In 1921, Dujarrier, a French surgeon, curetted a ballerina’s knees to create a better shape, but the patient developed gangrene and required amputation. In 1964, Schrudde developed curettage and suction. Italian surgeons, Georgio and Arpad Fischer, developed cannulae and an internally rotating planatome and cellusuction-tome. Yves Gerard Illouz was the true pioneer of the cannula liposuction technique. In 1977, he described the first technique allowing for the removal of fat collections without large incisions or prolonged recovery [1].

Also referred to as liposculpture, lipoplasty and suction-assisted lipectomy, liposuction remains, to this day, an extremely popular procedure. This increasing popularity is associated with the evolution of techniques and equipment for fat removal and body reshaping. Besides traditional liposuction, other options include ultrasound-assisted liposuction (UAL) and external ultrasound-assisted liposuction, power-assisted liposuction, and laser lipolysis. Efforts in the search for alternatives and new tools primarily seek to reduce downtime, decrease operator fatigue, reduce bleeding and promote skin contraction.

This review aims to describe traditional liposuction and laser lipolysis, and discusses the difference between the two techniques.

Different types of fat
To understand the indications and limitations of liposuction and laser lipolysis, different types of fat must be distinguished.

In 1921, Dujarrier, a French surgeon, curetted a ballerina’s knees to create a better shape, but the patient developed gangrene and required amputation. In 1964, Schrudde developed curettage and suction. Italian surgeons, Georgio and Arpad Fischer, developed cannulae and an internally rotating planatome and cellusuction-tome. Yves Gerard Illouz was the true pioneer of the cannula liposuction technique. In 1977, he described the first technique allowing for the removal of fat collections without large incisions or prolonged recovery [1].

Also referred to as liposculpture, lipoplasty and suction-assisted lipectomy, liposuction remains, to this day, an extremely popular procedure. This increasing popularity is associated with the evolution of techniques and equipment for fat removal and body reshaping. Besides traditional liposuction, other options include ultrasound-assisted liposuction (UAL) and external ultrasound-assisted liposuction, power-assisted liposuction, and laser lipolysis. Efforts in the search for alternatives and new tools primarily seek to reduce downtime, decrease operator fatigue, reduce bleeding and promote skin contraction.

This review aims to describe traditional liposuction and laser lipolysis, and discusses the difference between the two techniques.

Different types of fat
To understand the indications and limitations of liposuction and laser lipolysis, different types of fat must be distinguished.
(back rolls and epigastric skin), too thin (inner thighs and arms), too lax (post-weight-loss or pregnancy), and stretch-marked skin will all have some difficulties in retracting. A skin lift may then have to be accompanied with liposuction. This is a major limitation of the technique.

Finally, the ideal liposuction patient is healthy, eats a well-balanced diet, has good skin elasticity, is within 20–30% of ideal body weight and wants to improve localized fatty deposits resistant to diet and exercise that may be of a genetic nature. All other indications are more limited and results are often less predictable.

Liposuction
The principle of liposuction is to remove fat through very small skin incisions, using atraumatic and blunt-tipped cannulas. These cannulas are attached to a closed, negative-pressure system, allowing for the safe and sterile aspiration of excess fat cells. Since these fat cells are unlikely to remultiply, there will be no recurrence of the overcrowding of adipocytes. While sounding simple, this technique, when used inappropriately, may lead to serious complications that range from simple aesthetic sequela to very serious complications, including death.

Procedures & technical evolution

Standard procedure
The first step in the procedure is to obtain the patient’s consent. Photographs are taken, a marking pen is used to draw a topographic map of the areas to be aspirated while the patient is standing, entry points are identified and marked, and the skin is disinfected.

• Under general anesthesia, the patient is placed on sterile drapes and/or towels;
• Tumescent fluid is injected. Infiltration begins by creating a small stab incision, just enough to accommodate the infiltration needle. Blunt-tipped cannulas of varying lengths are used to infiltrate the fluid into the desired deep subcutaneous adipose layer, using either a handpiece or foot pedal to control administration;
• The suction cannula is introduced into the deep fat layer. The vacuum is activated and the cannula is pushed through the fat, creating a radial pattern. Cross-hatching, or inserting the cannula from two different axes (usually perpendicularly), creates a smoother result. Connected to the aspirator (or sometimes a syringe), the liposuction cannula is placed through the insertion site while the nondominant hand (also known as ‘the thinking hand’) continually monitors the placement and trajectory of the cannula, enabling the surgeon to feel the progress in the area and to determine the end point of surgery.

Smaller caliber cannulae may also be used to suction the superficial fat layer in a similar fashion. Owing to the superficial location of this fat, caution must be exercised in order to not injure the skin or create contour irregularities (Figure 1). At the end of the procedure, access wounds are closed with one to two buried absorbable sutures, and sterile dressings are placed. Compression garments and absorptive pads are applied to the wounds immediately postoperatively and may be worn for up to 1 month or more, depending on the surgeon.

The immediate swelling is related to the anesthetic fluid and, as this is absorbed, surgical swelling then becomes noticeable. Return to normal physical activities is possible 1 week after the procedure.

Evolutions
Over the years, many evolutions and modifications have been proposed to minimize risk and to improve the cosmetic outcome of the contouring procedure of liposuction, including in areas of infiltration, superficial liposuction and UAL.

The tumescent fluid, infiltrated into the fatty tissues required to anesthetize the region, effectively produces a ‘dissecting hydrothomy’. It also magnifies the fatty layer, significantly reduces bleeding and allows for aspiration of pure fat. The usual formula for liposuction infiltration is the Klein Formula. The Klein Formula combines 1 l of normal saline with 50 ml of 1% lidocaine, 1 ml (1 amp) of 1:1000 epinephrine and 2.5 ml of 8.4% sodium bicarbonate. The bicarbonate is added to balance the pH of the lidocaine and to decrease the pain of the injection, as well as increase analgesic potency. Several modified formulae are also proposed (2). In the USA, the formula typically contains more lidocaine (1000 mg) and 12.5 ml of sodium bicarbonate, as well as epinephrine.

Historically, four types of wetting solutions have been used for liposuction: dry, wet, superwet and tumescent. The essential difference between these techniques focuses on the amount of fluid infiltrated into the tissues and the resultant blood loss as a percentage of aspirated fluid.

Wetting solutions
Dry
No fluid is injected into the subcutaneous fat layer before suctioning. The dry technique involves no infused fluid and results in approximately 25–40% blood loss of the volume removed. This technique is not commonly used, except for small volume suction.

Wet
Illoz pioneered this technique in the early 1980s. The wet technique uses an infusion of 100–300 ml of fluid (with or without epinephrine) into each site to be treated, resulting in a reduction in blood loss of 10–30% of aspirate without epinephrine, and 15% with epinephrine. These two techniques have fallen out of favor and have been replaced by superwet and tumescent techniques because of excessive blood loss.

Superwet
This technique was devised in the late 1980s. It consists of an infusion of fluid containing epinephrine and low doses of local anesthesia in a 1:1 ratio to the volume of expected aspirate. Blood loss is reduced to approximately 2% of the aspirated volume.
Tumescent
In the tumescent technique, large volumes of saline containing 1:100,000 epinephrine and 0.05% lidocaine are injected subcutaneously before suctioning, until the tissues are tense. Again, several modified formulae have also been proposed. The injected fluid volume is greater than that expected to be suctioned. Blood loss is approximately 1% of aspirated volume. Extensively used in the USA, the tumescent technique has not fallen out of favor in Europe, but it must be outlined that this technique should not be used together with general anesthesia in order to avoid mortality. This is an important issue that has been stressed several times in the literature. The other point is whether or not volumes greater than 4000 ml should be used. Major complications are associated with the massive quantity of infiltration (pulmonary edema for example).

Recently, the American and European Societies of Plastic Surgery have recommended the use of the superwet technique to reduce the need for infiltrating solutions and its associated surgical risks. Approximately 50–70% of the infused fluid is estimated to remain at the end of the lipoplasty procedure. The superwet technique is the most useful procedure to date because the procedure allows for easy and good-quality aspiration, and reduces blood loss without the risks associated with tumescent technique.

Superficial liposuction
The use of thinner cannulas can theoretically permit a more superficial liposuction to improve skin retraction and reduce postoperative irregularities (waves). Traditional liposuction treatments involve removal of fat in the deeper layers. However, superficial liposuction is performed in attempt to improve skin contour in individuals with flaccid skin or cellulite in specific areas.

The hope with this technique is that superficial treatment initiates skin retraction: rolls on the back, inner thigh or arm, banana roll, upper abdomen, flank and/or lumbar roll breasts are considered most likely to respond effectively to the procedure. Individuals with cellulite of the outer and anterior thighs have been shown to be most likely to respond well.

Superficial liposuction is still debated, and results seem to be very operator dependent. Incidences of skin irregularities and contour deformities have increased. Other complications include seromas, hematomas, hyperpigmentation, dyschromia, skin sloughing (even necrosis) and dysesthesia.

Ultrasound-assisted liposuction
Michele Zocchi from Italy and Ralph Kloen from the USA are credited with developing and introducing internal UAL [4,5]. The observations that adipose tissues were effectively emulsified while connective tissue structures were preserved in vitro led to the concept of using ultrasound adjunctively in vivo. Three generations of devices are used. First-generation devices use blunt, solid, 4–6-mm probes, followed by aspiration with standard cannulas. Second-generation devices use hollow cannulas for simultaneous aspiration and ultrasound delivery, allowing the quality of the aspirate to be monitored. However, second-generation devices have certain disadvantages. They are relatively large in diameter (≥5 mm), which requires longer incisions in order to accommodate skin protectors. The lumen is small, resulting in inefficient aspiration; therefore, a two-stage procedure is generally performed with a second, aspiration-only component. Additionally, the ultrasound energy is focused in a longitudinal direction, directly away from the tip, increasing the potential for burns. Third-generation technology, again, uses solid probes with some design changes (vibration amplification of sound energy at resonance [VASE]) and focuses the ultrasound energy in a transverse direction, reducing the potential for burns.

Ultrasound-assisted liposuction allows for the treatment of areas (i.e., back, upper flank, chest and male breast) that previously did not respond well to conventional liposuction. Ultrasonic energy is exothermic, so it can cause heat injury to surrounding tissues. This may improve the results of liposuction by increasing contraction of the skin and subcutaneous tissues, but it also increases the risk of injury to the skin during superficial suctioning. The promise of enhanced fat removal with minimal blood loss and claims of improved skin retraction and safer large-volume procedures resulted in intense interest in UAL in the USA. However, enthusiasm was tempered by reports of skin burns, dysesthesias and high seroma rates. This technique is now largely abandoned in France owing to the risk of secondary complications (i.e., burns).

Complications of liposuction
Short-term complications
Hypesthesia, paresthesias, edema, ecchymosis, hematoma, seroma and infection usually resolve quickly. Hematomas and seromas may need to be drained with large needles or skin incisions. Infections often resolve with oral antibiotics, although a low incidence of devastating necrotizing fasciitis has been reported. Fat emboli can be fatal but are rare. Skin necrosis can occur, usually as small areas, but it can usually be treated conservatively with local wound care. Pulmonary edema has been reported as a complication of tumescent liposuction.
Table 1. Liposuction versus laser lipolysis.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Liposuction</th>
<th>Laser lipolysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial objective</td>
<td>Removal of fat deposit</td>
<td>Removal of fat deposit</td>
</tr>
<tr>
<td>Additional effect</td>
<td>Depending on the spontaneous ability of the skin to retract: prior satisfactory skin elasticity is mandatory, quality of skin underneath is the decisive factor for the end result</td>
<td>Laser thermal action over tissue enhances skin retraction</td>
</tr>
<tr>
<td>Principle</td>
<td>Fat cells are sucked out</td>
<td>Destruction of adipocytes leading to a delayed melting of fat</td>
</tr>
<tr>
<td>Mechanism</td>
<td>Mechanical action by aspiration</td>
<td>Thermal action through laser fiber</td>
</tr>
<tr>
<td>Indications</td>
<td>Moderate-to-large fat deposits Aspirated fat volume can represent 5–10% of total bodyweight</td>
<td>Moderate fat deposits Theoretically limited to daily metabolism ability of the body, namely 1800 kcal/day or 300 g of fat</td>
</tr>
<tr>
<td>Preferential treated areas</td>
<td>Deep localized or large amounts of fat overload</td>
<td>Superficial or deep localized fat deposits or liposuction failure</td>
</tr>
<tr>
<td>Indications limits</td>
<td>Superficial fat deposits: cellulite</td>
<td>Deep fat deposit</td>
</tr>
<tr>
<td>Counterindications</td>
<td>Thick skin, too thin skin; primarily lack of elasticity because risk of insufficient secondary skin retraction or secondary skin depressions</td>
<td>Substantially overweight, large areas</td>
</tr>
<tr>
<td>Anaesthesia method</td>
<td>Depending on the size of the area to be treated: local anesthesia, general anesthesia</td>
<td>Local anesthesia, owing to minimal operative trauma</td>
</tr>
<tr>
<td>Hospitalization</td>
<td>From a few hours to 2 days, depending on the anaesthesia method and the amount of aspirated fat</td>
<td>A few hours: local anesthesia and smaller treatment areas</td>
</tr>
<tr>
<td>Procedure</td>
<td>Short incision: 3–4 mm Tunneling and fat aspiration using a cannula to avoid damage to large vessels and nerves</td>
<td>Short incision: 2 mm Tunneling with a 1-mm cannula containing a 600-µm-thick fiber</td>
</tr>
<tr>
<td>Duration of the procedure</td>
<td>Proportional to the amount of aspirated fat and number of area to be treated From 20 mins to 3 h</td>
<td>For a similarly sized area, laser lipolysis takes longer as work on several planes needs to be performed to achieve an homogeneous thermal effect</td>
</tr>
<tr>
<td>Postoperative pain</td>
<td>Moderate to severe, mainly depending on the number of treated areas and amount of fat removed</td>
<td>Moderate or no pain</td>
</tr>
<tr>
<td>Side effects</td>
<td>Large edemas and ecchymosis (hematomas ± diffuse) Fading of edema and ecchymosis within 15 days to 1 month Postoperative tiredness</td>
<td>Moderate edemas and moderate or no ecchymosis Fading of the edemas within 3–7 days</td>
</tr>
<tr>
<td>Return to work</td>
<td>Return to work after 1 week (depending on the amount of fat removed)</td>
<td>Immediate return to work (moderate-sized treated areas)</td>
</tr>
<tr>
<td>Postoperative compression</td>
<td>3 weeks to 1 month</td>
<td>15 days</td>
</tr>
<tr>
<td>Assessment of results</td>
<td>As soon as the edemas disappeared, between 15 days and 1 month Improvements seen until the 6th month</td>
<td>Delayed, usually after 3 months Improvements seen until the 6th month</td>
</tr>
<tr>
<td>Complications</td>
<td>The larger the areas treated, the more frequent the complications Thromboembolism, anemia and metabolic disorders if excessive lipoaspiration and complications due to anesthesia</td>
<td>Localized burns</td>
</tr>
<tr>
<td>Quality of the result (see Table 2)</td>
<td>Depending on the ability of the skin to retract spontaneously</td>
<td>Depending on the homogeneity of laser delivery by the operator (localized overheating must be avoided)</td>
</tr>
</tbody>
</table>
Long-term complications
The most common long-term complication is contour irregularity. This relates to the experience of the individual surgeon and may respond to massage therapy. It should be treated conservatively for at least 6 months. Autologous fat grafting, further liposuction or skin excision should be performed as needed. Various studies state minor revision rates of 2–10%. Skin color changes are rare but are more common with aggressive superficial UAL. Specific incidences for complications from liposuction are difficult to ascertain. Physicians of various specialties perform liposuction in hospitals, surgical centers, and private offices. The most devastating complication of liposuction, death, has been reviewed statistically. In January 2000, Grazer published an article in which he reported the fatal outcomes of liposuction using a census survey of cosmetic surgeons [6]. He surveyed 1200 actively practicing, board-certified, North American esthetic plastic surgeons who were members of the American Society for Aesthetic Plastic Surgery (ASAPS). Of those surveyed, 917 surgeons reported that from 1994–1997, 95 fatalities occurred after 496,245 lipoplasties. This yields a mortality rate of 1 in 5224 (<0.5%). This is similar to rates quoted elsewhere. Pulmonary thromboembolism was the major cause of death in 23.4 (±2.6%) of these deaths.

The American Society of Plastic Surgeons recommends that outpatient lipoplasty be limited to 5000 ml of total aspirate, irrespective of the technique.

Liposuction according to areas
Face & neck
Cervicofacial liposuction involves the application of negative pressure through a hollow cannula in the subcutaneous plane to gently avulse fat cells and precisely sculpt undesirable fat deposits in the face and neck. Skin elasticity should be good-to-fair to predict good retraction of the skin. Performed alone, one of the main problems is the limited capacity of secondary skin retraction. When there is a lack of skin elasticity, results are poor; this is why cervicofacial is often used in combination with other facial plastic procedures (facelift). Patients who cannot undergo face-lift surgery due to ongoing smoking, diabetes or other medical problems may be candidates for liposuction because of the lower complication rates, although caution should be exercised in these patients because of the risk of skin loss. The risk of sagging submental or jowl skin, which can result in deformity, depends on the elasticity of the skin. This problem can be corrected by assessing this preoperatively, informing patients who have borderline elasticity of this risk and a possible formal facelift.

Calves & ankles
Liposuction of the lower extremity, from thigh to ankle, is an important adjunct to many plastic surgeons’ practice. Having succeeded in reducing particular bulges in the thigh, lower

Table 2. Efficacy of liposuction and laser lipolysis as a function of the location of fat deposits.

<table>
<thead>
<tr>
<th>Topography</th>
<th>Liposuction</th>
<th>Laser lipolysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saddlebags (usually elastic skin)</td>
<td>+++</td>
<td>+ to +++ if moderate amounts of fat deposits. Consider combining laser lipolysis with liposuction if there is large amounts of fat deposits with lax skin</td>
</tr>
<tr>
<td>Hips (love handles) usually elastic skin</td>
<td>+++</td>
<td>+ most of the time, large fat deposits</td>
</tr>
<tr>
<td>Internal side of knees (usually elastic skin)</td>
<td>+++</td>
<td>+++ most of the time, localized fat deposits</td>
</tr>
<tr>
<td>Inner-thighs (usually thin skin, spontaneously flabby)</td>
<td>+</td>
<td>+ to +++ if moderate amounts of fat deposits. Consider combining laser lipolysis with liposuction if there is large amounts of fat deposits with lax skin</td>
</tr>
<tr>
<td>Inner-side of arms (usually thin skin, spontaneously flabby)</td>
<td>+</td>
<td>+ to +++ if moderate amounts of fat deposits. Consider combining laser lipolysis with liposuction if there is large amounts of fat deposits with lax skin</td>
</tr>
<tr>
<td>Inner-side of thighs</td>
<td>Counterindicated: risk of undulated sheet metal effect</td>
<td>+ to ++ depending on the type of cellulite</td>
</tr>
<tr>
<td>Lower abdomen: below the navel</td>
<td>+++ if tonic and young skin Contraindicated if the skin is not elastic</td>
<td>+ rarely advisable on its own because of the size of the area. Consider laser lipolysis associated with liposuction in order to improve skin tightening</td>
</tr>
<tr>
<td>Upper abdomen: above the navel</td>
<td>+ thick skin, insufficient secondary skin contraction</td>
<td>+++ if moderate amounts of fat deposit. Associate with liposuction if there is large amounts of fat deposits with lax skin</td>
</tr>
<tr>
<td>Back (rolls of fat)</td>
<td>+ thick skin insufficient secondary skin contraction</td>
<td>+++ if moderate amounts of fat deposits. Associate with liposuction if there is large amounts of fat deposits and lax skin</td>
</tr>
<tr>
<td>Neck</td>
<td>+ to +++ depending on skin elasticity, result generally unpredictable</td>
<td>++ to +++ improve significantly skin contraction</td>
</tr>
</tbody>
</table>

+: Partially effective; ++: Effective; +++: Very effective.
Extremity liposuction has now advanced to providing a curvier lower extremity with techniques of circumferential and superficial liposuction. The most frequent complication is persistent ankle thickness in 10% of patients, partly due to edema and under-resection of the ankles. Contour deformities can occur, as in other areas of liposuction, with an increased propensity for edema (Figure 2).

**Inner thighs & arms**

Overlying skin should have sufficient elasticity so that it will contract. In the early days of liposuction, being older than 40 years was a contraindication for liposuction because of the assumption of poor skin elasticity. Time and experience have shown that this absolute is not reasonable, and each patient must be judged individually. Nevertheless, when preliposuction examination reveals poor skin elasticity, stretch marks and extreme laxity, the surgeon should reconsider, unless the location is amenable to skin resection. In some locations (abdomen, upper inner thigh and arm [Figure 2]), excess-skin-removing surgeries are possible. These must be discussed thoroughly with patients, and they must be made aware of additional scarring and associated risks. Unfavorable esthetic results can be seen: the patient may experience asymmetry, divots and dimpling, lumpiness and waviness, and skin laxity.

In the medial thigh, where skin is fairly thin and the subcutaneous fatty layer modest, conservatism is the key. More aggressive liposuctioning can easily result in excessive skin laxity, an appearance of skeletonization and concavity, as well as skin discoloration. The desired result is a smooth line from the upper border of the inner-knee to the groin, with slight concavity above the knee, transitioning to slightly greater fullness of the upper inner-thigh but without a bulging roll in the final 6–8 cm before the groin crease. With the heels together, the upper inner thighs should either barely graze each other or have a slight separation.

**Summary**

Liposuction is an extremely effective surgical tool that affords excellent results. Patients still can gain weight after undergoing liposuction, but their shape remains more balanced than before the procedure. In most published studies on liposuction, approximately 10% of patients require a minor touch-up within a few months of surgery. In appropriately selected patients, liposuction performed by skilled surgeons yields patient satisfaction rates of greater than 90%. Its simplicity, quality of results and relatively rare complication rates explain its success and its use as a tool in combination with other surgical techniques (e.g., abdominoplasty and body lift). Its main limitation is the limited amount of skin retraction after the procedure. To improve skin reshaping, new refinements have been developed (e.g., superficial liposuction and ultrasound liposuction), but poor preoperative skin quality will inevitably lead to insufficient and disappointing results.

Liposuction does not improve skin elasticity, which may explain why new laser lipolysis techniques, whose thermal effect assists in skin retraction, are increasingly looked upon as an interesting alternative (Table 1).

**Laser lipolysis**

Apfelberg is credited for describing the laser–fat interaction in 1992 [7]. Blugerman’s [8], Schavelzon’s [9] and Goldman’s [10] works followed, where each demonstrated their own experience with lasers on adipose tissue. Badin et al. reported its utility in the upper abdomen and periumbilical region [11]. Initially, the neodymium-doped yttrium aluminium garnet (Nd:YAG) laser was proposed owing to the deep penetration of its 1064-nm wavelength. Although this laser is still used, diode lasers, typically emitting at 810, 940 and 980 nm, are also proposed as an alternative. While in the same spectral region, their wavelengths offer the inherent benefits of diode technology, namely greater efficiency (usually 30%) and high-power outputs (≥25 W). More recently, the use of 1320-, 1440- and 2100-nm wavelengths have also been proposed [12–14]. These longer wavelengths may provide more aggressive heating due to a higher absorption by fat and water. However, their high absorption restricts their use for volumetric fat heating, and they are increasingly touted for skin contraction alone. However, their high absorption in water makes the rise in skin temperature difficult to control and increases the potential for burns. Therefore, the benefits of these new wavelengths remain to be demonstrated.

Figure 2. Areas treated with liposuction.
**Principle**

Laser–tissue interaction is achieved through absorption of laser energy by receptive chromophores (blood, fat and water), producing sufficient heat to cause the desired thermal effect. Heat acts on fatty cells and on the extracellular matrix to produce both reversible and irreversible cellular damage. At low energy settings, reversible damage is confirmed by the tumefaction of adipocytes. An increase in their diameter of up to 100 µm is usually observed. The heat generated by the laser alters the balance of sodium and potassium of the cellular membrane, allowing the free transport of extracellular liquid to the intracellular atmosphere [15]. At higher energy settings, rupture of adipocytes and coagulation of collagen fiber and small vessels have been observed. This was demonstrated in a recent paper [16]. Biopsies show coagulation of small vessels in the fatty tissue, rupture of adipocytes, appearance of small channels produced by laser action, reorganization of the reticular dermis and coagulation of collagen in the fat tissue [17, 18]. This observation was confirmed by scanning electron microscopy in adipose tissues after laser lipolysis. Hollows of approximately 300 µm, equal to the diameter of the fiber and heat-coagulated collagen fibers, were seen in a low-power field. Degenerated cell membrane and dispersed lipids were apparent. Heat-coagulated collagen fibers were observed. In the absence of laser exposure, cavities created by cannulation were seen but adipocytes were round in appearance and not deflated [19].

The rupture of the membrane liberates lipases from the adipocyte that are responsible for tissue liquefaction, further facilitating the subsequent aspiration. The liquefactive effect of the laser loosens the fat without the abrupt and repetitive back-and-forth motion of the cannula, as performed in traditional liposuction. The heat induced also coagulates small vessels in fat tissues, leading to reduced trauma and bleeding. Liposuction removes significant amounts of fat, serum and blood. Therefore, in cases where large amounts of fatty tissue are to be removed, a physiologically significant loss of blood can provoke metabolic alterations. Laser-assisted liposuction has the benefit of removing larger volumes of fat without hemodynamic repercussions [19]. Moreover, the thermal effect of laser causes skin shrinkage or contraction, since laser lipolysis leads to heating of surrounding tissue. In a recent study, DiBernardo et al. demonstrated superficial subdermal heating (within ~5 mm of the surface)
in abdominal tissue [13]. Direct comparison between tissue temperature and histology illustrated tissue injury at surface temperatures above 47°C, and surface necrosis and blistering at surface temperatures above 58°C.

More importantly, these results suggested an optimal laser energy dose and, correlativelly, an optimal surface temperature range for safe lipolysis. Consequently, if the main objective of laser lipolysis is fat liquefaction, reduced bleeding and tissue tightening are also important. As demonstrated by the numerous wavelengths used for laser lipolysis, it seems that the laser wavelength is not a critical variable but, instead, laser intensity and total laser energy dose are.

Parameters

In 2009, it remains difficult to compare the parameters reported in the literature since, in most of them, the cumulative energy used to treat a given volume is usually not reported. Prado et al. used a 1064-nm Nd:YAG laser and applied 400 J in the submental zone [20]. Key performed a submental laser lipolysis with a 1320-nm laser, using a cumulative energy of 560–1040 J [21]. However, in both clinical studies, the reduction of fat volume remained unknown. Using MRI before laser lipolysis and at 3-month follow-up, Kim and Geronemus determined fat volume reduction in the submentum [22]. In the submental zone, approximately 3000 J was applied to produce a mean volume reduction of 5.2 ± 2.8 cm³. Similarly, in a recent paper, Mordon et al. also quantified the fat volume reduction in the submental zone using 3D photography. They found a similar reduction: 10 ± 1 cm³ for a total energy of 6600 J [23]. In a recent study, Reynaud et al. reported that the total energy depended on the location of the treated area. It varied from 8100 J in knees to a maximum of 24600 J in abdomens. The highest cumulative energy reported in this clinical study was 51000 J in abdomens (Figure 3) [24]. When compared to previously published studies, the cumulative energy reported in this last study is much higher. However, as suspected by Kim and Geronemus, it is evident that subjects treated in early studies were actually undertreated with insufficient total cumulative energy delivered at the treatment site. This is probably attributable to the initial learning curve of this novel procedure [22].

Since total irradiation varies with treatment regions, the average energy density (J/cm²) is also used. Sun et al. used 51.3 J/cm² in the face and mental area, 92.6 J/cm² in the neck, 37.7 J/cm² in the upper arm and 28.1 J/cm² in the abdomen [25]. Similarly, Di Bernardo et al. observed that energies greater than 67 J/cm² mediated coagulation of blood vessels during laser lipolysis. However, they also stated that for large areas, cumulative energy levels should be limited to a maximum of 133 J/cm² to avoid injuries associated with bulk heating [13].

Technique

All procedures involved in laser liposuction are performed in an outpatient clinic setting. Typically, patients are given pain medication and an anxiolytic pretreatment. After marking the treatment site with a surgical marker, patients are prepped and draped in sterile fashion. First, local anesthesia is performed using the wet infiltration technique, with adrenaline 1:500,000 in Europe and 1:100,000 in the USA. After infiltration of the tumescent fluid, a small incision of 1–2 mm is made with an 18-gauge needle. A 1-mm microcanulla is then inserted through the incision into the subcutaneous fat (Figure 1). During the laser lipolysis procedure, both patient and staff wear protective eyewear. To achieve optimal lipolysis, enough energy must be cumulatively delivered throughout the different fat layers (superficial, medium and deep) and into the subdermal plane so as to reach the collagenous layer. Further, a homogeneous distribution of light energy is required in order to achieve an optimal temperature tissue elevation in the fat layer. This can only be achieved through optimal positioning and movement of the cannula during the procedure (Figure 4).

The protocol is usually as follows:

• The cannula is inserted in the hypodermis;

• This cannula is moved back and forth in the fat layer at a velocity of approximately 50–100 mm/s in a vertical plane that is parallel to the surface. This back-and-forth motion is repeated ten to 15 times while maintaining the same horizontal plane;

• After the ten to 15 back-and-forth motions have been completed, the cannula is moved horizontally to the adjacent area (by approximately 1° or so) and this area is again treated with another ten to 15 back-and-forth motions. This is repeated until the entire area volume has been treated;

• To provide a homogeneous treatment of the fat layer, the cannula is inserted at a distance of 120 mm from the previous insertion point so that trajectories cross. Steps 2 and 3 are repeated a second time.

During laser lipolysis, one hand is used to move the cannula while the other hand (the ‘thinking’ hand) maintains contact with the treated area. When the cannula is forced through the adipose layer, the tip can meet resistance at the septae. The ‘thinking’ hand is then used to immobilize tissues during the back-and-forth movement of the cannula. This hand is also used to control the temperature...
Laser lipolysis versus traditional liposuction for fat removal

Side effects

Laser lipolysis has proven to be less traumatic than conventional liposuction methods. Primary reasons for this are the small-diameter (1 mm) cannula and the effects of laser–tissue interaction. Other hypotheses have been postulated to explain that the effects are attributed to the reduced pain, the absence of bruising and edema, and faster recovery associated with laser lipoplasty. One such hypothesis is that the laser seals lymphatic and arteriovenous vessels [20].

The absence of bleeding is a very important issue. In a clinical report on submental Nd:YAG laser lipolysis on 82 patients, Goldman published histology evidencing the coagulation of small blood vessels in fatty tissue and the rupture of adipocytes [17]. By liquefying fat, concern arises regarding free circulating lipids. Mordon and coworkers reported no increase in the levels of total cholesterol, HDL cholesterol, LDL cholesterol and triglycerides at different intervals after the procedure (1, 7, 14 and 30 days) [26]. Goldman et al. also found no significant change in triglycerides and lipid profiles at 1 day, 1 week and 1 month after the procedure [27]. These two studies confirm that the absence of fat aspiration during laser lipolysis does not lead to higher concentrations of free fatty acids. Consequently, there are no potential risks of possible hepatic and renal toxicity, as speculated by Prado et al. [20].

Katz reviewed 537 cases retrospectively to determine the number of adverse events associated with the laser lipolysis procedure [28]. No systemic complications were identified, and only five local...

---

elevation of the skin. Optimal dosage is reached when the skin feels warm to the touch. This superficial skin heating is clearly felt when the temperature reaches 40°C.

After lipolysis, liquefied fat can either be aspirated with a small diameter cannula or massaged out. Aspiration is usually performed in large treated volumes and in locations that are easily accessible. Massage is performed in small volumes and in areas that are not easily accessible (e.g., knees or arms). It is at this point that clinical results can be gauged by analyzing the immediate body or facial contour improvement. Micropore™ or Tensoplast™ adhesives are affixed to the skin to better compress and remodel certain areas, such as the banana fold, the external thigh and the infralateral part of the buttocks. The tape remains in place for 1 week, and compression garments should be used for 1 month. There are no restrictions to activity, except sun exposure, which should be avoided for 1 month. Finally, the total energy delivered during the laser lipolysis procedure is recorded. After the procedure, an antibiotic is usually prescribed. Patients are required not to resume physical activities (especially those involving mechanical shocks) for a minimum of 8 days. Physiotherapy sessions are sometimes prescribed (mainly when no aspiration is performed) to assist with eliminating the fat. These sessions typically begin a few days after the procedure.

The interaction between laser and biological tissue induces a reduction of fat volume as well as a remodeling of the collagenous tissue, with clinically evident skin contraction, as can be observed immediately after the procedure. Ultrasound imaging clearly shows that the thermal effect obtained after laser lipolysis results in melting and rupturing of collagenous and subdermal bands [24]. The wound repair that follows the laser treatment leads to the creation of new collagen and elastin fibers, and leads to subsequent tissue contraction. Histological analysis confirms that collagen denaturation occurring in the deep reticular dermis and the conjunctive septum of the subcutaneous tissue constitutes a pro-inflammatory stimulant, leading to vascular proliferation and collagen neosynthesis [15]. Skin contraction becomes gradually more pronounced, as demonstrated by several clinical studies [11,21,24,25]. Figure 5 shows a good example of skin contraction.

Figure 5. Skin contraction. (A) Before and (B) at 6-month follow-up. 980-nm diode laser; power: 6W; continuous-wave output power (back-and-forth motion): 100 mm/s; total energy: 3500 J.
complications were found: one local infection and four skin burns. This represents a complication rate of 0.93%. Similarly, in a series of 534 procedures, Reynaud did not observe scarring, infection, burn, hypopigmentation, bruising, swelling or edema. Ecchymoses were observed in almost all patients but were resolved in under 1 week. Only ten patients reported ecchymoses lasting 2 weeks and two patients reported ecchymoses lasting 3 weeks [24]. Performed in an outpatient setting, patients undergoing laser lipolysis were able to return to normal daily activities after the first postoperative day. Pain and discomfort were evaluated at 1 week, 1 month and 3 months. At 1 week, 83% reported no pain/discomfort and 17% reported mild pain/discomfort. At 1 month, mild pain/discomfort was reported by 5% of patients. At 3-month follow-up, only three patients reported discomfort due to paresthesia. In all three patients, paresthesias could be explained by microecchymoses resulting from a premature resumption of sporting activities.

**New developments**

The laser fiber should be kept moving whenever the laser is emitting to avoid skin burns from excessive energy accumulation. To overcome this problem, newer lasers integrate a sensing device, adjusting the energy as a function of the cannula speed. For example, Cynosure has developed the SmartSense™ delivery system [29]. This system contains an accelerometer (an advanced microchip) inserted into the intelligent handpiece. The laser power is automatically adjusted by taking into account the setting (high, medium or low) and the motion of the cannula. Similarly, Osyris has developed the LipoControl™ system. This system integrates a magnetic tracking system to determine the position of magnetic sensors in the cannula. Owing to the tracking system, an automatic adjustment of laser power is performed to compensate for cannula movement (Figure 6). Consequently, the laser power varies in step with the speed of the cannula so as to continually deliver the optimal energy [30].

At last, laser lipolysis could be combined with other techniques to treat other disorders of adipose deposition. Goldman also mentioned a new treatment approach combining subdermal Nd:YAG laser lipolysis with autologous fat transplantation in the treatment of cellulite [31].

**Expert commentary**

Laser lipolysis is a new technique still under development. Key benefits of this technique are quicker recovery, reduced operator fatigue and concurrent skin contraction. Laser lipolysis uses the thermal properties of lasers, especially their ability to vaporize and melt irradiated tissues. Adipose tissues are located under the skin and above the deeper tissues, which both include nerves and large vessels. Collateral injury to those tissues must be avoided as much as possible, especially in facial lipolysis.

To achieve satisfactory therapeutic results, laser energy must be optimized in relation to the treatment area, with more cumulative energy being required when treating adiposis containing fibrous or compact tissues.

Laser lipolysis is more suitable for treating small and compact areas. Furthermore, it can also be used to improve localized irregularities following conventional liposuction.

Laser lipolysis offers several key benefits over conventional liposuction. The laser coagulates small vessels, reducing peri-op erating bleeding. Its effect is uniformly distributed, so the skin surface is less uneven after the procedure. The laser stimulates collagen formation, enhancing skin elasticity and promoting skin contraction. The laser also breaks down compact fibrous tissues of localized adiposis, reducing the resistance of the suction cannula, thus making the procedure less strenuous for the operator. Finally, trauma is minimal and recovery is rapid with fewer complications of edema, neural damage and adipose embolism.

In the near future, laser lipolysis performed with energy mapping monitoring and power regulation should allow the safe use of higher power levels, allowing for the treatment of large volume areas as quickly as with traditional liposuction. Since speed is currently the only benefit of traditional liposuction, it may well be superceded by laser lipolysis in the near future.

**Five-year view**

A growing body of experience and evidence indicates that the laser lipolysis technique can expand the base of patients who are candidates for primary liposuction as well as those who desire secondary procedures.

In the coming years, refinements to this new laser technique will follow conventional marketing strategies; laser companies will propose:

- An increase in maximum laser output power; however, the use of higher power levels invariably involves higher risks;
- Using lasers emitting other wavelengths. However, wavelengths in the near-infrared range (920–1320 nm) have already been shown to achieve similar efficacy levels. Consequently, thermal elevation achieved with the various systems and the differences in terms of results are more likely to be dependent on operator movement or the amount of cumulated energy used.

In fact, the main challenge will be to reduce side effects due, in all likelihood, to an overaccumulation of energy in a given part of the treated area; if too much energy is deposited in one place, the temperature increases too much and induces ecchymoses or small burns. This accumulation of energy (quantity and distribution) is exclusively dependent on the physician’s movement; if the physician moves too slowly or if the physician delivers the laser energy to a previously treated location, the accumulated energy will be above the thermal damage threshold. More research should be undertaken to develop new types of monitoring and feedback technology aimed to optimize treatment safety and efficacy. These new systems would focus on correlating total energy applied with fat volume reduction, and determining the optimal fluence required to achieve effective subcutaneous fat lipolysis with concurrent focal dermal coagulation with minimal epidermal destruction.

**Acknowledgements**

The authors wish to thank Pascal Servell for the careful review of the English language used in this manuscript.
Laser lipolysis versus traditional liposuction for fat removal

Key issues

- Liposuction is an extremely effective surgical tool that affords excellent results. Its simplicity, quality of results and its relatively rare complication rates explain its success.
- The main limitation of liposuction is the quasi-absence of skin retraction after the procedure.
- Laser lipolysis uses the thermal properties of lasers. Lasers can vaporize and melt irradiated tissues. It coagulates small vessels, reducing the incidence of bleeding during surgery.
- Laser lipolysis stimulates collagen formation, enhancing skin elasticity and promoting skin contraction.
- Laser lipolysis is more suitable for treating small and compact areas. Furthermore, it can also be used to improve local irregularities after conventional liposuction.
- Laser lipolysis is a new technique still under development. More research should be undertaken to develop new types of monitoring and feedback technology required to optimize treatment safety and efficacy.

Financial & competing interests disclosure

The authors have no relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript. This includes employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties.

No writing assistance was utilized in the production of this manuscript.

References


**Affiliations**

- Serge Mordon, PhD
  INSERM-U703, Université Lille Nord de France, Lille University Hospital, 152, Rue du Dr Yersin, 59120 Loos, France
  Tel.: +33 320 446 708
  Fax: +33 320 446 708
  serge.mordon@inserm.fr

- Eric Plot, MD
  Plastic Surgeon, 23, Rue de Saint Petersbourg, 75008 Paris, France