Cosmetic

Laboratory and Histopathologic Comparative Study of Internal Ultrasound-Assisted Lipoplasty and Tumescent Lipoplasty

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Despite the advantages of using internal ultrasound-assisted lipoplasty instead of the classic tumescent lipoplasty, such as reduced bleeding and tissue damage, the authors found no objective or comparative study of these techniques in humans. For this reason, they conducted a clinical study to determine the amount of bleeding and tissue damage caused by each of the techniques. A simple clinical assay was accomplished at the Jalisco Plastic Surgery Institute on seven female patients scheduled for abdominal lipectomy. Two similar sections of the surgical area were marked for lipoplasty techniques: classic tumescent lipoplasty on one side and internal ultrasound-assisted lipoplasty on the other. Both areas were treated simultaneously by surgeons experienced in each technique. Laboratory tests and histologic studies were performed on the aspirated material and the manipulated tissue, respectively. The fluids sent to the laboratory were analyzed to determine the amount of bleeding and tissue damage. In the laboratory, the degree of lesion and tissue damage was evaluated in the dermis, nerves, blood vessels, and adipose cells. With internal ultrasound-assisted lipoplasty, indicators of tissue damage such as glutamic oxalacetic transaminase, pyruvic oxalacetic transaminase, cholinesterase, and myoglobin showed higher values than with tumescent lipoplasty. The same was found for hemoglobin levels and in the histologic data indicative of tissue damage; both values were statistically significant at $p < 0.001$. Internal ultrasound-assisted lipoplasty was not demonstrated to be more innocuous or to have a selective effect in adipose cells, and it generally resulted in more tissue damage and bleeding than the classic tumescent technique. (*Plast. Reconstr. Surg.* 110: 1158, 2002.)

With the development of liposuction[1,2] more than two decades ago, a new area in surgical procedures was initiated in plastic surgery, a discipline that is constantly evolving.[3–5] The resulting innovations have given the name to several techniques (e.g., dry-to-wet, superwet, tumescent).[1,2,6–8]

Advances in lipoplasty techniques include the use of internal or external ultrasonic energy to improve the results of the procedure.[9–16] The application of internal ultrasound for lipoplasty, introduced by Zocchi in Europe in the 1980s, has many advantages[9,17,18] (e.g., greater volume of fat aspiration; less blood loss; preservation of connective tissue, lymph vessels, nerves, and blood vessels; greater skin retraction; minor postsurgical discomfort to the patient; and less fatigue for the surgeon).[9,13,14,17,18] However, in some studies the results are not conclusive[19] and the advantages of the techniques are questioned.[20] Also, the potential long-term results seem unclear.[21] For these reasons, we undertook a clinical study to compare tumescent lipoplasty with internal ultrasound-assisted lipoplasty, using laboratory and histologic parameters for analysis.

Materials and Methods

A clinical comparative study was undertaken in the Jalisco Plastic Surgery Institute in seven multiparous patients scheduled for abdominoplasty. The area of study was the caudal portion of the flap to be eliminated during the abdominoplasty. Simultaneously in this area, tumescent lipoplasty was performed on one side and internal ultrasound-assisted lipoplasty on the contralateral side. For the internal ultrasound-assisted lipoplasty, a LySonix 2000 machine

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(LySonix, Inc., Carpinteria, Calif.) was used, with an operation frequency generator of 22.5 kHz and 150 W. For the tumescent lipoplasty, a Cosmetech SSB-IV (Cosmetech, Inc., Alpine, Calif.) was used, with 3-mm and 4-mm stems of the same type. In both techniques, a Masterflex Pump Infusor Model 7553-50 (Barnat Company, Barrington, Ill.) was used. Each procedure was performed by a different plastic surgeon who was expert in the respective technique. Before surgery, the area planned for removal was marked and divided into two equal sections by a line down the center. A margin of 3 to 4 cm in the center of the surgical area was indicated and left untouched during the lipoplasties to avoid superimposition of the two techniques (Fig. 1). The operation was performed using a continuous peridural blockade. After the patient was anesthetized, infiltration of the two areas was performed until tumescence by using 1 liter of 0.9% saline solution plus 1 mg of epinephrine. Infiltration was identical on both sides in terms of quantity and a pause of 15 minutes for the vasoconstriction effect. The study areas were randomly assigned to the respective technique, and the procedures were initiated and conducted simultaneously. Internal ultrasound was applied with an intensity of 3 to 5 mHz in variable time according to the characteristics of the individual patient. To eliminate complications, the technique used was similar to that described in a previous study.[22] The total time of ultrasonic energy application was that required to eliminate resistance to passage of the probe in the specific fat layer to be treated; the time was calculated according to the surgeon's experience. Hollow titanium cutting bullet probes of 3 to 5 mm were used. For the superficial fat layer, a 3-mm bullet probe was used for 1 to 2 minutes with a power setting of 3. For the deeper fat layer, a 5-mm golf tee tip probe was used with a power setting of 5. The latter probe was used for 5 to 6 minutes, until resistance to passage of the probe was eliminated. All ultrasonic energy application was performed continuously until complete. This part of the operation required approximately 8 to 10 minutes. After conclusion of the ultrasound application, complete elimination of fluids under the flap proceeded with the conventional lipoplasty stems, which were always connected to the normal wall suction equipment. Lipoplasty with the tumescent technique was achieved with the accelerator-type 4-mm stem in the deep adipose layers and with the 3-mm stem in the superficial layers, using the conventional machine previously mentioned. Both surgeons performed the procedures simultaneously, evaluated the two treated areas, and left the areas with the same thickness. The material aspirated with each technique was left to decant for more than 1 hour. The infiltrated and extracted fluid was measured in cubic centimeters, as was the infranatant and supernatant quantity of the extracted fluid. The liposuctioned material was sent to a specialized laboratory for determination of indicative substances of bleeding and tissue damage, such as hematocrit, lipocrit, hemoglobin, myoglobin, cholinesterase, triglyceride, glutamic oxalacetic transaminase, and pyruvic oxalacetic transaminase levels. The Coulter method was used to evaluate the red blood cell, hematocrit, and hemoglobin levels. This technique is based on flow cytometry, which measures the quantity of cells present per volume unit, without the use of a centrifuge. To determine the transaminase, cholinesterase, and triglyceride levels, the multipoint kinetic technique was used, which is derived from the spectrophotometry reflection pattern of the suspended particles. The myoglobin value was determined by an immunoassay technique based on immunochromatography.

FIG. 1. Area of the abdominoplasty with delimitation of the sections to which the tumescent lipoplasty and the internal ultrasound-assisted lipoplasty were applied.

After the lipoplasty, three flap thickness patterns of 1 × 1 cm were taken for histopathologic analysis, one from the central area, one from 5 cm distal to the central region, and one from the flap margin for a control. For each biopsy sample taken, a hematoxylin and eosin stain was performed in the pathology laboratory. The same pathologist evaluated all of the biopsy specimens and was blinded to the surgical technique used on the tissue. Blood vessels, nerves, adipocytes, and dermal tissue were evaluated, as were several histologic parameters. In the blood vessels, the integrity of the vascular wall, thrombosis, lesions of the endothelium, lesions of the muscular and adventitious layer, changes to the nuclear cells of the vessel, and edema were evaluated. In the nerves, Schwann cells or demyelination and edema were evaluated. In the adipocytes, the integrity of the cellular wall and alterations in the organization of the whole cell were evaluated. In the dermis, the pathologist searched for lesions of the basal layer, tissue degeneration, edema, and inflammatory infiltrate. The pathologist assigned values to the damaged structures (i.e., light, moderate, or severe) and gave a numeric value of 1, 2, or 3, respectively, for statistical use.

The abdominoplasty was completed according to the established plan by the surgeon in charge. During removal of the flap, the macroscopic differences between the techniques and the underlying tissues were evaluated.

RESULTS

Seven multiparous patients were included in the study, with ages ranging from 27 to 48 years (mean, 33 years). The patients' weight ranged from 58 to 81 kg (average, 71.8 kg). The quantity of infiltrated fluid required for tumescence averaged 628.5 cc per side (range, 400 to 800 cc). The average amount of fluid aspirated from the tumescent side was 481.4 cc, or 76.6 percent of aspirated fluid in relation to infiltrated fluid. The average aspirated fluid in the internal ultrasound side was 425.7 cc, or 67.7 percent of aspirated fluid in relation to infiltrated fluid. The difference between the quantities of aspirated fluid from both sides was not significant. With the traditional tumescent technique, the average of the overlying fluid was 51.5 percent, and that of the underlying fluid, 48.5 percent. With internal ultrasound lipoplasty, the average was 53.7 percent for the overlying fluid and 46.3 percent for the underlying fluid. The differences between the techniques for overlying and underlying fluids were not significant and are shown in Table I.

Different substances were evaluated in the liposuction liquid. For all statistical analyses, the Student's paired t test was used. The average hematocrit value with internal ultrasound-assisted lipoplasty was 0.13 percent per volume; the average value with tumescent lipoplasty was 0.23 percent per volume (or 1.77 times greater with tumescent lipoplasty, not significant at $p < 0.086$). The average hemoglobin level with internal ultrasound-assisted lipoplasty was 0.59 mg/dl, whereas with tumescent lipoplasty it was 0.23 mg/dl (or 2.57 times greater with internal ultrasound, significant at $p < 0.001$). The average myoglobin level with tumescent lipoplasty was 83 ng/dl, and with internal ultrasound-assisted lipoplasty, 536 ng/dl (or of 6.46 times greater with internal ultrasound, not significant at $p < 0.27$). The average cholinesterase level with internal ultrasound-assisted lipoplasty was 0.45 U/ml, whereas with tumescent lipoplasty it was 0.38 U/ml (or 1.18 times greater with internal ultrasound, not significant at $p < 0.1996$). The average triglycerides level with tumescent lipoplasty was 38 mg/dl, and with internal ultrasound-assisted lipoplasty, 64 mg/dl (or 1.68 times greater with internal ultrasound, not significant at $p < 0.06$). The glutamic oxalacetic transaminase value was 66 U/liter with tumescent lipoplasty and 103 U/liter with internal ultrasound-assisted lipoplasty (or 1.56 times greater with internal ultrasound, significant at $p < 0.035$). Finally, the pyruvic glutamic transaminase value was 142 U/liter with tumescent lipoplasty and 231 U/liter with internal ultrasound-assisted lipoplasty (or 1.63 times greater with internal ultrasound, not significant at $p <$

TABLE I
General Results of Infiltrate and Aspirated Liquid*

Technique	Infiltrated Quantity (cc)	Aspirated Quantity (cc)	% Aspirated versus Infiltrated Fluid (%)	Underlying Fluid (%)	Overlying Fluid (%)
IUAL	628.5	425.7	67.7	46.3	53.7
TL	628.5	481.4	76.6	48.5	51.5

* IUAL, internal ultrasound-assisted lipoplasty; TL, tumescent lipoplasty. Results were not significant.

TABLE II

Determination of Indicative Substances of Bleeding and Tissue Damage in the Liposuction Material of All Patients*

	Hematocrit (vol%)		Hemoglobin (mg/dl)†		Myoglobin (ng/dl)		Cholinesterase (U/ml)		Triglycerides (mg/dl)		Oxalacetic Glutamic Transaminase (U/liter)*		Pyruvic Glutamic Transaminase (U/liter)	
Patient	IUAL	TL	IUAL	TL	IUAL	TL	IUAL	TL	IUAL	TL	IUAL	TL	IUAL	TL
1	0.3	0.2	1.1	0.4	97.7	21	0.3	0.4	40	12	109	110	334	347
2	0.1	0.2	0.2	0.1	9.6	4.5	0.6	0.3	105	12	25	18	107	35
3	0.1	0.2	0.2	0.1	237	10	0.4	0.5	40	25	112	66	86	55
4	0.1	0.1	0.7	0.1	38	21	0.2	0.2	10	5	86	53	123	84
5	0.1	0.3	0.7	0.4	124	102	0.6	0.5	189	185	101	95	348	298
6	0.1	0.2	0.2	0.1	386	255	0.6	0.4	25	14	157	77	498	103
7	0.1	0.4	1	0.4	2861	168	0.5	0.3	42	10	130	40	123	75
Average	0.13	0.23	0.59	0.23	536	83	0.5	0.4	64	38	103	66	231	142
SD	0.08	0.1	0.4	0.16	1033	97	0.2	0.1	62	65	41	31.7	161	126

* IUAL, internal ultrasound-assisted lipoplasty; TL, tumescent lipoplasty; SD, standard deviation.
† Significant difference.

0.13). The values of the preceding data for all patients, including averages and standard deviations, are shown in Table II.

In the evaluation of the histologic findings of the biopsy specimens taken from the flap with the two techniques, the pathologist assigned a grade of light, moderate, or severe damage to the structures, giving a numeric value of 1, 2, or 3, respectively. A comparison of the average amount of tissue damage found in all patients is presented in Table III. Lesions considered moderate and severe were found in patients treated with internal ultrasound-assisted lipoplasty, and lesions considered light-to-moderate were found in those treated with tumescent lipoplasty. According to the values of several histologic parameters, the average value with the use of internal ultrasound was 2.18, and for the tumescent technique, 1.61 (significant at $p < 0.001$). Also, we used a Wilcoxon signed rank test for nonparametric values to analyze the histologic findings (i.e., changes in dermis, nerves, blood vessels, and adipocytes) individually according to the tissue that was evaluated ($p < 0.001$ for dermis, adipocytes, and blood vessels; $p = 0.002$ for nerves; all significant).

The macroscopic findings indicated a more homogeneous aspect of the structures on the tumescent technique side. The internal ultrasound-assisted lipoplasty side revealed a nonsmooth surface and hyperemia on the fascia, the rectus abdominal muscle, and the oblique external muscle (Fig. 2). In addition, a greater quantity of free fluid was found within these structures on the internal ultrasound side.

Discussion

With the development of liposuction, a new field in the management of the human corporal contour has evolved.[1–3] Technological advances have greatly modified the initial concepts on this surgical technique.[6–8] Undoubtedly, one of the most significant advances was the application of internal ultrasonic energy to facilitate surgical procedures.[9] Some of the advantages credited to the use of internal ultrasound-assisted lipoplasty are the preservation of connective tissue, blood vessels, and nerves; greater skin retraction; minor postsurgical discomfort to the patient; and less fatigue for the surgeon. The main indications for internal ultrasound-assisted lipoplasty are areas with an abundance of connective tissue, the need to manipulate the superficial adipose layer, and irregularities caused by previous lipoplasties.[19,20,23] Many plastic surgeons cur-

TABLE III

Values of Histologic Findings in Each of the Patients*

	Tumescent							Ultrasonic						
Tissue Damage	P1	P2	P3	P4	P5	P6	P7	P1	P2	P3	P4	P5	P6	P7
Blood vessels	2	2	2	1	2	2	1	3	2	3	2	3	2	2
Nerve	2	2	2	1	2	1	1	3	2	2	2	3	2	2
Adipocytes	2	2	2	1	2	1	1	2	2	2	2	2	2	2
Dermis	2	2	2	1	2	1	1	2	2	1	2	3	2	2

* P, patient; 1, light; 2, moderate; 3, severe. The difference in overall average value between the two methods was significant.

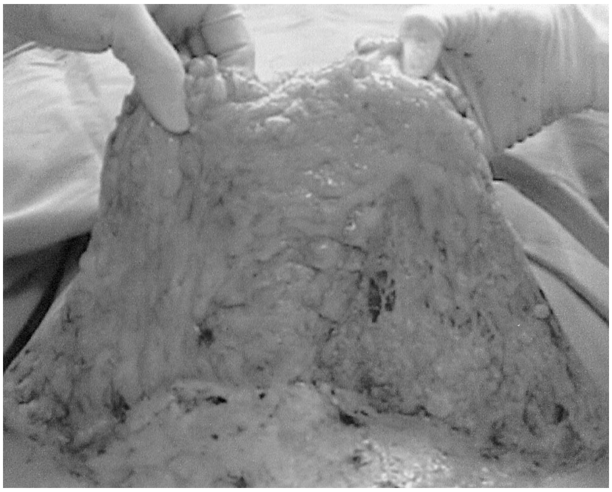

FIG. 2. Flap lifted during the abdominoplasty for evaluation of the structures where internal ultrasound (left side) and the tumescent technique (right side) were used.

rently use ultrasound-assisted lipoplasty in combination with the classic tumescent technique on the same patient, especially for larger-volume lipoplasty procedures. However, many of these advantages have been determined only subjectively in clinical studies.[13,19,24] At the same time, well-experienced surgeons have questioned some of the advantages of the ultrasound-assisted lipoplasty compared with the classic tumescent technique.[20] Kenkel et al., in a thorough comparative study on pigs, found few important differences between the techniques, and only when using a covered rather than uncovered stem to apply the ultrasound. When an uncovered stem was used, the histologic findings in the tissue lesions were similar to those with the tumescent technique.[14]

The effects of ultrasonic energy applied directly to the tissues during lipoplasty remain under discussion[21,25,26] and can generally be described as one of three types: thermal, cavitation, or direct. The basic effect of lipoplasty is cavitation, which ranges in ultrasonic frequency in the adipose tissue. The ultrasonic energy produces a microflow in the subcellular structure level and on the cell membrane. This microflow produces microscopic bubbles that induce positive and negative pressure sufficient to break the structures where they locate, such as on the adipose cells. This causes the adipose cells to implode, forming a coat of emulsified fat, which can be obtained using internal ultrasound-assisted lipoplasty.[9,18,27,28] The principal idea of classic tumescent lipoplasty, conversely, is based on avulsion of the fatty cells from their contour due to the negative pressure on the machine and stem system; in other words, the effect is completely mechanical.[19] Consequently, the techniques are controversial because diverse studies have procured results that favor both techniques in several aspects.[8,13,15,17,19,20]

The results of previous investigations were confounded mainly because of the selectivity of the internal ultrasound technique to act exclusively on the adipose tissue without damaging adjacent structures.[17,18,29,30] For this reason, the current study was designed so that the only variable would be the application of ultrasonic energy for the realization of lipoplasty. Both participating plastic surgeons had expertise with application of each of the techniques used. The ultrasound technique was performed according to previous work[22] while trying to minimize differences for adequate comparison. The procedures were conducted simultaneously, using the same vasoconstriction time and applying each technique to the same patient, to allow a matched analysis. The same flap thickness was left on each side according to the combined determinations of both surgeons, and both conducted the macroscopic observation when the flap was lifted.

The percentage of fluid extraction, in relation to the infiltrated quantity, was a little larger (8.3 percent) with the traditional tumescent technique compared with the internal ultrasound-assisted technique. This coincides with the macroscopic findings during the abdominoplasty, in which a greater quantity of free fluids was observed in the fatty tissue and adjacent tissue on the internal ultrasound-assisted lipoplasty side. However, the amount of overlying and underlying fluid was similar in the two techniques, with only a 2.2 percent greater percentage of the overlying fluid where internal ultrasound was used. The small difference in fluid extraction between the two techniques did not influence the laboratory results, because the values were measured according to a volume unit instead of total volume obtained. Furthermore, the differences between the liquid extractions were not statistically significant.

The laboratory results show obvious differences between the techniques. Considering the seven parameters used to evaluate tissue damage (Table II), six were more elevated where internal ultrasound was used. The only discrepancy found in all values was the difference between the hematocrit and hemoglobin values, which were used to estimate bleeding produced by each of the techniques. The hematocrit value showed an increase of 1.77 times in the traditional tumescent technique compared with internal ultrasound. The hemoglobin value was 2.57 times with internal ultrasound compared with the tumescent technique. This discrepancy between the hemoglobin and hematocrit values can be explained by the laboratory procedure used to determinate the hematocrit (i.e., Coulter method). Based on flow cytometry, this method measures the quantity of cells present per volume unit through an electric field; in this manner, only the undamaged red cells are measured. If the crash waves of the ultrasound were to somehow damage the red cells, it would explain a minor quantity of hematocrit in the ultrasound fluid, despite the significant elevation of the hemoglobin level compared with the tumescent technique.

Myoglobin, a cytoplasm protein present in the skeletal and the heart muscles, increases after damage to these structures, such as in trauma, ischemia, surgery, exercise, and so forth. The myoglobin level was 6.46 times greater with ultrasound-assisted lipoplasty, which suggests greater damage to the skeletal muscle structures than with the tumescent technique. Elevated transaminase levels are present with lesions to the heart, liver, kidney, or muscle. An elevated level of pyruvic glutamic transaminase is more specific than oxalacetic glutamic transaminase for damage to the musculoskeletal structures and was the first to increase in greater proportion with the ultrasound technique. Similar to myoglobin, an elevated transaminase level suggests greater damage to the musculoskeletal structures with the internal ultrasound technique. The macroscopic view showed greater roughness and marked hyperemia in the muscular fascia in the internal ultrasound side, indicating greater tissue damage to the subjacent muscular tissues with that technique. The level of cholinesterase increases with damage to the nervous tissue, destruction to the red cells, or hepatic alterations. The cholinesterase level was 1.18 times greater with internal ultrasound, suggesting more damage to the nervous structures and/or to the red cells than with the tumescent technique. Because of the large differences in some of the values and the very wide standard deviations, we used two different statistical tests to validate the results. Using the standard deviations, we obtained statistical significance with both tests.

It is of note that no previous point of reference existed with regard to these values, because laboratory base data values are for normal blood patterns, not for fluids extracted during lipoplasty. Nevertheless, because this study compared two patterns with only one variable, the resultant values are completely reliable and statistically significant. Both techniques were performed under parallel circumstances; therefore, the difference between the values indicates the differences between the techniques. In these determinations, hemoglobin level showed a statistically significant elevation in the internal ultrasound side compared with tumescent lipoplasty ($p < 0.001$).

The histologic findings of the biopsy specimens taken from both sides were substantially different. Both sides showed lesions consistent with alterations in blood vessels or loss of endothelium, edema of the muscular layer, nuclear change, and partial loss of the adventitia. In the nerves, there was Schwann cell fragmentation. In the adipose cells, a loss of organization and alteration of the cell membrane were evident. The dermis showed degeneration of the edema and vacuoles, which is encountered in moderate-to-severe trauma to the dermis. According to the severity of the damage, numeric values were assigned to the pathologists' observations. Then, a sum of the reported aspect values for each was made (blood vessels, nerve, adipose cells, and dermis) and an average of these values was obtained. For internal ultrasound-assisted lipoplasty, the average value of the damage was 2.18 (moderate-to-severe). With traditional tumescent lipoplasty, the damage was light-to-moderate with the average value at 1.61. The difference was statistically significant ($p < 0.001$). The damage reported with the internal ultrasound technique was as great for the central zone as for the outlying area of the lipoplasty, whereas with the tumescent technique the biopsy results showed moderate damage mainly in the central zone.

The main advantages attributed to the use of ultrasonic energy on lipoplasty versus the tumescent technique are minor bleeding and minor tissue damage. However, this study, using objectives and measurable parameters, did not demonstrate that internal ultrasound-assisted lipoplasty has selectivity in adipose tissue. The study found that internal ultrasound generally produced greater tissue damage and bleeding than the classic tumescent technique, with values that were statistically significant.

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