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Ultrasound-Assisted Liposuction: An Analysis of 348 Cases

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Abstract. The early experiences using ultrasound-assisted liposuction in treating difficult fibrous cases, such as gynecomastia, have led to the evolution and improvement of ultrasound-assisted liposuction techniques. This prospective study examined 348 consecutive patients treated with ultrasound-assisted liposuction over two and a half years, from October of 1998 to July of 2001. We use a three-stage technique consisting of infiltration, ultrasound-assisted sculpturing, and suction-assisted liposuction. This technique has improved our final outcome, with better skin contraction, shorter operative time, and minimization of complications, resulting in the optimization of liposuction as a safe procedure.

Key words: Ultrasound-assisted liposuction—Fibrous liposuction—Gynecomastia—Secondary liposuction

The techniques and the use of traditional liposuction have been advanced by the introduction of thinner cannulas, utilization of subcutaneous infiltration, and superficial and intermediary liposuction techniques. The evolution of liposuction has revolutionized the possible body contour results. Since the beginning in 1976, when Fischer described the first liposuction and through the popularization of this procedure by Illouz, we can follow the birth and the development of this effective technique [4].

We would like to highlight the role of infiltration in the evolution of liposuction both conventional and ultrasound-assisted methods. Early liposuction use (by Fournier in 1983) relied on the dry method without subcutaneous infiltration. In 1980 Yves Gerard Illouz, the pioneer of modern liposuction, introduced the use of blunt-tipped cannulas and a liquid solution with hialuronidase. In 1984 Hetter introduced epinephrine into solutions. The superwet infiltration technique, the use of 1.5 ml of solution for each 1 ml of aspirated fat, has been utilized since 1986 popularized by Fodor. In 1993 Klein discussed the tumescent technique that used massive infiltration of the subcutaneous tissue [3]. The proportion of infiltrated liquids to aspirated liquids has developed as follows: dry liposuction, 0:1; wet, 1:1; superwet, 1.5:1; tumescent >2:1. With these modifications, liposuction has become a safe and effective procedure.

Nevertheless, with traditional liposuction, the treatment of fibrous area (as in the dorsum, gynecomastia, and secondary liposuction cases) may become difficult [7,16]. The use of ultrasound for lipoplasty was first introduced by Kloehn using a solid cannula. In 1995 Zocchi and Maxwell introduced perforated cannulas [25].

With the advent of ultrasound-assisted liposuction, concepts of infiltration have been studied intensely, since infiltration is essential for its success. Ultrasound is the process which turns electric energy into mechanical vibrations that cause thermal effects and micro-mechanical effects (acoustic) or cavitational effects in contracting and expanding circles. This causes microcavities in the fat tissue, which burst, resulting in cell destruction and fat liquefaction [9,10]. The thermal effect in fatty cells spreads to the surrounding tissues which are infiltrated by liquids at ambient temperature. The ultrasound liposuction device transforms electric energy into high-frequency sonic waves and then into mechanical vibrations in a hand piece that contains piezoelectric crystals. These mechanical oscillations pass through a titanium cannula that emits the waves from its tip [22].

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There are three main physiological effects the ultrasound has. The micromechanical effect is the injury produced directly by the unidirectional action of the ultrasonic waves through intracellular, organic molecules. It has minimal effects. The cavitational effects, as previously mentioned, produces important cell fragmentation and diffusion of the lipidic matrix through the intercellular space. The thermal effect is caused by acoustic waves, cannula friction, and the conversion of the ultrasonic waves into heat as they pass tissue. The heat must be dissipated by tissue infiltration [26].

The principal change in second-generation ultrasonic liposuction devices was the introduction of perforated cannulas. Both preforated and solid cannulas used are titanium for more efficient energy transmission. The solid cannulas are more efficient at creating the cavitational effect because they maintain the local liquid environment created by the infiltration, as described by Zocchi [26]. Also, the solid cannulas seem to be less traumatic and more durable than perforated cannulas.

However, the use of solid cannulas requires a separate phase, after the ultrasound phase, to remove all of the waste produced by cavitation, lengthening surgical times [7]. It is difficult for surgeons using solid cannulas to determine the extent of cavitation while they are applying ultrasound because they do not see the amount of waste produced until the second phase—it takes a long time for surgeons to get a feel for this. On the other hand, perforated cannulas are easier to use because the cannula lumen can aspirate the cavitation waste as it is produced, providing intra-surgery feedback about how much the area being treated has been affected by the ultrasound and shortening surgical times [13].

Materials and Methods

A total of 348 patients underwent ultrasound-assisted liposuction from October of 1998 to July of 2001. A Lisonix 2000 was used. Its main parts are a generator, a hand piece, and some ultrasonic liposuction cannulas (Fig. 1). The generator converts standard electric current into a high-frequency, high-voltage signal. This signal is converted into ultrasonic mechanical vibrations. The energy generated in the tip of the cannula then causes adipocytes to rupture by a process called cavitation [2].

Ultrasound-assisted liposuction was used for patients that had localized fat deposits at the dorsum, upper abdomen, lower abdomen, waist, thighs, hips, arms, and gynecomastia, for example [18,19]. The patients were marked, in a standing position, with circles identifying the areas containing concentrations of fat deposits, deformities, and assymetries.

Of the 348 patients, 97% were given peridural anesthesia with sedation and 3% required general anesthesia. Peridural anesthesia was administered between T6 and T12 when the liposuction area included the dorsal region (80%) and between L1 and L4 (20%). The hydration rate was 500 ml per hour and hypervolemic hydration was not necessary [14,15].

The liposuction technique has three steps: infiltration, treatment with ultrasound-assisted liposuction, and evacuation by conventional liposuction.

Step 1

An isotonic saline solution with epinephrine, 1:500,000 was infiltrated in a subcutaneous plane. The wet infiltration method was used—1 ml of infiltrated liquid to 1 ml aspirated. All the volumes were recorded so that the same amount was used in similar areas. We waited 10 min to allow the constrictive effects of the epinephrine to act on the vessels.

Step 2

Stab incisions were made for the ultrasound-assisted liposuction. The incisions must be placed to allow multiple areas to be treated through the same incision while being as inconspicous as possible. After the incisions are made, skin protectors are inserted and wet compresses are placed around the incisions to prevent skin burns (Fig. 2).

A Lisonix 2000 was used with 32-cm-long, 3-mm-wide cannulas. Golf-type tips were used for deep liposuction and Rome or Bullet tips were used for superficial liposuction (Fig. 1B). In the first six months of our practice, we used an amplitude of 5–6. Over time, as we gained experience, the amplitude was increased to 8–9. An increase in the number of complications followed and the amplitude was lowered to 5 [21].

Ultrasound-assisted liposuction removes differently than conventional liposuction. The fat is removed by a process called cavitation, the rupture of the adipocytes followed by lysis and emulsification [24,25]. The emulsified fat is then removed with the cannula. Ultrasonic energy must be applied with the wet infiltration method. Gingrass and Kenkel showed temperature elevations as high as 50 C° in experimental models when subcutaneous tissue infiltration was not utilized [5,17]. It is important to keep the cannula in motion. Extended contact with the cannula tip may cause thermal injury resulting in erythema, followed by blisters, and finally, a full-thickness skin lesion with deformities and scars. The non-dominant hand must continuously palpate the skin in order to feel the tip cannula position. The skin must never be pinched or compressed when the ultrasound is active.

The ultrasound was stopped when there was no tissue resistance to the cannula and the aspirated fluid contained a major concentration of blood [11]. The surgical time and the volume extracted were evaluated.

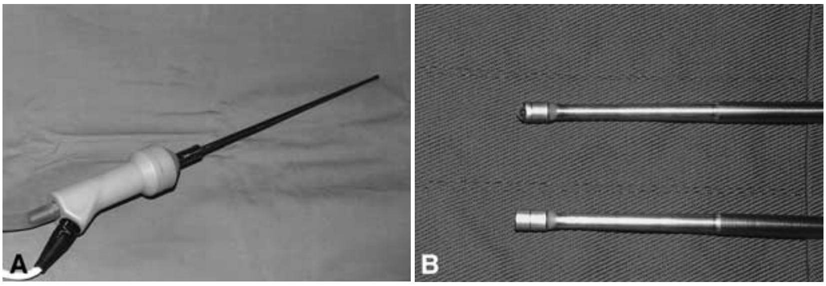

Fig. 1. The hand piece (**A**) and the cannulas (**B**) used in UAL.

Fig. 2. UAL is shown in progress. Note how the compress is used to protect the skin.

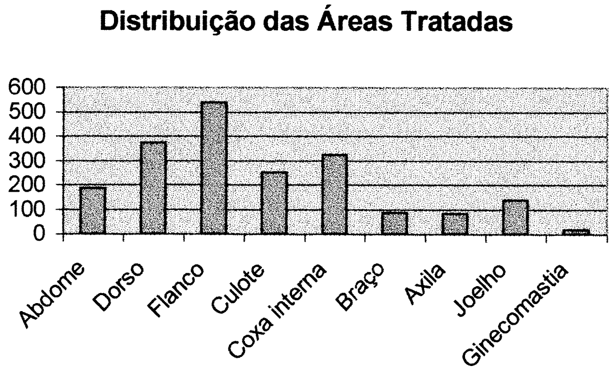

Fig. 3. Distribution of the areas treated.

Step 3

Conventional liposuction was used to extract the remaining content. Cannulas 3–3.5 in diameter were used. The asymmetries, deformities, and bulges were treated at this time. Because the diameter of the ultrasound cannula is relatively small and the emulsification process is very efficient, the emulsification rate will be higher than the evacuation. It is necessary to do the evacuation with thin to medium diameter cannulas. Once the emulsion is created it must be evacuated because the free fatty acids are very irritating and may increase the chance of seroma formation and postoperative inflammation if they are not evacuated [5]. After finishing the conventional liposuction, the ultrasound-assisted liposuction must not be reapplied. After the final contouring and digital skin pinching to evaluate the treated areas, the incisions are closed with absorbable sutures in the dermic plane and non-absorbable sutures in the skin. A dressing of bandages and a cotton compress is used and replaced with compressive garments in 24 hours. During the first week, the patients are restricted by the lymphatic drainage device.

Results

From october 1998 to July 2001, 348 patients (330 female, 18 male) underwent ultrasound liposuction. At first this technique was used only in cases with large volumes of fat, but with the refinement of the technique it was used in all cases to treat lipodystrophy. The infiltrated to aspirated volume in the first three months averaged 6350 ml to 3146 ml, with a ratio of infiltrated to aspirated volume of 2.01 ml to 1 ml. In the next seven months this average became 3009 ml to 2237 ml, that is, 1.35 ml to 1 ml. This average was maintained in the following months. The tumescent infiltration method was used first (2–3 ml infiltrated solution per 1 ml aspirated volume). With refinement of the technique, the wet method was attempted (1 ml infiltrated solution per 1 ml aspirated volume). Differences in blood loss and suction strength were not observed [17]. Postoperative swelling was reduced in the cases in which the wet method was used. The total aspirated volume, including both ultrasound-assisted liposuction and conventional liposuction, varied 440–6500 ml. The average total aspirated volume in ultrasound-assisted liposuction was 1245 ml and the average total aspirated volume in conventional liposuction was 1277 ml.

The supernatant liquid percentage average was 75% for ultrasound-assisted liposuction and 63% for conventional liposuction.

The areas treated by this method were the abdomen (n = 185), back (n = 372), flank (n = 536), outer thigh (n = 250), inner thigh (n = 22), upper arms (n = 86), axilla (n = 82), inner knee (n = 138), and gynecomastia (n = 16)—the number of treated areas includes both sides, with the exception of the abdomen (Fig. 3).

Descriptions of all the areas treated (counting each bilateral procedure as two), including mean time of

Table 1. Relation between the treated areas, mean infiltrated volume (in ml) on each side, mean time of ultrasound liposuction (in min), mean aspirated volume by UAL (in ml), and mean aspirated volume by SAL (in ml)

Areas treated[1]	Avg vol in filtrated (ml)[2]	Avg time UAL (min)[3]	Avg vol aspirated by UAL (ml)	Avg vol aspirated by SAL (ml)
Abdomen (n = 185)	980	15:60	395	353
Dorsum (n = 372)	364	5:75	145	139
Flank (n = 536)	306	5:50	155	175
Outer thigh (n = 250)	390	4:60	183	151
Innerthigh (n = 322)	228	3.50	110	89
Arms (n = 86)	126	2:85	82	63
Gynecomastia (n = 16)	258	3:80	113	98
Inner knee (n = 138)	86	2:25	46	59
Axilla (n = 82)	136	2:40	88	62

[1] n is total number of areas treated counted as two per surgery, except abdomonal surgery.
[2] Average volume per side.
[3] Average time per side.

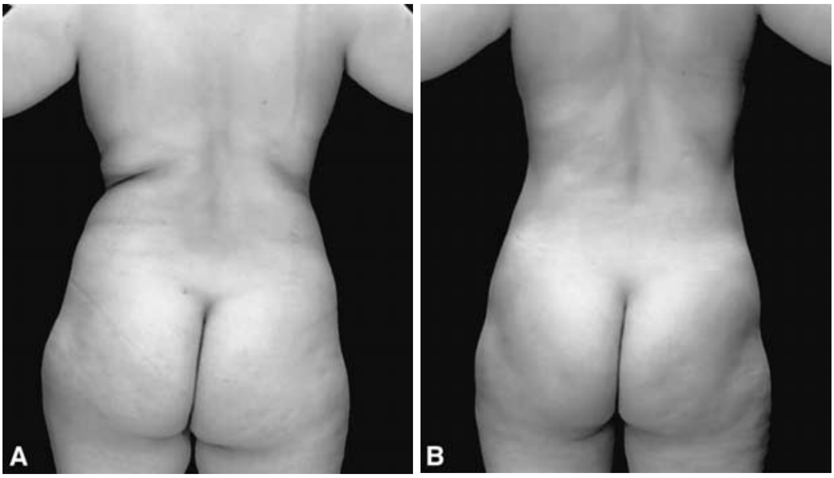

Fig. 4. A 47-year-old patient, who underwent UAL for her dorsum, flanks, inner thighs, and outer thighs, is shown preoperatively (**A**) and 18 months postoperatively (**B**).

ultrasound liposuction and mean volume of infiltrated and aspirated liquids in ultrasound-assisted liposuction and conventional liposuction are listed in Table 1.

At first we used amplitudes of 4–5, which results in lower cannula velocity during the procedure. After a year and based on the papers of Tebbets, we started to use an amplitude of 8 in order to diminish operative time and to allow faster cannula movement during ultrasound liposuction [21].

An increase in the incidence of immediate postoperative pain, swelling, seroma, and fibrosis of the treated areas was observed with the amplitude of 8. After six, months using this amplitude, it was lowered to amplitudes between 5 and 6. Complications were reduced. In all cases, ultrasound-assisted liposuction was followed by conventional liposuction.

A better body contour was noticed after the use of ultrasound-assisted liposuction compared to the isolated use of conventional liposuction. The number of complications was very small, with 12 seroma cases necessitating aspiration with a syringe and just three cases of superficial burns near the incisions (Figs. 4–8).

Discussion

Liposuction is one of the methods utilized most by plastic surgeons.

The advent of ultrasound-assisted liposuction inspired many studies in a short time and today it is used all over the world with safe and predictable results.

We hope our experience and personal approach add more information about the benefits of using this technique.

One of the most important aspects that distinguishes ultrasound-assisted liposuction from other methods of liposuction is the final result on the postoperative hematocrit level. Hetter reports a reduction of the hematocrit for each 150 ml of aspirated fat with conventional liposuction; Lewis reports 1 point/300 ml of aspirated fat with syringe; Klein/Hunstad reports 1 point/600 ml by liposuction with infiltration; Zocchi reports 1 point/1400 ml of aspirated fat by ultrasound-assisted liposuction [26].

With ultrasound-assisted liposuction there is better vessel preservation and consequently, less hematocrit

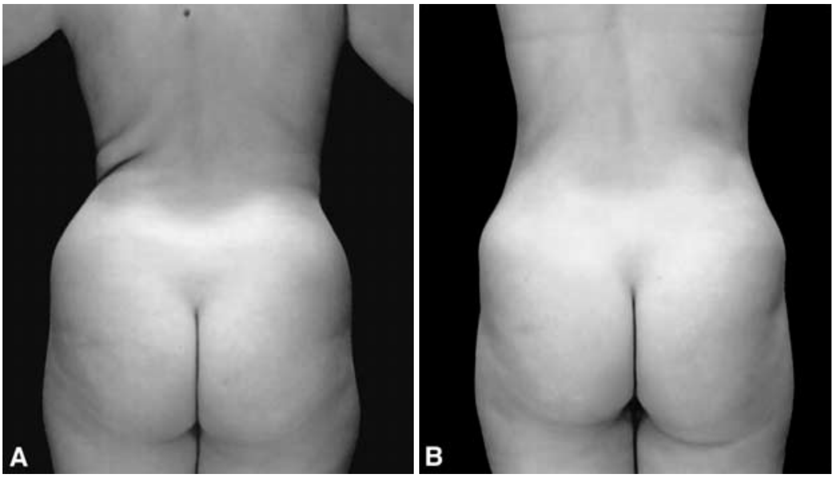

Fig. 5. A 52-year-old patient, who underwent UAL for her outer thighs, dorsum, and flanks, is shown preoperatively (**A**) and 2.5 years postoperatively (**B**).

Fig. 6. A 26-year-old patient who underwent UAL for her dorsum, flanks, inner thighs, and abdomen is shown preoperatively (**A**, **B**) and 18 months postoperatively (**C**, **D**).

decrease. Another positive aspect of this technique is the possibility of greater skin retraction in the treated areas, as the increased local temperature stimulates colagen contraction. Zocchi reports that superficial ultrasound-assisted liposuction has 40% more skin retraction than other methods.

Restrictive factor that may discourage the use of ultrasound are the thermal effects on the skin, vessels, and nerves. In 1999 IIoward and Rohrich studied the ultrasound effects on the sciatic nerve in experimental animals, up to the maximum amplitude [8]. At all amplitude levels there was no functional compromise in the treated areas. However, more complications were observed when the amplitude used was between 8 and 9, as described previously.

In 1999 Trott studied sensory changes and observed that there is transitory numbness for longer in

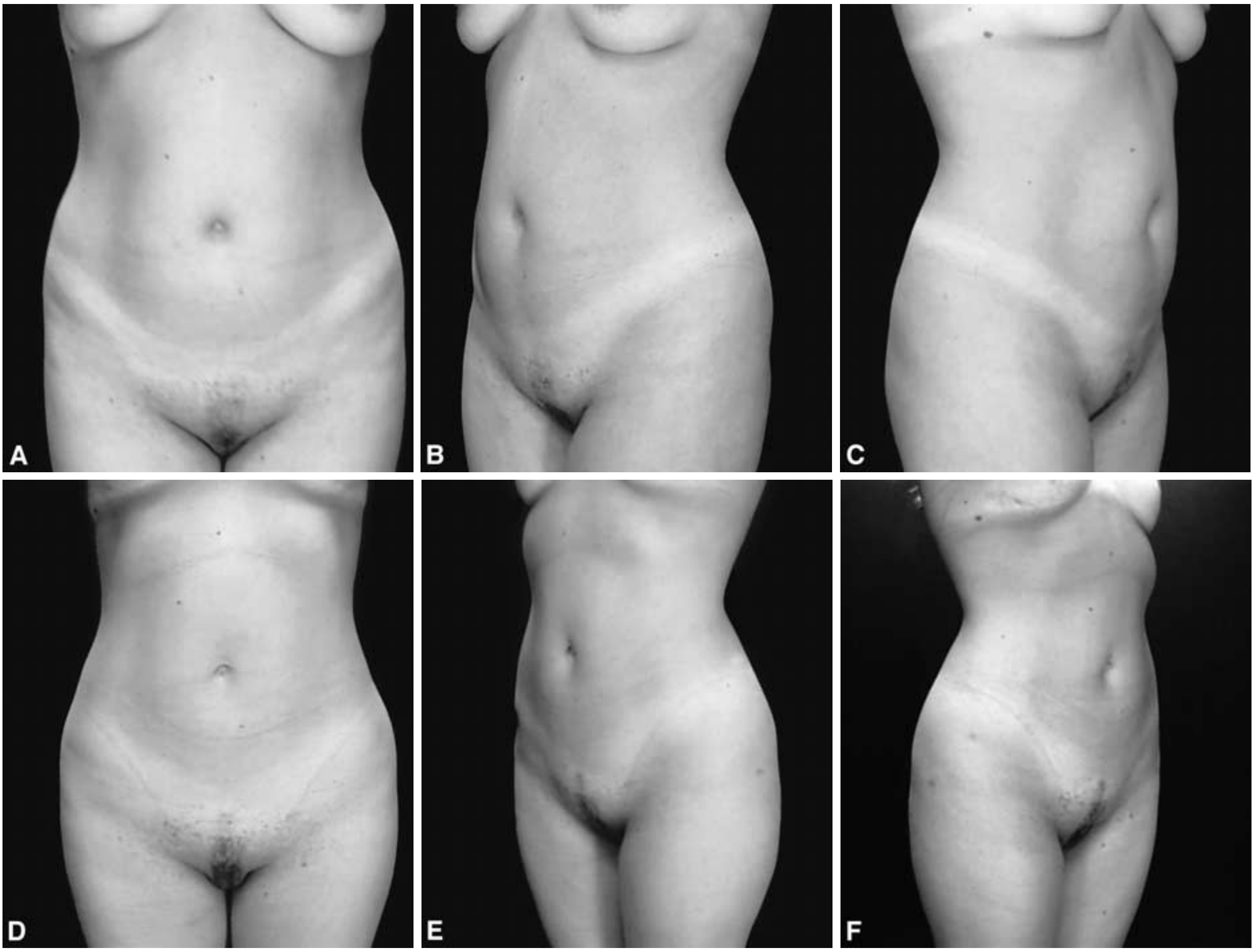

Fig. 7. A 23-year-old patient who underwent UAL for her abdomen, inner thighs, outer thighs, flanks, and dorsum is shown preoperatively (**A**, **B**, **C**) and two years postoperatively (**D**, **E**, **F**).

those patients exposed to ultrasound extensively [23]. Ablaja Maxwell studied skin temperature during ultrasound application in 1996 [12]. They concluded that the method is safe if used with tissue infiltration patterns and continuous cannula movement. We observed that with tumescent infiltration, the number of seromas was higher than with the wet infiltration method we now use.

In 2000 Howard and Rohrich studied cell rupture after liposuction (internal ultrasound, 70–90%; conventional, 5–25% external ultrasound, 5–20%) using creatinine kinase as a marker. It was 30% higher in ultrasound-assisted liposuction than in conventional liposuction [20].

Another interesting factor in the evolution of ultrasound-assisted liposuction is the formation of free H_2O_2 in treated areas that acts as a bactericidal, reducing the chance of infection.

Two factors indicating that the liposuction procedure should be stopped must be considered. The first is how easily the cannula slides over the tissue—there should be no resistance to the cannula. The other factor is how long the ultrasound has been in use and the average active time.

We observed a minor incidence in postoperative hematomas that is explained by the number of vessels that remain intact during the procedure—the aspirated solution is clearer than in conventional liposuction and it is possible to return to normal activities quickly, including exercises after the first week (Fig. 9).

Ultrasound-assisted liposuction promotes excellent results in those cases where conventional liposuction has limitations, such as areas with greater than average fibrosis (secondary liposuction) and areas like the dorsum and in cases gynecomastia.

During our first year using ultrasound-assisted liposuction, we had 12 seroma cases. These were due to the use of tumescent infiltration in the first cases. After using wet infiltration, a reduction in the swelling and seroma formation was observed.

The disadvantages of ultrasound-assisted liposuction are the increased operative time and the training necessary for to efficiently use the technique and the equipment. In addition swollen and fibrotic areas necessitate extended postoperative lymphatic drainage. Despite these disadvantages, we observed better body contour results six months postoperatively compared to the results of conventional liposuction.

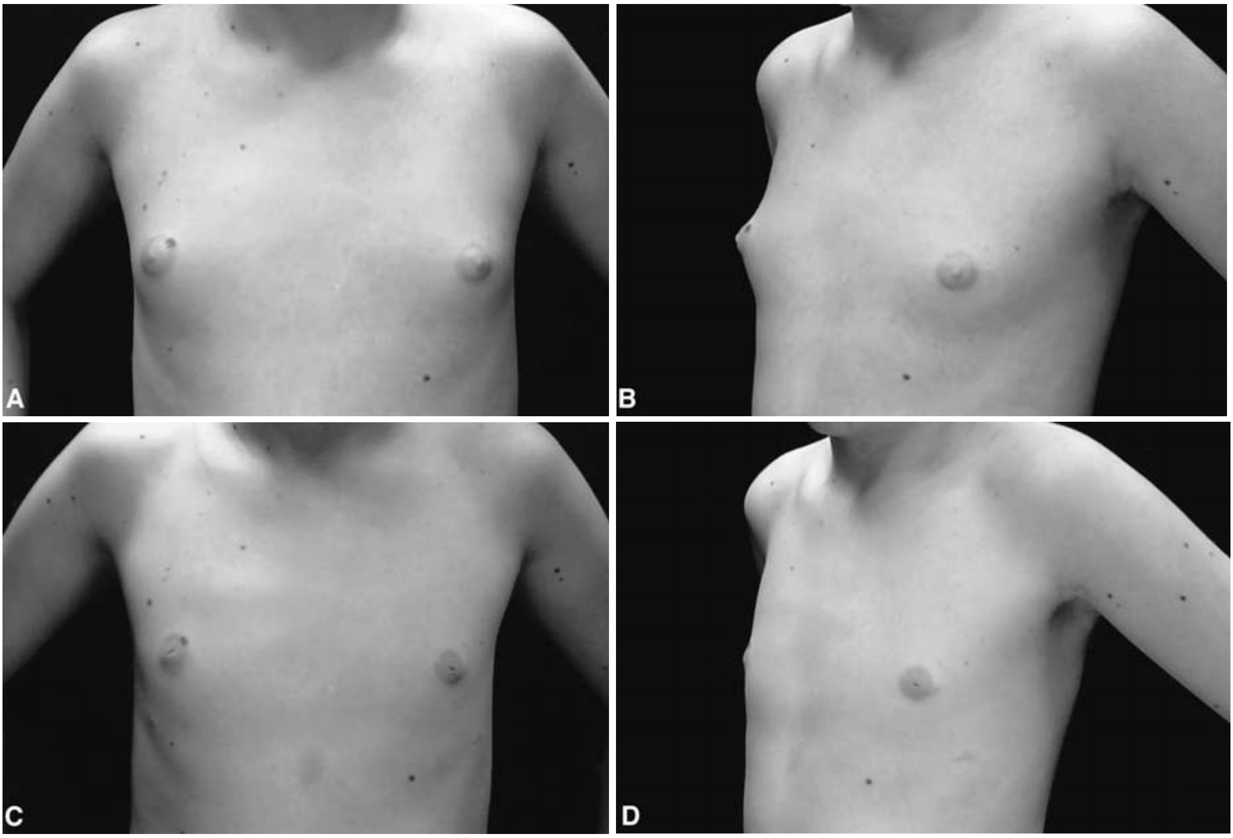

Fig. 8. A 16-year-old patient, who presented gynecomastia that we treated with UAL, is shown preoperatively (**A**, **B**) and six months postoperatively (**C**, **D**).

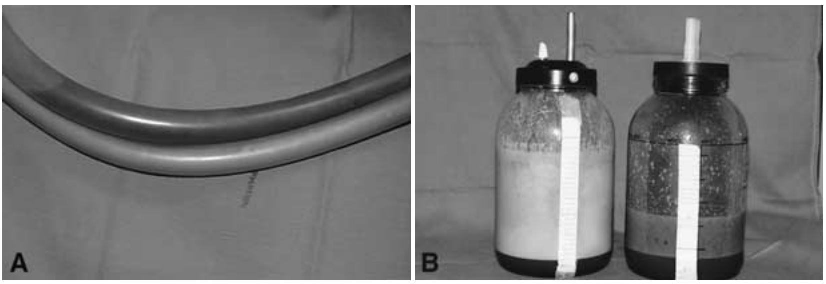

Fig. 9. Comparison of bleeding in UAL (right in **A**, bottom in **B**) and conventional liposuction (left in **A**, top in **B**).

This positive result is probably due to greater homogeneity in the fat removal, the increased temperature in the deep dermis that stimulates collagen contraction, and consequently skin retraction, and the ability to remove more fat because the technique inflicts less vascular injury and consequently less bleeding.

Conclusion

We believe that ultrasound-assisted liposuction is an excellent method for the treatment of lypodystrophy, mainly in difficult areas, such as the dorsum, secondary liposuction sites, and gynecomastia. Compared to conventional liposuction, some effects are good, like the selective destruction of undesired fat tissue while maintaining the integrity of vessels and nerves, the potential for better skin retraction in the treated areas, faster and less traumatic healing [1]. Conventional liposuction is by far the best procedure for localized, lax, and non-fibrous fat tissue, in patients with good skin tone and minimal surface irregularities. The use of ultrasound liposuction allows us to make significant changes in body contour with minimal complications, demonstrated by the high patient satisfaction index in the late postoperative period.

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