, the most popular of which is Ultherapy[®] (Merz Aesthetics, Raleigh, NC, USA). High-frequency ultrasound energy generates heat at the target sites that are attached to the external transducer. This heat induces coagulative necrosis of the adipocytes and stimulates collagen remodelling within the tissue matrix.³⁵ Tissue temperatures above 56°C facilitate the necrotic process whilst sparing the surrounding nerves and vessels.³⁶ Targeting both fat and collagen leads to gradual skin tightening and reduced adipose tissue.³⁶ A short-duration approach helps ensure minimal epidermal damage. Alternatively, focus-pulsed ultrasound uses low-frequency waves to cause mechanical disruption of adipocytes and is usually better tolerated due to its non-thermal mechanism.

The focal depth and energy output on these devices can be adjusted based on the thickness of the patient's facial and body skin, which ultimately determines the treatment outcome.³⁷ Each procedure lasts for approximately 30–90 min, depending on the treatment location on the body. The high-frequency energy may be painful for some patients.³⁷

This procedure is safe to perform with no serious adverse events. Common side effects include erythema, localised pain or tenderness, swelling and mild bruising, all of which typically resolve within hours to days.³⁷ Strict adherence to correct treatment technique minimises the risk of burning and scarring. Rare adverse outcomes include temporary muscle weakness, numbness and tingling due to the effect of high frequency ultrasound on local nerves. There is no evidence that high frequency ultrasound alters baseline serum lipid levels, liver function or inflammatory markers during or after treatment.³⁸

Some studies have reported improvement after a single treatment,³⁹ but in clinical practice, multiple treatments are needed usually 3–4 weeks apart, and gradual improvement is seen over the following 2–6 months.^{37,39,40} The ideal candidate for this procedure has mild-to-moderate skin laxity, but results will not be as impressive as ablative forms of skin tightening or surgical lifting procedures.

CONCLUSION

As the clinical evidence supporting non-invasive body contouring devices continues to build, patient demand will rise accordingly. These less invasive modalities may be preferred due to an improved safety profile and minimal or non-existent recovery time. However, patients should recognise the limitations of non-invasive methods, as results are much less dramatic than surgery. For this reason, liposuction remains the gold standard for body contouring, and non-invasive modalities should be reserved for patients with a low BMI who are physically fit and only require small areas of fat reduction. Treatment of obese patients is unwarranted as clinical trials have not adequately assessed the devices' effects in these individuals. Further high-quality studies are needed to better establish the role of these devices for body contouring and tightening.

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