47 Low-Level Laser-Assisted Liposuction

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47.1 Introduction

It is human nature to strive for and look for the best method to obtain an ideal and a human's well-being. In this anxious seeking to find answers to many questions for what is the best for our patients, the author, in collaboration with a multidisciplinary group, has attempted to gain knowledge and research the equipment to elucidate the interaction between low-level laser energy and adipose tissue. All the answers have not been resolved but in the near future and with the collaboration of others, liposuction techniques will be developed that have less risk to the patient.

47.2 History

The author began using low-level laser-assisted liposuction (LAL), large and small volumes, to liquefy the fat and reduce inflammation and pain as well as to have a better and faster recovery of the patients. Low-level laser energy has been used increasingly in the treatment of a broad range of conditions and has improved wound healing, reduced edema, and relieved pain of various etiologies. The laser used for liposuction is an external-beam cold laser, electric diode, with 635-nm wavelength that irradiates adipose tissue at 1.2, 2.4, and 3.6 J/cm^2 [1–5] at 2, 4, and 6-min exposure in each area.

Samples were taken from abdominoplasty tissues treated with a laser and studied by light microscopy, magnetic resonance imaging [6], scanning electron microscopy (SEM), transmission electron microscopy (TEM) [7], physics quantum optics studies, and human cell culture studies [7, 8]. Different biophysical effects were noted in the laser effects on the adipose tissue. After using SEM and TEM, the fat could be seen coming from the inside to outside of the cell [4, 5]. The same effect was noted on treating human cultured cells with a laser. The pores in the adipocyte membrane were noted and an interesting phenomenon with the laser light was seen [7, 8]. It was concluded that the laser light did not destroy the adipocyte but just permitted the mobilization of the fat, keeping the cell membrane in very good condition [7]. This same number of cells could be cultured in vitro. The penetration of laser light, the different effects such as scattering, diffraction, and penetration, and conjugate effects were studied [1–3].

The use of low-level LAL was then tried with the traditional techniques [9]. All of the procedures were performed under local anesthesia assisted by the anesthesiologist [10, 11].

47.3 Laser Energy

Many studies have been conducted on the most efficient use of and the most effective application of laser energy, the results of which were dependent on three factors:

1. Coherent light verses non-coherent light
2. Power
3. Wavelength [4]

47.3.1 Coherent Light

Frohlich [12], in 1968, predicted on the basis of quantum physics that the living matrix (i.e., the sets of protein dipoles) must produce coherent or laserlike oscillations if energy is supplied. The coherent radiation field of a laser and the biochemical energy form the surrounding which provides that energy. Frohlich deduced the existence of an acousto-conformational transition, or coherent photons [13, 14], giving a Bose–Einstein condensate [15].

47.3.2 Optimum Wavelength

Research supports 630–640 nm as the optimum wavelength [16]. Such coherent vibrations recognize no boundaries at the surface of a cell or organism and

they are a collection of cooperative properties of the entire being. As such, they are likely to serve as signals that integrate processes such as growth, repair, defense, and the functioning of the organism as a whole. Research on electrically polarized molecular arrays of biological systems reveals that interactions repeated by the millions of molecules within a cell membrane give rise to huge coherent or Frohlich-like vibrations [16–22]. This singular response shows that the components of a living matrix behave like a coherent molecule radiating and receiving signals. In this way, coherent Frohlich excitations in cytoskeletal microtubules have been suggested to mediate information processing [15–17, 21–23].

Similar mechanisms could be evoked to explain low-level laser therapy (LLLT) effects. Nevertheless, the successful use of LEDs in LLLT in the last few years proves apparently that coherence is not an essential light property for the clinical effects of laser therapy [24–26]. It seems to be more important for light propagation and diffusion, producing speckle patterns from inhomogeneous tissues which leads to local heating [27].

47.3.3 Optimum Power

The photochemical energy conversion implies generally the light absorption by special molecular light acceptors. But also the light absorption by non-specialized molecules plays a significant role in medical applications, because of the capacity of molecules to absorb light at certain energies and the possibility of energy transfer between molecules. An activated molecule can cause biochemical reactions in the surrounding tissue. Karu [27–29] established the most essential mechanisms of light–tissue interaction. She noted that, "The photo acceptors take part in a metabolic reaction in a cell that is not connected with a light response. After absorbing the light of the wavelength used for irradiation this molecule assumes an electronically excited state from which primary molecular processes can lead to a measurable biological effect in certain circumstances." Karu analyzed and discussed the most important findings concerning LLLT. In explaining the experimental results, she concluded "that one key event among the secondary reactions of cellular responses was the change in overall redox state of the irradiated cell," so "that the cellular response is weak or absent when the overall redox potential of a cell is optimal or near optimal for the particular growth conditions, and stronger when the redox potential of the target cell is initially shifted to a more reduced state." [25, 27, 30–35].

The author studied adipose tissue samples according to the literature [36–41]. The tissue samples were irradiated for 0, 2, 4, and 6 min with and without tumescent solution, and were studied using TEM and SEM (Fig. 47.1). Non-irradiated tissue samples were taken as references. An excess of 180 images were recorded and professionally evaluated.

SEM and TEM show that without laser exposure the normal adipose tissue appears as a grape-shaped node. After 4 min of laser exposure, 80% of the fat is released from the adipose cells, and at 6 min of laser exposure, almost all of the fat is released from the adipocyte [5]. The released fat is collected in the interstitial space. TEM images of the adipose tissue taken at ×60,000 magnification show a transitory pore and complete deflation of the adipocytes [4].

Low-level laser energy has an impact on the adipose cell consisting in opening a transitory pore in the cell membrane, which permits the fat content to go from inside to outside the cell. The cell's interstice and capillaries remain intact. After 4-min exposure, partial disruption of the adipose cell was observed, but in vitro human adipocyte culture was performed and showed that the adipose cells opened a transitory pore after they have been irradiated, and also that the cell membrane was deformed and lost its fat content [5].

The irradiated cells were recultured and showed that they recovered the normal anatomy and were alive. After this, samples were taken of adipose tissue from lipectomy and were irradiated for 0, 2, 4, and 6 min and were then submitted to visible-light microscopy. Although the initial results of the optical studies were inconclusive owing to the initial sample testing procedures, the clinical team decided to continue the case study because the preliminary clinical evidence obtained was clearly impressive.

Both SEM and TEM were performed on superficial and deep fat samples to establish cellular effects correlated to the penetration depth of the laser beam after application of the tumescent technique. Samples without tumescent technique and exposure to a laser for 0, 4, and 6 min were also taken. The results indicated that the tumescent technique facilitates laser beam penetration and intensity; fat liquefaction is thus improved.

Fat samples were processed as follows and sent to be analyzed by SEM and TEM. The adipose cell membrane was also studied in detail with TEM in order to study the transitory pore.

Twelve healthy women who had undergone lipectomy were selected for random fat sampling. The abdominal fat was analyzed after 0, 2, 4, and 6 min of external laser exposure. Patient follow-up was 24 h after surgery and up to 12 months after the procedure.

The tumescent technique was applied followed by external laser therapy using a low-level-energy diode laser, with a nominal wavelength of 635 nm, and a

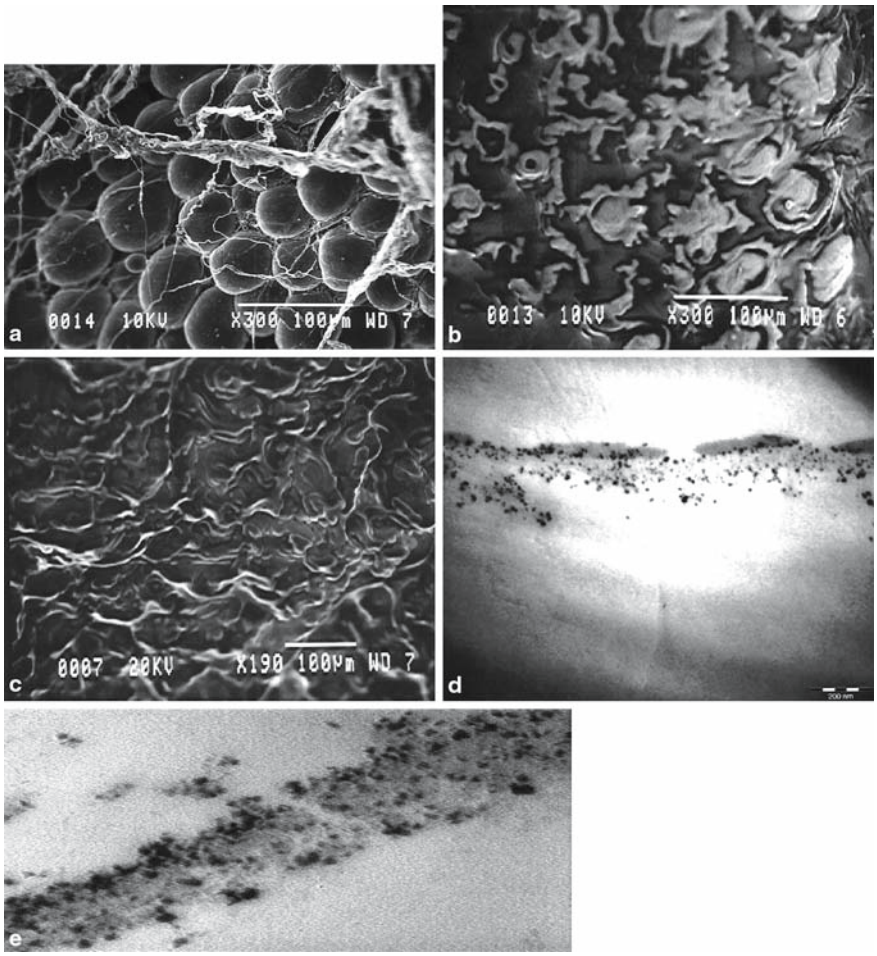

Fig. 47.1. **a** Round adipose cells with the surrounding connective tissue. **b** Scanning electron microscope image at 4-min of laser exposure. It can be seen that 80% of the fat is coming out from the adipose cell through the disrupted membrane; there are fat particles inside and outside the cells **c** Scanning electron microscopy findings at 6 min of laser exposure. The fat is almost completely (100%) liquefied outside the cell. Adipose tissue has externalized the fat from the cell with 6-min exposure. Fat cells and cell membrane appear intertwined and their distribution is irregular. **d** Transmission electron microscopy findings after 6 min of laser exposure, ×60,000. There is a disrupted site of the cell membrane. **e** Pore visualization. The adipocyte cell has a diameter of 100,000 nm and the pore size is 40 nm

maximal power of 14 mW. The laser had a diffractive optical system with a line generator, and allowed four power settings. The line generator produced a 60° fan angle, with a maximum width of 3 mm. The length of the line generated is factored at an average of 23.7 mm/in. of the line generated for each 25 cm of distance from the patient.

As the dose is the magnitude generally used to define the laser beam energy applied to the tissue, it is useful to reduce the aforementioned total applied energies to these normal units, which are given in joules per square centimeter. In this case, dose is calculated as the laser power measured in watts, multiplied by treatment time in seconds and divided by area in square centimeters of the laser spot directed toward the tissue. Considering the properties of the laser output optics , and a normal laser-to-target distance of 6 in., the aforementioned energies correspond to doses of a 1.2 , 2.4, and 3.6 J/cm^2.

Superficial and deep fat samples of laser-treated tissue were taken from the infraumbilical area in all patients studied. Biopsies were taken with a scalpel from extracted abdominoplasty tissue and then introduced into a 0.1 ml glutaraldehyde phosphate 2.5% buffer at pH 7.2 and 4°C. Furthermore, fat samples extracted without the tumescent technique were also taken and irradiated following the aforementioned sequential procedure.

These samples were then submitted to SEM and TEM to study the laser beam effects on fat cells. Regarding the changes in the adipose tissue, there were no major observable differences between samples exposed to 2 and 4 min of laser radiation. The samples were to be standardized to those taken for 4- and 6-min exposure time, where cell effect differences could be observed under SEM (Fig. 47.1a–c) and TEM (Fig. 47.1d)

The SEM and TEM findings, after 6-min laser exposure, in samples taken without the use of tumescent solution, correspond to those observed in samples exposed to 4-min laser irradiation of equal intensity (10 mW) combined with the use of a tumescent solution. Laser penetration through adipose tissue decreased when the tumescent solution was not utilized,

suggesting that the application of the tumescent solution is an important enhancement factor.

Special effort was used in studying the membrane in order to clarify the suspected pore in the membrane. Figure 47.1e shows a ×40,000 magnification photomicrograph of the adipose membrane taken of a non-irradiated sample. The membrane remains intact when the laser is not applied. Figure 47.1d shows a cell membrane at ×60,000 magnification, taken of a tissue sample with 6 min of laser exposure. It is possible to see that after irradiation the membrane is temporarily disrupted, creating a transitory pore (Fig. 47.1d), which allows the fat to come out of the cell and be released into the interstitial space.

In summary, without laser exposure the adipose tissue remains intact and adipocytes maintain their round shape (grapelike shape) as shown in Fig. 47.1a. After 4-min laser exposure, the membrane of the adipocyte is partially disrupted, and 80% of the fat outside the cell. Fat particles build up, forming a "cell helmet." Adipocytes suffer partial disruption of their membrane, exposing fat bodies outside the cell (Fig. 47.1b). At 6-min laser exposure, SEM shows almost total disruption of the adipose cell membrane and evacuation of fat (Fig. 47.1c). Over 180 photomicrographs were recorded in order to study and to demonstrate the resulting technique described herein. SEM and TEM verified the suspected lipolysis.

To our knowledge, to date, the use of low-level laser energy to open a transitory pore in the adipose cell membrane has not been reported [35]. Therefore, the technique described in the following is a new application in the field of plastic surgery and this chapter provides the scientific support for it. We also demonstrated the effect of the laser beam on the adipose cell through in vitro human adipose culture.

47.4 Discussion

Liposuction techniques and coadjuvants have been used for many years. However, each time a new method or procedure appears, there are expectations about its potential benefits. The scientific evidence provided in this chapter suggests that the LAL technique will serve as a valuable contribution to this specific field of medicine and generate the same expectations as other techniques previously described by other authors. Among its benefits are the reduced risk and improved quality of life for patients.

Random samples taken from 12 patients and submitted to SEM and TEM studies demonstrated that the application of the tumescent technique is an important coadjuvant to laser beam application because it facilitates beam penetration, and as a result, fat extraction.

Certain findings were consistently observed with use of the laser (Fig. 47.1). The SEM and TEM results indicate that the results from 6-min exposure to the laser beam with application of the LAL technique and without the tumescent technique were comparable to the recorded result from 4-min exposure to the laser beam combined with the application of the LAL technique and the tumescent technique. The tumescent technique therefore empowers the laser beam to impact the cell. Transitory pores were also observed in the cell membrane with the subsequent spillage of fat into the interstitial space.

In samples from the tumescent technique, and without laser exposure, SEM shows that the adipocyte retained its original shape in this three-dimensional picture. Several collagen fibers can be observed in the interstice. At 4-min laser exposure, without tumescent technique, liquefaction of only a few adipocytes occurred. At 6-min laser exposure, without tumescent technique, SEM showed liquefaction of a higher number of adipocytes but not all.

When the traditional tumescent technique was combined with 4-min laser exposure, SEM showed partial disruption of the adipocyte membrane with 80% of the fat extruded from the cell (Fig. 47.1b). By increasing the laser exposure to 6 min, SEM showed almost total disruption of the adipocyte membrane, which is empty and flexed with irregular contours (Fig. 47.1c).

Samples obtained from the traditional tumescent technique without laser exposure showed with TEM adipocytes completely saturated with homogeneous fat. When the LLLT was applied with 4-min laser exposure, TEM showed partial loss of intracellular fat and increased intercellular space with loss of the round cell shape (Fig. 47.1b). Capillaries remain completely intact after 4- and 6-min laser exposure.

When the LAL technique was applied with 6-min laser exposure, TEM shows almost total disruption of the regular contours of the adipocyte, intracellular fat is completely removed from the cell, and, therefore, the adipocyte is deformed and does not preserve its original shape (folding, and disruption of the adipocyte membrane) (Fig. 47.1c).

An explanation of the study findings, regarding the biological performance in the adipose tissue, is that the interaction between the laser light and the tumescent solution creates new environmental and different properties in these tissues, and experimental studies show a 0.3–2.1% transmittance of red laser light in 2-cm-thick normal skin, depending on the laser wavelength [36]. Further, it was found that the transmittance of granular tissue is 2.5 times higher than that of the normal skin. Moreover, in the search for a method to increase light transport well into target areas of tissue, the effects of a hyperosmotic agent

on the scattering properties of rat and hamster skin were investigated and a transient change in the optical properties of in vitro rat skin was found [37]. A 50% increase in transmittance and a decrease in diffusive reflection occurred within 5–10 min of introducing glycerol [23]. In our case, it is known that fat contains glycerol; therefore, laser transmittance through the adipocyte could be very effective. In addition, the tumescent solution has two action mechanisms:

1. It is a polar solution that destabilizes the adipocyte membrane, thus facilitating the penetration of the laser beam. This was demonstrated by the findings in samples subjected to SEM and TEM.
2. The aqueous portion also serves as a coadjuvant to laser action . These effects are coadjuvants to the laser action, making the low-level-energy laser a powerful tool in liposuction procedures.

The adipocyte membrane is activated by different cyclic AMP concentrations, which stimulates, in turn, cytoplasmic lipase that triggers the conversion of triglycerides into fatty acids and glycerol, both elements that can easily pass through the cell membrane. The adrenaline, also found in the tumescent solution, stimulates adenylcyclase, which, together with the effect of the laser beam on the internal and external media of the adipocyte, changes its molecular polarization. The exit and removal of fatty acids and glycerol into the extracellular space enhance this effect.

The effectiveness of low-power laser light to produce changes in biological tissues and laser action on cells, even by low doses, was recently reported by different authors [38–40]. Reproducible light-induced changes in the transmission spectrum of human venous blood under the action of low-intensity radiation from a He–Ne laser was found, showing not only that laser light induces the changes, but the possibility of their spectrometric studies [38]. Besides these, the influence of low-level laser irradiation on the mast cell degranulation process was investigated on mesentery mast cells of the rat intestine and showed that laser radiation (890 nm in this case) stimulates mesentery mast cell degranulation [39]. This study also shows that the effect is dose-dependent, and maximal degranulation was registered after laser irradiation with power of 25 mW, and an exposure time of 15–30 s.

Confocal microscopy has been used for irradiation and simultaneous observation of low-power laser effects in subcellular components and functions, at the single-cell level [39, 40]. Cultures of human fetal foreskin fibroblasts (HFFF2) were prepared for in vivo microscopic evaluation. Cells were stimulated by the 647-nm line of the Ar–Kr laser of the confocal microscope (0.1 mW/cm^2). Laser irradiation caused alkalization of the cytosolic pH and an increase of the mitochondrial membrane potential. Temporary global Ca^{2+} responses were also observed. The effects were localized to the irradiated microscopic fields, and no toxic effects were observed during experimentation [27].

Low-level laser-assisted lipoplasty consists of the tumescent liposuction technique with the external application of a cold laser (635 nm and 10 mW in intensity, for a 6-min period). This technique produces a transitory pore in the adipocyte membrane, preserving the interstice, particularly the capillaries. When adipose tissue is exposed to the laser beam for 4 min, 80% of the adipocyte membrane is disrupted and this increased to almost 99% with 6-min laser exposure as demonstrated by SEM and TEM.

The laser facilitates the release of fat and contributes to the disruption of the fat panicles, allowing the fat to go from inside to outside the cell, placing it in the interstitial space. With easier fat extraction, surgical trauma is reduced as well as ecchymoses and hematomas and patient recovery is facilitated.

The transitory pore formation induced by the laser occurs exclusively at the level of the adipocyte membrane. When tumescent solution was used as a coadjuvant, almost 99% of the fat was released into the interstices, while capillaries and the remaining interstices were preserved. The result of this development is a safer, more effective procedure as the need for pretunneling has been eliminated [14, 15, 35].

47.5 Low-Level Laser-Assisted Liposuction Procedure

1. The completely naked patient is washed with Isodine in the standing-up position. The Isodine is also sprayed on the body, including hands and feet.
2. Two blankets of sterilized rubber are placed on the operating table, one on top of the other. These blankets are covered with sterilized fields. The patient is instructed to lie down on the operating table.
3. Local sedation [fentanyl and Dormicum (midazolam) and propofol] is used intravenously.
4. Tumefaction is performed in the different target areas, 2-mm incisions are made with a no. 11 scalpel, and cannulas for infiltration are introduced.
5. The greater the hydration of the tissue, the deeper the transmission of the laser beam. When the tissue is not well hydrated, the beam does not reach the desired depth and the results are not as good.
6. Almost simultaneously with the initiation of infiltration, the assistant begins to continuously apply the laser at 10 mW at a focal distance of 30 cm to obtain two lines of light of 20 cm until 3.6 J/cm^2 is reached.

7. Laser radiation is then applied to the different areas to extract fat, beginning with the left or right hemi-abdomen, for approximately 12 min. The infiltration may last approximately 30–40 min, time during which the assistant simultaneously lasers all tissues being infiltrated. This saves time because the surgeon begins infiltration at the same time as the assistant begins to apply the laser. After the infiltration has been completed, it takes approximately 10–12 min more to finish lasering the tissue in the target areas.
8. Maximum tumescence is sought in all tissues. Excellent tumescence is believed to contribute to the successful use of the laser. Laser penetration and effectiveness was less than expected in those cases where tumescence was suboptimal.
9. Fat is then extracted with 3- ,4-, 5-, and 6-mm Becker or Mercedes-type cannulas.
10. The back also requires the ultrawet technique to extract the greatest amount of fat possible. This fat, in particular, is extremely reticular, dense, and hard. Fat extraction is easier when the laser is applied.
11. The author always begins with 3-mm cannulas, for superficial fat, and then 4- and 5-mm cannulas are used until the fat is completely extracted. Good results are obtained only if the ultrawet technique is utilized, especially in the dorsal area.
12. Wounds are not sutured. They are covered with Micropore and the patient is completely wrapped in adult diapers, which are kept in place by the garment.

As soon as the infiltration and laser irradiation are complete tunnels are started in superficial layers without suction. Fat is extracted later with the cannula, 3 or 4 mm, with syringe or regular wall vacuum, without special machines. Deep fat is extracted, touching the deep fascia at all times, feeling the tip of the cannula "kissing" the fascia taking care to not cause any damage. Observations indicate that a smoother and more uniform surface is obtained this way.

Fat is extracted from the superficial layer first, working downward toward to the deep layer, where fat can then be extracted using 2- and 3-mm cannulas, without touching the skin. The assistant can help keep the skin stretched, thus avoiding damage. Because the fat is more liquefied, no nodules or condensed fat remains in the different tissue parts undergoing fat extraction.

During the postoperative period, 3 days after surgery, the laser can also be applied for 3 min at 5 W per area to reduce the duration of inflammation. There is also a gradual reduction of residual adipose tissue. Massage is initiated 4 or 5 days after surgery.

Improved skin retraction is observed within 3 months, and patients have expressed their satisfaction with the results obtained with this procedure.

47.6 Complications

Fluid collection in the sacral area occurs in about 20% of patients without a garment. It should be drained through the same incision with a syringe under local anesthesia.

Pain is seen in almost 20% of patients and is controlled by non-steroidal anti-inflammatory drugs and codeine.

Irregularities occur in the skin in 4% of patients and can be difficult to manage. The author uses massage and an external beam laser for a couple of weeks. Itching of the body is sometimes seen and is treated with antihistamines and olive oil.

Redness after surgery may occur and is treated with a laser for 6 min every day for 1 week (Fig. 47.2). Flap problems are treated with subcutaneous oxygen every day for 3–5 days and 3 min of laser exposure in the area. Edema of the hands and feet 3 or 4 days postoperatively is treated with 20 mg furosemide for 2–3 days. Infection, occurring in 1% of patients, is more frequent in the sacral area. If infection is suspected a hemogram, urinalysis, and hemodynamic evaluation should be performed. If these are positive the wound may still need to be drained and antibiotics, 500 mg ciproxaciline orally, started as soon as possible. There should be careful follow-up and if there is no response within 8 h, vancomycin should be administered.

Serosanguinous liquid that collects in the sacral area is extracted usually 1 week after surgery and one or two times is enough. Since the back is a declivitous

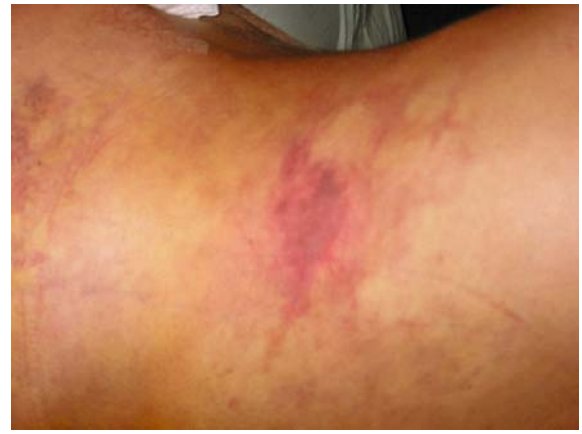

Fig. 47.2. Postoperative erythema

plane that is why the liquid is collected there, and we do not call it seroma, since it does not have a capsule.

Coadjutant techniques for liposculpture, such as external and internal ultrasound, have been innovative and the literature shows good postoperative results [11].

47.7 Conclusions

This innovative technique allows the surgeon to produce an adequate body contour in the medium and long term (Fig. 47.3). The patient is not exposed to skin burns nor risks. The time needed to extract fat is reduced as well as surgical trauma and, as a result, postoperative edema is less. Postoperative pain and medical leave from work are minimal. Ecchymoses are reduced as well as postsurgical fibrosis. The resulting skin surface is even. The results are highly satisfactory for both the patient and the surgeon. The postoperative recovery of patients is fast and it presents intraoperative and postoperative advantages. This technique is simple, easy to apply, and has low cost. There is no risk of burns and skin retraction is adequate. This is a coadjutant tool for the surgeon practicing liposculpture.

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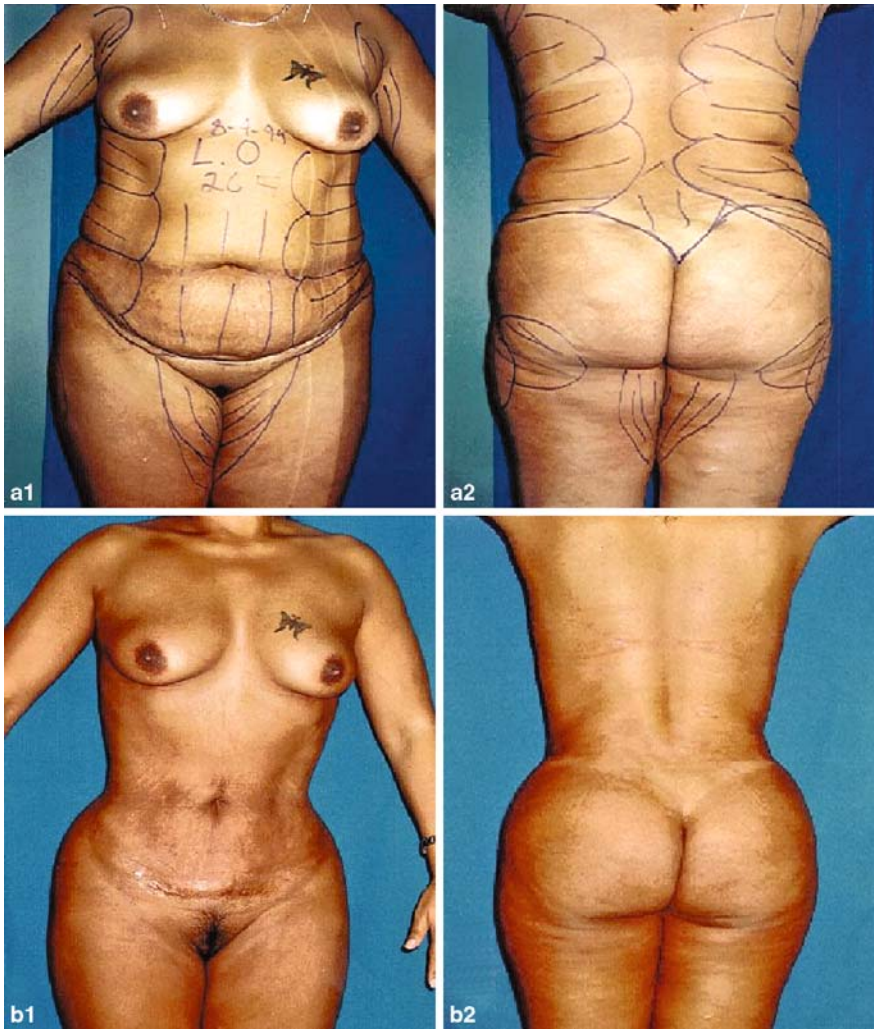

Fig. 47.3. **a** A 26-year-old woman with lipodystrophy. **b** One month postoperatively after laser liposuction with improved contours

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