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Power-Assisted Liposuction (PAL) vs. Traditional Liposuction: Quantification and Comparison of Tissue Shrinkage and Tightening

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1. Introduction

Traditional liposuction with blunt-tip fenestrated cannulas remains the most commonly performed surgery for localized fat deposits. Refinements in the use of tumescent solutions, improvements in technique/instrumentation and selection of optimal candidates are critical to maintain its safety profile and effectiveness[1]. Since the introduction of power-assisted liposuction (PAL) by MicroAire Surgical Instruments (FDA 510(K) December 1998, the device has undergone developmental changes to improve mechanical disruption of normal and fibrotic fatty areas, in gynecomastia and within firmer tissues after secondary surgery for superior fat extraction[2-8]. To date, however, there have been no studies that objectively determine whether the effects of mechanical injury, produced by a PAL device with potential increased surgical trauma, result in increased tissue shrinkage and tightening, after extraction of fat which is not apt to occur with traditional manual liposuction (TL).
The purposes of this chapter were to review a 12-year clinical experience with powered-assisted liposuction and, in a limited study, obtain additional quantitative data on tissue shrinkage (accommodation or retraction) and tightening (elasticity) comparing PAL liposuction vs. traditional manual liposuction alone.

1.1 Device

The current upgraded MicroAire™ PAL device was an electrically powered and ergonomically re-designed model that was lighter and transmitted less vibrations, allowing easier penetration, removal of fatty tissue and reduced surgeon fatigue. A multi-fenestrated 4.0mm helix triport 3 cannula reciprocated at 2000 to 4000 cpm at a 2-3mm stroke. Although the speed of cannula movement could be adjusted by surgeon-preference, the instrument was operated either at full power (4000 cpm) or without power (manual) for this study.

1.2 Clinical protocol

From 1998 to 2011, ASA 1 patients presented for body contouring with PAL. Treatments were indicated for patients with moderate collections of adiposity and mild to moderate

amount of tissue laxity. Patient exclusion criteria included pregnancy, uncontrolled diabetes mellitus, collagen disorders, cardiovascular diseases, and bleeding disorders. Standardized digital photography was obtained before surgery, along with data about each patient's weight, height, percentage body fat, and body mass index. Patients were marked in the standing and sitting positions to the localized zones of treatment. Patients were offered preoperative oral medication for pain and sedation. An intravenous line and urinary catheter were inserted for access before surgery and removed upon discharge

All surgeries were performed in an office setting under tumescent local anesthesia (500mg lidocaine, 1mg epinephrine, 20ml 8.4% sodium bicarbonate, 1000 ml 1 normal saline), utilizing superwet technique (1:1 ratio of tumescent fluid infiltration:lipoaspiration). Multiport blunt cannulas (2.4-4.0mm openings) removed fat, tissue debris, and tumescent fluid under a vacuum pressure between 450-500mm Hg for small-to-moderate volume cases for safe and effective fat removal in one session. The maximum amount of lipoaspirate did not exceed 5000ml in any one patient, respecting the safe maximum 35mg/kg of lidocaine dosage, while monitoring fluid replacement, hemodynamic stability, blood loss, and urinary output during surgery and in the post-operative recovery period. Temporary 0.25-inch (0.635-cm) Penrose drains were inserted into dependent sites and removed within 1-2 days. Compression garments with sponge inserts were applied for 2-3 weeks, after which a series of weekly external ultrasound treatments were given to reduce irregularities and swelling.

1.3 Study design for quantitative tissue shrinkage and tightening

A randomized, controlled study was designed to measure tissue shrinkage and tightening in 3 female volunteers who presented with localized lower abdominal adiposity, minimal-moderate skin laxity, and absence of rectus abdominis diastasis. Conditions for exclusion included abdominal surgeries, current weight reduction programs, diabetes mellitus, collagen disorders, cardiovascular diseases, local infections and bleeding disorders. Biopsies from treated sites were obtained at baseline and 6 months later to correlate histologic observations with tissue shrinkage changes. At the completion of the study, a complete abdominal liposuction was offered to achieve an aesthetic result in each patient. Informed consents were obtained with IRB and HIPPA-approved protocols.

In the upright position, patients' skin-fat folds were measured across by a caliper (Harpenden Skinfold Caliper, Baty International, West Sussex, UK). Two 10cmx10cm square templates were marked on the lower half of each abdomen and were separated by a 5cmx10cm rectangular zone at the midline of the abdomen. The corners of each treated site were tattooed with India ink deposited through a 21 gauge multipronged needle. The Vectra 3D System software (Canfield Scientific, Fairfield, New Jersey) would capture the permanent markers around each targeted site and calculate quantitative changes in tissue shrinkage by measuring the horizontal, vertical, diagonal and perimeter distances at baseline compared to findings at 3 and 6 month follow up visits (Figure 1).

Tissue elasticity was evaluated by three repetitive measurements a tattooed site at the center of each targeted zone with the Reviscometer® RVM 900 (Courage-Khazaka, Colone, Germany) at baseline and 3 months after manual or power-driven liposuction. Measurements were calculated on the principle of stress-strain relationships when the skin was drawn up with negative pressure of 400mbar within 3 seconds and then released and moves back to its original position for another 3 seconds. The pressure differential between measurements, determined optically during suction and relaxation, is expressed as a percentage: tissue resistance during negative pressure = A; tissue's ability to return to original position=B

$$\frac{\text{A-B}}{\text{A}} \text{x } 100 = \text{ E } (\text{elasticity in } \%)$$

Internal subdermal temperatures were recorded with a thermal sensing device at baseline and during the end of the procedures along with simultaneous surface skin temperatures with a handheld infrared noncontact thermometer (MiniTemp® MT6, Raytek Corp, Santa Cruz, CA, USA).

One subject consented to tissue punch biopsies within the target zones at baseline, 3 and 6 months after completion of the study. Samples were fixed in 10% formaldehyde-buffered solution, paraffin embedded, sectioned at 4-5 μm, and interpreted with hematoxyline-eosin and trichome stains. The pathologist interpreted the microscopic findings in each specimen without knowledge of the given treatments.

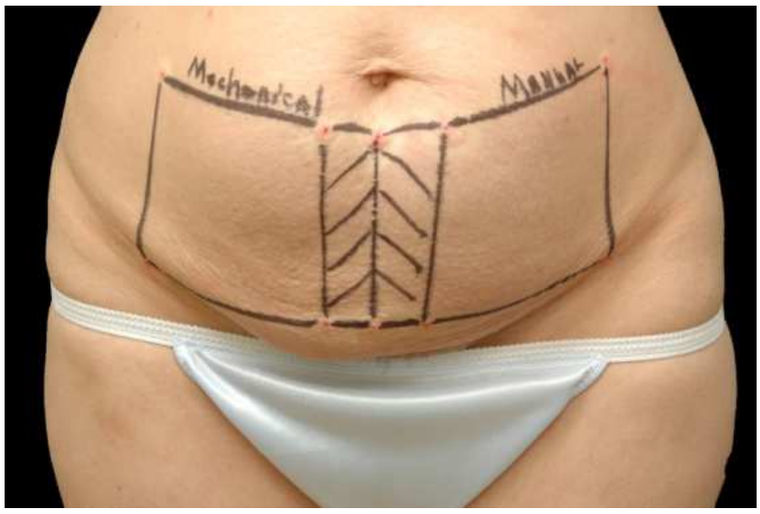


Fig. 1. Two 10cmx10cm target zones are identified by 8 tattoos whose surface areas are assessed by Vectra 3D Analyses between manual and powered-driven procedures.

1.4 Study protocol

Upon completion of their markings, measurements and photographs, patients were offered preoperative medications and prescribed a postoperative antibiotic. A 2mm incision below each of the square target zones permitted access for treatment. In a random fashion amongst the three subjects, once each of the 10cmx10cm areas received one of the following assignments, that zone remained as either a manual or power-driven site through baseline, three months and 6 months treatments regimens (Table1). During passages of the cannula in the **non-suction mode** within panels A & B at baseline treatments, simultaneous recording of temperatures were determined in the deep subcutaneous fat and surface of the skin. Identical temperature recordings were obtained during passages of the cannula in the suction mode within panels A & B at the 3rd month study period. Final Vectra 3D quantitative evaluations, elasticity measurements, and punch biopsies were obtained at the 6th month evaluation period, 3 months after the liposuctioning phases were completed. After each surgical procedure, access incisions were closed with a single suture. Subjects were dressed with sponge inserts and compression garments. Postoperative antibiotic and pain medications were prescribed.

Time	Panel Zone	Treatment
Baseline Vectra 3D & Intraop Temp. Monitoring	A	200ml tumescent solution (500mg plain Lidocaine, 1 mg epinephrine, 20ml of 8.4% sodium bicarbonate in 1000ml normal saline); 500 **manual** passes of a 4.0mm helixed triport 3 cannula in the **non-suction mode*** throughout the superficial and deep layers of subcutaneous fat.
Baseline Vectra 3D & Intraop Temp. Monitoring	B	200ml tumescent solution; 500 **power-driven** passes of a 4.0mm helixed triport 3 cannula in the **non-suction mode*** throughout the superficial and deep layers of subcutaneous fat.
3 Months Vectra 3D & Intraop Temp. Monitoring	A	200ml tumescent solution (500mg plain Lidocaine, 1 mg epinephrine, 20ml of 8.4% sodium bicarbonate in 1000ml normal saline); 500 **manual** passes of a 4.0mm helixed triport 3 cannula in the **suction mode*** throughout the superficial and deep layers of subcutaneous fat (250 ml aspirate).
3 Months Vectra 3D & Intraop Temp. Monitoring	B	200ml tumescent solution; 500 **power-driven** passes of a 4.0mm helixed triport 3 cannula in the **suction mode*** throughout the superficial and deep layers of subcutaneous fat. (250ml aspirate)
6 months	A & B	Vectra 3D & Elasticity Measurements, Biopsies

*MicroAire Surgical Instruments, Inc. Charlottesville, VA, USA

Table 1. Assignment and Treatment per Target Zone

2. Results

2.1 Clinical patient demographic data

Beginning in February 1998 to April 2011, 547 patients (498 women, 49 men) received PAL treatments in the author's private practice were able to be evaluated. Patients had a mean age of 48.3 years (range, 19 to 67 years), mean height of 162.7 cm (range, 146 to 192 cm), a mean weight of 69.2 (range, 53.6 to 115 kg), a mean body fat of 28.6% (range, 25.4.2% to 36.5%), and a mean body mass index of 24.6 (range, 18.2 to 32.2). Among the 547 patients, liposuction was performed in 13 anatomical sites (face, neck, brachia, axillae, brassiere/lumbar/hip rolls, breasts, abdomen, saddlebags, banana rolls, thighs and calves). Four hundred sixty-eight patients (85.6%) elected to undergo liposuction more than one site at the same session (average 4.2 sites; range, two to eight sites).

The average volume of tumescent infiltration was 2700 ml (range 1250ml to 3500ml), while the average aspiration volume was 2500ml (range 1750ml to 3200ml). The average infiltration:aspiration ratio was 1.08:1.0 (range, 0.9:1.0 to 1.2:1.0). The average volume of fat was 1785ml (range 1500ml to 2700ml). The average lidocaine dosage was 3.5mg/kg (range, 1.7-4.7mg/kg), below the recommended safe level of 7mg/kg in the *Physicians Desk Reference*[10].

In general, patients reported 85% satisfaction with the changes in their bodies after PAL liposuction at the six-month postoperative visit (Figures 2-3). Ten patients (1.8%) requested excision of redundant skin after liposuction to the brachia, upper inner thighs and lower abdomens. The majority of patients experienced skin accommodation or retraction after volume reduction of the fat. Nineteen patients (3.5%) requested surgical revisions because of incomplete fat removal of at selected sites or asymmetries. Each patient was asked to record his or her impression of the degree of intraoperative pain on a visual analog scale from 0 to 10. Patient responses indicated an average intraoperative pain level between 1 to 4 and a postoperative pain level of 1 to 3 on the second or third day after surgery. Almost all patients were able to resume their presurgical routines by the tenth postoperative day, depending on the extent and number of treatment sites.

During surgery, and the first forty-eight hours after surgery, none of the patients demonstrated any hemodynamic instability due to larger infiltration and aspiration volumes. Patients did not observed or exhibit lidocaine side effects such as prolonged lightheadedness, euphoria, digital or circumoral paresthesias, tremors, blurred vision, tinnitus or severe nausea and vomiting. Total blood loss was negligible, as determined by lipocrit measurements of less than 1.0% in lipoaspirates in over 50 patients.



Fig. 2. 43 Year old female with lipodystrophy to the brassiere, lumbar, and hip rolls



Fig. 3. Tissue accommodation after PAL procedure provided contour improvement

Patients developed fibrotic nodules (5.0%), prolonged indurations (3.0%), and seromas (less than 1.0%) but did not experience cellulitis, skin necrosis, blisters or prolonged edema. Nodules resolved spontaneously or were successfully managed by intralesional steroid injections along with a series of external ultrasound treatments. Prolong indurations took longer to resolve by 3 months with ultrasound treatments and lymphatic massages. Seromas resolved spontaneously without aspiration. Surgeon fatigue was negligible during surgery, while the learning curve was not steep.

2.2 Study patient demographic data

The mean age of the three female patients was 46.7± 2.2 years. The average pretreatment weight (57.7 kg), percent body (fat 33%), BMI (25 kg/m^2), waist diameter (85.3 cm), and hip diameter (95cm) varied during the post-treatment measurements at 3 and 6 months (Table 2). Abdominal skin-fat fold thickness, measured by calipers, varied between 1.7-2.3 cm. Subjects experience no complications from surgery and returned to their normal activity levels within 1 to 3 days.

Subject	Weight (kg)			Body Fat %*			BMI (kg/m2)*			Waist (cm)			Hips (cm)		
	0 Months	3	6	0	3	6	0	3	6	0	3	6	0	3	6
Pt. #1 (48y)	58	56	59	33.5	34.4	36	23.6	22.6	23.9	81	81	85	95.5	91	93
Pt. #2 (45y)	61	64	67	34.6	37.6	38.7	24.7	25.8	27.1	86	88.5	92.5	95	94	96
Pt. #3 (47y)	54	54	54	31.2	32.9	32.9	21.7	21.9	22.1	89	88.5	85	95	93	92

*Body Fat Analysis Futrex-5500

Table 2. Patient Demographic Data

2.3 Vectra 3D skin shrinkage surface area changes

Results of surface area changes from baseline measurement, as determined by Vectra 3D Analyses at 3 months after **non-suction** manual or power-driven cannulations and at 6 months after manual or power-driven **liposuctions**, are shown in Table 3. A positive change in percentage surface area within the tattooed square reflected an increase of target site compared to baseline value. In contrast, a negative percentage value in surface area indicated a smaller area after treatment compared to baseline measurement. Outcomes were tested for significance with a paired *t* test, using $p<0.05$ as the cutoff value.

	Zone A Manual/ Non-Suction 3 Mos	Zone B Power-Driven/ Non-Suction 3 Mos	Zone A Manual/Suction 6 Mos	Zone B Power-Driven/ Suction 6 Mos
Subject 1	0.0%	-2.40%	-1.70%	-5.20%
Subject 2	3.30%	6.10%	-10.10%	-3.80%
Subject 3	0.70%	-2.90%	-0.90%	-7.50%
Average	1.3%	0.27%	-4.2%	-5.50%

Table 3. Zonal Surface Area Changes after Manual or Motor-Driven Procedures over Time

As depicted in Figure 4, manual cannulations without suctioning demonstrated an small increase in the area measurement from its baseline value (average 1.4%), while power-driven cannulations without suctioning resulted in no appreciable surface area change from its baseline value (average 0.2%) at the 3 month evaluation period. At 6 months, the surface area after power-driven suctioning exhibited a greater reduced surface area (average -5.8%) than after manual suctioning (average -4.2%) from their baseline values.

2.4 Skin elasticity changes

Calculations of biomechanical measurement for skin elasticity at 6 months (3 months after completion of liposuction) and expressed as mean percent changes over baseline. No statistically significant elasticity changes were observed in zones treated by either manual or power-driven suctioning from their adjacent control sites.

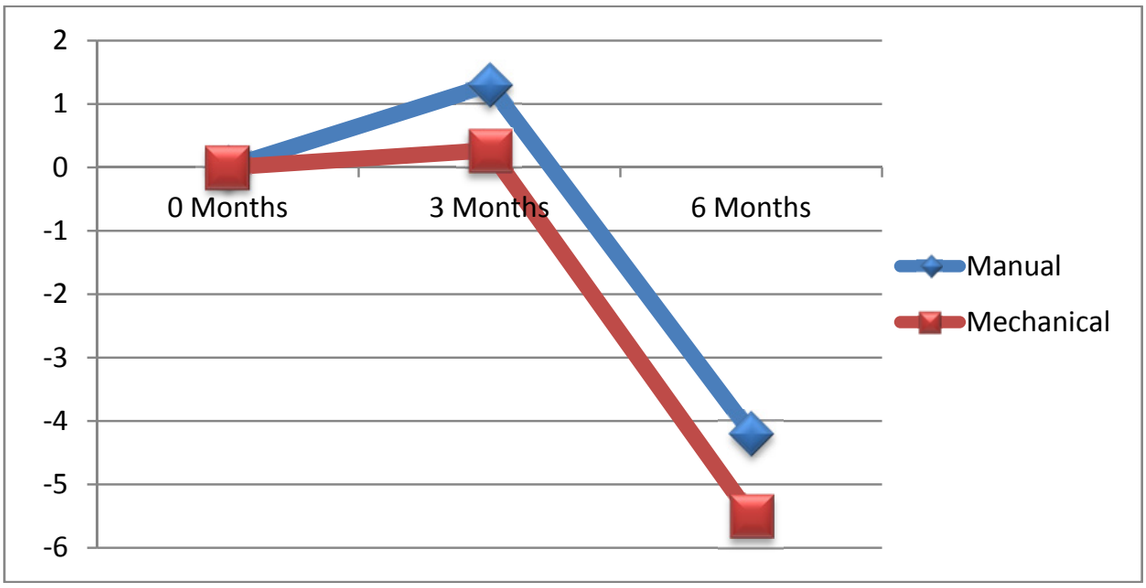


Fig. 4. Vectra 3D Analyses of reductions in surface changes at 3 and 6 months compared to baseline measurements after manual or power-driven procedures.

2.5 Subdermal and surface skin temperatures

The average oral temperature for the three subjects at baseline was recorded at 36°C (range 36.4-37.2°C). Throughout each of the assigned treatments, as listed in Table 4, the deep subdermal temperatures did not significantly differ from the simultaneously measured surface skin temperatures in each patient. Since manual/motor-driven cannulations or active suctioning did not result in any elevation of the subdermal or skin temperatures, the area changes observed during treatments, as tabulated in Table 3, is unlikely to be attributed to localized tissue trauma or thermal denaturation of collagen/elastin fibers and their secondary remodeling/contraction.

Pt	Zone A (3 Mos) Manual/Non-suction	Zone A (3 Mos) Power-driven/Non-suction	Zone A (6 Mos) Manual/Suction	Zone A (6 Mos) Power-driven/Suction
1	T_D* 30°C	31°C	29°C	30°C
	T_S** 27°C	28°C	27°C	29°C
2	T_D* 29°C	29°C	30°C	29°C
	T_S** 25°C	26°C	26°C	27°C
3	T_D* 31°C	31°C	30°C	31°C
	T_S** 29°C	28°C	27°C	28°C

* Temperature in deep subcutaneous fat (1-2cm below dermis)
** Temperature of surface skin

Table 4. Deep and Surface skin Temperature during Assigned Treatments

3. Histology

Microscopic examination of punch tissue biopsies of in panels A & B after the 6th month procedures did not demonstrate any significant epidermal, dermal or subdermal changes by hematoxyline-eosine and trichome staining (Figure 5). The use of manual suctioning or motor-driven suctioning did not produce any visible damage within the epithelial cell layers, dermal collagen or elastin fibers, and subdermal septae.

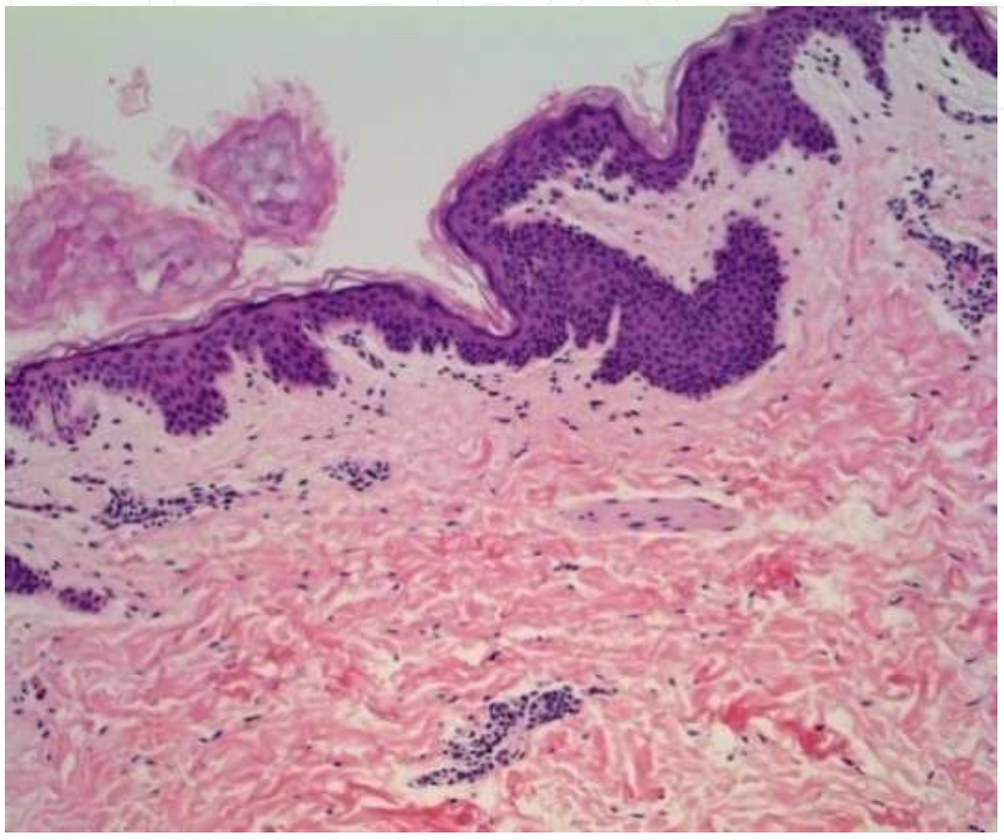


Fig. 5. Histologic changes in Panel B at three months after motor-driven suctioning in subject 3 demonstrating no observable damage to the epidermal, dermal or subdermal structures.

4. Discussion

Power-assisted liposuction has been shown to be effective and safe for small-to-large volume liposuction cases. Studies[2-3,9] that compared power-assisted to traditional liposuction found that power-assisted liposuction was superior in the ease and speed of fat extraction, faster healing and recovery time for patients, shorter procedure times with less surgeon fatigue, and lower incidence of touch-up secondary procedures. However, neither technique demonstrated a distinct advantage over the other in the post-operative evaluations for ecchymosis, edema, results, recovery times and complications.

Our extensive experience confirms previous findings that PAL represents a safe and efficient method for small-to-moderate volume cases with superwet tumescent technique. About 85%

of the aspirate volume was composed of fat, while blood loss was minimal with lipocrits less than 1.0% of the lipoaspirates. The average lidocaine dosage was calculated at a safe level of 3.5mg/kg, which resulted in no overt signs or symptoms of lidocaine toxicity. All patients experienced stable hemodynamics during surgery and in the 48 hour recovery period.

Over 85% of patients were satisfied with their surgical results with an acceptable revision rate of about 3.5%. A secondary procedure for removal of excess skin after liposuction occurred only in 1.8% of patients in areas of primary skin laxity (brachii, upper inner thighs, and lower abdomen). In the vast majority of cases, the overlying skin accommodated or contracted to its new environment after fat debulking. Patients rated their intraoperative and postoperative pain at relatively low levels and returned to presurgical activity levels by the tenth day. Postoperative complications, such as nodularity, induration and seromas, were low and resolved spontaneously or with postop massaging and external ultrasound treatments.

The limited clinical study for quantitative tissue shrinkage and tightening determined that the mechanical injury produced by the power-assisted device resulted in no significant difference in abdominal tissue shrinkage (accommodation and/or retraction) 3 months after powered mechanical cannulations compared to manual identical manual cannulations by 3D Vectra Analyses after the passage of the same number of strokes with a 4.0mm helixed triport 3 cannula without liposuction. Patients served as their own controls in a paired comparison analysis of powered cannulations and traditional manual cannulations within adjacent 10cmx10cm target zones. When powered mechanical liposuction was compared to manual liposuction, utilizing the same diameter and designed cannula, identical negative aspiration pressures, and similar lipoaspirated volumes, an increase in abdominal tissue shrinkage was observed with PAL over TL. Since power-assisted liposuction did not generate any temperature changes to the skin or subdermal tissues compared to manual liposuction, as determined in this study, there were no thermal effects on tissue elasticity or histology detected at the 6th month evaluation period. Since PAL did not elicit any significant thermal injury to the collagen fibers in the septae and dermis, no active tissue contraction was observed clinically or determined in the elasticity study. Although the number of patients in this limited study was small for statistical significance, the observed results indicated a trend in greater tissue accommodation after PAL treatments. However, the study did not provide an explanation for power-assisted liposuction's ability to result in a small increase in the amount of tissue shrinkage (accommodation and retraction) over manual liposuction, after fat extraction and in the absence of temperature effects. Further studies will be necessary to examine this salutary tissue response from powered mechanical liposuction over traditional liposuction that, if confirmed, may provide an additional advantage, resulting in safer, more effective and precise surgery.

5. Conclusions

Power-assisted liposuction represents a safe and effective method to remove small-to moderate collections of fat for body contouring purposes. With super-wet tumescent technique, the average infiltration to aspiration volumes approaches a ratio of 1.08:1.0 in most surgeries. PAL appears to be an efficient method because the average percent of fat within the lipoaspirate approaches 85% in the majority of cases. Over 85% of patients were satisfied with the body contouring procedure with only 3.5% of patient requesting revisional surgeries for incomplete fat removal. Appropriate tissue accommodation or retraction

occurred after liposuction in most treated sites, except in areas that exhibited preoperatively a significant degree of tissue laxity (brachii, upper inner thighs, and lower abdomen) that required tissue excision after surgery in 1.8% of cases. All patients were hemodynamically stable during and after surgery, and did not exhibit any signs or symptoms of lidocaine side effects. Complication rates were low and involved temporary tissue fibrous nodularity, induration and seromas.

The study for quantitative tissue shrinkage and elasticity indirectly confirmed the postoperative findings among the 547 patients. The limited clinical study obtained quantitative measurements of non-significant differences in shrinkage of tissue surfaces in zones treated by either manual cannulations without suctioning or by power-driven liposuction without suctioning under other identical assignments (blunt cannula, tumescent volumes, number of stroke passages). Greater differences in surface area reductions were observed, however, in the same zones that were treated by power-driven liposuction than by manual liposuction only, under the same identical treatment conditions (blunt cannula, tumescent volumes, number of stroke passages, and volumes of aspiration). Since skin surface and deep subcutaneous temperatures did not approach threshold levels for collagen denaturation of 40-42^{o}C with these non-thermal treatments, the observed shrinkage of surface areas may be due to tissue accommodation and retraction from volume reductions rather than to active skin contraction from denatured collagen fibers and their subsequent reorganization. These conclusions are substantiated by the normal microscopic findings after manual or power-driven liposuction at the 6th month evaluation period within the skin and subdermal layers. Further objective studies will be required to validate these observations.

6. Acknowledgement

The author wishes to thank Dennis DaSilva, Canfield Scientific, Fairfield, CT for Vectra 3D Analysis and Margaret Gaston, BS for statistics and computer assistance.

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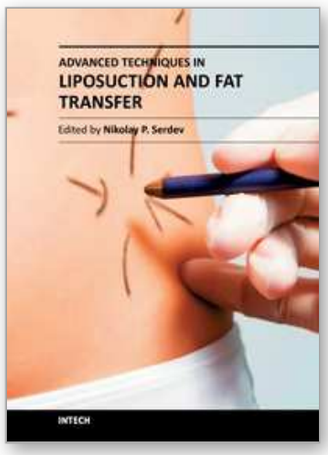
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Advanced Techniques in Liposuction and Fat Transfer

Edited by Prof. NIkolay Serdev

ISBN 978-953-307-668-3
Hard cover, 230 pages
Publisher InTech
Published online 12, September, 2011
Published in print edition September, 2011

Liposuction is the first cosmetic procedure to change beutification surgery from open extensive excision surgery into a more atraumatic closed one. It gave rise to the modern understanding of minimally scarring and minimally invasive surgery and changed the understanding and preferences of both patients and doctors. It also became the most common procedure in cosmetic surgery world-wide, practiced by an increased number of physicians from various specialties. The techniques of fat grafting, closely bound with liposuction, have found widespread application and fat stem cells seem to be changing the future of many areas in medicine. Turning the pages, the reader will find a lot of information about advances, tips and tricks, as well as important milestones in the development of the different methods available, such as classic, power, ultrasound, laser and radio-frequency assisted liposuction etc. Most useful anesthesia techniques are described and discussed, and guidelines have been established for medical indications. Special attention is paid to good patient selection, complications and risks.

How to reference

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Gordon H. Sasaki, Ana Tevez and Erica Lopez Ulloa (2011). Power-Assisted Liposuction (PAL) vs. Traditional Liposuction: Quantification and Comparison of Tissue Shrinkage and Tightening, Advanced Techniques in Liposuction and Fat Transfer, Prof. NIkolay Serdev (Ed.), ISBN: 978-953-307-668-3, InTech, Available from: http://www.intechopen.com/books/advanced-techniques-in-liposuction-and-fat-transfer/power-assisted-liposuction-pal-vs-traditional-liposuction-quantification-and-comparison-of-tissue-sh

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