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Overview of Ultrasound-Assisted Liposuction, and Body Contouring With Cellulite Reduction

Neil S. Sadick, MD, FAAD, FAACS, FACP, FACPh

Body contouring is a rapidly growing sector of esthetic procedures and dermatologic surgery. Currently, liposuction is one of the most popular cosmetic procedures with considerable research being conducted into devices that would facilitate fat emulsification. The advent of ultrasound-assisted liposuction presented physicians with a great tool in approaching more superficial as well as fibrous adipose irregularities. Additionally, our increasing understanding of laser, light, and radiofrequency interaction with adipose tissue is allowing for these energy sources to be used noninvasively to improve body contours. This article will provide an overview of the vibration amplification of sound energy at resonance third-generation ultrasound device for liposuction as well as the VelaShape platform for noninvasive adipose and cellulite reduction. As body contouring technology and coinciding experience grow, so will the ability to achieve the aims of more efficient, safer, and cosmetically pleasing body sculpting.
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There is an increasing public, medical, and scientific awareness regarding disadvantages of excess adipose tissue. Excess body fat poses systemic health problems, and is frequently associated with dissatisfaction of the body shape. Diets, exercise, medications, and/or gastric surgeries may effectively control obesity, but frequently cosmetic procedures and devices are necessary to remove areas of fat deposits refractory to the above interventions and to improve body contour.

Body contouring is changing the shape and/or topography of the soft tissues, particularly on the legs, thighs, arms, and abdomen. Any device that improves the appearance of unwanted fat or skin laxity will also have an effect on body contour. Various devices are aiming to selectively deliver energy to the subcutaneous fat or dermal layers to alter the shape of the body. The selectivity of such modalities is achieved by the physical interaction between the tissue and the emitted energy. This article will provide an overview of 2 popular devices used for body contouring purposes. The first section will be devoted to the use of vibration amplification of sound energy at resonance (VASER) ultrasound device in lipoplasty procedures and will illustrate the use of body contouring technology as an invasive procedure. The second section will cover the application of VelaShape technology for noninvasive body contouring and cellulite treatment.

Department of Dermatology, Weill Cornell Medical College, Cornell University, New York, NY.

Address reprint requests to Neil S. Sadick, MD, FAAD, FAACS, FACP, FACPh, Department of Dermatology, Weill Cornell Medical College, Cornell University, 911 Park Avenue, Suite 1A, New York, NY 10075. E-mail: nssderm@sadickdermatology.com

Vibration Amplification of Sound Energy at Resonance

Historically, a variety of approaches have been used to evacuate fatty deposits during lipoplasty. Since the advent of lipoplasty in the 1970s, several improvements have been made to the original technique. Initially, improvements in lipoplasty were linked to advances in aspiration cannula tip design and changes in cannula diameter. These were followed with the introduction and use of wetting solutions. Lipoplasty performed without the infiltration of wetting solutions (dry technique) produces significant blood loss (aspirate contains 20%-45% blood) and postoperative bruising.[1,2] The "wet technique," which involves the infiltration of small amounts of saline solutions regardless of the volume of aspirate, was improved by Hetter,[3] with the addition of dilute epinephrine to reduce blood loss to 15%-30% of the aspirate. Klein[4] advocated using higher volumes of infiltration (infiltration-to-aspiration ratio of 3-6:1) to the point that tissue developed significant turgor; this was generally defined as the "tumescent technique." The use of wetting solutions diminished blood loss, enhanced patient comfort, and improved the safety profile of the procedure.

Despite these advances in traditional liposuction, limitations of the technique included postoperative edema and

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ecchymosis, surgeon fatigue, limited effectiveness in more fibrous areas, and difficulty in avoiding contour irregularities. To address these complications, energy-based devices have been introduced to facilitate fat removal, allow for faster procedure time, reduce strain on the surgeon, and reduce postoperative pain. These devices are particularly useful in larger-volume cases and areas of more fibrous tissue, such as backs, male flanks, and breasts, as well as secondary liposuction procedures.

Ultrasound-assisted liposuction (UAL) was developed in the early 1990s to improve penetration through fat, including fibrous areas, while decreasing work for the surgeon. UAL is designed to work in conjunction with traditional liposuction as a pretreatment method for difficult-to-treat areas before suction lipoplasty. Ultrasound, when applied internally to fatty tissue by a metallic probe or cannula, is thought to break down cells by 3 mechanisms: cavitation, thermal effect, and direct mechanical effect.[5-7] An ultrasonic generator is used to convert electrical energy to vibration using a piezoelectric crystal in the hand piece at a frequency of 20-30 kMz. Ultrasound waves cause repetitive expansion and passive contraction of adipocytes, resulting in rupture of their cellular membrane and liquefaction of fat.[8]

First-generation UAL devices delivered continuous ultrasound through solid, blunt-tipped probes (4-6 mm in diameter) to pretreat fat before evacuation. Second generation UAL machines (LySonix, Mentor Santa Barbara, CA) used 5-mm diameter hollow cannulas that would allow for simultaneous fat fragmentation and aspiration.[9,10] Even using a cannula with this external diameter, the internal lumen was only 2 mm, making aspiration generally inefficient. Notwithstanding, the design improvements of the second-generation UAL devices, the energy applied to the tissues was still too high for safe use for extended periods or in proximity to the skin.

Despite initial enthusiasm for UAL, there were both equipment limitations and surgical complications attributed primarily to application of excessive amounts of ultrasound energy during lipoplasty.[11,12] Many UAL training courses failed to clarify the relationship between ultrasound energy and efficiency of fat fragmentation. Without a sufficient understanding of power, probe efficiency, and design, it was possible to inadvertently apply excessive ultrasound power to fragment fatty tissue, often at the expense of clinical outcomes and increased procedure complications. Excessive application of ultrasound produced internal cavity formation that lead to seroma as well as delayed resolution of swelling.[13] Lateral movement of UAL cannulas or probes produced thermal damage to deep tissues along the sides of the cannulas. In addition, painful dysesthesias and sensory changes caused by UAL were reported, possibly due to the demyelinization of sensory nerve fibers.[14] The prolonged application of ultrasound against the dermal undersurface produced end-hits or burns leading to esthetic complications and possible hyperpigmentation. Clinical outcomes with first- and second-generation UAL systems varied from excellent results to significant complications not routinely encountered with suction-assisted lipoplasty.[11,15,16]

From a theoretical perspective, ultrasound energy as used within lipoplasty is safe and effectively breaks adipose tissue. However, the increased potential for complications as well as bulky instrumentation caused hesitation among many US surgeons in using UAL. To reach the full potential of ultrasound energy for fat reduction, basic science studies have addressed ultrasound's effect on tissues and attempted to quantify the amount of ultrasound power necessary for safe clinical outcomes.[17-20] The objective of this research was to guide engineering efforts to create an innovative device that would focus on safety, improve efficacy, reduce complications, and allow for faster recovery. The result of these research endeavors was the development of a third-generation UAL device from Sound Surgical Technologies (Louisville, CO)—the VASER device (Fig. 1).

The VASER platform represents a technologic advance over earlier generations of UAL equipment and addresses the shortcomings that prevented earlier platforms from achieving an acceptable safety profile. This device uses pulsed low-power ultrasound and high-efficiency, small-diameter solid titanium probes with grooves near the tip to increase fragmentation efficiency. The grooved probe design redistributes the ultrasound energy, transferring some of the vibration energy from the front of the tip to a region just proximal to the tip (Fig. 2). In traditional UAL devices, the power of ultrasound energy was a function of the diameter of the probe necessitating larger probes to be used.[17] With VASER, the grooved design increases the efficiency of the fragmentation/emulsification process allowing for smaller-diameter probes (ie, 2.9 and 3.7 mm) to be used to achieve rapid and effective fragmentation. For example, a single-grooved 3.7 mm VASER probe applied at a power of 11-13 W delivers the equivalent energy to tissues as a 5-mm second-generation UAL probe applied at a power of 20-25 W.[21] This demonstrates that probe design can result in a 50% reduction in applied power, decreasing the risk of burns and tissue necrosis.

Further reduction in applied power is achieved using the VASER pulsed mode. This approach of pulsed delivery of energy is used to achieve the benefits of higher probe vibration amplitudes, but only for short bursts of time. The vibration energy is essentially "off" more than 50% of the time in VASER pulsed mode. The pulsed mode used in conjunction with the grooved probes results in nearly a two-thirds reduction in applied power.[22] In addition, the VASER system débuted smaller, less cumbersome, and more user-friendly instrumentation that incorporated surgeon feedback and ergonomic design, such as curved probes. These improvements have expanded the use of VASER lipoplasty to the safe treatment of the male and female breast, face and neck, axillary hyperhydrosis, fibrous body areas (trunk and back), and combined excisional body contouring procedures of all types. A clinical analysis by Garcia and Nathan[23] recently confirmed that VASER-assisted lipoplasty (VAL) results in significantly reduced blood loss than traditional lipoplasty. The study analyzed the hemoglobin and hematocrit content of aspirate from fibrous areas such as the back and flanks, where traditional suction-assisted lipoplasty (SAL) is associ-

Figure 1 VASER lipolysis system from Sound Surgical Technologies (Louisville, CO).

ated with a high degree of ecchymosis. Results showed that VAL yielded a more consistent aspirate with 7.5 times lower hemoglobin content and 6.5 lower hematocrit values. Consequently, VAL should be considered for patients undergoing large-volume lipoplasty procedures or lipoplasty in tight, fibrous areas such as the back and posterior flanks where increased blood loss is expected.

During the VASER procedure, there is a risk of skin irritation around the entry sites with a beginning surgeon. Skin protection is recommended through the use of specially designed skin ports that cover the incision edges and wet towels adjacent to port locations. The towels protect the skin from inadvertent contact (external burns) with the shaft of the vibrating probe. The probe movement should be performed with a simple axial back-and-forth motion, and levering (applying torque) of the probe should be strictly avoided.

Figure 2 Grooved probes that accompany the VASER system and allow for decreased ultrasound energy delivery.

Probe selection during a VASER procedure should be determined based on the characteristics of the localized fat deposit being treated. In general, the 3.7-mm probes are intended for rapid debulking of larger volumes of fat. The 2.9-mm probes are intended for smaller volumes and for contouring. Probe diameter and the number of side grooves on the tip influence how the probe will pass through any given tissue type. For a given diameter, probes with more grooves fragment tissue more efficiently but do not penetrate fibrous tissues as easily. Therefore, when treating fibrous tissues and choosing between probes of equal diameters, probes with fewer grooves are more appropriate. Additionally, smaller diameter probes will penetrate fibrous tissues more readily than larger diameter probes, irrespective of the number of grooves.

The recommended energy settings for the VASER device are influenced by tissue type, ultrasound mode, and probe selection and can be obtained from the manufacturer. The device can function in 2 ultrasound modes—the VASER or the pulsed mode and the continuous mode. In general, the continuous mode is only necessary when emulsification is not readily achieved with the VASER mode, such as in extremely fibrous tissues. The primary end point of emulsification is loss of resistance to probe movement, but the skin should not become warmer than the hand of the surgeon. Achieving a loss of resistance without heat generation is a key to avoiding complications. Further, it is important to infuse sufficient wetting solution when using VASER. Smaller vol-

umes of wetting solution may result in very rapid heating of the tissues and contribute to complications.

The clinical studies that have reviewed the VASER device[22-26] have reported that pretreatment of fat through VASER ultrasound with grooved, small-diameter probes is efficient and safe. Satisfactory to excellent clinical outcome were reported first by Jewell,[22] who noted that the aspirate contained approximately 80% or greater supernatant fat, minimal blood loss, and very infrequent edema or ecchymosis. There were no occurrences of prolonged discomfort and bruising sensations that have been reported with earlier UAL devices (Fig. 3).

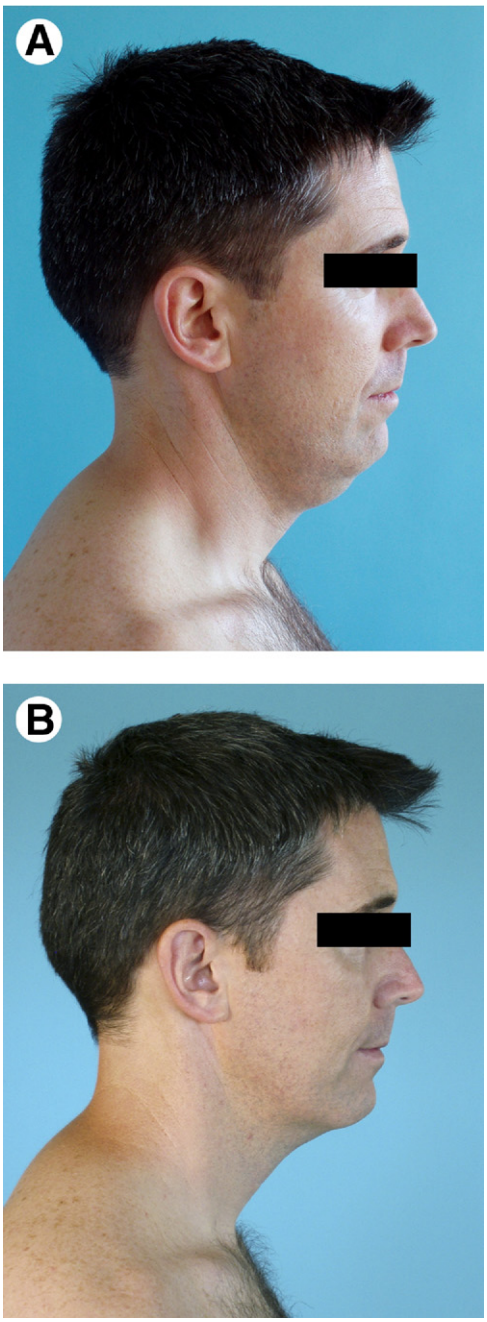

Figure 3 Typical results of VASER-assisted lipolysis on the male chin. (A) Before and (B) after the treatment. Photos courtesy of Sound Surgical Technologies LLC.

Several recent studies have explored the expansion of VASER technology to newer indications. Hoyos and Millard[27] investigated the application of VASER for "high definition liposculpture" (HDL) designed to enhance surface anatomy and give the appearance of highly developed musculature. HDL was traditionally developed for athletes with between 8% and 15% body fat and limited to the anterior abdominal wall—it was an artistic approach designed to emulate and enhance surface anatomy. VASER-assisted HDL (VAHDL) was theorized to allow a more precise, less traumatic procedure with improved clinical outcomes. The authors found that the addition of VASER to HDL improves the accuracy and symmetry of the procedure. VAHDL provided faster and less painful recovery than HDL alone. The degree of patient satisfaction with VAHDL was also superior to HDL alone. However, this study did report a higher complication rate of seroma formation (6.5%) than earlier studies. This was due to the increased work in the superficial layer and the expansion of the technology to a new area. Seroma formation can be minimized by the use of drains in the sacral area in females and the inguinal area in males.

Commons and Lim[28] reported on the treatment of axillary hyperhidrosis using VASER ultrasound only, without traditional liposuction. The primary objective of their work was to assess safety and efficacy of VASER for this indication as well as refine the treatment protocol. The authors reported no significant complications for the 26 axillae treated. For all patients treated, there was a statistically significant reduction in both sweat and odor at the 6-month follow-up with a high patient-satisfaction rate. The authors find VASER safe and effective for the treatment of axillary hyperhidrosis and advocate for the use of third-generation UAL devices in this setting. Recommendations on technique include leaving the axillary areas unshaven, treating the target areas very superficially, constant manual assessment of skin temperature, and treating 1 cm beyond the hair-bearing area.

Through these applications and a proved record of safety and efficacy, VASER has been confirmed as an enabling technology to address irregular contour in the adipose layer. VAL uses less energy than second-generation UAL devices, does not remove protective wetting solutions using a solid probe, implements pulsed energy delivery, and presents an improved probe design by reducing probe diameter and introducing grooves near the tip. These technical advances reduce the risk of complications and confirm VASER as a safe and exacting technology.

VelaShape

VelaShape (Syneron Medical, Ltd, Israel) is a noninvasive device used for cellulite reduction as well as body contouring (Fig. 4). It is a second-generation device of the previous VelaSmooth technology and uses Electro-Optical Synergy (ELOS) technology and mechanical manipulation of the skin and fat layer to noninvasively improve the appearance of cellulite. ELOS is a combination of bipolar radiofrequency (RF) and optical energies. The preheating of the dermis with optical energy is beneficial because RF is preferentially drawn

Figure 4 VelaShape body contouring system from Syneron Medical, Ltd, Israel.

to warmer tissue. In this manner, the preheating of the dermis with the optical energy makes the RF more efficient. Because RF energy does not heat the epidermis, the likelihood of adverse effects such as scarring and skin pigmentation is reduced.[29] In addition to delivering ELOS, the VelaShape uses a handpiece that exerts a negative pressure massaging action on the tissue.

It has been proposed that microcirculation is improved by the vasodilatory effect and enhanced lymphatic drainage of the negative pressure mechanical massage of this system.[29] At the same time, neocollagenesis, collagen contraction, and controlled tissue inflammation are induced by heating tissue through RF and optical energy.[30,31] The RF energy makes the ELOS technology effective because of its ability to penetrate deeper layers of skin due to the preheating with optical energy. By combining 2 energy sources into ELOS technology, the amount of delivered energy that is administered to an individual is reduced. This reduces the probability of adverse events such as skin pigmentation and scarring. Because RF does not target melanin, heating of the epidermis is much lower.

The first-generation device, VelaSmooth, provides 20 W of infrared (IR) power, 20 W of RF power, 1 MHz RF frequency, and 150 mbar of vacuum suction in 100-300 ms pulses, all delivered directly to the skin through a handheld applicator. The IR light spectrum is 680-1500 nm and the treated area is 40×40 mm^2. The vacuum suction prepares the skin to receive RF energy that penetrates 10 mm.[29,32] The vacuum suction improves circulation and reduces dimpling by loosening connective tissue around the fat deposits, whereas the IR and RF energies, by heating the skin, enhance the rolling action of the massage unit. Both tissue bulk and dimpling are thus lessened by the massage-induced increase in lymphatic drainage.[33] Like VelaSmooth, the VelaShape device delivers bipolar RF energy, IR light energy, and vacuum suction pulses to the skin surface with a handheld applicator. RF energy penetrates 2-20 mm beneath the skin, whereas IR energy penetrates up to 3 mm beneath the skin. RF power is available at 50 W rather than 20 W (as in VelaSmooth), and the vacuum pattern is modified. With these alterations, treatment duration is shortened by approximately 30%, and fewer treatments[4-6] are required to achieve clinical benefit. Additionally, the VelaShape platform is available with the VContour applicator. This applicator is smaller and designed for harder to reach areas such as the arms and neck. Recently, VelaShape II has been released, which has made further improvements to the ELOS technology. The new platform reduces treatment time by 20% by allowing a higher energy output of 75 W. Additionally, it features an advanced ergonomically designed handpiece as well as a new and improved massage system that is completely noiseless and increases patient comfort.

It is believed that heat created by the 2 energies increases the dissociation of oxygen from oxyhemoglobin and diffusion of heat to adipose tissue. The increase in available oxygen may facilitate an increase in fat metabolism.[32] This claim presents an interesting theory about the efficacy of this device but necessitates more clinical evidence to become a valid theory. The accompanying mechanical massage manipulation of the skin helps to improve circulation and fibrous connective tissue.

Wanitphakdeedecha and Manuskiatti[34] suggested a mechanism by which VelaSmooth treatment improves the bumpiness and dimpling in cellulitic skin. The bumpiness is reduced when the RF current heats the adipose tissue at depths of 5-10 mm, causing lipolysis and fat chamber shrinkage. Penetration of RF energy is enhanced as the rollers knead the skin. The heat also improves peripheral circulation and diffusion of molecules in the treated tissue, thus increasing fat metabolism. Dimpling improves because of the repeated kneading of the skin between the rollers, which ruptures fat cell clusters and temporarily stretches the vertical septa and connective tissue.

Treatment Protocol

The following protocol is typical for a 30- to 45-minute session. It is used for both the VelaSmooth and VelaShape. The skin should be hydrated skin with an oral intake of greater than 8 oz of water up to 1 hour before treatment. Immediately before treatment, the skin should be hydrated with a conductive lotion provided by the manufacturer. Using the handheld applicator, the area should be treated with 4-6 passes by moving the hand-piece back and forth several times over the treatment area. The energy levels should be adjusted to the patient's comfort and tolerance. Gentle but firm pressure should be used to ensure adequate contact. Treatment should continue until erythema, and a warmth is felt in the treated areas. Erythema and warmth should disappear within 2 hours after treatment. The treated areas should be hydrated with the conductive lotion again after treatment. Patients should be advised to avoid hot baths and showers for 24

hours after the treatment. The target areas should be treated twice weekly for 4 weeks and monthly thereafter (or less frequently) for maintenance. Temporary bruising may occur after the first several treatments.

The largest study evaluating the efficacy of VelaSmooth was performed by Sadick and Mulholland[32] on 35 patients. This study evaluated the efficacy by observing changes in the circumference of the thighs and estimating improvement (%) from photographs taken before and after treatment. Energy levels depended on patient tolerance and comfort and were increased with continued treatments. Patients were treated until the appearance of erythema (5-10 min).

All patients achieved some level of improvement in cellulite appearance and skin smoothing as judged by comparing pre- and post-treatment photographs. Physician-rated improvement was very good-to-excellent in 23% of patients, good in 35% of patients, and mild in the remaining 42% of patients. Average improvement in cellulite appearance was 40% as judged by a dermatologist unaware of the data. Histologic analyses of skin biopsy specimens of the lateral thighs taken from 3 patients before treatment, after 2 treatments, and after 8 treatments showed no evidence of structural damage, either epithelial or mesenchymal.

This initial study was followed up by several other groups. Wanitphakdeedecha and Manuskiatti[34] were the first to report cellulite improvement 1 year after a series of treatments with the VelaSmooth, and for both the thigh and abdomen. For the thighs, mean circumference reductions were 6.23% immediately after the final treatment, 6.26% 4 weeks later, and 5.50% 1 year later. Mean reductions for the abdomens were 6.32%, 4.04%, and 4.64%, respectively. These results suggest that most of the circumferential reductions are maintained for at least 1 year after the final of 8-9 treatments at 2 per week.

Romero et al[35] evaluated improvement before and after treatment at several time points by biopsy. Skin biopsy specimens were taken from the buttocks of 6 of 10 patients before treatment, 2 hours after the first treatment, and 2 months after the final of 12 treatments. Specimens taken after the final treatment showed improved epidermal and dermal morphology due to tightened dermal collagen and improved organization of epidermal cells compared to the baseline samples. Specimens taken 2 hours after the initial treatment showed dermal fibers aligned with the dermal–epidermal junction, contraction of the papillary dermis, and adipocytes moved close to one another compared to baseline samples. The authors suggested that these histologic changes may be due to microinflammatory stimuli produced in the treated tissue and subsequent standard tissue repair.

Work done by Goldman and coworkers[36] compared the efficacy of treatment of cellulite with the previously described TriActive versus VelaSmooth. Patients were treated twice weekly for 6 weeks with either VelaSmooth or TriActive. This study calculated a 28% vs a 30% improvement rate, respectively, in the upper thigh circumference measurements, with a 56% vs a 37% improvement rate, respectively, in lower thigh circumference measurements. Statistical difference of these results was $P > 0.05$. Incidence and extent of bruising was higher for VelaSmooth than TriActive, which may be attributed to higher mechanical manipulation.

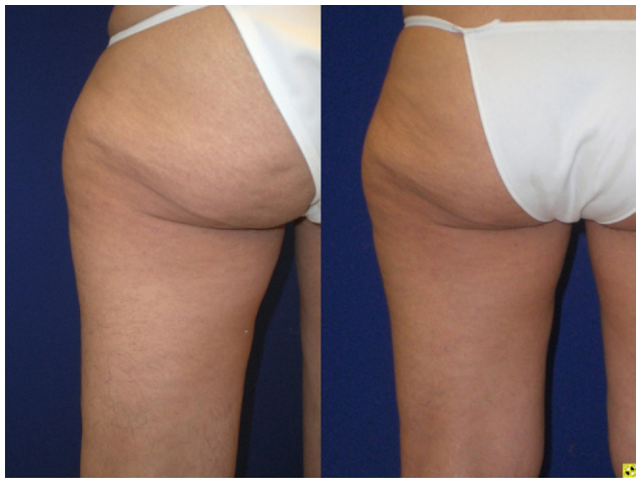

Figure 5 VelaShape clinical results. Before and after 4 treatments.

Conclusion

With the growing demand for more substantial body-contouring technology, body shaping is becoming a new and exciting frontier of esthetic dermatologic surgery. The tremendous growth of this sector has been fueled in large part by the search for minimally invasive modalities, making it possible to reduce excess adipose tissue, tighten lax skin, and slim and smooth body contour with or without surgery. Although there is no replacement for more invasive modalities when significant contour irregularities exist, ultrasound, laser, and RF sources for fat reduction and skin tightening offer alternative therapies for patients with milder degrees of defect who prefer minimal side effects. Continued advances in technology and techniques are likely to improve future methods increasing the efficacy and consistency of results while maintaining favorable adverse-effect profiles. (Fig. 5).

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