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Enhanced Liposuction
New Perspectives and Techniques

Edited by Diane Irvine Duncan

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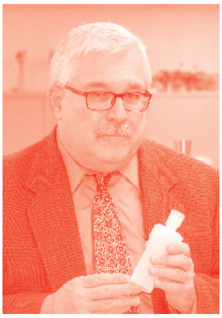

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Meet the editor

Dr. Diane Irvine Duncan is a US-based board-certified plastic surgeon known for research and international education. She has published frequently in peer-reviewed journals, books, and video format. She is on the editorial board of the *Aesthetic Surgery Journal*, and reviews for LMS and JCD. Dr. Duncan is a coordinator for the Lasers and EBD alert section and a member of the IMCAS faculty. She has recently completed a BBC documentary and has participated in and moderated many educational panels and webinars. Her current area of focus is regenerative modalities for the treatment of skin and soft tissue, including reversal of age-related sarcopenia.

Contents

Preface

When surgeons began performing liposuction regularly in the mid-1980s, the procedure was a bit rough and inexact. Patients were told that they would look better in clothing, but not necessarily without clothing. Due to the increasing popularity of minimally invasive body contouring over the years, new approaches rapidly developed. The advent of radiofrequency-, ultrasound-, and laser-assisted techniques reduced contour irregularities and residual skin laxity. A power-assisted handpiece decreased operator fatigue. Waterjet-assisted liposuction improved fat grafting harvests. Non-excisional skin tightening in conjunction with liposuction was developed, and both helium plasma and argon plasma were used to coagulate soft tissue. Combination techniques were developed for the face, neck, torso, and limbs so that minimal scarring and optimal outcomes could be achieved.

Our sophisticated clientele is no longer satisfied with the simple reduction of adipose content; a dramatic aesthetic improvement has become an expectation. From the reader who is just beginning in the field to the expert seeking a few pearls, *Enhanced Liposuction - New Perspectives and Techniques* is a compendium of comprehensive knowledge. This book addresses patient selection, patient marking, equipment, techniques, and expected outcomes with a variety of energy sources. Combination therapies can generate results far better than those originally achieved with dermolipectomy. Best practices that have taken years for the authors to develop are generously shared so that the entire group of aesthetic practitioners might benefit.

It is important to understand the limitations and risks of any new technique. Because many of the energy-assisted contouring outcomes take time to become fully evident, sometimes the clinical endpoint is not as clear as it might be with simple liposuction. A good clinical practice would dictate a conservative surgical approach with a longer post-treatment follow-up than one might normally consider. Patients perceive value in a treatment that is done once, has no need for revisions or later corrections, with results that last the better part of a lifetime.

Many thanks to the kind and thorough publishing team of Lucija Tomičić-Dromgool, Sandra Bakić, and Sandra Maljavac at IntechOpen.

The major credit for the excellence of this volume goes to each and every author, who spent many hours developing techniques, treating patients, writing, proofreading, and revising their contributions during a worldwide pandemic in order to help produce an outstanding publication.

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Section 1

History

Chapter 1

History of Body Contouring

Malcolm D. Paul and Garrett Wirth

Abstract

The evolution of body contouring follows decades of procedures and technologic advances in body shaping. Beginning many decades ago with extensive surgical resections of skin and subcutaneous fat, the evolution was dramatically changed with the introduction of suction assisted lipectomy (liposuction). Further refinement in the technique of liposuction allowed more precise sculpting of the body and, most recently, has evolved to high definition liposuction. Following the introduction of liposuction in the early 1980s, energy based devices were developed to allow non or minimally invasive procedures to sculpt the body. The energy sources include laser energy, radiofrequency energy, ultrasonic energy, and plasma based energy. This evolution has provide the cosmetic surgeon with a variety of options to obtain optimal body contouring in a variety of clinical presentations. The safety and the efficacy of these procedures are the most important considerations in adopting new technology and techniques.

Keywords: liposuction, radiofrequency, energy

1. Introduction

Physical appearance has been of immense importance for centuries B.C. including the wives of Persian rulers (**Figures 1–3**) and as seen in portraits dating back to the Italian Renaissance (**Figures 4** and **5**). Although there were no procedures available to address unwanted excess truncal fat and loose skin, artists in the above cited figures portrayed the ideal male contour and the unattractive body contour in a young child. The child demonstrates early obesity with neck, truncal, and extremity lipodystrophy. Unaesthetic fat deposits or loose skin, especially the ones without response to diet or physical exercise, are a major concern to patients. Witness the frequency of body contouring procedures throughout the world where liposuction is the most common esthetic surgical procedure. There are, however, differences in the distribution of the body fat between male and female patients. Men have less body fat around the waist, especially in the abdominal area; women generally have a higher percentage of body fat than men, especially around their thighs and buttocks, which is called gynoid fat. In overweight women, normally, the deposition is mainly found below the waist.

2. Early treatment of abdominal lipodystrophy and skin excess

The earliest procedures that addressed excess skin and subcutaneous fat in the abdominal area were performed for functional indications, not for esthetic

Figure 1.
Symbols of beauty from the Persian Culture.

Figure 2.
Symbols of beauty from the Persian Culture.

improvements. Certainly, removing skin and fat (dermo-lipectomy) had the secondary benefit of having the patient look better. In 1880, in France, Demars and Marx reported a large resection of skin and fat from the abdominal wall. In 1899, Dr. Kelly (a Johns Hopkins Gynecologist) performed a panniculectomy with an elliptical transversal incision around the umbilicus [1]. In 1901, Peters described a similar surgery extracting 7450 g from a patient, including the umbilicus, without the undermining [2]. Gaudet and Morestin extracted fat and skin with correction of an umbilical hernia while preserving the umbilicus. Eventually, Babcock in 1916 described dermo-lipectomies using a vertical incision [3].

Figure 3.
Symbols of beauty from the Persian Culture.

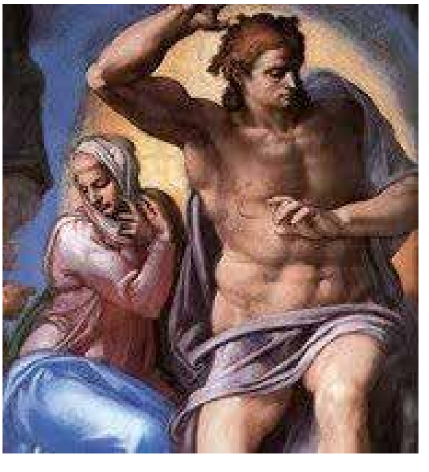

Figure 4.
Symbols of beauty from the Renaissance.

3. Evolving procedures in body contouring

Thorek performed the first umbilicus-preserving abdominoplasty in 1924 [4]. This was the first abdominal contouring procedure with esthetic benefits. Passot's contribution was to use undermining as a modification of Kelly's technique [5]. Vernon in the 1950s developed a novel concept by combining extensive undermining with the umbilical transposition and relocation, which is a procedure still in use today.

Figure 5.
Symbols of beauty from the Renaissance.

Callia described aponeurotic suturing as an important component of his procedure in 1967, which involved an infra-inguinal incision. Pitanguy in the same year published a series of 300 abdominal lipectomies with an infra-inguinal incision [6]. Previously, the published literature consisted mostly of case reports of a few patients. In the 1970s, Regnault modified the Pitanguy's incision into the "W" incision [7]. In 1973, Grazer championed the "bikini line" incision used frequently today [8]. Grazer and Goldwyn in 1977 observed that abdominoplasty decreased anterior projection of the abdomen but did little to change waist diameter This led to Psillakis' assertion in 1978 that muscular aponeurotic suturing was an underutilized tool to decrease waistline dimensions [9]. Somalo and Gonzalez-Ulloa extended the transverse abdominal incision circumferentially and introduced the belt lipectomy [10]. This concept would provide the background for many subsequent more aggressive procedures.

4. Evolution of liposuction

Describing the evolution of body contouring procedures would be entirely inadequate without presenting the chronologic events in the development of closed liposuction techniques. For certain, the most significant advancement in body contouring WITH OR WITHOUT concomitant excision of skIn and subcutaneous fat was the development of closed liposuction.

Removing excess fat from localized body sites is not a new idea [11]. In 1921, in France, Charles Dujarrier tried to remove subcutaneous fat using a uterine curette on a dancer's calves and knees [12]. Unfortunately, he damaged the femoral artery, and the patient has lost her leg. One of the original and creative initiatives came from Schrudde in 1964, when he extracted fat from lower areas of the limb, through a visibly small incision, utilizing a curette. The unfortunate results from this surgical initiative were unpleasant hematomas and seromas [13]. Pitanguy, on the other hand, was in favor of a removal of both fat and skin in a block, in order to remove excess thigh adiposities in one act [14]. Of course, this was an excisional procedure, not closed liposuction. Significant visible incisions made this method quite unpopular and made closed, non-excisional, procedures preferred, but, at that time, not discovered. The field of modern liposuction began with the technique and new instruments developed by Arpad and Fischer [15, 16]. During their work in Rome, Italy, they managed to develop a blunt hollow cannula, with additional function of suction. Some of the previous cannula designs contained a cutting blade also. They made their results public in 1976 [17] Fischer also started the crisscross tunnel formation method, from several incision sites. The new instruments brought very promising results avoiding the above complications.

Kesselring and Meyer [18] published their surgery results of sharp curettage aided by a suction device in 1978, but their method did not receive a wide acceptance. Fournier, in Paris, showed an early interest in the Fischer's liposculpture technique [19]. He was an initial enthusiast of the "dry technique" in which no fluids were infiltrated into the patient prior to liposuction. Fournier would become a world leader in liposuction and fat transplantation, eventually insisting on the benefits of tumescent anesthesia and making a great contribution in opening new horizons and ideas to surgeons from different parts of the world. Illouz, a French gynecologist, was quite attracted by the Fishers' work. His preferred method was the"wet technique", which consisted of a solution of hypotonic saline together with hyaluronidase inserted into the adipose tissue before the aspiration. Lllouz thought that the solution itself was a "dissecting hydrotomy" which would catalyze the removal of fat and thus reduce trauma, as there was smaller amount of bleeding. Lllouz received worldwide publicity and promoted this method. The first US surgeon to visit France to learn the new area of liposuction was Lawrence Field in 1977, a Californian dermatologic surgeon. Other surgeons from the States, coming to conferences and educating themselves about new methods in the literature, also showed an interest in the area. One of them was Norman Martin, an otolaryngologist. He visited Illouz in 1980 and quickly started with liposuction surgeries in Los Angeles in 1981 [20, 21]. It was 1982 when a group of physicians from various specialty disciplines received lectures from Illouz and Fournier. At the annual meeting of the American Society of Plastic Surgeons (known at that time as The American Society of Plastic and Reconstructive Surgeons) in 1982, Dr. Illouz, for the first time in front of an audience of Board Certified Plastic Surgeons presented his technique of closed liposuction utilizing hollow cannulas of 1 cm in diameter connected to a suction pump with one atmosphere of negative pressure to extract fat that was pretreated with his wetting solution. The photographs (presented in carousel slide format) showed pre and pos-op photos of women who underwent liposuction of their "saddle bags" with only one cm. scars. This was remarkable in light of the existing treatment option which required large incisions (as published by Pitanguy) for the performance of dermo-lipectomies of this area. After this meeting, a task group formed by the American Society of Plastic and Reconstructive Surgeons visited Europe to learn and form opinions about this new procedure. Several pioneers in the closed technique of liposuction visited Dr. Fred Grazer after the national presentation in 1982 and I had the privilege of attending this small group course. Dr. Frank Ashley, former Chairman of the Division of Plastic Surgery at the University of California attended as well to learn this revolutionary technique. Dr. Grazer named this new procedure Suction Assisted Lipectomy. Important pioneers in the closed liposuction technique had developed cannulas which were quite aggressive when compared to the 5 mm and smaller cannulas in widespread use today. Schrudde, Kesselring, and Ilouz left their cannulas in Dr. Grazer's office and they are of historical importance as one studies the refinement in the performance of liposuction (**Figures 6–9**). Julius Newman, otolaryngologist and cosmetic surgeon, together with his associate Richard Dolsky, who was a plastic surgeon, together taught the first American course on liposuction, held in Philadelphia in 1982. The five live surgery workshops were held in Hollywood, California, in June 1983, under the authority of the American Society of Cosmetic Surgeons and the American Society of Liposuction Surgery. There were altogether 10 dermatologists in attendance. The American Society of Plastic Surgeons and The American Society for Esthetic Plastic Surgery subsequently developed teaching courses and symposia to teach closed liposuction to fully trained, Board Eligible and Board Certified Plastic Surgeons. Subsequently, the core curriculum in accredited Plastic Surgery Resident Training Programs included didactic and hands-on training in liposuction.

Figure 6.
Examples of first generation suction cannulas.

The development of the Tumescent (from Latin meaning swollen or being swollen) Technique for performing Liposuction, described in publications by Dr. Jeffrey Klein [22–26], a Dermatologist, had an enormous impact in the safe and more easily performed liposuction procedure. The formula currently includes Lidocaine 2%, Sodium Bicarbonate, and Epinephrine (1–1,000,000), added to 1 liter of Sodium Chloride (if Ringers Lactate is substituted for Normal Saline, sodium bicarbonate is not added to the solution). The tumescent technique was modified such that only a 1:1 or 1.5:1 ratio of tumescent fluid to expected aspiration volume is injected rather than a 2 or 3:1 ratio which was the initial ratio in the Klein tumescent solution. The introduction of the tumescent liposuction technique allowed for the office- based removal of fatty deposits under no sedation, minimal Class 1 sedation, intravenous sedation, or general anesthesia. (Safe guidelines and other safety considerations are described below).

As the number of cases increased dramatically over the years, important additions to the options in body contouring occurred. Lockwood's observance and, perhaps the discovery, of the SFS (superficial fascial system) [27–29] resulted in his landmark publications wherein he utilized this fascial system for important

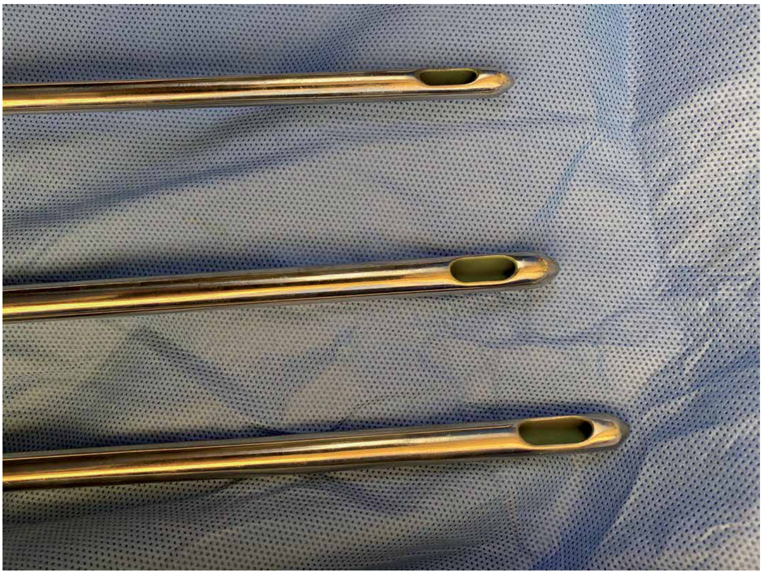

Figure 7.
Examples of first generation suction cannulas.

Figure 8.
Examples of first generation suction cannulas.

support of elevated soft tissue flaps including abdominal and lower extremity flaps that were elevated and repositioned to correct soft tissue ptosis. Liposuction was a component of his body contouring procedures. Certainly, liposuction allowed remodeling of the abdomen and lower extremities combined with, based upon the clinical anatomical findings, surgical excision of excess skin and subcutaneous tissues. Prior to Lockwood's description of the SFS, lower extremity medial thigh lifts were accompanied by migrating, unattractive scars. He also utilized the SFS in his High Lateral Tension Abdominoplasty to obtain improved contours and favorable scars as a trade-off for important excision of redundant soft tissues.

Figure 9.
Examples of first generation suction cannulas.

Prior to liposuction, upper extremity unwanted fatty deposits with or without accompanying excess skin required large excisions of skin and subcutaneous tissue with resultant unfavorable scars. Liposuction has allowed fatty deposits to be removed through small access incisions and the incisions needed for skin and subcutaneous tissue removal have decreased in length.

Combined with available energy-based devices, soft tissue retraction can be an important component to body contouring of the head and neck, extremities and anterior and posterior trunk.

Fat grafting, although introduced by Gustav Neuber (1850–1932) late in the 19th century [30], was authenticated and refined with the landmark work of Sydney Coleman [31]. He introduced structural fat grafting which required small amounts (macrografts) of fat carefully placed in parallel tunnels, separated by adjacent blood vessels which nourish the grafted fat. Without a doubt, his contribution brought fat grafting to the armamentarium of cosmetic physicians and surgeons with a method that proved that grafted fat, when obtained, processed, and carefully injected in tiny amounts (0.1 cc or less) survived. He also showed how the stem cell component of fat grafts rejuvenate the skin, improve dermatologic skin conditions, with improved texture, etc. Fat grafting has evolved to include soft tissue augmentation of the face and breast, revision of breast reconstruction, treatment of post-augmentation mammoplasty contour deformities (including capsular contracture), contour deformities from prior liposuction and/or skin and subcutaneous fat excisions, and treatment of depressed scars. It is included in High Definition Liposuction further defining the underlying abdominal wall musculature. Fat grafting has evolved to the production of smaller particles including nanofat introduced by Tonnard [32].

Recently, cosmetic surgeons have injected Tranexemic Acid (TXA) and have observed an impressive decrease in blood loss. It has been used intravenously and topically as well, but the addition of tranexemic acid to the liposuction infusion has seen its' application in closed liposuction. TXA is safe and its' application has been studied in other cosmetic procedures with a notable decrease in blood loss [33].

When one looks at the statistics regarding obesity and morbid obesity with 40% of Americans considered obese and 18% considered severely obese as of 2019 with severe obesity defined as a BMI greater than 35 (Research performed at the Harvard T.H. Chan School of Public Health) it is clear as to why liposuction which is consistently listed in position 1 or 2 of the 5 most frequently performed cosmetic surgical procedures in the U.S. and dermolipectomies (270,670 liposuction and 140,381 abdominoplasties performed by Board Certified Plastic Surgeons) are so popular, increasing in numbers yearly (American Society of Plastic Surgeons Annual Statistics, 2019). Moreover, bariatric procedures to treat morbid obesity have evolved in tandem with body contouring procedures to address excess skin throughout the body after significant weight loss.

In summary, Liposuction has evolved from the removal of fatty deposits in the neck, upper and lower extremities, and anterior and posterior trunk to artistic remodeling of the shape of the face, neck, extremities, and trunk, performed alone or in combined treatment with various energy based devices.

5. Safety considerations in performing liposuction

5.1 Combining suction lipectomy with other procedures

Safety in liposuction combines proper education, patient selection, and proper application of science while achieving the goal of esthetics. Providing safe surgery in a hospital or accredited surgery center (or Ambulatory Surgery Center (ASC) has become increasingly a topic of discussion as the roles of fat grafting (breast surgery, Brazilian Butt Lift, facial surgery, etc.) have increased. Office based procedures can be done safely and should still follow proper guidelines. As noted above, the role of wetting solutions allowed safe and reproducible results over the past several decades.

There are various oversight organizations and governmental regulations that have been well established. These are designed to help ensure patient safety. As this is not a comprehensive review of each organization, some general parameters are presented below. For those that will be using freestanding ASCs through Medicare and or Medicaid, rules include An ASC must be certified and approved to enter into a written agreement with CMS, The regulatory definition of an ASC does not allow the ASC and another entity, such as an adjacent physician's office, to mix functions and operations in a common space during concurrent or overlapping hours of operations., and ASCs are not permitted to share space, even when temporally separated, with a hospital or Critical Access Hospital outpatient surgery department, or with a Medicare-participating Independent Diagnostic Testing Facility (IDTF), as noted on CMS.gov. (REF- CMS.gov). ASCs must comply with a multitude of state as well as federal regulations and statutes. This includes proper licensing, Health Insurance Portability and Accountability Act (HIPAA) and more (REF ASCassociation.org). Furthermore, the ASC is also responsible to ensure that the providers comply with all the standards that govern ensuring professional training, equipment, medications, physical layout of the facility and operational safety. Outpatient surgery is suited best for healthy people undergoing minor or intermediate procedures (plastic surgery, ob-gyn, limited urologic, ophthalmologic, or ear, nose and throat procedures and procedures involving the extremities). However, health care reform and the Affordable Care Act of 2010 have expanded the types and complexity of surgical procedures, with much of the growth driven by advancements in anesthesia and technology. (REF AAAASF.org).

5.2 Wetting solutions and volume extractions

Wetting solutions were covered earlier in this chapter. The surgeon should become familiar with the various solutions. Furthermore, the amount of blood loss with the different must be accounted for by the surgeon to maintain safety.

(ADD TABLE FOR APPROXIMATE BLOOD LOSS?) That percentage of blood loss can range from 1% with solutions such as tumescent and superwet to nearly 40% in the infranatant with the dry technique. (REF?) Preoperatively the patient should be healthy and optimized and laboratory studies should be checked to help guide proper patient selection. These solutions can also vary in terms of lidocaine load to the patient. The surgeon should be familiar with the correct calculations to not over-deliver lidocaine to the patient as well as understanding that absorption can be variable between patients. As lidocaine absorption from the subcutaneous fat, the plasma lidocaine levels may not peak until 10–12 hours after delivery. Furthermore, chronic disease, stress, tobacco use, hormones, and more will influence the protein binding and when the peak will effect the patient. Care must be taken and individualized for each patient.

Volume extraction concerns have evolved to help protect patients, but discussions continue how to apply and ensure proper application. In general, the most commonly accepted guideline is based on "Large volume lipoplasty" as greater than 5000 cm3 of supranatant fat during a single surgery. Volumes greater than this can be done, and patient safety parameters should be utilized and regulations followed. These large volume liposuction procedures can be completed in a hospital setting or often mandate overnight monitoring. Patient age, general health and even the percentage of body surface are examples of considerations. While we have discussed lidocaine issues previously, general fluid shifts should be considered for patient safety as well. High quality teamwork and communication with all team members are critical. Volume overload, shock, pulmonary edema, hypovolemia, myocardial infarction are all risk factors, as is fat embolism. Proper teamwork, communication, monitoring, etc., are so important to add to proper patient selection.

Cannula selection is another component of patient safety, from tissue injury to contour irregularities. Proper cannula selection is a combination of education, experience, esthetic goals and more. While there is a role for some of the cannulae that can cut (release of fibrous bands) or "post-tunneling" (such as basket cannulae), the accepted safe cannula systems are generally blunt tipped. These most commonly range from 2 to 5 mm, but larger are available for harvesting and smaller are often used for fat grafting. Furthermore, the number of holes, location and patterns of the holes will all play a role in both efficiency of fat extraction and patient safety. While the cannulas play a role in patient safety, so do the aspiration devices and assistance devices (syringes, pumps, oscillating tips, energy based, etc.) must be considered for patient safety. Proper education on the devices, mechanisms of action, technique, etc. must be employed to avoid complications such as thermal injury, contour irregularities, incorrect cannula positioning and more.

Beyond the previously mentioned complications of liposuction, the surgeon must also be concerned about several other issues and these include Fat Embolism Syndrome, bleeding, and Deep Vein Thrombosis among others. Bleeding and clotting issue concerns should be addressed pre-, intra-, and postoperatively. A complete history should discuss any family history of blood clots, early myocardial infarction, multiple miscarriages, bleeding history, previous deep vein thrombosis, etc. Several measures can be done on the day of surgery such as proper patient and operating room temperature, placement and application of sequential compression devices before induction and not being removed until after the patient is fully awake (home compression therapies are also available), and even consideration for pre and post operative anti-thrombotic (chemoprophylaxis) medications. Early ambulation has been a largely accepted proper therapy to help minimize deep venous thrombosis and pulmonary embolism risk. Fat Embolism Syndrome (FES) is less understood, but classically demonstrates respiratory distress, petechial rash along with cerebral dysfunction. Other concerns include tachycardia, fever, hypocalcemia and even thrombocytopenia. FES is the syndrome that is a secondary consequence of Fat Embolism. Proper diagnosis is critical for the patient long term outcome and the surgeon should be familiar with the diagnosis and willing/able to work with other team members to get early and proper treatment for the patient.

Proper patient selection, maximizing pre-, intra- and post operative management is the responsibility of the surgeon. The surgeon should coordinate the team and maintain maximum communication so that all team members can maximize their experience and opportunities to protect the patient.

As suction lipectomy became universally accepted as a stand-alone procedure, it was quickly added to other body contouring procedures. Frequently, liposuction is performed along with reduction mammoplasty, abdominoplasty, high-definition liposuction, brachioplasty, thigh lifts, lower body lifts, gynecomastia, breast reconstruction, etc. Although liposuction can be safely added to other body contouring procedures, it has been shown to increase morbidity and mortality when combined with a full abdominoplasty especially worrisome in patients with a high BMI and/or a high Caprini score [34].

6. Evolution of energy based devices

The early methods of performing closed liposuction included hand held aspiration (Toomey syringe liposuction) connected to a cannula, or connecting the suction cannula to a suction pump with one atmosphere of negative pressure, but still requiring manual movement of the cannula to break up and remove the fat. One of the most important advances in facilitating the removal of fat in a closed system was the introduction of Power-assisted Liposuction. Several devices were manufactured and quickly adopted to facilitate the removal of fat with less effort.

Following the introduction of Power-assisted Liposuction, the development of Ultrasonic Energy based emulsification of the fat followed by suction lipectomy was introduced by Michele Zocchi, M.D. [35]. There was an evolution in the machinery required to perform the emulsification procedure, but the surviving technology was manufactured under the name of Vaser, engineered by Sound Surgical Technologies. This method of dissolving fat and causing energy to be delivered to the dermis has found its' most important application in "High Definition Liposuction", importantly advanced and refined by Alfredo Hoyos [36]. Other indications for ultrasonic emulsification of fat include the closed treatment of gynecomastia.

The technique of applying freezing temperature to dissolve the fat through apoptosis (CoolSculpt) has received important acceptance in the Cosmetic Surgery community, has enormous social media presence, but complications are common with neo-fat formation and "shark-bite" contour complications being reported.

Laser based energy has also been developed (Smart Lipo) where a small diameter probe is inserted into the fatty deposit and energy is applied to dissolve the fat. This requires a two step procedure, is quite tedious due to the small size of the fiber, with the risk of skin burns.

Radiofrequency based energy has emerged as the most commonly energy based method of emulsifying fat and stimulating fibrous septae contraction as well as dermal tightening. Impressive pre and post-op measurements of circumference are seen when this energy based system is used alone or in combination with suction assisted liposuction. Real time monitoring of internal and external body temperatures ensure safe application of the energy (InMode,Ltd., Yokneam, Israel).

Plasma based energy systems are available (Renuvion J-Plasma) which dissolve the fat, but lack sophisticated temperature monitoring.

High intensity focused ultrasound devices are available, but has enjoyed limited market penetrance due to the minimal improvement shown when compared to other energy sources.

7. Summary

In summary, physical image has always been important. The history of body contouring began with procedures that were performed for functional benefits and evolved to cosmetic improvement in multiple areas of the body. The introduction of liposuction provided an incredible option in body contouring and became the number 1 or number 2 most performed cosmetic surgical procedure. Often combined with open surgical techniques, liposuction frequently allowed procedures to be performed with smaller incisions and was advanced to allow important sculpting of the face, neck, extremities, and trunk. Fat grafting provided improved volume and contour to soft tissues. The introduction of energy based devices allowed for the tightening of fascial networks and dermal remodeling often performed along with liposuction.

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Chapter 2

The Safe Evolution of Liposuction into Liposculpture

Ali Juma, Jamil Hayek and Simon Davies

Abstract

Liposuction was described in the 1920s & popularised in 1977 by Illouz. He developed smaller diameter blunt cannulas. To add safety he also developed the wet technique to reduce blood loss. Tumescent anaesthesia described by Klein in 1987 made large volume liposuction safer allowing for more refined body contouring through significantly minimising blood loss. Liposuction journey started as mechanical debulking that evolved over the last 4 decades into a refined high definition body contouring and proportioning surgery, thus making sculpturing a shape of figurine possible. To achieve such high definition body sculpting technology including Laser, and Vaser not only added safety, however, they also achieved outcomes that cannot be matched with the older methods of liposuction, under local anaesthesia. In this chapter we aspire to discuss the journey of how liposuction evolved into body contouring surgery with large volume lipo-aspirates yet more safely.

Keywords: Liposuction, Liposcultpure, High definition body contouring surgery, Laser, Vaser, Tumescent, Safety

1. Introduction

Liposuction was described in the 1920s & popularised by Illouz in 1977. He developed smaller diameter blunt cannulas. He developed the wet infusion technique to reduce blood loss, thus adding safety.

Tumescent local anaesthesia described by Klein in 1987 made large volume liposuction safer allowing for more refined body contouring through significantly minimising blood loss without the risk of general anaesthetic. Furthermore the surgery could be carried out as a day case.

Liposuction journey started as mechanical debulking that evolved over the last 4 decades into a refined high definition body contouring and proportioning surgery. Thus making sculpturing a shape of figurine possible.

To achieve such high definition body sculpting technology including Laser, and Vaser not only added safety, however, they also achieved outcomes that cannot be matched with the older methods of liposuction, under local anaesthesia.

In this chapter we aspire to discuss the journey of how liposuction evolved into body contouring surgery with large volume lipo-aspirates yet more safely. We will also share with you our philosophy in patient selection and surgical outcomes.

2. The history of liposuction

Liposuction is defined as a technique in cosmetic surgery for removing excess fat from under the skin by suction. In this section we have focused on the history of evolution of this procedure since its inception, however, we excluded all the techniques, which originated early in the 20th century including excision or curating of adipose tissue [1, 2].

More than 4 decades elapsed when in 1975 a father and son cosmetic surgery team developed the technique of liposuction by introducing a cannula attached to a suction machine. In so doing they produced consistent results with lower risks [3].

Illouz in 1977 innovated modified liposuction blunt end cannulas of smaller diameter. He used cannulas of varied sizes thus extending the technique to the entire body. He injected saline and hyaluronidase into the fat prior to suctioning, allowing for hydro-dissection; hence reducing trauma to other tissues. This was the advent of the wet technique [4, 5].

Although initially the evolution in liposuction was related to the refinement of the blunt end cannulas the surgery was performed under general anaesthetic and in some instance without injecting fluid to hydro-dissect, which lead to significant blood loss in the lipo-aspirate.

The main evolution in the last 4 decades, however, has been with the anaesthesia and the composition of the fluid injected allowing the surgery to be performed under local anaesthetic with sedation and later also excluding sedation. This was popularised by Klein in 1987 using large volumes of very dilute local anaesthetic allowing for larger volume of lipo-aspirate and under local anaesthetic only [1, 2, 6–8].

Klein's infusion mixture included 0.05% Lidocaine, 1:1000,000 epinephrine and 10 mls of 8.4% bicarbonate per litre of saline. He also demonstrated that a large volume of this diluted mixture was safe, however, it also significantly reduced bleeding. Bleeding was a problem when using other techniques [6–8]. The tumescent technique meant less hospitalisation, reduced costs and risks to the patient even for large volumes of lipo-aspirate [9].

Liposuction uses a vacuum pump (a suction machine), however, in 1988 Toledo in Brazil used disposable syringes on which can be fitted blunt end cannulas. This technique allowed for more precision and refinement in liposuction in addition to usability of the fat to transfer. This gave the cosmetic surgeon choice; the vacuum pump assisted liposuction was used for large volumes and for more refined liposuction the syringe system was used [10, 11].

In 2006 laser assisted liposuction using coherent light to deliver energy preferentially targeting fat cells was a new advancement in liposuction surgery. The laser caused rupture of the adipocyte membrane releasing oily content into the extracellular matrix. The laser energy also leads to neocollagen formation and remodelling with reorganisation of the dermis. The fluid produced in this process was then aspirated using blunt end cannulas and a vacuum pump [12, 13].

Ultrasonic liposuction was first introduced in 1992 by Zochhi; it created an alternative to conventional blunt cannulas suction. The aim was to ease the surgeon workload, shorten surgical time, improve results of liposuction, and use smaller cannula, thus reducing tissue trauma and protecting important structures like the neurovascular bundles [14].

The ultrasonic technology required the tumescent technique to combine with the technology for safer outcomes. Titanium probes were used to deliver ultrasonic energy, followed by liposuction.

Refinement of ultrasound energy delivery using VASER technology (vibration amplification of sound energy at resonance), was first reported by Jewell on the clinical application of a third generation ultrasound device that deliver utilised pulsed low power ultrasound with high efficiency using different size small diameter strong titanium probes [15].

The energy applied to the tissues was approximately one-quarter that of previous devices, while the pulsed mode reduced heat generation. Expanded applications of VASER lipolysis and liposculpture include treatment of the male and female breast, face and neck; fibrous body areas (trunk and back), in addition to combined excisional body contouring procedures of all types [16].

Colombian plastic surgeon Alfredo Hoyos presented a vast improvement in technique in 2003 at a national Colombian meeting. Hoyos innovated the high definition liposcultpure HDL [17].

Hoyos elaborated that the nomenclature liposcultpure is not simple fat removal, but an artistic approach designed to sharpen the anatomy of the muscles through the skin. VASER high definition liposcultpure combines technology and technique unlike mechanical liposuction it reduces trauma to blood vessels, achieve better result, and removes superficial and deep fat. This allows for high levels of finesse in sculpting the human-form three-dimensional anatomy thus sharpening the body muscles details at the same time [17].

3. Infiltration techniques evolution

3.1 The dry technique

Fournier described the dry technique of liposuction in 1983, however, due to the significant volume of blood loss in the lipoaspirate reaching 20-40%, the technique has fallen out of favour [18].

3.2 The wet technique

Illouz introduced this technique and it included infiltrating 200–300 cc of infusate fluid regardless of the volume to be aspirated. The blood loss in the lipoaspirate was reduced to 8-10% [4, 5].

The wet technique evolved by introducing the addition of epinephrine further reducing the blood loss in the infranatant of the lipoaspirate as a result of the vasoconstriction of vessels, this blood loss was 4-8% [19].

3.3 The superwet technique

The superwet technique meant injecting 1 cc of infusion to 1.5 cc of lipoaspirate; Fodor 1986 described this technique. The technique meant the blood loss in the lipoaspirate was reduced to ~1% [20].

3.4 The tumescent technique

Klein, a dermatologist, introduced the tumescent technique, which lead to significant advances in performing liposuction and later liposcultpure including high definition body contouring under local anaesthetic as day cases. The lipocrit was low at 1%, which is not unlike the superwet technique. The tumescent technique was popularised in 1990s [9].

The tumescent infiltration technique uses the skin turgor and it colour change to white as end points on the volume injected in the area of liposculpture, allowing for larger volumes to be removed than other wetting solutions. The infusate to lipoaspirate is usually 2-3:1. It uses a mixture of 50 cc of 1% Lidocaine infiltrated in 1 litre of normal saline, 1 cc of 1:1000 adrenaline with 10 cc of 8.4% sodium bicarbonate solution, the later helps reduce the pain at infiltration. The pH of normal saline is 5; adding bicarbonate makes it less acidic and leaves less ionised Lidocaine outside the cell for absorption [21].

This means large volume of dilute Lidocaine with concentration of up to 35 mg/kg can be injected into the fat. This is much higher than the toxic doses when injecting undiluted Lidocaine mixture at 7 mg/kg. An added advantage of the tumescent infiltration is decreased need for intravenous fluid replacement [21].

It is of grave importance to consider the estimated volume to be removed when performing aspiration of fat. Hence, in our experience although we use the tumescent mixture of infusate; however, we tend to use infusate to lipoaspirate ration of 1:1, i.e. the superwet technique.

In our experience using the superwet technique equates to less fluid load, lower risks of local anaesthetic toxicity at diluted concentrations of Lidocaine not exceeding 35 mg/kg and limiting the infusate to no more than 4-5 litre for lipoaspirate of 4 litres.

When infusing large volumes and aspirating large volumes for example 3 litres or more one must replace for each ml of aspirated fat ~2 mls of fluid in the first 24 hours. For example in a case of 3 litres injected for 3 litres aspirated; it is estimated that ~20% of the injected fluid will be removed with the lipoaspirate. This will leave 2.4 litres in the extracellular space warranting a total fluid volume replacement of 3.6 litres in the first 24 hours.

It is important to stress that in such large volume lipoaspiration, urine output should be monitored for the first 24 hours, adding safety to the patient management.

4. Progressing from mechanical liposuction to energy delivery liposculpture

Liposuction in a large number of countries in the world is the most popular cosmetic surgical procedure. It is safe with pleasing cosmetic immediate visible results, which improve with the passage of time. In our experience in all liposuction and liposculpture techniques although results are immediate; however, they continue to improve for 6 months following the procedure, and the patients are counselled accordingly.

The evolution of liposuction into liposculpture was facilitated by advancement in technology from the early manual devices using vacuum and blunt cannulas into energy delivery machines including Laser and VASER.

4.1 Mechanical liposuction (SAL)

The 1980s and 1990s saw the introduction of three types of mechanical liposuction.

Suction assisted liposuction is a traditional method of liposuction using a blunt small cannula connected to a pressurised vacuum machine. Through a small incision the fluids infiltrated and the cannula inserted to extract the fat by high-pressure vacuum connected through suction tubing made of either polyvinylchloride or silicone [22].

The suction pump has two different performance diameters, maximum vacuum and maximum flow rate. The canisters come in different sizes from 250 ml to 3000 ml and can be reusable or disposable. Big choice of suction cannulas with different sizes, different function and all are reusable [22].

The procedure can be done under local anaesthetic depending on the area treated. It is less tiring than the syringe liposuction and faster for the surgeon to remove fat, however, it risks trauma to blood vessels and nerves.

Although (SAL) can remove the superficial fat, this comes at higher risks to the skin and its blood supply. Bruising and potential of longer recovery are also risks that have to be considered in this technique.

4.2 Syringe assisted liposuction (SaL)

Syringe liposuction technique (SaL) with blunt cannulas to extract the fat by syringe generated negative pressure and the syringe is single use [23].

The syringe technique can be slow and tiring for the surgeon to treat large areas. That is why it is recommended in treating small areas [23]. One of its advantages; it can be done under local anaesthetic as a day case or even an outpatient surgery.

The syringe technique is safe procedure; however, it has limitations. These include difficulty extracting superficial fat in addition to being challenging in treating secondary liposuction because of the resistance as a result of scar tissue [23].

4.3 Power assisted liposuction (PAL)

PAL implements either circular or reciprocating quick movements cannulas to aspirate fat. Mechanical cannula extracts the fat with small incision and shorter surgical time making it less tiring [24].

The power assisted liposuction technology was getting very popular for fat extraction and body contouring procedures. The vibrating cannula during the fat extraction makes it easier and less challenging in extracting more fibrous fat [24].

The power assisted liposuction technology has improved the surgeon's experience especially in large volume liposuction, fibrous areas, secondary work including in more superficial tissue planes. Surgeons fatigue and time is decreased during the procedure thus speeding the rate of fat extraction delivering good results for patients wishing body contouring [25].

Added benefits of PAL include intraoperative pain reduction, less swelling, and faster recovery. Fat harvested is 45% faster compared to suction assisted liposuction and syringe liposuction [26].

Another advantage of PAL is using the medinorm self-contained tank and the tubing system that guarantees the sterility. The whole system is latex free, and the harvested fat is less bloody than the manual liposuction and almost pure yellow colour making it useful for fat transfer [27].

In summary the PAL system is a convenient, fully sterile, time saving method to aspirate fat in various part of the body. This fat can also be used to transfer in other parts of the body. Furthermore donor site morbidity is minimised; and as time is saved it becomes less tiring for the surgeon and safer for the patient.

5. Energy delivered liposculpture (EDL); compared to traditional liposuction

The revolution of power-assisted liposculpture has changed both surgeon and patient's life. Over the last 20 years two energy delivery technology were invented released on the market. Energy delivery is divided into Laser and Vaser technology.

6. Laser and the Vaser systems

6.1 Laser lipolysis (LL)

Laser lipolysis technology was popularised following studies on the interaction between the laser and adipose tissue [28]. Laser assisted liposuction technology is one of the most advanced treatment of lipodystrophies and irregularities of adipose tissue. The laser beam preferentially targets the adipose tissue with which it keeps a direct contact [28].

Laser action causes the breakdown of the adipocyte membrane and releases the oily content into the extracellular fluid. It can cause neocollagen formation and remodelling with reticular dermis reorganisation [29, 30].

Laser technology has advantages and disadvantages compared to traditional liposuction and other energy delivered technology. The most common advantage is patient's quick recovery. Due to liquefaction of the fat and small laser probe size; less effort from the surgeon warranted to melt and remove the fat.

Some surgeons when treating small areas like submental, knees, thighs avoid aspirating the melted fat, further limiting direct tissue trauma. An important advantage seen in the early postsurgery stage is skin tightening related to laser energy delivery [31, 32]. Disadvantage of laser-assisted lipolysis is that the fat cannot be used for transfer following extraction. Skin burns have also been reported with Laser use [31, 32].

6.2 VASER liposculpture (VLs)

VASER energy delivery technology enabled the surgeon to melt, debulk large areas of fat including superficial fat layer, therefore creating high definition of muscles around the body (abdomen, back, arms and legs). It is imperative to avoid over-resection of fat and spare 1 cm of fat thickness from the deep dermis to avoid deep tissue scarring and irregularities [33, 34].

A Colombian plastic surgeon, Alferdo Hoyos, developed a significant improvement in the Vaser liposculpture technique adding a new approach to body contouring. He termed this High Definition Liposculpture (HDL). Dr. Hoyos defined his technique not just as a simple liposuction or fat removal, but as an artistic approach to sculpt the body and define the surface anatomy.

Vaser body sculpture technology allows the surgeon to go well beyond the simple fat removal of fatty bulges, and to use it as a sculpting tool to create the ideal profile [35].

VASER and high definition liposculpture allows great cosmetic outcomes with reduced trauma to the soft tissue and blood vessels. VASER assisted HDL breaks down the fat and allows it to be prepared for the surgeon to sculpt muscular anatomy in great details through gentle extraction aspiration, which cannot be achieved with traditional liposuction [36–38].

The combination of VASER and HDL can be challenging and more time consuming than traditional liposuction. It is important to keep in mind that VASER technology as in Laser technology adds one extra stage when compared to traditional liposuction; the emulsification of fat. High definition Three-dimensional sculpting, however, adds yet a further step namely the removal of the superficial fat [39].

Combining VASER with power assisted liposculpture-using Microair or Power-X systems atraumatically debulk the fat making it a less effortless and safer task [40]. Another advantage of the Vaser is the safety of the superficial emulsification and extraction of the fat from the subdermal lamellar layer to define relevant anatomy for each muscle group. As the subdermal plexus of vessels is not significantly affected with VASER or the PAL system, this in our opinion is a major component in safeguarding the skin blood supply allowing for further refinement in superficial fat extraction and three-dimensional body sculpting.

Vaser liposculpture technology, however, is time-consuming when used for treating large areas. Hence, we recommend it to be performed by an experienced team, and perhaps when possible more than one team working in harmony. Having an experienced team/teams adds safety, reduced surgical time, reduces surgeon's fatigue and makes for excellent patient outcomes.

It must be taken into consideration in all the techniques described in the sections above, that patient's selection is crucial in achieving the best results as much as the surgeon's experience and skills are of profound importance.

6.3 Our philosophy and liposculpture

Body contouring and three-dimensional sculpture surgeons are a self-selecting group who aspire to achieve excellence. This a commonality shared with artists who create 3 dimensional figurines.

It is important not to be bogged by the different names given to three-dimensional sculpturing of a human figure; however, the emphasis should be put on patient selection, safety, developing and refining skills. Embracing new advances in technology, is important, however, must come with appropriate training keeping patient safety at all times. We as plastic surgeons must stay true to form, and aspire to achieve more yet maintain a high level of safety and excellence in clinical outcomes.

Our philosophy is simple we use the relevant technology from traditional mechanical liposuction to energy delivery liposculpture based on what the patient and we wish to achieve.

For small areas like in submental fat removal we favour traditional syringe liposuction with fine cannulas (**Figure 1**).

When it comes to debulking and three-dimensional liposculpting we favour combining VASER, and a power assisted devices including Power-X and/or Microair for a safe, time efficient and excellent body contouring cosmetic outcomes (**Figures 2** and **3**).

Figure 1.
A 57-year-old female underwent syringe liposuction with 2 mm cannula for her neck. The figure shows preoperative and 3 months postoperative results.

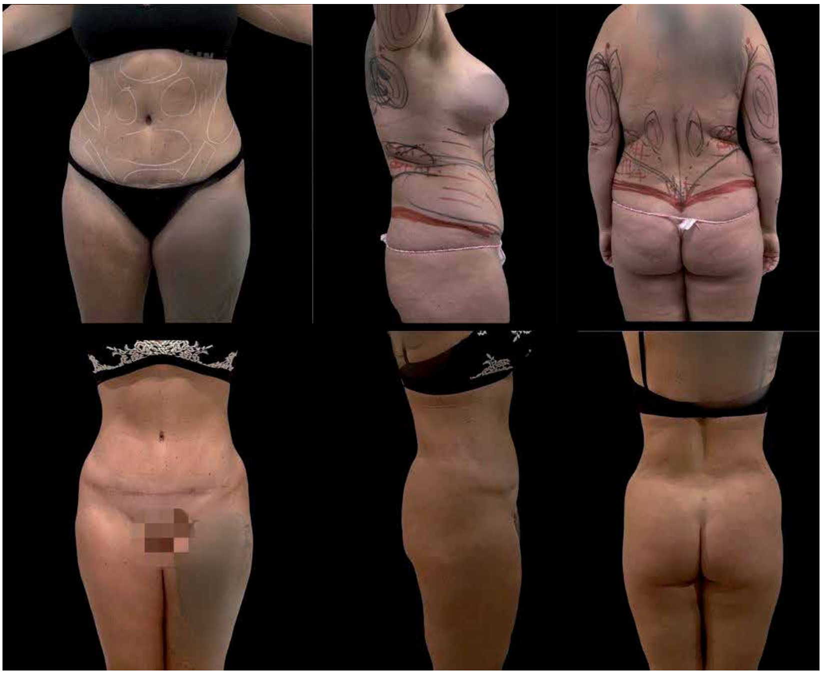

Figure 2.
A 36-year-old female BMI 28 underwent VASER body contouring and liposculpture. Figure shows preoperative and 7 months postoperative results.

Figure 3.
A 38-year-old female patient, BMI 29.5 underwent VASER body contouring, and body sculpture. The figure shows preoperative and 6 months postoperative results.

More importantly we perform a large number of the cases under local anaesthetic with or excluding sedation. This facilitates a quicker patient recovery, removing the risks of general anaesthetic yet maintaining a high level of safety.

Our choice of infiltration is normal saline 1 litre, 50 mls of 1% Lidocaine, 1:1000 1 mg of adrenaline with 10 mls of 8.4% bicarbonate to reduce the acidity of the local anaesthetic and normal saline. Tranexamic acid one gram is given intravenously 30 min prior to surgery and 4 hours after induction to reduce bruising, bleeding, and possible haematomas post op. The total dose of Tranexamic acid for the first 24 hours is 2-3 grams.

We use a ratio of infusate to lipoaspirate of 1:1, effectively the superwet technique, however, using a tumescent fluid mixture and we allow for 15-20 minutes of time prior to commencing the treatment. Accepting that BAAPS, ASPS, ASAPS limit the lipoaspirate volume to 5 litres per session; however, in our practice and based on our philosophy and experience we limit the lipoaspirate to 4 litres in any one sitting for safety reasons with an infusate of up to 4 litres. Hartmann's solution is another choice for the infusion mixture instead of normal saline as it is less acidic with a lesser sodium load thus reducing fluid overload in large volume liposuction. We do not exceed a Lidocaine dose of 35 mg/kg and we do not exceed an adrenaline dose of 0.07 mg/kg.

7. Patient selection and peri-operative management

We consider the BMI is one of the main factors in patients' selection and the choice of surgery to achieve safest and best results. We adhere to a BMI of 30 kg/m^2 or less for liposuction and body contouring. For high definition body contouring and three-dimensional sculpting our choice of BMI is 26 kg/m^2 or less. The patients are ASA I-II (American Society of Anaesthetist classification); smoking must stop 4 weeks before surgery, and 3 weeks after. Non-steroidal anti-inflammatory drugs must stop usually 48–72 hours before surgery.

We ask patients to stop certain herbals, which increase bleeding 2-3 weeks prior to surgery. The combined contraceptive pill and HRT are stopped 4-5 weeks before surgery and not commenced for 3 weeks after. All patients undergoing abdominal contouring undergo pre-operative ultrasound investigation.

TED stocking are used to reduce risk of deep vein thrombosis in addition to intraoperative compression boot in all cases. In long procedures low molecular weight heparin is used until the patient is deemed fully mobile.

Seamless compression garments are used in all liposuction patients; however, when we perform three-dimensions high definition liposculpture we add appropriate soft padding to help maintain the contouring where it was created. The garments are worn for 4-6 weeks. The patients also undergo manual lymphatic drainage for the first 3 post-operative weeks.

Since COVID-19 pandemic the patient is asked to shield with the appropriate period, which differs between countries and a PCR antigen test carried out 2-3 days prior to surgery. Following the surgery we ask the patient to shield for a period of 10 days too.

If the patient has been vaccinated then we allow 10 days prior to surgery; however, if the patient has a positive COVID-19 test we defer the surgery for a minimum of 8-12 weeks and repeat the PCR test.

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Section 2

Science and Physics of Liposuction and Energy Based Devices

Chapter 3

The Basic Science of Radiofrequency-Based Devices

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Abstract

This chapter outlines the basic science and specific principles of operation for radiofrequency (RF) technologies with a focus on minimally-invasive applications enhancing liposuction procedure. Before discussing the parameters, settings and techniques for radiofrequency-assisted lipolysis (RFAL) and fractional RF subdermal treatment, it is important to understand the fundamentals of the basic science of RF technologies and applications. The chapter accurately describes the physics of the processes occurring during RF-based treatment, and the factors affecting its safe and efficacious outcome. The discussion of RF-based devices will use terminology and definitions provided by FDA guidance for electrosurgical devices. Measurements and computer simulations conducted by the authors to illustrate importance of different parameters for the specific treatments of skin and subcutaneous fat are also presented.

Keywords: radiofrequency, monopolar, bipolar, RFAL, micro-needling

1. Introduction

1.1 RF treatment effect

The method of operation for the vast majority of esthetic energy-based devices (EBD's) is through the generation of heat causing physiologic modifications to the human tissue. RF energy is a method to deliver heat into the human body at a level and distribution required for the specific application. For sub-necrotic thermal applications, this heat can be a relatively low temperature for fibroblast stimulation and metabolism acceleration (hands free RF devices). Alternatively, the heat can be more aggressive, ablative coagulative and necrotic in nature (RF assisted lipolysis or Fractional micro-needling technology). It may occur that during the same treatment, RF energy effects will be both non-ablative on the skin and ablative-coagulative sub-dermally.

In most instances with RF, microwave and light-based technologies, heat is the result of a common pathway for the desired thermal effects. This understanding has given rise to an entire generic category of esthetic and medical EBD's. A variety of technologies and devices have been developed based on thermal treatment of tissue, either ablative or non-ablative, selective, or non-selective, using optical energy, RF electrical current, focused ultrasound to generate the heat. The common outcome of these devices leads to some heat-assisted transformation of local tissue. This thermally stimulated tissue alteration or remodeling typically results from:

- Selective thermal targeting of tissue by focusing energy at the desired spot internally or externally. Energy can be delivered to the selected volume in a minimally invasive manner by focusing energy to penetrate the tissue under the skin surface. An example of a minimally invasive treatment is electro-surgical devices which deliver thermal energy into the body via a tiny cannula or needle. Alternatively, electrocautery devices focus the energy on the tissue surface, ablating the tissue in proximity of the tip of the instrument to dissect the a soft tissue.

- Non-selective bulk heating, used mostly for sub-necrotic heating to stimulate natural processes in the body leading to increased production of collagen, elastin and ground substances. The result may include tissue tightening, circumferential reduction and wrinkle reduction.

RF energy is an important part of the armamentarium for treatment options comprising tissue cutting and coagulation, minimally invasive selective tissue targeting and bulk heating. RF current is the accepted type of energy used in four out of five surgeries conducted in the world and most industry leaders in the aesthetic field employ RF energy in at least one of their applications.

2. What is electromagnetic energy?

Electromagnetic (EM) energy travels in waves and spans a very broad wavelength spectrum from DC voltage, to very short wavelengths in gamma radiation (**Figure 1**).

RF energy is small part of electromagnetic spectrum having frequencies in the range of Kilohertz to Gigahertz. The shorter wavelength and the higher frequency, the more energetic are quanta of EM radiation and the more destructive it can be for the tissue. RF energy, Microwaves, Infrared and Visible Light has relatively low frequencies and represent non-ionizing radiation which is not able to modify the DNA (genes) inside the cells. High frequency radiation as UV, X-ray and Gamma are ionizing radiation which in natural conditions is generated by plasma or by radiative isotopes.

A very small part of RF spectrum range is used in EBD, and its properties will be the primary focus of the current chapter.

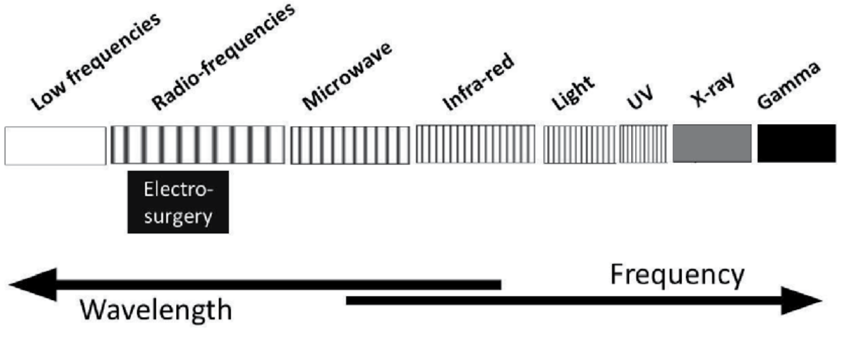

Figure 1.
Electromagnetic Spectrum.

3. The history of RF

RF energy has been used in medicine for over 100 years. Nikola Tesla, (1856–1943), Croatia-born electrical and mechanical engineer, is reputed as being the father of alternating high frequency current. But it was Dr. William Bovie (yes, of

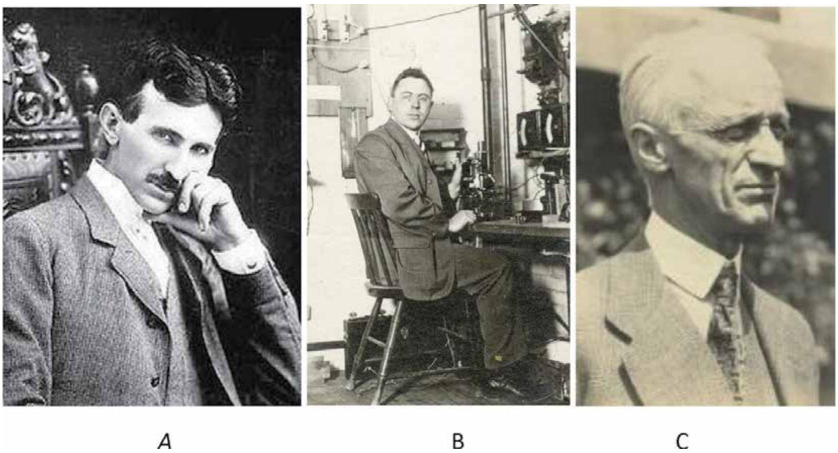

Figure 2.
The early pioneers of RF energy in medicine, [6] (A), [7] (B) and [8] (C).

the “Bovie cautery fame”) that developed the first electrosurgical device during the period of 1914–1927 at Harvard University [1]. The first reported use of an electrosurgical generator in an operating room occurred on October 1st, 1926 in a surgery performed by Dr. Harvey Williams Cushing [2, 3]. Since Dr. Bovie introduced RF energy and the electrocautery, RF had been used for ablation [4] and coagulation [5] in surgery and medicine. Over the past 20 years, RF energy has evolved and come to dominate esthetic medicine (for good reasons, as will be explained in this chapter). RF was first being used in non-ablative form for skin collagen remodeling and other esthetic applications (**Figure 2**) [9, 10].

4. Radiofrequency in medicine

The specificity of RF energy in medicine is that it acts as an electrical current flowing through the tissue but differently than radiation. RF energy is associated with electro-surgical devices and can be defined as high frequency alternating electrical current heating soft tissue without significant electrical nerve stimulation. It is critical to minimize nerve impact to avoid electric shock which may cause muscle spasm and cardiac arrest.

It is important to remember that tissue has ion conductivity with the most prominent varieties being Na+, K+, and Cl– (sodium, potassium, and chlorine ions respectively). Nerves are affected as a result of ion penetration through the membrane of neuron. Under normal conditions the nerve is surrounded by electrically neutral liquid where ions with positive and negative charge compensate each other and bound by Coulomb force preventing free diffusion of the electrical charge. As an electrical field is applied the ion starts to move and the nerve stimulating effect depends on ion displacement (D) in alternating electrical field that can be presented as following:

$$\boldsymbol{D} \sim \frac{\boldsymbol{\mu}\,\boldsymbol{E}}{\boldsymbol{f}} \tag{1}$$

where $\boldsymbol{\mu}$ is mobility of ions which is proportional to conductivity of tissue σ; $\boldsymbol{E}$ is electrical field strength; $\boldsymbol{f}$ is frequency of electric field.

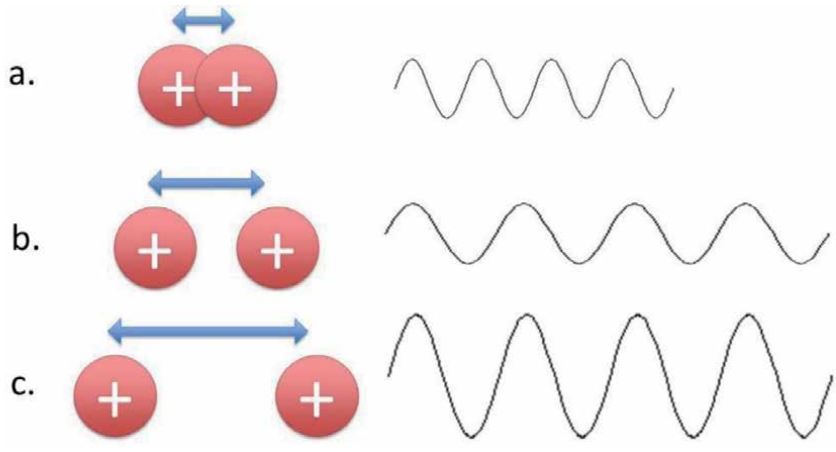

Figure 3.
Ione displacement for a) low amplitude and high frequency of electric field; b) low amplitude and low frequency; c) high amplitude and low frequency.

It is obvious the displacement of the ions is higher when electrical field is stronger and it is applied for longer time (**Figure 3**).

In general, polarity of RF voltage is changed so fast that ions vibrate in the same place without significant movement. However, users of RF may occasionally observe small muscle tweaking when high RF parameters are used. Therefore, RF energy used in electrosurgery is limited by lowest frequency of 100 kHz, while the recently developed esthetic devices operate at frequencies above 300 kHz.

The typical range of RF is 100 kHz to 5 MHz according to the FDA guidance [11]. This is intended to exclude other frequencies that may technically fall within the RF portion of the electromagnetic spectrum, but operate in a fundamentally different manner. However, there are few products with higher RF frequency of up to 40 MHz. If RF is higher than 5 MHz there is significant radiative component with reduced capability to predict the distribution in the patient's body and can even potentially affect the treatment attendant.

The ions oscillating in RF field interact with the surrounding tissue, losing its kinetic energy and generating the heat. The heat generated by electrical current in conductive media is described by Joule's law:

$$\boldsymbol{H} = \boldsymbol{\sigma} \boldsymbol{E}^2 \quad (2)$$

The heat generated in each point of tissue is proportional to tissue conductivity ($\boldsymbol{\sigma}$) and square of electric field ($\boldsymbol{E}$).

The Ohm's low in vector form allows to calculate the density of RF current ($\boldsymbol{j}$) in each point of tissue:

$$\boldsymbol{j} = \boldsymbol{\sigma} \boldsymbol{E} \quad (3)$$

While continuity equation allows to analyze RF current distribution in the tissue

$$\nabla \cdot \boldsymbol{j} = \boldsymbol{0} \quad (4)$$

The Eq. 4 states that electrical current coming into any volume of tissue is equal to the current going out of the same volume (**Figure 4**).

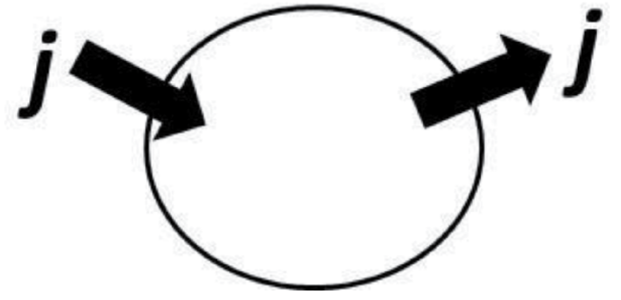

Figure 4.
Schematic illustration of continuity law.

The other conclusion from the charge continuity equation is that all RF current emanating from one electrode into the tissue flows to the other electrode. The current density on the electrode surface depends on the size of the electrode.

5. RF penetration depth

Penetration depth of RF energy depends on the electrode geometry and divergence of the RF current inside the tissue. We will determine RF penetration depth as the depth where RF energy is decreased by exponential factor (e = 2.71 …) and analyze a few typical cases (**Figure** 5).

The first case in **Figure 5** illustrates small electrode distant from the return electrode. The RF current density and consequently electric field in vicinity of the electrode diverges spherically and current density drops as square of distance from electrodes. Taking into the account that heat is proportional to square of electric field. Therefore, heat created by RF energy can be represented as following:

$$H = \sigma E_o \left(\frac{r_0}{r_0 + d} \right)^4 \tag{5}$$

Where E_0 is electric field on the surface of semispherical electrode, r_0 is radius of electrode and d is distance from the electrode. It is easy to calculate that heating drops by exponential factor at $d = 0.28\ r_0$. For the electrosurgical electrode having tip with radius about 0.5 mm the RF penetration into the tissue is about 140 microns. Such small RF penetration depth allows to cut the tissue with minimal thermal damage.

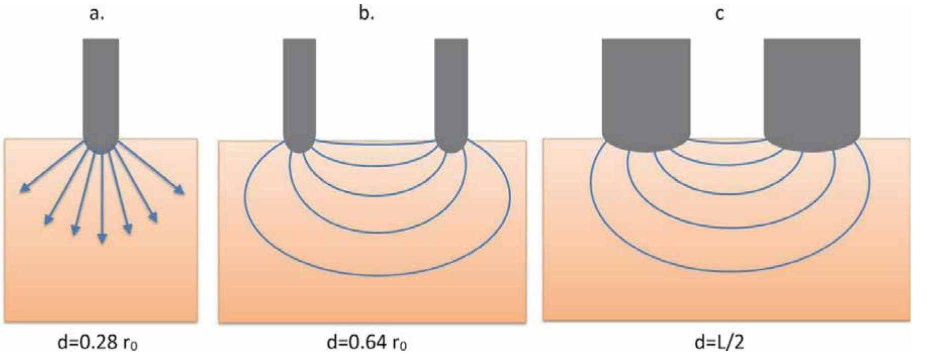

Figure 5.
RF current distribution for typical geometries of electrodes.

Figure 5b shows two long electrodes having cylindrical surface contacting the tissue. The distance between the electrodes is larger than an electrode size. In this case the heat distribution near the electrode can be calculated using the following equation:

$$H = \sigma E_o \left(\frac{r_0}{r_0 + d}\right)^2 \tag{6}$$

The heating drops by exponential factor at the distance of $d = 0.64\ r_0$. Such configuration of esthetic devices is commonly used, but the penetration depth is limited and most of the energy is concentrated near the electrode.

The case shown in **Figure 5c** represents two parallel electrodes having size comparable with the distance between them. Analysis of heat distribution required computer simulation but RF penetration depth can be estimated as half distance between the electrodes [10].

The thermal measurements conducted for the three cases described above are shown in **Figure 6**.

Thermal experiments were conducted using porcine tissue and a RF generator with the frequency of 1 MHz and 50 W power. The thermal camera FLIR A320 was used for thermography of tissue during RF application.

Heat conductivity, real geometry of electrodes and non-uniformity of tissue effect the thermal imaging but measurements correlate well with theoretical consideration.

6. Tissue conductivity and impedance

The electrical properties of tissue play important role in understanding of RF-tissue interaction.

Tissue conductivity is a strong function of tissue type. The fundamental article of Gabriel et al. [12] summarized data on electrical conductivity for different types of tissue. **Figure 7** shows tissue conductivity of fat and skin in broad range of frequencies.

In the RF range, the tissue conductivity is a weak function of frequency. The tissue has resistive and capacitive properties. The capacitance of tissue in RF diapason is determined by recharging of cell membrane.

The properties of different types of tissue are presented in **Table 1**.

Our measurements in-vivo for tumesced adipose tissue show that fat's conductivity is very similar to the one of skin and is in the range of 1 to 2 S m^{-1}.

Conductivity of tissue is a function of temperature and is changed in the range of sub-necrotic heating by 2%/°C [13]. Our measurements of tissue conductivity

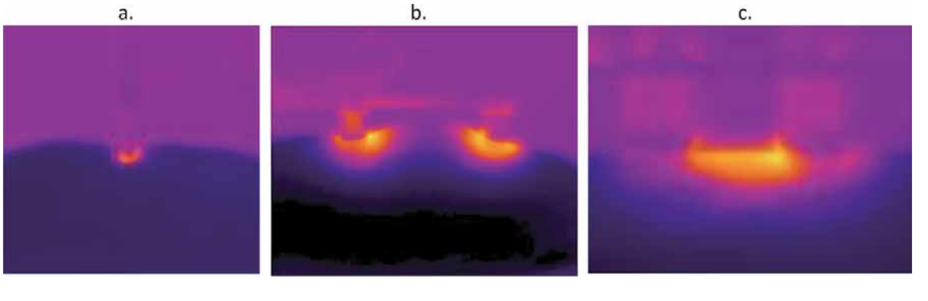

Figure 6.
Thermal measurements of tissue temperature generated by RF current for typical geometries of electrodes.

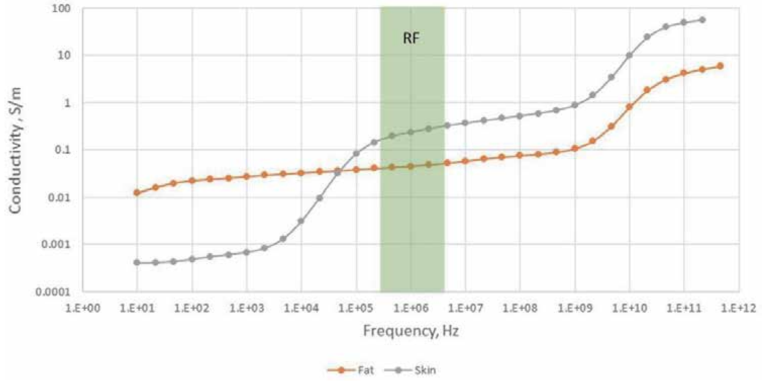

Figure 7.
Electrical conductivity of skin and fat as a function of frequency of electrical current.

Tissue	Conductivity, S m^{-1}
Blood	0.7
Skin	0.25
Fat	0.03
Bone	0.02

Table 1.
Tissue conductivity at 1 MHz [12].

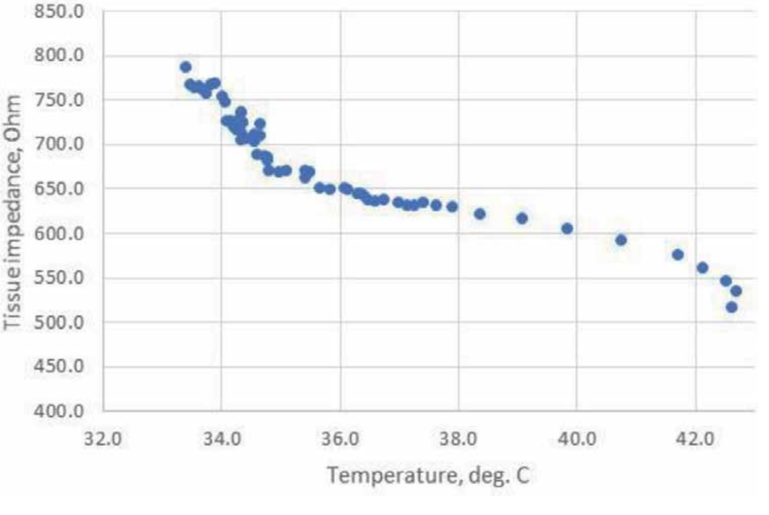

Figure 8.
Impedance of tissue measured between two electrodes applied to the skin surface.

between two electrodes in-vivo showed smaller change for the temperature close to the normal body temperature and larger change when tissue temperature deviated more (**Figure 8**). The tissue was pre-heated to 43 °C during 15 min and then tissue impedance was measured for short RF pulses during two hours as skin cooled down.

As tissue is heated to higher temperatures resulting in tissue coagulation and dehydration, the tissue impedance is increased dramatically [10]. Schematic change of tissue impedance as function of temperature is shown in **Figure 9**.

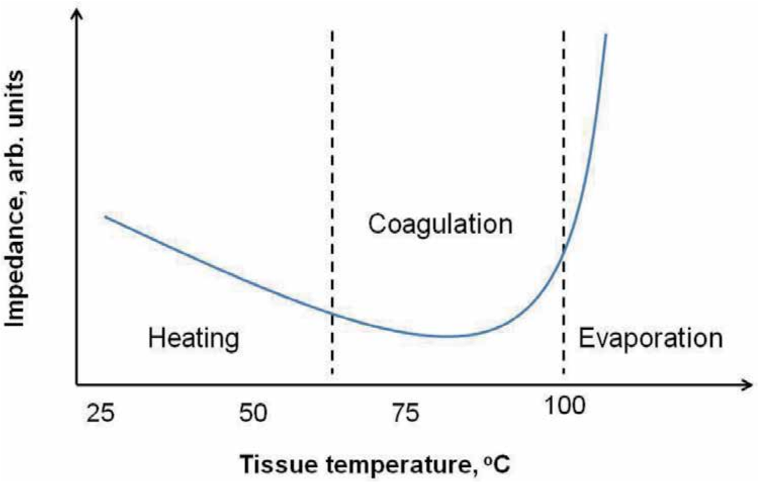

Figure 9.
Schematic impedance behavior as function of temperature.

As mentioned above regarding conductivity, heating of tissue reduces its impedance with a rate of about 2% per degree Centigrade [13]. This change is related to reduction of tissue viscosity which is reduced with temperature increase. Coagulation of the tissue causes a chemical change in tissue structure, subsequently changing the trend of impedance behavior. When heating up to 100 °C, the evaporation of liquids dehydrates the tissue, dramatically increasing tissue impedance. Additional heating of the tissue leads to its carbonization. Dependence of tissue conductivity on temperature is utilized by ELOS (Electro optical synergy) technology where tissue is preheated using optical energy creating a preferable path for RF current [14, 15]. This can provide treatment advantages for some applications.

7. RF waveform

The RF energy can be delivered in continuous wave (CW) mode, burst mode and pulsed mode (**Figure 10**).

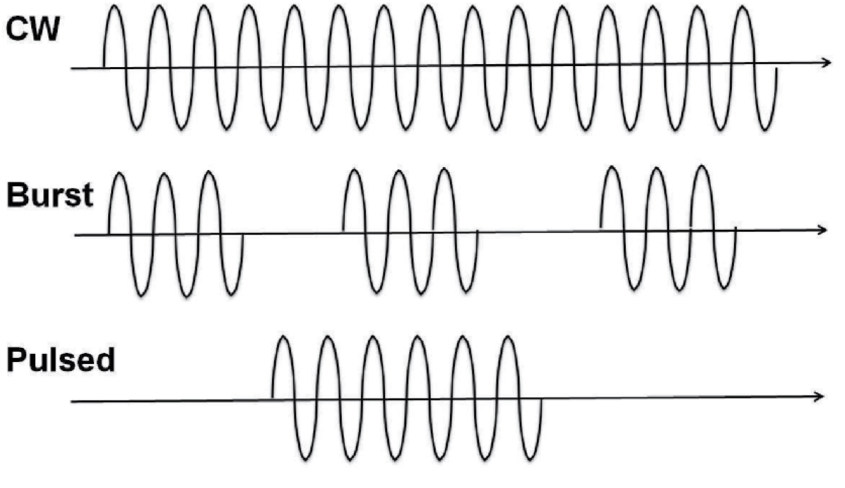

Figure 10.
Typical RF waveforms.

For gradual treatment of large areas, the CW mode is most useful, allowing for the slow increase in temperature in large tissue volume. It is used for treatment of cellulite, subcutaneous fat and skin tightening. CW mode typically delivered in device intended for moving over the treatment area.

The burst mode delivers RF energy with repetitive pulses of RF energy. It is used in applications where peak power is important while average power should be limited. Such an example would be blood coagulation. Also, it is used in hands free devices where energy is added by small portions maintaining the required temperature.

Pulsed mode is optimal when small tissue volume should be affected without heat spreading to the surrounding tissue. Pulsed mode is used in micro-needling devices.

8. Effect of spot size

In order to create tissue ablation, very high energy density is required. In electro-surgical cutting instruments, a very small electrode, or needle type electrode is used to concentrate electrical current to very small area, which increases the energy density to ablative levels. Coagulation instruments, which create energy and thermal profiles coagulating the cells and shrinking the collagen, usually have larger surface area electrodes than ablative devices. Typically, the surface area of such electrodes is a few square millimeters to generate heat in larger volume but at a lower level to create coagulation rather then ablation. Sub-necrotic heating is usually used for treatments related to stimulation of natural processes in the tissue, such as collagen remodeling, revascularization, speeding fat metabolism. In this case the spot size is about 1 square centimeter or larger. Schematical illustration of spot size effect is shown in **Figure 11**.

Generally, the smaller the electrode, the higher the energy density and the effect tends to be ablative (e.g., cutting cautery tips), whereas larger sized electrodes, have a gentler tissue effect, either coagulation (hemostasis) or sub-necrotic tissue heating [16].

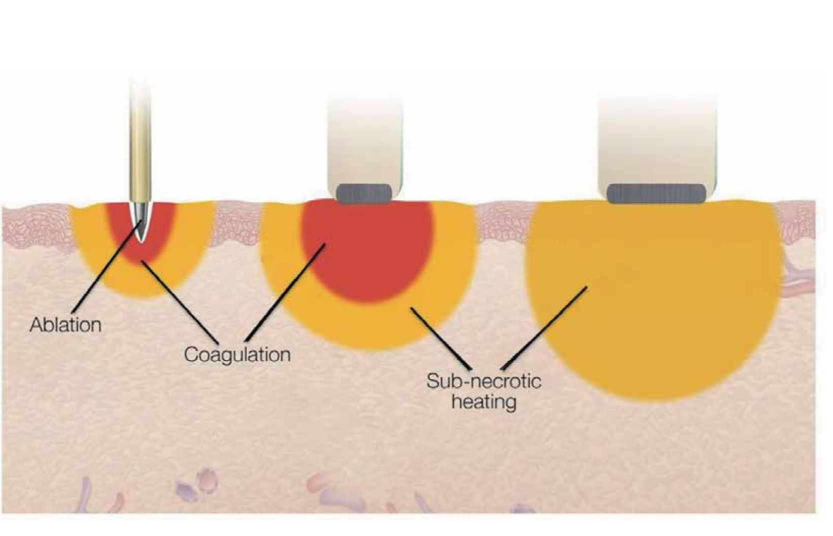

Figure 11.
The effect of electrode size, or spot size on the energy and power density.

9. Monopolar RF systems

RF current always flows between two electrodes having opposite polarity. The FDA definition of monopolar devices relates to the size and position of electrodes in respect to patient during the treatment. According to FDA guidance [11], monopolar is an electrosurgical technique in which the current flows from a single active electrode at the surgical site, through the patient, to a relatively distant return electrode.

The most common feature of a mono-polar device is a single electrode applied in the treatment area while the return electrode has a much larger contact surface and is placed outside of the treatment zone, usually in the form of a grounding pad. In this electrode geometry, the high RF current density is created near the active electrode and RF current diverges toward the large return electrode. The heat zone for this geometry can be estimated using analytic spherical model for continuity equation stating that electrical current flows continuously from one electrode to another.

$$\nabla_r \boldsymbol{j} = \boldsymbol{0} \tag{7}$$

Taking into account Ohm's law in differential form (Eq. 3) and the definition of an electric field, Eq. 5 can be rewritten as:

$$\frac{\boldsymbol{1}}{r^2}\frac{\partial}{\partial r}r^2\frac{\partial \varphi}{\partial r} = \boldsymbol{0} \tag{8}$$

Where $\boldsymbol{\varphi}$ is the potential of the electric field. The solution for this equation provides RF current density distribution between electrodes.

$$\boldsymbol{j} = \frac{\sigma V r_0 R}{r^2\,(R - r_0)} \tag{9}$$

Where $\boldsymbol{\sigma}$ is tissue conductivity, $\boldsymbol{V}$ is voltage between electrodes, $\boldsymbol{r_0}$ is radius of small electrode and $\boldsymbol{R}$ is the radius of the large electrode.

For the instance when the return electrode is much larger than the active electrode, the equation can be simplified as:

$$\boldsymbol{j} = \frac{\sigma V r_0}{r^2} \tag{10}$$

Correspondently, heat power according to Joule's law can be estimated as:

$$\boldsymbol{P} = \frac{\sigma V^2 r_0^2}{r^4} \tag{11}$$

This simple equation leads to a few interesting conclusions:

Heat generated by RF current near the active electrode does not depend on position of the return electrode when return electrode is much larger in size than the active electrode and located at a distance which is much larger than the active electrode size.

Heating decreases dramatically as distance increases from the active electrode. As was shown before, RF energy penetration depth is about one third of electrode radius (**Figures 5** and **6**). However, heating temperature on the electrode surface may reach hundreds of degrees centigrade and coagulation effect may be extended much larger than RF penetration depth. The other factor enlarging thermal zone is heat conductivity spreading heat around.

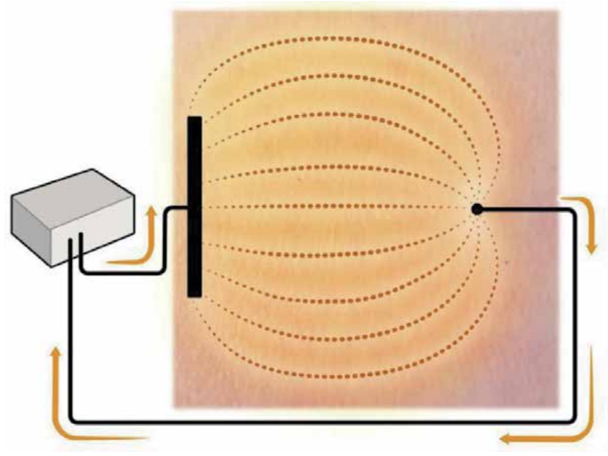

Figure 12.
Schematic RF current distribution between electrodes for monopolar system.

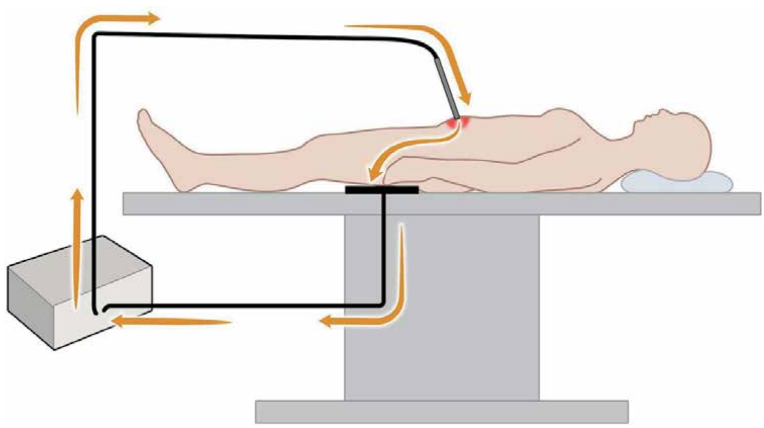

Figure 13.
Electrical current flowing through the patient and monopolar electrosurgical device.

RF current behavior in the body for monopolar systems is visualized schematically in **Figure 12**.

RF current is concentrated on the active RF electrode and rapidly diverges toward the return electrode.

Monopolar devices are most commonly used for tissue cutting. Schematically, the RF current flow through the patient for monopolar devices is shown in **Figure 13**.

The RF current is always flowing through a closed loop via the human body. As we showed above, the current density out of the vicinity of the return electrode is negligible. However, a malfunction where some low frequency current escapes out of a monopolar configuration holds high risk because the entire body is exposed to the electrical energy. Most commercially available devices have isolated output to avoid any unexpected RF current path to the surrounding metal equipment.

Treatment effects with monopolar devices depend on RF power and size of electrode. The classic use of monopolar technique is tissue cutting and ablation while occasionally it is used for soft tissue coagulation or sub-necrotic heating [9, 17–19].

The main features of monopolar devices are:

- Predictability of thermal effect near the active electrode
- Ability to concentrate energy on a very small area
- High non-uniformity of heat distribution which is strong at the surface of the active electrode and is reduced dramatically at a distance exceeding the size of electrode, thereby limiting penetration depth

10. Bipolar RF systems

According to FDA [11], bipolar is an electrosurgical device in which the current flows between two active electrodes placed in close proximity. In bipolar devices both electrodes create a similar thermal effect and are applied to the tissue treatment area (**Figure 14**). Bipolar devices create larger thermal zones and this circuit is used in electro-coagulators. The advantage of bipolar systems is the localization of all RF energy in the treatment zone (**Figure 14**).

Bipolar devices concentrate all RF energy between electrodes in the treatment area. This geometry is more suitable than a monopolar system to create uniform heating in larger volume of tissue. In order to understand heat distribution between electrodes the following three rules should be taken into the account:

- Heating is always higher near the electrode's surface and reduces with a distance because of current divergence. Divergence of RF current between electrodes reduces current density and correspondently generated heat.
- For any geometry, RF current density is higher along the line of shortest distance between the electrodes and reduced with distance from the electrodes.
- RF current is concentrated on part of the electrode having high curvature creating the hot spots.

A schematic distribution of electrical currents in uniform media in bipolar device is shown in **Figure 15**.

In bipolar devices, both electrodes create an equal thermal effect near each of the electrodes and the divergence of RF current is not as strong because of the small

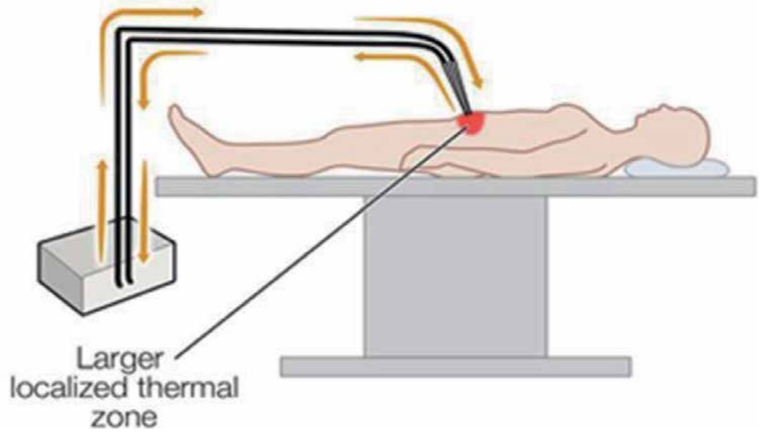

Figure 14.
Electrical current flowing through the patient and bipolar electrosurgical device.

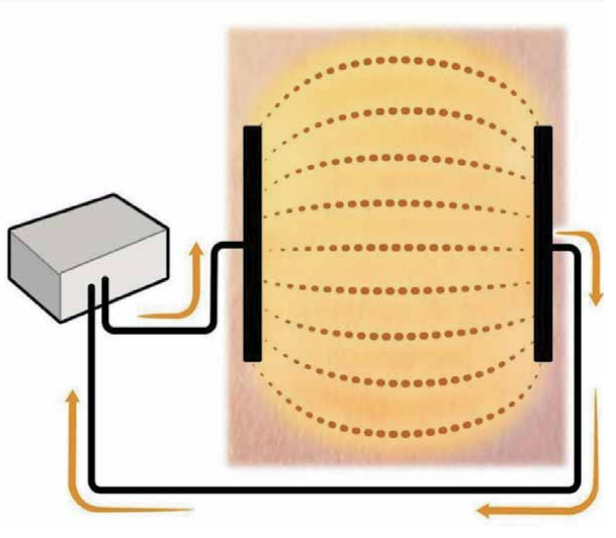

Figure 15.
Electrical current distribution for bipolar system.

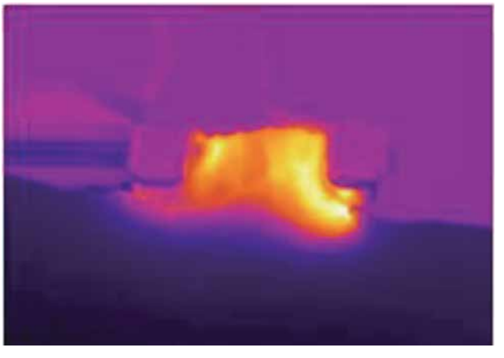

Figure 16.
Thermal image of heat distribution created in the skin folded between two parallel electrodes.

distance between the electrodes. For bipolar systems shown in **Figure 15**, most of the heat is concentrated between the electrodes.

Penetration depth of RF for bipolar devices is a function of electrode size and the distance between them. By increasing the distance between the electrodes, the electrical current can go deeper, but divergence is also increased. In case the distance between the electrodes is much larger than the electrode size, the heating profile will be similar to two monopolar electrodes. Schematically, bipolar current distribution and measured thermal effect are presented in **Figures 5b** and **6b**, respectively.

The most uniform distribution of RF current is obtained in planar geometry when tissue is placed between two large parallel electrodes. This can be realized when negative pressure forces the tissue to fill the cavity between the parallel electrodes. Measured RF energy distribution for the cavity filled with the tissue is shown in **Figure 16**.

11. Capacitive coupling of RF energy

High frequency current is able to penetrate through the dielectric material which behaves as capacitor. This effect is used to isolate metal electrode from patient. This method is called capacitive coupling. There are a number of devices in the medical esthetic market that use this technology for RF delivery [18, 19].

The capacitance of planar dielectric layer is described by the following equation:

$$C = \frac{\varepsilon\varepsilon_0 S}{L} \tag{12}$$

Where ε is dielectric constant of dielectric material, ε_0 is the vacuum permittivity, S is area of dielectric and L is thickness of the layer.

Impedance of the dielectric layer depends on frequency of current (f)

$$R = \frac{1}{2\pi f C} \tag{13}$$

For example, polyimide layer with area of $4cm^2$ and thickness of 100micron has capacitance of about 106 pF and impedance of this layer is 1.5 kOhm at 1 MHz and 375 Ohm at 4 MHz.

For cylindrical geometry capacitance is represented by the following equation

$$C = \frac{2\pi\varepsilon\varepsilon_0 L}{\ln\left(\frac{b}{a}\right)} \tag{14}$$

Where a is inner diameter and b is outer diameter of dielectric coating.

The leakage of RF current through the dielectric coating should be taken into the account at design of electro-surgical instruments.

12. Thermal relaxation time

The temperature dissipation is characterized by thermal relaxation time (TRT) of the targeted area. For localized treatment, in order to avoid significant heat transfer, the pulse duration should be less than the TRT.

The TRT is a function of tissue thermal properties, heated volume shape and size. Soft tissue has thermal properties close to the water.

For the planar object the TRT can be estimated as [20].

$$TRT = \frac{d^2}{4\,a} \tag{15}$$

Where d is thickness of layer, and a is tissue diffusivity. Diffusivity is equal to tissue conductivity divided by the heat capacitance and measured in $cm^2\,s^{-1}$.

For a cylindrical object, such as a blood vessel or hair, a similar equation can be used with different geometrical factors.

$$TRT = \frac{d^2}{16\,a} \tag{16}$$

where d is object diameter; one can see that cooling time is square function of the size.

Thermal relaxation time should be taken in to the account when thermal effect should be localized. It is critical in fractional RF technologies when thermal coagulation should by limited by small zones around the needle electrodes.

13. Tissue modification by RF energy

The thermal effect of RF on tissue is not different from laser or any other heating method. Multiple studies [21, 22] discuss the temperature effect on tissue. Since treatment effect is not only a function of temperature, but also of the period of time (when this temperature is applied), it is known that in the millisecond range the coagulation temperature is 70-90 °C, while if temperature is applied for a few seconds, the temperature of 45 °C causes irreversible damage. Hyperthermia studied intensively for treatment of cancer confirms strong dependance of tissue vitality on time that temperature is maintained [23]. RF induced hyperthermia was measured for adipocytes in a clinical study [24]. The fat cell viability was 89% after RF heating for 1 min at 45 °C while after heating during 3 min the vitality dropped down to 40% (**Table 2**).

There is extensive data on the correlation between tissue temperature, pulse duration and treatment effect. Moritz and Henriques demonstrated that the skin thermal damage threshold is a function of temperature and time [25]. Later it was demonstrated that skin damage function can be described by Arrhenius equation where pre-exponential factor is a linear function of pulse duration [22].

$$\boldsymbol{D} = \boldsymbol{At}\ \mathbf{exp}\left(\frac{-\boldsymbol{\Delta E}}{\boldsymbol{RT}}\right) \tag{17}$$

Pulse duration is one of the most critical parameters when utilizing RF energy in order to achieve a clinical response. It affects treatment results because timing influences the thermo-chemical process in tissue. The other effect of pulse duration is energy dissipation away from the treatment zone due to heat conductivity from the exposed area to the surrounding tissue.

In other words, the degree of damage is a linear function of pulse duration and an exponential factor of tissue temperature. This means that tissue temperature is more influential on the degree of damage than the pulse duration.

It is well known that sustained hyperthermia at 42 °C for tens of minutes causes death of most sensitive cells such as in the brain [26]. In laser medicine the pulse duration in the millisecond range causes tissue to burn at a temperature above 60-70 °C.

Dehydration and carbonization of the ablated treated tissue may cause the accumulation of a non-conductive tissue layer on the electrode surface. This tissue is sometimes called eschar and if it accumulates on the surface of the treatment electrode, it may affect significantly the energy delivery to the electrode and hence

Temperature	Tissue effect
37-44 °C	Acceleration of metabolism and other natural processes.
45–50 °C	Conformational changes, hyperthermia (cell death)
50–80 °C	Coagulation of soft tissue
50–80 °C	Collagen contraction
90–100 °C	Formation of extracellular vacuoles, evaporation of liquids
>100 °C	Thermal ablation, carbonization

Table 2.
Tissue thermal effect.

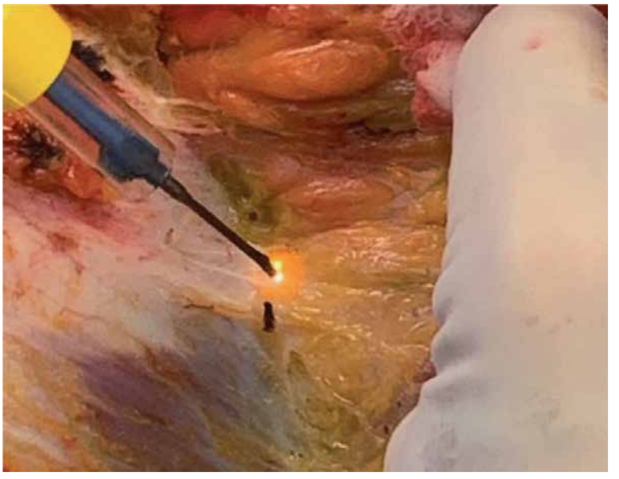

Figure 17.
Cutting Bovie electrocautery, with an eschar built upon the fine needle tip.

the treatment zone or even damage the hand piece. Carbonization or Eschar reduces or totally blocks the working area of electrodes and affects treatment efficiency, reducing the electrical current flow to the tissue (**Figure 17**).

Usually, the surgeon must clean an electro-surgical instrument periodically during the treatment to remove any eschar from the treatment electrode. Alternatively, companies, like InMode created a technological solution avoiding this problem. In InMode devices, impedance monitoring measures the increase resistance to flow (increased impendence) caused by eschar on one of the electrodes and cuts off the RF energy and flow of RF current briefly, minimizing the risk of the eschar built up at all.

The most important tissue modification induced by RF heating is a contraction of collagenous tissue. This effect is known for decades and is used intensively in orthopedy [27, 28] and ophthalmology [29].

Skin contraction was a primary focus for the first RF devices in esthetic medicine [9, 15, 17, 19]. Only in the last decade there is the understanding that the skin appearance is more affected by collagen in the reticular dermis and fibro septal network (FSN) binding skin with superficial fascia and muscles. A study published in 2011 [30] showed that skin has very dense collagenous tissue and shrinkage of collagen fibers is limited, while connective tissue in the subdermal space may contract above 30% during a few seconds of heating. The threshold temperature for collagen contraction was measured in the range of 60-70 °C.

In the experiments in our facility, the contraction of FSN was quantified on ex-vivo post abdominoplasty human tissue. The area was marked proximal to the RFAL cannula tip and monitored during RF energy application. The resulting measurements are presented in **Figure 18**.

One can see that thermal exposure of subcutaneous tissue with RF energy during three seconds resulted in area contraction by 42%.

14. Radiofrequency assisted lipolysis (RFAL)

RFAL technology was developed by InMode Ltd. to improve treatment results during liposuction procedure. The thermal contraction of collagen in dermis and subdermal FSN allows treatment of patients with saggy skin and patients for whom previously excessive skin was a main concern [31].

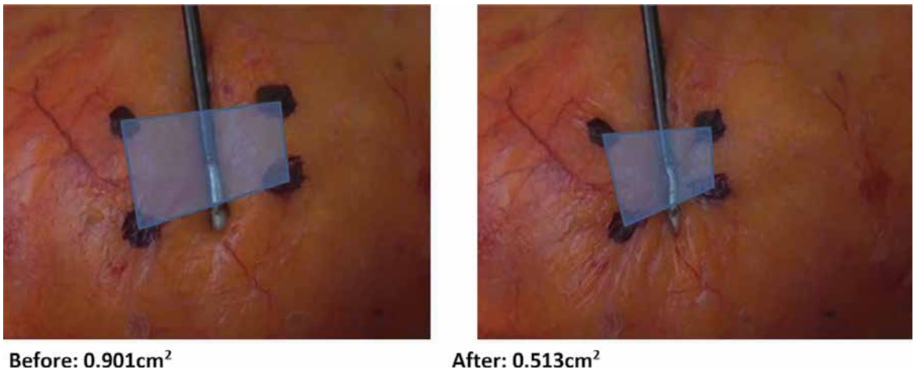

Figure 18.
Subcutaneous fat before and after application of RF energy.

The uniqueness of RFAL technology is that it does not fall under any standard device definitions. It combines features of monopolar and bipolar technologies, minimally-invasive and non-invasive technologies, creating very specific energy profile treating simultaneously subcutaneous fat, connective tissue forming FSN and dermis. Each of these tissue components requires different thermal exposure. Adipose tissue should be destroyed, FSN should be remodeled without denaturation of collagen while skin should be exposed to sub-necrotic heat to modify it without superficial burn [31–33].

The RFAL device geometry is shown in **Figure 19**. The RF current flows back and forth from the internal electrode (cannula tip), where the thermal effect is coagulative, to a larger, external electrode. The external electrode moves along the skin surface, in tandem with the internal electrode and creates a gentle, non-ablative bulk heating effect on the dermis. Ratio between size of internal and external electrode is selected to limit skin heating at sub-necrotic heating while temperature in the fat should reach 50-70 °C.

Moving the hand piece back and forth through the intended treatment area, uniform coagulation of adipose and vascular tissue is achieved. While the external electrode is always moved over the skin surface, the internal electrode should pass through the deep, intermediate and/or superficial fat layers to treat the adipose

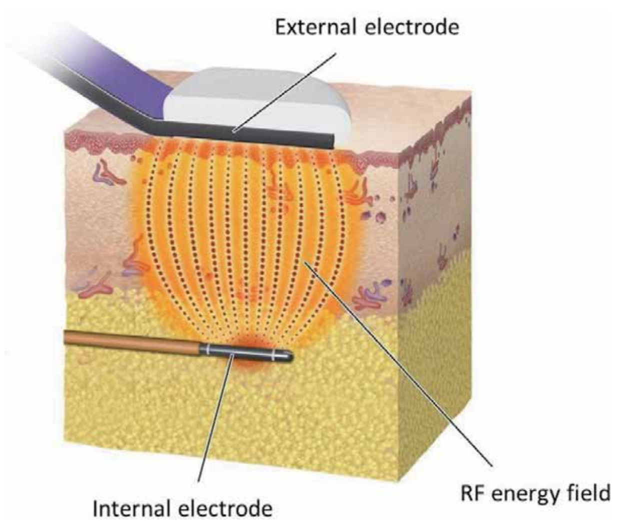

Figure 19.
Schematic depiction of RFAL treatment geometry.

tissue up to the depth of 5 cm. The Lipo-coagulation, results in liquefaction of the adipose tissue, hemostasis and stimulated contraction of adjacent vertical, oblique and horizontal fibers of the FSN, that connects the overlying soft tissue to the underlying muscle.

Figure 20 shows thermal profile created by RFAL cannula inside porcine tissue.

The temperature around the internal electrode is 70 °C. The volume exposed to high temperature around the cannula. The tissue between internal and external electrode is exposed to directional RF flowing between the electrodes.

Computer simulation shows similar thermal profile (**Figure 21**) to the measured thermography.

One of the advantages of RF energy is that it is can be delivered into the body though the very tiny sub-millimeter cannula. That allows to minimize incision and mechanical trauma at treatment of such delicate zones as face and neck [33]. Large size cannula results in higher non-uniformity and especially for subcutaneous fat.

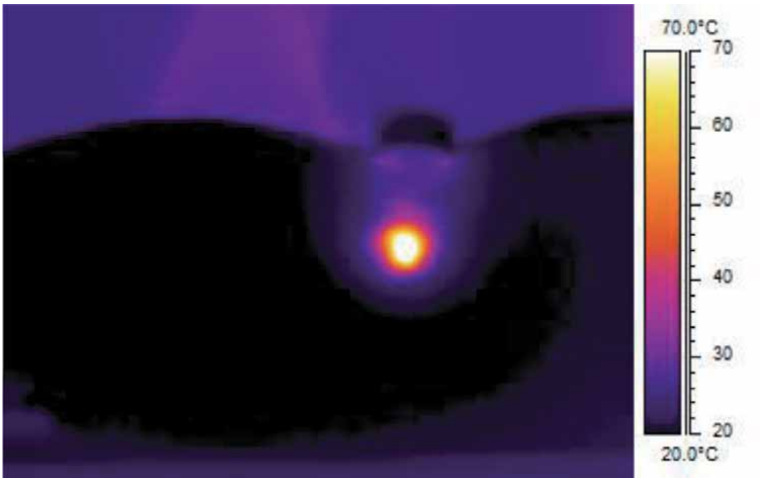

Figure 20.
Thermal profile in the tissue created by RFAL device.

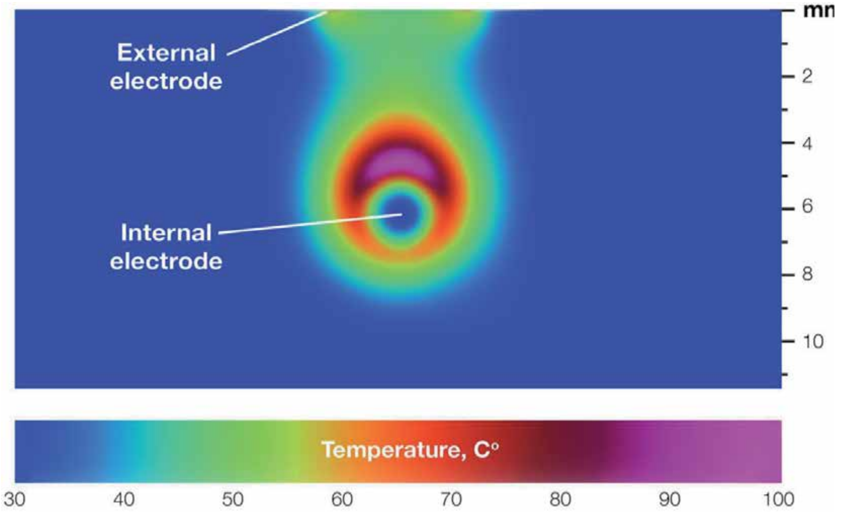

Figure 21.
Computer simulation of temperature field created by RFAL device.

15. Micro needling RF

Another RF based technology enhancing liposuction results is micro needling RF. The fractional coagulation of subcutaneous tissue helps tight the skin and reduce skin sagginess after liposuction [34].

Fractional skin treatment was introduced in esthetic medicine about two decades ago and has become one of the most popular modalities for the improvement of skin quality. This procedure is based on the coagulation of multiple small spots with a size of 100 microns to 0.5 millimeter. This allows the procedure to be very tolerable and with relatively short down-time. Focused laser beams or needle sized RF electrodes are used for ablation of micro-spots resulting in high efficiency and consistency of the treatment, with low risk of side effects and fast skin healing.

In contrast to lasers where the thermal effect is limited by the ablation crater, the RF energy flows through the whole dermis, adding volumetric heating to fractional treatment. This volumetric bulk heating adds a skin tightening effect to the more superficial improvement generated by tissue ablation.

RF fractional technologies are differentiated by needle length and size. The flat electrodes provide a more superficial effect improving texture and fine lines [34, 35] while longer needles penetrate deeper, providing deeper dermis remodeling and causing substantial skin tightening [36].

The needles can penetrate to the different depths allowing epidermal ablation and deep subdermal treatment. Recently the FDA cleared Morpheus8 device of InMode Ltd. for treatment up to depth of 7 mm.

Figure 22 shows Morpheus8 tip schematically with needles extended to the subdermal fat.

Needles coated with polymer and releasing RF energy only at the needle end provide better protection of epidermis and provide lower down time.

A microscope image of a coated needle is shown in **Figure 23**. The gold plated needle has diameter of 0.3 mm and coated with polymer of 20 microns thickness.

There are several different configurations of RF electrodes for micro-needling devices. The most common configuration is by applying RF energy between adjacent rows of needle electrodes. This method creates a coagulation zone in vicinity of the needle end.

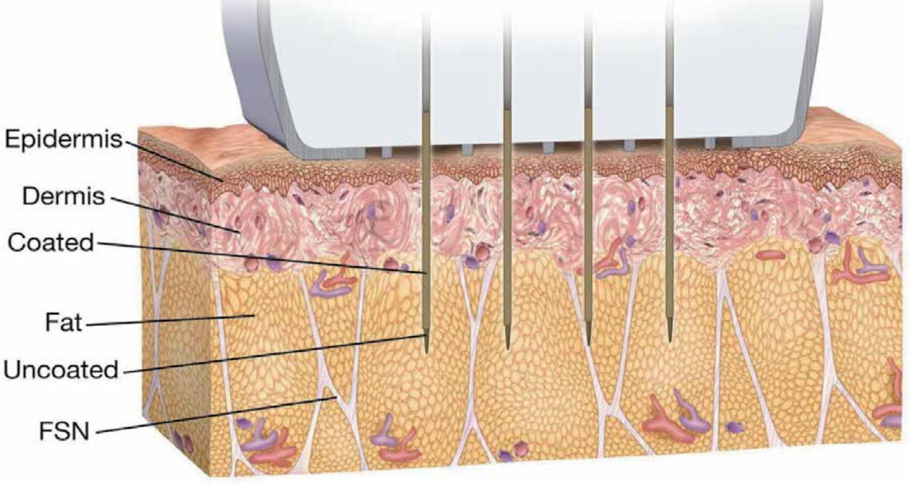

Figure 22.
Schematic illustration of Morpheus8 tip with needles penetrating into the sub-dermal space.

Figure 23.
Coated needle.

The alternative technology is used in the InMode Morpheus8 device where RF energy is applied between the needle and an external electrode applied to the skin surface. Each needle has a strong thermal effect near the needle end and gradient of bulk heating toward the external electrode, similar to RFAL technology. Each needle generates small bulk heating but superposition of the heat from multiple needles results in essential thermal effect. Morpheus8 device automatically treats tissue in multiple layers delivering RF energy sequentially during needle retraction. This burst mode creates three-dimensional matrix of coagulation zones and strong bulk heating. Schematically the burst mode treatment is shown in **Figure 24**.

Micro needling technology was developed for treatment of facial wrinkles but further development of the technology has extended its use to treat the body as well.

The micro needling technology supplements both regular liposuction and energy-based minimally invasive technologies and addresses the first few millimeters of body coagulating adipose tissue and tightening FSN.

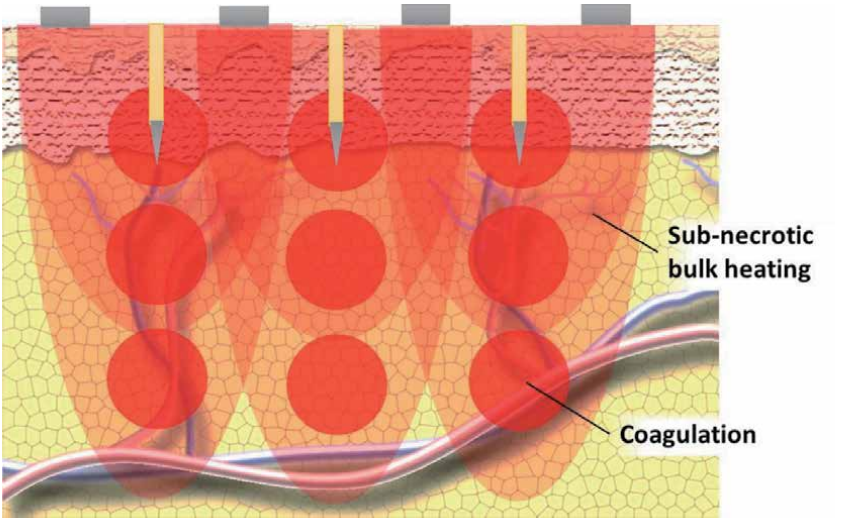

Figure 24.
Schematic illustration of burst mode treatment using Morpheus8 device.

16. Treatment control

One of the risks of any thermal treatment (laser, ultrasound, plasma or RF) is the possibility of a thermal skin injury. Thermal treatment in subcutaneous or subdermal layers may create full thickness skin burn. Therefore, monitoring of delivered energy, predictability of energy distribution and accurate measurement of tissue parameters during the treatment has crucial importance for the energy-based devices.

16.1 Tissue temperature measurements

Non uniform treatment or over-heating the treatment area may result in the risk of unwanted thermal damage to the skin during the treatment. To avoid or minimize this risk of a skin burn, real time thermal measurements are necessary. There are two basic methods of skin temperature measurements:

- Infrared (IR) thermometers measuring IR radiation of heated object.
- Contact measurements using a thermocouple, thermistor or thermo-transistors.

Advantages of IR thermometers is the speed of measurements and that they do not need to be built into the device thus are independent of the treatment. The obvious weakness of this method is collecting IR radiation from relatively large area which depends on distance from the measured area. You are also relying on a third party that is not linked in time of space to the thermal treatment being performed. Most importantly, you are not measuring the internal thermal profile.

A typical IR thermometer measures area which depends on distance between skin and thermometer and it varies from $1cm^2$ to a few square inches at large distance from the patient. It allows you to monitor average skin temperature in treatment area but does not protect from appearance of small hot spots that lead to the full thickness skin burns.

The thermistors or thermocouples are extremely miniature and can be embedded into the electro-surgical instrument. Limitation of such contact measurements is response time which depends on heat transfer from the tissue to the sensor. However, special design allows to reduce response time to sub-second range.

Ideally, the user should know the temperature inside the body where energy is utilized for the fat coagulation and FSN tightening, and temperature on the skin surface above the treatment zone to ensure skin safety.

In addition, during the procedure sophisticated mechanisms monitor the tissue temperature together with its dynamic characteristics as the speed of temperature rise, allowing precautional measures before the critical temperature is reached.

Temperature monitoring for EBD is important not only for safety but also for treatment efficacy. Collagen contraction occurs in relatively narrow range of temperatures from 50 °C to 80 °C and overheating may result in denaturation of collagenous tissue and uncontrolled scar formation.

RFAL technology has maximum thermal safety measurements including:

- Skin temperature monitoring;
- Fat temperature monitoring;
- Temperature surge protection catching fast temperature changes.

16.2 Monitoring of delivered energy

Most types of energy cannot be monitored directly but rather electrical supply to the energy source is monitored. RF energy has unique properties resulting from continuity Eq. (4) allowing to measure RF voltage and RF current flowing through the tissue and get in real time all information about energy deposition in the tissue. Measurement of electrical RF parameters is not difficult engineering project and it can be performed every micro-second that allows to control the RF energy delivery even for very short pulses.

Measurements of RF current ($\boldsymbol{I}$) and RF voltage ($\boldsymbol{V}$) allows to calculate RF power ($\boldsymbol{P}$) and RF impedance ($\boldsymbol{R}$) using Ohm's law

$$\boldsymbol{R} = \frac{\boldsymbol{V}}{\boldsymbol{I}} \tag{18}$$

and Joule's law

$$\boldsymbol{P} = \boldsymbol{V}\,\boldsymbol{I} \tag{19}$$

The RF energy can be calculated as integral of RF power measurement over the time:

$$\boldsymbol{E} = \int_{0}^{t} \boldsymbol{P}\, \boldsymbol{dt} \tag{20}$$

RFAL and Morpheus8 technologies of InMode Ltd. utilize all these measurements to control the treatment safety and efficacy.

16.3 Impedance sensing and control of RF output

Measurements of tissue impedance should be considered separately because of importance of this parameter for different aspects of treatment. The most obvious use of the impedance measurements is indication of contact between electrodes and treated tissue. Contact measurements are important to avoid poor coupling of the RF device with patient and avoid arcing. Contact monitoring has become a common feature for most RF-based devices.

Referring to **Figure 9** one can see that coagulation, dehydration of tissue and eschar formation result in impedance increase. Monitoring of tissue impedance can be used to limit heating process and avoid undesired treatment effect.

Another use of impedance monitoring is to control the lower limit, which may indicate that the distance is too small between electrodes. In RFAL technology it is used to reduce the risk of the cannula coming too close to the skin surface.

16.4 Safety features of the RF devices

All above mentioned measurements of RF parameters worth nothing if its not used for enhanced treatment safety helping physician to optimize the procedure.

The BodyTite device from InMode Ltd. uses RFAL technology, combines the maximal number of safety features, and should be used as the gold standard for safety features for RF devices.

Performing liposuction, the physician should be concentrated on safe manipulation with the minimally invasive accessory. Safety features related to the thermal component of the treatment should be implemented in automatic or in a very intuitive way not disturbing physician attention.

The skin impedance for each patient is different and may vary for the different treatment zones, amount of tumescent applied or treatment depth. RF energy is adjusted by the device automatically to provide the required optimal energy to the patient.

Tissue impedance is monitored constantly by the BodyTite and the device automatically cuts RF energy if some of the limits are exceeded.

The user may set desired temperature cut-off limits for skin and internal electrode. The device applies full power when the temperature is significantly below the threshold and starts to reduce power automatically as treatment approaches the required target temperature. This scheme allows to avoid thermal overshooting and maintains desired heat profile. RF energy delivery is accompanied by an audible signal which speeds up as the cut-off temperature is approached, similar to modern car approaching wall while parking. RF power is switched on and off automatically to maintain the desired temperature as the user scans the treatment area with the cannula.

If the cannula accidentally comes too close to the dermis, the tissue volume between the electrodes is reduced and the applied RF power heats the tissue extremely fast. To address this issue, a temperature surge protection is implemented in BodyTite device. When the temperature sensor measures a temperature increase as too fast, the device automatically shuts RF energy and produces an audible sound to attract the physician's attention.

17. Summary

RF based medical devices are a common tool for plastic surgeons, used during most surgical procedures. RFAL and RF fractional technologies have become important modalities for about 20% of plastic surgeons, for enhancing liposuction results or by its own for patients for whom reduction of adipose compound is not a main esthetic goal. Over the last 100 years extensive knowledge has been acquired about RF technology and RF-tissue interaction. The information in this chapter can help a potential buyer of new equipment make a rational choice, based on goals of treatment and physics of the RF device in question. Even more importantly, expanding the physician's understanding of his or her devices already in use can maximize treatment outcomes and minimize unwanted side effects and complications.

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Chapter 4

Contractile Effects of Radiofrequency Energized Helium Plasma on the Fibrous Septal Network

Vaishali B. Doolabh

Abstract

Body contouring with liposuction has evolved significantly from the early approach of simply debulking excess fatty tissue, to affecting the mechanical properties of different tissue types and layers. Operative paradigms have been expanded to apply energy-based technologies intraoperatively to provide more uniform aspiration, selective fatty tissue emulsification in soft and fibrous body areas, minimize trauma to nerves and vessels, expose the fibrous septal network, reduce operator fatigue and help deliver smooth shapes with less discomfort and bruising. Advanced refinements with the delivery of monopolar and bipolar radiofrequency energy for soft tissue heating have been shown to reduce the residual soft tissue laxity that often follows voluminous fat removal. The Renuvion® (Apyx™ Medical, Clearwater, FL) radiofrequency powered helium plasma technology introduces an emerging concept in which the delivery of subdermal thermal energy preferentially coagulates the fascia and fibrous septal network through a conductive helium plasma stream seeking the path of least resistance, which in turn results in collagen contraction and tissue shrinkage that permits re-draping of the skin and enhanced definition. The physics and mechanics of Renuvion® subdermal soft tissue coagulation will be presented, along with clinical applications that have provided the authors more contouring finesse and has augmented liposuction outcomes.

Keywords: Liposuction, Radiofrequency, Collagen contraction, Skin tightening, Body contouring, Plasma

1. Introduction

Liposuction is a well-established surgical procedure that is continuously evolving with refinements in surgical technique, safety, patient assessment, and care. The introduction of tumescent solution decades ago markedly reduced complications, such as blood loss, associated with dry liposuction. While reducing the overall volume of a given region is accomplished with traditional manual liposuction, the resultant soft tissue deflation has historically been the only means of contouring with minimum reduction in the actual surface area. Areas that were pendulous were still best treated with dermatolipectomy. Furthermore, concerns of iatrogenic post aspiration skin laxity frequently led surgeons to under-aspiration, while over resection driven by a desire for improved shaping, equally resulted in overall contour problems. Skin contraction in surface area one year post traditional manual liposuction was shown to be around 10% [1]. Over the past few decades, technologies have sought to further enhance liposuction treatment speed with economy of motion and reduced operator fatigue, while increasing fat emulsion and enhancing soft tissue contraction beyond the normal deflation that accompanies removal of internal turgor by fat removal and cannula stimulation. The resulting nonthermal inflammation, blood vessel ingrowth, and fibroblast production of collagen offers however, an uncontrollable and unpredictable skin shrinkage. The use of mechanical and ultrasonic powered disruption of fat has also been used to better treat fibrous areas. Some examples that deliver smoother, more uniform fat removal include power assisted liposuction with oscillating cannulas (MicroAire Surgical Instruments, Charlottesville, VA), light amplification by stimulated emission of radiation (LASER) fibers and vibration amplification of sound energy and resonance, VASER® (Solta Medical, Bothwell, WA). As an added benefit, enhanced adipose cell viability for fat grafting has resulted with the use of VASER® and Water jet assisted liposuction, a technique in which a dual-purpose cannula, and pulsating, fanning jets of tumescent solution are implemented along with simultaneous suctioning of fatty tissue. However, downsides to each of the technologies have arisen. The applications of mechanical powered disruption have been limited by the potential for damage to other tissues, including nerves, blood vessels and skin, while adding operative time and not offering skin or soft tissue tightening. Similarly, early ultrasound assisted technologies were also time consuming and plagued by complications of seromas, burns and undesirable contours. The still popular ultrasonic VASER® device, LASER assist and radiofrequency (RF) assisted liposuction have yielded many advantages and superior outcomes as outlined in later sections.

As more refinements in non-excisional body contouring emerge, patient expectations of enhanced definition and sleeker contours are driving research and innovations proportionately. Contemporary efforts now focus not solely upon removal of excess fat, but on composite tightening of skin and its underlying soft tissue support system. The Renuvion® (Apyx™ Medical) technology offers the latest advancement in composite liposuction results by thermally altering multiple different tissue types with a radiofrequency energized helium plasma stream. The combination of either LASER or VASER® lipolysis with Renuvion® subdermal coagulation creates superior soft tissue contraction and reductions in volume and surface area.

2. Thermal collagen contraction basics

Soft tissue contouring depends upon deflation and contraction. As we age, collagen stretches, fragments and attenuates whether in the dermis, fibrous septae, connective tissue around fat lobules, retaining ligaments, SMAS or other fascia. Soft tissue laxity is a result of decreasing underlying support from atrophy of the dermis, fibrocollagenous and vascular matrices, adipose layers, muscle and bony mass. In particular, skin laxity is evidenced by decreased type 1 collagen formation, increased degradation of the extracellular matrix and overall loss of dermal elastic recoil. Attempts at modifying the deep dermal tissue level with superficial liposuction have been met with mixed results of skin shrinkage, and not uncommonly are associated with adverse events such as pigmentation changes, chronic induration, seroma, surface irregularities, and full thickness skin necrosis. Consequently, attempts to restore collagen fibers safely and predictably has become the focus of liposuction research. Collagen fibers rapidly contract approximately one third the resting length, in response to heat to an extent that is dependent upon the temperature and duration of the temperature [2]. The temperature at which collagen denaturation occurs is 66.8° C, depending upon the tissue type [3, 4]. Thermally induced soft tissue contraction that follows is a product of the wound healing response that includes neo-collagenesis, restructuring of collagen fibers and tissue remodeling. These same changes reinforce the use of tumescent solution during liposuction to reduce the energy conductance of tissue, to reduce tissue impedance and distribute delivered heat. It has been observed that the behavior of collagen fibers changes with the aging process, making heat assisted lipo-contouring more challenging in older patients. It is believed that in older skin, collagen is less responsive to thermal energy because irreducible multivalent cross links replace the heat labile collagen intramolecular bonds found in younger skin [5]. Effectively altering the thermomechanical behavior of tissue constituents embedded in a plexus of collagen and elastin is then the primary mechanism of energy assisted lipo-contouring in patients of all ages.

3. Laser lipolysis effects

LASER assisted lipolysis offers efficacious fat extraction, better hemostasis and finessed sculpting with thermal heating of fibrous septae in areas difficult to obtain tissue retraction. Multiple wavelengths, such as the 1064 nm and 1320 nm., have been shown to effectively coagulate small blood vessels, rupture adipocytes, coagulate adipose collagen strands and help to reorganize the reticular dermis. Light energy is delivered to subdermal tissue through a small fiber threaded through a 1 mm microcannula with the tip extending a few mm beyond the microcannula end. Data established by the works of Havenith, et al. [6] and Salzman, et al. [7] offer precise calculations to determine the laser energy required to cause collagen fiber contraction without causing a burn. Havenith et al., showed that it takes about 2.51 joules of laser energy to raise the temperature of 1 ml of fat 1° Celsius. Since the density of fat is 0.9 grams/cc, the resultant requirement is 2.3 joules per cc. As damage begins to occur at 43° C, the goal should be to raise the temperature no more than 5° Celsius. The volume of fat to be liquified is estimated roughly by measurements of the length X width X thickness of the treatment area. Hence, the amount of laser energy that should be delivered is the product of volume X 2.3 X 5. Following laser application, higher mean skin stiffness and tightening has been demonstrated at 3 months when compared to traditional manual liposuction alone [8]. Notwithstanding, studies that have shown modest decreases in skin surface area reduction, added operative time, sequalae such as local skin burns, and limited longevity have tempered the recent popularity of this modality.

4. Benefits of VASER®

Like the LASER, the use of VASER® adds operative time but reduces operator fatigue. Yet, unlike the LASER, VASER® offered notable advances that allow for selective tissue emulsification, lower lipoaspirate hematocrit levels, and preservation of adipocyte derived stem cells for fat grafting [9]. VASER® probes designed with rings and grooves on the tip deliver vibratory energy from the end surface and sides, permitting mechanical penetration of fibrous tissue and micro-cavitation of adipose cell membranes, whilst preserving the musculocutaneous connective tissue matrix, nerves and vessels. Energy emanates from the probe tip and rings continuously or in pulsed mode, a feature that provides additional safety with high energy probe vibration for shorter time bursts. Following tumescent solution infusion, probes are cross tunneled through multiple skin protector ports, smoothly and continuously until there is a loss of resistance. As VASER® proceeds, the resistance in the tissue is palpably diminished as adipose cells liquify. The acoustic streaming by VASER® prepares fat for suctioning, but when used alone at low energy levels, there is minimal thermal energy generation. Some thermal skin tightening has been reported at 90% energy levels when delivered continuously for 2 minutes [10]. Overall, there has been inconsistent coupling of clinically observable skin contraction with subsequent fat removal when using VASER® alone. Notwithstanding, the addition of VASER® to the operative sequence helps to expose the numerous fibrous septae amidst densely packed fat in the supra-Scarpal space and the widely spaced fibrous septae that run amidst loosely packed fat lobules in the supra-Scarpal space. The author purports that the exposure of the fibrous septal network for subsequent thermal energy targeting by Renuvion® is key to optimizing the heating of the low impedance collagen fibers for increased soft tissue contraction overall.

5. Advantages of radiofrequency energy

Radiofrequency (RF) is a form of electromagnetic energy that can be converted to thermal energy. It does not target a particular chromophore. The early RF devices created bulk heating. When thermal energy emanated from the device tip, adjacent tissue heating occurred, leading to gradual warming and uneven heating, which became problematic and unpredictable in large treatment surface areas. With gradients of heat, areas of fibrosis can result from excessive heat delivery, which introduces further potential issues in regions of pre-existing compromised blood flow, little adiposity, and thin skin. Multiple RF devices, monopolar (Thermi) and bipolar (Invasix, InMode) with internal and external temperature probes and indwelling liposuction aspiration cannulas, were introduced in the past 12 years. With encouraging results, and safety features that monitor treatment depth and skin temperatures to help avoid visible burns, or the safety to offer rapid cooling to avoid burns altogether, the use of RF devices for enhancing body contouring have gained traction [11, 12]. In addition, other aesthetic applications have emerged to shrink lax soft tissue, as for SMAS tightening during rhytidectomy and popcorn capsulorraphy in breast implant repositioning surgery, and ongoing efforts to manage abdominal wall fascial laxity [13]. As described in the next section, a novel RF based device, Renuvion® (Apyx™ Medical), uses an energized stream of helium gas, known as a plasma, for the same purpose of precise soft tissue subdermal coagulation.

Like the lasers, the thermal energy delivered by an RF device can be calculated and provide treatment guidelines. The amount of energy is the product of the square of current multiplied by tissue impedance multiplied by the time of application [5, 14]. As adipose tissue has high tissue resistance or impedance to electromagnetic current, it has proven to be a good target for RF technologies to diminish iatrogenic tissue laxity and enhance liposuction results. Recalling that the total ability to re-drape the skin is related to the contractile nature of the dermis, as reflected by dermal thickness, the amount of FSN and fat to be aspirated, the delivery of RF energy to multiple tissue planes has proven advantageous. Treating the immediate subdermal layer leads to neo-collagenesis and subdermal remodeling, while treating above and below Scarpa's fascia maximally augments fat liquification, coagulates blood vessels, and creates an active fibroblastic reaction that replaces liquified fat [15, 16], neo-angiogenesis, and a compact, reorganized layer of collagen and elastin over 4–6 months [17]. The delivery of immediate heating between 60 and 80°C causes collagen fibrils to contract to one third their length and alters the microenvironment of the extracellular matrix toward favorable remodeling and healing. This begs the question as to whether repeated thermal effects on dermal ground substance can occur, and if there is a role for retreatment in secondary surgery to gain additional contraction. Notwithstanding, significant longevity of skin contraction has been demonstrated in clinical bipolar RF assisted liposuction studies that have shown 25% soft tissue area contraction at 6 months and 35–40% at one year [18]. As radiofrequency offers immediate and long- lasting thermal contraction of the FSN and inflammatory dermal heating, it has come to the forefront of contemporary energy assisted liposuction technologies, like Renuvion®.

6. Plasma background

Plasma is created when a gas is energized to a level that accelerates and frees electrons, resulting in a mixture of neutral atoms, charged ions and molecules. Plasmas occur in nature, within stars and the polar aurora. Early research on plasmas arose from controlled laboratory conditions and gave rise to applications within Medicine. Today, medical plasmas are in use for a spectrum of applications, including wound debridement, tissue regeneration, reducing cancerous cell proliferation and inducing selective apoptosis of neoplastic cells [19]. Medical plasmas are used in minimally invasive surgery in the fields of Gynecology, Urology, Otolaryngology and Gastrointestinal endoscopy. A well-known example is the Argon plasma technology used for soft tissue coagulation to reduce bleeding and tissue ischemia [20]. As discussed below, the use of a stream of ionized inert gas to deliver radiofrequency energy provides an advantageous alternative energy source for skin and soft tissue contraction.

7. Physics and mechanics of Renuvion®

Renuvion® is a helium-based plasma and radiofrequency technology that has been cleared by the Food and Drug Administration for cutting, coagulation and ablation of soft tissue. It creates a direct discharge, non-equilibrium, low temperature plasma beam at atmospheric pressure as helium gas is passed over a sharp, conductive point held at high voltage and high frequency. The system consists of a RF generator, supply of helium gas and an electrode within the tip of a handpiece [21]. The generator operates at a maximum of 4.0 kV, 40 Watts and 490 kHz frequency [22]. Independently tunable power levels, gas flow rates and pulsing of energy delivered provides a high level of precision. Unlike monopolar and bipolar instruments, the Renuvion® handpiece does not conduct heat after its application.

Renuvion® provides rapid heating of tissue in 360° with minimal depth of treatment. Heat is generated by two methods. The first is the ionization and rapid neutralization of helium atoms as the gas passes over the RF energized electrode. Second, a portion of RF energy used to energize the electrode is carried to the tissue by the plasma stream, whereby the tissue's resistance generates heat [23]. The electrosurgical generator maintains a consistent power output over a range of impedances [10]. In contrast, monopolar and bipolar devices have limited power output in tissues with greater impedance [10]. The mechanical movement of the handpiece and hence, the direction of plasma flow subcutaneously, is tracked by the light spray generated by the plasma streams. In Renuvion®, the colorless, monatomic, inert helium gas stream also delivers kinetic energy to clear the target tissue of fluid or debris [24].

At clinically equivalent settings, Renuvion® offered more control of tissue response with lower lateral and depth of thermal spread compared to monopolar, Argon, CO2 laser [25]. In a porcine model utilizing kidney, muscle, ovarian and uterine tissue blocks, the depth and spread of coagulation were found to be a function of the current density, gas flow rate, duration of application and distance of the probe tip to the target tissue [24]. Increasing the power increased the heat energy delivered to the tissue [24]. Histologic analysis demonstrated 2 mm depth of thermal spread following 5 sec of 100% power and 5 L/min Helium gas flow [24]. The same study demonstrated that prolonged exposure up to 30 seconds did not increase the depth of thermal effect over 3 mm, just the length and width of thermal spread, in all tissue types studied [24]. The depth of collagen denaturation was seen histologically to be 0.180–0.247 mm at both 50% and 100% power. Conductive heat transfer to surrounding tissues offers less heat transfer to the epidermis, thereby eliminating the need for external temperature monitoring.

The inherent resistance (impedance) to the flow of RF current through tissue increases as tissue is treated and desiccates. The RF current will preferentially flow through the path of least resistance characterized by the lowest tissue impedance. As such, the plasma beam alternates between treating different tissues surrounding the device. Continuous movement of the handpiece further introduces new, lower impedance tissue to the tip and delivers uniform energy to a large area. This lowers the need for the user to constantly redirect the handpiece. The RF energized plasma stream preferentially seeks tissue with the lowest impedance, like the fibro-septal network, to receive the majority of energy and undergo coagulation and contraction [26]. The low current of the Renuvion® device further disperses and prevents tissues from being over treated when multiple treatment passes are done. The increase in tissue impedance from coagulation preferentially diverts Renuvion® energy towards adjacent untreated tissue with subsequent passes. Subsequent live swine studies outlined the impact of device settings on the internal and external tissue temperatures with the use of a Forward-Looking Infrared Camera [26]. It was demonstrated that 6 passes of 60–80% power, at 1–4 lpm gas flow, and a handpiece speed of 1 cm/sec, raised internal temperatures to above 85° Celsius for a duration of 0.08 seconds, while external skin temperatures stayed within a safe range of 3.6° of baseline [26]. The internal tissue heating cycle lasted an average of 0.24 seconds from the time in which the handpiece tip approached to raise the target tissue temperatures, passed directly over and then moved past to lead to a rapid return to baseline temperatures. Maximum collagen contraction occurred within 0.044 seconds [2, 26]. The rapid rise to 85° Celsius is important as 10 times more time is needed to contract collagen for every 5° drop in temperature [17]. This makes Renuvion® technology very efficient compared to many other technologies. In contrast, bulk heating devices (Thermi, InMode) uses a radial pattern of heat directed primarily to the dermis that is maintained at optimal temperatures for comparatively prolonged time (>120 sec) for maximum contraction to occur, thereby increasing treatment times and requiring constant monitoring of epidermal temperatures [1].

Within the operative sequence, Renuvion® is utilized after tumescence and liposuction. It is important to note that the use of tumescent solution enlarges the space for handpieces to travel and provides a means for RF conduction, as adipose tissue is less conductive. Each access port is the apex and offers a fan shaped pattern for the handpiece strokes. The visible pattern and intensity of the plasma stream helps to direct depth during the process of multilayer volumetric heating. Prior to insertion of the handpiece, it is important to prime the handpiece by activating it against a metal instrument to visualize the plasma stream. For handpieces that have a retractable blade electrode, it is also important to ensure the blade is retracted prior to insertion. The minimal amount of helium gas (L/min) necessary to ensure a good bridge or connection to deliver the RF energy to the tissues should be utilized. The use of counter ventilation port permits egress of excess helium gas, avoidance of gas tracking and postoperative crepitus. Re-suctioning after use of the handpiece may also reduce gas related sequalae, remove liquified and fragmented cells and free fatty acids, and remove residual heated tumescent fluid that may lead to an unpredictable tissue response. The RF energy should be delivered using smooth, continuous movement of the handpiece. It can be monitored by the trans-illumination of the plasma stream in tissue, and activation should be stopped within 1 cm of the access port to prevent overheating of this area from repeated contact. There are indication lines on the handpiece shaft within 40 mm of the tip that visually guide the surgeon as to when to stop handpiece activation. A variety of handpiece lengths, diameters, flexibility and single or twin port options are available. Compressing or gathering the tissue around the handpiece with the other hand allows for directing and monitoring handpiece placement, intended plane and depth of treatment, provides more substrate to the RF energy path with each stroke, and avoids heating nontarget structures, like muscles. Tactile feedback from the non-handpiece hand offers a sense of decreasing soft tissue laxity and confirms there is no rise in skin temperature. Recall that the threshold for epidermal burns is significantly lower than the optimal temperature for collagen contraction. Error codes will provide audible warnings of gas occlusions from tip obstruction and immediately stop the delivery of RF energy in the handpiece. Deactivation of the unit and power output will occur with gas flow faults. Like bulk heating devices, the amount of time-on-tissue and energy delivered should be reduced in areas of thin skin, thin adipose layers, pre-existing scar tissue or compromised blood flow [13]. Moreover, Renuvion® is not well suited for patients with collagen vascular diseases, poorly vascularized tissue, pre-existing fibrosis or skin compromise, or lifestyles that might impair collagen remodeling such as smoking, poorly controlled diabetes, chronic NSAID use, and in patients with implantable devices that can attract the RF energy preferentially over the grounding electrode [27]. Results are likely to be limited in regions of compromised soft tissue as evidenced by open wounds, severe pendulosity, severe laxity and/or striae.

In general, Renuvion® provides reproducible, safe, well-tolerated soft tissue contraction three dimensionally and abrogates the risk of laxity. There is a 2D or linear contraction of collagen changes in the deep dermis, and 3D contraction of fascia, septal connective tissue that separates fat lobules and connects fascia to dermis, and reticular fibers that provide the framework of collagen fibers that encase fat cells [28]. Histologically, collagen bundle alignment in multiple directions is seen. The nonuniform geometry of the different components leads to a range of soft tissue remodeling results, regardless of the energy applied. Targeting the interstitial connective tissue bands without the need for full thickness dermal heating provides faster treatment times in comparison to bulk heating devices, with superior overall soft tissue contraction. Given interpatient variability in available FSN substrate, establishing clinical guidelines for consistent and predictable results is proving challenging. Recent single and multi-center chart reviews have demonstrated high patient satisfaction along with the safe and effective use of Renuvion® as an adjunct to enhance liposuction outcomes [21, 29, 30]. Consistent and reproductible soft tissue contraction was demonstrated even in the clinically challenging area of the neck area by subjective and quantitative analyses of before and after photographs [21]. Current studies are underway attempting to quantify the amount of energy deposited as kilojoules delivered per area and correlate them with resulting changes in soft tissue laxity.

8. Case selection

The following cases illustrate the effectiveness of Renuvion® technology in patients with compromised skin quality and soft tissue gliding planes because of weight fluctuations and aging. Patients were considered good candidates as they had no prior surgeries or energy-based treatments in the proposed treatment areas, desired improvements in soft tissue laxity without excisional scars, and demonstrated mild pendulosity that was felt could notably improve with the expected 30% contraction. Benefits were seen in the treatment areas of the upper arms, back bra rolls, and abdomen. The topography for liposuction and tightening was marked preoperatively in the upright patient. Portal sites were planned to permit crisscross patterns, pre-tunneling with LASER or VASER® and liposuction cannulas, allow easy strokes with the Renuvion® handpiece, as well as ventilation of residual helium gas. Sterile prep and drape with induction of general anesthesia followed. Tumescent solution utilized in all patients was composed of 1 Liter NaCl solution with 25 ml of 1% Xylocaine and 1 cc epinephrine. Residual gas was always aspirated. No worrisome clinical adverse effects such as skin compromise, erythema, etc. were seen. The patients minimized activity and used ice packs intermittently for edema control the first few days. Each was placed in postoperative compression garments for 6 weeks minimum. No unexpected sequalae were seen, including skin necrosis, seroma, fibrosis, altered sensitivity, portal burns, infection, dyschromia or long- lasting contour irregularities. Patients reported little tenderness postoperatively. All patients were pleased with their outcomes.

Figure 1 shows a 39-year-old woman who underwent a large amount of fat removal from each arm that contoured well with adjunctive Renuvion® treatment of residual laxity. She was a G1P0, nonsmoker, who had undergone an 85 lb. weight loss following gastric sleeve operation 4 years prior. She presented with a desire to reduce her arm sizes. Her current BMI was 33.08. She demonstrated grade 3 inner arm ptosis and laxity with more fat in the distal one third of each arm. She did not demonstrate axillary or forearm ptosis. She desired contouring but refused the excisional scars of brachioplasty. She demonstrated severe arm laxity but reasonable skin quality with good skin turgor, no striae nor fine wrinkling and had moderate adiposity in both proximal and distal arm regions. She was felt to be a good candidate with reasonably adherent soft tissue, suggestive of a more robust fibrous septal network substrate to target and contract with the RF helium plasma stream. A total of 700 cc tumescent solution was infused into each arm, followed by VASER® application. The 5-ring probe was used for uniform acoustic energy distribution, providing 10% energy dispersion from the 3.7 mm probe tip, and 90% from the sides. It delivered ultrasonic

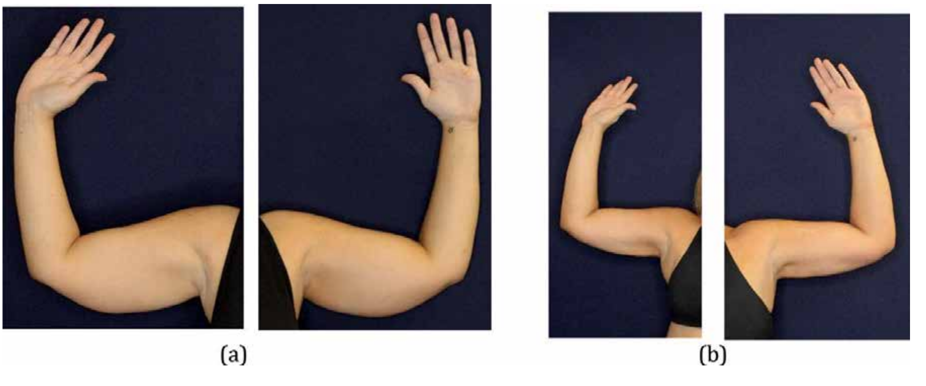

Figure 1.
(a) Patient presented with excess inner arm subcutaneous fat, laxity and grade 3 inner arm ptosis, and (b) pleasing contours are seen 3 months following VASER® and Renuvion® assisted liposuction.

energy in pulsed fashion for added safety at 70% energy levels for 7 minutes in each arm. Next, a 3 mm multi-directional liposuction cannula was utilized to remove 700 cc from the right upper arm and 575 cc from the left arm, nearly circumferentially. Renuvion® was then primed and the blade retracted. The handpiece was introduced and activated upon withdrawal through multiple tissue depths subdermally and deeper near Scarpa's fascia. Tissue was gathered around the handpiece to increase uniformity, and 6 multi-depth passes were completed in a radial fashion at an approximate speed of 1 cm/sec, 70% power, with 3 L/min helium gas flow. The set of 6 passes was completed in tissue areas that were 15 cm from the port radially.

Figure 2 shows a 40-year-old woman with minimal rectus diastasis and adiposity who obtained improved abdominal appearance with the use of Renuvion® subdermal coagulation. She demonstrates longevity of effect 2 years post-op. She was a G2P2, nonsmoker who experienced 50 lb. weight fluctuations with each pregnancy. At presentation 5 years postpartum, her BMI was 20.05 and she did not have a C section scar or tissue overhang, thereby making her a suboptimal candidate for traditional abdominoplasty. Since the abdomen has more fibrous septal network bulk to recruit, it was felt that the predictable fibrosis, remodeling and collagen contraction offered by Renuvion® subdermal coagulation could offset any exacerbation of laxity from liposuction. A total of 750 cc tumescent solution was infiltrated between the upper (above the umbilicus) and lower (below the umbilicus) abdomen, and 250 cc into each hip and waist area bilaterally. The VASER® was utilized at 60% power in pulsed mode until there was no resistance. Liposuction was completed with 50 cc lipoaspirate from the upper abdomen, 150 cc from the lower abdomen, and 100 cc from each hip and waist bilaterally. Next, the Renuvion® handpiece was set at 60% power, 2 L/min gas flow and 6 passes were completed in a radial fashion at 1 cm/sec. This was done in the upper abdomen, repeated in the lower abdomen, and each waist and each hip, 15 cm from the ports in all directions. Again, tissue was gathered with the non-dominant hand to increase uniformity and treat tissue at different depths. She demonstrated contraction as early as one week, and a two year progressive improvement, purportedly from new collagen ingrowth within the connective tissue stroma.

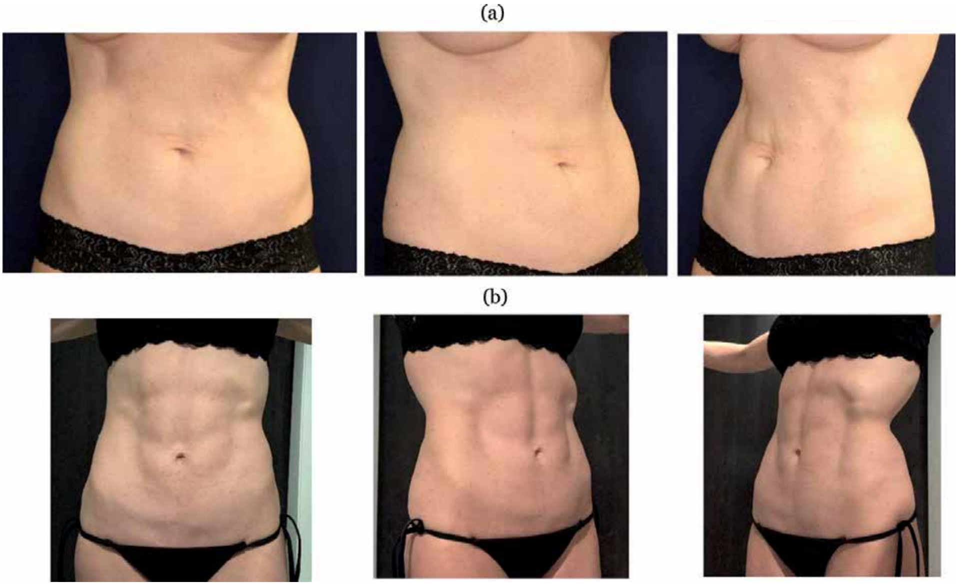

Figure 2.
(a) Patient presented with minimal abdominal subcutaneous fat and skin laxity, and (b) pleasing contours are seen 2 years following VASER® and Renuvion® assisted liposuction.

Figure 3 shows a 63 year old woman with marked skin laxity, poor skin quality and little adiposity throughout the arm, forecasting a poor result to traditional RF technologies. She obtained pleasing tissue contraction following Renuvion® subdermal coagulation. She was G3P2, nonsmoker with grade 3 inner arm ptosis and BMI of 20.50. She too desired improvement in her arm contours but refused brachioplasty. She did not have axillary or forearm ptosis. It was plausible that older skin contours would result as laxity would prevail following any fat removal without thermal contraction. She too would not accept lengthy brachioplasty scars and was willing to proceed with Renuvion® subdermal coagulation. The approach included near circumferential discontinuous soft tissue release, liposuction, and delivery of Renuvion® for subdermal coagulation of the superficial fascial system and was able to provide good contouring. A total of 25o cc of tumescent solution was infused into each arm, followed by VASER® application. The 5 ring, 3.7 mm VASER probe was utilized at 60% power in pulsed mode, for 2 minutes in each arm. The 3 mm multidirectional liposuction cannula removed 125 cc of fat from each arm. Given her thin skin, little adiposity, and probable minimal target fibrous substrate, Renuvion® energies were reduced to 50%, 4 lpm gas flow and 6 passes were completed in all directions for 15 cm from the port. Similar to the other patients, the tissue was gathered and the handpiece speed of 1 cm/sec was maintained. End hits were avoided by remaining deep and maintaining constant handpiece motion.

Figure 4 shows a 59 year old woman with marked laxity and curtaining of back tissue that achieved significant improvement following treatment with Renuvion®. She was a G3P2, nonsmoker who had undergone an 85 lb. weight loss following a gastric sleeve operation 3 years prior. At presentation, her BMI was 32.92. A total of 750 cc of tumescent solution was infiltrated into each waist, hip, and bra roll area bilaterally. The VASER® 5 ring, 3.7 mm probe was utilized at 90% power in pulsed mode for 5 minutes on each side. The lipoaspirate totals from each side were 500 cc. To assist flattening and resolution of the curtaining, Renuvion® was utilized at 60% power 4 lpm, 6 passes to the waist, 6 passes to the waist and hip and 6 passes to the bra roll on each side, 15 cm radially from each port. The techniques detailed in the previous patients were applied here.

These cases illustrate therapeutic and beneficial soft tissue contraction in patients that either were not a candidate for excision or who were but did not accept the concomitant scars of tissue excision. The use of Renuvion® effectively extended liposuction as an option to a non-traditional patient group of large weight loss patients that demonstrate damaged FSN. As all patients were satisfied and there have been no reoperations, the question of whether there is potential for further improvement or longevity with a subsequent Renuvion® treatment remains unanswered.

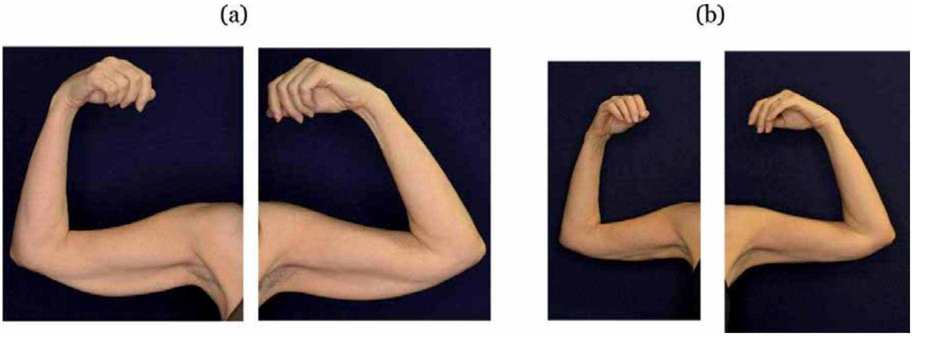

Figure 3.
(a) Patient presented with little inner arm subcutaneous fat, laxity and grade 3 inner arm ptosis, and (b) pleasing contours are seen 3 months following VASER® and Renuvion® assisted liposuction.

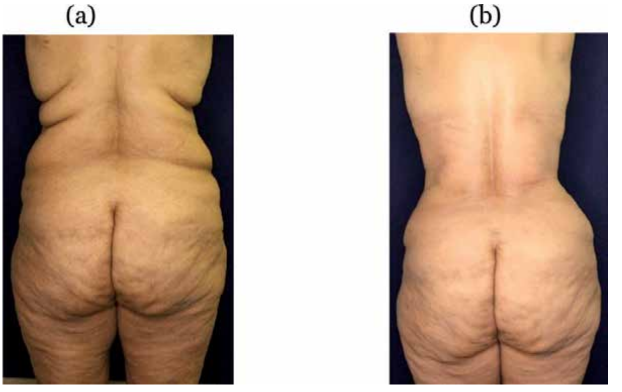

Figure 4.
(a) Patient presented with excess back, waist and hip subcutaneous fat, laxity and curtaining of tissue, and (b) pleasing contours are seen 3 months following VASER® and Renuvion® assisted liposuction.

9. Conclusion

Renuvion® technology transfers heat to the subdermis and connective tissue matrix through the ionization and rapid neutralization of helium gas atoms and through passing RF current through the resistance of the tissue (Joule heating). The RF helium plasma technology offers the contemporary, judicious liposuction surgeon a way to abrogate host skin laxity, and coagulate adipose, connective, and vascular tissue, thereby reducing traditional liposuction downtime associated with discomfort, ecchymosis, and edema. It provides an option for body contouring in patients that do not qualify for or want tissue excision, who cannot achieve skin tightening with other modalities or who present with unresolved laxity following excisional procedures. The addition of energy-based technologies to minimize traumatic fatty tissue extraction, expose and contract the total tissue collagen burden is a useful adjunct to enhance traditional liposuction results. The changes in the mechanical behavior of connective and deep dermal tissue from Renuvion® result in thermal collagen denaturation and contraction that beneficially reduces volume and surface area of the soft tissue envelope. This makes it a viable alternative to dermatolipectomy procedures and their concomitant risks, scarring and protracted recovery. Future studies will establish optimal energy levels, treatment time on tissue and objective measures of clinically apparent soft tissue contraction and reduced skin laxity.

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Conflict of interest

The author has no commercial, proprietary or financial interest in the products or companies described in this chapter.

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Section 3

Energy Based Devices and Liposuction

Chapter 5

Use of Technologies to Improve the Liposuction Outcome Including Skin Texture and Form

Mohan Thomas, James D'silva and Amal Abraham

Abstract

Liposuction as the word suggests involves sucking out fat from the subcutaneous layers. In many parts of the world it is used interchangeably with weight loss and non-surgical fat reduction procedures. The gold standard for liposuction for many decades has been the "Suction assisted Liposuction' also called SAL. Newer technologies have been introduced with varied claims about skin retraction, painless and complete evacuation of fat as well as a faster recovery. This chapter elaborates the personal experience of the Authors with regards to the discussed newer technologies bringing into perspective their indications, mechanism of action as well as clinical outcomes. At the outset the Authors would like to state emphatically that technologies are as good as the surgeon holding them and that somewhat same result can be achieved through a traditional liposuction in most of the cases. A surgeon looking to incorporate these technologies in practice should first achieve a mastery of traditional SAL for the best outcomes.

Keywords: Liposuction, Ultrasound assisted Liposuction, Waterjet assisted Liposuction, Power assisted Liposuction, Radiofrequency assisted Liposuction, Laser assisted liposuction, J-Plasma assisted liposuction, VASER liposuction

1. Introduction

The first and most important thing to know is that not all patients are candidates for liposuction as it is not a weight loss procedure rather is only for body contouring. The satisfaction of a good outcome for both the patient and the operating surgeon would come from selecting the right patient. Liposuction is most effective for treating localized adipose deposits, particularly combined with a targeted weight loss and lifestyle changes. The gender-specific distribution of typical subcutaneous adipose accumulation that are eminently amenable for removal through small incisions allowing the entry of small cannulae connected to constant suction have been taught to us through experience. One of the most groundbreaking medical developments of our time is liposuction.

The suction-based removal of excess fat – which is the most basic requirement of liposuction – is the simple part. The creative part includes determining how much fat to remove for an overall contouring, how much to leave behind for a smooth coverage, and how retractile the skin is.

We classify patients based on their BMI, and if the BMI is greater than 33, we recommend bariatric surgery, which is a SLEEVE GASTRECTOMY generally depending on assessment by the Bariatric Surgeon. Liposuction and skin removal may still be required in such cases to achieve the ideal shape for the person once the weight has been stable for more than a year.

At first glance, liposuction may be considered to be one of the simplest treatments especially for someone seeking to be a cosmetic surgeon however it requires an artistic skill and experience.

2. History

Liposuction has its origin as a procedure involving subcutaneous scissor dissection with curettage and debris suctioning in the second step.

Modern fat extraction began approximately 40 years ago, initially as a closed technique, when the German physician Schrudde [1] first published his technique (called lipexeresis) using a uterine curette to remove subcutaneous fat. Several other surgeons, including Kesselring and Meyer, used this technique in the mid-1970s, and combined this with aspiration to remove more fat. Further stages of development included the intriguingly named 'cellulosuctiontome' [2] and 'aspiradeps' [3] that defined the second generation where sharp dissection and suction were combined as a single stage.

The prime originator of contemporary liposuction is Illouz [4], from France who ushered in the third generation by innovating a blunt-tipped cannula and the use of wetting solution to aspirate a lipoma from a patient's back. The latter aided aspiration and for the first time a procedure with acceptable morbidity and reproducibility was available to address fat deposits. Visiting Americans embraced liposuction with such a vigor and it was an US dermatologist Jeffery Klien [5] who first introduced the tumescent technique. Such direct infiltration of tumescent fluid produced regional anesthesia of both the skin and subcutaneous tissue allowing avoidance of general anesthesia and its use as ambulatory day care procedure thus could be done by Non-surgeons and/or those not having formal admitting rights to hospitals. Moreover, the combination of dilution and active removal as part of the lipoaspirate allowed higher doses of lignocaine to be used, but a safety limit of 35 mg/kg was proposed to limit toxicity [5, 6]. A firm structure for protection (especially for intra-abdominal viscera in those with abdominal laxity) and a more controlled harvest to reduce post-operative contour irregularities are two other advantages of the tumescent technique. Suction-assisted liposuction (SAL) is the general term for this method, and it is the gold standard by which all others are evaluated.

The fourth generation are the use of novel lipolysis technologies, the first of which was ultrasound-assisted liposuction (UAL) [7]. With less physical effort put into the aspiration and sound energy breaking down the adipocytes, more attention could be placed on the end product, a term known as "liposculpture." Unexpected cutaneous burns from the extra energy transmitted to the tissues specially the skin dampened the excitement, but the idea of 'assistance' was born nevertheless. This is well discussed in **Figure 1**.

Laser-assisted liposuction (LAL or Smart lipo) [8], power-assisted liposuction (PAL such as from MicroAire) [9], and, most recently, radiofrequency-assisted liposuction (RFAL) [10] are some of the other choices available for the Liposuction surgeon.

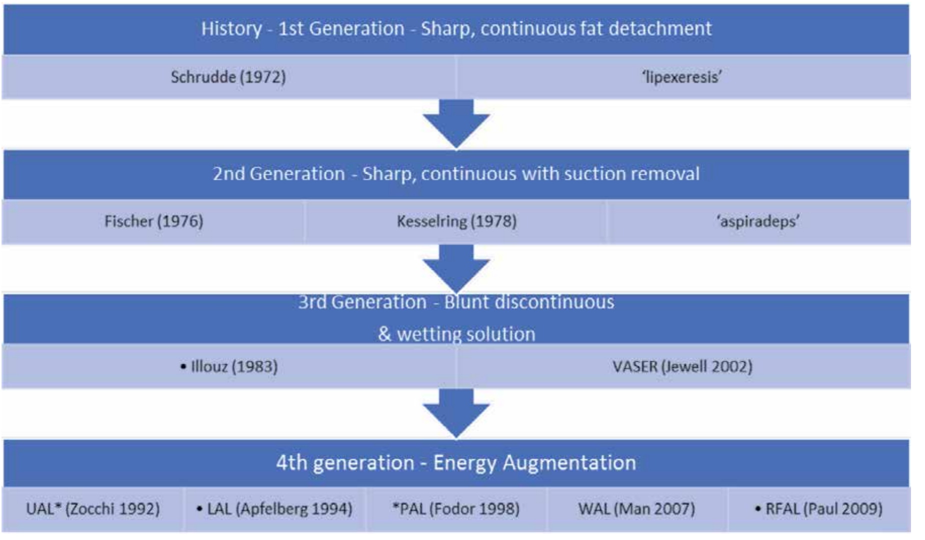

Figure 1.
The development of liposuction and the use of modern technologies for ease of fat removal.

3. Material and methods

The Authors have used the below mentioned technologies over the last 15 years and hence this section is dedicated to a discussion about individual technologies, their indications with respect to body contouring, method of undertaking the procedure, long term results of some patients who have undergone the procedures along with the complications that may be associated with the procedure.

3.1 Ultra sound assisted liposuction

Zocchi [7] is credited with the first person to use ultrasonic energy to more specifically target adipose tissue. The prototype UAL was a two-stage process that involved first breaking or lysing the fat followed by its suction. It began with use of 4–6 mm solid titanium probes which in contrast to steel, was better to harness the heat released by converting acoustic to mechanical energy. Electric energy is converted into mechanical energy using piezoelectric or quartz crystals, which is then transmitted and magnified by the probe as high-frequency (in excess of 16 kHz) acoustic energy inaudible to the human ear. The sound wave has alternating expansion and compression sections which produces negative pressure and induces an interstitial cavity, hence the term cavitation (**Figure 2**).

These microbubbles ultimately implode, resulting in cellular fragmentation and intracellular material release [7, 11]. The selectivity and tissue specificity of UAL are based on the assumption that this happens most rapidly with adipose tissue. Since this method generates a lot of heat, there should be plenty of wetting solution to aid dispersion and limit any negative thermal effects. The technological end point varies from SAL in that it is not simply the traditional 'pinch test,' but lack of resistance to probe progression that suggests adipocyte liquefaction and the 'end point'. Lipoaspirate is also homogeneous and macroscopically acellular, with a slightly higher level of the intracellular glycerol 3-phosphate dehydrogenase isozyme unique to adipocytes [12].

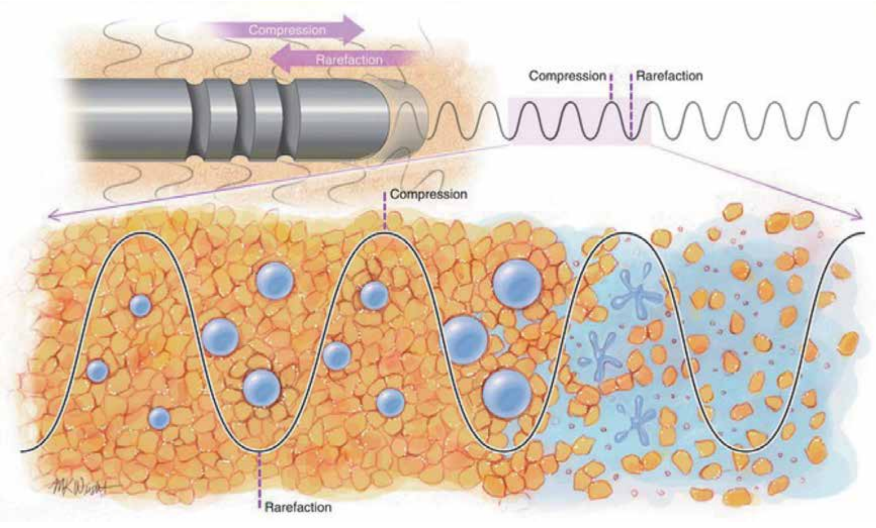

Figure 2.
The compression and rarefaction of the ultrasound waves causing breakage of the fat cells.

American doctors accepted UAL leading to the creation of second-generation UAL devices with hollow cannulae for simultaneous aspiration [13]. Unfortunately, the wetting solution's simultaneous cooling effect is lost which led to the appearance of third-generation machines.

The VASER® (Vibration Amplification of Sound Energy at Resonance, Sound Surgical Technologies, Louisville, CO, USA) device [14] is one of the most commonly used. It comes in two models (**Figure 3**).

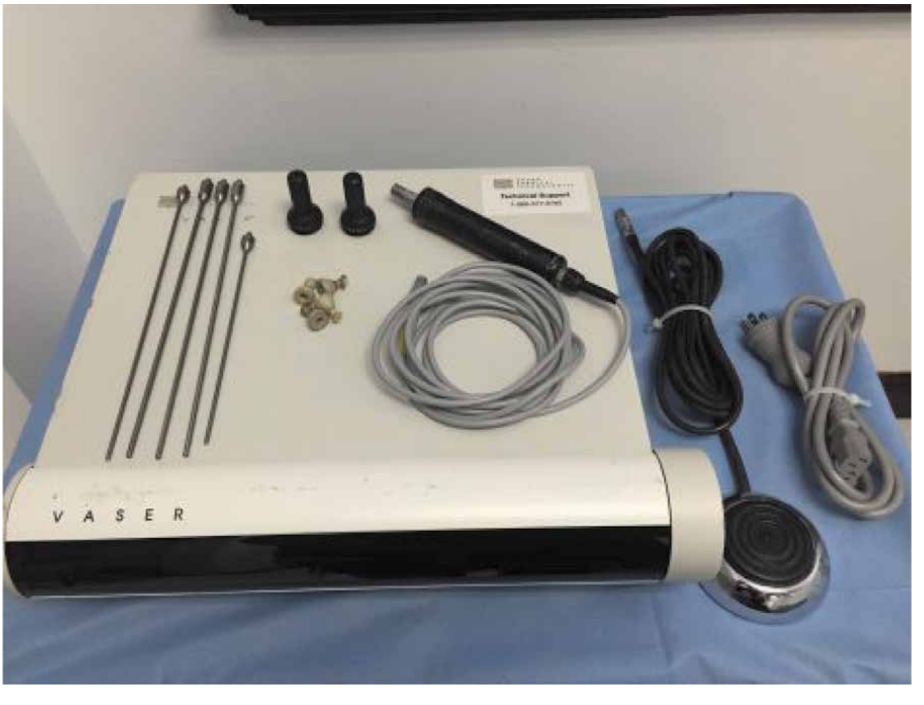

Figure 3.
VASER machine with its probes and other accessories.

The first uses pulsed energy rather than continuous energy, and the second uses concentric rings near the narrower (2.9–3.7 mm) probe tip to maximize performance. At lower and safer energy environments, substantially greater fragmentation efficiency can be achieved [15].

The VASER system uses a method for pretreating fatty tissue with ultrasonic energy, which induces fragmentation/emulsification by three biologic effects, similar to the previous devices.

1. The damage caused directly by the unidirectional action of ultrasonic waves in intracellular organic molecules is known as the micromechanical effect. This is a minor effect.

2. Thermal effect, which is a byproduct of the cannulas passing through the fat and the surrounding tissues' causes conversion of ultrasonic waves into heat energy.

3. Microcavitation effect, which involves gaps between cellular membrane molecules.

When ultrasonic waves reach their higher amplitude plateau, they cause expansion and when the ultrasonic waves reach their lower amplitude plateau it is followed by passive contraction of the gaps, resulting in a cycle of active expansion and passive contraction. The frequency at which the cycles occur, however, prevents the contraction process from being completed before the expansion cycle starts again. As a result, the gaps grow wider until they exceed 120 metres and implode, rupturing the cellular membrane and releasing the lipid content into the extracellular environment [16–18].

Tiny diameter titanium solid probes (2.9 and 3.7 mm) with grooves near the tip are used in the VASER method to improve fragmentation efficiency (**Figure 3**). The grooves close to the tip redistribute ultrasound energy and move some vibration from the tip to a region proximal to the tip. Less energy is thus needed to achieve the desired fatty tissue fragmentation due to the improved efficiency. As compared to the continuous mode, the probe design will result in a nearly 50% reduction in applied power with improved fragmentation capability. Another important difference is that the handpiece and instrumentation of the VASER system are lighter, smaller, less bulky, and more convenient than those of previous systems [19–22].

3.2 Vaser lipoplasty technique

For any procedure involving liposuction and body contouring pre – operative marking with the patient standing, is a must. Once marking is done and after administrating Local or General Anesthesia. The tumescent fluid is infiltrated to the planned operating site, until the skin is blanched. The tumescent fluid composition used by us is mentioned below.

Tumescent fluid composition:

Lidocaine – 35 – 55 mg/kg body weight.

Epinephrine – 1: 1000000 meq/ body wt.

Sodium Bicarbonate – 12.3 meq / body wt.

Hyaluronidase – 1500 IU/ 1000 ml of fluid.

Ringer Lactate / Normal Saline – Mix all in 1 liter.

A minimum of 7–10 mins after the infiltration is required for the vasoconstrictive effects to take place. The access incisions of 4-5 mm are made using 11 no: blade and skin protectors (ceramic or plastic) are placed. They're made to prevent injury to the incision edges during the fragmentation process [19]. The skin near the port should be covered with a wet towel to prevent unintended burn lesions if a probe comes into contact with exposed skin. This safety is particularly important in curved areas, where the surgeon's maneuvers to reach the treatment area can expose the skin to probe touch causing collateral damage due to the heat generated.

The first step in the VASER use is to create tunnels in the subcutaneous area so as to prevent damage to the Ultrasound probe. The probe must then be inserted via the port; simple axial back-and-forth motions should be used, with no levering to the sides or up and down. Without unnecessary pressing, the probe should be pushed smoothly at a pace that the tissue and VASER settings allow. It's best to travel at a pace that's close to or slightly slower than normal suction cannula movement. The probe should never be stationary and should always be kept moving parallel to the skin.

Cross-tunneling is highly desirable and should be used wherever possible to achieve more uniform emulsification and better aspiration. If the probe is vibrated in the air, it can cause damage hence the distal 1 or 2 cm of the probe must always be in contact with tissue or fluids or within the skin port and subcutaneous tissue. End-hits and scratching the dermis from below should be avoided to prevent burns to the skin.

The diameter of the probe and the amount of grooves on the tip has an effect on how well it penetrates any given tissue. Probes with more grooves emulsify fat tissue more effectively for a given diameter, but they do not easily penetrate fibrous tissues due to the large amount of vibratory energy transmitted to the sides of the probe rather than the tip.

For fibrous tissues, probes with less grooves are better. Apart from the number of grooves, smaller diameter probes penetrate fibrous tissues more easily. The 3.7-mm probes are designed for rapid debulking and contouring of soft to fibrous tissues in medium to large volumes. The 2.9-mm probes are used for fine contouring and treating smaller soft to highly fibrous localized fat deposits and sensitive areas.

In general, the continuous mode should be used in fibrous tissues for faster fragmentation and when tissue emulsification with the VASER mode is difficult. For more delicate work, finer sculpting, or softer tissues, use the VASER mode. The probe must pass smoothly through the tissue after the system has been calibrated. If the probe fails or drags, the amplitude should be increased, or a probe with less grooves or a smaller diameter should be chosen.

Initial application times with the VASER or continuous mode are recommended to be no more than 1 minute per 200 mL of infused solution, but this method typically results in only partial fragmentation of a targeted area. The manufacturer recommends these settings, but experience and practice allow for up to 1 minute per 100 mL infused. In general, the surgical endpoint occurs anywhere between the tissues' loss of resistance to the probe and that according to the time guidelines.

Suction-assisted lipoplasty or power-assisted lipoplasty may be used to aspirate the targeted localized fat deposits after emulsification [19–26]. Additional aspiration may be needed for optimum esthetic refinement, and since the site is dry, the probe cannot be reapplied after aspiration. Sutures are used to close the incisions, and a typical liposuction postoperative treatment begins.

3.2.1 Clinical outcome

When used in combination with suction-assisted lipoplasty or power-assisted lipoplasty, the VASER system operates in a complementary manner. It's a fatty tissue pretreatment process that uses ultrasound energy to fragment/emulsify fat before aspiration. It uses the least amount of ultrasound power possible to precondition fatty tissue for subsequent aspiration while preventing damage to other elements of the tissue matrix and surrounding tissues thanks to its smaller diameter and specially built probes. Without extending the operative time, it is possible to treat a larger number of area with more cross tunnels for more consistent fragmentation as seen in **Figure 4**.

Histochemical analysis of the aspirate confirmed 70 percent to 90 percent cellular disruption when using VASER energy. Ultrasound energy splits the cellular membrane and releases the lipid content into the extracellular environment, but it does not induce the release of fatty acids from the triglyceride molecular structure, so the fat tissue that remains is not damaged.

Figure 4.
(A) VASER technology being undertaken on the back with cross tunneling. The photograph shows the VASER probe being used to melt fat. Note the skin protection using a ceramic shield. (B) Pre and (C) post procedure photographs (4 weeks after surgery) of a 32 year old male patient who lost 10 kgs with diet and exercise and further wanted to shape his body to get a flat abdomen and not so protruding chest underwent VASER assisted liposuction.

3.2.2 Complications

The most recent series comparing the VASER device to first- and second-generation UAL devices found that the VASER device has a low to zero incidence of complications, while the average incidence of complications with earlier UAL devices is about 5%. Seromas or delayed bursa formation, prolonged dysesthesias, burns, induration, contour irregularities, hyperpigmentation, cellulitis, and prolonged swelling are the most common UAL complications, although these have been attributed to the use of excessive energy or prolonged application. When it comes to neural injury, studies have shown that the length of exposure is more important than the use of ultrasound energy.

The lower need for energy required for emulsification due to the optimization of the applied energy by the grooved probes and the pulsed emission of energy in the VASER mode may explain the lower incidence of such complications with the use of VASER. Burns and ischemic injuries associated with UAL systems have been documented in the literature, and they tend to be linked to execution issues such as end-hitting and intimate contact with the dermis from below [19].

3.3 Water jet assisted liposuction

A small, targeted, fan-shaped jet called Body-Jet (Human Med, Mecklenburg-West Pomerania, Germany) (**Figure 5**) is used to infuse fluid during water jet–assisted lipoplasty (WAL) (**Figure 6**). The fluid's goal is to loosen fat cells with as

Figure 5.
Water jet device.

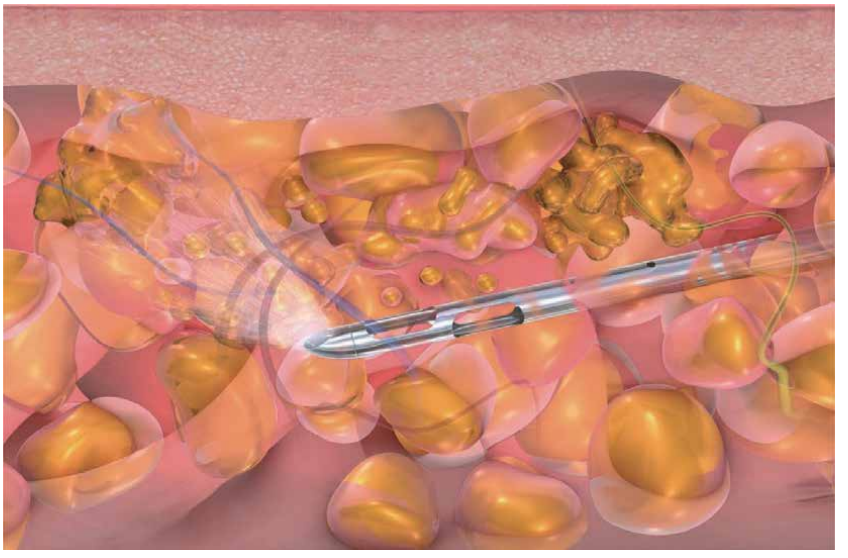

Figure 6.
The fan shaped jet of water infused into the tissues.

little collateral damage as possible, rather than cutting sharply through tissue. The jet is guided into adipose tissue to loosen the tissue structure and allow adipocytes to escape. This is an active method that replaces the conventional passive fluid entry processes of diffusion and osmosis [27].

3.3.1 Technique

WAL employs a dual-purpose cannula (**Figure 7**) that delivers pulsating, fan-shaped jets of tumescent solution, accompanied by simultaneous suctioning of fatty tissue and infused fluid.

The infiltration solution is pumped through a closed tubing system into a passageway within the device cannula by a variable-force infusion pump. The fluid is sprayed at a 30° angle from the cannula's nozzle tip to loosen the fatty tissue. A separate channel inside the cannula is connected to an integrated suction unit, and washed-out fatty tissue is evacuated from surgical sites. The diameter, arrangement, and sharpness of the openings differ among cannulas. Depending on the intent, the flow rate of the infiltrate as well as the application of variable intensities of negative pressure may be selected. To collect the aspirate without centrifuging

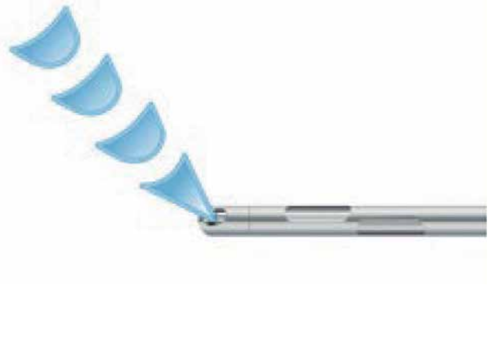

Figure 7.
Image of a dual purpose cannula.

under reduced negative pressures, a sterile container can be connected between the operating cannula and the suction pump.

Long-lasting, maximum anesthesia with minimal side effects is achieved using a two-stage procedure involving two separate tumescent solutions. Preinfiltration, for instance, induces rapid generalized anesthesia and vasoconstriction in the treatment area. Aspiration with a "rinsing solution" containing only small amounts of analgesic is then performed to enhance the analgesia effect and optimize vasoconstriction. The infiltration solution consists of a relatively short-acting analgesic with rapid uptake coupled with a long-acting analgesic with gradual uptake (based on pharmacokinetics). The goal of this formulation is to extend the spectrum of efficacy while keeping each agent's side effects to a minimum [28, 29].

We currently use lidocaine which is considered very safe when used in sufficient doses [30, 31]. We also use epinephrine to induce vasoconstriction.

3.3.2 Method

WAL treatments are recommended for patients who have moderate adiposity with mild to moderate skin laxity, as well as those who want fat augmentation at the same time [32]. Pregnancy, uncontrolled diabetes mellitus, collagen disorders, cardiovascular diseases, and bleeding disorders are considered as an exclusion criteria.

3.3.3 Infiltration of anesthetic solution

To fully anesthetize the sensory nerves, low volumes of buffered 0.5 percent lidocaine containing 1:200,000 epinephrine (eight parts lidocaine, two parts 8.4 percent sodium bicarbonate) were injected above the fascial planes to anesthetize the surgical area. Separating the skin-fat layers from the underlying muscular-fascial layers was made easier by gripping the tissues in a fold.

For more extended periods of anesthesia, smaller amounts of 0.5 percent bupivacaine, up to 50 mL, were injected into sensitive areas over bones (costochondral rib margins, iliac crests, paraumbilicus) and along the boundaries of the planned suctioning areas.

3.3.4 Phase 1: infiltration of tumescent solutions

With the exception of lidocaine concentration, the tumescent solution used in Phases 1 through 3 contained similar ingredients (**Table 1**). After the skin-fat folds were grasped away from the underlying musculofascial structures, an infiltration cannula was inserted in the deep subcutaneous fat. The Body-Jet system was set to "1," which sprayed the prewarmed wetting fluid at the lowest rate, 90 mL per minute, about 2.5 cm in front of the nozzle. The cannula was slowly moved back and forth in the same tract, resulting in a path of hydrodissection as the spray was directed downward (toward the fascia) on the first pass and upward (toward the

Phase 1	ml	Phase 2 and 3	ml
Normal saline	1000	Normal saline	1000
Lidocaine 1%	50 (500 mg)	Lidocaine 0.5%	25 (250 mg)
Epinephrine 1 mg/mL	1	Epinephrine 1 mg/mL	1
Sodium bicarbonate 8.4%	20	Sodium bicarbonate 8.4%	20

Table 1.
Standard wetting solutions.

skin) on the second pass in a twisting motion. Hydrodissection corridors were created in a fan-shape pattern, covering the entire suctioned zone. The low infiltration rate provided adequate anesthesia, effective fat lobule rinsing, and minimal tissue bogginess in preparation for suctioning.

3.3.5 Phase 2: simultaneous irrigation and aspiration

Low infiltration settings were preferred over higher infiltration settings during Phase 2 to allow for more efficient aspiration of minimally turgid tissues. Once the skin-fat folds were distracted from the underlying muscle fascia, a slow, deliberate "to and fro" motion of the cannula was the most effective method for removing fatty tissue through the predetermined fan-shaped pathways. When dealing with denser fibrotic tissue, a cannula with a larger or sharper orifice was chosen. At 750 mm Hg of negative suction, a higher infiltration rate was found to be possibly more efficient for fat removal. A lack of fatty tissue withdrawn in the tubing, a decrease in the diameter of the grasped fat fold, and the occurrence of minimal resistance during repeated cannula passages were used to assess the clinical endpoint.

3.3.6 Phase 3: drying

Step 3 involved using a cannula with fenestrations on the underside to scrape fat remnants under the dermis with a low rate of tumescent solution penetration and a high degree of negative suctioning. The cannula was threaded back and forth slowly during this process, with openings guided away from the dermis to reduce skin irregularities. To remove any residual abnormalities, the irrigating and suctioning functions were switched off to "feather" the tissues.

3.3.7 Post-operative management

To allow drainage over the course of 24 hours, a Penrose or a tube drain can be placed into one of the dependent openings. Other incisions were closed loosely with a single suture and foam sponges were used to provide compression as well as absorb the drainage. Patients were advised to wear a compression garment around the affected region for at least four weeks before returning to normal activities.

3.3.8 Advantages

- In contrast to the amount of tumescent solution used in typical manual lipoplasty, an average of 20–30% was used in preinfiltration, according to the authors' findings.

- As compared to all other tumescent-based lipoplasty methods, the suggested penetration solutions have a substantially shorter period of tumescent solution in the tissue, as well as absorption times.

- In an office-based operation, it allows surgeons to impact fatty tissue with a pulsating stream of tumescent solution while simultaneously removing aspirate under local anesthesia. Sterile fat can be collected for immediate transfer without the need for centrifuging (**Figure 8C**).

- Hematocrit changes were determined to be less than 1.0 percent, indicating that no or minimal blood was lost.

Figure 8.
Pre (A) and post operative (B) photographs (6 weeks later) of a 40 yr old patient who underwent liposuction of the abdomen and flanks along with fat transfer to the face. Fat was collected in a sterile manner using water jet technology. Fat was collected in a closed system as shown in the photograph (C).

- As compared to normal tumescent technique, there is substantially less pain-related impairment before and after the operation. Patients heal well and return to their regular routines faster.

3.4 Radiofrequency assisted liposuction

In the early 2000s, radiofrequency-assisted liposuction (RFAL) was undertaken through two main platforms: a monopolar point source with grounding pad and a novel asymmetric bipolar configuration that did not need a grounding pad. The energy is delivered between two electrodes in the latter device: an external one that maintains contact with the skin and an internal probe that is inserted into the subcutaneous fat layer. Separate temperature targets can be reached with different energy distribution (more internally than externally) (**Figure 9**). The dermis and external temperature can reach about 40°C and higher, while internal temperatures can reach up to 70°C. In addition to subtractive body contouring, these energy modalities are often combined with SAL to maximize soft tissue contraction [33, 34].

The second-generation asymmetric bipolar system (**Figures 10** and **11**) has many added safety features. When done with and without SAL, many RFAL users record substantial soft tissue contraction as a result of the applied energy [33–35].

The second generation bipolar RFAL system can be used safely and efficiently in a number of anatomical regions under local anesthesia, with a low complication rate and a quicker return to daily activities than conventional SAL and anesthesia techniques.

3.4.1 Techniques

The treated area was injected with tumescent solution (1000 mg lidocaine per 1000 mL Ringer's Lactate, 10 mL $NaHCO_3$, and 1.5 mL 1:1,000 concentration epinephrine) into the subcutaneous adipose layer of the treated area through an

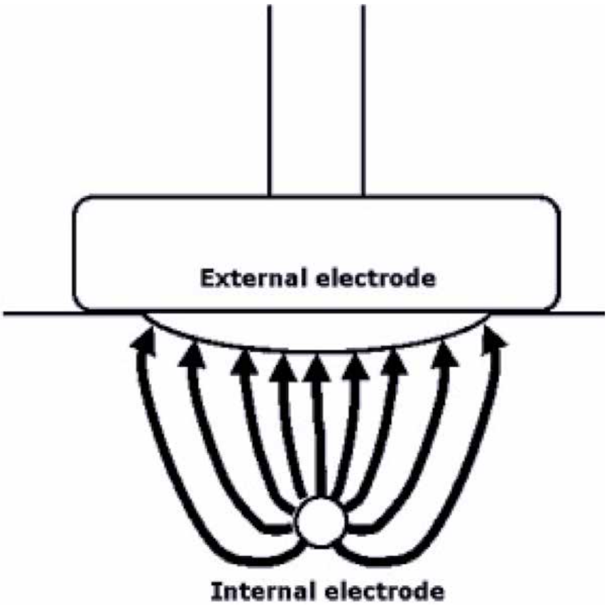

Figure 9.
The power distribution between the internal and external electrode of the radio frequency probe.

Figure 10.
Radiofrequency assisted liposuction device platform.

access incision made after careful marking of the topography of the areas to be treated. To achieve sufficient touch, the internal probe of the bipolar radio-frequency handpiece (BodyTite, InMode Company, Lake Forest, Calif.) (**Figure 11**) was inserted into the intermediate subcutaneous adipose layer, and the corresponding external probe was placed onto the skin covered in a water-based, sterile ultrasonic gel.

The device's maximum external and internal temperature parameters were then set in accordance with the operating surgeon's clinical indications. The RF system was then turned on, releasing asymmetric electromagnetic radiation to gently heat all the soft tissues between the external and internal probes until the desired temperatures were reached on both the skin and the collagen/fat layer. Once the optimum temperatures for both layers were reached, the heating was retained for several seconds according to the clinical presentation, and the energy deposition process was repeated until all treatment zones received the desired amount of energy.

Any areas requiring contouring were treated with regular manual suction-assisted lipectomy (SAL) or power-assisted liposuction (PAL) to remove excess fat

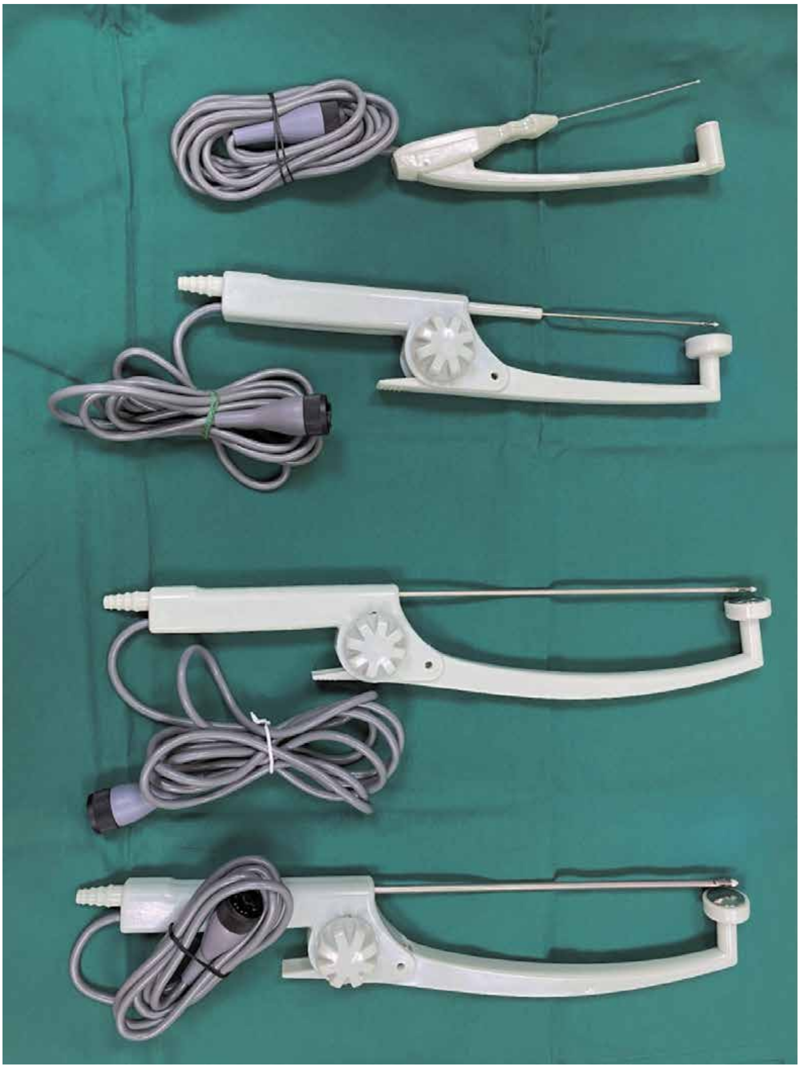

Figure 11.
Radiofrequency probes.

and fluid after this was accomplished. All access incisions were closed with 5–0 nylon sutures, and compression garments were worn on the treated areas for 3–4 weeks after surgery.

3.4.2 Final conclusion

Jowls, neck, upper arms, axillae, bra rolls (midback), flanks, hips, abdomen, male chest, female breast, medial/lateral thighs, and knees were among the common areas treated using radio frequency assisted liposuction. **Figure 12** showing Pre and Post surgery photographs of patient who has undergone RFAL liposuction of the arms.

The procedure usually takes 90–120 minutes to complete, with a tumescent injection volume of approximately 2000 mL.

The mean temperatures outside and inside were 35–42°C and 50–70°C, respectively. Following the protocols, all patients would be discharged home, with follow-up appointments set for one week and three months afterward.

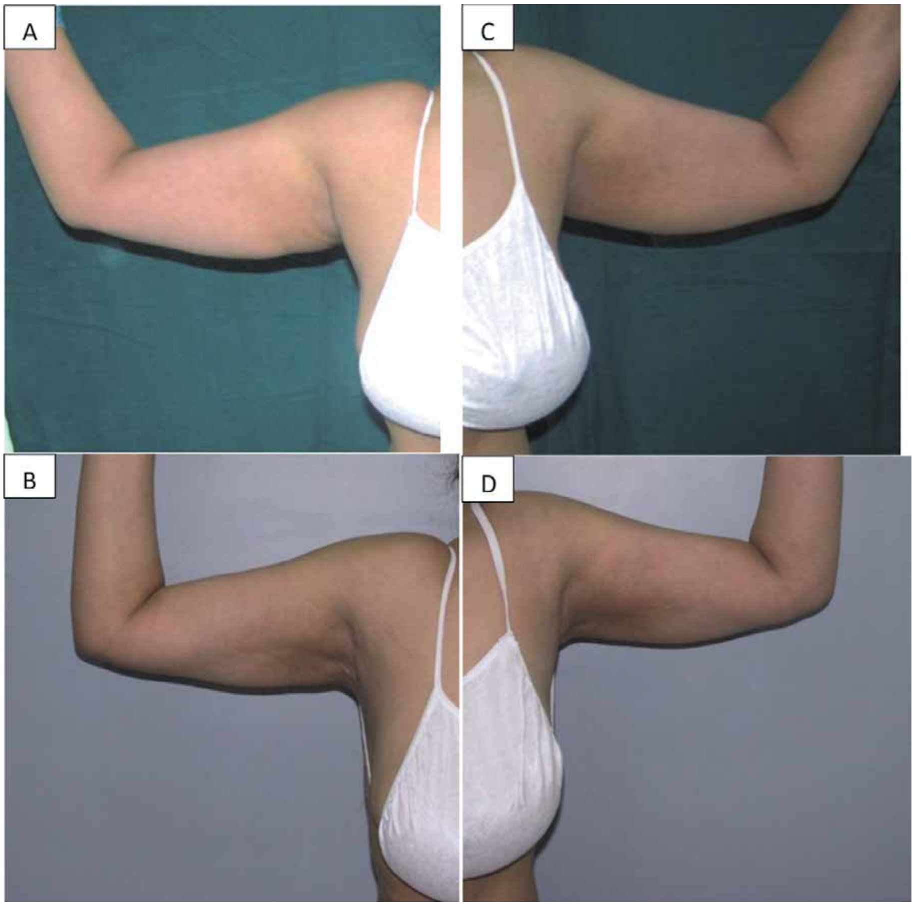

Figure 12.
(A and C) Pre-operative photograph of a 50 year old lady who has fat deposits with moderate skin laxicity in her arms. RFAL can achieve consistent and reproducible results with excellent soft tissue contraction as seen in the above post-operative images 12 weeks after surgery (B and D).

3.4.3 Complications

Temporary weakness of the marginal branch of the mandibular nerve caused ipsilateral weakness of the depressor anguli oris was observed in one case of neck and lower face RFAL. After 5 weeks of monitoring and no action, the issue was finally resolved. Two patients with burns were published in a report [35].

3.5 Laser assisted liposuction

In 1990, a 34-year-old man with abdominal lipodystrophy underwent the first laser-assisted lipoplasty under an IRB procedure. The findings of a multicenter analysis of the laser-assisted liposuction system were announced by Apfelberg et al. [36, 37] and Fodor [38]. There were 51 patients in the study, 15 of whom had laser-assisted liposuction on one side and traditional liposuction on the other. The laser-treated areas had somewhat less discomfort, edema, and ecchymosis, but the hematocrit findings were inconclusive.

The effect of low-level transcutaneous 635-nm, 10-mW diode laser radiation on the subcutaneous fat was studied by Neira et al. [39] in 2002. On human adipose tissue taken from lipectomy samples of 12 patients, total energy values of 1.2, 2.4, and 3.6 J/cm2 were added. Transmission electron microscopy and scanning electron microscopy were used where the standard adipose tissue appeared as clusters of grapes without laser exposure. 80 percent of the fat was released from adipocytes after 4 minutes of laser exposure, and 99 percent of the fat was released after 6 minutes of laser exposure. The fat that had been released had accumulated in the interstitial space. At 60,000 magnification, transmission electron microscopic images of adipose tissue revealed that the adipose cell was affected by the low-level laser energy by causing a transitory pore in the cell membrane to expand, allowing the fat content to escape from the cells.

The interstitial space cells and capillaries remained unharmed. Since red light (635 nm) does not penetrate effectively underneath the skin surface and into the subdermal tissues, Brown concluded that low-level laser therapy is ineffective. The word “greatest active depth” refers to the point at which the light intensity is so minimal that no biological impact can be measured. Just 0.3 percent of laser photons penetrate to a depth of 2.0 cm in a 50 mW/cm2 exposure.

By 2005, laser lipoplasty (SmartLipo, Deka, Florence, Italy) as seen in **Figure 13** with a pulsed 1,064nmNd:YAG laser was commonly used in Europe and Latin America, and had recently been introduced in Japan and the United States. The SmartLipo hand piece is a cannula with a handle that has a diameter of 1 mm. The glass laser fiber extends through the cannula to the open end, and the laser energy is directed to the fat from the cannula tip. On the market, this cannula was the first so-called bare fiber free beam laser lipolysis kit. On October 31, 2006, Cynosure obtained FDA approval for the Smart Lipo product for sale in the United States.

Figure 13.
The Smart Lipo machine by Deka with a pulsed 1064 nm Nd:YAG laser.

3.5.1 Technique

The tumescent anesthesia technique remains the same as mentioned in 3.1 above. After waiting for an adequate period of time the laser cannula is slowly passed through the tissue to achieve lipolysis in the different levels of fat (superficial, medium, and deep) and into the subdermal plane where enough accumulated energy must be delivered. When the laser is used in the subdermal plane, the skin feels warm to the touch. Once the laser was used for lipolysis, the fat was aspirated using a 3 mm liposuction cannula. Acute adipocyte rupture and subdermal collagen band rupture is seen in histological studies. Tiny areas of fat deposits, areas with moderate or possible flaccidity, highly vascular areas, and secondary liposuction with defects, fibrosis, or other difficult cases are ideally suited for this procedure, which takes longer than traditional liposuction.

LAL is a surgery technique that has been recently introduced. However, credible studies comparing its advantages, protective features and effectiveness to those of the well-established technique of conventional liposuction are lacking. Five studies [40–44] indicated that LAL has advantages over conventional liposuction, and only two [45, 46] failed to find statistically significant differences between the techniques in the evaluated endpoints. Histological review [40, 42] shows that subcutaneous fat reduction [41, 43], skin retraction [41–43] and patient satisfaction [41, 43] were the key endpoints assessed in the studies.

Patients who have conventional liposuction procedures can experience ecchymosis, bleeding, and discomfort, which may lead to a longer recovery time [47] Jecan's [40] histological research shows that the LAL technique has potential benefits over the traditional technique, such as the protection of nerve endings and increased blood vessel clotting with less blood loss and milder grades of ecchymosis. Furthermore, the coagulation-modified collagen seen by microscopy could clarify the esthetic advantage of skin retraction after laser use, as shown in other studies [48].

However, promising outcomes in histological evaluations should be backed up by randomized trials that look at specific clinical endpoints.

Two studies [41, 43] found that the LAL technique produced superior results in terms of subcutaneous fat reduction as measured by ultrasound analysis after the procedure. The use of a laser could potentially aid in the destruction of adipocyte membranes, making removal simpler and more uniform, as well as improving the clotting of tiny blood vessels and lymphatic vases. Huge amounts of fat may be eliminated thanks to these benefits, reducing the risk of hemodynamic complications [49, 50].

LAL has the ability to cause collagen formation as well as fatty tissue rupture and liquefaction, allowing for further remodeling and skin retraction [50–52]. Wolfenson's major skin retraction could mean that the use of a dual-wavelength diode laser (924–975 nm) allows for subcutaneous cell tissue and deep dermis remodeling. The most important advantage of laser-assisted liposuction is the skin tightening effect. For that to occur, as previously described, achieved internal temperature should be within the 48–50°C range. That temperature promotes desired thermal injury within the dermis (**Figure 14A**). Subsequently the physiologic healing process is initiated which leads to fibroblast stimulation and neocollagenesis. At the same time, the heat itself shrinks the existing collagen. The final effect is superior skin redraping. Significant decrease in blood loss can be observed during the laser-assisted vs. conventional liposuction. Goldman reported coagulated blood vessels in fatty tissue in the histological analysis of lipolytic tissue.

The use of laser during the liposuction procedures enables the use of smaller cannulas. The fat is being liquefied during the laser lipolysis and in the melted form

Figure 14.
(A) Laser fiber being used for lipolysis in the cervicofacial area. A red colored hue can be seen in the subcutaneous layer when the laser is fired. Patient pre (B) and (C) 7 days post-operative photographs in a 48 year old lady who had lost her jawline due to weight gain.

can be suctioned through smaller cannulas. The liquefaction of fat combined with smaller cannulas for suction enable the treatment of smaller areas as well as the areas that are highly fibrous and where the fat is enclosed in smaller compartments. That advantage is especially significant when treating post-liposuction irregularities, face, male chest, knees, hips and back. **Figure 14B** and **C** are the pre and post photographs of a lady who has undergone cervico facial Liposuction.

3.5.2 Complications

The most common concern regarding the use of lasers in the subcutaneous area is the overheating of the tissue and subsequent burns and skin necrosis. It is important to bear in mind that the injury came from the subcutaneous plane. Therefore, if any blistering occurs in the postoperative period it will definitely result in a full-thickness burn although initially it may appear as superficial one. Due to the scarring of the full-thickness burn, this has to be avoided at all costs.

3.6 J plasma/renuvion assisted liposuction

One of the newer entrants to the energy-based device market is Renuvion® (Apyx Medical, Clearwater, Florida), which is powered by helium plasma. Cold Atmospheric Plasma (CAP) in a highly reactive (partly) ionized physical state that comprises a mixture of physical and biologically active agents and thermal levels of varying degrees is used for this purpose. Through the interaction of the plasma beam (He) with the surrounding air (N2, O2) or the water in the tissue (H2O), cold plasma generates radical species. Reactive oxygen species (ROS) and reactive nitrogen species (RNS) are understood to cause cell proliferation and cell death, while extreme amounts of reactive oxygen and nitrogen species can induce protein, lipid, and DNA apoptosis and damage. These interactions can lead to epigenetic changes at the cellular level [53].

The unique Renuvion energy—helium plasma and proprietary radiofrequency (RF)—allows for precisely controlled delivery of heat to tissue, with minimal thermal spread and rapid heating with near-instantaneous cooling in part aided by the cooling effect of helium gas under the skin (in subdermal applications), which allows for shorter duration of activation and, therefore, less diffusion of heat to the skin. For just a brief interval, it flows through the application site and then disperses, leaving very reliable, predictable results.

There is no net electrical movement across the body, so there is no return electrode needed.

The cold plasma effect is extremely localized, reducing collateral damage to healthy tissue surrounding it. With its reduced tissue spread, Renuvion uses nonconductive currents and limits direct injury, reducing the chance of direct and capacitative coupling.

In addition, Renuvion facilitates secure and efficient coagulation/ablation/incision of tissue with controlled accuracy when tissue is ablated and decreases fear of damage to healthy surrounding structures. The Renuvion thermal ablation zones are illustrated in **Figure 15** and contrasted with normal electrosurgical ablation zones based on current.

In a number of tissue types and contrasts with various instruments, the Renuvion helium unit has limited lateral and thermal spread depth and its tissue effect depth varies from no apparent effect to approximately 2.0 mm with a lateral spread varying from 1.0 mm to 4.0 mm overall diameter for normal use [54].

3.6.1 Renuvion/J-plasma subdermal method of action

The average body temperature is 37° and can rise to 40° with normal illness without permanent effect or damage to the body cells. However, when the cell temperature in the tissue exceeds 50°, cell death takes place in around 6 minutes. Cell death occurs when the temperature of cells in the tissue exceeds 60° instantaneously [55].

Between the temperatures of 60° and just below 100°, 2 simultaneous processes take place. Protein denaturation leading to coagulation is the first. The second is desiccation or dehydration, since the adipocytes lose water through the thermally damaged cellular wall. Intracellular water transforms to steam as temperatures rise above 100°, and tissue cells begin to vaporize because of the massive intracellular expansion that occurs. Finally, organic molecules are broken down into a mechanism called carbonization at temperatures of 200° or more.

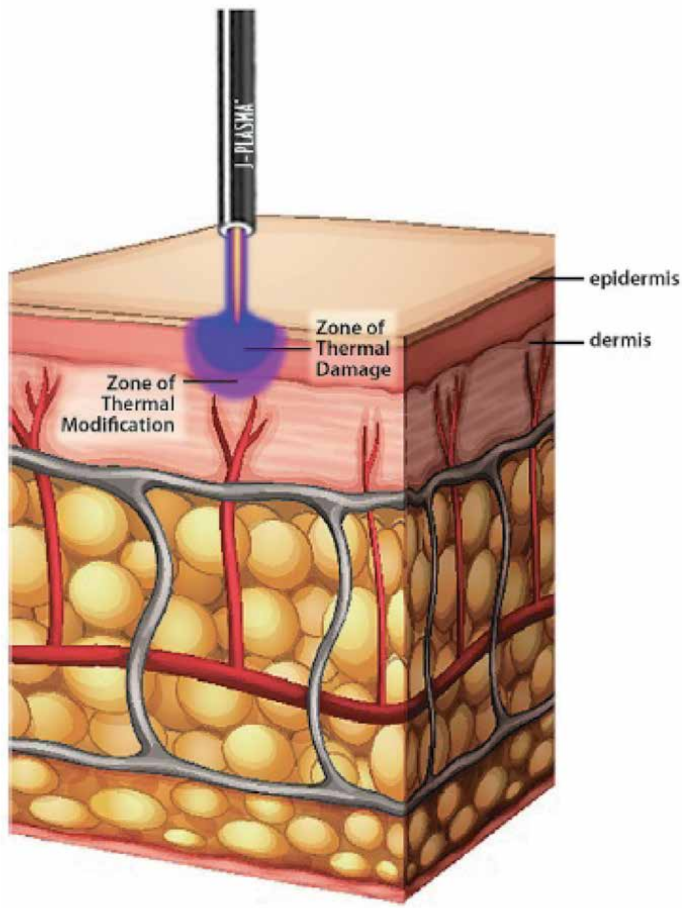

Figure 15.
Precise thermal ablation zones demonstrated with CAP/J-plasma. (Courtesy of Apyx Medical, Clearwater, FL.)

This carbonization leaves behind molecules of carbon that give the tissue a black and/or brown look. These heat effects of RF energy on cells and tissue will make it possible to use predictable changes to achieve beneficial therapeutic results.

Protein denaturation which leads to coagulation of soft tissue is one of the most commonly used tissue effects. Protein denaturation is the mechanism in which protein hydrothermal bonds (cross connections), are instantaneously destroyed and then easily reformed as tissue cools.

This step is followed by coagulation, which contributes to the formation of uniform clumps of protein commonly called coagulum. Inside the cellular proteins are altered but not killed in the coagulation process and form protein bonds that create homogenous, gelatinous structures. The resulting coagulation tissue effect is extremely helpful and is most widely used to occlude blood vessels and induce hemostasis.

One of the major proteins present in human skin and connective tissue is collagen. Collagen's coagulation/denaturation temperature is conventionally stated to be 66.8 C, although this can vary for various types of tissue [56].

Once denatured, as fibers shrink to one-third of their total length, collagen quickly contracts. However, the amount of contraction depends on the temperature and duration of the treatment. The hotter the temperature, the shorter the amount of maximum contraction treatment time required [57].

In medicine, this phenomenon of thermally induced collagen contraction by denaturation and coagulation of soft tissue is well known and is used in ophthalmology, orthopedic applications, treatment of varicose veins, and cosmetic plastic surgery procedures to produce beneficial results.

The use of thermal-induced contraction of collagen/tissue has recently been extended to minimally invasive procedures. Subcutaneous tissue coagulation results in the contraction of collagen/tissue that decreases skin laxity. The helium-based plasma technology of BMC's Renuvion (formerly branded as J-Plasma) has FDA approval for soft tissue cutting, coagulation and ablation.

The Renuvion device consists of a generator unit for electrosurgery, a handpiece, and a helium gas supply (**Figure 16**). RF energy is delivered to the handpiece by the generator and is used to energize an electrode.

A helium plasma is generated when helium gas is passed over the energized electrode, which enables heat to be applied to tissue in 2 distinct ways. First, through the ionization and rapid neutralization of the helium atoms, heat is generated by the actual production of the plasma beam itself. Secondly, because plasmas are very good electrical conductors, a portion of the RF energy which is used to energize the electrode and produce the plasma passes from the electrode to the patient and heats the tissue by passing current through the tissue resistance, a method known as Joule heating.

These 2 tissue heating sources give the Renuvion device some unique advantages for the purpose of coagulation and contraction of subcutaneous soft tissue during use as a surgical tool.

3.6.2 Renuvion for skin tightening and skin rejuvenation

Renuvion may be used for skin tightening using tumescence anesthesia with or without liposuction. Different areas of applications commonly include jawline, submental region, posterior arms, trunk and upper medial thighs (**Figure 17**).

Figure 16.
The J-plasma compressor and the probe.

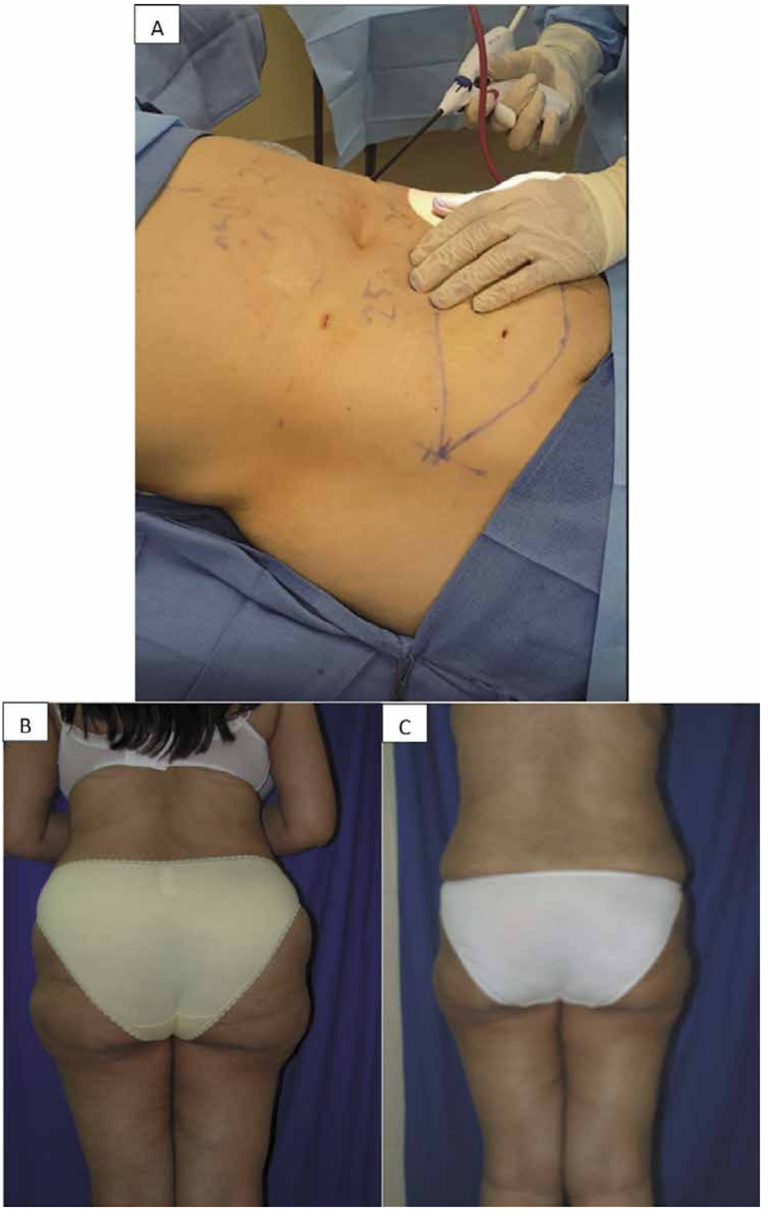

Figure 17.
(A) Renuvion being used for skin tightening in the abdomen after traditional liposuction. Pre (B) and post (C) procedure photographs of a 47 year old lady who wanted to drastically reduce her buttocks as they were in congruent with the shape of her legs. She underwent renuvion for the buttocks along with suction assisted liposuction to take out 5 liters of fat just from her buttocks. The post-operative photograph was taken 8 weeks after surgery.

One of the main key points to achieve good tissue response and proper results with Renuvion® is to assess tissue thickness and depth. The thicker the treatment area is, the higher power and more passes are needed and vice versa. For example, treating submental region and jawline represents an area with thin skin and not significant amount of subcutaneous tissue as compared to the trunk. So, when treating the submental region and jawline, keep the power setting at 60% with Helium flow of 1.5–2 liters/minute and based on the thickness of the tissue perform 1 or 2 passes only. It is very important to avoid crosshatching in this area as this can cause thermal injury and disfiguring scarring of the neck. Staying in the superficial subdermal plane is essential to avoid injury to the marginal mandibular nerve. It is important to keep in mind that thinner areas need less power and lower flow to avoid overzealous treatment.

3.6.3 Complications

Renuvion patients typically do not encounter any new or different complications than those identified as possible complications for the operation being performed. In fact, when compared to other energy-based devices used in the subcutaneous or interstitial space, such as fiber lasers or RF devices, whether temperature regulated or not, the complication profile is lower, thanks to the volume of unionized helium gas under the flaps, which acts as a simultaneous air conditioner. Renuvion's thermal profile, combined with unionized helium gas, produces a more balanced atmosphere than energy-based systems operating on their own.

Renuvion has a low risk of damage to surrounding tissue because of the following factors:

- Minimized thermal spread in depth and laterally;
- controllable and precise micron-level plasma stream length;
- Smoke, odor, and eschar are reduced;

There are no conductive currents going through the patients' bodies thus safe and effective on multiple types of tissue.

3.7 Power assisted liposuction (PAL)

Liposuction, a surgical procedure that removes unwanted and resistant fat from the body has been a labor intensive process for the Surgeon as well as the patient, but now there is a procedure that is less intensive and less traumatic: power assisted liposuction (PAL).

Since the introduction of power-assisted liposuction (PAL) by MicroAire Surgical Instruments, the device has undergone many advances to improve mechanical disruption of normal and fibrotic fatty areas and also works within firmer tissues after secondary surgery for superior fat extraction.

PAL is an advancement over traditional SAL that involves using a rapidly reciprocating cannula tip, in "to-and-fro" motion of the operator's arm but at a lower amplitude of 3 mm [58]. The microcannula eases through the fat and sucks the fat out. The cannula is attached to a hand piece, powered by micromotor device, that causes it to vibrate. The vibration (or reciprocation), is 4000 times per minute. This low-speed reciprocation delivers enough energy to the tip of the cannula, so it passes easily through the substance of the fat with almost no physical effort by the surgeon. This causes a "jack hammer effect" causing the breakdown of resistant parcels of fat tissue which are also avulsed and sucked by the reciprocating cannula [59]. This results in greater control of the area to be liposucked and less trauma to the patient. The vibration also assists in passing the cannula through fibrous and scar tissue.

The MicroAire lipoplasty handle (**Figure 18**) is powered by an electric power source. Both the suction and the power source, which reciprocates the cannula, are attached to the proximal end of the hand piece. As in traditional lipoplasty, the incisions are made to comfortably accept the introduction of the cannula chosen for the procedure. A guard should be preferably used to prevent injury to the entry

Figure 18.
Microaire handle and cannula attached.

points. The use of mechanical energy avoids the side effects and tissue injuries associated with thermal energy, such as deep tissue and skin burns, increased seromas, and painful recovery [60].

The MicroAire powered cannula should be moved slowly so as to break the resistance in the tissue. The sensation of gliding through the tissue should be felt. The end point is the pinch test as well as the obvious absence of lumps and depressions. **Figure 19** shows the pre and post surgery photographs using PAL.

3.7.1 Advantages

1. The PAL cannula breaks up fibrous fat more readily and thus becomes less laborious even when treating fibrotic areas such as Gynaecomastia and back and even in secondary Lipoplasty. It is also very beneficial if done safely for body sculpting when superficial liposuction is required.

2. The PAL cannulas do not get plugged with fibrous tissue as compared to small diameter traditional cannulas. The lipoaspirate can be used for fat grafting too.

3.7.2 Disadvantages

1. Discomfort to the surgeon due to the vibration in the hand piece which is proportional to the speed of the cannula.

Power assisted liposuction (PAL) has several advantages over ultrasonic assisted liposuction: the cannulas used in PAL are usually smaller (micro cannula), that

Figure 19.
Pre (A) and post-operative (B) pictures of a 27 year old man who had already worked hard to create a good body but wanted further definition of his abdominal muscle. The muscle definitions were created using the power assisted liposuction technique. Pre (C) and post-operative (D) pictures of a 22 year old male who wanted to get rid of his gynaecomastia surgery using PAL. The result seen is 4 weeks post-surgery in both the patients.

result in smaller scars: there is no potential for burn injury with the PAL; liposuction procedure takes less time with PAL, therefore is safer for patients; and postoperative pain is less with PAL.

4. Conclusion

This chapter deals with the various technologies which are present in the market and in some way affect the liposuction outcome, be it to improve speed, complete evacuation of fat and achieving tightening of the overlying skin.

VASER is the single best technology in our opinion which not just helps in complete fat evacuation in normal and resistant regions but also helps in skin retraction to an extent.

J-Plasma and Radiofrequency of the tissues helps in skin retraction without any significant side effects which can become the surgeon's next investment. Overall how effective the technology is depends on the right indications, precautions taken and not being cavalier while using it on a patient. Ultrasound and heat can destroy fat cells in therapeutic range but can also injure other tissues if used aggressively.

Conflict of interest

The authors declare no conflict of interest.

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Chapter 6

Internal and External Radiofrequency Assisted Lipo-Coagulation (RFAL) in the Control of Soft Tissue Contraction during Liposuction: Part 1 "Inside Out" Thermal Tissue Tightening

Robert Stephen Mulholland

Abstract

Radiofrequency Assisted Lipo-coagulation (RFAL) BodyTite is a contact, impedance, internal and external thermal regulation controlled, internal, minimally invasive, non-excisional procedure providing soft tissue lipo-coagulation and contraction that has been used for over 10 years to optimize skin and soft tissue contraction during liposuction procedures. The device deploys a bipolar applicator inserted into the liposuction zone. The internal, coated, electrode is positively charged and emits a coagulative, ablative injury that results in adipose liquification and Fibroseptal Network (FSN) contraction. The RF flows from the internal electrode after ablation and coagulation up to the external negatively charged return electrode moving on the skin, which heats and tightens the papillary dermis non-ablatively. The body areas that most benefit from this BodyTite technology and procedure include those areas most in need of non-excision contraction include the abdomen, upper arms, inner thighs, bra-line, neck and jaw line. Studies, show, that the combination of BodyTite internal thermal coagulation and external Morpheus8 (see Part 2) at the time of liposuction can result in 40–70% area skin contraction, greatly improving the soft tissue contours and Body shaping outcomes following lipo-contouring procedures.

Keywords: Liposuction, Radiofrequency, BodyTite, Morpheus8, Soft Tissue contraction, RFAL Skin Tightening, Cellulite, Stretch Marks, Mommy Make overs, Tummy tuck, Armlift, Brachioplasty and Thigh Lift

1. Introduction

This is an opportune time for Dr. Duncan's IntechOpen book on "Enhanced" Liposuction. Liposuction and body contouring is the world #1 surgical procedure. For the modern Liposuctions surgeon, the simple removal of fat has been replaced with adipose contouring in concert with the soft tissue contraction and skin remodeling to deliver body shaping enhancement with an optimized skin envelope. We might even call this book "Enhanced Lipo-contraction", as many times, in smaller areas we are not aspirating fat. Our current Lipo-contouring patients include older patients with laxity, younger patient with atrophic striatum and encompasses soft tissue contouring and remodeling of the periocular, perioral, jawline, neck and all body areas, including formally "too risky" zones such as the lax upper arm, braline, inner thighs and post weight loss abdomens and mommy tummy's. In the current body contouring market, the modern liposuction surgeon must invest in energy based internal devices and technology that offers "enhanced liposuction' to address the diverse and challenges needs of suboptimal skin elasticity and contours.

As a result of InMode's innovations and development of RFAL technology, there has been the creation of a whole new market segment they have call the GAP patients [1]. RFAL or BodyTite treatments can often provide results that are reasonably comparable to a modest tummy tuck, arm lift or thigh lift procedures, but without the extensive scars [2–8]. This RFAL procedure can bridge the gap between non-invasive treatments with very minimal/modest results, minimally invasive treatments that lack the soft tissue contraction, or safety of RFAL and the standard open plastic surgery excisional procedures (**Figure 1**).

The FaceTite, AccuTite RFAL applicators and the Morpheus8 percutaneous OUTSIDE-IN RFAL remodeling tips are all available on the BodyTite workstation, as well as the Embrace RF and EmpowerRF workstations. Each applicator and Hand piece was specifically designed, engineered, produced and sold to serve a very large and growing market segment in the esthetic plastic surgery space; that is, the non-excisional Body contouring, face and neck lift and *GAP skin tightening market*. Non-excisional skin tightening technology and procedure growth has shown 30–40% year-over-year growth rates over the past five to eight years.

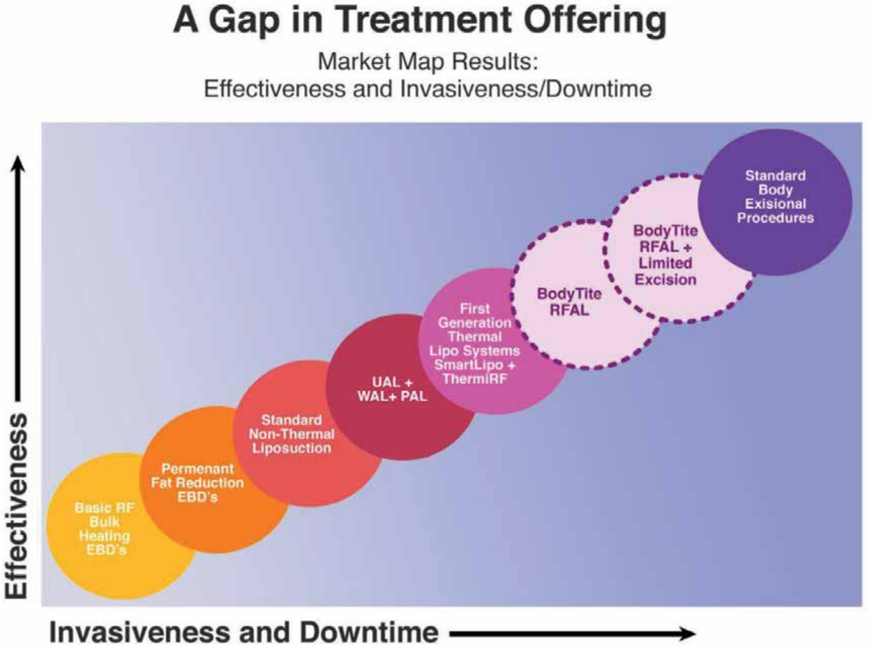

Figure 1.
BodyTite RFAL procedures can serve as a GAP procedure between non-invasive, non-thermally invasive and standard excisional procedures.

2. Basic science of RFAL

2.1 Understanding RFAL and "enhanced liposuction"

Over the past 25 years, I have had the benefit of working with virtually every major external and internal energy-based device (EBD). As an EBD physician, I feel fortunate to have been practicing through this 2 decades plus renaissance in the non-excisional EBD face and body contouring. All of the major technologies I have used have their advantages and disadvantages and like all tools, a good tradesman gets good with what they have. The Astute surgeon will quickly be able to see the InMode BodyTite workstation, although not the cheapest, offers the most versatile, safe and effective GAP procedure offerings lipo-coagulation and contraction of the Face, Neck and Body and thus, the extra money of capital outlay, result in a multiple of ROI that make the purchase price differences compared to its competitors worthwhile.

It is now irrefutable that thermal stimulation of the deep subcutaneous and sub-dermal space works to achieve a degree of lipo coagulation and skin contraction that exceeds non-thermal techniques alone. The excellent work of Dr. Barry DiBernardo using a laser lipolysis system (SmartLipo, Cynosure) has shown a good 17% area contraction, 25% increase in dermal thickness and 29% increase in skin elasticity following sub-dermal thermal stimulation using a laser fiber [9]. This SmartLipo study was measuring only the thermal control of the subdermal space and skin contraction. The limiting factor in the 15–20% skin tightening component of soft tissue contraction is the thermal safety features of devices that work directly under the skin. Most of these devices (Vaser, Laser, Plasma or mono-probe RF) you would be hesitant deploying then on the face, eyelids, or neck, or even low-fat content small body areas where the incidence of burns and seromas' would be too high. The medical-legal liability of not using a state-of-the-art enhanced, automated external and internal thermally controlled Lipo-contouring device as the "standard of care" would be a decision that would be very hard to defend.

Because of the risks of thermal injuries and burns, prior to InMode and RFAL, most technologies sell features and tissue effects that work in the deeper adipose tissue. Ultrasound (VaserLipo), Laser (SmartLipo), Plasma (Renuvion) and mono-probe internal RF, are all most safely deployed in the adipose tissue, NOT IN THE immediate Subdermal space. All these competitive energy devices have value and benefit, but I will also highlight in these two chapters why the BodyTite, workstations provide the most effective "Total Tissue thermal contraction" (adipose + Skin) and bulk heating, in the safest construct, with automated feedback RF and thermal control, facilitating the industry leading 60–70% contraction **IN ALL TREATMENT** areas from the delicate eyelid tissue to large abdominal collections. It is this **"Total Tissue",** bulk heating, thermal control and contraction proposition and the far more **ROBUST ROI from its safety and versatility,** that continues to have InMode as the world's leading Thermal Contraction System **BY FAR** [10–15].

As physician owners you can deploy your AccuTite anywhere on the face, from the brow and lids, midface, perioral region and neck and the Morpheus externally for tightening and wrinkle reduction; the FaceTite on the jawline and neck, upper arms, breasts and BodyTtie on all body areas with the Morpheus used in combination from the outside-in. With the BodyTite applicators you get your 20–25% skin contraction with safe predictable subdermal and transdermal work (Morpheus) and the FSN contraction of 40% the RFAL inside applicators.

The BodyTite, FaceTite, AccuTite and Morpheus Contraction Formula = Total Tissue Contraction = the summative effect of

RFAL FSN		30–40% +
Morpheus Subdermal		15–20% +
	=	60–70% Total Tissue contraction

2.2 What is RF?

RF, or Radiofrequency energy is part of the electromagnetic spectrum, with a frequency range that is dependent upon the industry and device. In medicine, in general, radiofrequency energy is high frequency alternating electrical current that operates in a frequency in the range of 100 kilohertz to 6 megahertz (**Figure 2**). The most common frequency of medical equipment alternating electrical current is one million cycles per second. The RF deployed in esthetic medicine is generally a pure thermal effect (the InMode BodyFX and Evovle TRIM being the exception, where its effects are both thermal and electroporation). The action potentials of nerves are not sensitive to RF current at the frequencies deployed in esthetic medicine (*one million cycles/second*) [16].

The FaceTite, AccuTite, BodyTite and CelluTite RFAL technology uses an alternating electrical current operating in the frequency of one million cycles per second. When one looks at the electromagnetic spectrum in medicine, very low frequency energies such as iontophoresis are deployed in medical devices. This is followed by radiofrequency energy, microwave, infrared laser and light devices, visible laser and light devices and x-ray systems. In the cosmetic space, radiofrequency energy has been deployed internally for surgery with necrotic and ablative devices, such as monopolar and bipolar electrocautery, or the classic Bovie, as well as non-ablative external devices, such as Thermage or the moving non ablative, temperature-controlled RF system from InMode the Forma.

At a cellular level, the alternating current of radiofrequency flows between positive and negatively charged electrodes of the device. The alternating nature

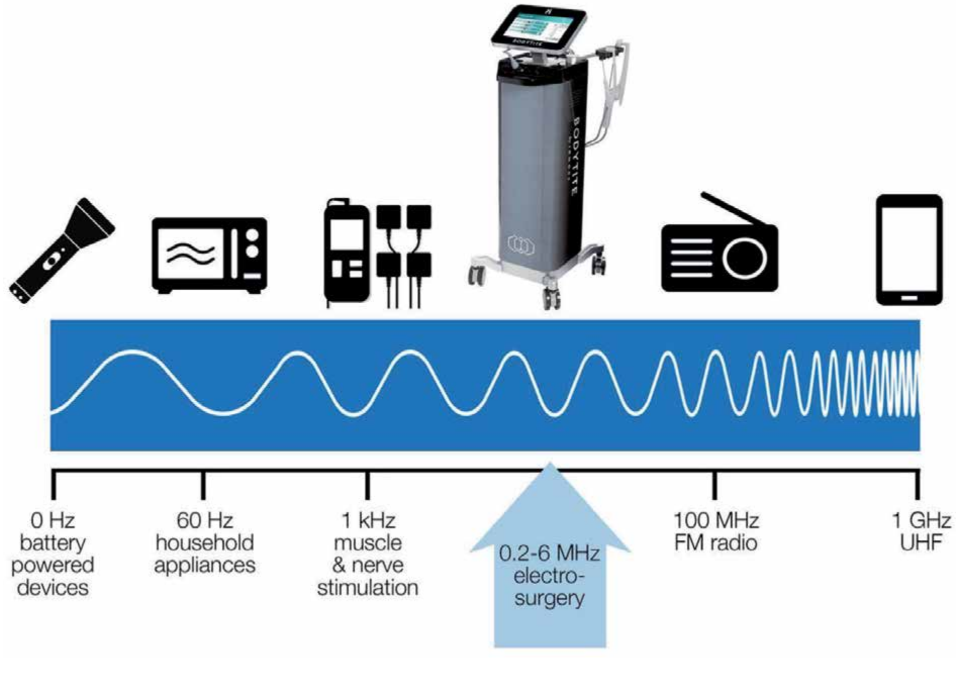

Figure 2.
The electromagnetic spectrum and commercial devices and where RF energy and the esthetic space resides.

of the radiofrequency current causes micro-oscillations in molecules throughout the tissue the RF is flowing through. The micro-molecular motion and micro-oscillation results in heat and heat is a final end pathway to the desired therapeutic effect of radiofrequency energy. There are three main types of radiofrequency thermal effects and InMode through and its various Esthetic workstations, deliver all types of RF injury to tissue and biological systems: (i) RF Ablation of Tissue

Figure 3.
The 40 watt BodyTite RFAL workstation. RFAL heats in an automated fashion the soft tissue at the optimal "rate of rise of temperature per volume of tissue", an automated BodyTite feature called temperature Surg protection or TSP. optimal thermal volumetric velocity, as determined by in-vivo studies, is <20 degrees Celsius/cm3/second. BodyTite RFAL will deliver just the amount of energy needed to heat a volume of adipose at this rate (rarely the whole 40 Watts are required). TSP is the automated control of this rate of rise. If the rate of rise of temperature rises to between 20 and 35 degrees Celsius, then the BodyTite workstation will automatically drop the power to the system, lower the RFAL energy on tissue until the adipose temperature quickly returns to less than 20 degrees celsius/cm3/second. Importantly, if the rate of rise of adipose tissue is >35 degrees/cm3/second then the energy to the BodyTite workstation is cut-off and the user hears dull, flat "TSP audible". By the time the BodyTite user repositions the RFAL hand piece and takes the foot of the pedal for a second, the adipose tissue temperature will drop, allowing the physician to begin treatment again.

(ii) RF coagulation of tissue and (iii) RF subnecrotic, non-ablative heating of tissue. The BodyTite workstation provides the physician the versatility of combinations of these 3 tissue effects [1]. (For more on details on the Basic Science of Radiofrequency energy, see Dr. Kriendel chapter on the same in this book.)

2.3 What are the BodyTite and RFAL specifications?

BodyTite is the RFAL (Radiofrequency assisted Lipo-coagulation or Liposuction) applicator used for lipo-coagulation and Suction Assisted Lipoplasty of moderate to larger sized patients. And is powered by the BodyTite Workstation (**Figure 3**). The BodyTite 2.4 mm diameter applicator has an internal electrode that is silicone coated, silastic capped and 2.4 mm in diameter and 17 cm long. In international (in non-USA markets) there is also a BodyTite 3.9 mm diameter internal electrode, with a 25 cm applicator, which shares the exact same thermal and monitored safety features as the 2.4 mm RFAL applicator. The FaceTite is a 1.2 mm internal electrode that is 12 cm long. The Facetite external electrode is proportionately much larger in diameter than the BodyTite 2.4 mm applicator. The smaller RFAL BodyTite applicator external electrode geometry means the power density and RF skin heating capability is much more efficient than the FaceTite (**Figure 4**).

The BodyTite workshop station can emit up to 70 W of energy and this is more than enough for large volume lipo-contouring patients because of the much higher power density of the smaller 2.4 mm RFAL external electrode. 120 seconds of continuous treatment time is allotted before having to double click the foot pedal. The surgeon does not enter the fluence, rather the machine delivers only the amount of RF energy needed to ensure the rate of rise of tissue temperature is <20 degrees Celsius/cm3/second.

Figure 4.
The BodyTite external electrode (top) is much smaller than the FaceTite (bottom), with a larger internal RF emitting electrode (2.4 mm vs. 1.2 mm) and this creates a much stronger power density and coagulation for at the same wattage. Up to 70 W of energy will be emitted automatically, as much as is required (raising and lowering automatically) depending up the rate of rise of adipose tissue.

Unlike the FaceTite, where the distance between the internal and external electrode is controlled simply by pinching the proximal hand piece, which brings the two electrodes closer together to achieve the desired inter-electrode distance, with the BodyTite RFAL hand pieces there is electrode dial to set the desired inter-electrode distance. With the BodyTite, there is an actual dial on the hand piece that controls and fixes the distance between the electrodes. There is a relative scale for the inter-electrode distance (**Figure 5**).

Practically speaking, each number on the Inter-electrode distance dial, corresponds to the number of centimeters between the external and internal electrode (**Figure 6**).

Level	Inter-electrode Distance (approximate)
Level 1	1.0 cm
Level 2	1.5 cm
Level 3	3.0 cm
Level 4	4.0 cm
Level 5	5.0 cm
Level 6	6.0 cm

The high tech, industry leading thermal, high and low impedance, contact sensed, and TSP safety features are the same for the BodyTite as for the FaceTite. The internal electrode is silicone coated with silastic, bullet shaped cap on the end and has thermistor temperature-controlled RF release and adjustable cut off temperatures as high as 70 degrees Celsius. The External electrode houses the contact sensor, external skin thermistor for continuous temperature-controlled skin temperature monitoring, with cut offs ranging from 36 degrees – 42 degrees Celsius, high and low impedance sensor and finally, the Temperature Surge Protection sensor (**Figure 7**).

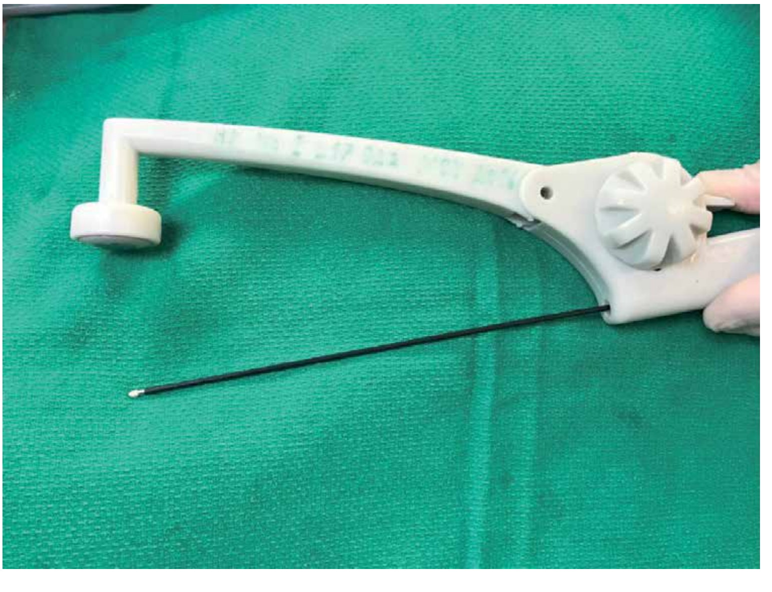

Figure 5.
On the BodyTite RFAL handpieces, there is an inter-electrode distance control dial, numbered 1–6, which determines the distance between the internal and external electrode.

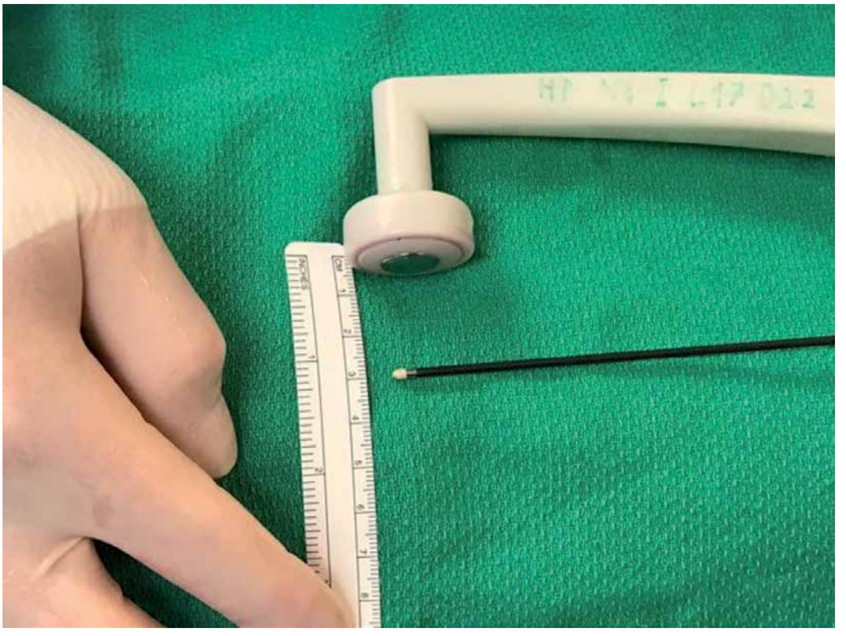

Figure 6.
The dial has settings numbered 1 through 6. Below is the practical inter-electrode distance for each level on the BodyTite dial.

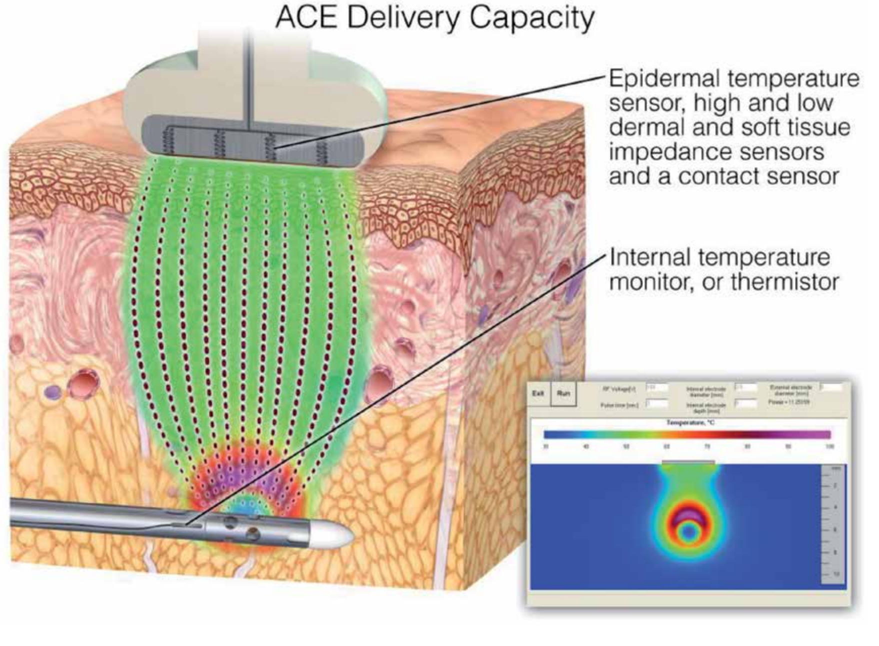

Figure 7.
BodyTite handpiece. RF flows from the internal electrode, where the temperatures a very strong and coagulative, with FSN contraction and adipose liquefaction, to the external electrode where the temperature is more moderate and the effect is a non-ablative heating, remodeling and tightening of the papillary and reticular dermis.

Over the past 10 years, through constant RnD and innovation, InMode has delivered to the marketplace and its physician users increasingly smaller and smaller, more elegant RFAL handpieces, culminating the in the AccuTite (and Aviva on the

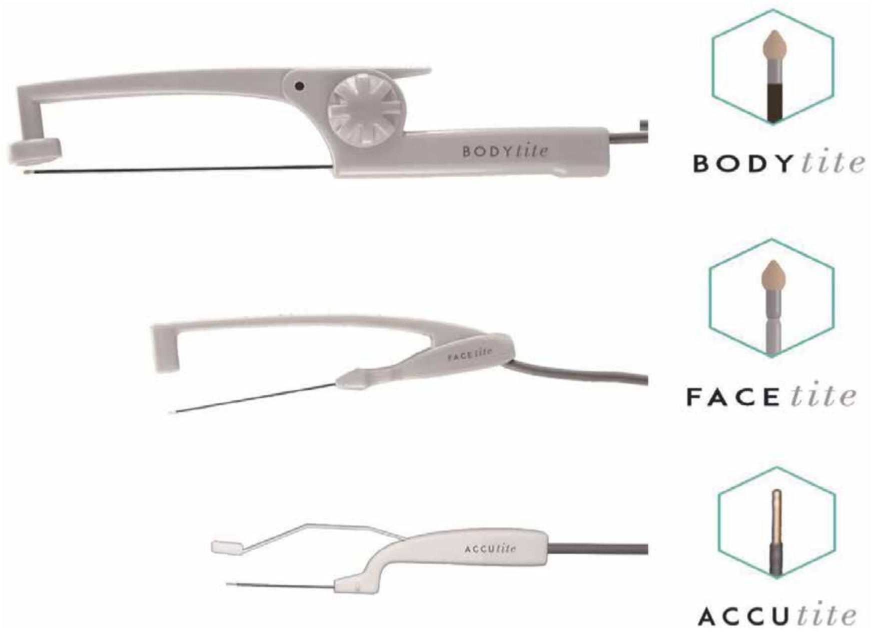

Figure 8.
The InMode RFAL family of handpieces. All the handpieces, even the tiny AccuTite have the same elegantly engineered thermistors and sensors that make the treatments effective and safe.

EmPower RF Gynecologic system), which are no bigger than the palm of your hand (**Figure 8**). All the RFAL applicators, even the tiny ones, operate on the same RF principle and with the same array of thermistors and ACE sensed and automated controlled RF delivery for the responsible delivery of soft tissue heat.

2.4 AccuTite: the injectable skin tightening handpiece

2.4.1 Injectable skin tightening? What does that mean?

The AccuTite RFAL has become so small and easy to use, it has created a whole new category of anti-aging treatment I call, "*Injectable skin tightening*". What does this mean? The AccuTite RFAL is so small and elegantly engineered, that is now smaller than the microcannula systems I use to inject my soft tissue dermal fillers (**Figure 9**). The microcannula technique facilitates the safe, quick and even injection distribution of Hyaluronic Acid gel fillers into the subcutaneous and supraperiosteal space. With the AccuTite being actually a smaller diameter than my microcannula, I can now use the microcannula port to "inject RF, inject heat, inject subdermal skin remodeling and tightening. What an awesome concept?

In esthetic non-invasive medicine, for too long now, we have *tended to over inject* our patients suffering from skin laxity with soft tissue fillers to provide and lift and tightening effect. And while this Filler, VolumaLift, Liquid Lift (many names) strategy works for modest laxity and in certain facial zones, when laxity increases, we use more fillers and end up with the dreaded **"FILLER FACE"**, or **"PILLOW FACE"**, an unattractive, over injected, over-filled look. Would it not be nice to tailor our treatments and Inject Skin Tightening where required and volume only where needed and only to replace what was lost….. **AND THAT IS THE CONCEPT OF ACCUTITE, the INJECTABLE SKIN TIGHTENER. NO SUCTION NEEDED! Just simple AccuTite injection of RF thermal skin contraction in the subdermal space** (**Figure 10**).

Figure 9.
The AccuTite RFAL handpiece is smaller than the actual microcannula I use to inject my soft tissue dermal fillers (a 22 g, 2 inch, Dermasculpt, blunt tipped, rigid cannula).

Now, when treating the aging skin envelope of the face or neck, I will add the necessary neuromodulator to shape the face, use the *AccuTite to Inject Skin and Soft Tissue Tightening* where needed and, using the same access port, I will use my #22 g microcannula to add the necessary judicious and artistic soft tissue filler. Add to that Formula, fractional RF skin resurfacing, and you can now achieve truly amazing non-excisional, minimally invasive skin rejuvenation.

2.5 Where can we use the AccuTite injectable skin tightening procedure?

The following areas all respond well to using the AccuTite, with safe and effective soft tissue skin tightening and significant esthetic improvement (**Figures 11** and **12**).

i. **AccuTite and the Face**

   a. Brow

   b. Upper and Lower lids

   c. Nasolabial and labiomental folds

   d. Pre-Jowls and Jowls

   e. Jawline, submentum and Turkey Neck

ii. **AccuTite and the Body**

   a. Upper arms

   b. Breast Tail

c. Supra umbilical abdomen

d. Inner thigh

e. Suprapatellar knee skin

f. Orange peel, mild cellulite

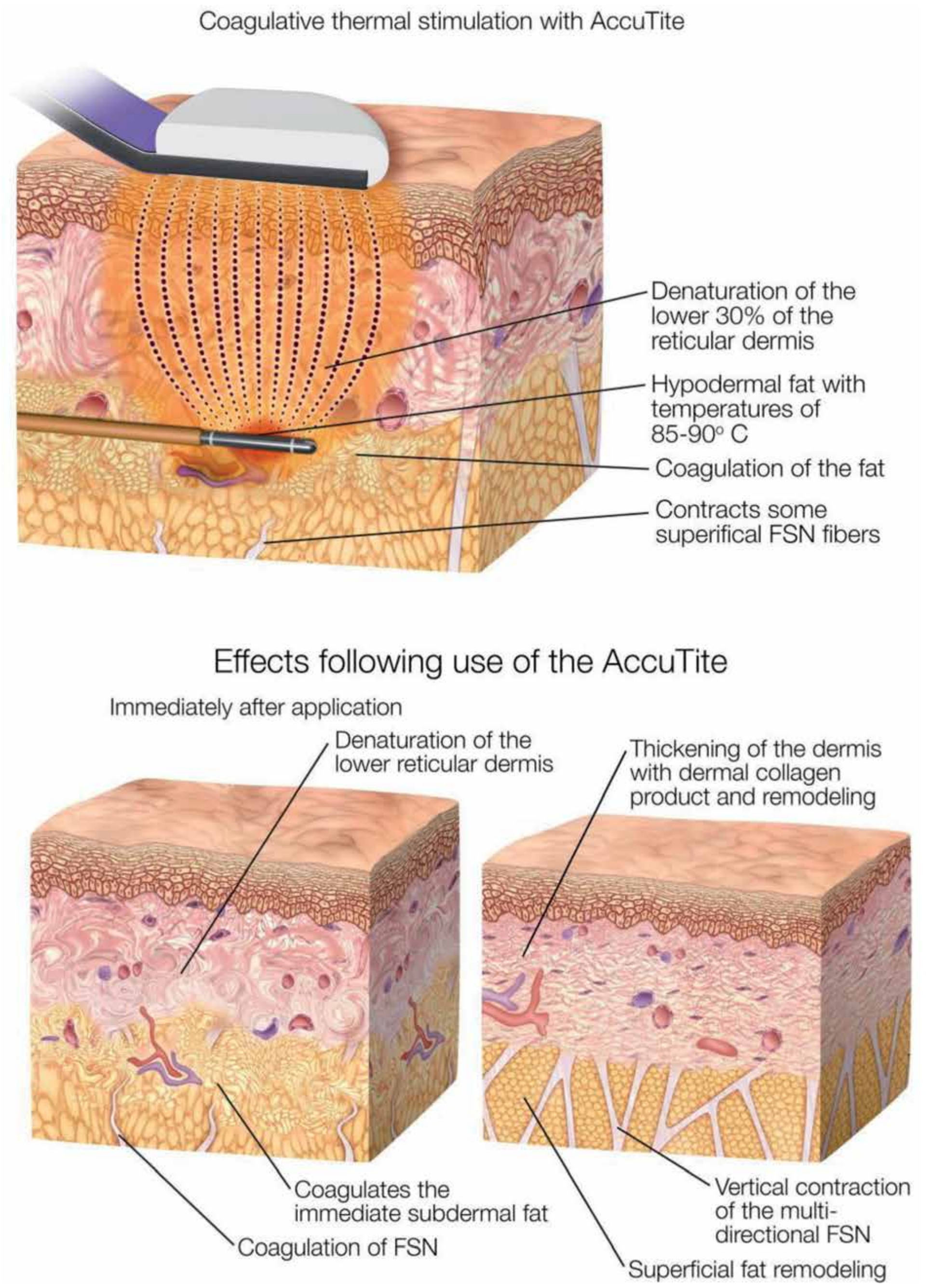

Figure 10.
The AccuTite thermal coagulation ablative and non-ablative effects (top) and the soft tissue contraction and remodeling effects of the ***AccuTite Injectable skin tightening****.*

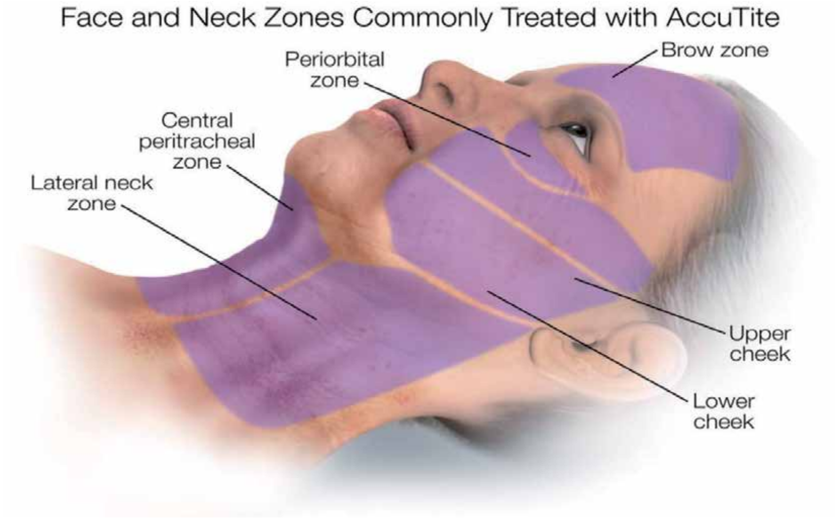

Figure 11.
Common facial areas treated with the AccuTite injectable skin tightening.

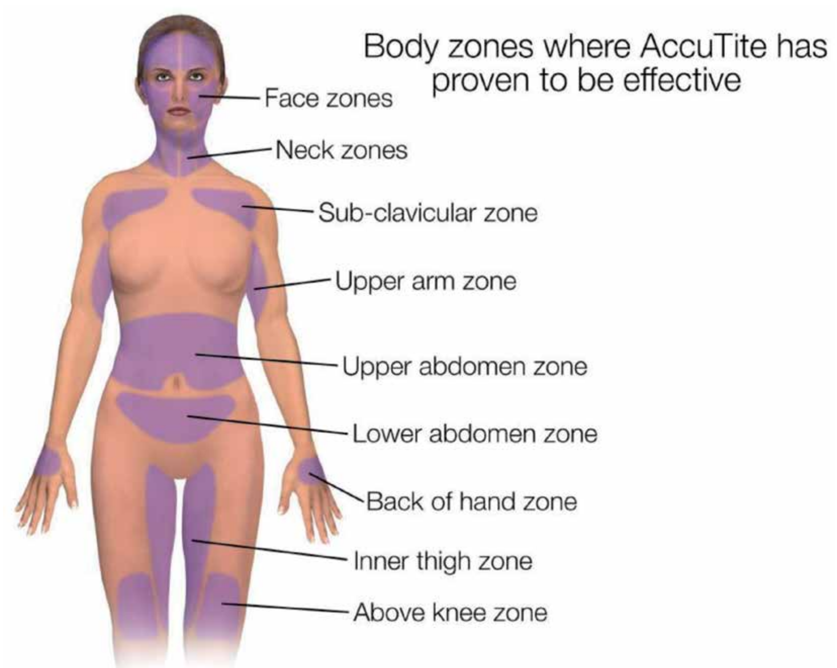

Figure 12.
Body areas where AccuTite injectable skin tightening can be very effective.

3. RFAL adipose FSN contraction

With the BodyTite RFAL applicators, BodyTite, FaceTite, AccuTite (and CelluTite internationally), RF flows from the small uncoated region of the 2.4 mm or 3.9 mm electrode, just proximal to the silastic cap and flows through the adipose tissue from the internal electrode to the external. Up to 70 watts of energy will be delivered automatically by the BodyTite workstation to ensure the most efficient and optimal rate of rise of adipose temperature, which is 20 degrees Celsius/cm3/second. The external electrode moves smoothly along the surface of the skin, in tandem with the internal electrode in a bipolar configuration. The RF provides a strong ablative and coagulative effect on the adipose tissue, vascular tissue and the multi-directional Fibroseptal network (FSN) within 1 cm of the internal electrode, the temperatures are coagulative in intensity (70 degrees Celsius) with FSN and tissue contraction and adipose liquefaction (**Figure 10**). The FSN contracts optimally and maximally at 69 degrees Celsius [15]. At higher temperatures, that are prolonged, the chemical damage to the adipose tissue can result in fibrotic changes to the soft tissue. The RF flows from the internal to the external electrode is strongly ablative and coagulative within 1–2 cm of the internal electrode (**Figures 7** and **10**). As the RF current flows from the internal ablative tissue effect to the external electrode, which is much wider, the diameter of RF thermal heating increases, and the tissue heating becomes non ablative, gentle bulk heating when the RF reaches the external electrode. The smaller "relative" diameter of the 2.4 mm and 3.9 mm external electrode means a higher power density and more efficient RF flow and heating of the soft tissue and skin and temperature end points are achieved much faster than with the 1.2 mm FaceTite, which has the larger external electrode.

The BodyTite is used prior to or after performing SAL on those patients who:

i. need optimal soft tissue contraction to enhance contour and minimize the risk of loose skin

ii. for small venule and arterial vessel coagulation of these small vessels to minimize post op ecchymosis

iii. to coagulate and liquefy the adipose tissue for easy extraction and less post-operative swelling and pain.

iv. Need to achieve a multi-level, sequential stimulation of the FSN and dermal tightening, combined with Morpheus Fractional external RFAL on the dermis and sub-dermal envelope for an overall 60–70% area contraction [10–15].

3.1 RFAL electrode geometry

RFAL is intended for simultaneous coagulation of adipose tissue, blood vessels and sub-necrotic heating and contraction of the **soft tissue FSN** (Fibro-septal Network) matrix and, summatively, the subdermal space and dermal skin collagen (**Figure 13**). This technology combines some of the best features of surgical RF coagulators and non-invasive skin tightening devices. RFAL technology utilizes a geometry shown in **Figure 14**.

By slowly moving the RFAL applicators (AccuTite, Aviva, FaceTite and BodyTite) back and forth through the intended treatment area, uniform ablation and coagulation of adipose and vascular tissue and FSN is achieved. While the external electrode is always moved over the skin surface, the internal electrode should pass through the deep, intermediate and/or superficial fat layers to treat the adipose tissue between 1.5-5 cm. The internal electrode Lipo-coagulation, results in liquefaction of the adipose tissue, vessel coagulation of small venules and arterioles and stimulates the contraction and shortening of adjacent vertical, oblique and horizontal fibers of the FSN, or Fibro-septal network that connects the overlying soft tissue to the underlying muscle.

The hand piece of the RFAL device has a cannula/probe/electrode (internal electrode) with a conductive tip and external electrode with significantly larger surface area. Electrical current through both electrodes is the same but the *resistance for smaller electrode is much higher***.**

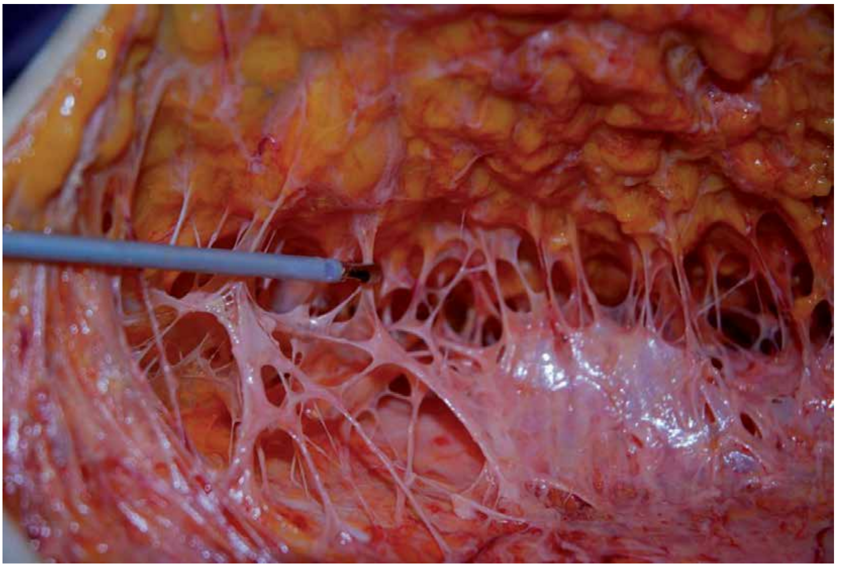

Figure 13.
The vertical, oblique and horizontal fibrous septa of the FSN is the vehicle for RF mediated contraction. The vertical, oblique and horizontal fibers act like "check rein ligaments" holding our skin to the underlying muscular fascia. Heating these fibers to 69 degrees results in contraction of up to 40% immediately. Over 6 months the entire soft tissue envelope remodels and demonstrates 25% contraction, which increases to 40–50% at 12 months and, if you add the Morpheus8 multi-level, multiple pass combination protocol 60–70% soft tissue contraction can occur. The reticular and papillary dermis will be heated, non-ablatively to between 36 and 42 degrees and will also deliver some horizontal soft tissue contraction.

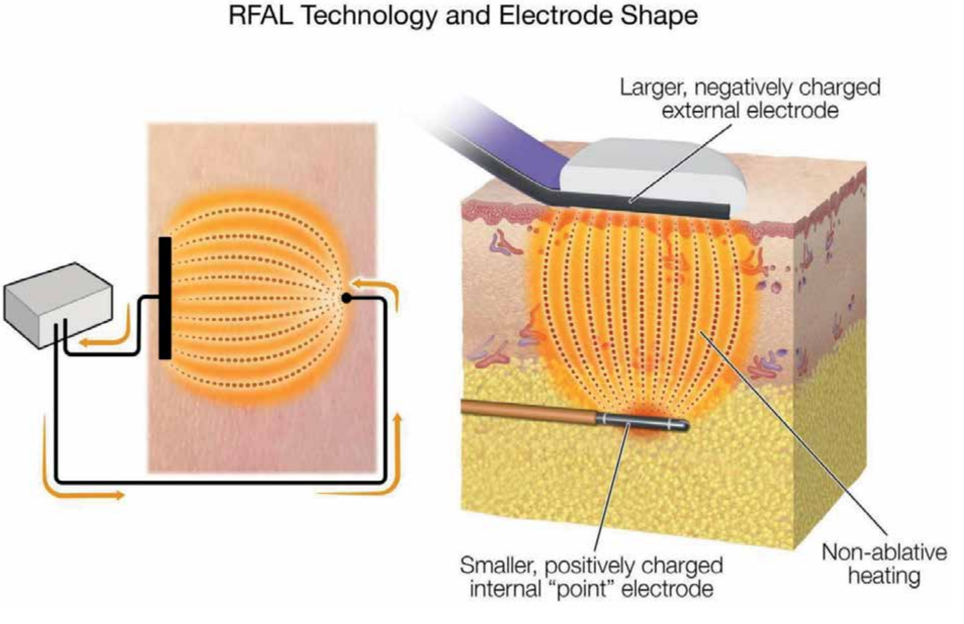

Figure 14.
*In the RFAL technology (**and the Morpheus family of tips**) the RF flows back and forth from the very small tip of an internal, silicone coated, positively charged "point type" electrode, which is placed in the deeper subcutaneous adipose, where the thermal effect is ablative, to a larger, negatively charged electrode that moves along the skin surface, in tandem with the internal electrode and creates a gentle, non-ablative bulk heating effect on the dermis (with the Morpheus, of course, the tip sits on the skin and is static during RF application).*

Initial temperature of the patient body after tumescent anesthesia is about 28–30 degrees Celsius. Desired skin temperature is 38–42 degrees Celsius and required fat temperature is 68–70 degrees Celsius.

The desired thermal coagulative temperatures for adipose coagulation, FSN contraction and small venule and arterial coagulation is 70 degrees. The maximum thermal cut-off in the internal thermistor of the FaceTite and NeckTite is 70 degrees. As RF flows to the relatively large geometrical configuration of the external electrode, a gentle non-ablative, non-necrotic heating of the papillary and reticular dermis occurs with denaturation of the collagen occurs for remodeling and thermal tightening. This bipolar configuration allows the double benefit of internal FSN coagulation and contraction, as well as gentle trans-epidermal papillary and reticular dermal remodeling from the external electrode.

The InMode BodyTite, FaceTite and CelluTite user screen allows the physician user to set the cut-off temperature for the external epidermal monitored electrode as well as the internal coated electrode. The desired endpoint generally, internally is 70 degrees, while externally the desired cut off is between 36 and 42 degrees Celsius, depending upon the soft tissue laxity of the target soft tissue (**Figure 15**).

The silicone coated internal electrode prevents direct thermal stimulation and injury to the external access port and the silicone cap at the end of the FaceTite, NeckTite and BodyTite electrodes is bullet shaped, facilitating easy passage through soft tissue and minimizing the risk of end-dermal hits when going around a curved surface.

3.2 RFAL safety monitoring

One of the risks of any thermal treatment (laser or radiofrequency) is the possibility of a thermal skin injury [17]. Thermal treatment in subcutaneous or subdermal layers may create full thickness skin burn. Therefore, one of the most significant advances InMode has been able to develop and patent, are the contact, thermal, and impedance measurements and software algorithms of automatized RF cut-off feedback control that allow for the most controlled, effective and safest thermal delivery.

3.2.1 Skin temperature measurements and the importance of sensing

Non uniform treatment or over-heating the treatment area may result in the risk of unwanted thermal damage to the skin during the treatment. To avoid or minimize this risk of a skin burn, online real time thermal measurements are necessary. There are two basic methods of skin temperature measurements:

- *Infrared (IR) thermometers measuring IR radiation of heated object.*
- *Contact measurements using a thermocouple, thermistor or thermo-transistors.*

Advantages of IR thermometers is the speed of measurements and they do not need to be built into the device and are independent of the treatment. The obvious weakness of this method is collecting IR radiation from relatively large area which depends on distance from the measured area. You are also relying on a third party that is not linked in time of space to the thermal treatment being performed. Most importantly, you are not measuring the internal thermal profile.

A typical IR thermometer measured area is about 1cm^2 or larger and allows you to monitor average skin temperature in treatment area but does not protect from

Figure 15.
The InMode FaceTite and BodyTite physician treatment screen with the internal thermistor set to cut off at 70 degrees celsius and the external RF temperature cut off at 40 degrees celsius and the treatment time to 120 seconds. The real time temperatures on the right-hand side show the epidermal cut off temperature of 40 degrees and internally of 70 degrees have both be reached. The treatment time is allotted in renewable 120 second allotments (and FDA requirement) and, when the system indicates a time down, a simple release and the depression of your foot starts automatically another 120 seconds are allotted. The BodyTite workstations (FaceTite, BodyTite and CelluTite), release just enough energy to ensure the rate of rise of temperature is 20 degrees celsius/cm3/second. If the rate of rise of temperature is between 20 and 35 degrees celsius/cm3/second, the energy emitted from the system is automatically reduced to ensure the rate of rise is 20 degrees/cm3/second. If the rate of rise of temperature is >35 degrees celsius/cm3/second, the first of thermal injury is unacceptably high and the energy to the applicator is automatically interrupted and a low, flat audible will sound and you will see temperature Surg protection (TSP) on the screen. Simply take your foot off the pedal, re-position the applicator, put your foot on the pedal and begin treatment again. The exquisite safety feature (TSP) has just minimized the risk of the thermal injury.

appearance of small hot spots that lead to the full thickness skin burns. The current "Standard of Care" would now be based upon the advanced on-board, built in InMode thermal, impedance and contact controls and not a third-party IR skin monitoring system. The synchronous and simultaneous measurement of internal and external thermal temperatures and cut-off targets, electrode contact sensing, high and low impedance sensing and rate of rise of temperature sensing and RF cut-off control is the "state of the art" InMode thermal control. All these "sensed" safety features are designed in the software to regulate the flow of RF to the emitting electrodes and is present on all the RFAL family of electrodes (BodyTite, FaceTite, AccuTite and Aviva), the external non-ablative RF devices (Forma, Plus, BodyFx, Evolve Tite, Evolve Trim and Evoke Jawline and Sub-mentum AND is present on the Morpheus Resurfacing and Remodeling tips. NOW that is one smart line of products!

These "sensed" features are measured through the engineering and insertion in each applicator and handpiece an elaborate array of thermistors and sensors and they consist of the following:

3.2.1.1 Internal and external thermal measurement

Internal and external contact methods of thermal measurement allow the device and user to measure the temperature of small areas, both inside and out. The internal thermistors are only on the internal minimally invasive RFAL applicators. The internal thermistor will measure the tissue temperature around the ablative internal tip of the electrode, while the external thermistor measures the skin temperature. The user can set independent internal and external cut-off temperatures that will automatically control the flow of RF energy to the internal electrode when the external and/or internal target temperature has been achieved. The disadvantage of this method is that the response time of the sensor is limited by thermal conductivity. Typical response times can vary by as much a 1 second. When the internal probe is moving quickly and in a uniform heated area the temperature response of the sensor is not sufficiently fast enough to monitor tissue temperature in real time and the clinical technique needs to be modify for slow and steady movements to ensure the most accurate thermal, contact and impedance feedback.

3.2.1.2 Rate of rise of temperature and temperature surge protection (TSP): Optimal safety and efficacy

The InMode RFAL applicators and non-invasive RF handpieces also measure the rate of rise of temperature, each millisecond and which can help overcome the moving applicators and the thermal end point limitations mentioned above. The optimal rate of rise of temperature, as determined by in-vivo abdominoplasty specimen measurements is 20 degrees Celsius/cm3/second. The current InMode RF devices no longer allow the user to enter the RF energy, but rather, deliver just the right amount of RF power, to allow the rate of rise of tissue temperature to be 20C/cm3/second. When this rate of rise of tissue temperature is 20-35C/cm3/second, then the RF energy is reduced until the rate of rise is <20C/cm3/second. When the rate of rise of tissue temperature exceeds 35C/cm3/second, then the RF energy is cut-off, the user hears a temp surg alarm and the user's foot must be released from the pedal and then re-applied to start the flow of RF again, which is enough time for the rate of rise of tissue temperature to drop below 20C/cm3/second.

3.2.1.3 Contact sensing

All InMode RFAL applicators and non-invasive RF handpieces have an external contact sensor and, if contact is broken between the external electrode and the surface of the skin, or is reduced significantly, but lifting the electrode partially off, the contact sensor will alarm and RF energy to the internal electrode will be cut-off. This contact sensing helps prevent arch burns or injuries.

3.2.1.4 Impedance sensing and control of RF output

The BodyTite RFAL system **(and Morpheus**) deploys a very sophisticated, online, Realtime impedance regulatory system to help control clinical circumstances where high thermal temperatures may occur. There are a several RFAL procedural situations when the contact sensing, external and internal tissue temperature and rate of rise of temperature measurements and RF energy control may require the additional of impedance measurement and control as well.

Tissue impedance measurements may improve procedural efficiency and safety of the treatment. Below are a few examples of how continuous, online impedance monitoring and control, in additional to external and internal thermal end point control, contact control and temperature surge protection control can prevent adverse effects.

- When the external electrode exhibits bad contact with the skin surface, high current densities occur on the skin surface, leading to rapid rise in temperature and a sudden drop of impedance (resistance to RF flow through tissue) and this can result in skin damage. The sudden impedance drop can often be "sensed" or "measured" before the internal or external tissue temperature end points or, even the rate of rise of temperature is measured. Occasionally, especially in fibrous areas, the internal electrode may bend slight off the path of the overlying external electrode leading to high impedance on the skin surface and the risk of the burn. By monitoring high impedance, or resistance to flow, as well as the various thermal measurements and limiting power, or turning of the RF power when a high impedance levels are detected, the user reduces the risk of thermal skin side effects significantly from bad external electrode contact or when the internal electrode strays laterally from under the path of the overlying external electrode.

- Touching the under surface of the dermis from the inside by internal electrode may cause thermal skin damage. When this occurs, the impedance will suddenly drop, and the temperature will rise possibly leading to a low impedance burn. By placing a silastic cap on the tip of the internal electrode, this risk of a subdermal injury is greatly minimize, but, as you get close to the subdermal space, by monitoring tissue impedance and limiting lower impedance levels, the device switches off RF power when distance between electrodes is too small and impedance is low, thereby reducing the risk of low dermal internal electrode impedance burns.

Coagulation of tissue is often accompanied by tissue dehydration and carbonization and eschar will accumulate on the internal electrode, which will increase the impedance between the electrodes. When this occurs, the impedance will rise and the Impedance measuring system is adjusted to switch off RF power when tissue is dehydrated, and carbonization or eschar begins to occur near the internal electrode. That prevents eschar effect and increase efficiency of RF power delivery and save surgeon time. *It is also why you will never have to clean eschar off the internal electrode with the BodyTite RFAL system.*

4. The thermal evidence for soft tissue contraction using RFAL

RFAL has been available internationally for 12 years and most recently, in 2016, has been approved for the intended use of soft tissue coagulation, by the FDA in the United States. There is a large body of literature that validates the use of internal thermal stimulation for soft tissue contraction, over and above what non-thermal techniques can deliver, as well as the increased efficiency and efficacy of using radiofrequency energy.

The first question most surgeons will ask is, does RFAL and heat really work to enhance soft tissue contraction?

Internally applied RF energy also travels preferentially up and down the vertical FSN, especially with RFAL, as the current is already flowing vertically from the deep electrode to superficial electrode direction, parallel to the vertical FSN. These concepts were outlined in a number plastic surgery, peer reviewed articles [13–15]. The FSN acts as the conduit for low impedance transport of radiofrequency energy from the internal electrode up to the external electrode. The vertical fibrous septa comprise the vertical encasing septa of the adipose tissue and thus the casing around the adipose tissue is more selectively and rapidly heated by the vertical FSN.

The FSN acts as the conduit for RF conduction and experience a higher concentration of the RF power density and result in more efficient vertical contraction. *It is the vertical, oblique and even horizontal contraction of the FSN that leads to most of the thermal contraction effects of the soft tissue* [4]. This contraction of the FSN, in the vertical, oblique and horizontal vectors *lead to a 3-dimensional contraction in the X, Y and Z axis.* The bipolar-contained energy in the RFAL configuration leads to more efficient bulk heating of soft tissue with no dissipation of heat below the electrode. Dissipation of RF energy and mono-probe RF systems such as ThermiRF and the diffuse radiant heat of laser, although effective and provide heating and certainly when end points are achieved result in tightening, are less efficient than the RFAL bipolar patented configuration of InMode RF.

There is a large body of evidence in peer-reviewed articles that shows the highly efficient nature of the RFAL contraction experience [13–15]. An article published in 2011 in Esthetic Plastic Surgery, using perfused abdominoplasty specimens and the RFAL bipolar electrode applicators to heat the internal soft tissue to various temperatures [15].

The various named horizontal fascia fibers throughout the soft tissue such as camper's and Scarpa's fascia in the abdomen need to be heated to approximately 61.5 degrees Celsius to exhibit contraction and the contraction is in the order of 14%. *This is certainly substantial contraction, but it turns out that the vertical, oblique and horizontal fibrous septa, the vertical, oblique and horizontal FSN, when heated to 69.4 degrees Celsius resulted in an on-the-Table 33% 3-dimensional contraction. And 60–70% contraction measured overtime and with superficial thermal RFAL treatment as well* [10–15]. This paper was the first to point out that internal thermal stimulation to a temperature of 70 degrees can result in immediate contractions in the range of 33% [2]. Using even smaller internal electrode FaceTite applicators in the order of 1.2 mm, contractions of up to 43% -50% have been reported.

4.1 The role of RFAL in superficial skin tightening and dermal remodeling

RFAL also works on tightening the superficial soft tissue and dermis. In fact, in many areas of the body and in many patients, there may not be much subcutaneous fat, which means less FSN. In other patients, there is lots of fat and FSN, but the soft tissue is very loose (tummy, inner thigh and upper arm) and the clinician must tighten the deeper adipose tissue and FSN as well as the superficial fat layers and provide safe and effective dermal heating to optimize "best in class" contraction. Technologies, such as Plasma (Renuvion), Vaser Ultrasound (Sound Surgical), Laser (Cynosure) cannot provide a safe subdermal and superficial subcutaneous thermal control and become dangerous in these body areas. When it comes to the jawline, face, upper and lower lid, the AccuTite and FaceTite are unparalleled for subdermal skin tightening and *"best in class"* thermal contraction and cosmetic outcomes. Add to the list, the Morpheus 8, which also comes loaded on your BodyTite or Embrace workstation and no wonder, InMode RFAL technology is by far the *worlds #1 thermal soft tissue contraction system,* as it adds so much certainty to the patient and the physician practice that deploys it.

The external electrode and the RFAL system provide gentle heating through non-ablative, sub-necrotic remodeling of collagen. There is biopsy-proven evidence in published papers on the nature of this gentle trans-epidermal heating and sustaining epidermal temperatures to 38 to 42 degrees over a series of treatments can result in increased messenger RNA up regulation of 35%. When between four and eight treatments are provided, increased collagen contents of 8–15% have been demonstrated [7–9]. *Combining the FSN RFAL contraction with superficial subcutaneous and dermal remodeling and, even Morpheus, 60–75% soft tissue contraction can be achieved* [10–15].

When we combine the internal RFAL, vertical, oblique and horizontal *FSN 33–43%* 3-dimensional contraction produced on the table, with the gentle trans-epidermal, dermal, papillary dermal or reticular **10–25% remodeling**, significant soft tissue, non-excisional, contraction can be achieved with RFAL technology. An excellent published paper that documents accurately the effect of RFAL skin tightening was published by editor of this Intech Open book, Dr. Diane Duncan in the Esthetic Surgery Journal in 2013 [17, 18]. In Dr. Duncan's article she replicated the study performed by Dr. Barry DiBernardo except this time using RFAL bipolar radiofrequency heating technology; the FaceTite and NeckTite and replicating the same clinical protocol (**Figure 3**). India ink tattooed rectangles were made on each side of the lower abdomen. On one side, after tumescent anesthesia, RFAL was performed heating the deep subcutaneous tissue to 69 to 70 degrees with an epidermal end point of only 36–38 degrees Celsius. Following heating to these thermal end points, standard suction-assisted lipoplasty was performed. On the contralateral side, after tumescent anesthesia, standard suction-assisted lipoplasty was performed without RFAL thermal stimulation or coagulation.

Dr. Duncan followed these abdominal-tattooed soft tissue individuals for six months and twelve months. Dr. Duncan's article is the only long-term thermal contraction study in the literature. Many physicians raised the question that perhaps internal thermal stimulation led to short-term contraction, but by one year perhaps there was no appreciable effect and the Dr. Duncan article this was refuted this quite demonstrably. What she found on the SAL non-thermal side was a 14% contraction at six months, which had fallen to 6% at 12 months showing the stress relaxation of the non-thermal aspiration technique. Six percent contraction by subdermal stimulation and stimulation of the viscoelastic fibers in the adipose tissue can be important, especially in those individuals who have inherently good skin tone. For those individuals, however, who have decreased skin tone or elasticity and laxity, 6% contraction at 12 months will not be enough.

On the RFAL side, she found there was a 24% contraction at six months, and this had increased to 35% area contraction at 12 months. This excellent peer-reviewed and randomized, blinded trial using an extremely accurate contraction instrument, the Vectra 3D and proved quite conclusively that RFAL definitely provides long-term contraction. 35% area soft tissue contraction at 12 months is by far the industry-leading thermal coagulation system. This long-term contraction of 35% (single level FSN RFAL) can give significant non-excisional tightening to the neck, jawline and face as well as body areas where laxity-post contouring or without fat contouring at all is one of the primary clinical outcomes of the esthetic intervention. *However, what is even more impressive, the 35% area contraction at 12 months in this study, was achieved without superficial subdermal work at skin temperatures of only 36 degrees Celsius. By adding superficial RFAL and subdermal work, together with the Morpheus8 studies have shown 60–70%, 12-month soft tissue contraction is achieved* [10–15].

Additional thermal contraction can be provided by not only superficial and subdermal RFAL, but by the simultaneous use of the Morpheus and/or the Fractora, particularly the silicone-coated applicator, and radiofrequency ablative needling and radiofrequency ablation. Simultaneous Fractora with the 24-pin coated will provide a deep papillary and reticular ablation that can be combined with the ablative and necrotic experiences soft tissue effects of the internal electrode combined with a non-ablative bipolar heating of the FaceTite RFAL external electrode (**Figure 16**). Simultaneous use of the Morpheus 8 or Fractora combined with FaceTite, NeckTite and even BodyTite is outlined in chapter are an additional soft tissue coagulation tightening tool to optimize clinical results [19–21].

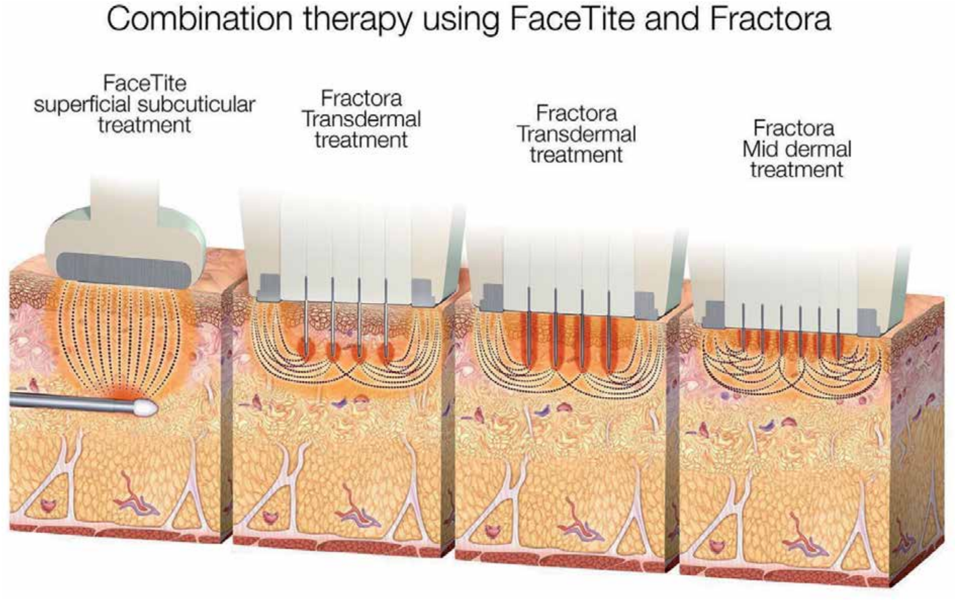

Figure 16.
Optimal soft tissue contraction and tightening can be achieved by combining the 35% contraction with RFAL and the Fractora dermal contraction following fractional RF resurfacing being performed immediately after RFAL.

4.2 How much soft tissue contraction can RFAL applicators deliver?

Excellent peer reviewed studies show that, depending upon characteristics of the patient's soft tissue, anatomic location (high or low FSN zones) and degree of dermal and skin elastosis, *soft tissue contraction and skin tightening of 35–70% (30–40% FSN + 20–30% sub-dermally and dermally) can be achieved (**Figure 17**). WOW, and with exquisite and elegant thermal control leading to a very, very low incidence of thermal injury* [10–15, 22, 23].

In the next chapter, Part 2 of the RFAL phenomenon, we will explore the external RFAL applicator, or "Outside-In" RFAL, the Morpheus 8 and how it works. Part 2 will also synthesize the combination of the Inside out RFAL and outside in Morpheus 8 RFAL to deliver an amplified Lipocoagulation and "enhanced Liposuction.

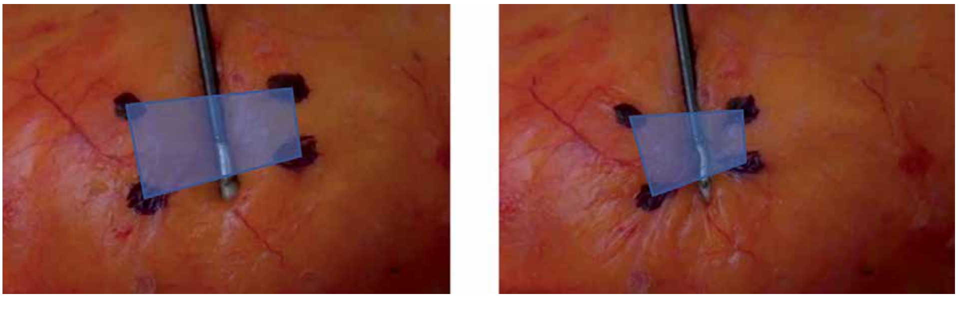

Figure 17.
Excellent peer reviewed articles, from multiple authors and continents have confirmed that RFAL can deliver 40–70% soft tissue area contraction, through combination of adipose coagulative ablation, FSN contraction and non-ablative dermal remodeling.

4.3 My experience with other enhanced liposuction devices

The modern face and body contouring surgeon must embrace energy-based devices to offer advanced "enhanced" liposuction and soft tissue contouring through the face, neck and body. The ability to deliver adipose, FSN and dermal modeling with or without fat aspiration has emerged as a critical factor in the treatment of both delicate face and neck rejuvenation as well as body contouring in challenging soft tissue envelopes. Like the editor and the world renown authors, I have deployed energy-based technologies in offering "enhanced liposuction for over 20 years. The evolution in my "enhanced" liposuction work mirrored the development of more sophisticated energy-based technologies that minimized the trauma of fat extraction and optimized the contraction and, hence control of the overlying soft tissue envelop.

For a number of years, Ultrsonic Liposuction (Vaser) and Water-assisted Lipoplasty (Waterjet) offered my patients less bruising and ecchymosis and viable stem cells, but both lacked efficient, predictable and significant soft tissue contraction. The emergence of thermal assisted lipo-contouring, with laser lipolysis (Smart Lipo, Cynosure and Lipolite, Syneron) combined the coagulation of small vessels, minimized ecchymosis, edema and recovery, while offering, for the first time, a subdermal and FSN thermal contraction and was my favored technology for a number of years. However, the suboptimal efficiency of laser transmission in adipose resulted in only modest soft tissue contraction and the lack of integrated external and internal thermal controls resulted in thermal complications is less trained hands. Thermigen's monopolar RF coagulation device ushered in radiofrequency "enhanced" liposuction in the USA. Although small and less effective for most moderate to large zone "enhanced" liposuction zones, the i incorporation of a 3rd party infrared monitor on the skin and internal thermistor temperature monitoring made this technology safe in small zone and facial contouring, as well, as motor nerve to the corrugator ablation. The FDA pathway with Thermi opened the regulatory door for the FDA's approval of BodyTite and RFAL. BodyTite's integrated, automated RF controlled thermal adipose and dermal bulk heating lead to industry soft tissue contraction and control. The addition of the Morpheus to the BodyTite workstation, with external RFAL, fractional superficial fat and dermal contraction (see next chapter, Part 2) has allowed me total thermal control of the skin dermis and superficial subdermal fat tightening, as well as the well document deeper FSN and adipose contraction. In my hands, the BodyTite experience offers, a truly versatile face, neck and body "enhanced" liposuction and contour system. While all the "enhanced" liposuction technologies I have used and covered so expertly in this book offer undeniable advantages over traditional SAL, we must control **BOTH THE ADIPOSE AND SKIN** contraction to produce the most consistent and optimal results from the eyelids down to the inner and anterior thighs and all lax and suboptimal soft tissue in between. In my hands, the BodyTite experience offers, the most versatile and successful face, neck and body "enhanced" liposuction and contour system.

5. Conclusions

It has become imperative for the modern liposuction surgeon to include an energy based surgical device that facilitates "enhanced liposuction". The emergence of a market segment of consumer, The GAP patients, who are looking for significant non-excisional soft tissue tightening, contraction and wrinkle reduction has created a whole next market opportunity for esthetic physicians. These GAP patients want more than the non-invasive market of toxins, external non-invasive body contouring energy-based devices can offer, but also wants to avoid the scars, recovery and stigma of more extensive excisional procedures. InMode has created the technology to serve this GAP market with the internal and external RFAL applicators, the BodyTite, FaceTite, AccuTite and Morpheus8. Non excisional, minimally invasive procedures can now be offered under local anesthesia in your office and the face and body options are impressive. In the Operating room, even many excision procedures can be enhanced, the outcomes improved or the scars reduction with the soft tissue contraction and wrinkle reduction results of the RFAL technology.

This "Enhanced Liposuction" InTech open book is well timed, as this kind of technology is not only here to stay, but in the case of RFAL, has created a whole new market segment of face and body consumers, the GAP patients. In Part 2 of the RFAL technology, External lipocoagulation and "lipocontouring" using an external adipose fractional ablative device, the Morpheus 8 and its role in "enhanced liposuction" will be outlined.

Conflict of interest

The Author is a paid workshop consultant for the company, co-patent developer and a founding shareholder.

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Chapter 7

Internal and External Radiofrequency Assisted Lipo-Coagulation (RFAL) in the Control of Soft Tissue Contraction during Liposuction: Part 2 "Outside In" RFAL Thermal Tissue Tightening

Robert Stephen Mulholland

Abstract

The new Morpheus8 is a novel external RFAL device that uses the proven soft tissue contraction of BodyTite in an external, non-invasive procedure. This external RF applicator, which is also powered by BodyTite, inserts up to 40 positively charged, coated electrodes 8 mm into the subcutaneous, soft tissue envelope. A monopolar ablative lesion is generated from the tip of the electrode, stimulating contraction of the FSN and adipose coagulation. The RF then flows up to the distant negative, return electrodes on the surface of the skin, providing a non-ablative thermal stimulation to the papillary dermis. The "burst" feature of the Morpheus8, delivers simultaneous multiple levels of internal coagulation in a single one second pulse, amplifying the adipose ablation and contraction effect. Studies, show, that the combination of BodyTite internal thermal coagulation and external Morpheus8 at the time of liposuction can result in 60–70% area skin contraction, greatly improving the soft tissue contours and Body shaping outcomes following lipo-contouring procedures.

Keywords: liposuction, radiofrequency, BodyTite, Morpheus8, fractional RF skin resurfacing, RF micro-needling, soft tissue contraction, RFAL skin tightening, cellulite, stretch marks, mommy make overs, tummy tuck, arm lift, brachioplasty and thigh lift

1. Introduction

The facelift growth rate has been relatively stagnant across the statistics monitored by American Association Esthetic Plastic Surgery, The American Academy of Cosmetic Surgery and the American Society of Dermatologic Surgery and Facial Plastic Surgery. The relatively *flat growth of excisional facelifts* bears witness to the fact that many consumers and potential patients want a non-excisional option, even the results are less significant than an excisional facelift or an excisional skin tightening procedure. With the advances that have led to the development and FDA approval of products such as the FaceTite NeckTite and BodyTite, the non-excisional face/neck lift and lower lid, brow and cheek lift market, as well as the minimal excision or Non excisional Body shaping market is significant. Most esthetic plastic surgeons now offer a broad offering of non-invasive options such as microdermabrasion, skin care, intense pulsed light and other laser cutaneous enhancement treatments, often including non-evasive skin tightening, neuromodulators and fillers. At the end of this ascending stair-stepladder approach to skin and face rejuvenation, the next stop is usually an excisional facelift, mini-facelift, neck lift, blepharoplasty and/or body excisional procedures, such as inner-thigh lift, brachioplasty and mini-tummy tuck or abdominoplasty. The advent of significant radiofrequency-assisted lipocoagulation (RFAL) skin tightening techniques now offers plastic surgeons, facial plastic surgeons, surgical dermatologists and cosmetic physicians the opportunity to *offer patients a significant Facial or Neck skin tightening experience without excisional consequences of visible scars* (**Figure 1**). InMode's BodyTite, Embrace RF, Votiva and EmpowerRF workstations are true revenue empowering GAP procedures, driving patients that would not be interested in excisional facelift, blepharoplasty or neck lift surgery or patients undergoing excisional surgeries but require more contraction AND excision [1].

The skin tightening market, both face and body, is growing rapidly, but, until now, consumers have been limited to trans-epidermal technology such as radiofrequency devices, laser devices and high-frequency-focused ultrasound (HIFU) devices that offer *modest improvement* after two or three treatments with significant

Figure 1.
Facial rejuvenation procedure ascending map of options as function of invasiveness, downtime, recovery, patient age and outcome. FaceTite fills the void between completely non-invasive injectables and energy-based devices and open facelift surgery.

pain and expense. The advantage of FaceTite, AccuTite and the Morpheus 8 is the ability to offer patients a single-treatment, non-excisional Facial rejuvenation and tightening procedure, under local anesthesia with significant soft tissue tightening outcomes. Of course, the BodyTite, FaceTite, AccuTite and the Morpheus 8 can also be combined with mini excisions or lateral-based excisions of the face, or mini skin-only tummy tucks, or axillary arm lifts or mini-inner thigh lifts to enhance and improve the result, but the prime market opportunity is not the improvement of one's open facelift or body excisional techniques, which is important, but to access patients that are looking for a significant but non-excisional surgical experience. However, it would be more appealing and versatile to offer patients the same RFAL adipose contraction concept but from outside.

2. InMode and the morpheus innovation

Now, would it not be even **COOLER**, even more accessible to providers and patients, if this RFAL lipo-coagulation, "enhanced Liposuction" and significant soft tissue contraction and remodeling was available **EXTERNALLY,** a sort of **PERCUTANEOUS RFAL ACCUTITE**? *WELL, now you have it…. the Morpheus Family of soft tissue remodeling applicators and tips,* a trans-epidermal, percutaneous, fractional adipose coagulation, soft tissue contraction and skin remodeling device. In just a few short years, the Morpheus has become the world's #1 fractional skin tightening, wrinkle reduction and soft tissue remodeling tool!

2.1 Trans-epidermal RF systems

The fact that your BodyTite workstation also comes loaded with the world's most successful effective transcutaneous, fractional skin and soft tissue tightening, wrinkle reduction and elastotic treatment device (The Morpheus 8) makes BodyTite system your Total Tissue Contraction, lifting, tightening and smoothening tool. The concept was to take 12–40 pins/electrodes, coat them with silicone, but leave the tip uncoated. Each needle, or micro-electrode is positively charged, like the tip of your AccuTite, or FaceTite electrode. The needles area inserted into the dermis (Fractora) or the adipose tissue and sud-dermal space (Morpheus 8) and then, like with AccuTite, FaceTite, or BodyTite, the RF does not flow between two closely spaced positive–negative needles (micro-needling) BUT the RF thermal energy creates a large monopolar ablation in the fat (Morpheus) or dermis (Fractora) and then, the energy flows up to the negative, return electrodes far away on the skin, creating a non-ablative heating of the superficial papillary dermis.

2.2 Fractora: dermal fractional RFAL resurfacing

This was InMode's first generation of *OUTSIDE-IN*, transcutaneous RFAL for *DERMAL* skin resurfacing and tightening. There are several trans epidermal, needle-based heating technologies that also provide dermal contraction and skin tightening. The most notable is the Profound (Syneron Candela), which is a series of six paired silicone coated needles that have significant bipolar RF ablative energy between them. Each of these coated needles have internal thermistors built into them, they sense the temperature and are able to cut-off the RF energy when the endpoint is met. An endpoint of 67–70 degrees is sustained for 3–5 seconds between these six pairs of internal electrodes providing dermal contraction.

The other effective deep dermal RF system for soft tissue contraction is the Fractora (InMode), which has silicone coated needles that are 3000 microns in length with the proximal 2200 microns being silicone coated and the distal 800 microns being uncoated (**Figure 2**). Multiple passes or stacking in the Fractora tip sustains the Monopolar ablations with the gentle bipolar RF flow to simulate the types of contraction energy that needle-based technologies such as the Profound can achieve [2–6].

The epidermal thermal sparing effect of the Fractora and the newer Morpheus fractional adipose technology make these devices safer on darker skin types [2, 3].

The other needle-based RF technologies such as the Infini, Intensif and Intercell are very different to Fractora or Profound, as they have small micro-current flowing between narrowly spaced positive and negative electrodes and the amount of ablative index or power density is relatively low, accounting for a minimal thermal contraction and the need for multiple treatments to achieve modest improvements. The eMatrix (Syneron Candela) is a low epidermal impact, trans-epidermal, smooth electrode system that can deliver mild to moderate skin tightening after 3–6 treatments. HIFU, or Ulthera, is a fractional trans-epidermal focused ultrasound dermal ablative system, that, like the eMatrix, can deliver noticeable, modest skin tightening after 2–3 treatments.

The advances in esthetic medicine have led to a wide array of trans-epidermal fractional and non-fractional laser techniques, high frequency focused ultrasound and non-ablative RF technologies that can enhance skin tightening. These technologies are ideal when combined with multiple approach protocols for mild to moderate results, but never compete with deep subcutaneous heating techniques such Smart Lipo laser lipolysis, mono.

probe, Monopolar ThermiRF heating *systems or, the market leader in soft tissue contraction and safe thermal coagulation, bipolar RFAL technologies.* It is the combination of the externally applied Morpheus 8 and the internal RFAL that has resulted in

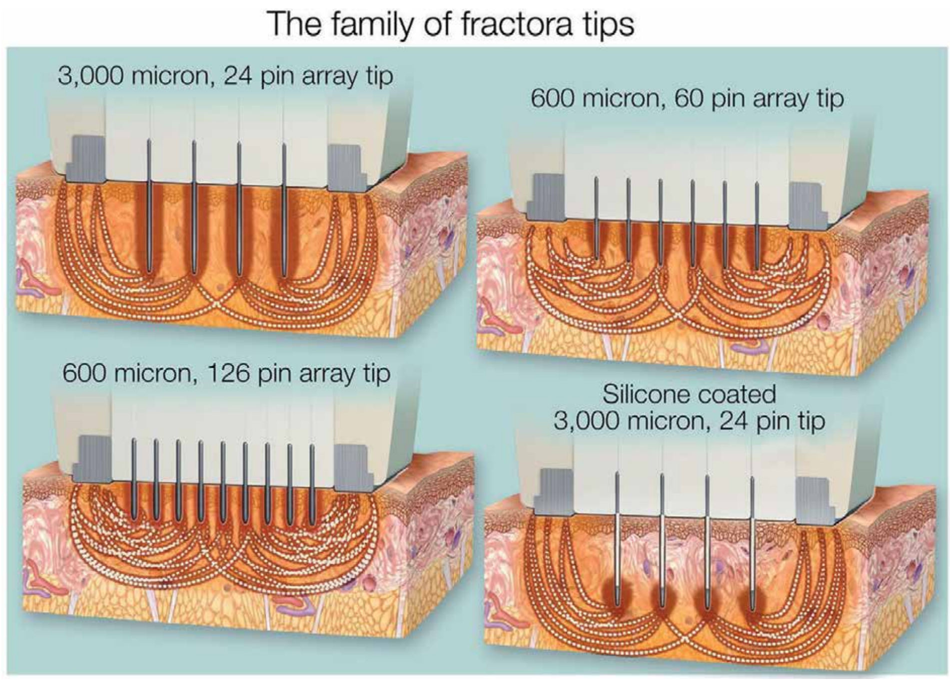

Figure 2.
The Fractora family of treatment tips. The 60 pin (low density) and 126 pin (high density) 600 micron depth, uncoated needles for general skin resurfacing. The 24 pin, uncoated and silicone coated, 3000 micron needle tips applicators for transdermal ablation. The 24-pin silicone coated needle affords the valuable epidermal thermal sparing effect for selective deep dermal, thermal ablation and remodeling.

the extraordinary soft tissue contraction and non-excisional face and body contouring opportunities outlined in this chapter.

3. What is the morpheus concept?

The Morpheus is a *"hand shake"* between the **BodyTite, FaceTite and AccuTite RFAL and the Fractora.** *Whereas Fractora was external, percutaneous DERMAL RFAL, the Morpheus is external RFAL applied to the Adipose and subdermal space* (**Figure 3**).

The Fractora, is a vertical, silicone coated, fractional RF *dermal remodeling system* that delivers fractional, monopolar-like, deep dermal ablative lesions with RF flowing from the positively charged tip of the silicone coated pins to very widely space negative return electrodes on the skin, resulting in a synchronous non-ablative dermal remodeling. The Morpheus is a physiological handshake between these two concepts. It takes the silicone coated pins-electrodes of the Fractora and extends them into the superficial fat. Each pin-electrode, like the internal electrode of the RFAL BodyTite® family of applicators is silicone coated, except for the positively charged tip which releases strongly coagulative RF energy directly into the fat. The BodyTite® and RFAL applicators, and the Morpheus pin-electrodes result in adipose coagulation and ablation, which in turns provides significant FSN contraction and skin tightening. The RF flows up to the negative charged electrode, moving in tandem with the internal electrode along the surface of the skin and results in gentle dermal, non-ablative RF heating and dermal remodeling. The Morpheus return electrodes are also located on the skin, just static and not moving.

3.1 How does the morpheus work?

Morpheus is an innovative, nonsurgical skin and soft tissue enhancement device from InMode. It is an external delivered, bipolar radiofrequency coagulation system

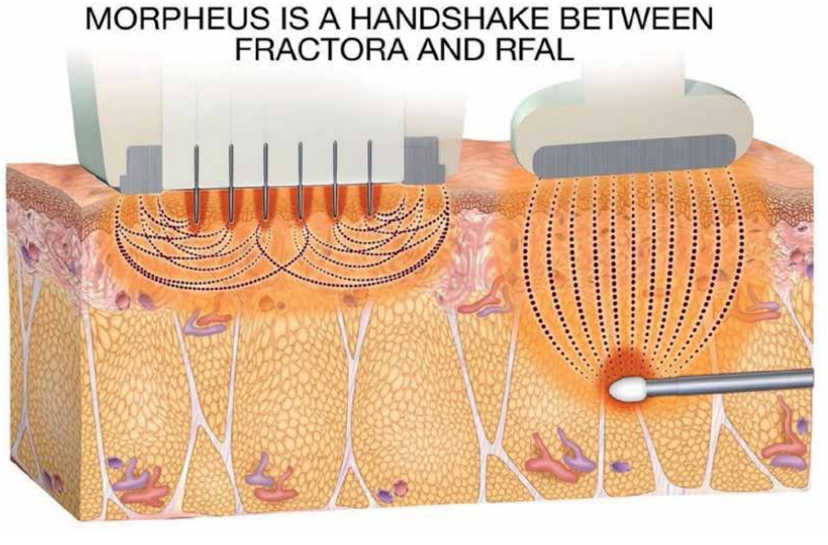

Figure 3.
The Morpheus® is like a physiologic "hand shake" or hybrid of the Fractora® horizontal fractional RF dermal resurfacing on the left together with the RFAL subcutaneous adipose coagulation and FSN contraction, with gentle non ablative RF dermal remodeling from the BodyTite®, FaceTite, AccuTite, or the Aviva gynecological labiaplasty applicator on the right.

of the subcutaneous fat and non-ablative dermal remodeling system. In short, it is externally applied, and it tightens the soft tissue through ablative coagulation of the sub-dermal, superficial fat and FSN (Fibroseptal Network) fibroseptal connection system and simultaneously tightens and smoothens the overlying wrinkled loose skin. At level one, there is also direct reticular dermal remodeling (**Figure 4**).

3.2 How does the morpheus RF flow and induce soft tissue contraction?

The Morpheus handpiece delivers 24, "monopolar-like", silicone coded positively charge, RF emitting electrode pins beneath the skin into the superficial fat. A specific and proprietary pulse of radio frequency electrical energy is then delivered to the fat, which coagulates (tightens) the sub- dermal adipose and, importantly, shortens the horizontal, oblique and vertical connections to the skin called the FSN and, or the fibrous septal network. This action of FSN contraction provides a significant tightening of the soft and reducing overlying wrinkles, scars, irregular texture, pores and even stretch marks and acne scars. The silicone coated needles protect the skin from any thermal injury (**Figures 5** and **6**).

The RF energy then flows up toward the skin surface, along the silicone coated needle and along the FSN to the negatively charged triangular-shaped electrodes on

Figure 4.
The Morpheus hand piece and tip is a reciprocating motorized device that propels silicon coated pin-electrodes through the skin and into the superficial fat just under the skin. The uncoated, positively charged tips of the pins-electrodes release strong radiofrequency (RF) energy that causes a localized adipose coagulation and RFAL tightening of the fat and contraction of the FSN connections to the skin. The fat and FSN contraction tightens the overlying soft tissue. The RF energy then flows from the tip of the positively charged electrode-pin up to the surface of the negatively charged, triangular shaped electrodes, which sit statically on the skinthrough which the pin-electrodes are protrude. (lower left and right) the RF also flows to other negatively charged external return electrodes on the sides and this is gentle, non-nectrotic in nature, and tightens the dermis non-ablatively.

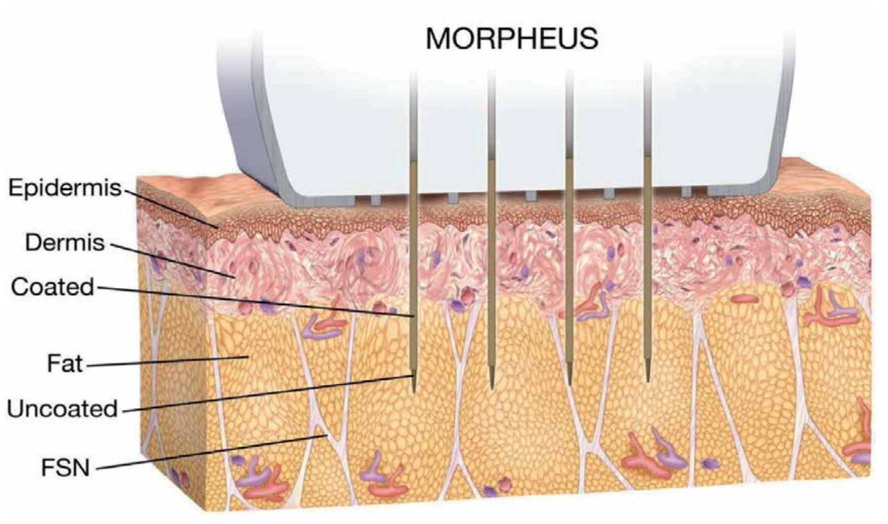

Figure 5.
The Morpheus delivers positively charged, silicone coated needle electrode through the skin into the superficial fat. The skin and epidermal-dermal junction is protected by the silicone coating. The tip of the electrodes are not coated and are embedded in the fat. The tip of each probe-needle is positively charged, and strong RF energy is emitted that heats, coagulates and tightens the fat, FSN and overlying skin. The RF flow distantly to negatively charged, larger surfacing area negative return electrodes that sit statically on the surface of the skin (and NOT ADJACENT the needle tip, hence NOT micro-RF micro needling).

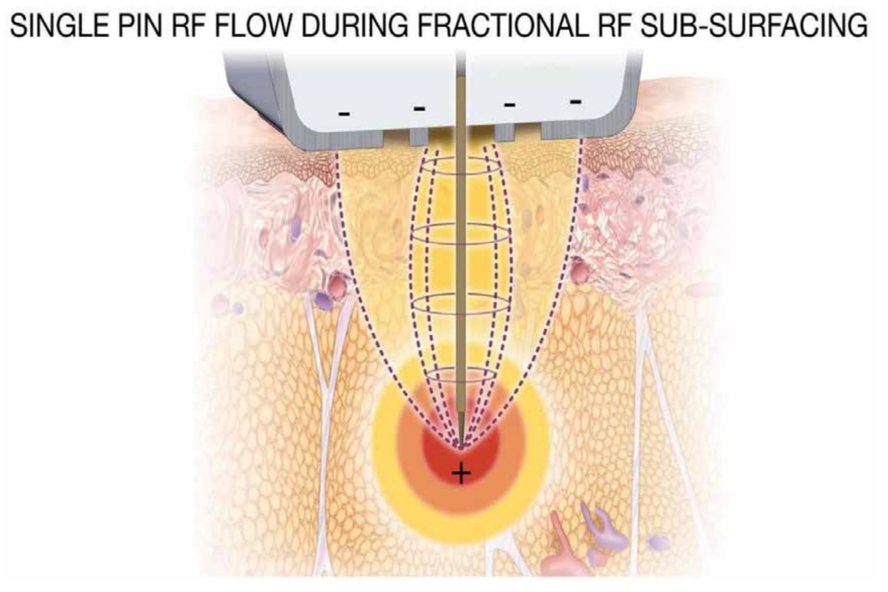

Figure 6.
The uncoated tip of the Morpheus pin-electrode is positively charged and results in a strong coagulative and ablative lesion in the fat and surrounding FSN. The RF then flows up the pin-electrode, along the FSN to the negatively charged triangular return electrodes that the pin-electrode protrude through and return electrode on the sides of the tip. This superficial RF is non-ablative in nature and results in a non-necrotic heating and tightening of the papillary and reticular dermis.

the surface of the skin, that surround the pins-electrodes and this delivers a non-ablative, non-necrotic and significant direct heating of the papillary and reticular dermis and skin which stimulates new collagen, elastin and ground substances, further tightening the soft tissue envelope and smoothening overlying wrinkles, folds irregular texture, scars and even in large pores, stretch marks and acne scars (**Figure 6**).

The protrusion of the needle-electrode through the dermis into the fat is a mechanical, fractional dermal injury, which will lead to some remodeling and dermal enhancement from the mechanical nature of the injury, however, this fractional dermal injury is non-thermal, due to the silicone coating. The epidermal-dermal thermal sparing nature of the Morpheus, focusing more on the FSN and adipose contraction, makes this device more effective at tightening lax skin and can avoid many of the epidermal-dermal junctional complications of thermal fractional dermal technologies (**Figure 7**).

During the nonsurgical face and neck lift, the Morpheus can be applied to the neck, face, upper and lower lids and brow, as well as lax body areas, to achieve a state-of-the-art, industry-leading nonsurgical facelift and skin contraction. At my clinic, SpaMedica, the Morpheus has replaced other, formally new and innovative technologies such as the 5-year-old Profound and 8-year-old Ulthera and other external radiofrequency devices, all of which offer a good non-surgical lift, Morpheus provides a **GREAT** improvement [2–8].

3.3 Horizontal and vertical sequential fractional coagulation and tightening

The Morpheus user has the capability to set the depth the Pins to different levels within the fat, that creating a **vertical and horizontal** fractional coagulative matrix. By sending the pin-electrodes into *different levels* of the superficial, subdermal

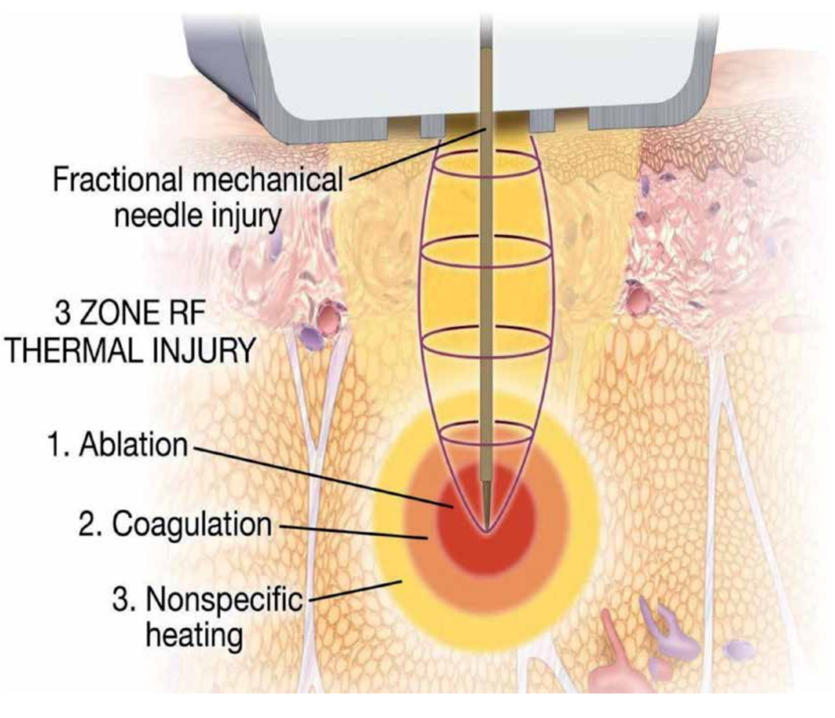

Figure 7.
The Morpheus releases RF energy from the positively charged tip, embedded in the fat, leading to RFAL like coagulation of the superficial fat and tightening of the bands (Fibroseptal bands or Fibroseptal network FSN) that determine skin tautness and, with the FSN contraction there is a very strong contraction and tightening of the skin. The RF also flows back up the pin-electrode, to the negatively charged, triangular shaped external electrode (through which the pins-electrode protrude), heating the dermis and skin directly leading to new collagen and elastin.

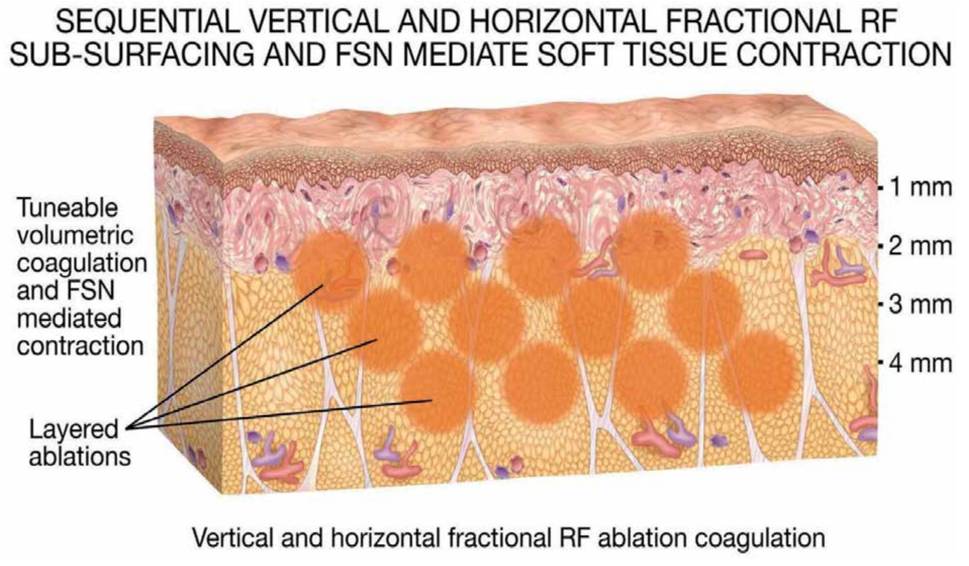

Figure 8.
By performing multiple passes [2–3] at different pin-electrode depths, one can summate the FSN and adipose coagulation and contraction volume, resulting in more skin tightening and dermal remodeling.

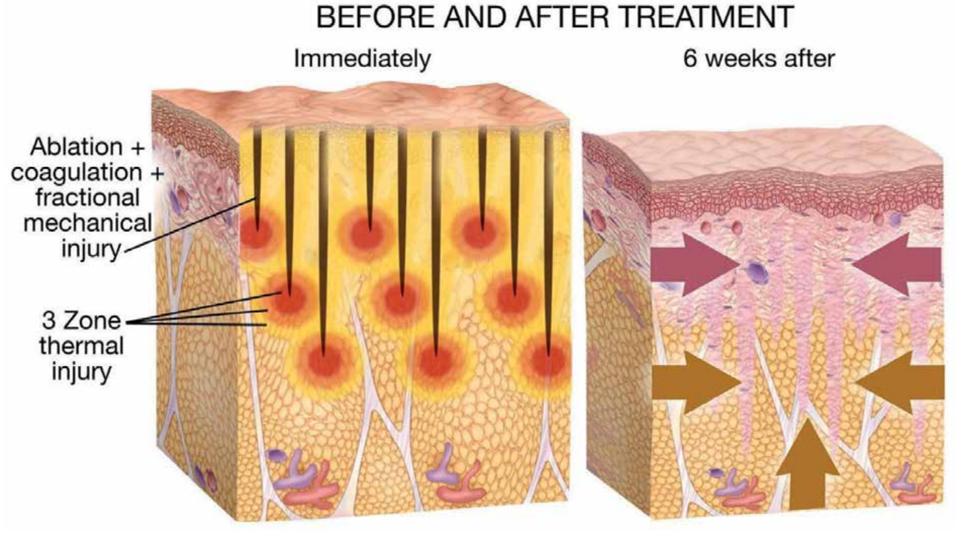

Figure 9.
Multiple passes at different levels, results in a horizontal and vertical fractional remodeling of the adipose and FSN with dermal remodeling for optimal skin tightening and soft tissue contraction.

fat, more volumetric fat coagulation and FSN contraction and recruitment occurs resulting in more effective soft tissue tightening. By performing several passes with the Morpheus, with the pins-electrodes propelled into the fat at different depths with each pass, optimal volumetric adipose RFAL like coagulation and FSN shortening can occur (**Figures 8**–**10**). Just like the sequential vertical FSN contraction that occurs by performed RFAL and BodyTite, FaceTite and AccuTite at multiple levels (see Part 1: Internal RFAL chapter and basic science) by performing Morpheus at multiple depths, you achieve a summative adipose and FSN coagulative effect with an enhanced degree of soft tissue contraction (**Figures 8**–**10**). After stimulation of the

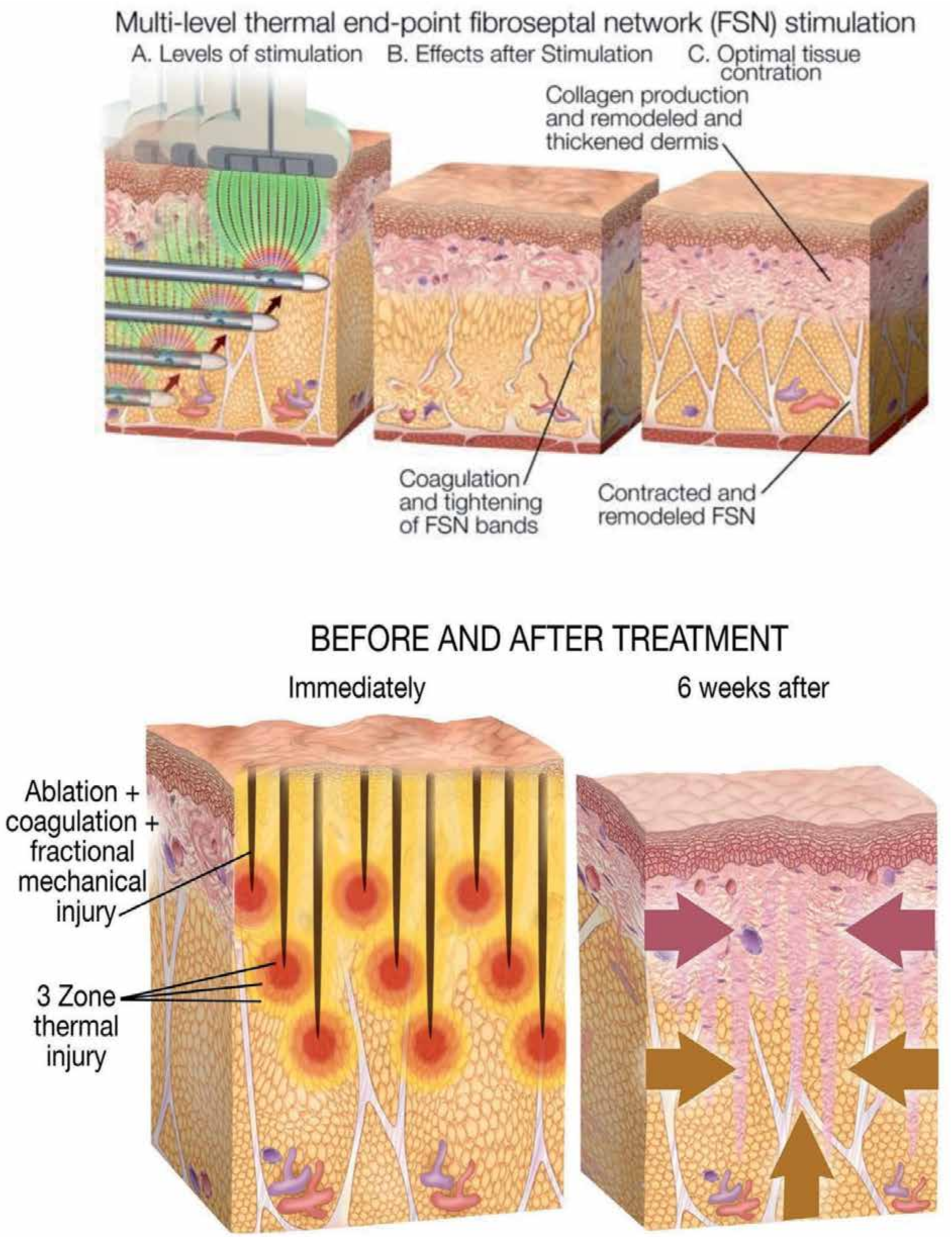

Figure 10.
Multiple variable depth vertical pass RFAL (left) and multiple, variable depth vertical pass Morpheus facilitate and amplified recruitment of the FSN contraction effect.

FSN at multiple levels, on the most superficial settings, Level ONE, there is a direct sub-reticular dermal remodeling and direct skin tightening effect.

The Sandwich thermal contraction of the "INSIDE-OUT" RFAL BodyTite, FaceTite and AccuTite FSN adipose contraction handpieces, combined with the "OUTSIDE-IN" adipo-dermal contraction of the Morpheus affords the BodyTite physician unprecedented control of the **ENTIRE SOFT TISSUE ENVELOP** and is the reason why clinicians can achieve the kind of "scar less" skin tightening results that are best in class and without compare, as they optimize the outcomes for all those **FACE AND BODY GAP patients**, who need control of the adipose FSA (30–40% contraction) subdermal space and transdermal remodeling (20–30%)

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and contraction, for a potential overall 60% Total Tissue Thermal contraction during enhanced liposuction [7–14].

4. What is the morpheus burst?

The Morpheus Burst offers the next level of InMode innovation. The Morpheus BURST comes with the Morpheus BODY applicator (**Figure 11**). The Morpheus BURST is automated multiple, sequential Vertical Fractional adipose RFAL ablation and coagulation in a single cycle. The first FDA approval gained for deepest penetration depth up to 7 mm of ablation and 8 mm of heat and allows to use Morpheus8 applicator for multi-level energy release during one insertion cycle.

There are two options for the 3 level RFAL automated Morpheus BURST fractional Coagulation:

i. 7 mm, 5 mm and 3 mm OR, (**Figure 12**)

ii. 6 mm, 4 mm and 2 mm (**Figure 12**)

iii. And two options for the 2 levels of automated coagulation treatment

iv. 5 mm and 3 mm OR

v. 4 mm and 2 mm (**Figure 13**)

With each of the pulse sequence options above, the Morpheus BURST software will automatically embed the 40-pin needle array at deepest level and deliver the coagulation and ablative pulses automatically stopping every 2 mm during retraction (**Figures 12** and **13**).

Figure 11.
The Morpheus BURST comes with the Morpheus BODY applicator. 40-pin electrodes that penetrate 2-7 mm with single pulse, automated double or triple pulse ablation and coagulation.

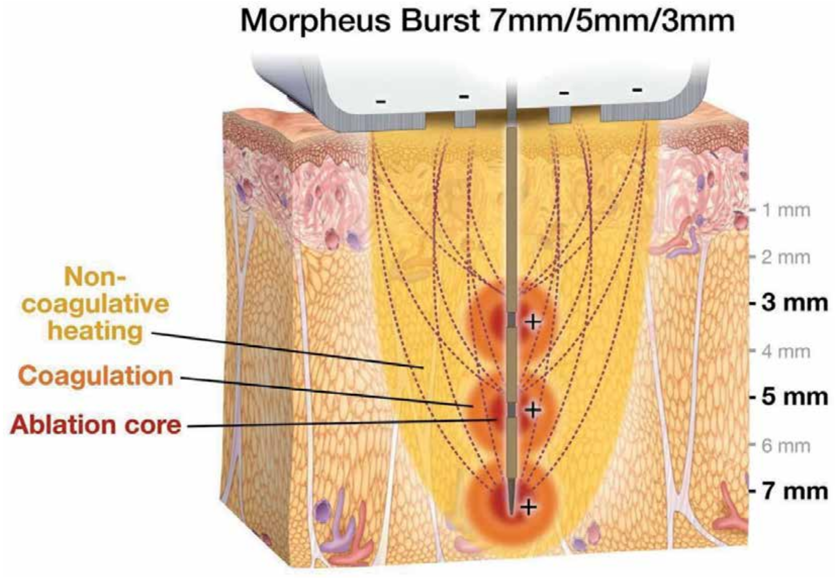

Figure 12.
The new Morpheus BURST offers automated, single pulse vertical, fractional adipose coagulation and contract in a single 1 second pulse. The triple depth can be either 7 mm/5 mm/3 mm, or in thinner tissue zones, 6 mm/4 mm/2 mm. There are also 2 double automated ablative and coagulative soft tissue contraction of 5 mm/3 mm and 4 mm/2 mm.

This **"BURST"** of soft tissue ablation and coagulation at multiple levels with each cycle, optimizes and greatly increases the amount of soft tissue contraction and fat reduction that can be delivered in each second. In essence, one pass of the Morpheus BURST, is equivalent to the summative contractile effect of 3 passes with the non-burst Morpheus (**Figure 14**). This tripling of the coagulation index provides 300% increase in the single pass soft tissue contraction and fat reduction. Automatic delivering energy in 3 levels also increase uniformity of treatment allowing delivery of precise number of ablative and coagulative zones for each level and exactly the same treatment area.

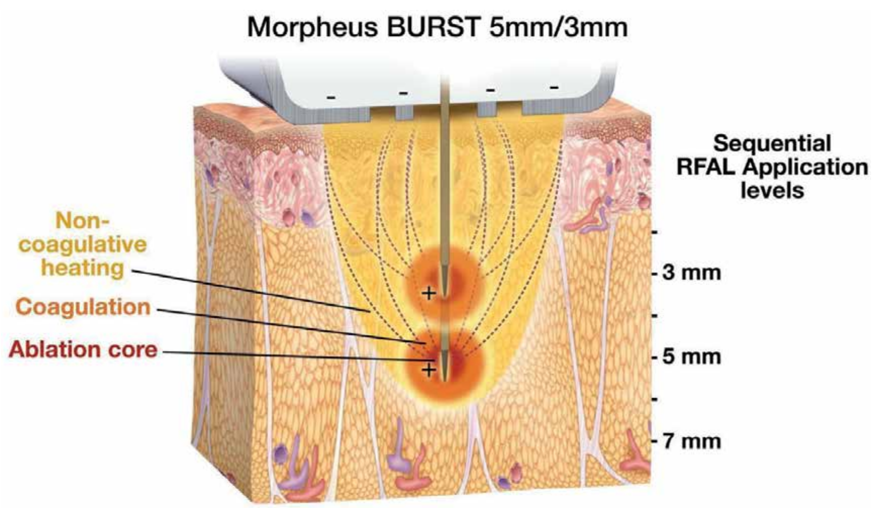

Figure 13.
The Morpheus burst allows a double synchronous double burst, single pulse ablation and coagulation injury for thinner, soft tissue areas.

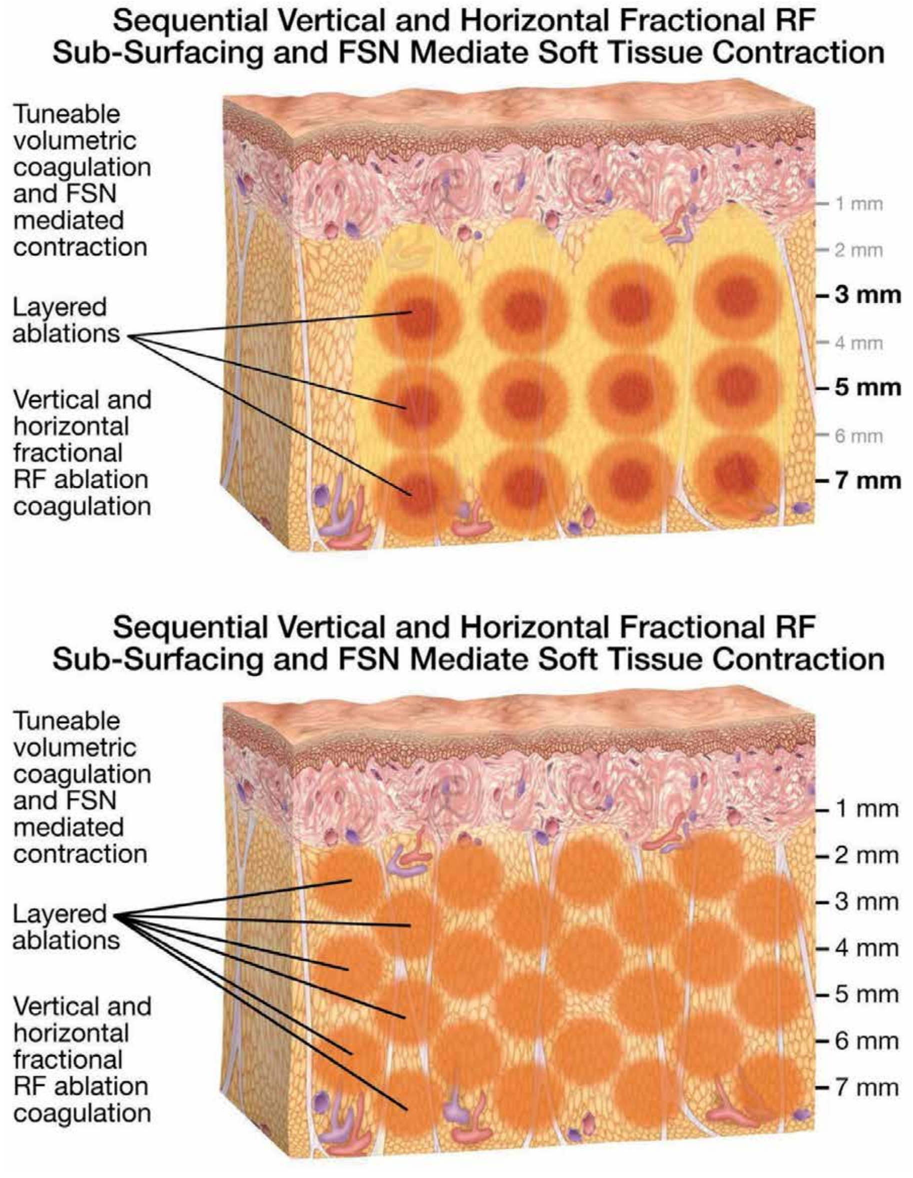

Figure 14.
Top: *Shows the synchronous, automated, single pulse 3 zone thermal effects of the Morpheus BURST.* ***Bottom:*** *The synchronous, automated multiple vertical depths of coagulation simulate 3 passes in a single pulse, amplifying and efficiently delivering optimized soft tissue volume ablation, coagulation and ultimately, single pass contraction. With 2 passes, one at burst 7 and the other burst 6, coagulation zones can be deposited every 1 mm.*

The Burst Pulse Configuration at each level is as follows:

1. 100 milliseconds stationary for each energy release for each of 3 levels, 7 mm/5 mm/3 mm or 6 mm/4 mm/2 mm.

2. 100 milliseconds for position change movement

3. **TOTAL cycle time is 700 milliseconds.**

4. **Total tissue ablation and contraction up to 300% greater per second**

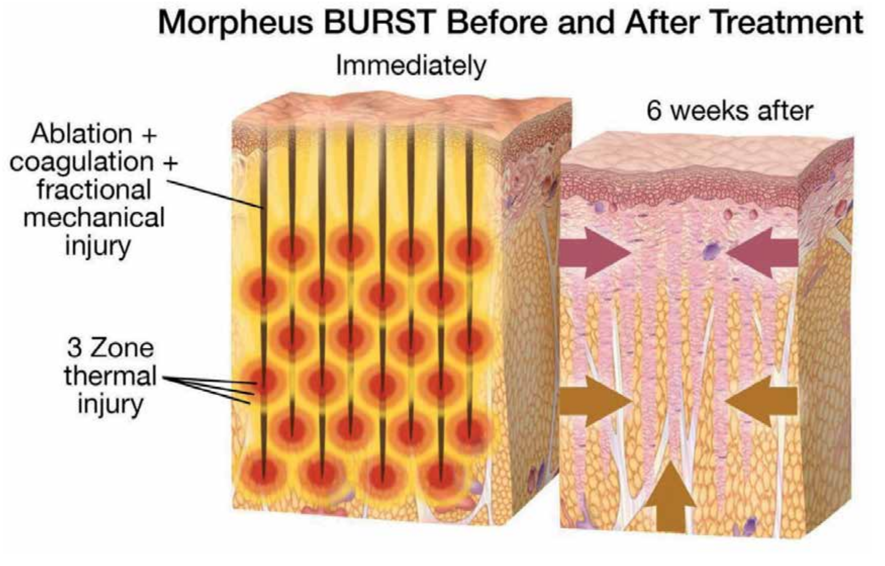

Figure 15.
The aggregate soft tissue coagulation and enhanced volumetric soft tissue contraction of the Morpheus BURST.

Each Morpheus BURST pulse is like making 3 sequential passes, with the single depth coagulation Morpheus. Thus, with a single pass in a given zone, is then equivalent to 3x's the number of passes with 3x's the ablative and coagulative index and GREATLY enhanced soft tissue contraction (**Figure 15**).

5. What is the difference between the Morpheus 8 and microneedline and RF micronieeling systems

The Fractora was the first external Fractional RFAL skin tightening device and was *intradermal Fractional RFAL*. The Fractora is completely different to the safe, but far less effective RF micro needling systems. In all the micro needling systems, the RF energy flows between closely approximated rows of needles having opposite polarity and embedded side by side into the tissue (**Figure 16**). RF micro needling systems have minimal ablative capacity and a very low ablative tissue index. The closely approximately rows of positive and negative pins in the RF micro needling systems lead *to minimal thermal tissue ablation, minimal soft tissue contraction and are basically acting similar to non-thermal micro needling devices.* The RF micro needlers, as I call them offer extreme safety, but negligible thermal coagulation and contraction. They require multiple treatments [6–8], to deliver minimal tissue remodeling, but are quite safe and inexpensive (Micropens often deliver as much).

6. The morpheus adipose fractional RFAL

The Morpheus8 took the *"outside-in"* Fractora RFAL concept from the dermis and expanded the application and thermal targeting to the most important layer for body contouring, the adipose tissue and FSN. The Morpheus electrodes (pins) have 500 microns of uncoated electrode at the tip for the ablative RFAL energy. The fractional array range from 12 Pins on the Morpheus PRIME, 24 pin electrodes on the Morpheus BASIC to 40 pins on the Morpheus Body. The Morpheus body offers Fractional Adipose, thermal ablation and needle penetration depths of

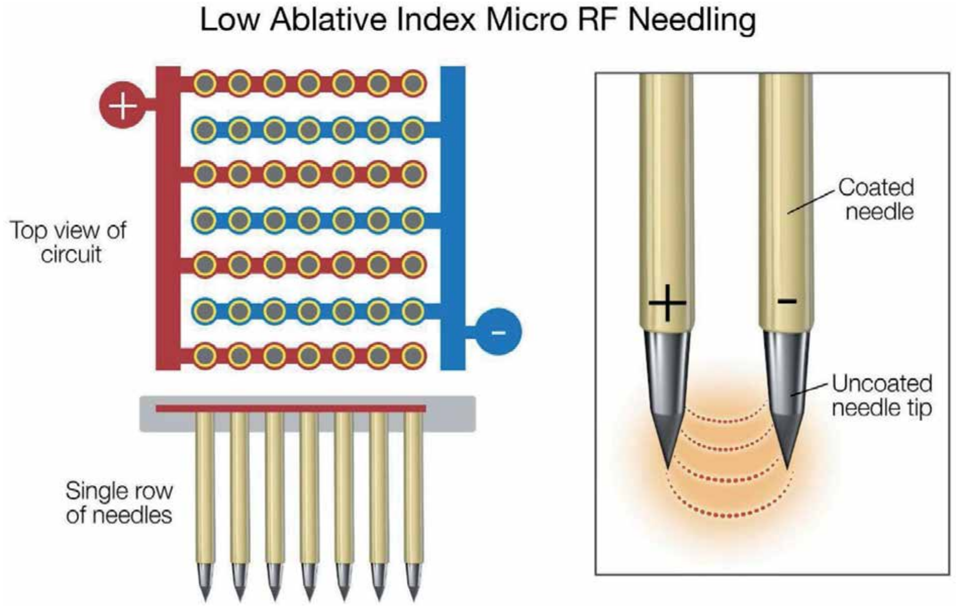

Figure 16.
Bipolar RF micro needling*. The polymer coated needles protect the surface of the skin, but the RF current flows between very closely spaced electrodes, resulting in a very small area of tissue ablation compared to the massive aggregate soft tissue ablation, coagulation and contraction of the Morpheus family of fractional adipose applicators.*

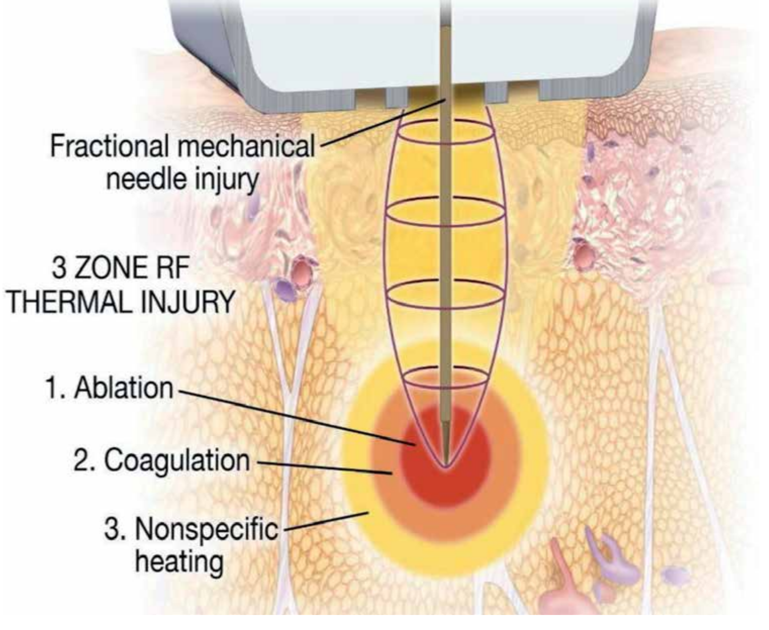

Figure 17.
The Morpheus releases RF energy from the positively charged tip, embedded in the fat, leading to RFAL like coagulation of the superficial fat and tightening of the bands (Fibroseptal bands or Fibroseptal network FSN) that determine skin tautness and, with the FSN contraction there is a very strong contraction and tightening of the skin. The RF also flows back up the pin-electrode, to the negatively charged, charged side rail electrodes.

2 mm, 3 mm, 4 mm, 5 mm, 6 mm, and 7 mm with thermal effect up to 8 mm for a BiFractional (horizontal and vertical adipose fractional effect) ability to ablate and coagulate adipose tissue from the *"outside in"* (**Figure 17**). Like the RFAL minimally

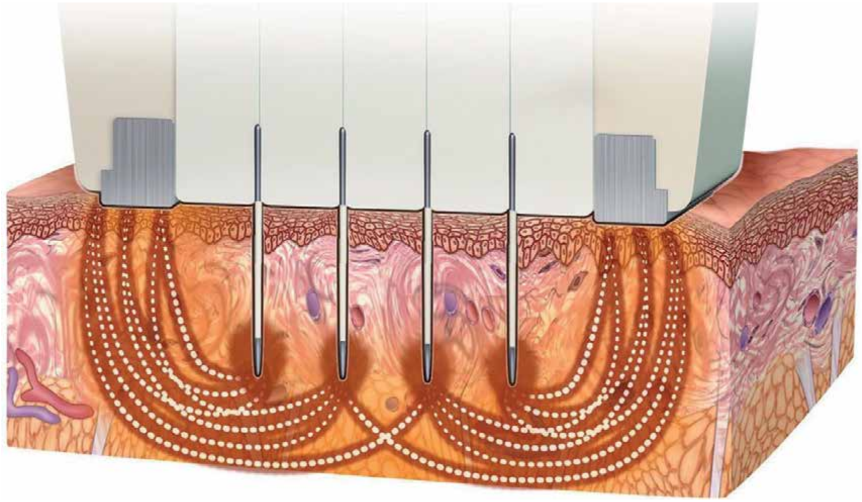

Figure 18.
The 24 pin Fractora tip, has needles that are 2500 microns in length and can be uncoated or coated. The 24-pin, 2500 micron coated needles have polymer coating along the proximal 2000 microns leaving the distal or last 500 microns uncoated. The coated portion spares the epidermal- dermal junction the thermal injury and allows very aggressive deep dermal fractional injuries and remodeling without the risk or fear of excessive superficial crater injuries and hypopigmentation or scaring. The 24-pin coated Fractora tip is called a "low epidermal impact" tip and is an important tool in deep tissue tightening and deep wrinkle and scar improvements.

invasive applicators, and the dermal Fractora before it, with the Morpheus8, the RF energy flows from the deeply embedded array of needle electrodes to the return electrodes on the surface of the skin.

The Morpheus facilitates fractional adipose tissue ablation and coagulation as well as FSN contraction resulting volume reduction and tissue tightening. Safety is optimized by the contact and impedance monitoring that automatically control RF flow between the electrodes.

The Morpheus8 family of Adipose and Dermal fractional RFAL ablation have become the most successful and commonly use fractional ablative devices in the world.

In contrast to micro needling devices, the Fractora has needle electrode embedded to the depth up to 2.5 mm and external electrode applied to the skin surface above the needles. All pin electrodes have the same polarity and release deep dermal ablative energy that then flows up to the return electrodes located on the skin. These large arrays of intradermal positive electrodes create multiple, zones of dermal ablation around each of the individual needle electrode. In addition to these zones of ablation, there is a large zone of non- ablative dermal coagulation and then finally, a large region of non-coagulative dermal tissue heating stretched toward skin surface (**Figure 18**). The Fractora was very effective, but only harnessed the power of dermal contraction and not the FSN or adipose tissue, like the AccuTite, FaceTite or Bodytite.

7. Clinical applications of the morpheus burst

The Morpheus BURST has greatly enhanced our ability to shape, contour, coagulate and contract tissue using the RFAL from the outside in.

7.1 Morpheus burst body

I will use Morpheus BODY and BURST to treat large zone body contouring from the outside in with a single pass, often in combination with RFAL BodyTite

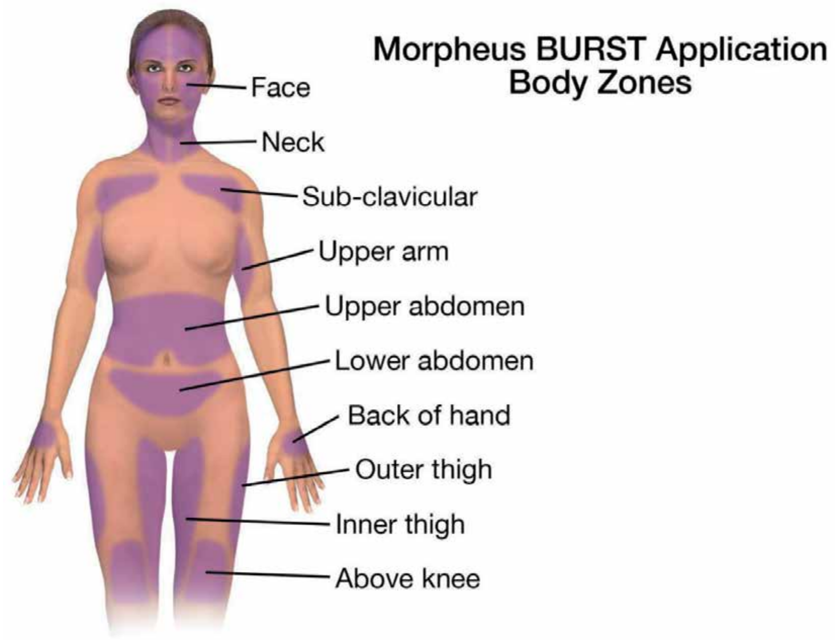

Figure 19.
The Morpheus BURST is very effective at fat reduction, soft tissue tightening and cellulite reduction in zones all over the body.

treatment. The Morphus Burst can be used on thicker necks and jawlines, but the Morpheus 24 pin Face (black handpiece), 12 pin Prime and 60 pin resurfacing tip are more common on the Face itself (**Figure 19**).

8. Clinical cases of RFAL

The following 2 cases are clinical examples of the BodyTite workstation and its applicators: the integrated use of the RFAL internal BodyTite, FaceTite, AccuTite applicators used in concert with the externally applied Morpheus8 RFAL and how they can be combined to deliver soft tissue contours, face and body shaping through "enhanced liposuction" technology and techniques.

8.1 CASE 1: BodyTite RFAL, M8 and the body

A young male presented with significant post Coolsculpting Abdominal Paradoxical Adipose Hyperplasia (**Figure 20**). Other consultations with Plastic Surgery colleges had recommended an excisional abdominoplasty. The patient was reluctant to undergo an excisional procedure and the extensive scar that would be required. After meeting with the patient, I felt a non-excisional BodyTite and Morpheus RFAL enhanced liposuction would achieve good results.

8.2 The RFAL procedure and settings

The RFAL procedure was performed in the office under local tumescent anesthesia and oral sedation. The 2.4 mm BodyTite RFAL applicator was used and the settings were: 40 degrees Celsius skin cut-off and 70 degrees Celsius deep adipose cut-off. Stamping and slow-moving passes were made at the level 6 deep supra-fascial depth, Level 4 mid adipose depth and level 2 superficial adipose level. Following the RFAL treatment, PAL and SAL aspiration was performed

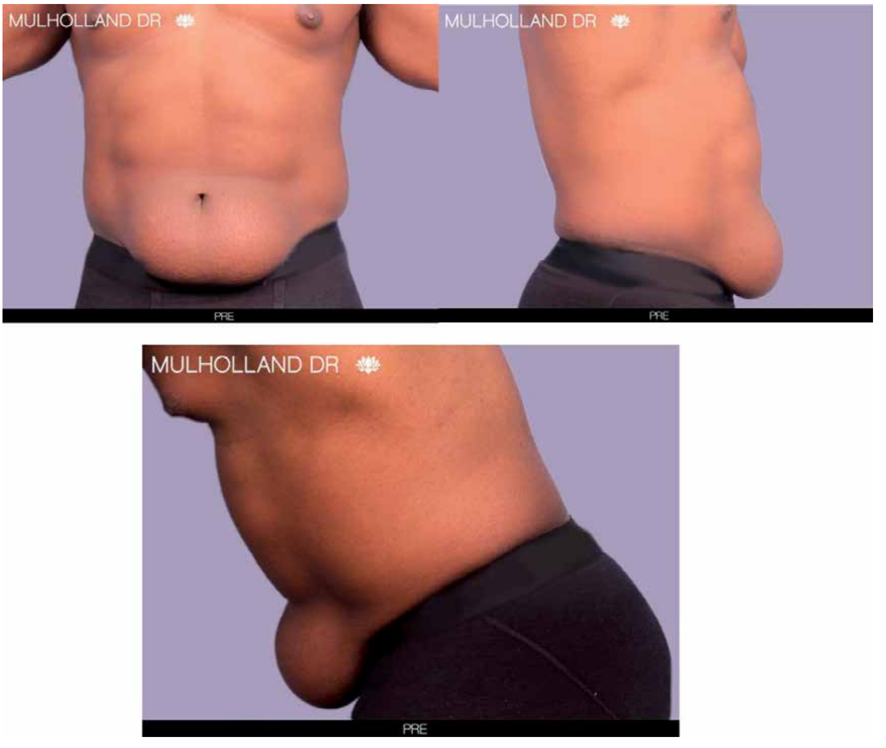

Figure 20.
A patient presented for BodyTite RFAL and Morpheus8 after significant post CoolSculpting abdominal paradoxical adipose hyperplasia.

until there was a 3–4 cm thickness soft tissue flap remaining. Following aspiration, a second RFAL pass was performed at level 2. Following the BodyTite treatment, the Morpheus8 was used in the BURST mode at level 7 mm/5 mm/3 mm and 25 mj/pin.

8.3 Postoperative care

Standard postoperative drain, garmenting and foam was deployed. At 6 months, patient was very happy with his results. The patient is from out of the province and, not living in Toronto and so emailed some cell phone photos. The patient was very happy with his abdominal reduction and contraction and is contemplating a second RFAL and Morpheus8 at one year (**Figure 21**).

8.4 CASE 2: BodyTite RFAL, M8 and the face

A woman in her 60's presented with advanced facial aging concerns: upper lid hooding, periocular laxity, elastosis and extensive wrinkling. She also complained of perioral laxity, deep nasolabial folds, labio-mental folds and periocular wrinkles and laxity. Her primary concern, however, was her jowls, double chin and neck laxity (**Figure 22**).

8.5 The procedure

The procedure was performed in the office Under local anesthesia, tumescent infiltration and oral sedation.

Figure 21.
BodyTite RFAL and Morpheus8 results performed on a post CoolSculpting abdominal paradoxical adipose hyperplasia.

Figure 22.
Patient presented with periocular aging, laxity and rhytids along with pan-facial and cervical descent, rhytids and laxity. Her desire was a non-excisional face and neck tightening, wrinkles reduction, along with a skin pinch upper lid blepharoplasty.

Periocular: The Accutite was used in the supraorbital brow, upper and lower lid. The supra-orbicularis plane and sub-frontalis plane was used in the brow, above the orbicularis in the upper lid and above and below the orbicularis in the lower lid. The Morpheus Prime was used on the upper and lower lid skin The Morpheus 24 pin was used on the brow skin. **Settings:** The AccuTite was set at 40/70 degrees Celsius skin and deep thermal cut-off's and the Morpheus8 Prime and 24 pin at 4 mm/3 mm/2 mm using 45 mj/pin. A limited extension, 6 mm skin pinch upper lid blepharoplasty was performed after the AccuTite and the Morpheus resurfacing tip used for 3 passes on the lower lid skin at 30 mj/pin

Perioral and Cheek: The AccuTite 40/70 degrees Celsius cut-off was used overtop and lateral to the Nasolabial fold, the labio-mental fold and jowl. Stamping and moving techniques were uses. The Morpheus8, 24 pin tip was used across the cheek and perioral skin using 3 passes at 4 mm/3 mm/2 mm with the resurfacing tip at the end at 30 mj/pin

The Jawline and Neck: The FaceTite 40/70 degrees Celsius cut-off was used on the jawline and jowl, sub-mentum and neck followed by modest aspiration using a 1.8 mm microcannula. Following the FaceTite the Morpheus8 Body applicator in BURST mode one pass at 7 mm/5 mm/3 mm and a second pass at 6 mm/4 mm/2 mm, each with 30 mj/pin was performed.

One pass of IPL was performed on the face and neck at the end of the procedure to help with the dyschromia using the Lumecca 515 nm handpiece and 14 j/cm2 and a 10 ms pulse duration

The postoperative care consisted of skin cleaning with tepid water and Aquaphor.

The patient was ready in make up at 2 weeks and very pleased with her results (**Figure 23**).

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Figure 23.
A patient underwent a combined procedure with FaceTite and Morphesu 8 burst o the neck and jawline, following by aspiration of the submentum and jowl. Good soft tissue lipocoagulation and contraction was achieved. AccuTite RFAL and Morpheus 8 was performed in the perioral, lower lid, upper lid and brow region with no aspiration but good lipocontraction and elastotic wrinkle reduction. A skin pinch upper lid blepharoplasty was performed in conjunction with the AccuTite and M8.

9. Conclusions

It has become imperative for the modern liposuction surgeon to include an energy based surgical device that facilitates "enhanced liposuction".

Lipocoagulation leading to optimal and enhanced Lipo-contraction and soft tissue tightening has become a very large element of the modern contouring practice. Further, the modern surgeon no longer performs only body contouring, but also deploys more delicate and thermally controlled applicators and handpieces to deliver soft tissue contraction and contouring of the brow, eyes, perioral, cheeks, jawline and neck.

The emergence of a market segment of consumer, the "GAP patients", who are looking for significant non-excisional soft tissue tightening, contraction and wrinkle reduction has created a whole next Body AND Face market opportunity for esthetic physicians. These GAP patients want more than the traditional non-invasive market of toxins, fillers and external non-invasive energy-based devices, but also want to avoid the scars, recovery and stigma of excision procedures. Using the InMode internal and external RFAL applicators, the BodyTite, FaceTite, AccuTite and Morpheus8, non-excisional, minimally invasive procedures can now provide compelling in office procedures for the face and body, performed under local anesthesia that are deliver impressive results. "Enhanced Lipocoagulation and contraction" is here to stay as are the GAP patients who demand a non-excisional but effective solution to their esthetic concerns.

Conflict of interest

The Author is a paid workshop consultant for the company, co-patent developer and a founding shareholder.

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Chapter 8

VASER Liposuction - How to Get Natural Results with Ultrasound Assisted Liposuction?

Dinko Bagatin, Tomica Bagatin, Judith Deutsch, Katarina Sakic, Johann Nemrava, Eduardo Isomura and Martina Sarec Ivelj

Abstract

Ultrasound assisted liposuction technology is a selective technique to emulsify fatty tissue and improve the removal of fat. This technique can be used on many areas of the body such as: chin neck, back, buttocks, abdomen, legs, arms. Fatty areas, as well as, skin and cellulite can be molded in a process known as ultrasound cavitation. Results can produce significant skin contraction and smoothing of areas. Using this method reduces the need for surgical intervention and requires less energy to achieve similar results. This method is also good for treatment of fibrous scar tissue, producing less bruising and blood loss. The advantages of the VASER ultrasound prepared liposuction in comparison to the mechanical liposuction method are better with fat extraction, less blood loss, and smoother results. While the disadvantages of VASER ultrasound method are possible thermal injuries, the need for larger incisions for protective ports, increased incidence of seromas, slightly increased cost and longer preparation and operative times. However further presentation will show the benefits of this newer generation of liposuction method. Also, various probes for better fat extraction and specific treatment areas will be discussed.

Keywords: ultrasound liposuction, emulsification of fat, cavitation, skin retraction, natural result

1. Introduction

A brief historic introduction to liposuction and surgical body contouring, the method has been around since the 1970's. Developed and enhanced throughout the passing years, most notably in 1988 by Michele Zocchi. The ultrasound assisted liposuction (UAL) method was created and used in 1,057 patients (875 women and 182 men) from 1989 to 1996, by Zocchi [1]. He was able to remove larger quantities of fat than the manual liposuction method and suggested that this technique had great potential in treating specific patients. The results are excellent and with no major complications, opening the door to a more effective liposuction method. Of the minor complications encountered, there were mild burns at cannula sites and discoloration of skin (dyschromia).

Further technique development and increased popularity began in the 21st century, with Alfredo E. Hoyos. He introduced high-definition body sculpturing [2–4].

VASER liposuction means vibration amplification of sound energy at resonance (VASER).

VASER ultrasound technology enables the fragmenting of large fat into smaller fat pieces. The method uses an infiltration technique with tumescent fluid comprised of a combination of saline, adrenalin, lidocaine and sodium bicarbonate. The released fat molecules are then extracted from the body using liposuction cannulas. A more sparring and less aggressive manual extraction is needed with this method, than what is used with the classic liposuction technique [5, 6].

The use of tumescent fluid not only releases the fat molecules but also reduces bleeding and provides analgesia.

A presentation and discussion of the VASER modes used (continuous or intermittent), tumescent fluid (amounts and preparation), method of achieving natural results, differences between sexes and areas being treated will all be covered thoroughly.

My personal experience with liposuction began in 2008, as a plastic surgery resident. Attending several congresses, notably an annual Congress of the Turkish Society of plastic Surgery in Istanbul. There an American surgeon, Mark Jewell, described VASER as, "the best thing to ever happen to him in his life". He stated, "this method gave significant better results compared to earlier methods" [7]. This was intriguing and Polyclinic Bagatin purchased the device and began implementing it, after several hands on courses. The results were immediate. The method of liposuction was easier and more efficient in fat extraction. At the start, several patients (5–10%) had to have additional corrections until the technique was perfected. However, results were good, and patients were very satisfied. There were a few cases where the results were not as anticipated. Even after attempted corrections, the results were not great. This suggests actual limitations of the VASER technique in some cases [8–10].

Overall, it is always important and crucial to listen to patients what they want and what can be realistically achieved [11]. It is better not to make promises that cannot be kept. An honest open approach is best as to what can be done. Results depend on patient age, skin quality, amount of fat deposits and their locations, as well as eating and drinking habits and patient motivation. An ideal patient is one who knows exactly what they want, realistic expectations, good skin tone and texture.

2. Materials and methods

Performing an ultrasound assisted liposuction method involves thorough preparation and planning.

Patient candidate consultation, discussion, planning, visual aids (VECTRA, drawings, examples of results) and clear achievement goals are needed prior to operating.

Once a goal and plan has been reached, the operating team is debriefed and steps to start the procedure can begin.

Klein's original fluid combination uses saline, a local anesthetic (lidocaine), a vasoconstrictor (adrenaline), and sodium bicarbonate. Dr. Klein uses for each 1000 mLs of saline, 12.5 mL sodium bicarbonate (8.4%), 0.5–0.75 mg adrenaline, and lidocaine 500 mg (using up to a maximum of 55 mg/kg patient body weight) [12]. At Poliklinika Bagatin a significantly lower maximal dose is used,

	Klein	Hunstad (modified)	Poliklinika Bagatin	Pitman	Toledo	Zocchi
0.9% NaCl (saline) (mL)	1000		1000	1000		
0.45% NaCl (saline) (mL)						1000
Ringer Lactate (mL)		1000			1000	
1% Lidocaine (mL, mg)	50 mL, 500 mg	50 mL, 500 mg		50 mL, 500 mg	80 mL, 800 mL	50 mL, 500 mg
0.5% bupivacaine (mL, mg)			10 mL, 50 mg			
8.4% Sodium Bicarbonate (mL)	12.5		10	5	7	10
Adrenaline (mg)	0.5–0.75	1	1	1	2	1

Table 1.
Tumescent solution variations.

35–45 mg/kg. Interestingly, Hunstad created a modified solution using a 500 mg lidocaine within 1000 ml Ringer Lactate and 1 mg of adrenaline [12]. However, Dr. Hunstad opts not to use sodium bicarbonate in his modified solution. Various mixtures of tumescent fluids are used worldwide. Others such as Pitman, Toledo and Zocchi, as seen in the table provided, have their preferred combinations (**Table 1**).

3. Various combinations of tumescent solutions

Whatever the variations used, in general a mix of similar ingredients are combined.

The tumescent fluid is prepared using a specified amount of saline required for certain areas of the body. This depends on body surface area to be performed on. For example, the chest can require 3–4 liters, while the legs or arms may need 1–3 liters. The abdomen may require 6 liters. The surgeon decides on volume amounts, reducing this if multiple operative sites are to be performed, with or without surgical reduction.

At Poliklinika Bagatin, each liter of tumescent fluid used is a combination of standard intravenous saline, 1 mg adrenaline (epinephrine), 10 mL bupivacaine (5 mg/mL), and 10 mL sodium bicarbonate (8.4% w/v) [13]. More than 35–45 mg/kg bupivacaine in total, is never used [14, 15], reducing the risks of possible overdosage. A larger amount of anesthetic can be used, since it will not be placed intravascularly, is combined with adrenaline and the majority will be removed during extraction liposuction. The half-life of lidocaine and bupivacaine is about 2–2.5 hours and both are metabolized 90% hepatically. The procedures are often lengthy, and can last more than 3 hours. This further reduces the possibility of local anesthetic toxicity.

The final tumescent solution looks similar in color to champagne.

Patient preparation is performed as usual, from preoperative anesthesia exam, induction, monitoring, surgical wash and sterile drape coverings.

Following the standard surgical time out, infiltration with 20mLs tumescent fluid (for easier application) is used to infiltrate areas where ports will be placed. Ports are protective portholes used for the various cannulas (VASER, liposuction VentX, infiltration probe), and protect the skin surface areas below from thermic burns that can occur without using them. The ports used are a standard diameter of 3.7 mm. Skin incisions for the ports are 3 to 5 mm wide. Care is taken to carefully choose positions, of these port incision areas, as well as how many ports will be placed. This is important for achieving natural and proper results.

When the ports are in place, tissue infiltration with the remaining tumescent fluid begins with the infiltration apparatus (**Figure 1**).

The infiltration device has various injection settings. Each are used specifically to apply the tumescent fluid into various layers and depths in the areas being treated. Surface layers are injected using the VASER variable flow (start-stop-start). While deeper layers are injected with a continuous flow. This is important to protect against burns and bleeding of more sensitive surface layers. The flow rate used is not faster than 100mLs per minute.

Following the successful tumescent fluid application, there is a waiting time (cooking time) of 10–15 minutes. During this time, fat cells are enabled to bloat and

Figure 1.
VASER machine.

explode into smaller fatty fragments, which will then be more easily extracted by the various cannulas.

The tumescent fluid is prepared using a specified amount of saline required for certain areas of the body. This depends on body surface area to be performed on. For example, the chest can require 3–4 liters, while the legs or arms may need 1–3 liters. The abdomen may require 6 liters. The surgeon decides on this amount by determining operative site area, as well as procedure to be performed (possible surgical combination of area reduction).

Each liter of tumescent fluid used is a combination of standard intravenous saline, 1 mg adrenaline (epinephrine), 10 mL bupivacaine (5 mg/mL), and 10 mL sodium bicarbonate (8.4% w/v) [12]. More than 35–45 mg/kg bupivacaine, in total, is never used [13, 14], reducing the risks of possible overdosage. A larger amount of anesthetic can be used, since it will not be placed intravascularly, and the majority will be removed during extraction liposuction.

When the ports are in place, tissue infiltration with the remaining tumescent fluid begins with the infiltration apparatus (**Figures 2**–**4**).

The infiltration device has various injection settings. Each are used specifically to apply the tumescent fluid into various layers and depths in the areas being treated. Surface layers are injected using the VASER variable flow (start-stop-start). While deeper layers are injected with a continuous flow. This is important to protect against burns and bleeding of more sensitive surface layers. The flow rate used is not faster than 100mLs per minute.

Following the successful tumescent fluid application, there is a waiting time (cooking time) of 10–15 minutes. During this time, fat cells are enabled to bloat and explode into smaller fatty fragments, which will then be more easily extracted by the various cannulas.

High-definition extraction can be achieved in various regions of the body. A gentle fanning, in-out motion of the cannulas is used. This process is continued until desired results are achieved. Following maximal extraction, it is mandatory to place overflow release drains. This helps reduce formation of seromas and faster normalization of the liposuction area, removing excess remaining trapped fluid and reducing build

Figure 2.
All needed instruments for VASER liposuction.

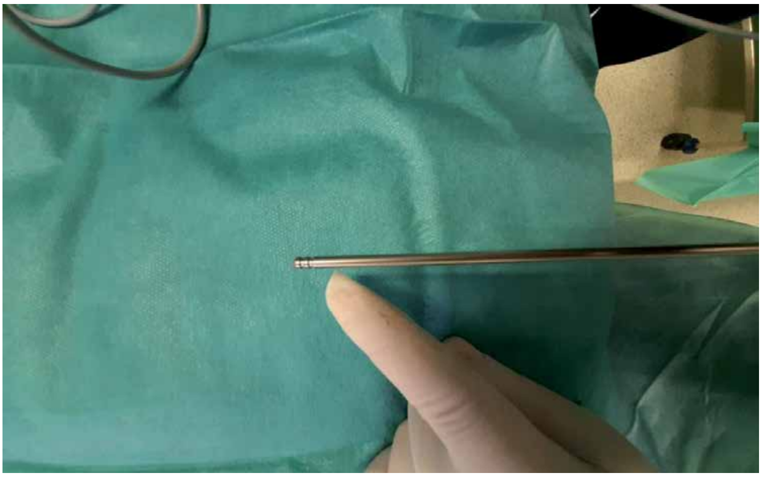

Figure 3.
Two rings VASER probe.

Figure 4.
Standard 3,7 mm VentX cannula.

up. Patient follow-ups need to be frequent, recommended daily for the first 7 days. During the early postoperative period, deformities are possible and can be then attended to, before becoming permanent. Later, if any lasting deformities present, they can be corrected a year after the initial operation. This is important to allow all tissues to heal, settle into a formed position and give a final view of procedure results.

4. Various featured techniques based on specific areas of the body

4.1 Double chin: men and women

Double chin sagging correction, regardless of sex, can be performed by placing ports of under 2.9 mm in locations under the chin and laterally on both sides under the ears. Tumescent fluid infiltration should be with about 200–300 mL. The VASER device strength should be set between 20 and 40%, a stronger strength can cause the cannula probe to break. Following tumescent fluid insertion, a 5–6-minute waiting time is needed. For a more pronounced double chin and neck region, this can be increased to 9 minutes. Liposuction duration can be up to 10 minutes, until desired results. This region is very delicate and a baby VENTX cannula is used, to prevent injury and for ease of suctioning and movement. Flat cannulas up to 5 mm can also be useful to use. It is important not to feel any resistance while the VASER converts larger pieces of fat into smaller ones. A large quantity of fat is rarely present, in this area, as compared to other areas of the body. It is also important to postoperatively check neurological facial mimicry functions (smiling, whistling, frowning) to assess possible peripheral nerve injury, which can be common. However, with exercises and anti-inflammatory medications this will resolve in time.

4.2 The back area: men and women

The back can be defined as the upper, middle and lower areas. Each section can be combined with lateral side areas for liposuction. The upper and middle are often combined with the areas under the armpits and lateral sides of the rib cage – posterior part of chest girth. While the lower back is combined with love handles and buttocks. Differences among the sexes varies only in liposuction definition sections. Women often prefer the lower back with buttocks defined, while men prefer the love handles [16]. However, most opt for a thorough combination of a more complete coverage. Liposuction preparation is the same for both. Ports are regularly distributed, usually 3 to 5 of them, to adequately cover each area for various movement directions of the cannulas. Infiltration is performed with 2–3 liters of tumescent fluid, the amount used depends on coverage area. The VASER device strength should be set at 70–80%, with a waiting duration time of 10–15 minutes. The liposuction duration can last between 15 and 30 minutes, for each area, using VASER probe cannula and VENTX cannula with a diameter of 3.7 mm. The continuous mode is used depending on fibrous tissue (**Figures 5**–7).

4.3 Buttocks: men and women

Liposuction of the buttocks often includes the lower area and sides. This procedure is reserved for specific cases and deformities. If VASER is performed, it should be at 50% VASER device strength, with a waiting time of 10–15 minutes, and tumescent fluid of 1–2 liters. However, instead of liposuction of the buttocks, fat grafting is preferably used. In practice, it is a much better defining and contouring procedure, with more natural results, where the surrounding excess buttocks fatty tissue is removed. The process starts by first emptying the supragluteal region, followed by the infragluteal region. The upper thigh area, lower side areas, and lower buttock area, on both sides, are evaluated for appropriate reduction. Once these areas are defined and reduced, sculpturing of the buttocks can begin [17, 18]. Depending on the sex of the client, certain specific areas are chosen for enhancement. For women, higher side segments are applied, while in men the central and upper areas with concaving sides is defined. Women prefer more of a curvature effect, while men prefer a more athletic figure, with an emptying effect of the lateral sides. Performing the contouring and defining in this area with the cannulas, extreme caution of the tip is needed since it can be easily punctured through the surface, leaving scarring. Gentle in-out motions should be used, and a significant amount of quality fatty tissue should be used to instill when space is created, using

Figure 5.
Before and 3 months after VASER liposuction.

about 200–300 mL. In some cases, more can be used, such as in more obese clients, while more slender clients will need less volume to achieve adequate results.

4.4 Abdomen: men and women

The abdomen area is the most popular area treated by VASER liposuction [19]. A nicely balanced and well-defined abdominal wall is usually what defines a healthy body figure. This area is the focus of visible differences between males and females. As stated previously, men prefer a more athletic, six pack figure, while women prefer natural contours reducing the "tummy" area, not emphasizing abdominal musculature. Preparing clients for this procedure should be done in a standing position. Drawing directly on the surface and marking defined areas to correct, should be completely discussed, and planned with them. It is at this moment, a clear plan is developed and explained, as to what can be achieved and what is not possible. Planning for males, involves defining of flat abdominal wall muscles (six-pack),

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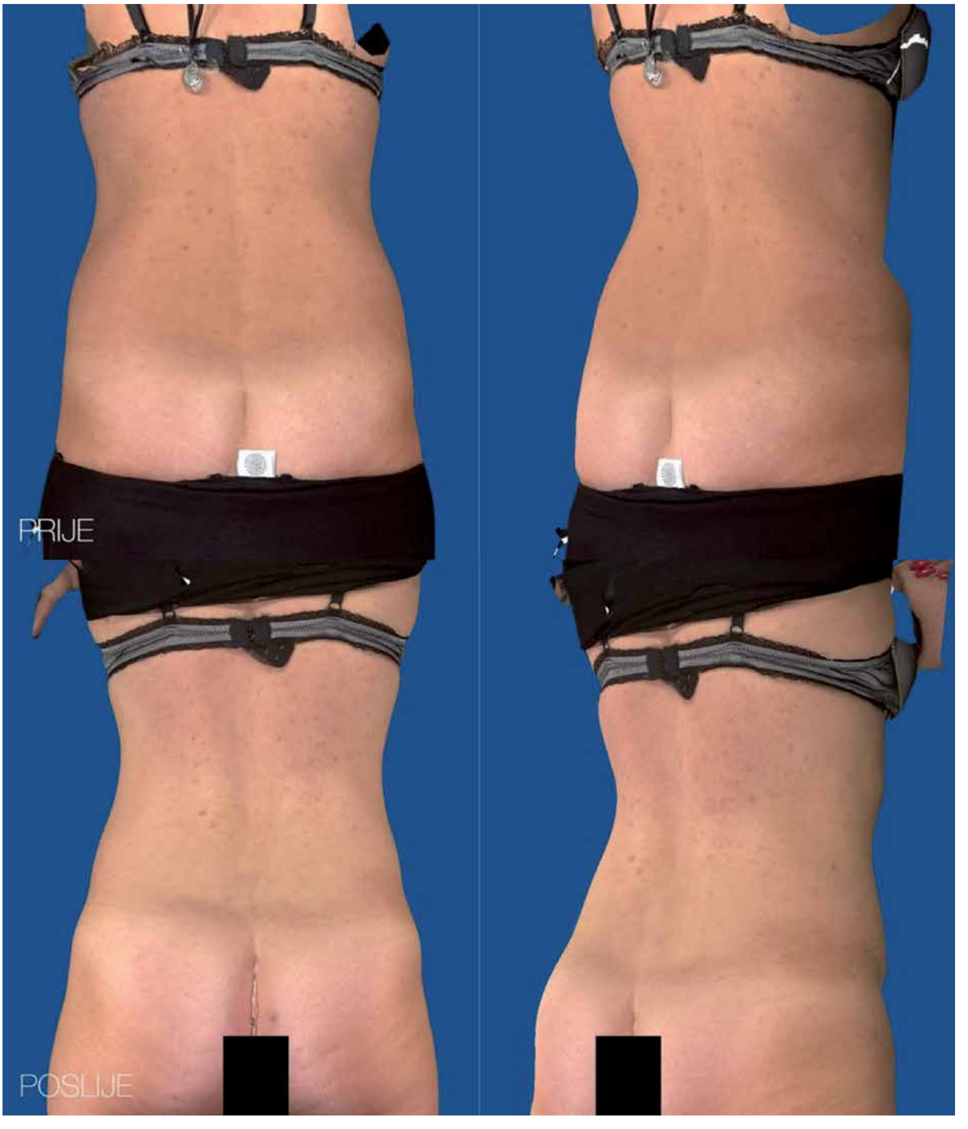

Figure 6.
Before and one year after VASER liposuction.

the linea alba and linea semilunaris regions. In women, a more subtle and gentler approach is used, creating more sensual contours defining linea semilunaris. In some instances, in women, linea alba can be defined as well, more often in slender clients. The procedure preparation is similar for both, using 3–4 liters of tumescent fluid, after application with VASER device at 70%, a waiting time of 10–15 minutes is needed. The ports used here are VENTX, with a diameter of 3.7 mm. The VASER probe cannula is set at a continuous mode, for deeper tissue reduction. However, if fibrous tissue is encountered, for example from previous operative scars, then an increased strength of the VASER device is needed, about 80–90%. A three grooved VASER probe cannula can be used. As this helps in producing maximal reduction of fatty tissue volume. At all times, the fatty tissue distribution and quality must remain symmetric. Leaving an abdominal wall subcutaneous fat layer of about 1–1.5 cm is important to retain a more natural abdominal wall contour. The liposuction process can last from 20 to 30 minutes as needed to achieve desired results (**Figures 8–10**).

Figure 7.
Before and 3 months after operation – Back view.

4.5 Chest area: men and women

Shaping the chest area is obviously significantly different in males and females. In males, this tends to be the most performed liposuction procedure. Excess fatty tissue under the nipple-areolar complex is the most common problem seen. However, this can be spread out wider, covering more of the breast plane. Correcting excess just under the areolar areas is usually not sufficient. Full redefining of the chest region is often necessary to achieve satisfying results. In performing reduction in this area, the sides and lower chest areas, underneath the nipple areolar complex are reduced. Providing a wider reduction area covered. This provides more definition and enhancement of the large chest muscles. Fat grafting is usually not performed in males in this area, since they usually prefer a slender leaner look, with minimal scarring. Preparation for this area include, performing incisions for ports

Figure 8.
Before and 6 months after VASER liposuction – Front view.

using the method Alfredo Hoyos uses [20], placing then directly under the nipple and in the peripheral armpit region, as to minimize visual scarring postoperatively. These incision areas also allow for easier access to all areas needed reduced. Again, VENTX ports are used from 2.9–3.7 mm diameter. Previously, larger diameter of 3–4 mm, when “Byrone” cannulas (wide diameter) for liposuction were used. However, now the more reduced diameters are preferred, especially in more sensitive delicate regions [21]. VASER device strength can be set from 70 to 90% depending on the presence of scar tissue, increasing strength if present. Tumescent fluid infiltration should be about 1–2 liters for each breast side. The waiting time is 10–15 minutes after application and liposuction should last 20–30 minutes, for each side performed. The combination of surgical tissue removal can be necessary, to achieve desired results. It is important to explain to patients that some loss of touch sensation can occur in the nipple region. Sometimes, this can be permanent.

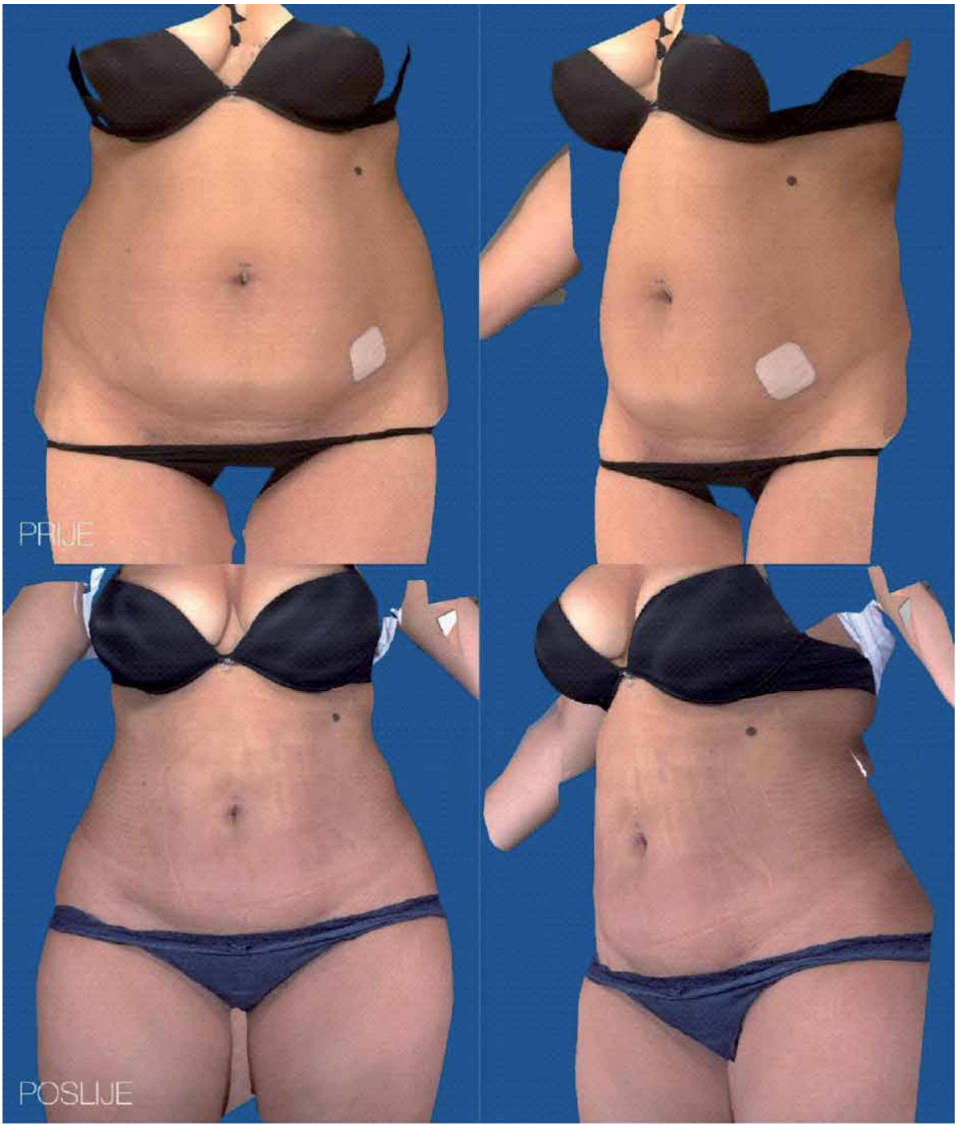

Figure 9.
Before and 3 months after VASER liposuction – Front view.

Drains are usually not placed, however at the side regions they can be placed to aid overflow in some selected cases.

For women, rarely isolated tissue reduction using VASER liposuction is performed. Instead, VASER is used for defining and contouring the lateral breast and chest areas. This method in combination with surgical reduction achieve very good results, in specific cases. If performed, 3.7 mm diameter VENTX ports are used. Tumescent fluid can be up to 1 liter per side, VASER device strength setting between 70 and 90%, waiting time of 10–15 minutes, and liposuction for 20–30 minutes. Mercedes cannulas with 3 openings can also be used. (For surgical breast reduction, incisions are made under the breast or through horizontal and vertical incisions (inverted T). More often fat grafting is a method used, providing supplement to the procedure on the breast [22]. Small incisions are made, only a few millimeters long in the areolar area, using cannulas of 2.1 mm in diameter for application. This reduces visible scarring postoperatively.

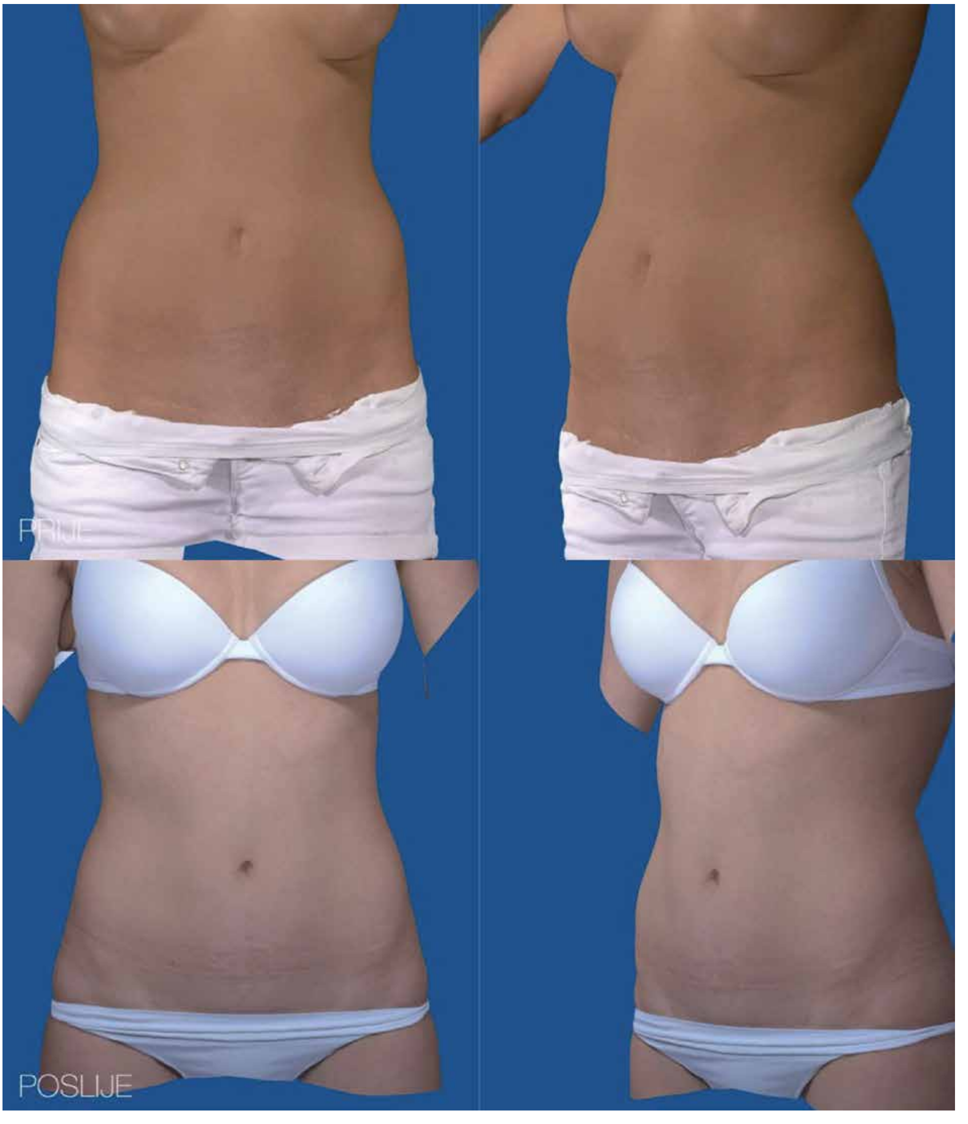

Figure 10.
Before and one year after VASER liposuction.

4.6 Thighs: men and women

Corrective thigh area procedures are rarely sought by men, this is a more problematic area for women. The upper thighs area is more pronounced, visually with clusters of fatty tissue, cellulite, forming distortions of the skin and contour. The procedure here is to reduce the volume in the front and side areas [4]. Tumescent fluid ordinarily used is 1–2 liters on each leg. VENTX Port diameter size is 3.7 mm, while the VASER device should be set at 50% at a continuous fluid injection stream. Port incisions are made at the groin and knees, medially in the inner thigh area. One placed at the groin, while two are placed lower halfway down towards the knee and at knee level. Liposuction time is again 20–30 minutes per side. Careful care should be taken, to avoid excessive liposuction in this area, because it can lead to the onset of "cutis marmorata" (marbled skin) [23]. Attention should be directed to sagging skin, and in selected cases surgical reduction may be required to tighten the area. Ordinarily, the knees are concurrently defined when the thighs are performed (**Figures 11** and **12**).

4.7 Calves: men and women

The calf, as well as the thigh region, is rarely corrected in males. If performed, it would be similarly done as in women. Incisions are placed in both the knee areas, posterior centrally (poplitea fossa), and in the upper ankle area medially, and at times laterally. This depend on the degree of tissue accumulation and reduction needed to be performed [4]. VENTX ports should be of a narrower diameter, 2.9 mm, the VASER device should be set at 50%, tumescent fluid used should be maximally up to 1 liter, waiting time is 10–15 minutes, and liposuction duration can be 20–30 minutes per side. Performing in this area depends on the thigh volume. This region when done can be swollen for an extended period. Drainage from the

Figure 11.
Before and 6 months after VASER liposuction – Front view.

Figure 12.
Before and 6 months after VASER liposuction – Back view.

thighs adds to this accumulation. Peripherally performed sites need more healing time and lymphatic drainage is disturbed. Hence, this region is rarely performed.

4.8 Upper arms: men and women

The upper arm area can be combined with chest definition, in selected male cases. In women, the defining process area is the triceps region, often saggy and hanging. It is important in both sexes to define the muscles, for men more the upper section, while in women the lower upper arm portion. The process is similar in both sexes. VENTX ports are placed in the arm pits and elbow region. Taking care that postoperatively scars will be hidden in skin folds, and less visible. Port size should be 3.7 mm, using up to 1 liter of tumescent fluid on each side, with reduced power of VASER device at 50%, using VENTX cannulas for liposuction and if fibrous tissue is present, use the VASER 2–3 grooved cannulas for better extraction of fatty tissue. Waiting times are similar as previous areas, 10–15 minutes with liposuction time of 20–30 minutes depending on visual achieved results.

4.9 Forearm: men and women

The forearm area is rarely requested as a corrective area from clients. As such, it is rarely performed. However, in the event this would be necessary to perform tumescent fluid of 200–500 mLs would be used. VENTX ports of a narrower diameter of 2.9 mm would be appropriate and placed in visually conspicuous areas. The VASER device should be at a reduced strength of 50%, using a 3 grooved cannula for liposuction. Waiting times again would be 10–15 minutes, with liposuction time of 20 minutes or more depending on desired results. Great care should be taken to stay away from the skin surface, to avoid breaking through and causing potential scarring.

5. Results

At Polyclinic Bagatin, there have been 409 VASER liposuctions performed in the last 9 years, including combination procedures with surgical resections. In about 15% of the cases, they involved male clients. The most frequent areas treated were the chest, abdominal wall, and lower back area. There were a few double chin procedures, as well. In women, most often VASER liposuction was performed on the abdominal wall, upper back area, hips and lower inside sections of the thighs. Patient postoperative monitoring lasted from 3 months to a year, or even more in certain cases. In both sexes, relatively few complications were encountered. The few seen were slight burns involving areas where ports were positioned, skin color changes, irregularities in the skin as depressions, dimpling or bulges, and some hardness, involving fat necrosis. In two cases, the thermal burns were caused at the ports and usage of over-heated tumescent fluid. Therefore, careful preparation and caution must be used throughout the VASER liposuction process. In 10% of the cases, additional corrections were necessary to achieve the desired results. Adjuncts used to enhance definition and contouring were the non-invasive Med2Contour, Zerona cold laser and the Venus Legacy radiofrequency methods. If liposuction was needed for addition touch up corrections, this was performed a year later. This would also include fat grafting to improve results. It was important to wait a year before redoing liposuction to give the body tissues time to heal and settle down into their new positions. This provided a more accurate visual of what needed to be corrected and exactly where to concentrate the liposuction correction. Patient satisfaction is the key. At Polyclinic Bagatin, patient satisfaction surveys show great percentage levels of satisfaction. Clients frequently recommend our clinic to others, as well as, continue their care and use many of our services offered.

6. Discussion

VASER liposuction itself can achieve great results. The combination of other liposuction methods and surgical methods, adds to the enhancement of desired results. Abdominoplasty is often combined with liposuction in correcting the abdominal area. Procedures to be performed depend on what clients prefer and want. It is the role of the plastic surgeon to explain what can and cannot be achieved, and what will yield the best results for individual cases. Patient satisfaction is a key part of what Polyclinic Bagatin strives for. The best commercial is a happy client.

In general, any liposuction technique used should be tapered to each client specifically. Of course, there are standard procedures and preparations to be followed.

Careful selection of port entries, tumescent fluid amounts, duration and extraction times should be used and again modulated for each case. The amount of tumescent fluid used can vary and is tappered to each case, especially if more than one region is being corrected. It is important to take the time to prepare well, and results will usually follow.

7. Conclusion

The method of VASER liposuction is an excellent technique to treat areas that previously were difficult to treat. Better depth control, VASER device strength and flow, and overall better tissue reduction are achieved by this technique. This is most certainly the case with difficult fibrous scar tissue, which has a level of skin retraction, thus needing increased device strength to be applied [24]. This method enables fatty tissue removal, in a far more efficient way, as well as, being less traumatic, than with just liposuction. This leads to fewer complications, like bleeding, distortion, breakthrough scarring, and a better recovery. The pain levels can be similar using either method, this can be alleviated by medications. Bruising can last 2–3 weeks. Drains are necessary to assist in carrying off collected excess fluids and secretions, and this can be up to 10 days. Recovery of patient with more extensive liposuction regions performed will need 7 or more days. The dosage of strength and action of flow (continuous or intermittent) using VASER technology has enabled more natural results. With every procedure performed, increased experience is gained. Combining various available methods and knowing specific tissue anatomy can help us create our goal of naturally defined body contours. VASER liposuction is a great and safe method, offering best results, at our disposal [25, 26].

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Chapter 9

Laser-Assisted Liposuction in Face and Body Contouring

Zoran Žgaljardić and Ivonne Žgaljardić

Abstract

Laser liposuction was developed as minimally invasive liposuction technique where energy breaks adipocytes (comparing with traditional liposuction where disruption is manual). After its implementation in the early 1990s, various academic reports were published that showed superiority of the laser assisted liposuction over standard tumescent technique. After tissue damage with photo-optical thermal energy, histological changes result in adipocyte disruption, blood vessel coagulation and neocollagenesis. The clinical manifestation of the latter is significant skin tightening and faster and more comfortable recovery. The diameter of the laser fiber is very small. Therefore, it is possible to reach adipose tissue entrapped in fibrotic areas and also superficially under the skin. The lysis of the given adipose tissue enables the subsequent suction with microcannulas. That explains the widespread use of the laser-assisted liposuction in the face and neck. Due to the significant skin tightening, the procedure can be done solely for rejuvenation purposes and is called endolight lifting. The possibility to reach fat in the fibrotic areas makes laser-assisted lipolysis/liposuction ideal procedure for contouring irregularities from previous body contouring procedures.

Keywords: laser, liposuction, endolight lifting, skin tightening

1. Introduction

Body contouring surgeries have been one of the most common procedures among all the procedures in cosmetic surgery. According to the report of the American society of plastic surgeons, in the 2019, liposuction has been the second most common procedure with 3% rise compared with the previous year [1]. During the last 30 years many new technologies have emerged and have been implemented in the liposuction procedure in order to improve the results and facilitate recovery. First report on the laser use for liposuction was made by Dressel in 1990 but the report was unable to prove clinical advantages so the technique did not get the FDA (Food and Drug Administration) clearance [2]. Significant breakthrough was made by Apfelberg in 1994. He conducted an FDA-approved study (subsequently he expanded the study in 1996) that proved the benefits of the laser use in the liposuction technique in terms of reduced bleeding, discomfort and tissue swelling. All of the latter resulted in faster recovery [3, 4]. Due to those reports, Apfelberg is considered to be the father of the laser assisted liposuction. Many reports followed that proved the superiority of laser assisted liposuction over the standard technique. The articles mainly emphasized diminished blood loss, oedema and recovery time. Besides that, maybe one of the most important features of the laser implementation was the neocollagenesis and consequently, the skin tightening effect after the procedure. Badin et.al were first to report that benefit [5]. The first laser to be approved by the FDA was 1064 nm Nd: YAG laser (smartLipo, Cynosure) on the 31st October of 2006.

2. Patient evaluation

Good indication is of the utter importance in achieving a satisfactory result. A good candidate for liposuction is considered to have localized subcutaneous fat accumulation without skin laxity. The advantage of the laser-assisted liposuction, as previously mentioned, is collagen formation and the skin tightening effect. Therefore, some amount of skin laxity can be tolerated when performing this method. Thanks to that feature, skin excision surgeries can sometimes be avoided. Unfortunately, there are no reports on the amount of skin laxity that is considered resolvable with this method so the indications are made by surgeon's subjective opinion based on his or her personal experience. Generally, younger patients with good skin tone respond excellent to the photo-thermal effect of the laser.

Special indications:

- Irregularities from previous surgeries
- Pseudogynecomastia with or without breast ptosis
- Turkey neck
- Facial adiposity
- High-definition result
- Multiple lipomas
- Hyperhidrosis

Exclusion criteria:

- Obesity
- Skin in excess with very poor skin quality
- Unrealistic expectations

Preoperatively pinch test should be performed to assess the amount of the subcutaneous fat and the skin in excess. In the beginning, one should avoid treating patients with skin in excess until enough experience is gathered in order to be able to assess the expected postoperative skin tightening effect. All irregularities should be marked and noted with patient in the standing position to avoid losing the 3D image when patient is in the supine position on the operating table. When performing high-definition laser-assisted liposuction, it is important to mark the borders of the underlying muscles. When treating the paranasolabial folds it is important to distinguish the subcutaneous fat from the bichat fat pad since the latter is treated with intraoral surgical excision.

All patient should be preoperatively advised that liposuction is not a substitute for healthy living habits and should not be used as a weight loss procedure but as a body contouring one.

3. Materials and methods

The authors have been using laser assisted liposuction for the past 12 years. The laser used is the diode laser 1470 nm. The settings are as follows: 12w (for abdomen, flanks, back, legs, pseudogynecomastia), 10w for the arms and 6w for the facial area and the submental fat with continuous wave in all areas besides the face (discontinuous wave is used in the face for safety reasons).

There are many advocates for performing liposuction in solely tumescent anesthesia but the authors suggest performing only smaller areas in such manner. If the laser assisted technique is used to achieve skin tightening, the treated area should be wider than the fat accumulation to allow good adaptation of the skin. The authors always perform liposuction under general anesthesia unless the treated area is small (face, flanks of knee area). When treating the submental area in tumescent or local anesthesia one should bear in mind that postoperative nerve palsy can emerge from the lidocaine effect and not due to the intraoperative nerve injury.

The disinfection is made while patient is awake and in standing position and subsequently positioned on the sterile operating table to avoid bacterial contamination.

It is recommended to infiltrate the tumescent fluid (or 0.9%NaCl with epinephrine in 1 L/1 ml 1:1000 ratio when surgery is performed under general anesthesia to avoid the risk of lidocaine toxicity) with the infiltration pump. The use of the pump enables faster performance and uniform fluid distribution. The mechanical pressure on the tissue made by the pump contributes to vasoconstriction and fat cell disruption.

When blanching of the area is achieved, the laser lipolysis can be performed. The back and forth movements of the laser fiber in the tissue should be smooth- the fat cells should be disrupted by the energy applied and not mechanically. The pop-corn sound effect should constantly be heard as a result of laser-tissue interaction. (Video 1, Video 2) Some lasers are equipped with internal thermometer to avoid overheating and subsequent burn and necrosis. If there is no internal subcutaneous thermometer (>50°C), external thermometer can be used as a control (38-42°C should not be exceeded) but authors suggest constantly moving the undominant hand over the treated area in order to feel the surface temperature and avoid the overaccumulation of energy. Cold packs can also be used to diminish the temperature of the skin. That is also why the laser fiber has to be in constant movement and care should be taken when treating areas near muscular sheath and near the skin (the former can cause rhabdomyolysis and postoperative pain and the latter can cause burn and necrosis). The laser fiber can be stopped at one place and more energy applied during few seconds if there is significant fibrosis and resistance. It is recommended to melt the deeper layer first followed with the superficial layer. When treating the pseudogynecomastia with some amount of ptosis, it is advisable to apply the energy on the breast but also around it-lateral chest and superior to the breast to induce the collagen formation and subsequent skin retraction (**Figure 1**).

Once the lysis is finished (no pop-corn sound, no resistance when passing the laser fiber, satisfactory pinch test), the standard suction is performed. Various reports exist on lysis only (without suction) but authors suggest to suction the melted fat whenever possible to avoid complications (contour irregularities, infection, seroma formation). The suction of the liquefied fat should be smooth without putting a lot of strain to the surgeon (there is no mechanical disruption of the fat). Pinch test should be performed to assess the amount of residual subcutaneous liquefied fat throughout the suctioning procedure (**Figures 2** and **3**).

In cases with skin laxity, additional pass of the laser fiber is performed at the end of the procedure in order to apply the energy on the remaining fibrous septa and the dermis to promote the collagen formation. If the laser beam is one-directional it can be rotated towards the skin (**Figure 4**).

Figure 1.
The arrows mark the area that should be treated with laser lipolysis only without subsequent suction to induce the collagen formation.

Figure 2.
Pinch test at the beginning of the suctioning.

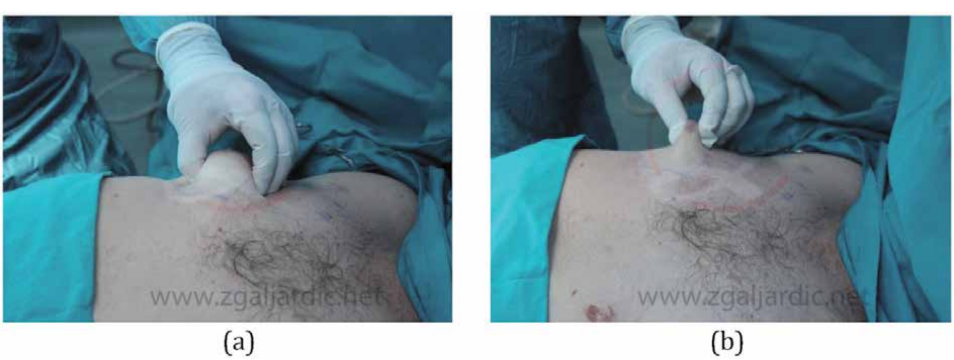

Figure 3.
(a) Pinch test in the middle of the aspiration process with visible residual fat. (b) Pinch test at the end of the procedure.

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Figure 4.
Directing the laser beam towrads the skin at the end of the procedure.

Also, when performing high-definition laser-assisted liposuction, additional energy is applied on the previously marked muscle borders over the tendinous parts of the muscle to emphasize the muscular definition. Additional incisions for laser entrance are made if necessary.

Incisions can be closed with one suture or left open especially if treating larger amounts of fat to allow the drainage. If significant fluid leak is expected, penrose drainage can be placed on the incision site upon discharge.

Postoperative garments are of the utter importance in achieving the skin retraction and its good adaptation on the underlying surface. The authors suggest wearing postoperative garments for 3 weeks. Also, additional support is put over abdomen, male breast and/or flanks. That support should be made of not too rigid, yet flexible material that can be tailored upon every patient individually (between the ribcage and iliac crests) to minimize the dead space. To avoid ischemic complications of the skin, the sponge or cotton wool can be placed on its inner surface.) Those additional plates are put in place during the first postoperative week.

When performing high-definition laser assisted liposuction, adhesive bandages are placed on the tendinous parts of the muscles (were at the end of the procedure additional pass of the energy was applied to promote neocollagenesis). Those bandages are put in place for 7 days.t

4. Results

Although there are many advocates for the use of laser assisted procedure only in certain indications, the authors always perform laser-assisted procedure. It is important to bear in mind that for the final result to be achieved, it could take up to 3 months due to the prolonged effect of the laser energy.

4.1 Body

4.1.1 Case 1

48-year-old female patient.

Procedure performed: laser-assisted liposuction of the abdomen, flanks, lower back and upper legs (**Figures** 5–7).

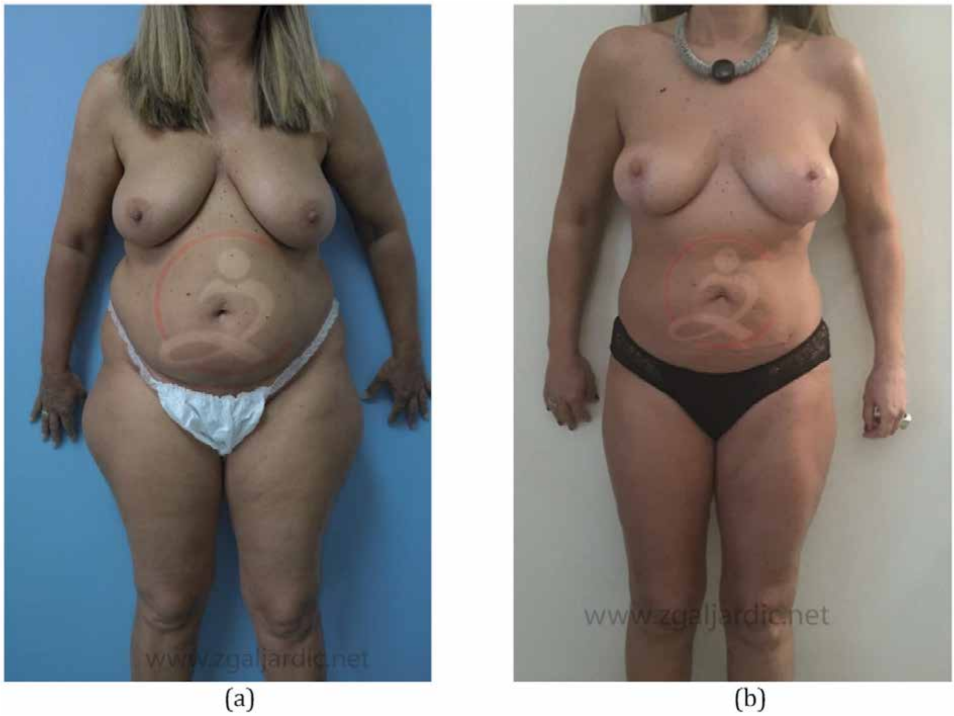

Figure 5.
(a) Before. (b) after 3 weeks.

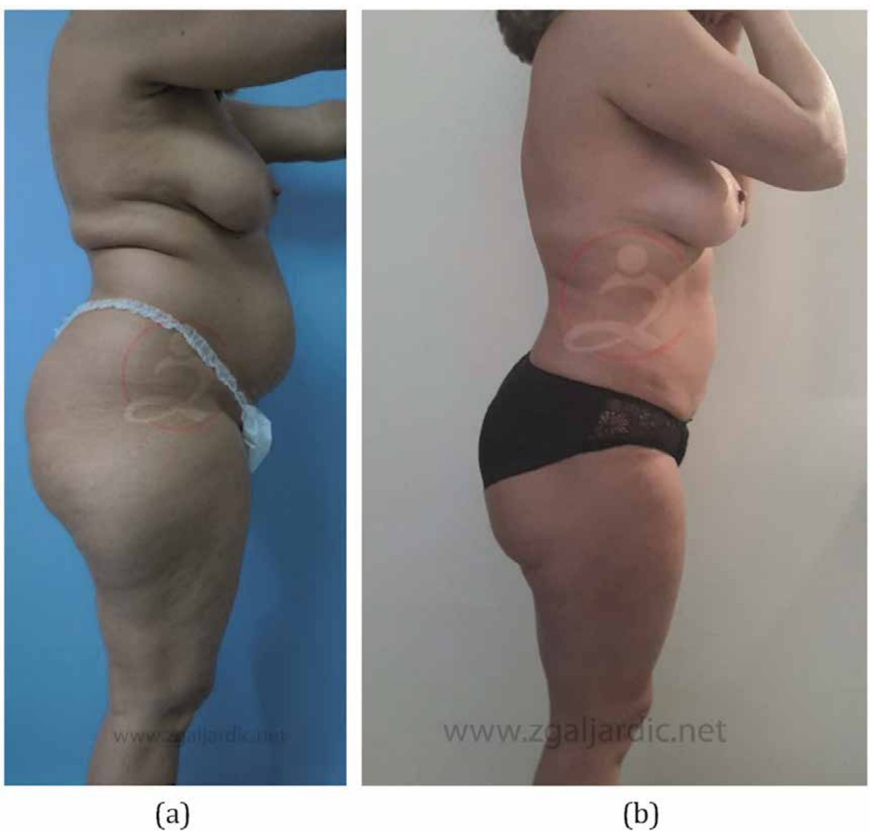

Figure 6.
(a) Before. (b) after 3 weeks.

Figure 7.
(a) Before. (b) after 3 weeks.

4.1.2 Case 2

32-year-old female patient.

Procedure performed: laser-assisted liposuction of the abdomen, flanks, lower back and upper legs (**Figures 8–10**).

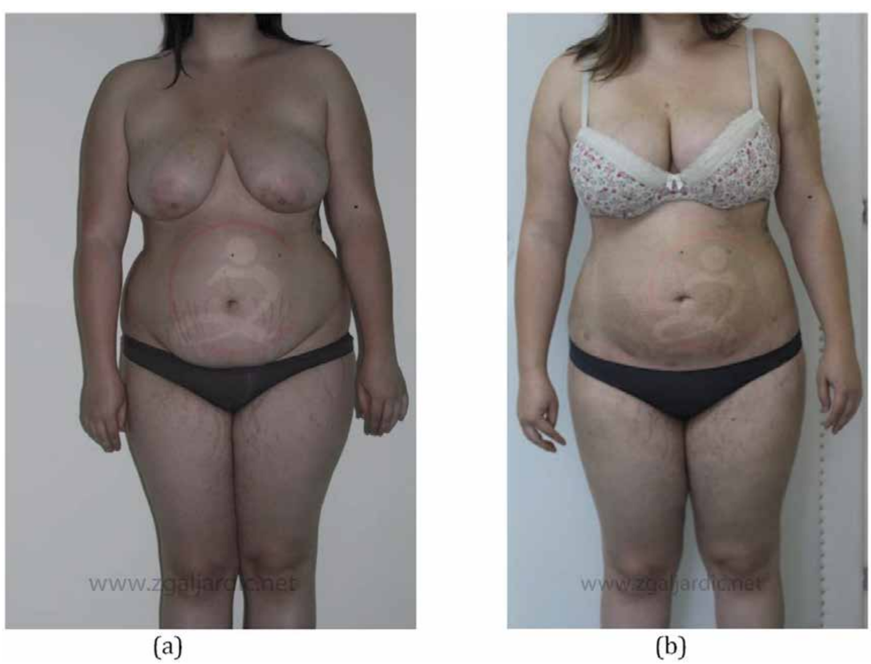

Figure 8.
(a) Before. (b) after 2 weeks.

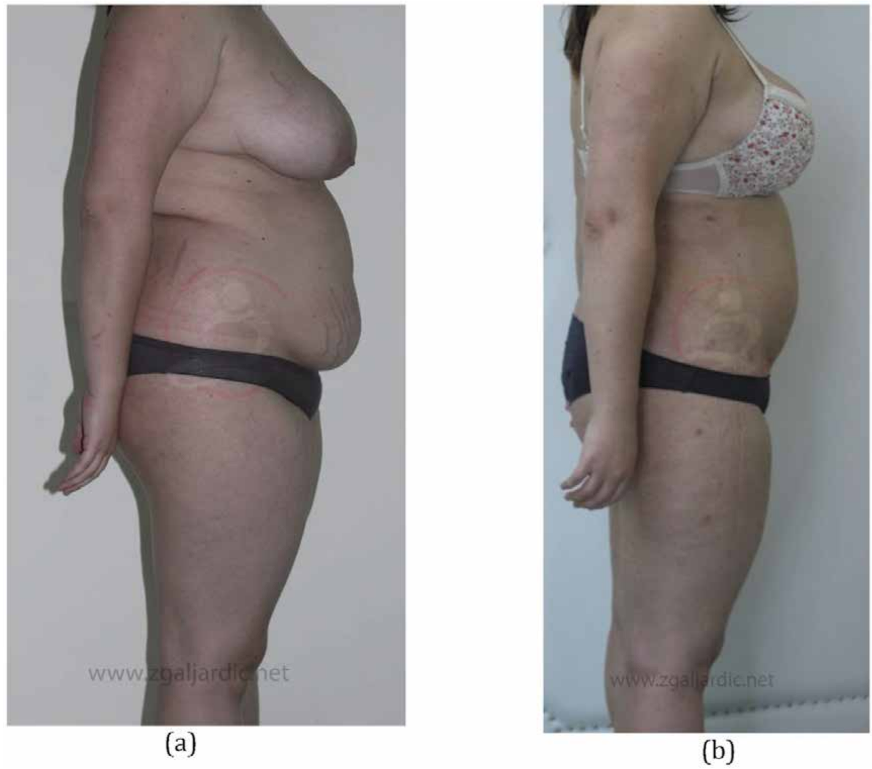

Figure 9.
(a) Before. (b) after 2 weeks.

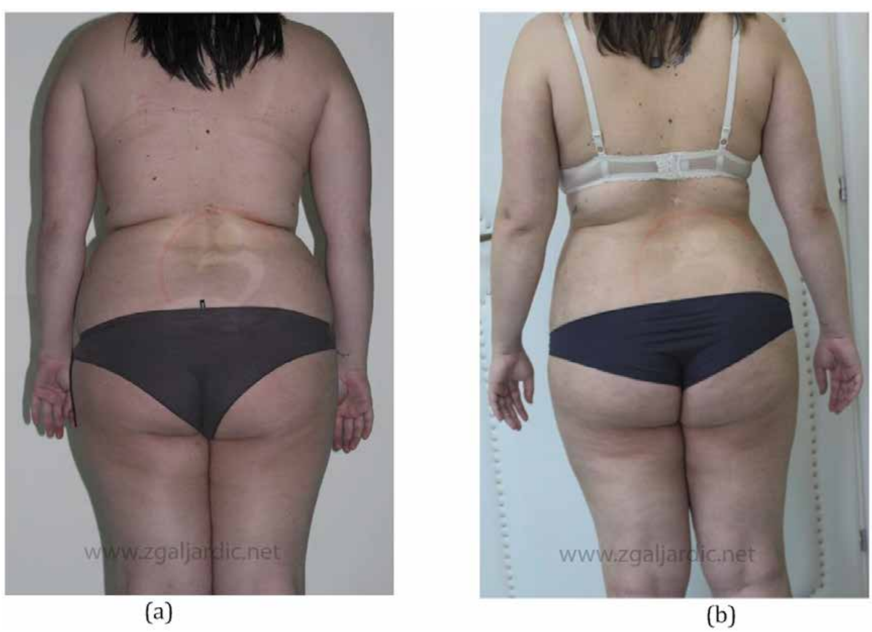

Figure 10.
(a) Before. (b) after 2 weeks.

4.1.3 Case 3

35-year-old female patient.

Procedure performed: laser-assisted liposuction of the abdomen, flanks, lower back and upper legs.

NOTE: few days prior to the procedure the patient went to the spray tanning salon (**Figures 11–13**).

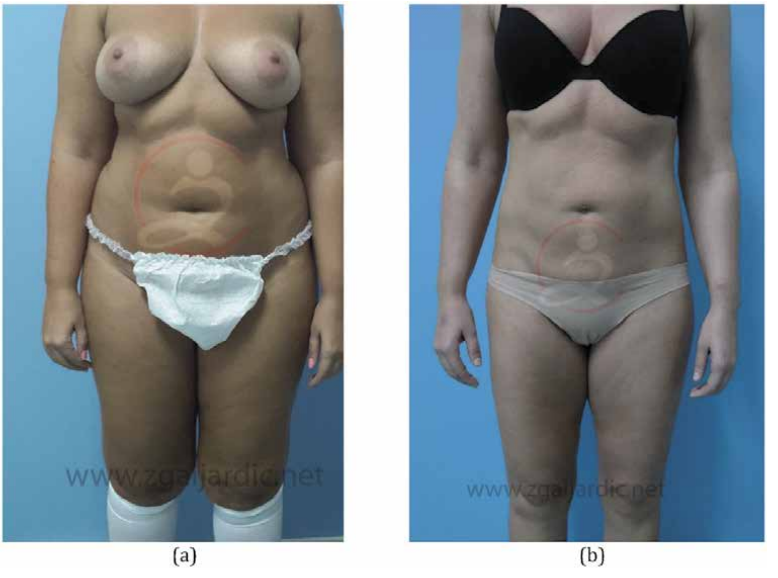

Figure 11.
(a) Before. (b) after 6 weeks.

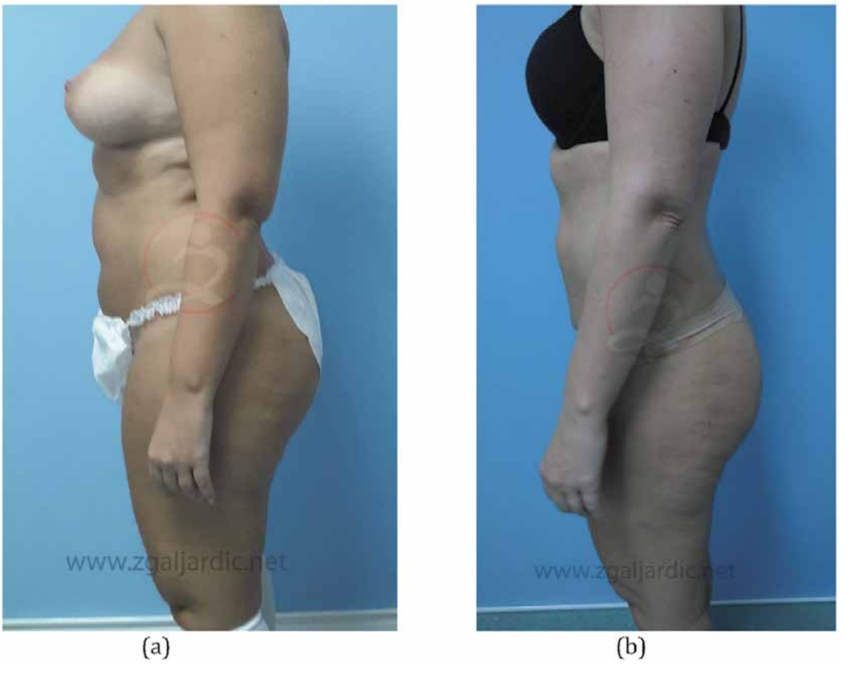

Figure 12.
(a) Before. (b) after 6 weeks.

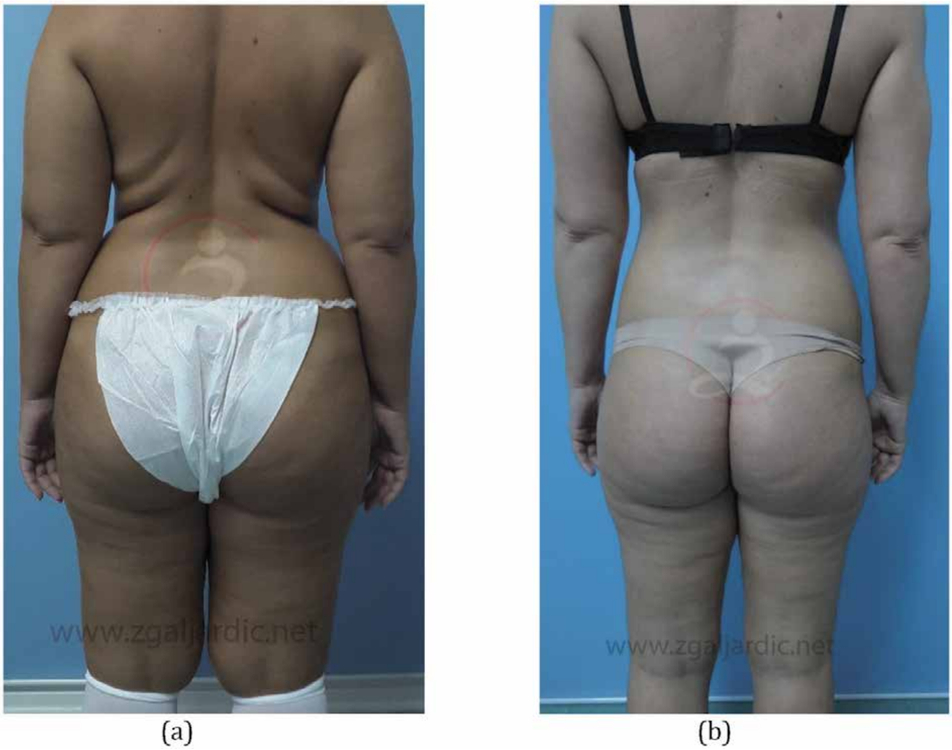

Figure 13.
(a) Before. (b) after 6 weeks.

4.2 Gynecomastia

Tips:

1. Infiltrate the larger area than the breast itself. Approximately 300-400 ml of tumescent solution should be infiltrated in each breast. Additional 100-200 ml should be infiltrated superiorly (up to approximately 5-7 cm below the clavicle) and laterally.

2. Perform laser lipolysis with subsequent liposuction of the breast. At the end of the procedure, perform laser lipolysis only (without liposuction) of the suctioned breast and surrounding area previously infiltrated in order to induce neocollagenesis in the fibrous septae and the superficial subcutaneous tissue. If the laser beam used is not multi-directional, rotate the tip of the laser beam towards the skin. Always control the surface temperature. If there is no internal thermometer, use the undominant hand to feel the surface temperature.

3. Apply maximal compression up to three weeks, especially during first 7 days. Compressive plates can be put in place below the garment and tailored individually. There are different types of compressive plates that can be found on the market. Compressive plates can be also individually tailored from the rubber mat used for exercise. In order to avoid ischemic complications from the pressure, a layer of cotton wool of gentle sponge can be put between the skin and the compression plate.

4.2.1 Case 1

43-year-old male patient.
Procedure performed: laser-assisted liposuction of the chest (**Figure 14**).

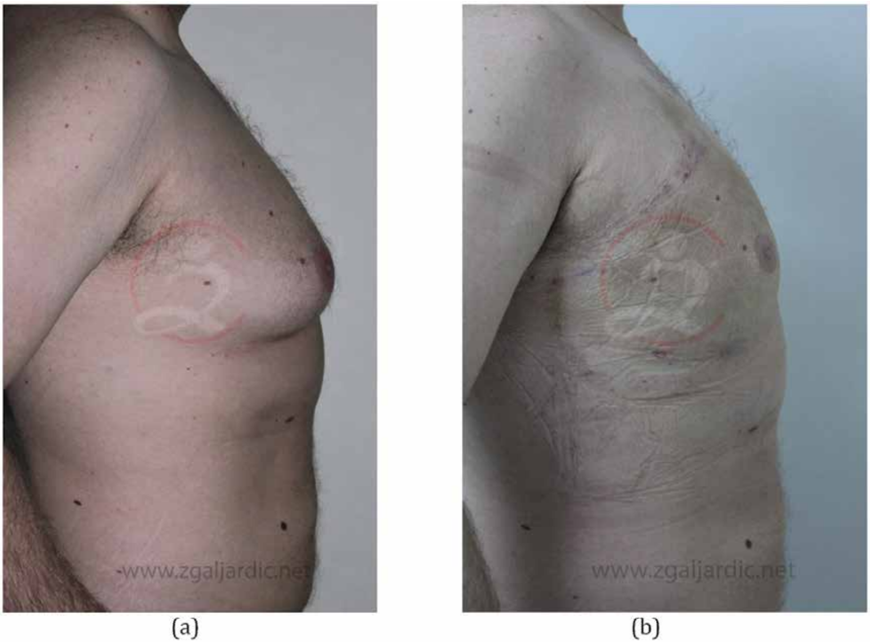

Figure 14.
(a) Before. (b) after 7 days.

4.2.2 Case 2

47-year-old male patient.
Procedure performed: laser-assisted liposuction of the chest (**Figure 15**).

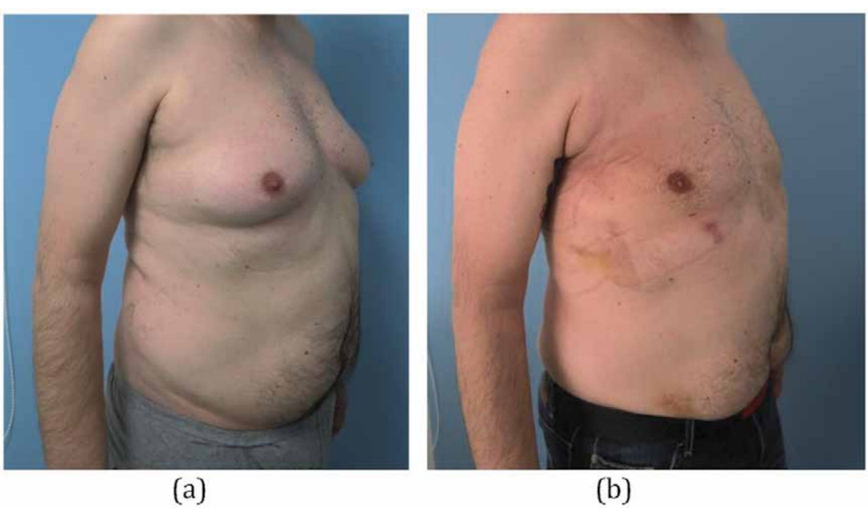

Figure 15.
(a) Before. (b) after 7 days.

4.3 High definition of the abdomen

Tips:

1. Before the procedure, mark the tendinous parts of the abdominal muscles.

2. After performing laser-assisted liposuction, additionally treat previously marked areas with laser energy only (laser lipoisys without liposuction) in order to induce neocollagenesis in the fibrous septae to mark the underlying muscles. If the laser beam used is not multi-directional, rotate the tip of the laser beam towards the skin. Always control the surface temperature. If there is no internal thermometer, use the undominant hand to feel the surface temperature. Make additional minimal skin incisions (for laser beam only) if the existing ones are not suitable.

3. Apply additional compression with adhesive bandages on the treated tendinous parts.

4.3.1 Case 1

24-year-old male patient.
Procedure performed: laser-assisted liposuction of the chest and abdomen (**Figure 16**).

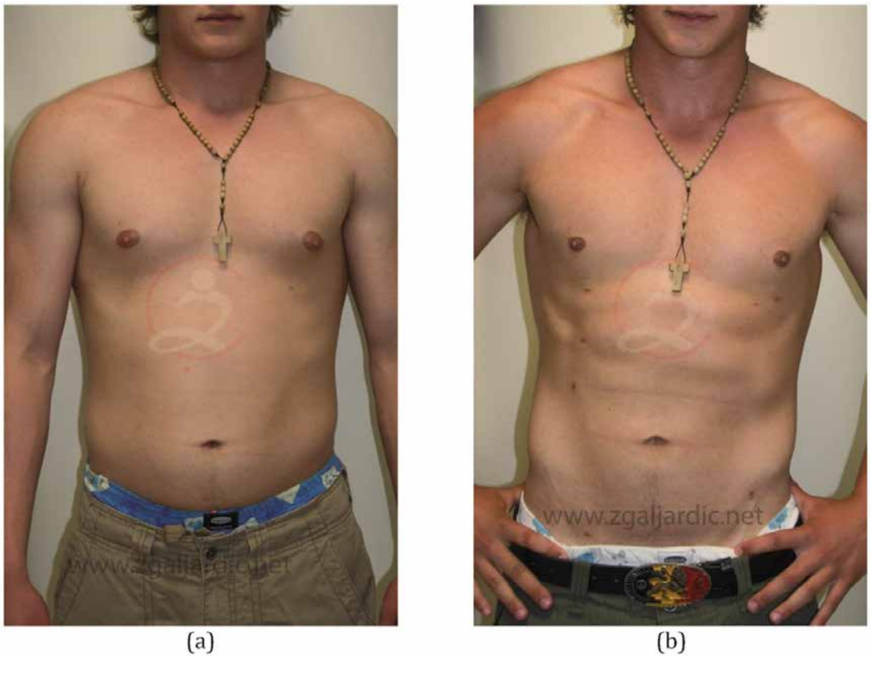

Figure 16.
(a) Before. (b) after 3 weeks.

4.3.2 Case 2

29-year-old male patient.
Procedure performed: laser-assisted liposuction of the chest and abdomen (**Figure 17**).

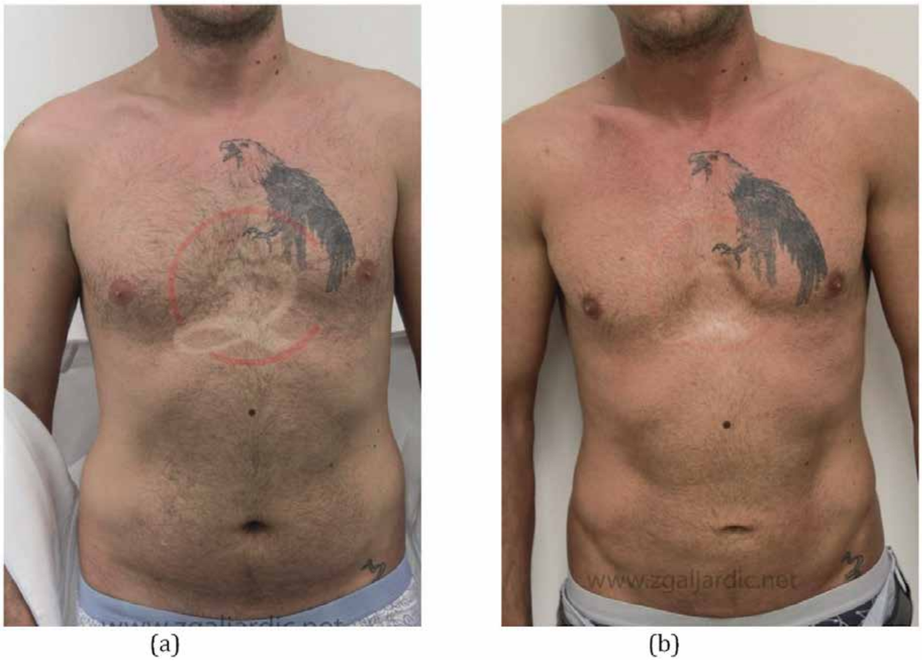

Figure 17.
(a) Before. (b) after 3 weeks.

4.4 Face

Tips:

1. Use lower energy than in the body(6 W) and discontinuous wave.

2. Infiltrate the subcutaneous submental area from jaw angle and the chin as a superior border below to the laryngeal prominence.

3. Use 2 mm or 3 mm cannulas for the liposuction

4. Apply additional laser energy after the liposuction if there is skin laxity or when performing the procedure as an endolight lifting only.

5. Put adhesive bandages above the treated area to promote skin retraction and to minimize the dead space.

6. Use commercial bandages for the face of wrap the bandage around the head for the first 7 days after the surgery and during the next 2 weeks advise patients to wear it over night.

4.4.1 Case 1

41-year-old male patient.

Procedure performed: laser-assisted liposuction of the submental area, lower jowls and neck (**Figures 18** and **19**).

Figure 18.
(a) Before. (b) after 3 weeks.

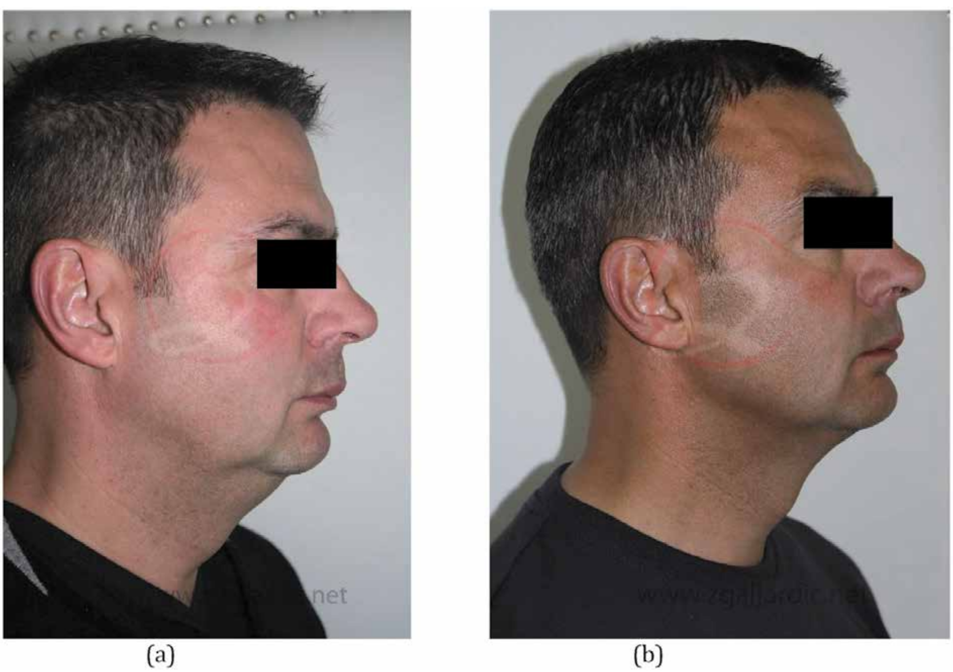

Figure 19.
(a) Before. (b) after 3 weeks.

4.4.2 Case 2

40-year-old female patient.

Procedure performed: laser-assisted liposuction of the submental area, lower jowls and neck (**Figure 20**).

Figure 20.
(a) Before. (b) after 1 month.

4.4.3 Case 3: patient treated solely for rejuvenation purposes- endolight lifting

50-year-old female patient.

Procedure performed: laser-assisted liposuction of the submental area, lower jowls and neck (endolight lifting) (**Figures 21** and **22**).

Figure 21.
(a) Before. (b) After 1 month.

Figure 22.
(a) Before. (b) After one month.

5. Discussion

The basis of laser-tissue interaction is considered to be the photo-termal effect [6, 7]. The emitted laser light energy is absorbed by the tissue and converted into heat. When lower energy is applied, it changes the sodium-potassium balance on the cell membrane and promotes the cellular inflow of the extracellular fluid. On the other hand, when applying higher energy, membrane rupture occurs along with blood vessel and collagen coagulation [8]. For the latter to occur, internal subcutaneous temperature of 50°C should be achieved. Internal temperature should not exceed 65°C. That is considered to be critical end point temperature and higher temperatures lead to unwanted necrosis and subsequent scarring [6, 9]. DiBernardo and Reyes suggest that when performing superficial lipolysis to obtain skin tightening, the surface temperature should not exceed 47°C and should be limited to 42° C.8 The undominant hand should always control the surface temperature. That is why Mordon and Plot called the undominant hand, in this case, the "thinking" hand [10]. Different laser sources and wavelengths have been used for the lipolysis of the fatty tissue. Different wavelengths target different chromophore in the tissue so it has been hypothesized that specific wavelengths have better effect on fat disruption and other for skin tightening [11, 12]. Parlette and Kaminer reported that the 924 nm wavelength has the best fat absorption and thus, the highest fat melting potential [13]. On the other hand, there are authors that suggest that the heat and subsequently the histological damage and repair mechanisms are primarily responsible for the final result [14]. There are not many reports on the safety aspects of the applied energy. Reynaud et al. were the first to calculate the mean values of energy applied to different body areas in 2009. The machine used in their study was 980 nm diode laser. In their study conducted after 534 procedures were following: abdomen 24 600 J (6- 51 kJ), outher thighs 14 600 J (2.2- 31 kJ), waist 9 500 J (4- 19 kJ), posterior face of thighs 13 100 J (4- 25 kJ), inner thighs 10 400 J (4- 20 kJ), submandibular 11 700 J (6.6- 16 kJ), arms 12 800 J (4.7- 17 kJ), inner knees 8 100 J (2.7- 20 kJ), back 21 900 J (11- 35 kJ) [15]. In 2018, Ali published an article proposing parameters for safe and effective laser lipolysis. The average cumulative energy applied for each treated area were as follows: 2000-2500 J (chin), 8000-12000 J (arm), 5000- 6000 J (gynecomastia in each side), 4000-5000 J (flanks), 10000-14000 J (abdomen), 12000-18000 J (back), 8000-15000 J (saddle bags), 10000-14000 J (thigh and 800-2000 J (knees). The study was conducted on 300 patients using 2 different Nd:YAG machines with incorporated dual wavelengths of 1064 nm and 1320 nm(Smart Lipo triplex Cynosure and DaVinci model Quanta) [16]. There are no scientific data to support the thesis but in authors' personal experience, larger amount of energy should be applied when working with diode laser. This observation is in concordance with the results of the previously mentioned studies. Mordon and Plot suggest that diode technology, in contract to Nd: YAG, has around 30% greater efficiency. They also suggest that higher wavelengths are better absorbed by fat and water therefore enable stronger heating. The latter, on the other hand, can increase the risk of thermal injury [10]. Wolfenson et.al suggest applying maximum of 5 kJ per 10x10cmof skin area treated in order to prevent complications of overheating [17].

Probably the greatest advantage of the laser-assisted liposuction is its ability to achieve significant skin tightening. Therefore, it is widely used in facial shaping, not just to achieve sculpting with fat removal but also to achieve rejuvenation effect. Given that, a term endolight lifting has been establish to describe the use of laser assisted liposuction as primarily rejuvenation procedure in the facial area. In 2011 Holcomb et al. have been first to publish the use of laser lipolysis on a larger series of patients. In total, 478 patients were treated with good final results [18]. In 2018, Valizadeh et al. conducted a study on female patients seekng submental liposuction for fat reduction and skin rejuvenation. The patients were randomly assigned to two different groups: one treated with laser assisted liposuction and the other treated with traditional liposuction. The thickness of the submental fat was evaluated pre and postoperatively with ultrasound. The residual fat thickness was significantly lower in the laser assisted group at a 2 weeks follow-up with even greater difference at a 2 months follow up. Subjective patient evaluation was also performed using a subjective scale from 0 to 5. Patients treated with the laser assisted liposuction were considerably more satisfied than those treated with traditional liposuction in terms of fat reeduction and final skin appearance [19]. On the other hand, many patients who are candidates for liposuction have some amount of skin laxity. This method offers excellent alternative for those where there is no clear indication for skin resection surgeries but are in higher risk in being left with some skin sagging after the procedure. There have been subjective reports on skin tightening after the laser assisted procedures but DiBernardo and Reyes were first to prove it in 2009 [9]. Several analysis and studies have been conducted to explain and measure the skin tightening effect. According to mathematical analysis and thermoregulatory measurement, internal temperature has to be between 48 and 50°C to obtain skin tightening effect [6, 20–22]. Although many reports exist and studies have been conducted, to date, there is no consensus on the amount of skin tightening that can be achieved and the indications are left to the surgeon's subjective opinion according to his or hers experience. Therefore, the drawback of this technique is the surgeon's learning curve.

Blood loss during the procedures significantly influences patient's recovery period. Many studies showed the superiority of laser-assisted liposuction over the standard tumescent technique regarding the diminished blood loss [9, 17, 23, 24]. Abdelaal and Aboelatta have conducted a prospective study to evaluate the amount of blood loss and have concluded that laser assisted liposuction can reduce the blood loss up to 50%n comparing to the conventional liposuction [25]. The reduction of blood loss diminishes the risk of postoperative anemia and fatigue which significantly contribute to the patient's wellbeing through the recovery.

Various reports have also been published on the improvement of superficial skin irregularities such as cellulite. Petti et al. evaluated the cellulite improvement through the results on the modified Nurnberger-Muller scale 3-6 months after the laser assisted liposuction. An average improvement score was 1.58 on a scale from 1 to 3 suggesting significant satisfaction rate on the final esthetic appearance [26]. The authors have used laser-assisted lipolysis to treat skinny patient with localized cellulite with high satisfaction rate.

Disruption of the fatty cells with laser energy enables the use of cannulas of the smaller caliber. Thus, smaller entrance point can be made. Nevertheless, care must be taken not to injure the entrance site with laser energy. In that case, the resulting incision scar can be esthetically unpleasing. In the same time, the procedure puts less strain on the surgeon as it is not his or her hand and mechanical manipulations responsible for the adipose cell disruption. The latter is also responsible for inflicting less trauma to the tissue that also contributes to the faster recovery. In a fibrotic area such as the male breast or the tissue that has previously been traumatized with liposuction, laser lipolysis is an excellent tool to melt the entrapped fat without additionally traumatizing the tissue. That is why laser assisted liposuction is an excellent tool in treating pseudogynecomastia or contour irregularities form previous surgeries.

The biggest disadvantage of the laser assisted liposuction is the possibility of the thermal injury, burn, necrosis and unwanted scarring. As previously stated, some reports on safety protocols have been made and can be used as guidelines when implementing the laser in one's practice [15, 16]. Generally speaking, when internal subcutaneous thermometer is incorporated in the machine one can precisely measure the temperature and avoid overheating. Unfortunately, not all the devices come with that equipment. As already mentioned, cold compresses and external thermometer can be used to avoid placing too much energy in one spot. In authors' experience, the use of the undominant hand to control the skin temperature is the best tool to avoid the thermal injury. Also, when starting to implement this technique, lower power settings and discontinuous waves can be used to avoid complications. One should bear in mind that in this situation the energy is applied from under the skin so any postoperative blistering (if not caused by the outside pressure from the garment) will surely result in full thickness necrosis.

If laser lipolysis without subsequent suctioning is used, postoperative mass formation is possible that on histological analysis is described as fluid-filled pseudocyst with characteristics of foreign-body granuloma [27]. Given that, the authors advise suctioning the liquefied fat whenever possible. Last, but not least, when suctioning is performed, there is less swelling and the final result is achieved sooner. The latter, in the end, contributes to the overall patient' satisfaction.

Another drawback of this technique is the increase in the operating time. Prado reported in their study that average duration of traditional liposuction was 45 min and the laser assisted one- 60 minutes [28]. Although there is an increase in the operating time, the overall procedure, especially the suctioning is easier to carry out compared to the traditional liposuction.

One case of acute kidney injury due to rhabdomiolysis has been reported [29]. Hence, the surgeon should avoid injuring the muscle aponeurosis during the procedure. Nevertheless, in patients presenting with symptoms of acute kidney injury postoperatively, he or she should react accordingly.

6. Conclusion

Surgeons, as well as technological companies, are in constant search for the "holy-grail" of body contouring. Emerging technologies, as in this case, the use of lasers in body contouring procedures has made significant improvement on the final result, reduced recovery and thus, increased the patient' satisfaction. Not only that, the indications for the liposuction procedure have been widened.

Advantages:

- Skin tightening
- Reduced blood loss and faster recovery
- Treatment of cellulite and contour irregularities
- Less strain for the surgeon and diminished tissue trauma

Disadvantages:

- Risk of thermal injury
- Longer learning curve
- Increased operating time

Due to that, it has become possible to avoid skin excision both in body shaping and facial rejuvenation.

In conclusion, one should always bear in mind that every technology in only a tool in a surgeon's hand. Therefore, the experience of the surgeon is of the utmost importance.

Conflict of interest

The authors declare no conflict of interest.

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Chapter 10

Non-invasive Alternatives for Liposuction

Diane Irvine Duncan, Suneel Chilukuri, David Kent, Klaus Hoffmann and Lim Tingsong

Abstract

Body dissatisfaction due to an increased amount of subcutaneous fat, muscle laxity and/or skin imperfection poses a great concern for today's society. Invasive surgical procedures intended for an immediate improvement of body contour such as liposuction were perceived as a means of restoring the optimum body shape. However, the invasive nature of liposuction plus a certain amount of discomfort and downtime leads to increasing popularity in the noninvasive esthetic procedures. This chapter aims to emphasize the use of latest noninvasive technologies as a viable alternative to the liposuction. Three patient cases with different levels of treatment outcomes were reviewed. Patients received treatments either with high-intensity focused electromagnetic field (HIFEM) procedure or a combination of HIFEM and synchronized radiofrequency (RF), optionally followed by the simultaneous therapy by targeted pressure energy (TPE) plus monopolar RF. HIFEM alone resolves muscle laxity, reduces the separation of abdominal muscles and reduces abdominal adipose tissue. When combined with synchronized RF, the effect on muscle and fat tissue is enhanced. Concomitant use of monopolar RF and TPE shows considerable improvements in skin quality, including diminished skin laxity or cellulite. The use of HIFEM, RF and TPE technologies can be a good noninvasive liposuction alternative.

Keywords: HIFEM, RF, TPE, laxity, toning, fat reduction

1. Introduction

Areas of exercise-resistant or diet-resistant fat, skin issues, and muscle concerns are many reasons the patients turn to cosmetic surgeries. Whether these concerns come from fatty areas at the abdomen, back, or thighs that would not budge, loose skin after dramatic weight loss, or pregnancy, many people try to find the best ways to eliminate these problems.

While skin excision is needed in some cases, liposuction is often the most preferred treatment for patients to contour or shape their bodies and eliminate the extra fat for different areas. Liposuction, also referred to as lipo, lipectomy, liposculpture suction, or lipoplasty, is a popular cosmetic surgery that breaks and sucks away the fat from the body. A cannula, a hollow instrument, is used to remove the fat during the procedure. The instrument is inserted into the skin, and a high-pressure, powerful vacuum is applied to the cannula to evacuate the fat. Due to its invasive nature, the whole procedure often requires anesthesia to combat patient discomfort associated with the insertion of a cannula. It is commonly used on the abdomen, flanks, upper back, neck, buttocks, thighs, and volar arms and calves.

The procedure is highly popular around the world and is one of the top-performing cosmetic procedures [1]. This treatment helps permanently remove the fat cells and enhance the shape of the body. Nevertheless, the remaining fat cells could grow bigger if the patient does not follow a healthy lifestyle after the surgery. Also, liposuction does not resolve skin irregularities as stretch marks, dimples, or cellulite. It does not affect muscle tissue by any means since it primarily focuses on enhancing or changing the body's adipose contour. Additionally, only a limited amount of fat can be eliminated, and there are certain risks and downtime associated with the treatment.

While most patients are happy with the outcome of their traditional body contouring procedures, a fair number of them are left with unresolved problems. Moreover, many are still reluctant to undergo surgery to reduce fat and prefer a procedure without any down time or scars. Fortunately, in recent years, numerous minimally invasive and non-invasive alternatives to liposuction have been introduced. These procedures for fat reduction and body contouring do not require any anesthesia or incision and have no downtime. The introduction of non-invasive treatments allows physicians to offer such patients with non-invasive fat reduction and body contouring treatments as an alternative to surgery-assisted liposuction (SAL).

While the numerous body-contouring treatments aim to target adipose tissue by utilizing light energy [2, 3], ultrasound [4, 5] or cold temperatures [6, 7], the new revolutionary non-invasive HIFEM technology [8–12] has brought attention to the underlying muscle tissue as well. In addition, the combination of High-intensity Focused Electromagnetic field (HIFEM) with synchronized [13] or externally applied radiofrequency (RF) and targeted pressure energy (TPE) [14] can provide a new solution for body contouring dilemmas, such as striae, skin contour irregularities, cellulite, residual subcutaneous fat, and diastasis recti without the need for any surgery.

This chapter aims to introduce non-invasive HIFEM, RF, and TPE technologies as a viable alternative to the conventional SAL procedure when used in a standalone regime or as a combination treatment. As always, patient selection and preferences are the key factors when prescribing the procedure that should fit his/her needs regarding the specific body area and imperfection that is going to be treated. Given the technological advancements in the non-invasive field of esthetics in recent years, we believe the technologies mentioned above may achieve competitive and perhaps advantageous results in some specific cases.

2. Technology and mechanism of action

Since patients who attend your practice are unique with varying goals and needs, it is essential to understand the importance of providing various solutions to help them accomplish their desired results. Over time, you might have encountered many patients who wanted to achieve a contoured body, tight muscles, and smooth skin appearance without the necessity of the invasive surgical procedure.

While this might have been impossible a decade ago, the non-invasive solution evolved greatly in the past few years. Today, with appropriate patient selection and treatment planning, it may offer an outstanding alternative to liposuction (see Section 3. Non-invasive technologies as an alternative to SAL). Not only these non-invasive solutions may provide an alternative to SAL, but they also have capabilities to enhance the results post-SAL. Physicians can combine these procedures to further enhance patient results post-liposuction based on the patient's expectations and goals. To understand the abovementioned procedures in detail, it is integral to learn about their mechanism of action (MOA).

A systematic electronic search by using the terms "HIFEM" and "targeted pressure energy (TPE)" was carried out to identify the relevant literature published since January 2018. Articles investigating the effect of the HIFEM procedure as a standalone tool or in combination with synchronized RF, and monopolar radiofrequency combined with TPE were further evaluated based on the Author's knowledge. In addition, the reference lists of analyzed articles were inspected to identify the additional valid source of information. Research that quantitatively documents changes in fat, muscle and skin tissue in response to the treatments was summarized with special attention given to histological studies, evidencing the induced changes at the molecular/tissue level. Besides, the outcomes, including but not limited to improvement of patient appearance, comfort, and satisfaction, have been reviewed as well.

2.1 HIFEM

The first-ever HIFEM based procedure was shown in 2018 when the Emsculpt device (BTL Industries Inc., Boston, MA) was introduced to the market and gained considerable popularity among patients and physicians. Emsculpt is FDA-approved for toning and strengthening the abdominal muscles, arms, calves and lifting and toning the buttocks. This technology treats muscle laxity in numerous parts of the body, including calves, thighs, biceps, triceps, abdominal areas, and buttocks. Its function is based on the law of electromagnetic induction. Hence it utilizes electromagnetic coil build-in the device's applicator, which generates a strong and varying magnetic field, penetrating the treated area and targeting neuromuscular tissue. Since medical usage did not require such an intensive magnetic field, broad spot size, and stimuli with a high repetition rate before introducing the Emsculpt device, HIFEM technology must be specifically engineered to meet the criteria necessary for esthetics.

Four treatment sessions are recommended to induce visible changes in the treated area. Nonetheless, some subjects may benefit from a few additional treatments to maximize their goals [10]. Each session typically lasts for around 30 minutes, including the pre-treatment preparations, and depending on the patient's availability. They can be scheduled 1–2 times a week. The device allows using two applicators simultaneously, enabling the concurrent application of HIFEM, especially over the buttocks, arms, calves, and abdomen in higher BMI subjects. It is necessary to take the subcutaneous fat thickness into account. Ideal candidates for HIFEM treatments are men and women with fat thickness up to 3 cm [15].

Overall, the treatment is safe without any side effects, and besides slight muscle soreness the day after the therapy due to the fatigue and muscle regeneration, it causes no discomfort. Emsculpt has shown considerable improvements in body image a few months following the final treatment [8–12, 16, 17], comparable to the progress one achieves after an intensive workout. Many patients claim that noticeable changes may be seen just after a few days of treatment.

2.1.1 Supramaximal contractions

HIFEM utilizes a rapidly changing magnetic field with intensities up to 1.8 T and penetration depth of roughly 7 cm, generated by the circular coil embedded in the device applicators. Based on the law of electromagnetic induction, this alternating field induces electrical currents in the targeted tissue. In general, the current passes across a nerve membrane into its axon. It results in depolarization, which is required to trigger the opening of voltage-gated sodium and potassium ion channels. Then, the action potential is initiated, and it is further propagated by the physiological mechanisms of nerve conduction, evoking a contraction of muscle fibers. The excitation is selective to muscle tissue due to the tailored parameters of the HIFEM field. The alpha motor neurons (a component of peripheral nerves) directly responsible for initiating muscle contractions are activated first [18, 19].

In normal conditions, the highest tension that can be physiologically held and developed is Maximal Voluntary Contraction (MVC), lasting for barely a second. The contractions with higher tension are referred to as supramaximal. The HIFEM technology can create supramaximal contractions and sustain them for multiple seconds to drastically enhance the physiologic stress required for muscles to adapt. On the contrary, in the voluntary means of muscle contractions, the muscles' fibers relax between every stimulus because of the inability of the central nervous system to signal the other impulse when it is still in action [18]. However, this non-invasive technology generates the impulses with such frequency that it offers no relaxation phase, thus generating the continuous contraction of high intensity. During one therapy, muscles are forced to contract several thousand times. When the muscle tissue is exposed to such overload, it adapts to these supramaximal contractions by remodeling its inner structure, leading to the growth of myofibrils (hypertrophy) and possibly generating new muscle fibers (hyperplasia) [20]. Consequently, this increase in muscle volume and density results in improved muscle definition and tone.

2.1.2 Breakdown of fat

Muscles require a sufficient amount of energy during any physical activity to generate contractions. This energy is primarily derived from Adenosine Triphosphate (ATP) and then from glycogen and creatine phosphate. However, if those compounds are insufficient, the body's catabolic processes occur through lipolysis, which refers to the breakdown of the lipid in glycerol and free fatty acids (FFA). FFA molecules are then utilized as the energy source required for body metabolism and muscle activity.

Supramaximal contractions demand a high amount of energy; thus, adipocytes – the basic unit of fat tissue – close to contracting muscles are depleted by lipolysis to compensate for the considerable increase in energy consumption. It has been evidenced that when FFA's are in a surplus, the fat cells get quickly overwhelmed and may enter apoptosis, otherwise known as a programmed adipocytes deletion, resulting in metabolically induced fat reduction [21].

2.1.3 Clinical evidence

So far, the abdominal and buttock body areas have received the greatest attention from researchers. Therefore, most clinical studies performed with HIFEM investigate the changes in fat and muscle tissue on the abdomen and buttocks. Although results may vary based on patient group and evaluation technique, the evidence is sufficient to extrapolate the expected results after the HIFEM procedure.

At first, various objective methods were used to assess changes in the treated abdominal tissues, including computed tomography (CT) [10], magnetic resonance (MRI) [8, 9], diagnostic ultrasound (USN) [11], and circumference measurements [17]. The results were consistent across the studies, with maximum improvement in fat and muscle observed 3 months after the last treatment. In the North American population sample, the average fat reduction was 18.9%, coinciding with a 15.6%

increase in muscle thickness, a 10.6% decrease in rectus abdominis separation, and a 4.1 cm decrease in waist circumference, on average. In specific patient samples, the results may have been offset even towards higher levels, as experienced in limited groups of post-partum subjects [8] or European patients [22]. Regarding the longevity of achieved results, Kinney and Kent [23], in their follow-up study, evidenced that results are maintained at 12 months post treatments in subjects who follow a healthy and active lifestyle. They also suggested an application of maintenance treatment after 1 year, which may be used as prevention against individual results decline. Also, the same authors recently unveil that HIFEM technology has a positive effect on visceral adipose tissue by using retrospective analysis of CT and MRI scans from the previous studies [24]. HIFEM was found to decrease visceral fat by 14.3% on average in reviewed patients, offering an interesting option to combat abdominal obesity non-invasively.

Correspondingly to the abdomen, reduction in fat and increase in muscle tissue was also observed when investigating HIFEM's effect on upper arms and calves. MRI examination revealed increment in cross-sectional area of musculus biceps brachii (+17.1%), triceps brachii (+10.2%), and gastrocnemius (+14.6%) while fat thickness on upper arms (−12.8%) and calves (−9.9%) was significantly reduced [16].

Finally, Busso, Denkova, and Jacob et al. have documented improvement of body image and lifting effect after HIFEM treatments on buttocks. In these questionnaire-based studies, the patients reported high satisfaction levels (up to 85%) and noticeable changes in buttock contour, visible on digital photographs. The buttock lifting effect was further explained by Palm's[12] MRI study, which found that a significant volumetric increase of gluteal muscles (+13.2% on average) occurs, while more prominent growth of musculus gluteus maximus, medius, and minimus was found in the upper buttock region. Interestingly, no significant changes in fat thickness were found, which was attributed to the different metabolic activity of adipose tissue on buttocks that shows considerably lower lipolytic rate [25].

2.2 HIFEM and synchronized radiofrequency

With an increasing demand for both fat reduction and muscle enhancement, with patients having to go for multiple procedures to target each, the further innovation of the HIFEM technology was inevitable. Since HIFEM is selective to muscle tissue only, there has been a strong focus on developing a novel technology simultaneously combining HIFEM's muscle conditioning with radiofrequency (RF) heating intended for fat elimination. Emsculpt Neo device (BTL Industries Inc., Boston, MA), introduced in late 2020, is the first device that combines RF and HIFEM in a single applicator. The combination of HIFEM+RF allows administering two distinct procedures in a single treatment. At the same time, the synergy of two proven technologies ensures a high level of efficacy even in subjects with considerable fat depots and fat thickness over 3 cm. The device has been FDA-cleared for non-invasive lipolysis, strengthening, toning, and firming. The treatment areas so far include the abdomen, buttocks, outer thighs, inner thighs, front & back thighs, calves, biceps, and triceps. Similar to its predecessor, four 30-minute sessions scheduled once a week is recommended. Combined treatments are safe and comfortable. The only documented side effects are skin redness that resolves within 30–60 minutes post-treatment without any further consequences and muscle soreness the day after the therapy due to the HIFEM component.

2.2.1 Radiofrequency component combined with HIFEM

RF is an electromagnetic wave in the frequency range of approximately 20 kHz to 300 GHz that can generate heat in the treated tissue by transforming its energy to the oscillation of molecules as propagating through. Utilizing specific frequencies of the RF spectrum allows for selective heating due to the difference in properties between the tissues in the targeted area. Most of the devices on the esthetic market utilize a solid metal electrode to emit RF energy. However, it would be impossible to simultaneously emit the HIFEM and RF alongside since there will be interference between them, resulting in the harmful overheating of the metallic electrode and increased risk of adverse events. Thus, the device employs a novel Synchrode RF electrode that eradicates this interference due to the unique interspaced design making it transparent to the propagating magnetic fields and allowing for synchronized emission of RF and HIFEM energy [13].

Fat tissue reduction is energy-dependent and may be achieved by reducing the lipids via lipolysis or permanently removing adipocytes. Therefore, the device's radiofrequency component (27.12 MHz) is designed to uniformly elevate the adipose tissue temperature to the levels of 42–45°C, inducing adipocytes deletion by the natural apoptotic pathways. Initially, the elevated temperature results in increased blood flow and acceleration of metabolic activity. In response, the lipids stored in fat cells are broken down into free fatty acids and glycerol. Also, the RF-induced fat loss is further enhanced during the intense localized muscle work provided by HIFEM, as described above. When the elevated temperature is sustained for a sufficient time period, the adipocytes exposed to temperatures up to 45°C lose viability. They are forced to enter the apoptotic process, i.e., natural and permanent cell deletion [26]. The apoptotic cells subsequently lose their membrane integrity and are ultimately digested by macrophages, responsible for clearing the degraded cells and the debris to maintain tissue homeostasis.

The combined use of HIFEM and RF not only enhances the effects on fat considerably but also introduces the synergy at the level of muscle tissue. It has been evidenced that controlled heating within safe limits for the muscle tissue (40–41°C) positively affects the muscle response during the workload. Additionally, muscle protein synthesis might be even more promoted when heat stress is combined with mechanical stress, as in the case of HIFEM application [27, 28]. The synergistic effect of simultaneous delivery of HIFEM and synchronized RF enhances muscle hypertrophy since it significantly increases the levels of myosatellite cells (muscle-derived stem cells), which activates the regeneration and strengthening of the existing muscle fibers through differentiation. Histology study in the animal model showed that the amount of activated satellite cells in muscle tissue after this dual-energy treatment is comparable with programs involving 12 to 16 weeks of intense exercise. Post-treatment, the increased number of large hypertrophic fibers and elevated levels of small-diameter muscle fibers were found, indicating that not only hypertrophy but muscle fiber hyperplasia may occur after the activation of satellite cells [29].

2.2.2 Clinical evidence

The synergistic effect of HIFEM+RF has already been studied and documented by several investigators [26, 30–32] by using proven diagnostic modalities such as MRI or USN. Like Emsculpt, device results improved with time and peaked at 3 months after the last treatment. However, the more profound effect on fat tissue due to the radiofrequency heating resulted in a bolstered average reduction of abdominal fat thickness by 29.6%, which showed to be highly consistent with a maximum reduction of 30.8% measured by MRI [31]. Muscle tissue benefited from elevated temperatures as well, since it reached an increase of 25.2% at 3 months on average. Most probably, due to the more developed musculature, abdominal muscle separation was reduced up to 19.8% when compared to the pre-treatment condition. At the same time, the considerable fat reduction inevitably contributed to circumference reduction exceeding 6 cm. Although the improvement in all aspects mentioned above was most recognizable at 3 months post-treatment, most subjects maintained the results up to 6 months with a slight but insignificant decline in some individual cases.

Since the technology is still relatively novel, it undergoes extensive research, which may possibly reveal the evidence for the superior efficacy of the RF + HIFEM procedure in other areas than the abdomen. Given the results from abdominal studies, it is strongly assumed that simultaneous application of RF and HIFEM will lead to more pronounced results in body parts previously treated by HIFEM alone. Also, combining two technologies of different modus operandi may allow efficient treatment of additional body areas, especially those with a high amount of subcutaneous fat overlying the muscle tissue. For instance, interim data gathered by Palm et al. showed promising results of RF + HIFEM treatment when applied on the lateral thigh, causing significant fat reduction [33]. Future studies should build upon the existing evidence and reveal all the possible use of RF + HIFEM technology, from which patients may benefit.

2.3 Radiofrequency and targeted pressure energy

Simultaneous use of targeted pressure energy (TPE) and RF for skin treatment was introduced in 2019 with the Emtone (BTL Industries Inc., Boston, MA) device, which is FDA-approved for reducing cellulite dimples appearance, and it is the first and only device that combines such technologies in a single applicator. The combination of monopolar RF with TPE allows physicians to treat major causes of loose skin and cellulite non-invasively and effectively. The synergistic emission of mechanical and thermal energy allows the procedure to focus on the root causes of the problem instead of focusing on merely treating the symptoms. The device treats major factors that cause cellulite, including loss of skin elasticity, loose connective tissue leading to dimpling and fat chambers protruding to the skin, metabolic waste accumulation, and lack of blood flow. RF and TPE treatment can be done in any part of the body affected by cellulite or skin laxity and has no downtime. Four treatments (often consisted of the bilateral application over both extremities) in a frequency of 1–2 sessions per week are recommended, while the duration of each treatment varies (10–25 minutes) depending on the area where it is administered. Application of monopolar RF + TPE is again safe and comfortable; harmless skin redness is visible up to 60 minutes after the therapy as a logical consequence of tissue heating.

The device uses monopolar RF (447 kHz) heating through a solid electrode that remains in direct contact with the patient's skin. The RF currents travel to the grounding pad, ensuring a safe flow of the energy through the treated area while controlling its delivery. TPE component consists of a tube with a floating projectile accelerated towards an applicator tip by the pneumatic system, transferring TPE energy of significant intensities (maximum of 4 bar) to the target tissue. A projectile is moved by the compressed air, hitting a transmitter that conveys energy from the impact to the patient's body. This process is repeated in quick succession (10 Hz). Both technologies are embedded in a single handpiece applicator, thus they are delivered simultaneously. During the therapy, the operator moves the applicator over the treated area to evenly distribute both energies. Handpiece also utilizes a build-in thermometer, providing immediate feedback to the physician regarding skin surface temperature, indicating whether the temperature stays in the expected range of 40–45°C, thus minimizing the risk of under/over-treatment [14].

2.3.1 RF and TPE for the reduction of cellulite and skin laxity

Collagen and elastin are primary elements of the connective tissue and an integral part of the structure of the papillary and reticular dermis and hypodermis. Skin laxity is manifested by the gradual degradation of dermal connective tissue. At the same time, cellulite is mainly characterized by the rigid structure of fibrotic collagen fibrils and the thickening of hypodermal connective septae. The simultaneous emission of TPE and RF activates the metalloproteinases (MMPs), responsible for degrading the protein structure of the collagen [34]. The mechanical stress leads to the fibrils dissociation that reduces the structural density and increases the conformational freedom while also decreasing the thermal stability of existing fibers.

Moreover, this phenomenon also reduces the temperature needed for collagen denaturation. The thermal stimulation interrupts the intramolecular hydrogen bonds and also partially shrinks the collagen triple helix [35]. Consequently, the neocollagenesis and remodeling of the collagen are initiated as a direct consequence to the treatment [36], since the fibroblasts' micro-inflammatory stimulation due to accumulation of heat leads to the proliferation process that significantly increases the procollagen mRNA production. Mechanical energy speeds up the fibroblasts' proliferative activity, creating an ideal environment for elastin and collagen synthesis by decreasing the tissue's oxidative stress [37]. In summary, the thermal and mechanical energy's simultaneous effect leads to a better organization and increased density of collagen and elastin fibers in the dermis and interlobular septa in the hypodermis. This leads to an increase in skin elasticity and thickening of the dermis. The skin thus becomes more tight and resistant to bulging caused by the underlying fat cells [36].

Also, due to the mechanical and heat stimulation exposure, there is a change in the cell membrane properties. The higher amount of cell membrane permeability enables the fluids to move throughout the membrane rapidly, and one can observe the increase in cell metabolism. Besides, both of the energies enhance the blood circulation and may contribute to the new blood vessels formation [36]. The accelerated cell metabolism and blood flow activate the enzymes that break down the fat stored in adipocytes underlying the skin. This leads to a significant reduction in the sizes of fat chambers protruded into the dermis and enhancement of the skin's visual appearance. TPE also positively affects lymph transport and waste removal, supposedly another key aspect associated with cellulite [38].

2.3.2 Clinical evidence

Recently, Fritz et al. utilized various means for cellulite and skin quality evaluation, providing ample evidence to demonstrate the clinical efficacy of RF + TPE simultaneous application. In their first study [39], significant changes at the level of adipose and dermal tissues were noticed. Ultrasound images and digital photographs showed diminished cellulite dimples and improved esthetic appearance of treated areas at 3 months post-treatment. Additionally, the enhancement of skin topography was also verified by the improved homogeneity of surface temperature. The high patient satisfaction correlates with objective results since cellulite was reduced in 93% of cases. The second study [40] was focused on improving abdominal skin laxity, showing promising results again. The elasticity measurement performed in this study showed considerable improvement in 90.9% of subjects.

In comparison, an even higher number of subjects (95%) responded to the treatment in terms of reduction in waist circumference. The primary outcome – reduction in skin laxity – was achieved in 86% of treated subjects derived from photography evaluation.

3. Non-invasive technologies as an alternative to SAL

The increased comfort level, lack of downtime, and low potential risks involved have made these non-invasive procedures popular among the patients and may provide a new solution for body contouring. With the capability of building, firming, and toning muscles without the need to go to the gym, the mixture of wellness and esthetic advantages offered through these technologies has attracted more patients who want to enhance their appearance and overall health. In addition, combining those treatments with RF and TPE technology for skin treatments in case of sagging or wrinkling may represent a complete esthetic solution that SAL alone cannot achieve.

We will be discussing the three specific case studies to highlight the clinical effects of these non-invasive alternatives for liposuction. Patients with different concerns who achieved significant improvements after combined therapies with HIFEM and/or RF with TPE are included. See a brief description of the cases below.

3.1 Straightforward case

Patient A presented with a localized region of abdominal fat and lax muscles. His chief concerns included muscle laxity and overall body contour. The patient underwent a set of HIFEM treatments. Two applicators were placed over the abdominal area with HIFEM intensity being gradually set to a maximum tolerable level, reaching 100% during his second session. The subject regularly goes to the gym for weight training 2–3 times a week and was looking for an improvement in muscle tone, strength, and laxity. His results are shown in **Figure 1**.

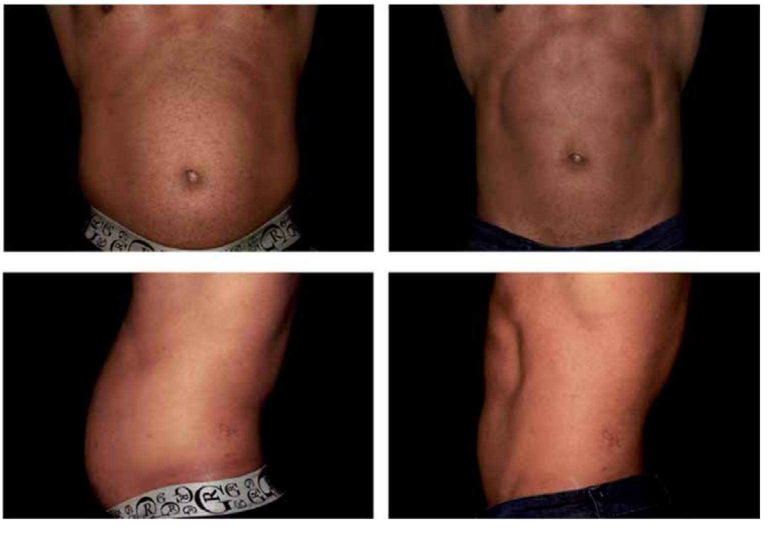

Figure 1.
Patient A - male 36 years old, BMI 26.6 kg/m^2, four treatments administered with HIFEM. 12 weeks after the last treatment (right), the subject showed significantly improved body contour and posture. The muscle laxity was resolved while the abdomen looks and feels tighter and stronger. The distribution of subcutaneous tissue changed considerably in response to the muscle enhancement.

3.2 Moderate case

Patient B presented with a protruding stomach due to excessive subcutaneous fat, visceral fat deposits, and loose muscles. The patient declined liposuction and abdominoplasty. He wanted to achieve both fat reduction and muscle strength. Therefore, he opted for HIFEM+RF procedure. Each treatment lasted for 30 minutes, starting with the HIFEM intensity set to 0%, increasing it to the maximum tolerable level. The RF intensity was set to 100% since the beginning of the procedure. Two applicators were used at the same time on the abdomen. Subject's results, captured in the digital photographs, are shown on the **Figure 2**. In addition,

Figure 2.
Patient B - male 57 years old, BMI 32.8 kg/m^2, 3 treatments administered with HIFEM+RF, digital photographs captured at baseline (left) and 1-month (right) post-treatment. The subject reported none to mild discomfort during the procedure and maintained his diet and exercise regime post-treatments. At 3 months, the MRI showed a 30.3% increase in muscle thickness, 35.3% subcutaneous fat reduction, and 17.2% reduction in muscle separation. Due to these extensive changes, the body contour was improved greatly just after three HIFEM+RF treatments.

Figure 3.
Patient C - female 35 years old, BMI 22.7 kg/m^2, four treatments administered with HIFEM, RF, and TPE. The subject showed considerable improvement of body contour and skin appearance 6 weeks after the last treatment (right). The patient reported a noticeable muscle tightening effect on top of the improvement in skin laxity.

an MRI examination was performed to identify changes in the abdominal fat and muscle tissue.

3.3 Challenging case

Patient C presented with concerns regarding all three: Skin laxity, loose muscles, and localized fat. After multiple childbirths, the patient suffered from the separation of abdominal muscles (diastasis), excessive fat accumulation on the abdomen, and skin laxity (so-called jelly belly). She opted for the combination of HIFEM and RF + TPE treatments to target the skin, muscle, and partly fat tissues. Each HIFEM treatment lasted for 30 minutes, and intensity was gradually increased to maximum tolerable level within the range of 0–100%. RF + TPE combined therapies lasted 15 minutes and were administered immediately post each HIFEM procedure. The RF intensity was set to 65%, and the built-in thermometer monitored tissue temperature to be in the range of 40–45 degrees Celsius. TPE was set to 4 at the device's pressure scale. Both procedures were tolerated well. The achieved results are shown in **Figure 3**.

4. Discussion

Although the technologies mentioned above are new and still evolving, the clinical evidence combined with our personal experience highlights that using HIFEM, RF, and TPE may target multiple types of patients with skin, fat, or muscle concerns. It needs to be considered that every patient is different and has specific requirements based on the physical constitution and personal preferences when it comes to visual appearance and body contour. Liposuction has always been perceived as a problem-solving procedure regarding the improvement of esthetic appearance. However, due to its invasive nature and discomfort, which limits patient's post-treatment, many would prefer a more convenient way of achieving desirable improvement. The interest in non-invasive body contouring procedures is therefore on the rise in recent years.

Considering the patient comfort and safety, the non-invasive alternatives to SAL were searched intensively in the past. In 2009, Zelickson et al. [41] established a concept of controlled and selective destruction of fat cells by inducing temperatures in the subcutaneous fat layer close to or below the freezing point, termed cryolipolysis. Using the Yucatan pig animal model, they found the reduced thickness of the fat layer associated with local inflammatory response, inferring that such treatments in humans may lead to subsequent changes in body contour. The further studies conducted by several authors evidenced the proposed effectiveness for fat reduction in human subjects. It was found that, in general, cryolipolysis causes a 22% reduction of subcutaneous fat thickness when used on the abdomen or flanks, i.e., the most frequent body parts treated by traditional SAL [42–49]. However, although these body parts' efficacy is relatively high, cryolipolysis solely focuses on the reduction of fat tissue, limiting its application and versatility. Also, although the majority of animal or human studies found no significant risks associated with cryolipolysis, still it has been evidenced that on rare occasions, treated subjects may develop adverse reactions referred to as paradoxical adipose hyperplasia (PAH) [50, 51], leading to sudden fat bulging and need of corrective surgical treatment.

Similar to cryolipolysis, focused high-intensity ultrasound (HIFU) was also introduced in the past decade as a possible substitute for invasive procedures in body contouring. HIFU technology primarily relies on disruptive mechanical effects on adipocytes with minimal damage to neighboring structures such as vessels, nerves, and connective tissue [52, 53]. According to various sources [5, 53–56], the therapy may result in substantial contour improvement with fat reduction above 20% after multiple treatment sessions. Nonetheless, Shek et al. [52] concluded that HIFU treatments showed insignificant changes among the Southern Asians, suggesting design modifications for this particular group of patients.

Most recently, modalities such as HIFEM, RF, and TPE have emerged in esthetic practices. Due to its effectiveness, great safety profile, convenient use, and multifactorial treatment effect, it may pose a promising and complex alternative to SAL, with treatment outcomes not limited to fat reduction only. HIFEM is a patented technology and the first of its kind to be used in the esthetic field to enhance the overall appearance of individuals and, most importantly, target the muscle tissue, which has been neglected for a long time. Before this technology was introduced in 2018 with the launch of the Emsculpt device, intensive magnetic fields for esthetic treatments were barely understood. Since then, physicians are getting more and more familiar with the technology, discovering all its possible applications. Emsculpt pioneered the use of non-invasive body shaping through enhancing muscle strength. Nonetheless, the patient demand for outstanding results and the strong emphasis on reliable fat reduction are still pushing the technological progress forward. Therefore, the Emsculpt Neo device launched in 2020 took the concept of Emsculpt further by combining HIFEM with radiofrequency. Due to the simultaneous application and synergistic effect of both electromagnetic fields, physicians have now available the efficient tool to deliver two types of treatment in a single procedure. Recent clinical studies documented the more pronounced results stemming from the HIFEM+RF combination, showing the significant changes at the level of muscle and fat tissues (−30% in fat thickness, +25% in muscle thickness, and 19% reduction in abdominal separation). In response to the treatments, patients demonstrated measurable changes in body contour and muscle definition [26, 30, 31].

Certain concerns cannot be resolved with the customary liposuction as it only focuses on fat reduction. For instance, skin pendulosity and laxity cannot be addressed and even worsened after SAL, as the skin naturally contracts due to fat removal. While liposuction reduces the fat efficiently, in some cases, it leads to deformities accompanied by sagging skin. Fortunately, all of these concerns can be addressed non-invasively utilizing RF and TPE energy to ensure complete esthetic enhancement after the fat reduction. Emtone is one of the first and sole device that delivers both mechanical and thermal energy simultaneously, removing the major causes of loose skin and cellulite non-invasively and effectively. The combination of mechanical and thermal energy is designed to treat the major factors of cellulite and skin laxity on top of that. It may help eliminate any irregularities due to skin aging as well as correct visible sagging post liposuction treatments.

These innovative technologies are an excellent alternative to liposuction, or they can be used in some specific cases as a complementary solution to profound the results. They can help in strengthening muscles, improving core muscles, enhancing the overall esthetics of the patients by skin improvements in addition to fat reduction. HIFEM, RF, and TPE have proven effective in a standalone regime or when used as combination treatments. Particularly, the combination treatments usually show to be highly effective for many individuals. Generally, the pre-treatment assessment often determines that the cosmetic concerns are of multifactorial origin. Therefore, combining multiple modalities that targets multiple tissues or causes can provide the best possible results. While HIFEM alone focuses on the deep tissues, inducing predominantly changes in the muscles, monopolar RF and TPE focuses on improving the condition of superficial layers, including dermal microcirculation, improved quality, tone of the skin, and laxity reduction. This type of therapy is ideal for addressing the concerns of the patients regarding body contouring. When combined, it is recommended to use Emsculpt first to restore the musculature and body contour before using Emtone to address skin concerns. However, in cases where extensive fat tissue changes are required, the subjects may benefit more from simultaneous HIFEM+RF therapy, which eliminates excessive fat tissue alongside muscle toning.

There are definitely some specifics that come with non-invasive treatments. As mentioned above, physicians should carefully choose the most suitable procedure (for instance, see presented cases in Section 3). The subject's lifestyle may also help determine appropriate treatment and dosage since individuals with better-developed musculature and active lifestyles tend to achieve high HIFEM intensities sooner. Typically, the treatments are done over the course of two to four weeks in four sessions, requiring 30-minutes per application. In general, achieved results may vary from subject to subject. Nonetheless, the improvement should be best recognizable from 1 to 3 months after the last treatment, maintaining the enhancement level at a minimum for 6 to 12 months depending on the subject's dietary and sport habits [23]. Based on the reported results from multiple investigations, we recommend to follow-up your patients 12 to 24 months after their last treatment, and in case that any significant decline in results occurs, identify the cause and consider the importance of the maintenance procedures.

5. Conclusion

Even after countless squats, crunches, cardio, muscle training, or diets, many individuals remain unsatisfied with the core strength and body contour. There are certain areas that cannot be tackled even with a strict diet and exercise. Many opt for liposuction to resolve those issues, but some problems still may remain unresolved. Also, a certain number of individuals hesitate to go for surgeries and are looking for non-invasive ways to deal with their concerns. HIFEM, RF, and TPE can greatly enhance outcomes for body contour independently or following traditional liposuction. Fat reduction and muscle contouring, as well as skin smoothing and tightening, can be safely achieved by combining those technologies without the need for any anesthesia, surgery, and downtime. These treatments offer not only fast and comfortable therapy but also provide reliable results for patients who are not willing to undergo a surgical procedure or who still have concerns after liposuction, looking for a faster and easier remedy for their concerns.

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Section 4

Liposuction and Fat Transfer

Chapter 11

Liposuction for Fat Transfer: The "Island Technique"

Roger E. Amar

Abstract

The material harvested during liposuction is discarded but the fat used for fat grafting must be preserved and not polluted by the products used for tumescent anaesthesia. The "Island technique" used for decades during the FAMI procedure (Fat autografting Muscle Injection), provides samples of fat which had no or little contact with the lidocaine. The first step of the injection is made between the muscle and fat deposit and the second step between the deep skin layers and the same fat deposit. It is one important factor of the successful outcome of our adipose SVF grafting in hundreds of cases of reconstructive and aesthetic surgeries since 1998.

Keywords: liposuction, harvesting fat, fat transfer, FAMI

1. Introduction

Autologous fat grafting has been used for over a century and is still considered as a technique of choice for soft tissue replacement in Aesthetic plastic and reconstructive surgery. However, the critical point of this technique was fat graft survival. The high percentage and variable amount of fat resorption were the main disadvantages of this procedure before the use from 1997 the FAMI technique, Facial Autologous Muscular Injection [1].

Autologous fat transfer has been subject to great evolution over the last century and became very popular after the fundamental clinical studies of Y.G. Illouz [2]. The material harvested during liposuction is discarded, but the fat tissues used in fat grafting needs to be preserved and not polluted by the products used during the tumescent local anaesthesia [3]. The presence of adipose stem cells in the harvesting samples found by Patricia Zuck and her team [4] emphasised the necessity of fat preservation during the harvesting process and some changes in the technique.

JA Klein, a Californian dermatologist [5], invented the tumescent liposuction which consists of infiltrating at the fat deposit with a local anaesthetic and a vasoconstrictor diluted in a large volume of saline. This technique allowed the patients to benefit from liposuction totally by local anaesthesia, thus avoiding the risks of general anaesthesia and promoting a short recovery time.

For providing samples of fat during fat transfer which no or little contact with the lidocaine, the "Island technique" was used for decades in the first step of the FAMI technique [6, 7].

This simple method will help all practician to harvest pure fat in the syringe with less saline mixed with Lidocaine.

2. Materials and methods

More than 1400 patients were injected with this protocol from 1997 to 2021. These patients were chosen in Group I and II of Ricardo Baroudi: Group I – Fat deposits with firm skin, and Group II – Fat deposits with moderate to flabby skin.

2.1 Anaesthesia

Loco-regional anaesthesia is commonly used with injection of Klein' Solution, (**Figure 1**). One litre of normal saline is mixed with 50 cc of 1% plain Lidocaine, 1 ml of 1:1000 epinephrine and 10 cc of physiological concentration of Sodium bicarbonate to reduce the acidity and therefore reduce the discomfort of injection.

In conventional liposuction the fat is not preserved, conversely, in fat transfer or in FAMI it is necessary to use a very conservative method similar to a biopsy in order to preserve intact the fat cylinders inside the 10 cc syringe.

2.2 Technique of injection

The adipose pads are wrapped by a relatively impermeable fascia that would prevent subcutaneous infections from spreading to the more fragile adipose tissue. It is therefore easy to inject above and under the fat pocket without "wetting" the fat.

As shown in (**Figure 2**), the first and most important injection put the anaesthetic solution in contact with the emerging nerves under the fat deposit just above the muscle aponeurosis using a 3-mm diameter cannula. The second very superficial of lower volume will use a thin 2 mm diameter cannula, immediately under the skin for a good vasoconstriction, under view control, above the fat pocket.

After few minutes the harvesting begins from the core of the fat deposit, generally free of liquids (**Figure 3A** and **B**).

Figure 1.
A sketch to figure the Klein' solution composition. [https://sketchymedicine.com/2016/01/tumescent-solution-for-burn-surgery-and-liposuction/].

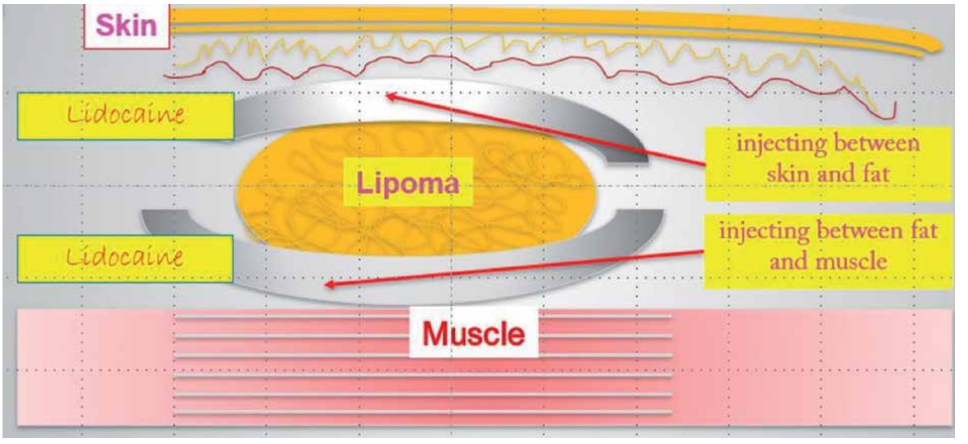

Figure 2.
The first injection is done under the fat along the muscle aponeurosis. The second injection is done immediately under the skin.

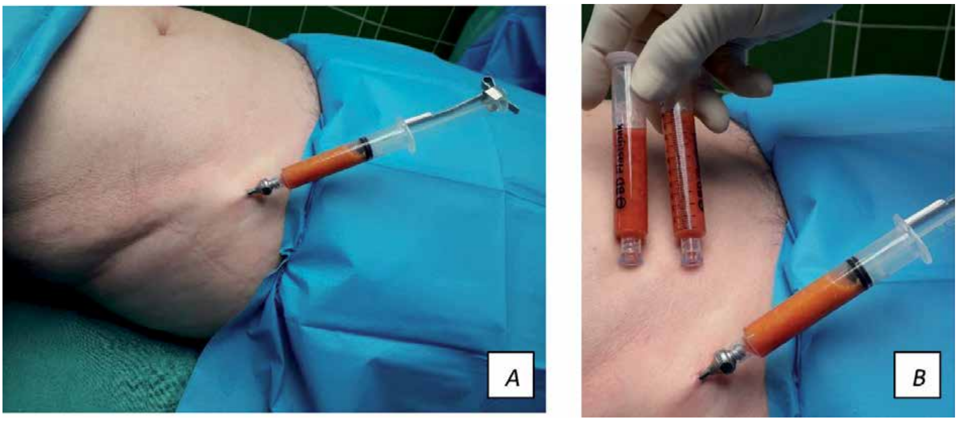

Figure 3.
A and B: During the FAMI technique a virtually lidocaine free samples are harvested using 10 cc Luer lock syringes ready to be put in the centrifuge for purification.

3. Discussion

Both men and women have attended consultations for fat transfer and more particularly for the FAMI procedure (Facial Autologous Muscular Injection) which was developed to avoid the two major disadvantages of the conventional lipofilling, the unpredictability and the longevity.

When longevity is considered, every step of the technique becomes important, from the local anaesthesia and the anatomy of the fat deposit to injection of facial targets.

The choice of the candidates for lipo transfer is important and they must be chosen among the two first groups of the four described by Ricardo Baroudi.

Group I – Fat deposits with firm skin. Patients are usually young, in their twenties with no flabbiness and no exaggerated volume.

*Group II – Fat deposits with moderate to flabby skin. The fat deposit is not excessive and the skin is no longer firm. If a large amount of fat is removed the significant flaccidity may produce undulations, waves, grooves and dimples. The patients of group II are generally between 20 and 35 years of age (**Figure 4**).*

Figure 4.
Fat deposits with firm skin or with moderate to flabby skin are good candidates for fat harvesting in lipo transfer.

We have to be very careful in choosing patients in the last 2 groups, to which I recommend the surgical approach (**Figure 5**).

Group III – Fat deposits with marked skin flaccidity. The liposuction is generally associated to traditional surgery to tighten the skin.

Group IV – Skin flaccidity without fat deposit. In these particular cases we can find only the fat deep in gluteal area or in the flanks.

The anatomy and histology of the adipose tissues were well described in his book by J.A. Klein [8].

- Fat cells are contained within fat lobules, which are within fat pearls, which are contained within fat sections, which are within fat compartments.

- The size and shape of these fat compartments are responsible for the differences in surface anatomy that exist between adult males and females.

- The fat compartments are surrounded and divided by fibrous formations or fasciae which are organised in tangential planes and oblique partitioning walls. The tangential planes above and under the fat compartment are made of connective laminated tissue, relatively dense, approximately oriented parallel and tangentially to the subjacent muscle fasciae. The more superficial subcutaneous fascia is a laminate of fibrous sheets, with each lamella a weblike, interwoven film of collagen and fibrocytes.

Figure 5.
Fat deposits with marked skin flaccidity with stretch marks are not good candidates for fat transfer.

- In the "Island method" it is easy to find the right plane for introducing the infiltrating cannula, above or behind these no leaks fibrous planes and leave the anaesthetics work during few minutes.

- Fat Areas to harvest are multiple and can be chosen according to each patient.

- **Figure 6A**, **B**, **C** shows the best areas with no flabbiness to harvest for the "island technique" in fat transfer.

Lidocaine, the first amino amide–type local anaesthetic, was first synthesised under the name 'xylocaine' by Swedish chemist Nils Löfgren in 1943 [9]. The local anaesthesia (LA) with lidocaine presents a rapid onset and an intermediate duration of action. Although lidocaine is the oldest aminoamide, this drug is widely used all over the world in the context of autologous fat transfer.

The effects of local anaesthesia with lidocaine on the viability of fat obtained by syringe suction lipectomy was studied in1995 by John H. Moore Jr. and Jerzy W. Kolaczynski [10]. They examined if adipose tissue viability is compromised by using syringe suction lipectomy and by infiltration of the tissue with lidocaine. They found that Lidocaine potently inhibited glucose transport and lipolysis in adipocytes and their growth in culture. That effect, however, persisted only as long as lidocaine was present; after washing, the cells were able to fully regain their function and growth regardless of whether the exposure was as short as 30 minutes or as long as 10 days. These preliminary results indicated that adipose tissue obtained by syringe lipectomy consists of fully viable and functional adipocytes, but local anaesthetics may halt their metabolism and growth.

Tao Wu and Jay Smith, published in 2018 an article on the Cytotoxicity of Local Anaesthetics in Mesenchymal Stem Cells [11] and found that local anaesthetics may have negative impact on Mesenchymal Stem Cells dosing because of cytotoxicity or other biological effects. They reviewed 11 studies that involve *in vitro* experimentation with MSCs using aminoamide-type anaesthetics including lidocaine, ropivacaine, mepivacaine, bupivacaine, articaine, and prilocaine and concluded lidocaine seems to have the most significant effects on stem cell viability. They conclude that local anaesthetic agents have time- and concentration-dependent detrimental effects on Mesenchymal stem cells (MSCs). They noticed that *in vivo* studies will be required to understand the interactions of these agents with MSCs, because *in vitro*

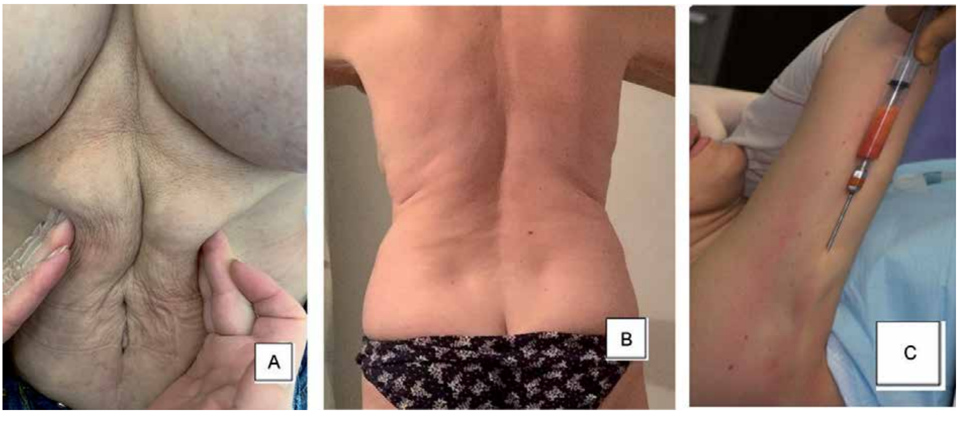

Figure 6.
A, B and C shows the best areas for fat removal. Abdominal region, lateral parts of the waist, and brachial fat pad.

studies cannot replicate the pharmacokinetics of anaesthetics *in vivo* or the recovery of (MSCs) in a more physiological environment.

The most recent study came from Felix Grambow and Rico Rutkowski (2020) [12]. They made a clinical research on a series of cases to conclude that lidocaine has no negative impact on the distribution, cell number, and viability of Adipose derived stem cells (ASCs) and preadipocytes. After centrifugation, only the middle fatty portion of processed lipoaspirate (PLA) in the syringe will contain Adipose derived stem cells (ASCs), which are crucial for successful lipotransfer. Adipose stem cells, which are restricted to adipogenic evolvement, were found to be significantly more common inside the Processed liposuction (PLA) than inside the Processed liposuction aspirate fluid (LAF).

4. Conclusion

The "Island" local anaesthesia followed by the mechanical purification with high-speed centrifuge, provide a bloodless and painless harvesting regardless of how much lidocaine is injected and its effect on the viability of ASC.

Collecting fat and obtaining SVF (Stromal Vascular Fraction) are the first steps of the FAMI technique that inject the surfaces and edges of the facial skeleton, the mimic muscles [13] and the deep fat pads. The precision in these two first steps in the technique are responsible for the excellent results obtained over the past 24 years with the technique FAMI full face or eclectic. Used on more than 1400 personal patients, this simple method of extraction will be useful to any surgeon who is beginning their experience in fat transfer.

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Chapter 12

The Versatility of Autologous Fat Transplantation in Abnormalities of the Craniofacial-Complex and Facial Esthetics

Yanko Castro-Govea, Cynthia M. Gonzalez-Cantu, Gabriel A. Mecott, Everardo Valdes-Flores and Mauricio M. Garcia-Perez

Abstract

In the historical pursuit of soft tissue augmentation, fat has seemed a natural choice for plastic surgeons. The use of fat transfer to replace volume or camouflage soft tissues is an increasingly popular method in craniofacial surgery and facial esthetics. Craniofacial malformations undoubtedly have a certain psychosocial effect. Children of early age are particularly vulnerable to comments, teasing, and harassment related to their appearance; therefore, improving the facial image is of great importance. We believe that volumetric lipoinjection represents an excellent alternative to obtain greater facial esthetic harmony, which directly increases patient self-esteem in children and adults.

Keywords: adipose stem cells, lipoinjection, lipofilling, craniofacial malformations, facial profiling

1. Introduction

Many procedures have been described throughout history in an attempt to increase lost tissue volume: dermo-fat grafts, omental free flaps, and musculoskeletal flaps, to name a few.

The history of autologous fat transfer began in Europe with Neuber presenting his first fat transfer work at the 22nd Congress of the German Society of Surgery in 1893 [1], followed by Mojallal [2], Lexer [3], and Rehn [4] who described its use in a variety of procedures including thoracic and abdominal surgeries, breast surgeries and the field of neurosurgery and orthopedics, within the so-called “open-air” era - before liposuction (1889–1977).

Brunning was the first, in 1911, to inject fat into the subcutaneous tissue for augmentation [5]. This technique continued to be promoted as an alternative to resolve depressive areas. Without a doubt, its incorporation into the field of plastic surgery is where it has had its maximum development.

The first attempts consisted of excising fatty tissue and placing it in small pockets in the subcutaneous layer. In the 50s, Peer observed that by placing small portions, at least 50% of their initial volume was lost in the long term and that this would depend mainly on early anastomosis of the recipient and donor vasculature, thus describing the theory of survival of fatty tissue grafts. It was established that the number of viable adipocytes at the time of graft placement directly correlates with the final volume that survives [6].

The concept of absorption of fat grafts began practically from the moment of its use. Due to this, throughout its development, different theories arose that tried to explain what happened with transplanted fat [7, 8].

For some time, fat transfer lost popularity. This led to the search for other alternatives, such as silicone, polymers, and hydroxyapatite crystals. It was in 1980 with the appearance of liposuction when the trend of obtaining fat for grafting was renewed [9]. From our perspective, we consider that different stages have contributed to the boom in autologous fat transfer in the field of cosmetic and reconstructive surgery. Ironically, during the development and refinement of liposuction techniques, the collected fat was thrown away. The question soon arose, *why not use it in other areas of the body to provide volume and solve depressions?*

In 1986, Fournier [10] and Illouz [11] presented modifications in the technique for obtaining fat through aspiration syringes. Coleman in 1994 introduced his technique, perfectly describing the steps for sampling, purification by centrifugation, and transfer (reinjection), which he later called: Lipostructure®, warning that any traumatic act to obtain fat should be avoided, thus dividing the times: "unpurified" (With the discovery of liposuction 1977–1994), and "purified or atraumatic" (after the descriptions of Roger Coleman from 1994 to date). The literature has described that fat tissue grafts can cause a lasting correction; however, it has also been documented that fat undergoes multiple manipulations in its reinjection process, which affects its survival [12].

Verderame described that the surgeon had to compensate for this "shrinkage" by transplanting a greater amount of fat than required, hoping that the initial desired result with this "overcorrection" would equalize with subsequent reabsorption [13].

This natural evolution on the improvement of the liposuction technique included improvements in equipment (suction machines and cannulas) and scientific bases to better understand the metabolism of adipocytes, their viability, and performance, and permanence over time [14–16].

There are reports in the literature that compare the benefits of centrifugation, decantation, and washing of fat tissue, in an attempt to ensure the best viability of adipocytes and, therefore, better permanence.

In a recent systematic review, Zhou et al. evaluated graft survival based on technique. The authors reported a statistically significantly higher facial fat graft survival rate of 71% in the cell-assisted lipotransfer group compared to 52% in the control group (standard fat grafting) [17].

From the beginning of stem cells obtained from adipose tissue, their potential therapeutic use was already envisioned at the level of tissue engineering and cell biology [18]. Matsumoto et al. in 2006, [19] described a technique called cell-assisted transfer (CAL). This technique consists of autologous transplantation of adipocytes enriched with stem cells derived from fatty tissue. Enzyme digestion is achieved using collagenase. With favorable culture media and different centrifugation steps, the stromal vascular fraction (SVF) is obtained. The SVF contains; stromal cells, endothelial progenitor cells, preadipocytes, ASCs, etc. In an adipogenic environment, ASCs can directly differentiate into adipocytes and contribute to volumetric restoration. They also promote graft survival through angiogenesis and the release of growth factors [20]. Yoshimura [21] described the use of this technique in cases of facial lipoatrophy and post-reconstruction breast augmentation and described the technique for obtaining the ASCs.

The current use of fat transfer to replace volume or camouflage soft tissues is an increasingly popular method in plastic surgery, especially in craniofacial surgery. Due to our current globalized and increasingly competitive environment, it is undeniable that in the field of esthetic surgery, volumetric lipoinjection with adipose stem cells as facial profiling or combined with facial rejuvenation surgical procedures has great acceptance.

2. Diagnosis/patient presentation

The ideal patient for this procedure is one with a volume deficit due to soft tissue atrophy. Multiple pathologies have soft tissue hypoplasia as a common characteristic. Hemifacial microsomia is one of the most frequent abnormalities of the craniofacial complex [22]. Progressive hemifacial atrophy or Parry-Romberg syndrome is characterized by a progressive deformation and reduced soft tissue volume on one side of the face. It is also accompanied by trigeminal neuralgia, alopecia areata, and eye alterations. This condition can benefit from the transfer of stem cell-enriched fatty tissue [23, 24].

We have recently described an alternative for postoperative cranioplasty for craniosynostosis. A specific population of these patients develops asymmetries categorized as depressions, particularly in the frontoorbital and temporal region, which are camouflaged using volumetric lipoinjection of adipose stem cells. This maneuver provides a volumetric effect and improves the inherent characteristics of the skin. All this contributes to a more harmonious facial appearance [25].

Its use has also been described in mild volumetric deficits of the middle and lower facial third secondary to skeletal fractures [26], even a camouflage option in patients with mild orthognathic alterations, such as micrognathia and microgenia [27]. We have used this alternative technique for more than a decade in our Craniofacial Surgery Clinic. In general, we use volumetric adipose stem cells in a wide range of disorders of the craniofacial complex, such as syndromes with a common characteristic, soft tissue hypoplasia, asymmetries secondary to facial skeletal trauma sequelae, and asymmetries due to craniosynostosis sequelae. Logically, this technical variant is also widely used to complement facial rejuvenation procedures or as an isolated facial profiling procedure.

Craniofacial malformations have a certain degree of psychosocial involvement, and children, particularly at an early age, are vulnerable to comments, ridicule, and harassment related to their appearance. Therefore, we consider it essential to provide an esthetic balance that promotes better facial symmetry. This is highly relevant since children at this stage are in the full development of their image, identity, and personality; hence, we consider that it is a priority to favor an adequate environment that facilitates greater self-esteem and better psychosocial development and integration. In some instances, it has a positive result in school performance [28].

3. Treatment/surgical technique

The surgical protocol should always include a complete medical history and an analysis of the degree of deformity to estimate the volume to be replaced. Also, photographic controls to assess its evolution in the medium and long term. Informed consent must be obtained.

Before starting the procedure, a tracing is made on the preoperative images to better estimate the required volume, the mini-approaches necessary for its application, and a projection of the desired result.

The lower abdomen of each patient is evaluated as the donor area of choice. Other areas may be the lower back and thighs since, in pediatric patients, the availability of abdominal fat may be limited.

An oral dose of cephalexin is indicated the day before surgery and will continue for 4 days after. In pediatric patients, the procedure is performed under general anesthesia.

3.1 Tumescence and fat aspiration

The lower abdomen is infiltrated with a tumescent solution (0.25 mg of epinephrine in 250 mL saline solution) to perform fat aspiration. The ratio of infiltration is 1 mL of solution per 1 mL of harvested fat. We perform fat collection using a blunt-tipped #20 1-mm sharpened holes cannula 10 cm long and 2.5 mm in diameter attached to a 10-mL Luer-lock syringe. According to the areas to be treated and their degree of deformity, the average number of syringes usually collected is 2 to 3. In adults, for facial esthetics, it varies from 3 to 6.

3.2 Fat processing technique and isolation of ASCs

The extracted fat is separated into two samples, one is used for the isolation of ASCs, and the other will be enriched with the ASCs. The second sample is processed according to the Coleman protocol [12]. The isolation of the ASCs is carried out according to the technique described by Yoshimura [20]. It is important to point out that, in our beginning, the protocol for obtaining and isolating stem cells was in accordance with what was previously described. We currently treat fat in a simple way. In this way, we obtain 3 types of fat grafts: Mini-fat grafts (where adipocytes provide an average of 85% of the cell volume), Micro-fat grafts (average volume 50%), and Nano-fat grafts (virtually no adipocytes and a higher cell concentration of elements of the stromal vascular fraction), very similar to that described by Tonnard et al., however, with some variants [29].

Once the fat has been collected with 10 ml syringes for mini-grafts, it is centrifuged for 1 min at 3000 rpm, and the infranatant fluid (composed mainly of tumescence fluid, blood, detritus, free fatty acids, etc.) is eliminated. We then connect a 2.5 mm diameter female-to-female transfer device at one end of the syringe, and on the other end, we connect 1 and 3 mL Luer lock syringes, ready to be filled and injected.

For micro-grafts, the centrifugation and obtention process is similar. Afterward, the syringes are connected to another 10 ml Luer lock connector through the transfer device and are passed to the empty syringe "round trip" 5 times. The product is centrifuged again for 1 min at 3000 rpm, the infranatant is eliminated, and the cell conglomerate is transferred to 1- and 3-mL syringes ready to be injected.

Mini and micro-fat injections are performed with short and long malleable fine cannulas, 1.5 to 2 mm in diameter. The process to obtain nano-fat is also similar to the previous one, with the difference that the fat is emulsified by making 30 "round trip" passes, with a 1.5 mm transfer. The syringes are then centrifuged for 1 min at 3000 rpm. Injections are performed with short and long, fine malleable cannulas, 1.5 to 2 mm in diameter.

Logically, we use mini-graft and micro-graft for volumetric increases. In nano-grafts, adipocytes are practically destroyed; therefore, they do not provide volume, and it has been shown that they have a higher concentration of ACSs with a vast potential for cell regeneration [30]. We use them to enrich the mini and micro-graft, and for injection into the subcutaneous and intradermal stratum (with 23-to-27-gauge needles) and to improve the inherent characteristics of the skin such

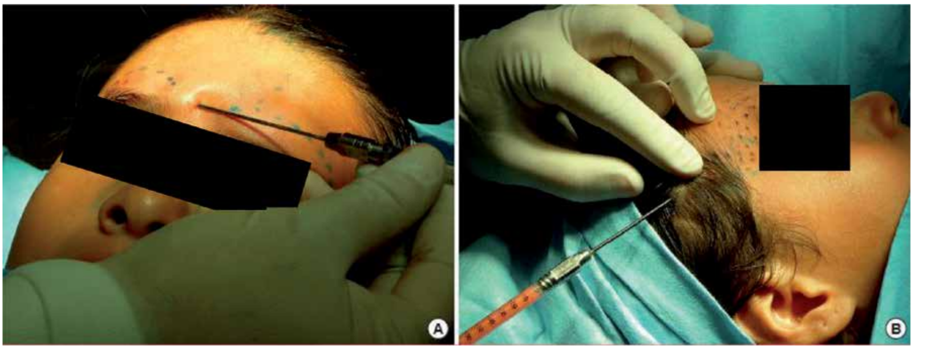

Figure 1.
Intraoperative view of the lipoinjection of adipose stem cells. (A) Glabellar approach. (B) Temporal approach (behind the hairline).

as shine and texture due to the thickening of the dermis, moisturizing, and better contraction quality. It even better unifies the natural tone of the skin. All this provides a more youthful appearance of facial expression. We have recently also used nano-grafts to improve the appearance of tear trough, dark circles of the eyelids, and camouflage scars in general.

3.3 Volumetric lipoinjection technique

We use 3-mL syringes and a 2-mm blunt-tipped cannula for lipoinjection. The micro-approaches to be made will depend on the area to be injected. We make these incisions initially with a 22-gauge needle. The area to which we will have access should be considered when performing our approaches to achieve a uniform "fan-shaped" distribution of the entire area to be lipoinjected and keep the cannula tip in mind (**Figure 1**).

The final step consists of manual manipulation and remodeling of the injected fat, and in some cases, removal of excess grafted fat through the entry site. We use a 6–0 nylon suture to close the micro-approaches and 4–0 nylon for the scalp. The sutures are removed on the 4th or 5th postoperative day.

4. Clinical cases

4.1 Case 1 – Parry Romberg syndrome

The patient is a 35-year-old man with no previous medical history, diagnosed with progressive right hemifacial atrophy of 10 years evolution and 5 years with a stabilized condition. On examination, alopecia was found in the parietal and temporal region, together with subcutaneous tissue atrophy of the temporal region and the right midface, tooth loss, decreased range of motion of the temporomandibular joint, and trigeminal neuralgia. Three-dimensional (3D) reconstruction computed tomography showed the absence of the temporomandibular joint and a significant reduction of tissue volume in the affected side.

Infiltration with enriched autologous fat containing ASCs reduced the severe depression of the frontotemporal region and provided better volume and symmetry. An acceptable improvement of the malar prominence and cheek was also achieved, with greater volume and projection on the front view and profile. From its angle to the chin, the mandibular contour was redefined, achieving a better balance; even the neck base benefitted volumetrically. It is important to point out the permanence of the fat graft in the lips, which allowed the teeth to be hidden because of increased lip volume. The graft's permanence remained stable in all the injected areas, even in the nasolabial folds and lips, which are areas of maximum mobility and reabsorption [24] (**Figure 2**).

4.2 Case 2 - Craniosynostosis

A 4-year-old male diagnosed with anterior plagiocephaly, which was initially treated with cranioplasty and frontal bandeau at the age of 12 months. A defect is observed in the frontal glabellar region. A fat transfer was performed to achieve symmetry in both regions through a minimally invasive approach [31] (**Figure 3**).

4.3 Case 3 – Congenital constriction band syndrome

Congenital bands are compressive rings with a groove of different depths that can be partially or wholly circular at one end.

Its etiology remains unknown. Its rupture has been described through the use of Z- and W-plasty and excision and primary closure; However, new alternatives to its treatment have recently been described.

A 36-year-old woman with no relevant medical history presents a simple congenital constriction band in the distal part of both legs, without functional impairment (Type 1 Patterson Classification). The right leg had an incomplete circumferential constriction band with minimal depth, and the left leg a circumferential constriction band of moderate depth. The left leg was treated. The procedure was performed under epidural anesthesia with intravenous sedation [32] (**Figure 4**).

Three approaches (2 mm) that were remote to the constriction band were marked. Initially, the fibrous band was released from the deep tissues with a flat-grove blunt-tipped 2-mm Toledo cannula, 10 cm in length. Afterward, with this same cannula, multiple perpendicular cuts were made in the inner surface of the

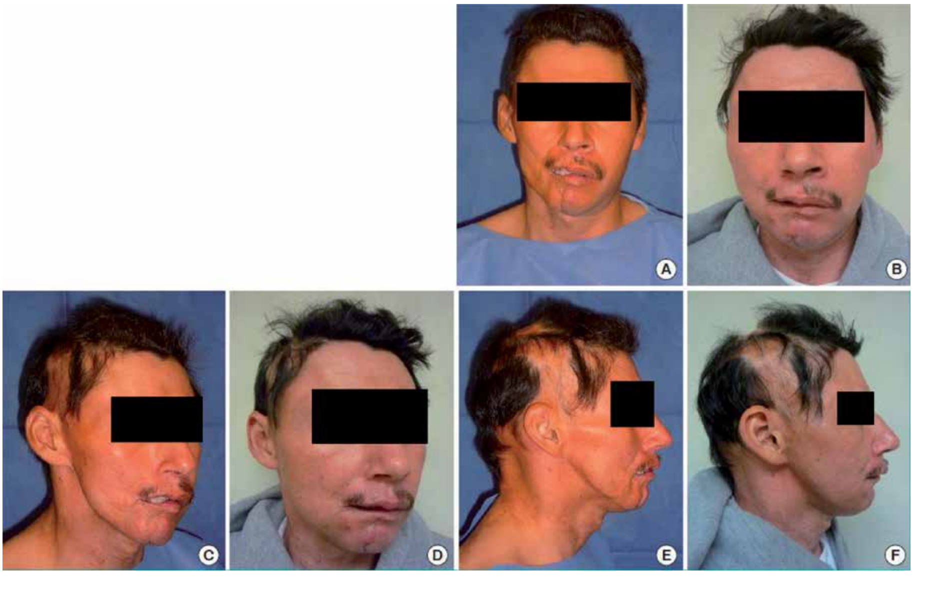

Figure 2.
(A, C, E) preoperative view. (B, D, F) postoperative view 12 months after lipoinjection enriched with stem cells and elements of the stromal vascular fraction.

Figure 3.
Intraoperative view. (A) Glabellar lipoinjection was performed in a fan shape until adequate symmetry was achieved. (B) the treated left area. (C) both treated areas.

Figure 4.
Preoperative images of the left leg. (A) Lateral view, (B) frontal view, (C) medial view.

fibrous ring leaving a 1 cm gap between each cut until completing the circumference of the band.

Lipoinjection was performed in the virtual subcutaneous space from a deep to a superficial plane with a 2-mm blunt cannula with 5-ml syringes. We injected the amount of fat needed to reverse the appearance of depression without overcorrecting (**Figure 5**).

4.4 Case 4 – Facial esthetics

A 27-year-old female with no significant history requested a facial profiling procedure.

The patient presented adequate skin quality; however, she was not satisfied with the definition of her facial frame and neck. Today, patients come to our consultation with a lot of Internet information, and in many cases, they request specific procedures. It is always good to listen to them, and in this way, know how to properly advise our patients. After an adequate clinical evaluation, we suggested carrying out the following procedures: Bichectomy, neck liposculpture, and enhance the definition of the entire lower facial frame by volumetric lipoinjection with adipose stem cells, in addition to a slight increase in projection on the upper lip in the philtrum region.

For seven years, we have developed an innovative alternative for nasal modeling. In this case, we also use fat and stem cells (in our practice, we have named this RINO-CELL®).

To a large extent, we consider that the success of any procedure in facial esthetics lies in obtaining an adequate definition of the full jaw contour. In this way, it is possible to visualize the border between the face and the neck, and it is also our objective to redefine the cervicofacial angle. All these characteristics represent a clear sign of beauty and youth (**Figure 6**).

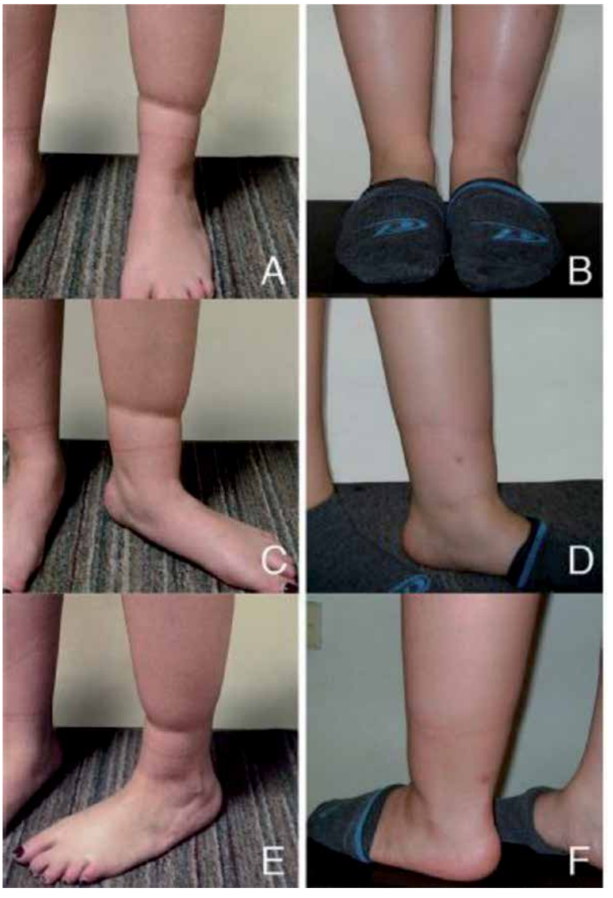

Figure 5.
Change in the concave surface ("hourglass sign") for a homogeneous surface. (A, C, E) preoperative view. (B, D, F) postoperative view 18 months after the procedure (note the three approaches with some degree of hyperpigmentation).

5. Post-surgical care/complications

In a recent systematic analysis, Gornitsky et al. describe 2.2% complications in facial fat transfer procedures, with asymmetry being the most common. Other complications are skin irregularities, prolonged edema, hypertrophy, fat necrosis, infection, telangiectasia, and acne reactivation [33].

Cases of emboli following autologous fat grafting to the glabella and nose have been attributed to retrograde arterial injection, facilitated by the abundant vascular supply in these regions; notably, the frontal and dorsal nasal arteries that are supplied by the ophthalmic artery [34].

In our experience, we have found a reabsorption percentage of 49% of the injected volume. We have concluded that when the results are not favorable, the volume of fat calculated and injected was insufficient or to other particularities that increase reabsorption in the specific area. These situations may be resolved with secondary or re-touch procedures.

Most parents reported feeling happier with their children's facial appearance. An important factor to consider is the variability of reabsorption of the injected fat. However, if necessary, the fat injection can be repeated as an isolated procedure.

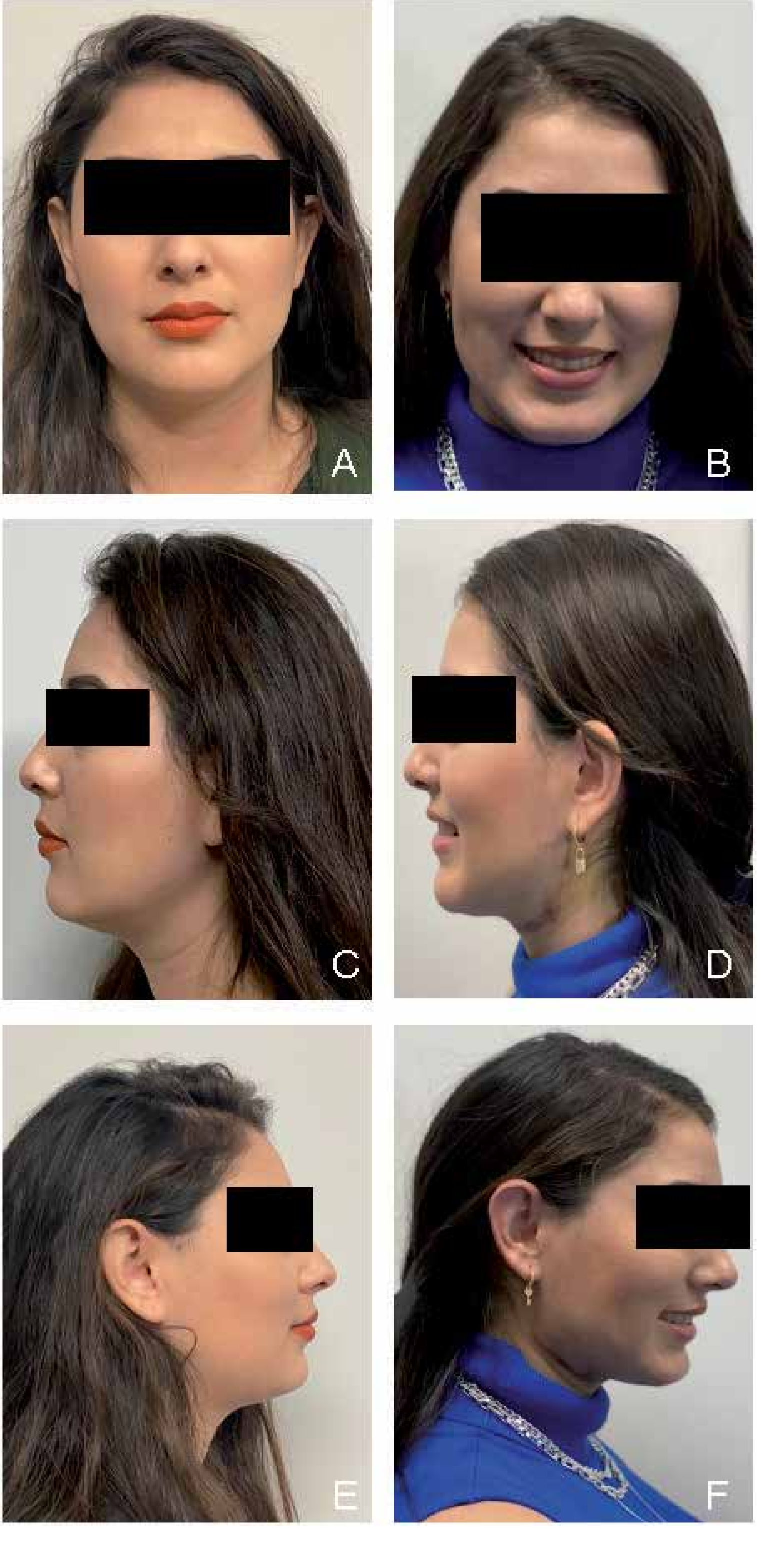

Figure 6.
(A, C, E) preoperative view. (B, D, F) postoperative view 10 days after the procedure.

6. Conclusion

It is important to comment that current evidence regarding lipoinjection with adipose stem cells suggests that they can increase the permanence of the grafted fat to a certain degree; however, it is essential to explain to patients that this procedure can be repeated to obtain a better result in the medium and long term.

We believe that lipoinjection alone or with adipose stem cells is an excellent alternative to improve appearance in patients suffering from a wide range of cranio-facial malformations or sequelae.

The search for a more youthful appearance is constant; therefore, we consider that lipoinjection as facial contouring, or in combination with other rejuvenation techniques, currently constitute an excellent therapeutic resource in facial esthetics.

Finally, we consider that the facial image plays a significant role in psychosocial development and integration. We believe that volumetric lipoinjection with or without adipose stem cells represents an excellent alternative to obtain greater facial esthetic harmony, which directly contributes to the self-esteem of children and adult patients.

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Conflict of interest

The authors declare no conflict of interest.

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Section 5

Regional Techniques

Chapter 13

Applications of Helium Plasma in Rejuvenation of the Face and Neck

Deirdre Leake and Janet Lee

Abstract

Energy based devices have been developed for the purposes of tissue contraction and skin tightening. Its application in the face and neck have been explored using lasers, temperature controlled monopolar and bipolar radiofrequency, and ultrasound. The purpose of this chapter is to explore the various applications for the face and neck using Renuvion™, a unique energy driven device based on plasma generated from the combination of helium gas and radiofrequency energy. The advantage of this technology is its ability to offer precise delivery of heat to tissue with minimal thermal spread, in part due to the rapid cooling aided by the helium gas. We will explore the options in which this technology can be incorporated to rejuvenate the face and neck, the patient selection considerations in choosing method of approach, surgical technique, anticipated outcomes, potential concerns and or complications associated with this and expected perioperative care. Applications in the face and neck include: (1) Subdermally in the neck as a stand alone procedure with or without liposuction. (2) Subdermally in a limited incision, non-excisional technique with a concomitant platysmaplasty either with an open approach or percutaneous use of suture suspension for the platysmal muscle. (3) Subdermally in conjunction with an open traditional rhytidectomy involving skin excision. (4) Ablative resurfacing—fractional or pulsed and full continuous modalities (non-FDA cleared at the time of this writing). It is the authors' experience that with appropriate patient selection this can be a powerful tool that can deliver skin tightening and rhytid reduction not seen by other technologies available.

Keywords: skin tightening, facelift, necklift, helium plasma, renuvion, facial rejuvenation

1. Introduction

The aging population is on the rise in the United States, with greater than 30% of the US population being over the age of 50 based on 2019 demographic data [1]. Traditional facelifting has largely been the gold standard for facial rejuvenation to address skin laxity in the face and neck. Energy based devices have emerged in the past several years as a treatment alternative to manage skin laxity either as a standalone procedure or used concomitantly with open surgical techniques [2]. The aging and the youth are looking for alternatives to traditional surgeries to improve their appearance. These devices can help tighten the skin and diminish subcutaneous fat with presumed less downtime, smaller incisions or less visible stigmata of having had surgery.

The normal body temperature is 37°C, at 50°C cell death begins over a 6 minute period [3] and at 60°C cell death occurs instantly [4]. At temperatures between 60° and 100°C, protein denaturation and coagulation occurs in conjunction with cell death, it is these two processes that results in tissue contraction and cellular regeneration [3]. Collagen is the primary protein in the skin and subdermal fibroseptal network. Denaturation of collagen begins at 66.8°C [5] resulting in rapid contraction by up to 1/3 of the collagen fiber length [6]. Furthermore, thermal injury initiates a wound healing response that results in neocollagenesis which can occur over 6 months. The Renuvion™ handpiece is a novel technology that uses helium plasma to achieve temperatures of 60–80°C in 0.08 to 0.04 seconds for maximum tissue contraction with subsequent rapid cooling reaching temperatures below 65°C within 0.1–0.2 seconds to reduce risk for thermal spread or collateral injury. In its subdermal applications, maximum change in external skin temperature was less than 4°C [7]. These unique thermoplastic properties allow for maximum tissue contraction and skin tightening with reduced risk for collateral injury. In applications of the head and neck, this is highly operator dependent and an understanding of how tissue contraction occurs is important in achieving optimal results whether it is used for a subdermal treatment or a resurfacing treatment.

The Renuvion handpiece is particularly appealing because it can be used in multiple applications. The subdermal technique can be used as a standalone treatment or be paired with a traditional facelift, while the ablative resurfacing produces unparalleled wrinkle reduction and skin contraction. Choosing optimal candidates is key. A patient seeking wrinkle reduction as well as achieving lift may be an excellent candidate. However, particularly with the ablative resurfacing technique, if the patient is unwilling to accept the downtime of 10 days to a month, there may be alternate options with less recovery time. It is also important to consider a patient's Fitzpatrick skin type and avoid this treatment for skin types greater than 3. Patients with type 3 should be treated with caution considering the risk of hypopigmentation. In addition, thin skin should be treated on the pulse setting, and the results will not be as significant as with thick skin.

2. Our evolution

It is first inherently important to understand this single device has two completely unique and distinctly different applications. One being used as a tool for subdermal "minimally invasive" skin tightening. This can be used in conjunction with other technologies such as liposuction with or without energy driven assistance (i.e., Vaser™), an open platysmaplasty or a limited incision/percutaneous suture suspension platysmaplasty such as MyEllevate™ to achieve optimal results of tightening the neck and jawline. In this technique, the energy is being delivered to the subdermis and fibroseptal network to allow the skin, subdermis and underlying fibroseptal network to contract en bloc uniformly to tighten and improve the neck and jawline. This is very patient dependent and not all patients get the same tightening without removal of skin.

The second, non-FDA approved, usage of this machine is the most powerful. It was noticed by many that wrinkle reduction with ablative resurfacing using Renuvion™ is wildly successful. The results can be profoundly amazing, but it is far from "minimally invasive". The authors found that not only did resurfacing result in dramatic wrinkle reduction, but a significant contraction of the skin along the jawline, eyelids, forehead and upper lip was noticed as well. The degree of skin contraction in many cases matched that of outcomes seen in surgical procedures involving skin removal—such as that of a blepharoplasty in the eyelids (**Figures 1** and **2**).

Figure 1.
One year after full face renuvion resurfacing, this patient's aged elongated upper lip was contracted that it almost restored the 1/3's proportions of the face.

Figure 2.
This patients' mid face and upper lip had elongated with the aging process and sun, full face Renuvion™ resurfacing shortened the cutaneous upper lip significantly. The pink portion of her lip was rotated outward lifting her vermilion border while also decreasing her lip lines. This is a one year postoperative picture.

Again, this technique is highly operator dependent which will be discussed in detail later in the chapter.

Noticing the degree of skin contraction that can be achieved with ablative resurfacing and delivering energy directly to the epidermis, the authors questioned whether similar results could be achieved by delivering energy directly to the subdermis when it was separated from the fibroseptal network. In an open facelift technique, wherein the skin flap is fully elevated and released from the underlying fibroseptal network, energy is delivered directly to the lifted skin and subdermis. The Renuvion™ handpiece is now used in every open facelift that involves excision of redundant skin in conjunction with a platysmaplasty, deep plane or SMAS suspension. Previously, when performing a deep plane lift in the patient with excessively redundant skin, the vector of elevation results in significant skin removal and a significant shift of existing horizontal neck lines into the cheek and excess skin

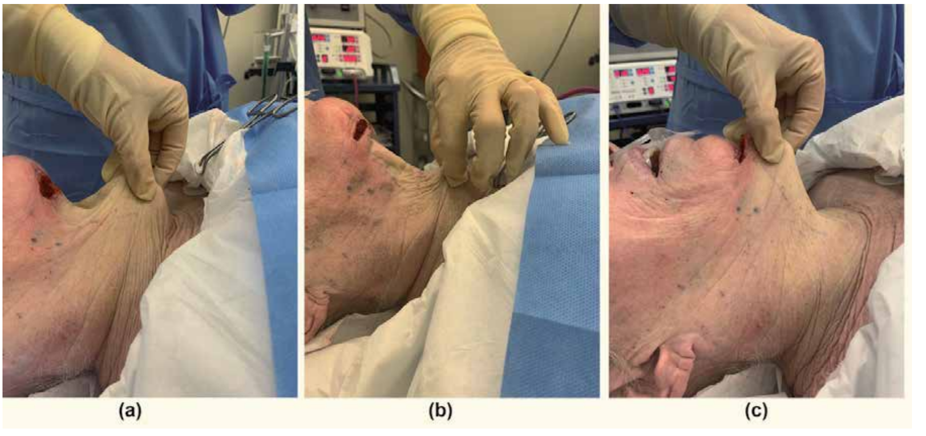

Figure 3.
(A-D) This intro-operative picture shows the excess skin with the neck flap is lifted inferiorly and superiorly. The Renuvion™ handpiece was used directly on the subcutaneous lifted flap and dermis. Approximately 6 passes were performed along the entire skin flap. Lifting the skin flap after the Renuvion™ had tightened the flap demonstrating the amount of skin contraction that can be achieved.

Figure 4.
This patient had an extended SMAS facelift on one side because she had a neck dissection 5 years earlier on the left side. The Renuvion™ was used subdermally to contract her skin in hopes to create a more symmetric look due to the previous dissected and irradiated neck skin on the left. The pictures shows preoperative, 6 months post op, and 2.5 year post op demonstrating the longevity of the skin contraction.

removal in the temporal area. With the use of Renuvion™ there is up to 1 to 1.5 cm of skin contraction seen directly on the table allowing less skin removal upon re-draping (**Figure 3**). An improved shrink wrap effect is seen along the jawline without abnormal shift of the lower horizontal neck lines. There is longevity to this skin tightening, patients seen at 3 years follow up have maintained results without further need of touch up, tuck ups at the submental area or jawline (**Figure 4**).

3. Patient considerations

Recognizing that there are several different applications and techniques in the approach to the head and neck with Renuvion™, it is important to discuss the patient variables to consider who will achieve the best outcomes with which technique and not to mention considering the variabilities of the settings.

Using the device to tighten the subdermal neck only with or without liposuction, the ideal patient candidate is the younger patient, with minimal laxity, absence of redundant skin and inherently responsive skin elasticity. For the patient with inherent deep structure concerns such as platysmal banding, submandibular gland ptosis, and more significant skin laxity, but mild skin redundancy, a minimally invasive subdermal approach with Renuvion™ can be considered in conjunction with other minimally invasive techniques such as suture suspension platysmaplasty or with MyEllevate™. In the patient with significant facial aging, skin laxity with excess skin redundancy, the authors' experience is that an open traditional facelift approach combined with subdermal Renuvion™ yields best results. For the Fitzpatrick patient I-III with significant rhytidosis, solar elastosis, ablative resurfacing—both fractional and full resurfacing using Renuvion yields impressive results unsurpassed by other technologies currently on the market.

The Renuvion handpiece affords the physician to use one handpiece for the subdermal and resurfacing approaches. Other technologies cannot be used this way which makes the renuvion technology more attractive. With CO_2 laser and erbium Yag laser, wrinkle reduction is noted and has been studied in depth [8]. The authors have found that not only is wrinkle reduction improved, but the skin contraction with lifting of the lateral brow, medial brow and upper lip is seen much more with Renuvion. A split face study would need to be performed to truly delineate the superiority of renuvion for improving sagging skin. The authors decided to resurface with renuvion when the patient's skin is more loose an could benefit from lifting otherwise CO_2 is their other method of choice for wrinkle reduction and improvement of skin texture with less downtime. Also hypo pigmentation is seen 19% of patients getting fully ablative CO_2 laser [9]. While the authors noted some hypo pigmentation, it was not as high as 19%.

4. Technique

The Renuvion™ handpiece is very user dependent and technique cannot be discussed enough. It is different than most currently used laser devices that have a precise pulse width, spot size, duration with an exact depth of penetration. The Renuvion™ energy delivery is akin to using a laser in continuous mode. For this reason technique will directly impact time on tissue, energy delivered and depth of penetration. When used in pulsed mode the Renuvion™ helps regulate the depth and time on the skin for the first time users, but does not give the same degree of contraction or wrinkle reduction as seen in the non-pulsed mode. The most important determination of usage is to know that too much time on the subdermis or epidermis will cause increased depth of injury and result in permanent scarring. Furthermore, placing the handpiece too superficially in the subdermis will cause undulating acne like scars. It is recommend that a physician train users prior to the use on patients.

4.1 Subdermal neck only

When Renuvion™ is used in a minimally invasive manner as a stand-alone device for the subdermal neck, the ideal patient candidate is the younger patient in whom there is mild skin laxity in the absence of excessive skin redundancy. The subcutaneous neck is liberally infiltrated in a tumescent technique, this can be extended to varying degrees above the mandibular border to improve and impact

Figure 5.
This patient had Renuvion™ resurfacing performed with improvement of wrinkles and skin texture. The tightening of the lower lid skin has improved her fat pseudoherniation and her forehead contracted 1 cm.

energy along the jawline. Subdermal tunneling is then performed through stab incisions as seen in **Figure 6** create channels to pass the Renuvion handpiece without complete disruption of the underlying subdermal fibroseptal network. This can be performed using a liposuction cannula or other blunt tunneling instrument ideally measuring up to 3.5–4 mm in width. At this point, depending on the patient, the surgeon may elect to perform submental lipectomy or neck liposuction. It is important to point out that there needs to be open communication in your tunneling between the access points to facilitate Helium gas egress when the Renuvion™ handpiece is used. It is the authors' experience that taking the time to create sufficient tunneling broadly and widely involving the entire anterolateral neck yields best results. The handpiece is then passed subdermally 5 mm from the subdermis using the created subdermal tunnels. Energy is typically deployed in a retrograde fashion as the handpiece is removed and it is important to understand the handpiece should be in continuous motion when the energy is applied. The speed of the handpiece should be at approximately 1 cm/second maintaining a distance roughly 5 mm from the dermis to reduce risk of scarring. Energy delivered typically depends on the inherent thickness of the skin. In the thin-skinned patient energy of 60% up to 80% in the thicker-skinned patient can be considered at flow rates of 1.5–2 L. Typically, the neck and jawline are divided into subunits including the jawline, midline neck/submental area, the lateral neck, and posterior to the SCM. Four to six passes are performed 1 cm apart in each area, at a subdermal depth where the light from the wand can still be seen, but the skin is not tented under tension. As the energy is being delivered above the mandibular border, in the minimal incision technique, it is important to place firm hand pressure at the mid-cheek to prevent helium gas from extravasating into the cheek and orbit.

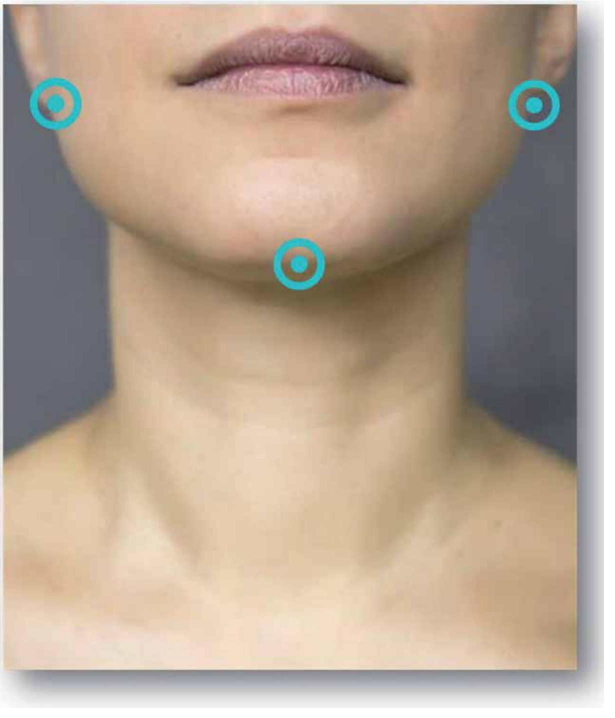

Figure 6.
Typically, 3 small entry point incisions (measuring 1 cm or less) are made—One is made under each earlobe at the facial junction as well as a small submental entry point incision.

Approximately a total of 4–6 KJ of energy is delivered to the neck and jawline in this technique. The exact energy delivered has not been studied to see what achieves optimal results.

4.2 Subdermal neck with platysmaplasty

In the patient for whom there is mild–moderate skin laxity in the presence of platysmal banding and or submandibular gland ptosis, addressing the underlying muscle in conjunction with subdermal Renuvion™ yields a better result than treatment of the subdermal neck alone. In this situation, the small entry point earlobe incisions remain the same, but the submental incision may be extended if an open platysmaplasty is to be performed. A novel limited incision technique is the combined use of platysmal band division and submental neck suture suspension using the LED light-guided device known as myEllevate™. In this case, the platysmal bands are percutaneously divided using the ICLED suture. The entry point incisions as described above remain the same. The neck is liberally infiltrated with tumescent solution. Subdermal tunnels are created in the midline and antero-lateral neck. At this point, the surgeon may proceed with submental and or neck liposuction if indicated. The Renuvion™ is then used at this stage, passing the wand through the created subdermal tunnels, delivering energy on withdrawal of the handpiece. Four to six passes are performed 1 cm apart as described above. Once more approximately 5–6 kJ of energy is delivered to the neck and jawline. Following completion of the Renuvion treatment of the fibroseptal network and subdermal neck, the MyEllevate™ suture is used to create a trampoline suture suspension from mastoid tip to mastoid tip to support the submental neck. The energy will not damage the previously placed sutures if the Renuvion™ needs to be passed again.

4.3 Open neck, facelift approach

In the patient for whom there is significant skin redundancy and laxity, an energy driven technology alone will be insufficient to achieve an optimal result. It has been the authors' experience, that best outcomes can be achieved when using the Renuvion™ handpiece in conjunction with a traditional open deep plane or SMAS face lift, neck lift approach. One may question why use the Renuvion™ handpiece at all if proceeding with a traditional facelift. Epidermal contraction was noticed by the authors when the Renuvion™ was used for ablative resurfacing. Consequently, the authors have speculated that similar tissue contraction can be achieved when the Renuvion is used in the subdermis. In the open facelift or neck lift, the skin has been fully released from the underlying platysma or SMAS, thereby completely releasing the fibroseptal network. In this situation, the energy is being targeted directly to the subdermis and not the fibroseptal attachments. When the Renuvion handpiece is being directly applied to the subdermis on an elevated skin flap, the authors have observed immediate contraction of the skin as seen in the figures above. The resulting shrink wrap effect permits less need for a vertical vector pull and less redundant skin to excise. Authors have found that the horizontal neck lines are less likely to be elevated into the lower cheek, and a smoother contour along the mandibular border is achieved. It was also noted that there is less skin to excise along the temporal anterior hairline creating well hidden incisions. For the open SMAS suspension face lifts, placing the handpiece along the jawline and medial jowl area creates a nice contraction and can obviate the need for a deep plane lift. It is not that a deep plane lift needs to be avoided, but this technique affords another option to the surgeon and patient.

4.4 Ablative resurfacing

The non-FDA approved application of the Renuvion™ for ablative resurfacing has been proven to be one of its most powerful applications. In the patient with significant rhytidosis and excess skin, wrinkle reduction and skin tightening can be accomplished with the Renuvion™ handpiece not seen with other technologies. Patients should expect significant downtime, which ranges from 10 days up to one month. As with most ablative resurfacing tools, this is not to be used in a Fitzpatrick skin type greater than 3 and even at times the Fitzpatrick 3 patient should be proceeded with caution. Thin skin should be treated on the pulse setting and results will not be as great. Diligent postop care is essential to the success of this treatment. Every patient experienced some milia and erythema, while some patients experienced hypertrophic scarring and hypopigmentation. The healing process may involve topical treatments such as tretinoin or adpalene, as well as laser treatments, kenalog injections and silicone sheeting to address minor complications.

The handpiece should be held no further than 5 mm from the skin in order to be effective. This is highly user dependent, requiring consistent, steady and constant movement across the skin surface maintaining uniformity in distance from the skin and speed of movement, moving at a speed of 1 cm/second [10]. Energy is being delivered directly to the epidermal surface, and therefore time on tissue is critical to achieve a good result and avoid complications. To accomplish wrinkle reduction and skin contraction, tissue coagulation and collagen remodeling needs to occur at the epidermis and epidermal/dermal junction just into the superficial papillary dermis. Delivery of energy into the deep papillary dermis or reticular dermis results in increased scar formation and hypertrophic scarring. For this reason, energy delivered, skin thickness, handpiece distance from the skin surface, and speed of movement are critical variables to outcome and reduced risk for complication.

The patient is prepped and draped in a meticulous sterile fashion. The skin is cleansed and degreased. Anesthesia is obtained, this can be accomplished using either systemic agents, sedation or with local anesthesia. If using local anesthesia, it is the authors' experience that a combination of local nerve blocks, mild tumescence and direct intradermal injections achieves best results. Selection of power setting depends on patient's skin type, skin thickness, and severity of wrinkles. The face is subdivided into zones of treatment. Number of passes and power settings vary based on zones of treatment (**Table 1**). Direction of movement of the handpiece, is optimally performed along the direction of the relaxed skin tension lines and it is the authors' opinion that this is less likely to result in hypertrophic scarring and potential webbing. While users have widely discussed ablative resurfacing using Renuvion™ with two passes at energies as high as 40%, the authors have found that satisfactory results can be achieved with one pass alone at 20% and less downtime. Early porcine studies performed by Bovie medical demonstrated the amount of tissue contraction using the BVX-044-BPS (now known as the Renuvion handpiece) is similar when comparing 40% power to 20% power, supporting the authors' opinion that optimal outcomes can be achieved at 20% [11]. The handpiece is held very close, within 5 mm of the skin and the endpoint looks similar to a toasted marshmallow (**Figure 7**). Continuous even movement is very important. Thin skin areas such as the upper and lower eyelid are treated at reduced energy

Zone	# Passes	Energy	LPM-Flow
Perioral	1–2	20–30	4
Periorbital	1	15–20	4
Forehead	1	20	4
Nose	1	20	4
Cheeks	1	20	4
Jawline	1	15	4
Neck	1	15 (pulsed/fractionated)	4

Table 1.
The different settings in different areas of the face.

Figure 7.
The skin that is treated looks similar to a marshmallow that has just been exposed to the flame. Pre Renuvion measurement, Post Renuvion measurement.

15–20% and only pass. Areas of deep rhytids in thick skinned patients such as the glabella or upper lip have been addressed at times with 2 passes at 20–30% energy and 4 L flow rates. As one approaches along the mandibular border the energy is reduced to 15% and wand distance from the skin is increased to defocus the energy and to reduce risk for hypertrophic scarring and forming a demarcation line. The user can also place the handpiece in pulse mode along the jawline which helps decrease hypertrophic scars. Pulsed mode should be considered for the thin skin lateral to the chin and medial to the MLF line because this skin has been noted to develop hypertrophic scarring.

As with other resurfacing modalities, treatment of the neck should be exercised with caution. However, nice results can be achieved at lower and fractionated or pulsed settings. The energy can be made fractionated by placing a meshed wet gauze on the skin and then firing the handpiece over the gauze or placed in a pulsed mode. This can be done on the neck or face for less of a result, but with faster healing time and a decreased risk of complications. When placing a head wrap on the patient, non adherent gauze is placed on the neck. No scarring has been noted with this treatment. However, the resurfacing must be defocused and fractionated. This affords the patient tightening of crepe like skin of the neck.

The machine now has a KJ counter which is helpful for both subdermal applications and ablative resurfacing, but this is not available when used in pulsed mode. Again, the exact energy that is best for the patient's skin type has not been determined.

4.5 Post procedure care and normal sequelae

The best start to post operative care starts before the procedure. It is essential that the patient has understanding and is prepared for the after care. Prior to surgery, sharing pictures during the healing phase will be helpful. Having detailed written instructions for subdermal and resurfacing cases is a must (**Figure 8**).

Subdermal neck and face procedures should wear a head wrap compression dressing for a few days and a head wrap at night for a few weeks which will help the skin contract and seal down to the underlying playtsmal muscle. The skin on the neck can look worse before it gets better similar to an elephant's foot. This typically settles down and can be improved with early treatment using IPL and non ablative lasers like Palomar 1540 XF. Delivery of energy to the subdermal neck is an intentional injury to the fibroseptal network, designed to stimulate collagen contraction. This resultant scar contracture can at times create tethering and bunching of the skin, particularly in the thin skinned patient. Dilute Kenalog 10 can help smooth out the skin during the healing process (**Figure 9**). The texture of the skin within a few weeks starts to improve. The thin crepe like skin will take longer and thick skin smooths out earlier. The platysmal muscle can create some bunching of the skin when it is overactive, so diluted neurotoxin can help smooth out the neck and hasten the healing process. Placing the handpiece too superficially or too long can cause a subdermal scar (**Figure 10**).

Resurfacing postoperative patients are very time consuming, require meticulous post operative care and must be seen frequently. During the first week, the regimen until re-epitheliazation includes washing with distilled water and a capful of vinegar and/or mild soap (vanicream or cerave) twice a day. It is very important to tell the patients to not remove the eschar or dead skin while washing and to leave it as a biological dressing. The authors have found that constant picking and rubbing will cause prolonged redness and itching, and increases the risk for hypertrophic scarring or hypopigmentation (**Figure 11**). Keeping the treated area moist and protected with aquaphor/vaseline or an occlusive silicone patches can help the process of epithelialization. Informing the patient that they may need to frequently change

Figure 8.
This patient is two weeks postop. She did not have any sequelae or complications from the resurfacing procedure. This redness and splotchy circular healing the authors have found is completely normal and fades slowly.

Figure 9.
This patient has some indentation and elephant looking edema along the jawline which dissipated with time and the use of IPL.

their skin care for resurfacing cases will be necessary. All patients are different and with the new skin they can have issues with dermatitis.

After epithelialization, several different sequelae can occur. Most have intense itching after two weeks and hydroxyzine works well to temper this. The hyperemia can be problematic and is worse after a shower or working out. This can improve with frequent IPL treatments and skin care. The redness seems to fade into circles

Figure 10.
This thinned skin patient had a subdermal scar after placing the wand too close to her dermis. This required IPL, 1540 XF, PRP injections and filler injections to resolve this indented scar.

Figure 11.
This patient suffered from redness and hypetrophic scars from too much mechanical irritation. Her scars developed 6 weeks post and were treated with IPL, 1540 XD, 1540 XF, injections of Kenalog 10, 5-FU, and PRP. The scarring has improved, but she has several permanent hypopigmented areas.

similar to a cheetah print. Most patients wake up after after 3 to 4 weeks and notice that the pattern has disappeared. Development of milia is common and frequent extractions may be necessary. Differen gel and Epi-duo can also help with the small white heads and milia that develop. This typically resolves after about 8–12 weeks.

5. Results

To achieve optimal results, appropriate patient selection for the various treatment applications is critical. If the patient has fat, it will need to be addressed. If the patient has significant redundant skin, a type of traditional lift will need to be performed with some skin excision. If rhytids are noted, the tool is diverse enough to perform fractional/pulsed or full ablative resurfacing causing a skin contraction and wrinkle reduction (**Figures 12–19**).

5.1 Resurfacing results

The resulting contraction, lift and wrinkle reduction achieved with the Renuvion handpiece are evident in the before and after photos. In fact, the authors did not originally plan to pursue a study of this modality, but after noticing significant results when comparing before and after photos, they began measuring and compiling the data. Immediately following the procedure there is some swelling from the numbing and trauma that resolves during the healing process and over time continued contraction and neocollagenesis occurs.

Resurfacing results had a quantitative measurements as seen in **Figure 20**.

With aging, the cutaneous lip elongates and the pink portion of the lip deflates and starts to roll inward. Resurfacing the cutaneous upper lip causes the pink portion of the lip to become more oblique or more in a vertical direction on a planar view which decreases the appearance of a disappearing pink lip creating a plumper three dimensional upper lip. The same is noticed with the lower lip. The skin contraction that was noted has shortened the cutaneous portion of the lip which has proven to have longevity. The rhytids will almost disappear and the texture will improve. Some of the dynamic lines will return, but the lines at rest will resolve.

Figure 12.
This patient underwent an open platysmaplasty with subdermal renuvion, no skin removal, only infraauricular entry point incisions were made and communicated with a midline submittal incision through which the platysmaplasty was performed. - 1 year post op.

Figure 13.
This patient underwent a SubSMAS rhytidectomy with subdermal renuvion - 2 year results.

Figure 14.
This patient had a facelift 10 years prior and wanted a better neck and jawline. She had a subSMAS rhytidectomy with subdermal Renuvion on the neck and jawline and full face Renuvion resurfacing - 6 month results.

Table 2 demonstrates the improvement with lip lifting and the contraction has longevity over 1.5 years for 35 patients.

Particularly of note, the data shows that patients had an average lip contraction of 16.6% immediately following treatment, and one year later, the results remained essentially the same, with an average of 16.5%.

Figure 15.
This patient had Subsmas rhytidectomy with subdermal renuvion and lower blepharoplasty - 3 year results.

Figure 16.
This patient was treated with full face ablative resurfacing 1 pass 20% 4 L - 1 year result.

The forehead skin, upper and lower lids contract similarly to the upper cutaneous lip. The brow and the hairline actually move closer together especially at the temple. The authors noticed a more natural brow lift than with endoscopic brow lifts. The deep, heavy glabella is lifted and the dynamic lines are reduced with longevity noticed without creating a widened midbrow. Minimal to moderate dermatochalasis of the upper and lower eyelids will resolve with this technique

Figure 17.
This patient had deep wrinkles around her perioral and mid cheek area only. Two passes at 30% 2 liters were performed to the upper lip and one pass everywhere else. She has signifiant reduction of wrinkles and contraction of her upper lip. However, she does have mild hypo pigmentation. This is 2 year results.

Figure 18.
This patient had minifacelift with fractional CO_2 laser to her cheeks and renuvion resurfacing to her upper lip only - 2 passes at 20% 4 liters. She is Fitzpatrick III and she did not have hypo pigmentation. These are 2 year results.

simulating a skin pinch. The horizontal lines of the forehead, oblique lines of the brow and crow's feet are significantly diminished (**Figure 5**).

Table 3 demonstrates the improvement of the lift in the brow and its longevity over 1.5 years for 35 patients.

Of note in this section is the continued improvement in contraction over time. Immediately following treatment the average contraction was 11.5%. However, a year later the average improvement was 35.4%, indicating continued contraction.

The overall texture and pore size is significantly improved after it has healed. The redness will take the longest to resolve and it fades in blotches. It seems to be worse for 3–4 months after a shower or after exercise. Lentigines have decreased in number and shade. There has been permanent hypopigmentation and demarcation

Figure 19.
This patient had cheeks, lateral brows, and upper lids only renuvion resurfacing - on pass 30% 4 liters which improved her jowls, deep wrinkles and skin texture.

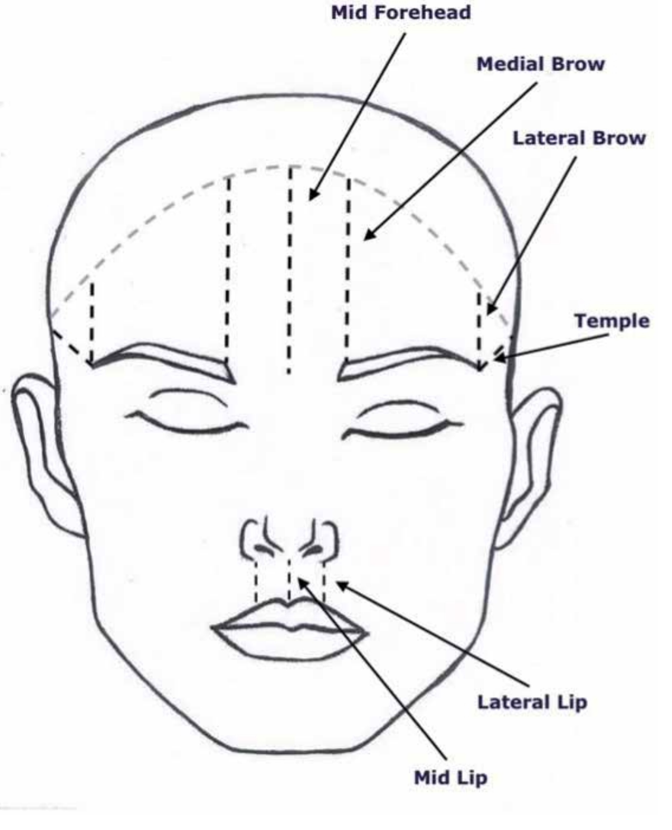

Figure 20.
Mid forehead - procerus line to the hairline at the mid forehead. Right and left medial brow- top of most medial brow hairs to hairline. Right and left lateral brow - top of most lateral brow hairs perpendicular to hairline. Right and left temporal brow - lateral brow obliquely to hairline. Mid upper lip - vermillion border to junction of columella and cutaneous lip. Right and left upper lip - vermillion border to junction of ala and cutaneous upper lip.

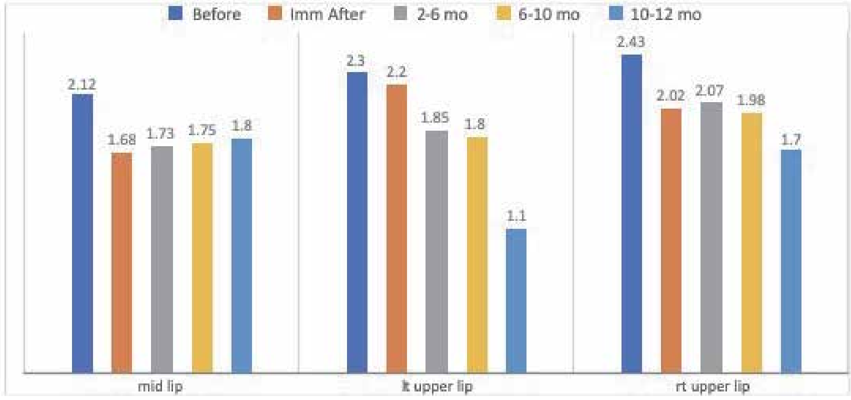

Table 2.
Lip data compiled by Abby Miller - medical student. The contraction of the upper lip has shown longevity.

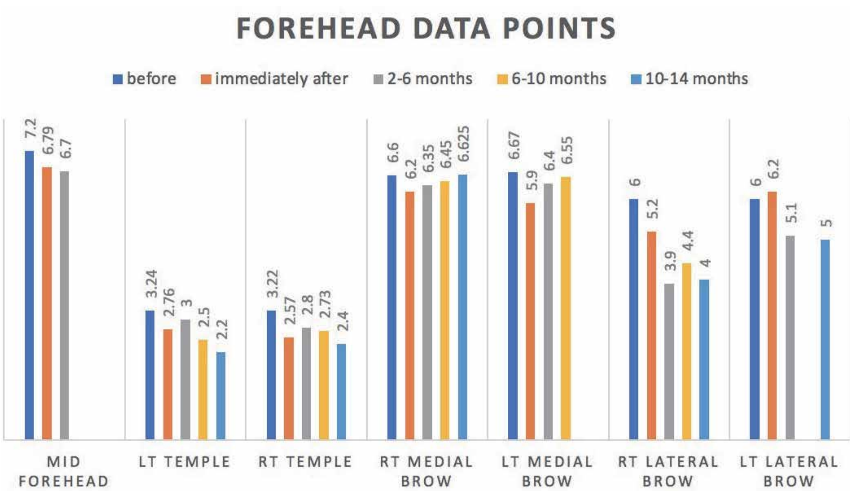

Table 3.
Forehead contraction has also shown longevity. Forehead data compiled by Abby Miller - medical student.

noted which will be discussed later. Those patients are typically Fitzpatrick I and II and have thinner skin. Darker Fitz II and III have not had long term color changes in their skin.

6. Complications

The complication profile from the subdermal technique and resurfacing technique differ greatly and again is mainly operator dependent whether it be poor patient selection or poor user technique.

Fewer complications are seen with the subdermal techniques. Retained helium gas can cause crepitus, prolonged swelling, eye issues, and embolus. This is prevented by holding pressure at the cheek and at the clavicle to prevent extravasation. Massaging the gas out of the incision sites helps prevent swelling and crepitus. Placing enough small incisions sites to help the gas escape is key to decrease swelling or crepitus.

Placement of the handpiece too close to the dermis and or moving it too slow can cause an indented scar similar to an undulating acne scar as seen in **Figure 10**. This patient had a linear subdermal scar with volume loss similar to the undulating acne scars seen in patients. This was caused by using the device too close to the dermis. The scar resolved with repeated treatments of of intense pulsed light, 1540 deep Palomar treatment, plasma rich protein injections, and hyaluronic acid injection. The technique can cause such a contraction of the dermis or fibroseptal network that it can cause the skin to bunch especially when it is too loose. This can take a few weeks to resolve ultimately leading to continued excess skin.

One of the most frustrating complications is the dissatisfied patient from lack of results which is mainly seen in the subdermal technique. This was found more when no skin was excised or platysmal work was not done. Once again the key to optimal outcomes arises from choosing the appropriate technique for the appropriate patient and detailed preoperative counseling. Patients with thick skin that when pinched has a fast recoil and has thicker subcutaneous tissue seem to have a better result with skin tightening when used subdermally than those with loose crepey like skin.

When using this device as a resurfacing procedure, there are many more chances for complications. This cannot be stressed enough, this technology in both treatment modalities is operator dependent. Time on skin is of utmost importance. Going too slowly over the skin causes deeper thermal injury and will lead to scarring. Setting appropriate energy settings dependent on the different areas of the skin and the patient's skin type plays a role in determining if they are going to have sequelae from this procedure. If the patient has thin skin, they can have hypertrophic scarring and ultimately hypopigmentation. Thicker skin patients do better having less scarring. Hypertrophic scarring is seen frequently along the jawline, upper and lower lids in a linear fashion, temples, and the triangle at the melolabial area. This is noted more where time on skin has been too long or if a patient has scratched or rubbed the area as seen in **Figure 11**. Treatment of the scarring includes IPL, 5-FU injection, 1540 deep Palomar, Kenalog injection, saline injection, silicone sheeting. At least 50% of patients developed hypertrophic scarring somewhere on the face, but 95% of those patients had resolution of scar with treatment. Everyone recommends tumescence with lidocaine prior to treatment. However, the porcine studies by Apyx shows that the use of tumescence resulted in more depth of thermal effect. This raises concerns that the use of tumescence may increase depth of injury and may be a contributing variable for increased risk for hypertrophic scarring.

Hypopigmentation is more common with two passes and can occur if the energy is higher, which more deeply embedded wrinkles require. Sometimes PRP injections can help take the alabaster appearance away, but does not completely revert the depigmentation. Transient hyperpigmentation is noted typically in darker skin patients. This has not been permanent and resolves easily with topical vitamin C, sunscreen, and hydroquinone.

Milia and erythema is seen in every patient during the healing process. Some worse than others. Milia typically go away after a few months and with the help of extractions, low dose tretinoin, adapaline, and/or benzyl peroxide washes. Erythema can be intense for the first month. If it is prolonged, it typically leads to hypopigmentation. Intense pulsed light, LED and infrared lights, and brief low dose topical steroids can help abate this. It seems to be worse after exercise or hot showers.

Itching is universal and very normal during the first and second week postoperatively and should abate. The more the patient rubs or uses ice, the itching worsens. Hydroxyzine works very well for this issue.

7. Conclusion

The Renuvion helium plasma facilitates rapid delivery of high intensity radio frequency energy with rapid cooling to tissue to achieve significant tissue contraction with diminished risk of thermal spread and collateral injury. This versatile tool has many powerful applications in rejuvenation of the head and neck and can be used both subdermally as well as for ablative resurfacing to accomplish significant skin contraction and wrinkle reduction. Deeply etched wrinkles will be erased and the skin contraction of the upper lip and forehead is worth noting. The subdermal application affords a lift of the jowls and neck without having to perform a deep plane lift which can cause skin bunching in temporal area when there is excess redundant skin. This technology requires a thorough understanding of how the energy delivery effects change to the tissue and is highly user and technique dependent. Once more research has been done regarding the settings - optimal energy, flow rates and number of passes based on patients' skin types, then a consensus of treatment methods can be decided.

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Chapter 14

Correction of the Lower Third of the Face and Submental Area in Various Types of Aging with Laser-Assisted Liposuction

Igumnov Vitaliy Aleksandrovich

Abstract

Age-related changes in the face - at all times were not a desirable phenomenon in socially active and successful people. In modern society, success is primarily identified with an attractive appearance and a healthy lifestyle. Healthy lifestyle is actively promoted in mass media, this message has many followers all over the world. The most striking manifestations of age-related changes are concentrated in the lower third of the face and submental area, which is manifested in violation of the contours of the jaw line, as well as in the smoothing of the cervical - chin angle. In some genetic features, such as micrognathia, these changes lead to the visual perception of the face less young than it actually is, even without obvious manifestations in other areas of the face. We have developed and put into practice a minimally invasive method for correcting the lower third of the face and the submental area, using laser-assisted liposuction, with various degrees of age-related changes. Which allows you to effectively deal with this problem.

Keywords: rejuvenation, lower third of the face, laser - assisted liposuction, minimally invasive surgery

1. Introduction

The fat accumulation in sub-mental area is a problem at the forefront of many minds, since excess adipose tissue leads to the drooping of lower face and causes further ptosis. These changes affect a full esthetic perception of the face, since a clear oval shape of the face is associated with young age and the smoothing of lines and corners with old age [1].

Plastic surgery offers a variety of ways to solve this problem, among which are different variations of platysmaplasty, combined lifts in combination with liposuction and other. However, all of them are tempered by significant stress of an invasive procedure, a long rehabilitation period, providing anesthetic procedures and a high risk of complications [2].

The realities of modern life and modern lifestyle determine that when choosing an operative measure most patients want a light invasion, a short rehabilitation period and no general anesthesia [3].

We use laser-assisted liposuction to correct the excess fat accumulation in submental area and at the lower face as well as to correct age-related alterations [4].

Many studies conducted by various authors on the effects of laser emission in tissues have shown that lipolysis was followed by small blood vessels coagulation in adipose tissue, cell lysis (bursting), reorganization of the reticular dermis and collagen coagulation in adipose tissue. Histological tests have demonstrated some of the advantages of using the Nd: YAG laser. These include formation of new collagen, reduction of intraoperative and postoperative hemorrhage as well as a reduction of adipocyte quantity [3–6].

Furthermore, a dermal flap retracts after laser, which in turn allows for reaching the lifting effect. In 2002 Badin published an article entitled "Laser Lipolysis: skin flaccidity under control", in which he demonstrated histological changes of tissue after laser treatment. During the operation of a laser, adipocyte membranes break down, blood vessels coagulate and collagen fiber restructures [7].

The research demonstrated that laser lipolysis with selective exposure to ND: YAG laser radiation with a wavelength of 1064 nm is less traumatic and is accompanied by tissue reactions, which appear by neocallagenesis and reduction of the dermal flap. In order to maximize the impact and minimize the negative consequences of laser, Badin recommended temperature control of the skin integument in the surgical area, range of safe temperatures is between 38-41C [7]. The laser lipolysis allows performing a surgery on the so-called hazardous areas, which include lower legs, arms, face [3, 8].

Thus, the development of algorithms for using laser-assisted liposuction in hazardous areas such as the lower face and the submental area continues to hold its relevance for greater effectiveness and minimum complications from this surgery.

2. Materials and methods

In the period from August 2011 to August 2019, we performed 570 surgeries using the laser-assisted liposuction method with the FotonsDinamic SP, Nd: YAG laser, 1064 nm wavelength.

The age of patients ranged between 28 and 70 years, the average age – (40 ± 5) years (**Figure 1**).

The choice of laser power as well as the number of accesses depends on the manifestation degree of signs of aging.

In our practice, we use the Baker's classification of deforming ptosis of soft tissues (**Figure 2**) [1], in which he categorizes IV types of patients:

I. Patients below the age of 40. Initial indications of aging, a small amount of body fat in the submental area. Skin elasticity and tone are normal.

II. Patients between 40 and 50 years of age. Mild ptosis of the tissues of the lower face, more expressed fat deposits in the submental area, a decrease of neck skin tone, platysmal bands are not expressed.

III. Patients between 50 and 60 years of age. Pronounced ptosis of the soft tissues of the lower face and fat deposits in the submental area. Moderate weakness of the neck skin and platysmal bands in dynamics.

IV. Patients between 50 and 60 years of age. Pronounced ptosis of the soft tissues of the lower face, significantly reduced tissue tension of the neck skin. Active platysmal bands are visible at rest.

Before the surgery all patients underwent comprehensive examinations, which included: medical histories, contraindications or indications to surgery, laboratory

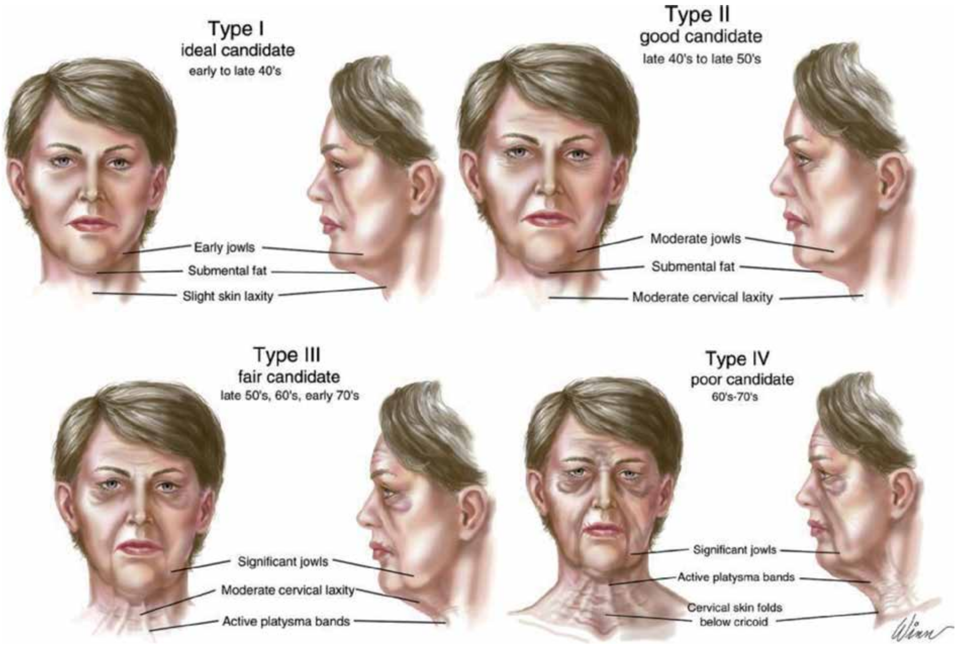

Figure 1.
Dividing patients into treatment groups based on types according to the Baker's classification: Group I-100, group II-170, and group III-260.

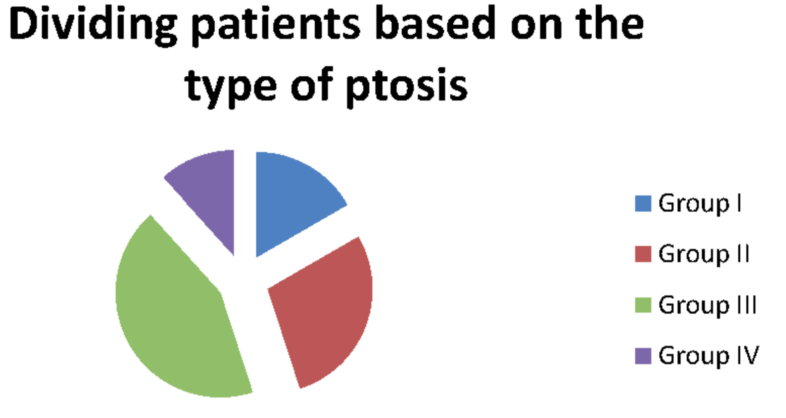

Figure 2.
Classification of deforming ptosis of soft tissues by Daniel C. Baker.

tests (biochemical and clinical blood analysis, blood group determination and Rhesus factor determination, HIV antibody test, blood testing for hepatitis); taking an electrocardiogram, as well as an examination by a therapist [9].

The operation protocol can be divided into several stages:

1. Photomacrography.
2. Anesthesia.
3. Setting up a certain laser program.
4. Laser-assisted liposuction.

It the first stage of macrophotography the surgery area was marked (in a vertical position) with the identification of the type of age-related changes and access options. Photography was made in five projections-full face, profile and at an angle of 45° on each side. When photographing, the horizontal position of the Frankfurt line was observed (**Figure 3**) [10, 11].

All surgical interventions were performed under local anesthesia in accordance with the operative areas, their localization, the volume of removed fat, and the marking. To do this, a tumescent solution was prepared, for which 50.0 1% lidocaine hydrochloride solution, 1.0 epinephrine, 12.5 8.4% sodium bicarbonate solution and up to 1000.0 ml of saline solution in the form of 0.9% NaCl aqueous solution were mixed. Skin punctures and injection of a tumescent solution into subcutaneous fat were performed using standard syringes along the contour lines of the operative area. They saturated the entire volume of subcutaneous fat to

Figure 3.
Photomacrography of patients before and after the surgery.

create local intracellular hyperhydration of lipocytes. The ratio of the volume of the tumescent solution injected into subcutaneous fat for its infiltration and the volume of subcutaneous fat to be liposucted was chosen as 1:2 [12].

The next stage was to set the laser parameters, which varied depending on the treatment area and the thickness of subcutaneous fat, as well as the severity of age - related changes.

Stage 1 - a slight decrease in the elasticity of the neck skin, a mild double chin, the contour of the lower jaw is not changed. One puncture was made in the submental fold of no more than 2 mm. in this case. The area under the chin was treated with the subsequent removal of fat and heating of the skin in the lower jaw area. Working conditions: power no more than 12 W, the total power consumption was up to 3000 J.

Stage 2 - moderate reduction in the elasticity of the neck skin, changes in the contour of the lower jaw, the formation of the double chin. In this case, the fat was removed both in the under-chin area and in the lower jaw area. With this degree of age-related changes, the parameters were changed to increase the power of 14 W; the total power consumption was up to 4000 J.

Stage 3 - moderate decrease in the elasticity of the neck skin, pronounced changes in the contour of the lower jaw, decreased platysma tone. With this degree of age-related changes, not only subcutaneous fat was removed under the chin area, in the lower jaw area, but also sub-platysmal fat was removed. In addition, the heating of the platysma was carried out to the level of the rannular cartilage. Working conditions: power 15 W, the total power consumption was up to 5000 J.

Stage 4 - flabby, atonic skin of the neck with deep circular wrinkles, significant changes in the contour of the lower jaw, double chin, severe platysmal bands. If there was evidence of aging, all supra - and sub-platysmal fat was removed in the lower jaw area, under the chin and neck to the jugular notch. Additional accesses were made at the corners of the lower jaw. Additional heating of platysma and the upper layers of the skin was conducted. Working conditions: power 16 W, the total power consumption was about 7000 J.

The next stage was lipoaspiration, 10–15 minutes after the beginning of infiltration of subcutaneous fat with a tumescent solution. The puncture in the area of the chin fold was expanded to 3 mm with a blunt dilator and an infiltration cannula was introduced into the widened puncture. By reciprocating movement of the infiltration cannula throughout the volume of the removed subcutaneous fat, infiltration tunnels were formed, while they were placed close to each other in the form of a fan-shaped network, with an approach to the submental area and the front surface of the lower jaw.

Then an optical cannula of a laser device with a diameter of 1 mm and a fiber-optic light carrier in it with the 600 micron thickness of the optic fiber was inserted into the infiltrated subcutaneous fat tissue through a puncture. Fat cells were treated with Nd:YAG laser radiation with a wavelength of 1064 nm. After performing the laser treatment, the optical cannula was extracted from the puncture and the resulting fat detritus of emulsified adipocytes was sucked out of the liposuction area by means of an aspiration cannula using a negative pressure of 0.2–0.3 Bar. After removal of fat detritus emulsified adipocytes from the liposuction area, the dermis was heated to 39–40°C by means of the same optical cannula with a fiber-optic light carrier in it.

At the end of the surgery, a suture with a nonabsorbable propylene thread Prolene 6–0 and an aseptic bandage were applied to the puncture site, and a compression bandage was applied to the neck and chin area.

Procedures for postoperative care were "standard" for all patients: dressings using alcohol chlorhexidine and water-soluble ointments. At the same time, for

7 days after the surgery antibiotic treatment was prescribed with broad-spectrum antibiotics and nonsteroidal anti-inflammatory drugs. The first 7 days after surgery the patient used a compressive dressing round the clock and following 21 days – only at night.

All patients followed a number of recommendations after the procedure:

1. Avoid heavy physical activity for one week;

2. From the second day after the surgery, patients were prescribed a course of physiotherapy: irritative current therapy No.5, from the 6th day patients received ultrasonics with hydrocortisone No. 10;

3. From the 8–12 days a course of 10–12 procedures of manual lymphatic drainage or mechanical massage (LPG, Icoon);

4. Control examinations after 3, 6, 12, 24, 36, 48 months.

Contraindications to laser-assisted liposuction are diabetes mellitus, coagulopathy, connective tissue diseases, etc.

As in any surgical practice with laser-assisted liposuction, there is a risk of complications. In his article, Blum described the most common complications: the appearance of bumps on the skin (0.17%) and prolonged edema (0.09%) [13].

Kutz described specific complications in the form of burns and skin infections, which occurred in 0.93% of cases [14]. Among the possible complications, the formation of hematomas and seromas is also named [15]. In case of aggressive treatment, the formation of retractions and scars is possible. Rare cases of fatal accidents of developing the pulmonary embolism have been described, but with laser-assisted liposuction of the lower limbs [16].

3. Results

Example 1. Patient O., female, 35 years old, came into our clinic complaining of local excess subcutaneous fat in the chin area, smoothed neck-chin corner. Local status: slight decrease in elasticity of the neck skin, slight local excess of subcutaneous fat in the chin area and a smoothed neck-chin corner, the contours of the lower jaw are not changed. Age-related changes of the face and neck according to the Baker's classification type 1. Lipolytic injections and machine cosmetology have failed to produce the expected results.

Based on the examination results, it was decided that the submental area will become the liposuction area constituting the surgical field. In accordance with this, the contour borders of the surgical field were defined and a single surgical access point was set in the submental fold. The contour lines of the surgical field and a given surgical access point were marked on the patient's body in a standing position. During infiltration anesthesia, 90 ml of a tumescent solution was injected. Fat cells were treated with Nd: YAG laser radiation with a wavelength of 1064 nm-12 W. The total power consumption amounted to 2500 J. At a single stage 35,0 of fat detritus was removed, while there was no damage to the surrounding areas, hemorrhage was minimal, and the rehabilitation period was reduced to 4 weeks. The achieved skin retraction gives a pronounced esthetic effect, which persists even one year after the surgery (**Figure 4**).

Example 2. Patient L., female, 44 years old, came into our clinic complaining on local excess subcutaneous fat in the submental area, smoothed neck-chin corner,

Figure 4.
Patient O., female, 35 years old, with age-related changes in the lower third of the face of type I according to the Baker's classification, before and 1 year after the surgery.

Figure 5.
Patient L., female, 44 years old, with age-related changes in the lower third of the face of type II according to the Baker's classification, before and 18 after the surgery.

ptosis of the lower third of the face. Local status: moderate decrease in elasticity of the neck skin, ptosis of the lower third of the face and pronounced change in the contour of the lower jaw, local excess of subcutaneous fat in the submental area associated with them. Age-related changes of the face and neck according to the Baker's classification type 2. She did not visit cosmetologists, and no therapy was carried out in this area.

Based on the examination results, it was decided that the submental area of the neck and the lower jaw will become the liposuction area constituting the surgical field. In accordance with this, the contour borders of the surgical field were defined and a single surgical access point was set in the submental fold. The contour lines of the surgical field and a given surgical access point were marked on the patient's body in a standing position. General clinical examination and tests were carried out. According to the planned scope of surgery, 110 ml of a tumescent solution was injected into the subcutaneous fat. Laser-assisted lipoaspiration was performed according to the protocol described above, based on the degree of soft tissue ptosis. Fat cells were destroyed by ND: YAG laser radiation with wavelength of 1064 nm-13 W. The total power consumption amounted to 3000 J. In addition to standard care after liposuction in the early postoperative period, the patient underwent physical therapy in the form of 12 ultrasound procedures with hydrocartisone. As a result of combined liposuction performed according to the said method, 50.0 of fat detritus was removed at a single stage. The patient was inspected 1.5 years after the surgery: the pronounced esthetic effect is preserved (**Figure 5**).

Example 3. Patient P., female, 49 years old, came to our clinic complaining on local excess subcutaneous fat in the chin area, smoothed neck-chin corner, and loose jowls. Local status: loose jowls, pronounced change in the contour of the lower jaw, local excess of subcutaneous fat in the submental area, smoothed neck-chin corner, neck skin laxity and decreased platysma tone. Age-related changes of the face and neck according to the Baker's classification type 3. The lipolytic injections over the course of one year did not provide the required esthetic result.

Based on the examination results and diagnosis, it was decided that the submental area, the lower jaw area and the neck area from its submental area to the level of the jugular notch will become the liposuction area constituting the surgical field. In accordance with this the contour lines of the surgical field and surgical access points were defined –one in the submental fold and two at the corners of the inferior jaw, one point of surgery access on each side of the neck. General clinical examination and tests were carried out and according to the planned scope of suction-assisted fat removal; 170,0 of tumescent solution was injected. Fat cells were destroyed by ND: YAG laser radiation with wavelength of 1064 nm-14 W. The total power consumption amounted to 3500 J. Postoperative wound treatment and care in the postoperative period were carried out in a similar way as in the above cases. In the early postoperative period after liposuction, the patient underwent physical therapy in the form of 12 ultrasound procedures with hydrocartisone and 12 ultrasound procedures with a drug based on the collagenolytic protease complex "Fermencol gel". As a result of combined liposuction performed according to the said method, 45.0 of fat detritus was removed at a single stage. The patient was inspected two years after the operation: the esthetic effect is preserved (**Figure 6**).

Example 4. Patient A., female, 58 years old, came to our clinic complaining on local excess subcutaneous fat in lower third of the face and neck area, loose jowls. Local status: loose jowls and pronounced change in the contour of the lower jaw associated with them, local excess of subcutaneous fat in the submental area and neck area, smoothed neck-chin corner, saggy neck skin with circular wrinkles, decreased platysma tone. Age-related changes of the face and neck according to the Baker's classification type 4. She did not visit cosmetologists and plastic surgeons.

Based on the examination results, it was decided that the submental area, the lower jaw area and the neck area from its submental area to the level of the jugular notch will become the liposuction area constituting the surgical field. In accordance with this, the contour lines of the surgical field and surgical access points were defined – one in the submental fold and two at the corners of the inferior jaw, one point of surgical access on each side. According to the planned scope of lipoaspiration, 180 ml of tumescent solution was injected into the subcutaneous fat. Fat cells were destroyed by ND: YAG laser radiation with wavelength of 1064 nm-16 W. The total power consumption amounted to 3500 J. In the postoperative period, the patient's wounds were bandaged using alcohol chlorhexidine and water-soluble ointments. At the same time, 7 days after the surgery the patient took broad-spectrum antibiotics and nonsteroidal anti-inflammatory drugs. The first 7 days after

Figure 6.
Patient P., female, 49 years old, with age-related changes in the lower third of the face of type III according to the Baker's classification, before and 2 years after the surgery.

Figure 7.
Patient A., female, 58 years old, with age-related changes in the lower third of the face of type IV according to the Baker's classification, before and 5 years after the surgery.

the surgery the patient used a compressive dressing round the clock and the following 21 days only at night. In the early postoperative period after the liposuction physiotherapy of the liposuction areas was performed in the form of 12 ultrasound procedures with hydrocartisone and 12 ultrasound procedures with a drug based on the collagenolytic protease complex "Fermencol gel", lymphatic massage – 10 procedures. As a result of combined liposuction performed according to the said method, 75 ml of fat detritus was removed at a single stage. The control examination 5 years after the surgery demonstrated that the esthetic effect is preserved (**Figure 7**).

4. Discussion

After surgery, all patients had been discharged to outpatient after-treatment and returned to active social life in 7 days. Among postoperative complications, in 15% of cases the formation of small infiltrates up to 3 cm^2 in the submental area at the subcutaneous fat level must be noted. However, they successfully responded to 4 weeks of treatment with medication and physiotherapy. In addition, there was III A degree skin burn with a diameter up to 1 cm in 2 (0.4%) cases, which ended in full-fledged epithelization within 1 month.

All clinical observations achieved good esthetic results. Control examinations conducted after 3 to 48 months demonstrate the persistence of the achieved effect.

Apfelberg first demonstrated the advantage of laser-assisted liposuction over tumescent liposuction in 1992, which involved reduction of pain syndrome, hematomas and edema of the surrounding tissues [17]. In 2006 by a magnetic resonance imaging examination carried out before and 3 months after this surgery Kim showed overt and significant reduction of adipose tissue in the submental area [18]. Mordon and co-authors calculated the amount of energy applied to adipose tissue to obtain the maximum effect with subsequent derma retraction, which usually is min. 3000 J of energy spent on 5 cm^3 [19]. Gain and his co-authors analyzed more than 300 sources in Russian and foreign scientific literature concerning laser lipolysis and the conclusion of this work is the proven effectiveness and safety of this surgery, as well as the continuing research interest in the effects of lasers on adipose tissue [20].

The main advantage of the Nd:YAG laser is skin retraction due to the formation of new collagen, reduction of intra- and postoperative hemorrhage, as well as reduction of the number of adipocytes. The surgeries that we have already performed and the developed algorithm demonstrate the best esthetic results over a long observation period (about 8 years), allowing us to solve esthetic problems of the lower third of face, submental area, neck, associated with not only excess fat deposit, but also gravitational ptosis. That being said, this approach provides an opportunity to reduce the recovery period. Positive results were achieved in all age groups under the different types of ptosis. In cases of I, II and III type of ptosis of soft tissues according to Baker's classification, we achieve proper correction of the lower third of the face with laser-assisted liposuction. In cases of patients with IV type of ptosis according to Baker's classification, this surgery allows for reverting involutional changes to I type.

5. Conclusion

Consequently, based on our experience it is safe to say that laser lipolysis is one of the most suitable methods of controlling various types of aging of the lower third of the face. The surgery is minimally invasive and does not require a long recovery period. This surgery can be used as a stand-alone method as well as in combination with the implantation of threads and with various face lifting methods, thus significantly improving the esthetic effect.

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Chapter 15

Power-Assisted Liposuction Mammaplasty (PALM): A Short Scar Mammaplasty in Gigantomastia

Nicolas Abboud and Marwan Abboud

Abstract

Breast reduction has been widely studied throughout the years, with different types of resection and breast reshaping techniques being described based on one or two pedicles. This chapter introduces the combination of parenchymal resection and liposuction to treat Gigantomastia, leaving a short scar. Liposuction improves breast remodeling, whereas breast glandular resection and repositioning enhances the upper pole fullness. The Power-Assisted Liposuction Mammaplasty (P.A.L.M.) technique is a safe and reliable procedure, insuring an optimal vascularization to the breast through the preservation of the central, superior and lateral pedicle, thus reducing the complication rate. In this chapiter we emphasize the importance of the preoperative markings, considered as essential for optimal results.

Keywords: Breast reduction, mammaplasty, power-assisted liposuction, tri-pedicled, central, superior and lateral based pedicle, short scar, gigantomastia, preoperative markings

1. Introduction

The various techniques of reduction mammaplasty and mastopexy include free nipple [1], wise pattern [2], bipedicle [3–5], inferior pedicle [6, 7], vertical pedicle [8–11], superomedial [12–14], superolateral [15, 16], and septal-based pedicle [17, 18]. There are specific advantages to each technique. However, the majority of those surgeries encounter the identical challenges of recreating upper-pole fullness, conserving the sensation of the nipple areola complex (NAC), and maintaining adequate blood supply with massive breast ptosis. Current reduction mammaplasty techniques identify parenchymal reshaping and resection as critical for maintaining shape. Liposuction of the breast [19–27] by itself or combined with resection of the parenchyma has been utilized safely and reliably since the early 1980s for reduction mammaplasty. One suitable technique for breasts of varying sizes is reduction mammaplasty with liposuction, with aspirate volumes greater than 2000 cc. Liposuction-assisted reduction mammaplasty has had positive results and is associated with very low morbidity rates. Over a 10-year postoperative monitoring period, the safety and reliability of liposuction-assisted vertical reduction mammaplasty has been verified [8, 9, 26, 28].

Liposuction-assisted vertical reduction mammaplasty has a few complications, such as kinking of the pedicle in the markedly glandular breasts, reduction in NAC sensitivity, an ill-defined inframammary fold, and delayed wound healing [28–33]. More recently, the senior author introduced a scarless breast reduction procedure for fatty breasts, associating an extensive breast liposuction to the use of internal threads [34]. We managed to treat fatty breasts mini-invasively by emptying the breast from its volume and molding it accordingly to its desired form and position utilizing loops [34]. The use of internal threads has proven its effectiveness in other breast and body contouring procedures [35–40]. Nevertheless, in breast reduction, this approach is limited to more massive glandular breasts necessitating glandular resection [34].

The power-assisted liposuction mammaplasty (PALM) technique was created to address the complications of liposuction-assisted vertical reduction mammaplasty and the limitations of existing breast reduction techniques [41].

The main procedural steps of PALM include the following:

1. Liposuction of the lower and external poles and areolar zones to minimize not only tension but also kinking of the gland and NAC during transposition.

2. Maximizing the NAC arterial supply and venous return by depending on breast liposuction for volume reduction as well as minimizing glandular resection and preserving the central, lateral, and superior pedicles.

3. Enabling glandular rotation and NAC elevation by creating a subcutaneous upper-pole pocket that can comfortably accommodate the elevated and transposed breast tissue without tension while providing upper-pole fullness.

4. Tunnelization of the area beneath the inframammary fold to promote skin retraction and redraping and to avoid puckering.

5. Liposuction of the lower lateral quadrant of the breast to improve breast contour and shape, or overall breast liposuction to further decrease breast size or improve symmetry. The authors share their experience by presenting their experience with the PALM technique's indications, surgical approach, and outcomes.

6. Suture placement from the dermis to the chest wall for glandular suspension to maintain and ensure longevity of upper-pole fullness and to recreate the inframammary fold.

2. Indications

Our procedure preserves maximal venous and arterial blood supply to the breast and NAC by basing the NAC on the central, lateral, and superior pedicles. Resected parenchymal tissue is minimized and parenchymal transposition is expedited with the use of power-assisted liposuction as the main tool for decreasing breast volume. Sturdy sutures from the dermis to the chest wall enable glandular suspension, keeping upper-pole fullness and recreating the inframammary fold. Because the PALM technique preserves blood supply to the breast and NAC, this technique can be safely performed for patients with gigantomastia, breast hypertrophy, and severely ptotic breasts (NAC elevation up to 28 cm). In our experience, the resection pattern relies on the planned NAC elevation. When the planned NAC elevation is less than 10 cm, vertical wound closure is planned preoperatively. For NAC elevations more than 10 cm, a short T or J wound-closure pattern is decided intraoperatively after elevation of the NAC to the desired position and redraping the parenchymal tissues.

3. Preoperative planning and markings

With the patient in the standing position, preoperative markings are made. The midline, infra-mammary fold, breast axis and anterior axillary lines are drawn. The nipple-to-sternal notch (N-SN) distance for each breast is determined with a measuring meter and then marked directly on the patient. The sternal notch to IMF distance is marked for both breasts, and the shortest length is reported on the breast to identify the position of the new nipple. This point is located 9–11 cm from the midline (distance x), and represents the medial border of the areola. Note that the distance between the lateral border of the areola and the anterior axillary line should always be x + 2 cm (**Figure 1**).

A mosque pattern is utilized to draw the periareolar markings as described by Le Jour et al. [9]. The mosque's circumference depends on the breast size [41, 42];

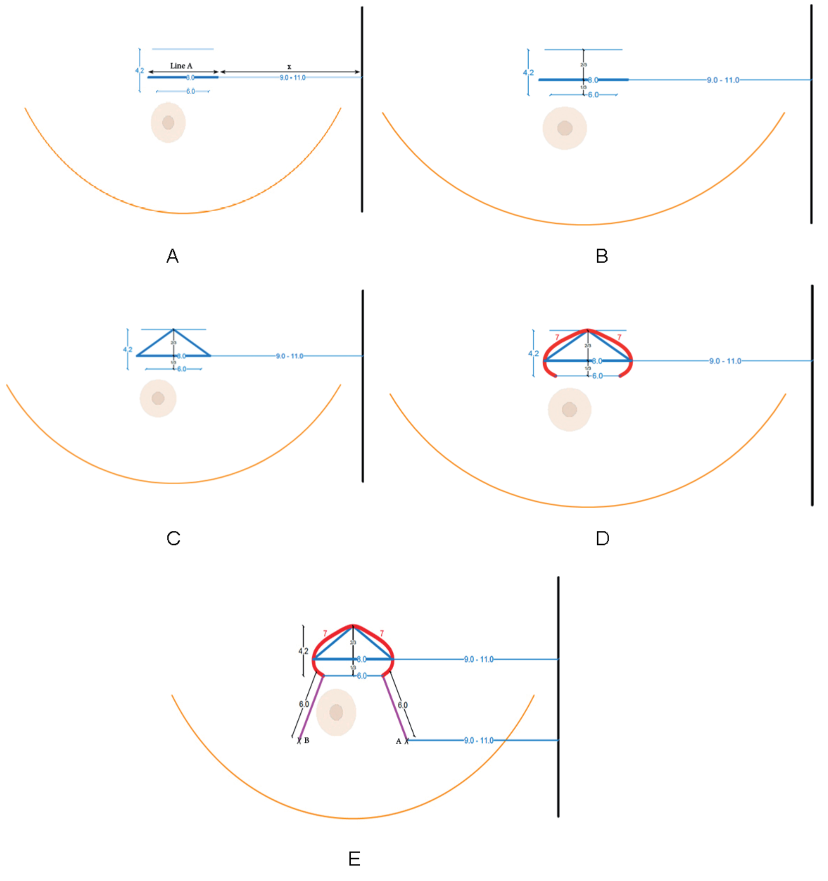

Figure 1.
(A-E) the sternal notch to IMF distance is marked for both breasts, and the shortest length is reported on the breast to identify the position of the new nipple. This point is located 9–11 cm from the midline (distance x), and represents the medial border of the areola. A mosque pattern is utilized to draw the periareolar markings with its circumference ranging from 14 to 16 cm long and 6 to 10 cm wide (line a). The distance between the upper and lower pole of the mosque is represented by the mediator to the line a, and measures 4.2 cm with two third of its length located above the horizontal line.

it ranged from 14 to 16 cm long and 6 to 10 cm wide (line A). The distance between the upper and lower pole of the mosque is represented by the mediator to the line A, and measures 4.2 cm with two third of its length located above the horizontal line. Rotating the breast superolaterally and then superomedially allows the vertical wound closure lines to be drawn along the breast axis, marking 6 cm from the lower edges of the mosque pattern (point A and B). To indicate the planned vertical wound closure, the lines are joined at the mid-distance between the native IMF and the points A and B (**Figure 1**).

3.1 Inverted T or J scar

When a short T or J wound closure is planned, the vertical lines are interrupted at 6 cm (point A and B) and continued as diagonal lines pointing both medially and laterally at 45° in opposite directions. To represent the position of the new inframammary fold, these diagonal lines are joined by a horizontal line located at mid-distance (named a and b) between the IMF and both points A and B (**Figure 2**).

3.2 Vertical scar

When drawing a vertical scar, a horizontal line is marked between both points A and B, followed by a mediator extending inferiorly to this axis until reaching a point located at mid-distance between the native IMF and both points A and B, named point C. Point C will be joined by two diagonal axes originating from both points A and B (**Figure 3**).

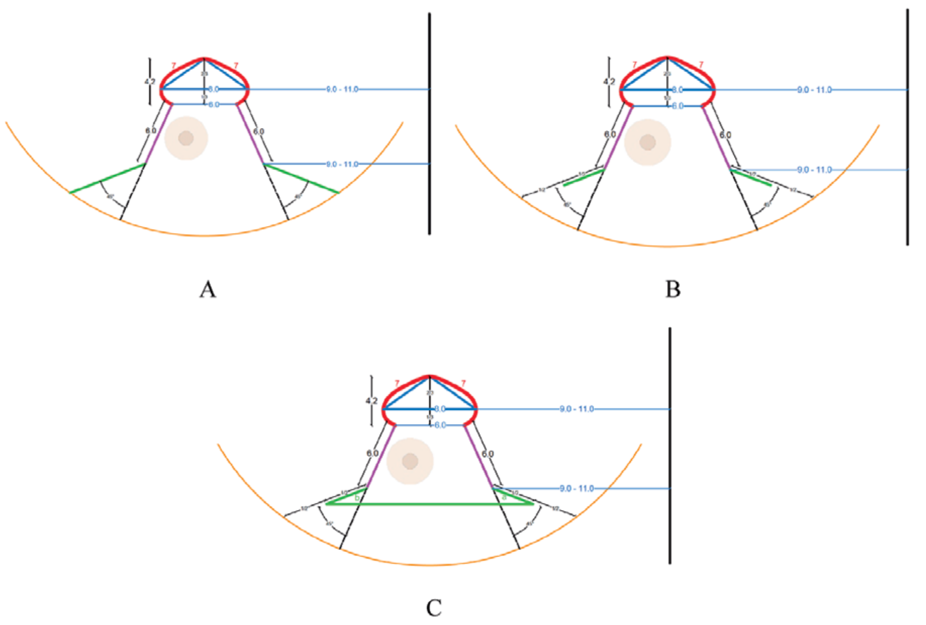

Figure 2.
(A-C) when a short T wound closure is planned, the vertical lines are interrupted at 6 cm (point a and B) and continued as diagonal lines pointing both medially and laterally at 45° in opposite directions. To represent the position of the new inframammary fold, these diagonal lines are joined by a line located at mid-distance (named a and b) between the IMF and both points a and B.

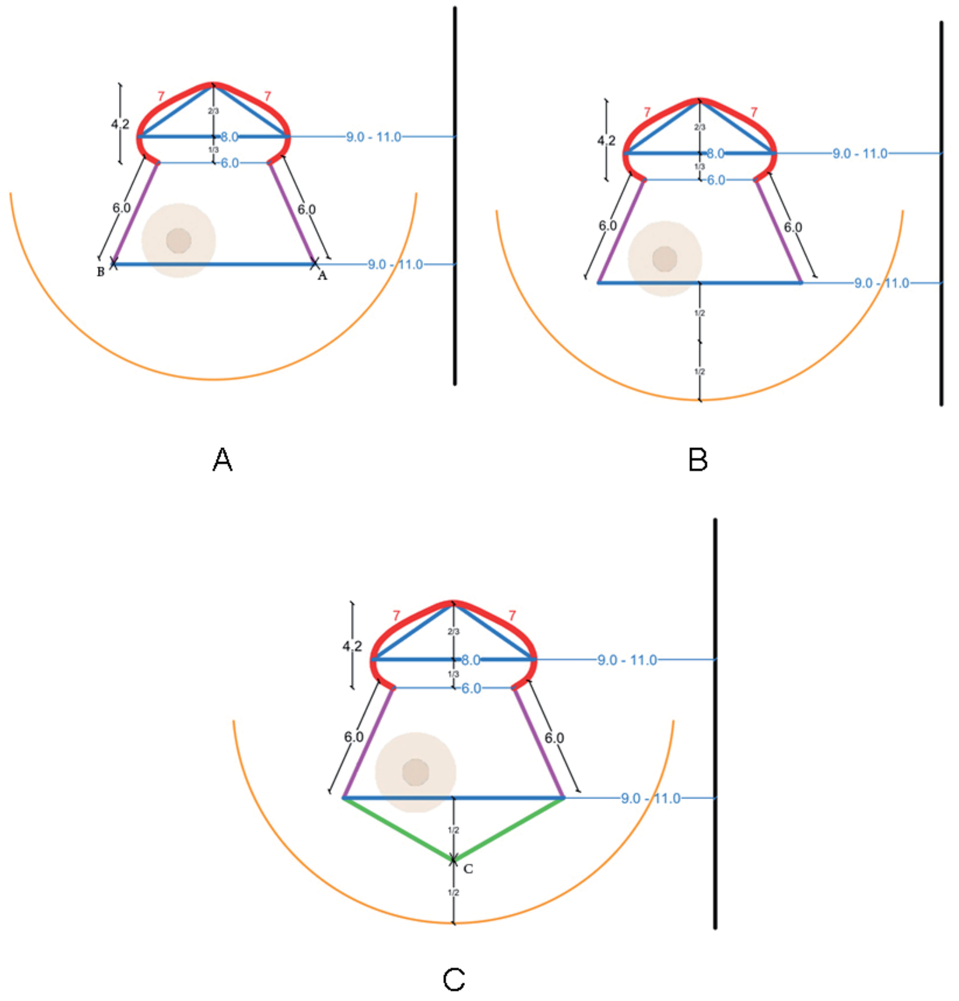

Figure 3.
(A-C) when a vertical scar is planned, a horizontal line is marked between both points A and B, followed by a mediator extending inferiorly to this axis until reaching a point located at mid-distance between the native IMF and both points A and B, named point C. point C will be joined by two diagonal axes originating from both points A and B.

After the preoperative markings are made on one breast, symmetric markings are made on the contralateral breast by pushing the breasts together and duplicating the periareolar and medial/vertical markings. All of the distances are checked per-operatively to adjust the pre-operative drawings, if judged necessary.

Additional preoperative markings include the zones of liposuction, borders of the superior pocket, position of the dermal-chest wall glandular suspension sutures. The planned superior pocket extends inferiorly to the third rib space, laterally from the pectoralis muscle, medially to 3 cm from the midline, and superiorly to the first rib. The dermal-chest wall sutures extend medially from the second, third, fourth, and sixth rib (**Figure 4**).

Video 1 shows the preoperative markings.

Video 1 PALM markings: https://youtu.be/234SxcYo9eE

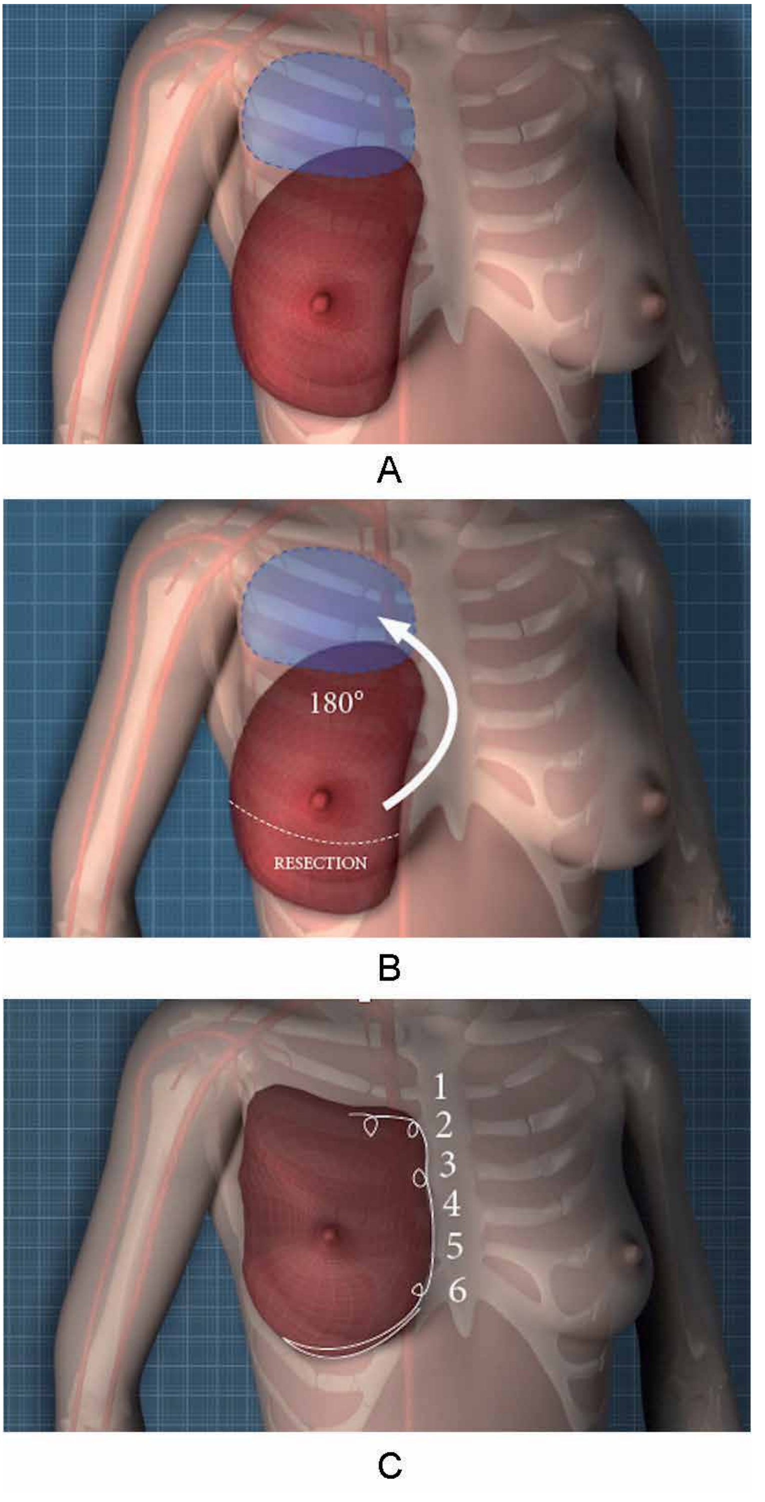

Figure 4.
(A) The blue dotted line and shading indicate the upper pocket. (B) the glandular excess located in the lower pole is resected (white dotted lines). The gland is rotated 180° supero-medially to lift the breast and fill the previously dissected pocket. (C) the glandular suspension is performed through the placement of a barbed suture passed from dermis to chest wall (solid white line). Suturing extends from the second, third, fourth and sixth rib spaces and is continued laterally from the sixth rib space to the breast axis to recreate the IMF. The numbers indicate the rib spaces.

4. Operative technique

4.1 Infiltration

General anesthesia is administered and then the patient is placed in the supine position with the arms abducted at 45°. The markings are verified and corrected if judged necessary. The zone of deepitheliazation, breast gland, and lower pole of each breast are infiltrated with a solution that contains epinephrine 1:100,000 per liter of normal saline associated with 5 mL of Exacyl® (tranexamic acid) 0.5 g/5 mL using a power-assisted liposuction system (Lipomatic, Eva SP, EUROMI SA, Verviers, Belgium) and a 3 mm multihole cannula [43]. The infiltration volume depends on the breast size, mean 280 mL (range 100 mL to 400 mL).

4.2 Breast liposuction

Breast liposuction is performed with the Lipomatic machine in a closed system following the Power-Assisted Liposuction and Lipofilling (PALL) principles, as described in previous articles by the senior author [41, 44–47]. However, liposuction of the breast can also be performed by using a conventional liposuction with the hand piece attached to a suction system. The authors' extensive experience with the Lipomatic device enables more precise zones of liposuction and decreased operative times through less surgeon fatigue. A multiple-hole blunt cannula (3 or 4 mm) is used to perform liposuction to the lower breast quadrants and the retroareolar area in a superficial plane to detach the skin and facilitate undermining. It is performed in a deep plane in the inferior and external poles of the breast in order to reduce the volume.

To enhance matrix dissociation, supplemental subcutaneous tunnelization is performed at the retroareolar space and at the lateral and inferior poles of the breast. Tunnelization extends inferiorly to the inframammary fold in order to accelerate translation of the breast to its new position under minimal tension and to assist with redraping of the skin. The aspirate volume depends on both the shape and size of the breast as well as the extent of breast ptosis, intended amount of breast tissue to be resected, and type of breast parenchyma.

4.3 Deepithelialization

A 42-mm to 45-mm areolar marker is used to delineate the NAC, and a scalpel is used to deepethialize the pedicle along the preoperative markings. At the border of the incision, the scalpel is beveled to deepithelialize more than 5 mm of the epidermis; this is an important maneuver for subsequent wound closure.

4.4 Pedicle dissection and inferior resection of the gland

An incision is performed on the gland along the preoperative drawings. Dissection of the dermis is then performed 5 mm from the edge of the wound with a rim of dermis extending beyond the epidermis along the wound edge. During NAC dissection, a large zone of deepithelialized skin is preserved circumferentially. Both inferior and lower lateral dissection of the gland is then performed to the pectoralis fascia. Lateral dissection, which is enabled by the liposuction and tunnelization performed earlier in the procedure, is started 6 cm from the base of the mosque pattern. The thickness of the inferior pole flap is similar to that of the postmastectomy skin flap because skin undermining is limited. Medial dissection is performed in a beveled manner 2 cm to 3 cm from the edge of the medial.

To maintain fullness of the medial flap, a vertical line is made to the pectoralis fascia. A wide upper-inner supra-aponevrotic pocket is created and dissected on the pectoralis fascia. This pocket extends inferiorly to the third rib space, laterally from the axis of the breast, medially 2 cm to 3 cm from the midline, and superiorly to the first rib. If a subcutaneous tension is judged too important in the upper pole of the breast, a vertical dissection through the gland can be performed to release the tethering fibers.

The upper-inner pocket is extended to minimize tension on the NAC and to ensure upper-pole fullness, because the upper-inner pocket will ultimately contain the upper bulk of the transposed gland. The dissection approach preserves the rich periareolar venous network of the NAC as well as the superior, central, and lateral pedicles (**Figure 4A**).

The excess fatty-glandular tissue in the lower pole of the breast is estimated and resected (**Figure 4B**).

The NAC and breast parenchyma are rotated superomedially by 180° to fill the upper-inner pocket and lift the breast (**Figure 4B**). The NAC is then affixed to its predetermined position. To suspend the breast tissue inside the subcutaneous pocket, barbed running sutures (V-Loc 180, 2–0, Covidien, Mansfield, MA) are placed from the dermis to the chest wall.

Needle bites at the caudal edge of the dermo-glandular flap are utilized to prevent medial tension on the NAC and a medially pointing nipple. The sutures extend medially in a horizontal manner from the middle aspect of the pocket at the level of the second edge to the medial edge of the pocket 2 cm to 3 cm from the midline. Suspension then continues caudally with V-Loc sutures placed in a vertical manner from the second, third, fourth, and sixth rib cartilages (**Figure 4C**).

To suspend the breast tissue inside the subcutaneous pocket, glandular to chest wall sutures are used to avoid tension on the transposed gland and to maintain adequate shaping of the breast mound. After transposition of the gland, the excess tissue localized in the lower part of the breast is originating from the inferior and lateral zone of the breast in the inverted T technique. An horizontal and lateral suture is performed using V-Loc sutures, facing the sixth rib space to the breast axis line and then continued in a superficial plane (**Figure 4C**).

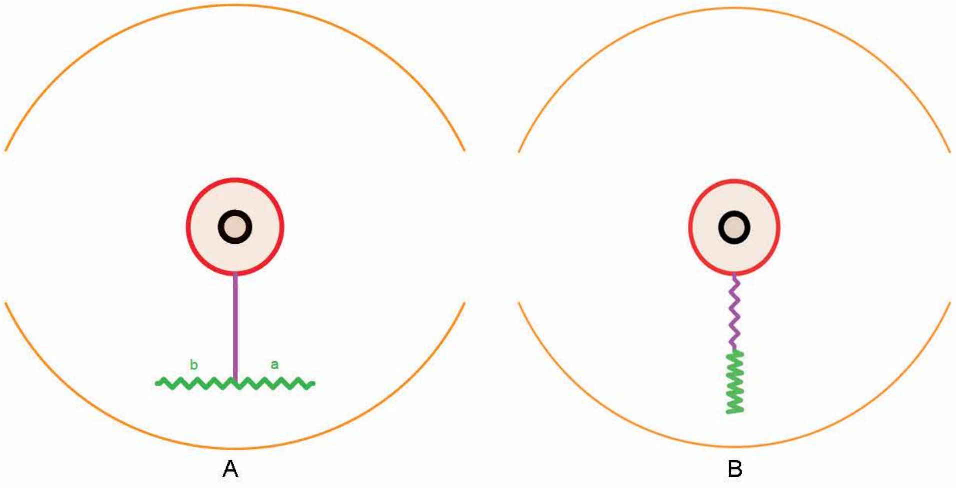

Figure 5.
(A-B) with the same barbed thread, suturing is continued superficially to close the wound. (A) Closure with a short T scar: The reported a and b lengths are equal to the previously measured a and b mid-distances located between the IMF and both points a and B in ***Figure 2C****. (B) Closure with a vertical scar.*

Redraping of the periareolar and vertical wounds is performed using skin staples, which are removed when the final skin closure takes place. In cases where vertical wound closure are not adequate, a peroperative decision regarding pattern of skin closure (either short T or J closure) is made (**Figure 5A**). Closure of the vertical and periareolar wounds is achieved under minimal tension using a 2–0 V-Loc running sutures (**Figure 5**). At the lower part of the wound closure, a subcutaneous drain is placed and secured to the skin. The same procedure is then performed contralaterally.

When necessary, subsequent liposuction is performed. The indications for additional liposuction include treatment of breast asymmetry or fullness at the lower lateral quadrant requiring correction, excess fat necessitating additional volume reduction, and the need for subcutaneous undermining of the lateral breast to relieve persistent tension after the transposition of the breast to its new position.

5. Wound closure

Wound closure is performed in two planes by a single surgeon. The deep plane consists of suturing the dermis to the costal perichondrium in a continuous fashion. The superficial plane is sutured utilizing a running barbed suture through the de-epithelialized dermis, allowing the apposition of the epidermis with minimal tension [48] (**Figure 5**).

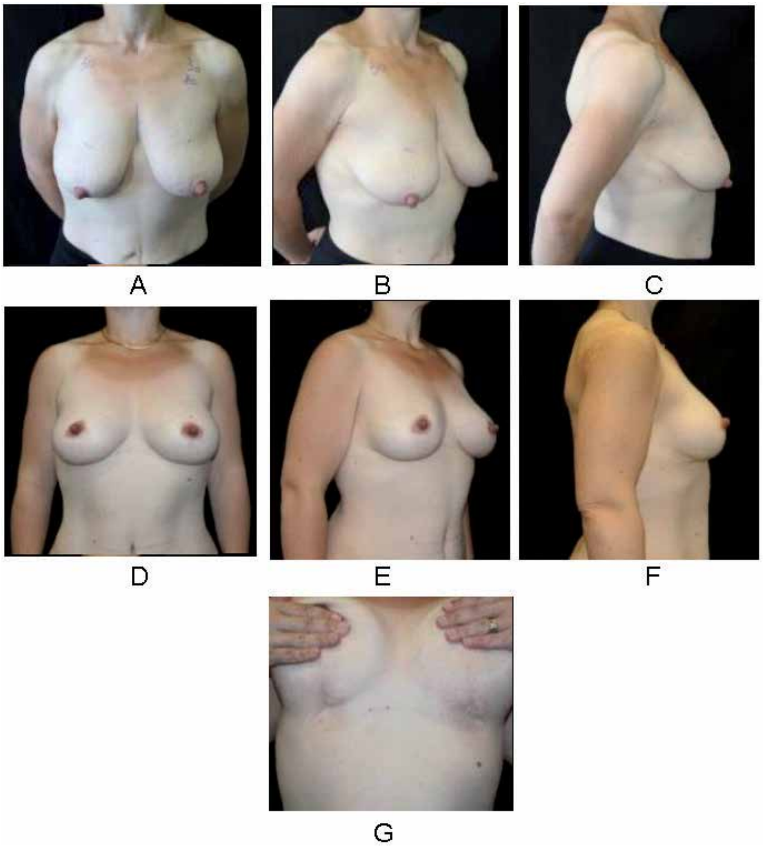

Figure 6.
(A, B, C) preoperative photo of a 45-year-old female patient presenting with bilateral breast hypertrophy and moderate ptosis. The patient underwent a P.a.L.M. procedure using a vertical scar with NAC elevation of 10 cm on the right breast and 10 cm on the left, liposuction of 650 mL on the right breast and 650 mL on the left breast, glandular resection 150 g on both breasts. (D, E, F, G) results at 24 months postoperatively.

Video 2 shows the surgical procedure.
Video 2 PALM surgery: https://youtu.be/BC2R5iYR7Fo
Clinical cases are shown in **Figures 6–11**.

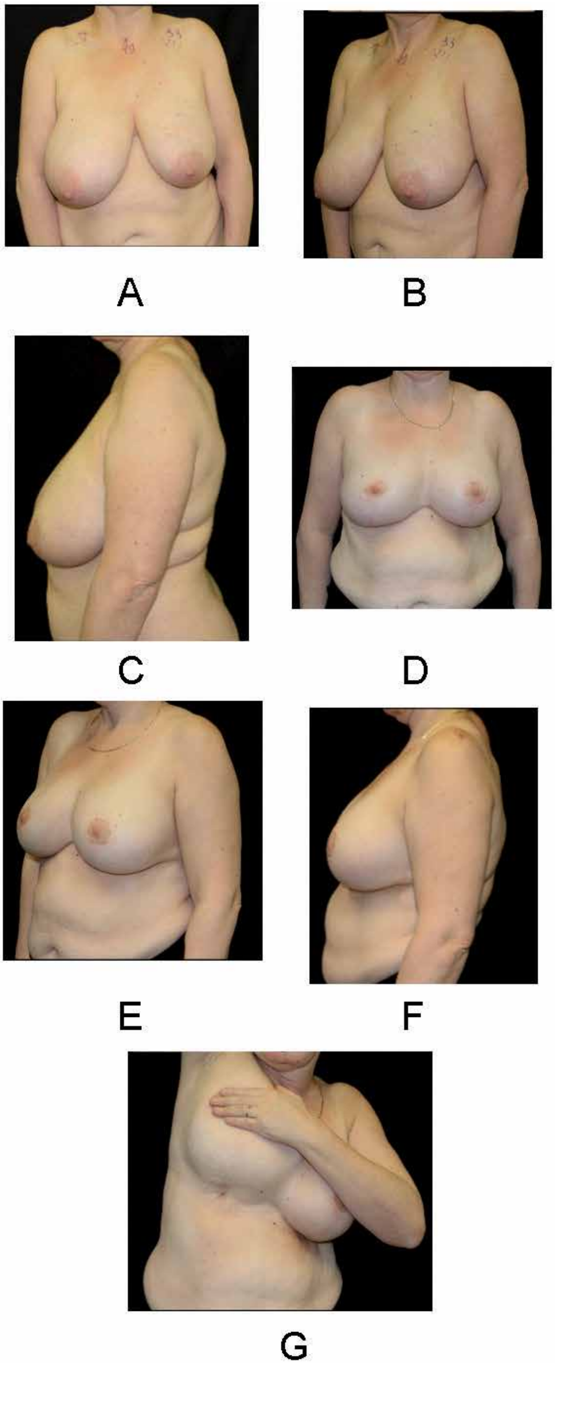

Figure 7.
(A, B, C) preoperative photos of a 49-year-old female patient presenting with bilateral breast gigantomastia, breast asymmetry and ptosis with distance from nipple-to-sternal notch of 52 cm on the right breast and 33 cm on the left. The patient underwent a P.a.L.M. procedure using a vertical scar with NAC elevation of 16 cm on the right breast and 12 cm on the left, liposuction of 800 mL on the right breast and 400 mL on the left breast, glandular resection of 260 g of the right breast and 150 g from the left. (D, E, F, G) results at 36 months postoperatively.

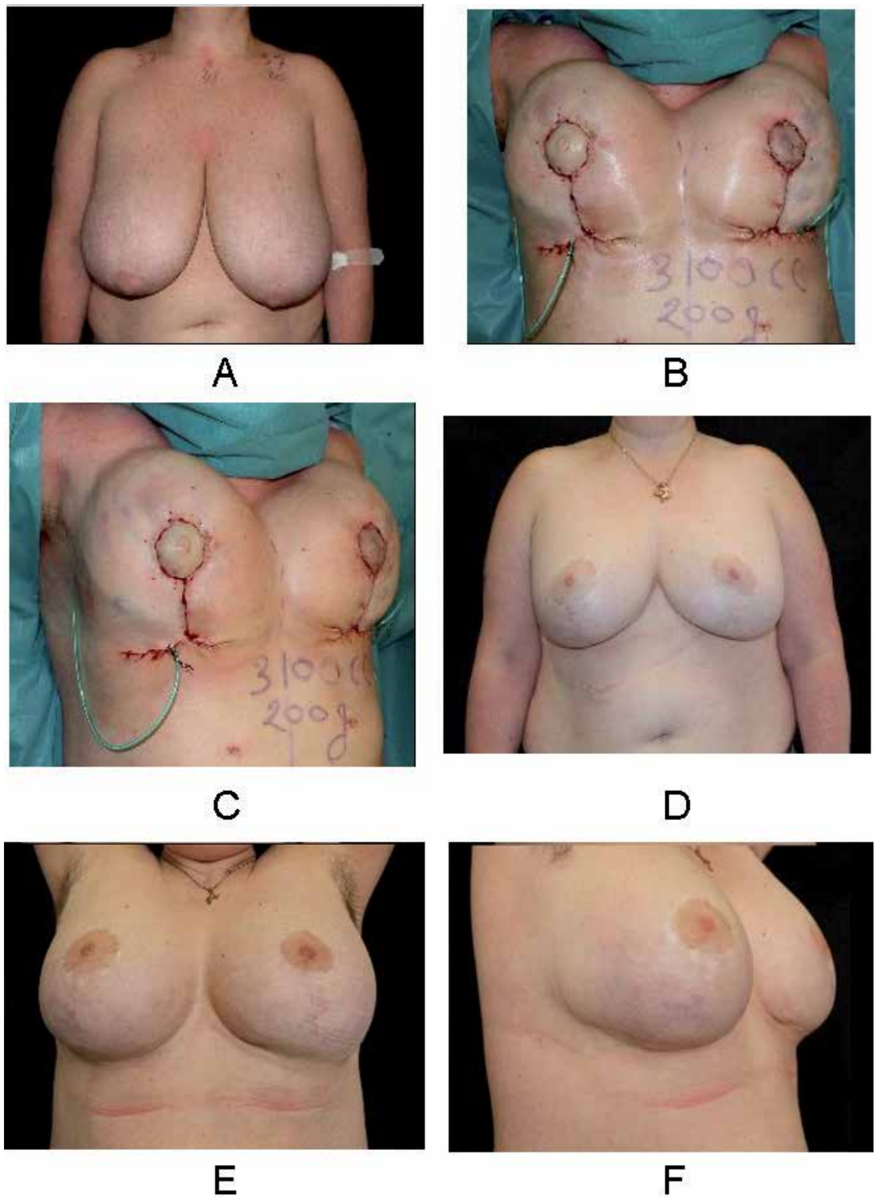

Figure 8.
(A) Preoperative photo of a 41-year-old female patient presenting with bilateral breast gigantomastia with asymmetry, breast ptosis and massive weight loss, with a distance from nipple-to-sternal notch of 37 cm on the right breast and 37 cm on the left. The patient underwent a P.a.L.M. procedure using a short T scar with NAC elevation of 17 cm on the right breast and 19 cm on the left, liposuction of 1450 mL on the right breast and 1650 mL on the left breast, glandular resection of 100 g of the right breast and 100 g from the left. (B, C) per-operative views. (D, E, F) results at 48 months postoperatively.

6. Postoperative care

A drain is left in place at the lower area of each breast for 48 hours or until the drainage becomes serosanguinous or serous and decreases in the daily average amount.

Gauze dressing is utilized to cover the breast wounds. One to two days postoperatively, the patient is discharged from the hospital with instructions to wear a compression bra for 6 weeks. Then, annually, patients receive postoperative breast imaging.

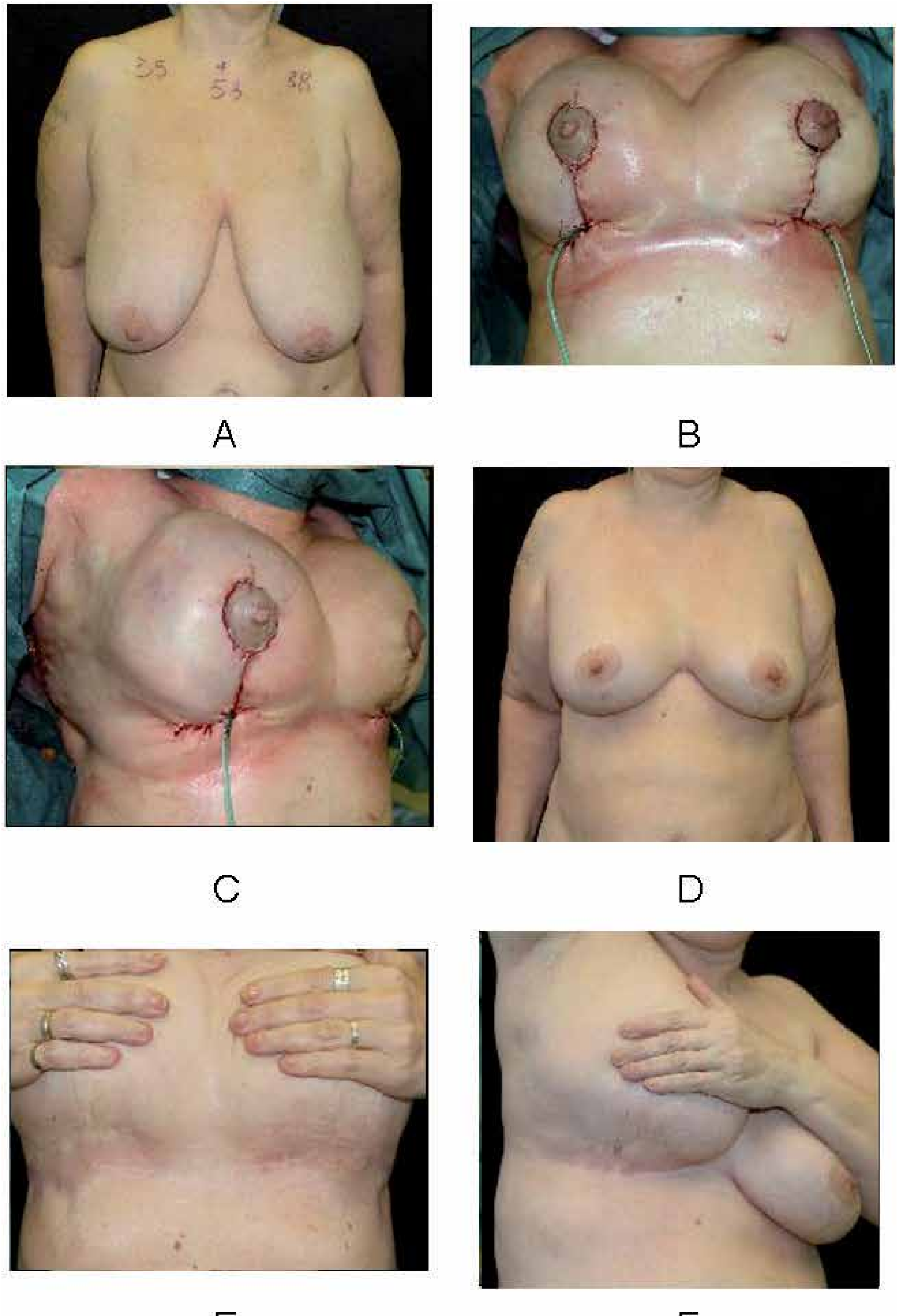

Figure 9.
(A) Preoperative photo of a 53-year-old female patient presenting with bilateral breast gigantomastia, severe ptosis and massive weight loss, with a distance from nipple-to-sternal notch of 35 cm on the right breast and 38 cm on the left. The patient underwent a P.a.L.M. procedure using a short T scar with NAC elevation of 14 cm on the right breast and 17 cm on the left, liposuction of 950 mL on the right breast and 1100 mL on the left breast, glandular resection of 150 g of the right breast and 150 g from the left. (B, C) per-operative views. (D, E, F) results at 36 months postoperatively.

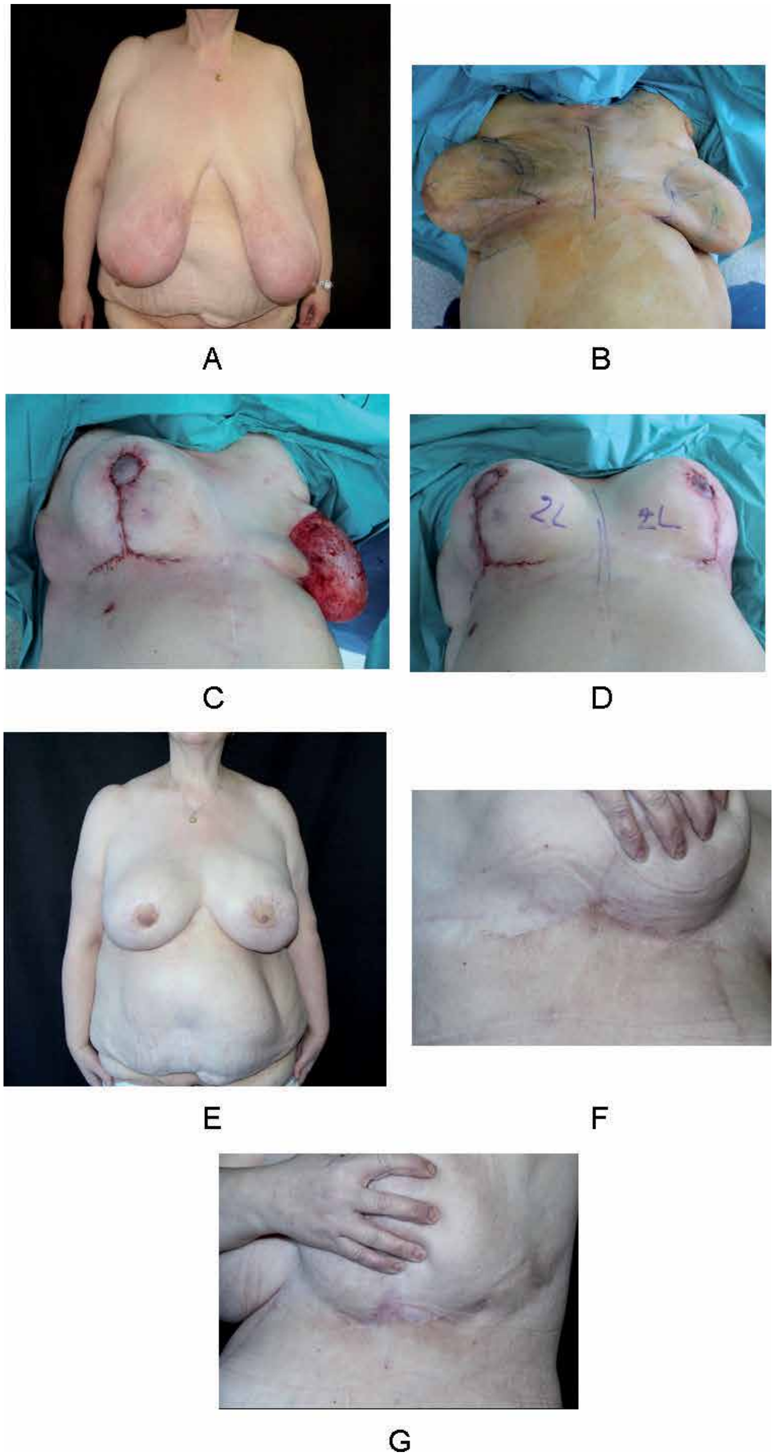

Figure 10.
(A) Preoperative photo of a 56-year-old female patient presenting with massive ptosis and massive weight loss. The patient underwent a P.a.L.M. procedure using a vertical scar with NAC elevation of 25 cm on the right breast and 29 cm on the left, liposuction of 2000 mL on the right breast and 2000 mL on the left breast, glandular resection of 200 g of the right breast and 400 g from the left. (B, C, D) per-operative views. (E, F, G) results at 24 months postoperatively.

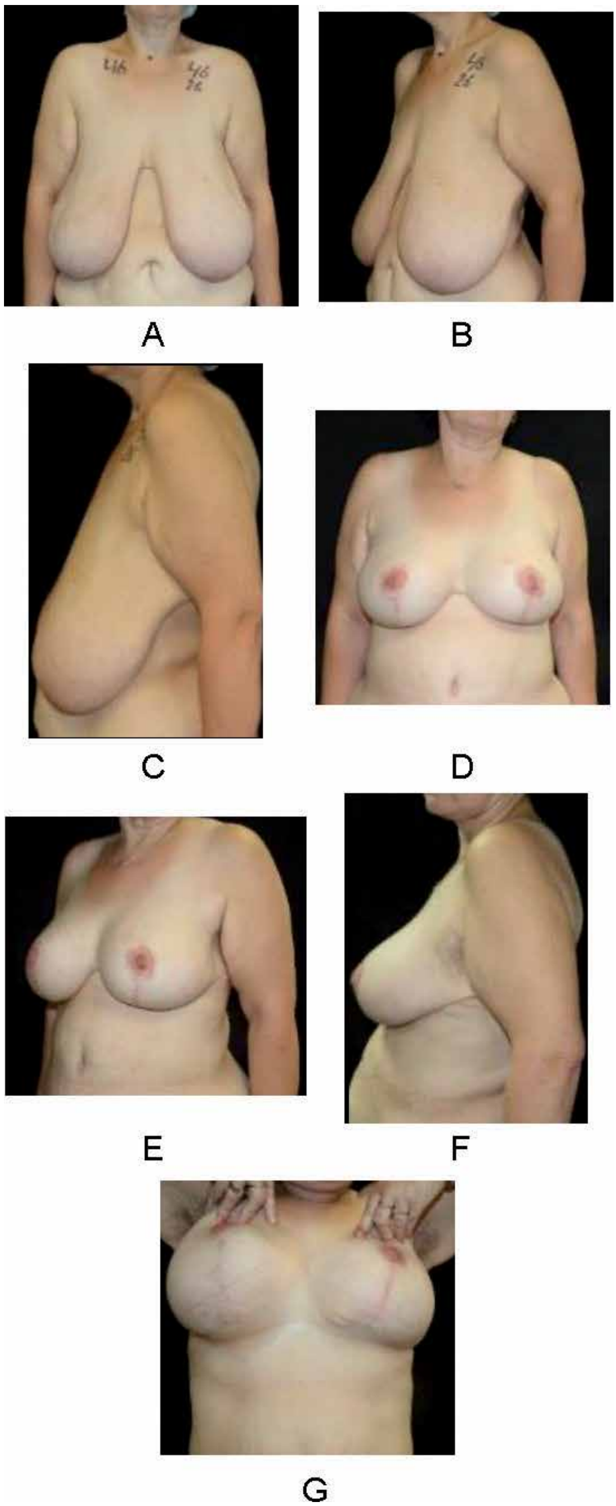

Figure 11.
(A, B, C) preoperative photos of a 50-year-old female patient presenting with gigantomastia, severe ptosis and massive weight loss, with a distance from nipple-to-sternal notch of 46 cm on the right breast and 46 cm on the left. The patient underwent a P.A.L.M. procedure using a short T scar with NAC elevation of 20 cm on the right breast and 20 cm on the left, liposuction of 2500 mL on the right breast and 2500 mL on the left breast, glandular resection of 120 g of the right breast and 150 g from the left. (D, E, F, G) results at 36 months postoperatively.

7. Outcome

A total of 426 consecutive women (852 breasts) underwent breast reduction with the PALM technique from January 2008 to January 2019. The NAC was based on the central, lateral, and superior pedicles. The parameters of interest included BMI, age, previous breast surgery, smoking, N-SN distance, weight of the resected specimen, preoperative breast size, extent of NAC elevation, total volume of fat aspirated per breast, and the type of final wound closure.

The patient comorbidities noted included diabetes mellitus, obesity, hypertension, coronary artery disease, smoking, and breast cancer. Patients presenting after implant removal, in addition to those presenting for unilateral or breast reduction after any type of breast oncologic surgery were excluded from the study. Complications such as hematoma, partial areolar necrosis, seroma, wound dehiscence and/or wound infection were also recorded. Data was integrated and analyzed in a computerized database. All patients are followed up for 2 years following surgery.

The mean age of the patients was 39 years (range, 20–69 years), the mean BMI was 31 kg/ m^2 (range, 24–43 kg/m^2), the mean NAC elevation was 17 cm (range, 10–30 cm), and the mean N-SN distance was 37 cm (range, 29–49 cm). Thirty-seven of the 426 patients (9%) were smokers. The mean glandular resection mass was 245 g (range, 40–630 g), and the mean lipoaspirate volume was 750 mL per breast (range, 270–3200 mL). Twenty-nine patients (7%) presented with gigantomastia. The mean glandular resection mass per breast was 3.1 kg (range, 2.9–3.5 kg), and the mean body weight of these 11 patients was 91 kg (range, 82–99 kg) (**Tables 1** and **2**).

A short T wound-closure pattern was applied for 596 of the 856 breasts (71%), whereas the vertical and J wound-closure patterns were applied for 204 breasts

Number of patients	426
Number of breasts	852
Age (years)	39 (range 20–69)
BMI (kg/m^2)	31 (range 24–43)
Number of smokers	37

Table 1.
Patients demographics.

NAC elevation (cm)	17 (range 10–30)
N-SN distance (cm)	37 (29–49)
Liposuction per breast (mL)	750 (range 270–3200)
Glandular resection	245 (range 40–630)
Number of breasts treated with vertical scar	204
Number of breasts treated with short T scar	596
Number of breasts treated with J scar	42
Follow-up (months)	26 (range 12–48)

NAC: Nipple-Areola Complex; N-SN: Nipple to Sternal Notch.

Table 2.
Operative data.

Complication	Number of breasts (%)
Wound infection	8 (0.9%)
Seroma	26 (3%)
Hematoma	6 (0.7%)
Wound dehiscence	8 (0.9%)
Partial areolar necrosis	4 (0.5%)
Total areolar necrosis	0
Revision surgery	**Number of patients (%)** 21 (5%)

Table 3.
Complications following PALM.

(24%) and 42 breasts (5%), respectively. The patients were monitored for an average of 26 months (range, 12–48 months) (**Table 2**). At ≥12 months postoperatively, all patients presented with maintenance of the upper-pole fullness (**Figures 6**–**9**).

Postoperative complications included seroma detection in 26 breasts (3%), the development of wound infections in 17 breasts (2%), and wound dehiscence in eight breasts (0.9%). No patients developed hematoma nor total areolar necrosis, but four patients, both of whom were current smokers had partial areolar necrosis (1%). The revision surgery rate was 5%. Each case with postoperative complications was successfully treated conservatively (**Table 3**).

8. Discussion

The goals of reduction mammaplasty and mastopexy include safety and predictability, fast recovery, long-lasting results, and minimal complications, as well as the achievement of an appropriate size, shape, and projection of the breast [49]. Successful results are ascribed to the surgeon's experience and understanding of breast anatomy, patient age and expectations, skin quality, and the degree of ptosis [17]. The PALM surgical technique provides a customizable approach to reduction mammaplasty and mastopexy that also accommodates patients with gigantomastia and massive breast ptosis, averting the challenges of conventional vertical mammaplasty such as reduced NAC sensitivity postoperatively, kinking of the pedicle, and venous congestion of the NAC.

Breast liposuction as a sole procedure or in conjunction with parenchymal resection has proven to be a safe and reliable [19–28] approach to decrease breast weight and volume. Our personal experience shows that liposuction is appropriate for breasts with lateral fullness and inferior excess. Liposuction facilitates longevity of a desired breast shape and delays ptosis when excess tissue is taken out, pulling forces are reduced, a natural contour is reestablished, and superior rotation of the breast is promoted. If there is asymmetry after bilateral breast reduction, liposuction is a sufficient and dependable option to restore breast symmetry and improve the breast shape. The PALM technique includes liposuction for breast shaping and volume reduction, restricting parenchymal resection to the inferior pole of the breast and ensuring tension-free folding of the NAC during its superior transposition. This procedure is even indicated for cases of severe ptosis in which massive folding and substantial NAC elevations are expected and when the superior pedicle does not supply adequate blood supply to the NAC. A better definition of the breast contour and enhancement of skin retraction can be obtained through liposuction and tunnelization below the inframammary fold using a Lipomatic system. This will further redrape the vertical wound closure to reduce puckering, wrinkling, and the need for scar revision.

By reducing the degree of tissue dissection and resection, the PALM technique aims to preserve an optimal blood supply to the breast. In this technique, liposuction is considered as a key step for volume and weight reduction. Dissection is restricted to a section of the inferior pole and the medial aspect of the breast, and minimal tissue resection is limited to a part of the lower outer quadrant.

To ensure a maximal vascularization to the breast parenchyma and NAC, it is essential to preserve the central, lateral, and superior pedicles. NAC sensitivity is also maintained in the PALM technique through a lateral pedicle containing Wuringer's horizontal septum [50], which carries a neurovascular supply to the NAC and can be combined into septum-based mammaplasty via the methods developed by Hamdi et al. [17]. Greater NAC elevations can be attained with a continuous blood supply to the NAC. Protection of the periareolar vein polygon is achieved through deepithelialization of a wide surface area of skin around the NAC [51], which also maintains the venous networks supplying the NAC. Breast tissue resection is reduced to a minimum with PALM to promote sufficient venous drainage of the NAC through large transposition distances that are necessary for patients with gigantomastia and noticeable breast ptosis. NAC elevations as big as 28 cm were accomplished with PALM.

The preservation of blood supply to the breast reduces the rate of wound healing complications with PALM. A 3-mm dermal rim is preserved around the edge of the breast wound; therefore, PALM facilitates wound closure and ensures apposition and eversion of the wound edges under minimal tension, enhancing wound healing and decreasing excessive scaring. Adequate preservation of a large area of deepithelialized tissue around the gland carrying the NAC also develops a firm anchoring structure at the deepithelialized edges for sutures from the dermis to the chest wall during glandular transposition. In addition, PALM enables the development of a superior pocket, supplying a comfortable fit of the transposed parenchymal tissue that reduces tension on the NAC upon final wound closure. PALM can be completed with just two V-Loc sutures. The V-Loc sutures are encouraged for glandular suspension and skin closure because they reduce operating times, wound complications, and foreign-body interaction because they require less suture material and fewer knots.

Additionally, V-Loc sutures decrease compression of the glandular and fatty tissue during suspension of the gland in its new position because fewer knots are needed. In our opinion, when approximating the two pillars in superior pedicle breast reduction, the application of V-Loc sutures can minimize fat necrosis from compression of the parenchyma and gland. There are various benefits associated with glandular suspension sutures from the dermis to the chest wall sutures. To affix the breast parenchyma in its new position, V-Loc sutures are placed from the second rib at the upper pole to the sixth rib inferiorly. Upper-pole fulness and parenchymal support is ensured through the use of strong V-Loc sutures, attaching the dermal edges of the breast glandular flap to the rib perichondrium in the presence of a superior pocket accommodating the flap. The new IMF is redefined utilizing 2 cm to 4 cm cephalad to its original location according to the extent of ptosis. This step is achieved utilizing V-Loc sutures.

After glandular suspension in the desired position, a single 3–0 V-Loc suture is applied for vertical and periareolar wound closure under minimal tension. Various patterns of skin closure are compatible with PALM. When the NAC elevation is less than 10 cm, a vertical wound closure is chosen preoperatively. However, when the NAC elevation is greater than 10 cm, the decision for a short T or J wound closure is decided intraoperatively after the NAC is elevated to the desired position and redraping of the parenchymal tissues.

In this study, most patients presented with ptotic breasts that required NAC elevations greater than 10 cm. Therefore, a short T wound-closure pattern was most common. Postoperatively, 24 patients (12%) became pregnant, specifically nine primary and 15 secondary or tertiary pregnancies. After PALM, all 24 patients were able to breastfeed, with the preservation of breastfeeding capacity attributed to reduced glandular resection and maintenance of the maximal amount of breast parenchyma.

Although liposuction is a frequently performed procedure in plastic surgery, few surgeons have much experience with breast liposuction and especially power-assisted breast liposuction. As a result, a limitation of PALM is the learning curve for surgeons to learn the skills necessary to undertake power-assisted breast liposuction. Due to the diligence, attention to detail, and precision required for surgeons to perform breast liposuction, the senior author recommends that liposuction be performed in small volumes and that cases of massive ptosis and gigantomastia be avoided entirely until the adequate skills are developed.

Fatty breasts are easily treatable using the PALM technique, whereas glandular breasts are considered as more difficult cases since liposuction is limited. Nevertheless, those glandular tissues are not contraindicated for the PALM technique. Various measures can assist is achieving satisfactory results and overcome the challenges associated with glandular breasts, such as precisely and delicately performing liposuction of the breast, expanding the amount of glandular resection from the lower pole while preserving the lateral septum, and dissecting a larger upper-pole pocket to accommodate the transposed glands.

Tips for making precise preoperative markings for PALM are fundamental for obtaining an esthetically pleasing and symmetrical breast shape. The main tips include:

- Performing liposuction of the lower lateral and areolar zones to minimize tension and kinking of the NAC and gland during transposition.

- Maximizing the NAC arterial supply and venous return by depending on breast liposuction and minimizing glandular resection.

- Liposuction of the lower lateral quadrant of the breast at the end of the procedure for improved breast shape and contour.

- Tunnelization of the area below the inframammary fold to enable better skin retraction and redraping; this also helps avoid puckering.

- Liposuction the breast at the end of procedure to fix asymmetry and provide additional volume and size reduction.

9. Conclusion

The Power-Assisted Liposuction Mammaplasty associates breast liposuction and mammaplasty into a surgical approach that provides an optimal vascularization to the breast by preserving the central, superior and pedicles as well as reducing skin undermining and glandular resection. PALM is a reliable and safe alternative for mastopexy and reduction mammaplasty. This technique is indicated for patients with extensive ptosis and gigantomastia because of the preservation of the blood supply to the breast. The long-term results of PALM include an esthetically pleasing breast shape with superior pole fullness and without any boxiness or bottoming out.

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Chapter 16

Enhanced Lipocontouring of the Arms

Julie Khanna and Maryam Saheb-Al-Zamani

Abstract

The visibility of arm contour in both men and women has been a source of discussion throughout time. Arm strength and athleticism is not limited to the male physique only. Iconic women such as Madonna and Michelle Obama have made discussions about arm contour more and more commonplace. Over the years arm contour has been a difficult area to address due to the thinness of the skin which often required surgical excision and unsightly scars. Liposuction of the arm has advanced to not only allow for improved contour but also options of refining muscular definition. With the addition of energy-based technologies such as radiofrequency, we can offer less invasive options to patients who may have previously only been candidates for excisional procedures. Liposuction of the arms can be performed under local anesthesia. This chapter introduces a new algorithm for assessment and treatment of arm contour which incorporates newer energy-based devices along with surgical options.

Keywords: Arm contouring, Liposuction, VASER, Ultrasound-assisted Liposuction, High-Definition Liposuction, Radiofrequency, Skin Tightening, Brachioplasty

1. Introduction

According to the 2019 Aesthetic Plastic Surgery National Databank Statistics [1], close to 20,000 upper arm lift procedures are performed annually. Although the appearance of the arms is a common concern among plastic surgery patients, with increasing emphasis placed on arm contour and definition in popular and social media, arm contouring via brachioplasty is consistently ranked as one of the least popular body contouring procedures. This is in no doubt owing to the conspicuous brachioplasty scar which is typically tolerated only by post dramatic weight loss (PDWL) patients or those with significant skin laxity from aging [1, 2]. At the other end of the treatment spectrum, non- or minimally-invasive treatment options such as liposuction are available to patients with mild to moderate arm fatty excess but good skin contractility and quality [3]. Until recently, there has been a large treatment gap between the two ends of the spectrum for patients with mild to moderate skin laxity, or even those with significant skin laxity who are intolerant of the brachioplasty scars. With the advent of energy-based devices that can be coupled with liposuction and excisional surgeries, treatment algorithms can now be broadened to serve the full range of patients with various levels of adiposity, skin laxity, and photoaging. In this chapter, we outline our preferred approach to arm contouring, which combines Vibration Amplification of Sound Energy at Resonance (VASER) liposuction with radiofrequency (RF) skin tightening treatments and other

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complementary treatments as needed to address adipose excess, enhance muscular contour, and improve skin tightening and quality.

2. Pertinent arm anatomy

The subcutaneous fat layer of the arm is divided into two layers: a superficial or areolar layer and a deep or lamellar layer, with the latter being more prone to fat accumulation [2]. With the arm by the patient's side, Hoyos [4] divides the arm into four regions: anterior, posterior, internal (adjacent to body), and external (away from body) (**Figure 1**). The major fat composition of the anterior, external, and internal regions is a thin layer of superficial fat. Pinch test in the internal region is commonly less than 1 cm and aggressive liposuction is typically avoided to prevent contour deformities [5]. The major neurovascular structures travel in the internal region, close to the bicipital groove, but are located deep to the deep fascia and away from zones of liposuction [5, 6]. The posterior region contains a distinct deep layer of fat that can vary in thickness with patient body mass index (BMI) and is focal to arm lipocontouring. The arm shape is primarily determined by the muscular composition of the deltoid, biceps, triceps muscles, and the overlying fat [4]. The ideal arm contour is defined by convexities and concavities, highlights and shadows that correspond to underlying musculature. With the arm and elbow abducted at 90 degrees, shape of the anterior arm is defined by the deltoid and biceps muscle mass convexities. The shape of the posterior arm is more intricate, with triceps muscle mass creating a convexity in the midportion and concavities proximally at

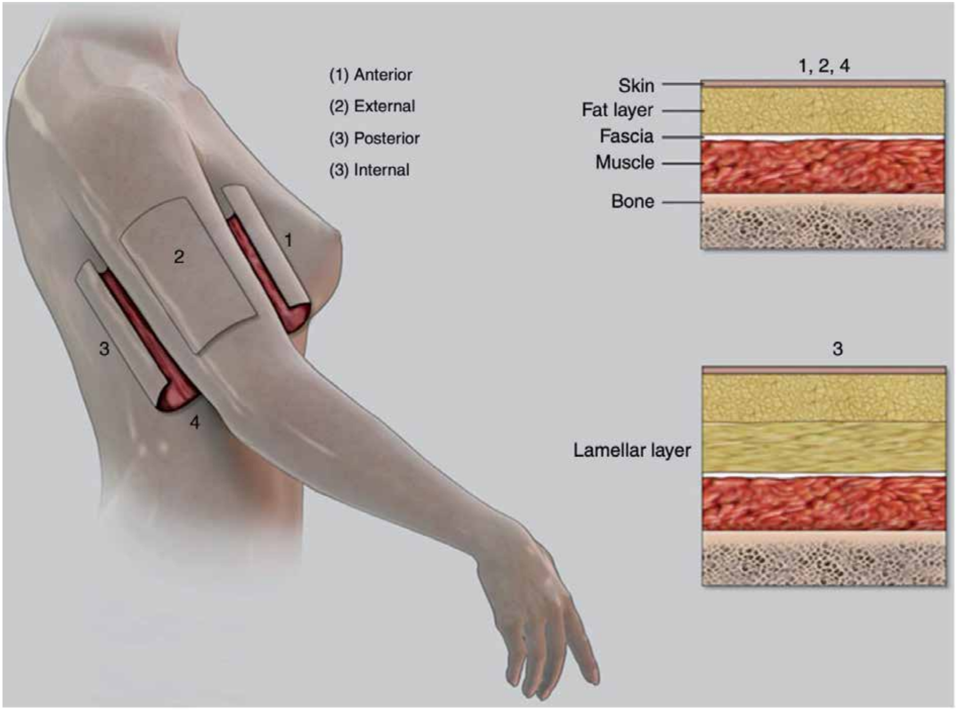


Figure 1.
Fat distribution and zones of contour assessment in the arm, according to Hoyos [4]. The arm is divided into 4 zones: anterior (1), external (2), posterior (3), and internal (4). Fat is divided into a superficial (areolar) and a deep (lamellar) layer in the arm. The posterior zone (3) is prone to fat accumulation in the deep layer. The remaining zones are largely comprised of superficial fat layer and less susceptible to fat accumulation in normal BMI ranges. (Image reprinted with permission).

muscle insertion and distally owing to the flat triceps tendon [4]. Arm contouring techniques, whether by liposuction or excisional surgery, aim to enhance these ideal aesthetic arm shapes, while respecting the patient's overall body habitus to create a desired and harmonious silhouette.

3. Favored technologies and adjuncts to liposuction

Our preferred approach to lipocontouring of the arms has evolved as different technologies and methods have become available over the years. Each modality and approach shared here with the readers has been clinically evaluated in our practice with regards to its application, enhancement of results, and patient safety.

3.1 VASER liposuction

The workhorse of our approach to lipocontouring of the body, including the arms, is using ultrasound-assisted liposuction (UAL) to prepare the fat for smooth extraction with some skin retraction and limited blood loss. We use VASER (Solta Medical, Bothell, WA), which is a third-generation UAL device. Following infiltration of tissues with tumescent fluid, the VASER blunt probe is gently moved through both the superficial and deep layers of fat. VASER uses ultrasonic energy to emulsify the fat for removal by suction-assisted or power-assisted liposuction (SAL, PAL respectively). The emulsification process occurs through a combination of cavitation, mechanical, and thermal effects. The cavitation effect occurs when the VASER probe, vibrating at ultrasonic frequencies, creates microbubbles that implode and release energy that disrupts the fat layer architecture, while preserving the integrity of the fat cells and tissue matrix [4, 7, 8]. The mechanical effect occurs when the vibrating tip comes into contact with adipocytes [4]. We compare this effect to shaking the grapes off of a vine. As a by-product of the high-frequency vibration, thermal energy is created [4], which contributes to a modest amount of skin tightening following liposuction. Care must be exercised to avoid accumulation of excess thermal energy at any one location by keeping the probe in constant smooth motion.

VASER liposuction offers several advantages over traditional liposuction, with respect to smooth fat harvest and minimizing irregularities, improved skin retraction, and limiting blood loss. Traditional forms of liposuction (SAL and PAL) can lead to contour irregularities, especially in the thin, soft tissues of the upper arm and in the superficial fat layer, that present as cannula lines, uneven fat pockets, and potential iatrogenic cellulite-like appearance of the thin internal skin. Loosening of the adipocytes with VASER emulsification prior to aspiration leads to smoother fat extraction as well as the ability to use finer cannulas. Further, the thermal energy from VASER can melt the superficial fat and tighten the fibroseptal network (FSN), leading to an improved arm contour and appearance [9]. VASER liposuction has been shown to result in significantly more (53%) skin retraction relative to SAL (17% skin retraction per liter of liposuction with VASER compared to 11% with SAL) [10]. In cases of negligible fat excess in the arms with limited need for liposuction, we still find VASER to be immensely helpful. The blunt probe of the VASER helps to gently pre-tunnel prior to the use of any other instrumentation (SAL/PAL aspiration or skin tightening with subdermal RF devices) to minimize tissue trauma and create smoother outlines. In addition, the moderate skin tightening effects of VASER can be synergistic with other skin tightening treatments.

By virtue of keeping the tissue matrix and neurovascular networks intact, VASER liposuction can result in 26% reduced blood loss compared to traditional liposuction [10], enhancing patient safety especially when arm liposuction is coupled with other concurrent surgeries or multiple areas of liposuction.

3.2 Skin tightening with radiofrequency (RF) devices

The greatest barrier to arm skin excision procedures has been the need for extended conspicuous scars that limit the choice of arm-bearing clothing, which is the common presenting complaint in the first place. While there is still no replacement for the extent of skin laxity correction that can be achieved by removal of skin, we find that the improvements achieved with minimally-invasive arm contouring methods frequently meet the desired goal of many patients, and at the very least may help shorten the length of any eventual skin excision scars. VASER can provide a modest amount of skin retraction following liposuction as discussed above which may be sufficient in patients with mild skin laxity. In most other cases, we utilize RF technologies devised for skin contractility as an adjunct to lipocontouring.

3.2.1 Subdermal application of RF

A number of studies have demonstrated that neocollagenesis occurs when soft tissues and the dermis are heated to a temperature of 60 to 80°C and skin surface to approximately 40°C [11]. When RF energy is applied subdermally, conversion of RF energy to heat in this temperature range can be achieved, resulting in collagen fiber restructuring and formation as opposed to tissue necrosis. RF energy in the subcutaneous and subdermal space is converted to heat and results in contraction by two mechanisms. First, cleavage of hydrogen bonds in the collagen fibrils results in shrinkage and thickening of the FSN immediately after energy application. Second, the wound healing cascade is initiated, which results in neocollagenesis, angiogenesis, and elastin reorganization with effects on the skin quality observed over the three to four months following treatment [12]. Subdermal RF heating has been shown to result in FSN contraction and soft tissue contraction of up to 47% [13]. A 50% reduction in vertical height of lax pendulous skin and skin surface contraction of 33.5% can be achieved in the arm with RF treatment [9].

There are two categories of subdermal RF devices available for skin tightening: (1) "bulk heating" devices that utilize RF energy for focal tissue heating (such as Thermi and InMode), and (2) a helium-based plasma device that utilizes RF energy to generate a plasma beam as well as creating thermal energy (Renuvion) [14]. These device categories are described below, and their similarities and differences are highlighted.

"Bulk heating" RF was initially introduced as a monopolar device, which consisted of an energy-emitting subdermal probe and required a grounding pad on the body (Thermitight, Thermi, Irving, TX). Since energy is focused at the tip of the probe, heat accumulates in a small region of tissues quickly ("hot spots") and dissipates slowly to surrounding tissues. Tissue heating can therefore be uneven and poorly optimized. An external monitoring device for heating at the skin surface device is required for safety and to avoid burns from hot spots [14]. Newer bulk-heating RF technologies utilize bipolar devices with two electrodes, an internal one inserted into the subcutaneous layer and an external one making contact with skin surface, to create a unidirectional transfer of energy through the tissues between the two probes. Since RF energy is directed between the two electrodes, only the intervening tissue is heating, limiting unintended thermal energy elsewhere. A grounding pad is not required. Bodytite (InMode, Lake Forest, CA) is a commonly used bipolar RF device for skin tightening with body contouring procedures. Bodytite handpiece has built-in internal and external temperature monitors that promote safety and eliminate the need for skin thermal surveillance with a separate camera [11, 15]. Bipolar RF devices circumvent many of the application and safety limitations of the earlier monopolar devices. As such, we no longer utilize subdermal monopolar RF in our practice.

The latest subdermal RF device to enter the market has been Renuvion (formerly branded as J-Plasma; Apyx Medical Corporation, Clearwater, FL). Renuvion utilizes RF energy to create a helium plasma in addition to traditional thermal heating. Briefly, RF energy is delivered to the handpiece to energize an electrode, while helium gas is passed over, creating a helium plasma which delivers heat to the tissues by two methods. First, production of plasma beams, by ionization and rapid neutralization of helium atoms, produces heat directly. Secondly, the plasma beam functions as an effective electrical conductor to transfer a portion of the RF energy directly to the tissues. Heat is generated as the current passes through the resistance of the tissues— a process known as "Joule heating" [14]. The Renuvion plasma beam heats soft tissue targets to temperatures greater than 85°C for less than 0.1 second to achieve desired coagulation and contraction. Unlike bulk heating, tissues surrounding the treatment target remain much cooler allowing for rapid cooling of target zones after treatment application by process of heat conduction and limiting hot spots. The plasma beam conducts through tissues that offer the least path of resistance for flow of RF energy: either through tissue that is closest to the electrode or tissue that has the lowest impedance (easiest for energy to flow through). In the subcutaneous plane, the collagen network of the FSN is typically the closest tissue and is the primary target of the heating and contraction process. As fibers are treated, they coagulate, contract, and present higher impedance. This, coupled with the withdrawal movement of the handpiece, results in the plasma beam quickly alternating between treating different and new tissue targets, which present lower impedance, in a 360° treatment field. The plasma beam efficiently results in focused treatment of FSN to result in maximal tissue contraction and skin tightening without heating the full thickness of the dermis [14].

3.2.2 Superficial and transdermal application of RF

Skin of the medial arm is thinner than other areas of the trunk and extremities and is therefore prone to early wrinkling [2]. In addition, the arms and shoulders undergo notable sun exposure resulting in further photoaging that leads to pigmentation changes, rough skin texture, and "crepey" skin appearance. In order to provide a harmonious improvement in appearance of the arms, skin quality must also be carefully assessed and addressed.

3.2.2.1 Superficial RF treatment

For gentle treatment of mild to moderate photoaging, superficial monopolar RF, such as Thermage (Thermi) can be used. Superficial monopolar RF utilizes gentle nonablative heat delivery from skin surface to the dermis at a controlled depth to result in visible improvements in skin tightening, texture, and rhytids, as well as significant histologic increases in collagen types I and III, and neocollagenesis [16, 17]. Although consistent results are seen with this technology on the face, results are less consistent when applied to the arm in our practice and thus infrequently used.

3.2.2.2 Transdermal RF treatment

More notable improvements to skin quality, including reduced laxity, roughness, and improved hydration, can be achieved when RF energy can be delivered to deeper levels of the dermis and subdermal tissues. Fractional RF devices (Fractora or Morpheus8; InMode or Profound, Candela Medical, Mississauga, ON, Canada), utilize (micro)needles or electrodes to heat the dermal and subdermal levels in a nonablative fashion. Heating of the subdermal tissues results in a degree of fat emulsification and mild contouring [12]. Skin needle puncture has been shown to improve skin texture and mild rhytids. These results are amplified when coupled with RF energy. Histologic changes consistent with increased reticular dermal thickness, dermal collagen, hyaluronic acid, and elastin content are seen following RF microneedling [15, 18]. These results are clinically notable as well. A randomized, blinded, quantitative study of skin laxity demonstrated a 16% improvement in skin laxity from baseline with fractional RF treatment as opposed to 49% achieved with surgical facelifting, and an improvement of 37% of that of facelifting with a single fractional RF treatment [19]. Fractional RF via (micro)needling can be applied in a multitude of fashions to enhance appearance of the arms. Fractional RF can augment the tightening effects of subdermal RF treatment in cases of severe skin laxity or more moderate cases of skin laxity who also present with moderate to severe skin roughness and photoaging changes. Additionally, due to its less invasive nature, RF (micro)needling can be used to address difficult-to-treat areas such as fat pads just proximal to the elbow or at the axillary-arm junction. Untreated islands of skin expedite recovery with fractional RF treatments, similar to fractional laser resurfacing [12, 15].

4. Preoperative evaluation

4.1 Treatment algorithm

Multiple algorithms for classification and treatment of arm deformities have been previously described [20–22]. These classifications all aim to address adipose and/or skin excess with liposuction, variations of brachioplasty, or a combination of these approaches. They do not incorporate energy-based methods of improving skin laxity and quality, which we find to be quite efficacious in improving arm aesthetics. Algorithms for assessment and management of the arm should be updated to accommodate new skin tightening procedures which may result in a decreased need or desire to proceed to more aggressive skin excision surgeries to achieve the patient's expected results. Theodorou et al. [11] proposed an algorithm that incorporates some energy devices to address arm adiposity, as well as skin laxity and quality, ranging from SAL, Laser-assisted liposuction (LAL), RF- assisted liposuction (RFAL), RFAL and staged skin excision, to brachioplasty. We expand upon this proposal by incorporating superficial and transdermal RF treatments as well as other adjuncts that are usually further required to improve poor skin texture and quality. **Figure 2** outlines our algorithm for assessment and treatment of arm aesthetics.

4.2 Photography and documentation

Preoperative assessment in liposuction is always the single most important step in proper surgical planning and the management of the patient's desires and expectations. Evaluation of the arms must not only include areas of excess fat but a

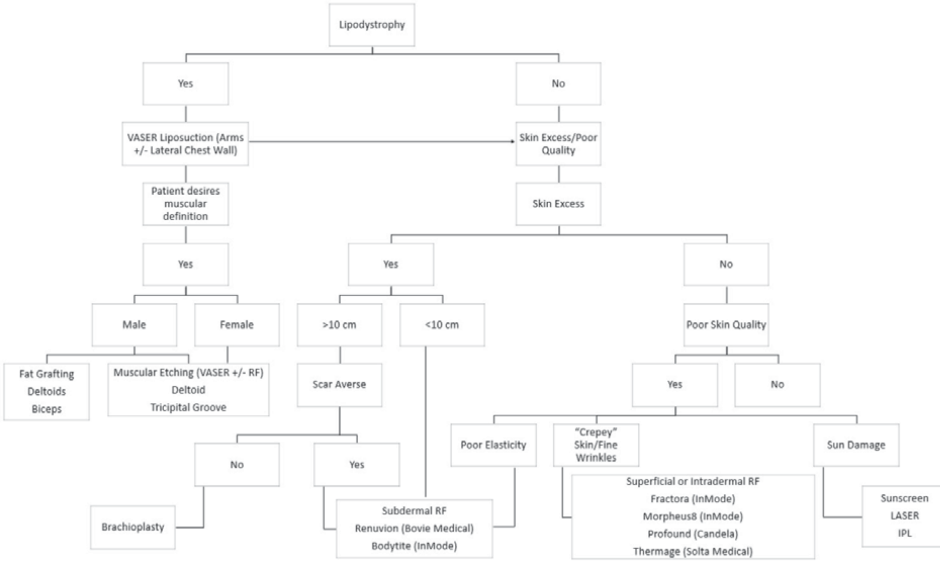


Figure 2.
Our approach to assessment and treatment of patients presenting for arm enhancement. It is important to identify lipodystrophy as well as excess skin and other markers of skin photoaging for comprehensive improvement of arm appearance. Liposuction is coupled with other energy-based devices as necessary. In some patients, skin removal with brachioplasty is still considered gold standard and recommended.

detailed examination of the quality and quantity of skin, as well as the underlining musculature. Furthermore, aesthetics of adjoining anatomical areas such as the lateral chest wall, anterior axillary fold, posterior axillary fold, and the forearm should be considered and treated if appropriate.

In obtaining a full analysis of the arm, it is imperative to ask the patient what disturbs them the most about their extremity and the view(s) in which they see the concern most prominently. Dynamic assessment of the arms is also important to establish the patient's desires and expectations. The terms "bat wings", "bingo arms", or "hello Helens" imply a significant amount of redundant and possibly pendulous skin in the upper arm which may require surgical excision to obtain a true decrease in the skin volume. Obtaining a preoperative video is an excellent way of documenting the amount and dynamics of loose skin. Such video can also help document the aesthetic concerns preoperatively and their improvements postoperatively. Preoperative measurement of arm circumference is helpful to assess asymmetries and to follow postoperative results. Assessment of skin tone, texture, stretch, loss of elasticity, and the presence of striae should be included and incorporated into the operative planning.

Standard photography of front and back with shoulders abducted and elbows flexed at 90 degrees, in front of an appropriate photographic background, is of critical importance. Close-up assessment of skin is also crucial both in the planning phase and in the photo documentation phase.

5. Surgical technique

5.1 Marking

The patient is marked in the standing position with the shoulders abducted and elbows flexed at 90 degrees. The position of the ulnar nerve is marked. The areas of excess fat where deep liposuction is required in the posterior zone, extending anteriorly and internally as needed, are outlined. The extent of liposuction is confirmed from front and back, and with the arms adducted and abducted. Adjoining regions of excess fat such as in the anterior axillary fold, lateral chest wall, and distal arm/elbow region are also marked (**Figure 3a**).

The zones of skin laxity are marked next. Due to the thinness of the skin in the internal aspect of the arm, this is the focal area of treatment with skin tightening devices. Treatment zones may extend more anteriorly and posteriorly as needed and beyond the area of the planned liposuction. The thicker skin of the external arm typically does not require treatment with subdermal skin tightening devices. If photoaging is present, that can be marked for treatment with adjunct modalities (**Figure 3b**).

When muscular etching is planned, we follow Hoyos' approach [4]. Muscular etching should reflect the patient's complete body habitus. A patient with higher BMI and poor muscle definition elsewhere will appear incongruent if muscular etching is performed on their arms. When appropriate in men, muscular etching includes enhancement of all three large muscles of the arm (deltoid, biceps, and triceps). This may include small volume fat grafting (approximately 25-50 cc) to the muscles, primarily deltoid +/− biceps, to enhance bulk. In women, it is important to establish the patient's desired degree of perceived athleticism that is in balance with their body shape. Many women want a softer look, in which case muscular etching is not performed. A large portion of women desire a toned appearance of the arms, in which case only the deltoid muscle is highlighted. In a small subset of women who strive for a full muscular appearance of their arms, further etching of the tricipital groove and biceps is added; fat grafting is rarely used in our practice for female patients (**Figure 3c**).

5.2 Preparation and anesthesia

Liposuction of the arm can either be done under local anesthetic or general anesthetic, and with or without the addition of other procedures. Arm liposuction under local anesthetic is well tolerated by patients. The patient's ability to participate in positioning and movement is very beneficial when local anesthetic is used.

Our preferred method of local anesthesia entails a combination of MKO jelly lozenge (locally compounded Midazolam 3 mg, Ketamine 25 mg, Ondansetron 2 mg) with inhaled patient-administered nitrous oxygen (Pro-Nox, Inc.; CAREstream Medical Ltd., Oakville, ON, Canada). A small access incisions is placed 2 cm proximal to the olecranon in the midline or more radially thus avoiding the ulnar nerve. If more ulnar-sided access is necessary, an additional surgical incision may be placed anterior to the medial epicondyle and lateral to the biceps tendon insertion. To obtain access to the proximal arm and the anterior axillary fold, an incision can be placed behind the lateral edge of the pectoralis muscle in the axilla. Occasionally a posterior axillary incision may be necessary, especially when trying to obtain muscular etching of the posterior deltoid and the tricipital groove.

When arm liposuction is done in combination with other body contouring procedures or breast surgery, general anesthetic may be the best choice. All areas are locally infiltrated with a combination of xylocaine with epinephrine tumescent fluid with both local and general anesthetic cases (**Table 1**). When arm contouring is combined with other procedures that involve the patient being prone, the posterior axillary fold, deltoid, and tricipital groove definition can be treated from posteriorly. The remaining arm liposuction is performed with the patient supine. Draping of the arm must allow 360-degree access (**Figure 4**). The use of ear oximetry probes and leg blood pressure cuffs are helpful in patient monitoring while keeping field sterility even when the arm is moved.

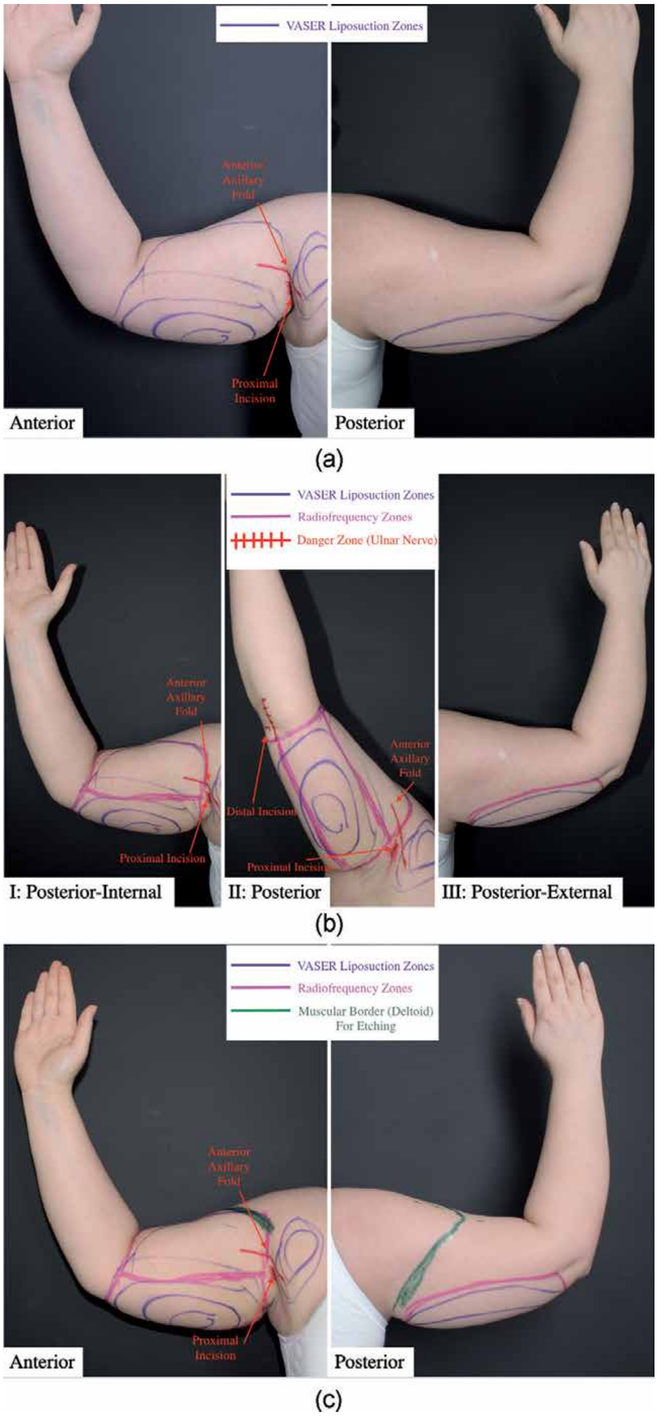


Figure 3.
Markings for arm lipocontouring. (a) Areas of excess fat for debulking are marked (purple). Fat excess build-up is mostly in the posterior zone of the arm in the deep layer and is the focus of liposuction. (b) Areas of poor skin laxity for treatment with subdermal RF are marked (pink). The region of skin tightening treatment can extend anteriorly and posteriorly beyond the region of liposuction as required. The path of the ulnar nerve is marked as a danger zone. Distal access incision is made away from the position of the ulnar nerve; similarly, VASER liposuction and subdermal RF are avoided in this area. (c) If muscular etching is required, the muscle borders are palpated and marked (green). In females, commonly the deltoid is enhanced with careful superficial liposuction. In men, muscular etching may involve enhancement of deltoid, biceps, and triceps muscles.

Tumescent Fluid	Local Anesthesia	General Anesthesia
Ringer's Lactate	1000 cc	1000 cc
1% Lidocaine (without epinephrine)	80 cc	20 cc
Epinephrine	1 mg	1 mg
8.4% Sodium Bicarbonate	10 cc	0 cc

Table 1.
Composition of tumescent fluids used for local and general anesthetic (GA) case. Sodium bicarbonate is used as a buffer to decrease the pain of the acidic lidocaine when procedures are performed under local anesthetic. Accordingly, less lidocaine is required for analgesia when patients are under general anesthetic.

Figure 4.
Draping allowing for sterile 360-degree access to the patient's arms used in both local and general anesthetic cases.

5.3 VASER liposuction

With the use of PAL, the tumescent solution is infiltrated with a 3 mm basket cannula (**Figure 5**). The average infiltration of tumescent amount is approximately a ratio of 1:1-1:5. Vibration from PAL infiltration of tumescent solution can be a helpful sensory distraction for patients having surgery under local anesthesia. Furthermore, PAL allows for even infiltration throughout tissues even in presence of significant scarring due to previous liposuction or other non-invasive fat reduction procedures such as cryolipolysis or deoxycholic acid injections [23, 24]. A UAL probe of 3 mm is used for fat emulsification followed by lipoaspiration with SAL, again using a 3 mm cannula. Our standard VASER settings are between 60 and 70% on VASER mode for fat emulsification and pre-tunneling in both the deep and superficial fatty layers of the arm. Tissue treatment with VASER is always performed in both the deep and superficial layers even if only deep liposuction is planned. Superficial fatty layer treatment with VASER provides a modest degree of skin tightening which may be sufficient on its own or can be coupled with other technologies as necessary. Deep liposuction below the superficial fascia layer (deep/lamellar fat layer) can be carried out aggressively in order to debulk areas of excess adiposity in the posterior arm region with limited risk of creating contour abnormalities. It is important to address lipodystrophy around the distal arm/elbow region as well as the anterior and posterior axillary folds as necessary. These regions are best addressed with small and short cannulas for focused liposuction with limited restriction in arc of instrument movement.

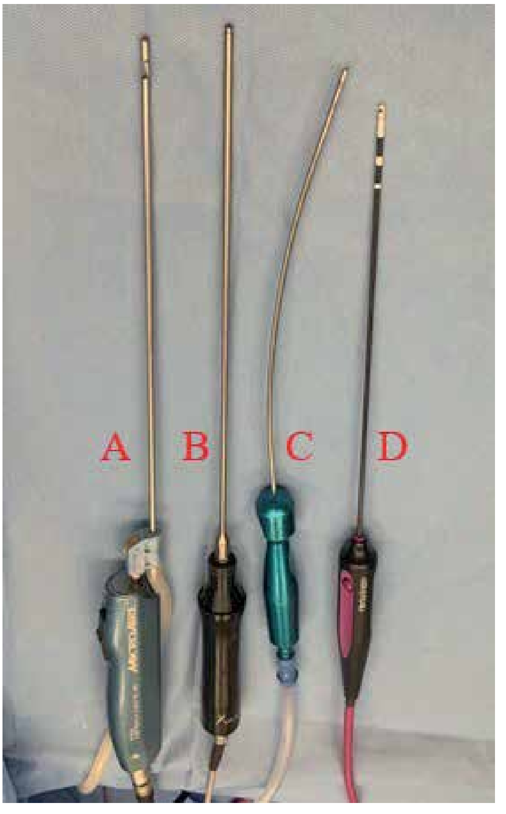


Figure 5.
Typical devices using during enhanced arm liposuction in our practice: (A) power-assisted device with gentle basket cannula for tumescence fluid infiltration (PAL, MicroAire surgical instruments, Charlottesville, VA); (B) VASER probe; (C) 3 mm curved suction-assisted liposuction (SAL) cannula; (D) subdermal radiofrequency (RF) device (Renuvion, 15 cm probe).

Strategic superficial liposuction may be carried out if required and/or when muscular etching is being performed. The authors try to avoid a complete 360° release of subcutaneous fat when possible as fat removal from the external zone of the arm is often limited or even unnecessary. Avoiding a complete 360° surgical release may allow for earlier resolution of swelling by decreasing the disruption of the venous and lymphatic systems. The addition of lateral chest wall liposuction if excess bulk is present there can provide added benefit by making the arms seem smaller as there is less tissue pushing the bulk of the arms out when adducted.

5.3.1 Artistic enhancement

To further enhance results of arm liposuction, we can incorporate the concepts of muscular etching [4] into the planning. For enhanced muscular definition and etching, careful compression while liposuctioning with a curved cannula is used to gradually create depression at the border of the muscle as desired. This is an advanced technique that should be gradually adopted as the surgeon gains experience and confidence in arm contouring [4]. Compression during liposuction elsewhere is not recommended as unwanted and difficult-to-correct depressions and irregularities can develop rapidly.

Removing a small amount of fat superficially to increase the definition of the anterior and posterior edges of the deltoid can push the aesthetic caliber of the result in arm liposuction. The posterior tricipital groove is not as clearly defined in all patients but is a pleasing appearance in lean, more muscular female and male patients and can be enhanced with superficial liposuction when in synchrony with the patient's body shape. Biceps enhancement with superficial liposuction in the anterior bicipital groove in our practice is less common and mostly performed for male patients. Care must be taken to protect underlying neurovascular structures.

The addition of fat grafting at this stage to further enhance results, particularly into the deltoid and occasionally into the biceps muscles, can help patients achieve the desired muscular definition that they are looking for [4]. Typically, a small amount of fat grafting of less than 50 cc per arm intramuscularly can achieve this result.

5.4 Skin tightening with RF

The thin nature of the arm skin has made it a challenging area for liposuction (similar to the medial thighs). Assessing the skin quality is critical. Many patients with arm skin laxity would prefer to be left with some loose skin and avoid the telltale sign of a brachioplasty scar. The adjunct use of RF can also possibly concert a patient who may have required a full, long brachioplasty scar to a shorter scar, limited to the mid upper arm.

The use of subcutaneous RF techniques have been beneficial in further improving skin tightening and quality [6, 9]. RF subdermal skin tightening is more powerful and is particularly advantageous as it avoids targeting dermal chromophores and epidermal injury, thus can be used in any Fitzpatrick skin type, unlike transdermal RF and laser treatments [12].

5.4.1 Subdermal RF

When incorporating subdermal RF into the treatment plan, tumescence followed by UAL of the deep and superficial adipose tissue is carried out first. Treatment with subcutaneous heating of the Renuvion device follows completion of liposuction. The area for RF treatment is divided into ergonomic, accessible sections for the surgeon. Typically in the arm, we have three zones for RF treatment (posterior, posterior-internal, and posterior-external). There must be a minimum of two access points on the arm to allow for egress of the helium gas. Treatments in the zone are performed by the radial application of RF energy on the outstroke only at speed of 1-1.5 cm/s. Care is taken to avoid applying energy within a 2-5 cm arc of the access incision to prevent overtreatment and the possibility of a burn. Each zone is treated with three passes only, then we move on to the subsequent area. Once all areas are treated, we retreat all zones with another three passes. This 3 + 3 technique avoids the deposition of excessive heat energy and possible injury. As per Duncan, a 10 x 15 cm segment of tissue is usually treated with approximately 5 kJ [14]. Surface skin heating is not an endpoint with this technology, unlike other energy devices, and may actually imply excessive energy delivery. Care is taken to avoid tenting of the probe underneath the dermis and to keep the probe in constant motion during energy activation. After completing RF, fine cannula SAL is gently used as a final stage to evacuate any residual helium gas and to correct fine irregularities.

Some surgeons advocate for the creation of an "internal seam" by depositing additional RF energy along the posterior border of the arm ("triceps midline meridian") [6]. We typically avoid concentrating energy deposition in a given location as it can result in irregular contraction and palpable fibrosis. Sufficient tissue tightening and circumferential volumetric contraction can be achieved with a systematic application of RF energy with limited overlapping.

5.4.2 Transdermal RF

Examining quality of a patient's superficial skin is very important. Combining subcutaneous RF technology with transdermal RF devices can enhance the result even further. A number of such technologies exist. In our practice, (micro)needling RF with Fractora or Morpheus8 (InMode) or Profound (Candela Medical) can be used to enhance the final result. RF (micro)needling parameters have been described elsewhere [15] and are beyond the scope of this chapter. One to three treatment sessions may be required to achieve desired improvements in skin quality. The first RF (micro)needling treatment session may be performed concurrently with more invasive surgical procedures, including liposuction, with or without subdermal RF, and/or brachioplasty to optimize anesthesia and post treatment recovery. Generally, three to six weeks of recovery time are allowed between treatment sessions. When picking the right technology, multiple factors must be considered, including specific patient concerns, tone and texture of the skin, and Fitzpatrick skin type.

5.5 Brachioplasty

Surgical excision of excess skin of the arm is the gold standard in improving arm contour; however, the conspicuous and sometimes hypertrophic scarring in a publicly visible area can make this option undesirable. Previously, surgeons have attempted to describe limited brachioplasty approaches by varying the length and position of the surgical scar, ultimately at the expense of the improvement that can be achieved. Small scars such as axillary-only obtain limited changes in arm contour, whereas extended brachioplasty scars from distal to the elbow and including the lateral chest wall result in transformative changes to the patient's shape in their arm and chest. We recognize that excision of skin in some patients is unavoidable to achieve desired results. A detailed discussion of brachioplasty surgery is beyond the scope of this chapter [25].

We advocate and implement a two-stage approach in order to limit scar length without compromising the amount of improvement and arm contour. In patients with excessive fatty tissue who are unable to lose weight through lifestyle changes, we first perform liposuction with or without skin tightening to recruit as much skin retraction as possible. As a second stage, a brachioplasty procedure with possible further skin tightening can be performed, thus hopefully resulting in a shorter surgical scar. On many occasions, patients are satisfied enough with the results of the first stage, that they often decline skin excision and request further enhancement with liposuction with or without skin tightening.

5.6 Adjunct non-surgical treatments

Treatment of sun damage to the skin with sunscreen, topical products, and laser treatments to improve skin texture and pigmentation changes should also be considered.

6. Postoperative care

Patients are all placed in a compressive garment post-operatively. Surgical garments are used for the first two weeks. Afterwards, patients are allowed to change into commercially available seamless, zipper-less compressive garments (such as Spanx™ or athletic compression shirts). The larger amount of fluid generated with UAL with or without additional RF treatment occasionally requires the use of drains, brought out through the posterior elbow. Alternatively, the elbow incision is left open to allow for drainage. Most commonly a 7 mm drain is used if required. They are asked to try and keep their arms elevated above their hearts when seated or sleeping for the first week. Patients are encouraged to begin lymphatic massage after one week. Patients are instructed to avoid any heaving lifting (above 10 lb) or vigorous exercise until four to six weeks post-surgery. After this period, activity level can be gradually increased as tolerated. Gentle range-of-motion is never restricted.

7. Clinical cases

7.1 Case 1: liposuction

This 41-year-old patient presented to our practice desiring enhanced contour of the arms along with her trunk. She was 5′7″, 144 lb., and worked out on a regular basis. She found the area of her arms were a persistent problem despite her workout regime. She underwent trunk and arm liposuction under general anesthetic. The arms were infiltrated with 500 cc of tumescent fluid per side and 200 cc of lipoaspirate was removed per side using VASER UAL. Liposuction was carried out predominantly in the deep layer with a small amount of superficial liposuction in the region of the deltoid groove to create the desired level of muscle enhancement for the patient. Pre- and post-operative results at 1 year are shown in **Figure 6**.

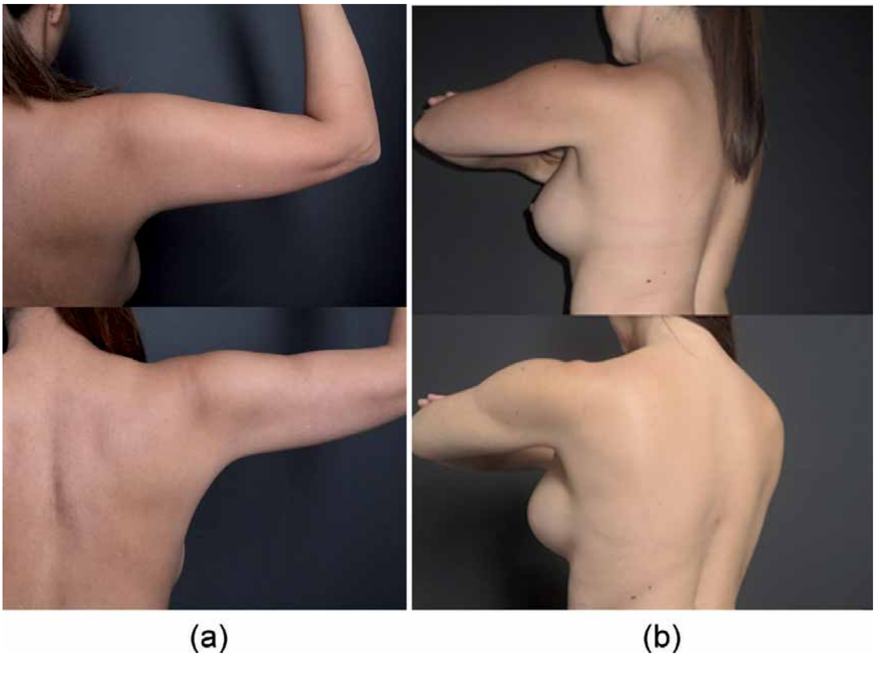


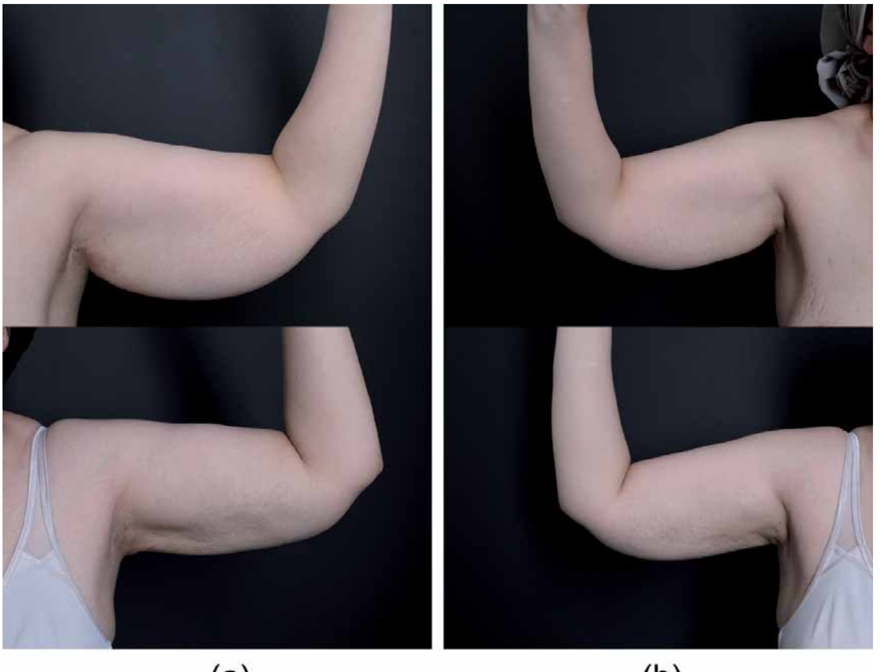
Figure 6.
Liposuction of the arms (case 1). This 41 year-old female with normal BMI and active lifestyle underwent arm and trunk liposuction for improved definition. Liposuction was performed with VASER UAL. Gentle liposuction of the superficial fat layer was performed to enhance the deltoid muscle and impart a more toned appearance of the arms. Results are shown pre-operatively and 1 year postoperatively on the right side posteriorly (a) and left side obliquely (b).

7.2 Case 2: liposuction and subdermal RF

This 51-year-old woman presented to our practice with concerns regarding the size of her arms and avoided sleeveless shirts. She was 5′2″ and 163 lb. Her medical history was notable for a previous thyroidectomy and her only medication was levothyroxine. The patient was noted to have diffuse upper arm lipodystrophy with significant striae. The distance from the bicipital groove to the most dependent area was greater than 10 cm. She did not wish to undergo any excisional/scarring procedure, even though it was made clear this would be the gold standard of treatment in her situation.

The patient underwent arm liposuction, along with a concomitant facial procedures, under general anesthesia. Each arm was infiltrated with 750 cc of tumescent fluid using PAL system, then VASER UAL was performed (60%, VASER mode, 3 mm VASER probe) in both the deep and superficial planes. Liposuction was carried out with a 3 mm standard liposuction cannula to remove 650 cc of lipoaspirate on each side from each arm. Subdermal RF treatment was then performed with Renuvion (80%, 2 L/min, for 3 + 3 passes as described above). No drains were used. Pre- and post-operative results at 1 year are shown in **Figure 7**. The option of repeating the RF at one year to obtain further skin tightening was disclosed preoperatively. At one year post surgery, the patient was thrilled with her results and declined further RF or alternative treatments.

The typical operative sequence of arm lipocontouring with VASER UAL and subdermal RF is outlined in **Table 2** and demonstrated in Video 1 (https://drive.



(a) (b)

Figure 7.
Liposuction and subdermal RF of the arms (case 2). This 51-year-old woman with BMI of 29.8 presented with lipodystrophy, skin excess, and poor skin quality and striae. She was averse to brachioplasty scar. As such, a staged approach was proposed beginning with VASER UAL (650 removed from each arm) and subdermal RF (Renuvion). Results are shown pre-operatively and 1 year postoperatively on the left (a) and right (b) sides. She was very pleased with the outcome following the initial procedure and elected not to proceed with further liposuction and subdermal radiofrequency treatments as planned.

Summary of Operative Approach to VASER UAL and RF Skin Tightening
Pre-operative: Markings: Patient is marked for proximal and distal access incisions, zones of excess adiposity requiring VASER liposuction, and, if indicated, regions of RF skin tightening. If muscular enhancement is planned, the borders of the arm muscles (deltoids +/− triceps) are palpated and marked. The course of the ulnar nerve at the cubital tunnel is marked as a "no-go" zone.
Intra-operative: Positioning: Patient is placed supine with arms extended on arm boards. The arm may be flexed at the shoulder and elbow at 90 degrees throughout the case as necessary to reach the posterior and external zones of the arm adequately. Under local anesthesia, patient can perform this movement by themselves; otherwise the limb is positioned by an assistant. To allow free movement, bilateral upper extremities and anterior chest are prepped and the extremities are free-draped. Anesthesia: If the procedure is performed under local anesthesia, the patient is offered Pro-Nox for comfort, which they self-administer. Additionally, they may be offered MKO prior to the procedure as an anxiolytic and mild oral sedative. Alternatively, the procedure can be performed under IV sedation or general anesthetic. Measurements: Arm circumference can be taken at 2 points along the upper arm prior to start of treatment and at the end of treatment with a sterile tape measure. These measurements are of particular benefit to denote and correct asymmetry between the two sides. Incisions: Access incisions are infiltrated with local anesthetic and a 1 cm skin incision is made with scalpel. Care is taken to stay away from the ulnar nerve distally. Tumescence: The zones of planned treatment are infiltrated with tumescent fluid until appropriate turgor is reached (variable between patients and dependent on body habitus). It is important that both the superficial and deep fat layers are adequately infiltrated. VASER UAL: Access ports are inserted to protect skin incisions. VASER pre-treatment is performed first with typical settings of 60% on VASER mode in superficial fat layer. Deep fat layer may be treated with 60% on VASER or Continuous mode, depending on amount of adipose excess. End point is loss of tissue resistance to VASER probe. Liposuction is then performed with a small (3 mm cannula). Care is taken to debulk in the deep adipose layer only. Superficial liposuction is performed carefully and only in areas where the muscle border is intended to be enhanced. RF Skin Tightening: Next, RF skin tightening is performed if indicated. We prefer Renuvion and use settings of 80% power and 2 L/min of helium gas flow. Treatment is performed with 3 passes initially followed by another 3 passes a few minutes later to allow sufficient tissue thermal relaxation (total of 6 passes). Alternatively, if Bodytite is utilized, we typically use internal and external temperature cut-offs of 70° C and 40° C. Skin is continuously monitored for overheating, redness, and end-hits are avoided with all technology devices. Minimal liposuction is performed afterwards to remove any debris and gas. Closure: Proximal incisions are closed with deep-dermal 4-0 Monocryl suture. Typically, the distal incision is left open and dressings are used to soak up excess drainage. If necessary, a 7 mm Jackson-Pratt drain may be utilized, exiting from distal excision.
Postoperative: Garment & Drain: Patient is placed in compression garment for 6 weeks postoperatively. Typically, the distal incision is left open and dressings are used to soak up excess drainage. If any drains are used, they are removed after 30 cc or less of serosanguinous drainage in a 24 hour period has been reached.

Table 2.
Summary of our typical approach to arm lipocontouring with VASER UAL and subdermal RF skin tightening.

google.com/file/d/1lUFLpe7koOBtZf7dCtcGFkU-RBsieNQq/view?usp=sharing) for a different patient.

7.3 Case 3: liposuction, subdermal RF, and brachioplasty

This 53-year-old woman was seen in consultation for changes to her arms following massive weight loss of 130 lb. through healthy lifestyle changes in diet, and exercise. She was 5′7″ and 183 lb. at time of assessment. The patient was concerned with the quantity of excess skin, as well as the poor quality, noted by striae, poor elasticity, and pendulous excess skin. After discussing the advantages and disadvantages of various procedures, the decision was made to proceed with bilateral extended brachioplasty with UAL liposuction and subcutaneous RF to improve the quality of the remaining skin. The nature of the scarring involved was discussed in detail.

Under general anesthesia, 1000 cc of tumescence fluid (**Table 3**) was infiltrated into each arm and lateral chest wall using a small basket PAL cannula. A 3 mm VASER probe was used for fat emulsification, followed by liposuction to remove 400 cc from each arm. Surgical excision of the redundant skin was carried out to remove 588 g of tissue from the right arm and 515 g of tissue from the left arm. Subdermal RF (Bodytite) was used to heat the remaining skin prior to final subcuticular closure to achieve further skin tightening. A drain was used on each side. Pre- and post-operative results at 1 year are shown in **Figure 8**.

	RIGHT ARM	LEFT ARM
Proximal Circumference (cm)	PRE: 50 POST: 34	PRE: 47 POST 34
Distal Circumference (cm)	PRE: 39 POST: 28.5	PRE: 36 POST: 28.5
Tumescence (cc)	1000	1000
Lipoaspirate (cc)	400	400
Skin Excision Weight (g)	588	515

Table 3.
Intraoperative measurements and weights of tissue excised from case 3. Circumference of the arm is taken prior to surgery (PRE) and intraoperatively following liposuction and excision (POST) to ensure relative symmetry at the end of the procedure. These measurements also help highlight pre-existing arm size asymmetries and differences in relative amount of tissues excised from each side.

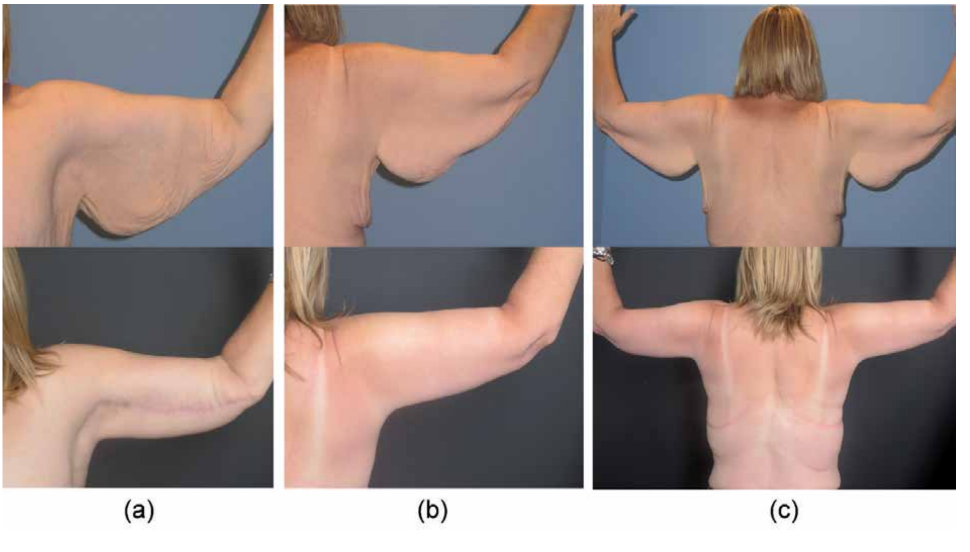


Figure 8.
Liposuction and subdermal RF of the arms coupled with extended brachioplasty. This 53-year-old PDWL woman presented with lipodystrophy and significant skin excess and poor quality of the arms and extending to the lateral chest wall. She underwent VASER UAL and extended brachioplasty. The remaining skin regions anterior and posterior to the brachioplasty excision were treated with subdermal RF (Bodytite) for further improvement in skin retraction and quality. Results are shown pre-operatively and 1 year-postoperatively from a left anterior (A), right posterior (B), and bilateral posterior (C) perspective.

8. Pearls

8.1 Surgery under local anesthesia with conscious sedation

One of the greatest advantages to minimally invasive approaches to arm contouring is the ability to perform the procedure under local anesthesia safely and comfortably for both the patient and the surgeon. A complete medical history, physical examination, and review of patient's medications and allergies is integral to safe administration of any medication, including for procedures performed under local anesthesia with or without sedation.

8.1.1 Nitrous oxide (Pronox)

We commonly utilize Pro-Nox, which is a combination of 50% nitrous oxide and 50% oxygen delivered through a one-way valve. The patient holds the mouthpiece and inhales the gas for comfort as needed. The device inherently minimizes risk of overdose as the patient is unable to hold the mouthpiece if they become too drowsy. It is therefore important not to assist the patient in holding or controlling the mouthpiece device. The use of nitrous oxide is well-established in dental literature and has been adopted to many dermatologic and aesthetic procedures, including tumescent liposuction, as a safe analgesic adjunct [26–28]. Additional monitoring with a pulse oximeter is advised for longer procedures. Surgeons must be aware of contraindications to its use which include but are not limited to pregnancy, certain pulmonary diseases (COPD, cystic fibrosis), recent tympanic membrane surgery, claustrophobia, and intoxication, etc. Adverse effects are mild and infrequent and include emotional lability (most commonly laughter and euphoria), nausea, and dizziness. It has a quick onset and recovery times are 5 to 10 minutes allowing for patients to drive themselves home following smaller local procedures [26].

8.1.2 Oral sedatives (lorazepam, MKO lozenges)

In order to reduce any stress or anxiety associated with the procedure, we have traditionally administered sublingual lorazepam to patients undergoing procedures under local anesthesia lasting greater than 45 minutes or those with underlying anxiety. Recently, oral formulations of midazolam, ketamine, and ondansetron have become available as prefabricated lozenges (MKO Melt, ImprimisRx, San Diego, CA), which can also be prepared at any compound pharmacy (Midazolam 3 mg, Ketamine 25 mg, Ondansetron 2 mg). We have found this new oral combination to be highly effective for longer duration procedures under local anesthesia, including arm lipocontouring. The medication provides anesthetic, sedative, and antiemetic effects that set in within 15 minutes and 30 minutes to peak effect. Anesthetic and sedative effects can last up to 4 hours after administration [29] and, as with any form of sedation, the patient is monitored post procedure until discharge criteria are met and released to the care of a responsible adult for 24 hours.

9. Pitfalls and complications

The usual complications associated with liposuction can be seen in arm lipocontouring including infection, seroma, irregularities, sensory or motor nerve injury, the need for further liposuction enhancement, and loose skin requiring (additional) RF treatment or skin excision. The added complication of burns to the skin with any energy-device (UAL or RF) must also be discussed with the patient preoperatively.

9.1 Asymmetries

As with any other procedure where two sides of the body are treated, it is important to note and educate patients on any pre-existing asymmetries during the consultation process and prior to any procedure. The circumference of the arm is measured at two landmarked positions on each arm prior to surgery. The measurements are confirmed again intraoperatively prior to start of surgery and at the end of surgery to ensure relative symmetry. It is important for surgeons to remember, and educate patients, that it is not how much fat or skin excess is removed that needs to be similar but rather the tissue that remains should be symmetric.

9.2 Irregularities

One of the most significant challenges with any form of body contouring, but particularly in the arm where there is less fat and high public visibility, is avoidance of irregularities and unsightly adhesions. Failure to address loose skin or poor quality in the appearance of skin can set the patient up for an undesirable or unrealistic outcome. The key to smooth liposuction is to recognize the superficial and deep adipose layers and make sure to debulk only the deep layer. Liposuction of the superficial layer of fat will result in visible divots and difficult-to-correct irregularities and asymmetries. Of course, when done carefully, superficial liposuction and purposeful creation of contours and shadows is the underlying principle and technique of muscular etching. We advise all surgeons to master lipocontouring of the deep fatty layer of the arm prior to attempting muscular etching. When performing muscular etching, less is more. It is also important to palpate the patient's own muscular boundaries and aim to only enhance the muscle borders rather than to artificially enforce muscles on the soft tissues to avoid odd-appearing contours, especially with movement and muscle activation.

Several principles can help surgeons avoid irregularities, in addition to staying in the deep adipose layer. We advocate using a small cannula (3 mm). A curved cannula is optimal for reach in cylindrical regions such as the arms (and medial thighs) and can help to enhance the smooth curvature of muscle boundaries where needed. We have a low threshold for performing fat equalization following aspiration as in the SAFE technique [30] with either a power-assisted or handheld basket cannula (off suction) if any irregularities are noted. When using energy-based devices (VASER or RF skin tightening), excessive heat application can result in fibrosis and uneven adhesions. As covered below, the key to any energy application is to protect the entry site, avoid end-hits and tenting up the device tip against dermis, and keeping the handpiece in constant motion to avoid such adverse outcomes.

9.3 Excess skin

We have found that energy devices provide a treatment gap for patients with mild to moderate skin laxity (with or without associated lipodystrophy) and those who are scar intolerant. We advise every patient that, while significant improvement in skin laxity and quality can be achieved with energy-devices, no alternative treatment is equivalent to lax tissue excision with surgery. There is also variability in individual response to skin tightening treatments, and multiple treatments, or even possible skin excision, may be indicated in the future.

The best candidates for energy-based minimally invasive skin tightening are those with mild to moderate skin laxity. PDWL patients and even those with significant striae typically have an irreversibly damaged dermis and are better suited for excision surgery. This does not mean that skin tightening with RF cannot be incorporated into their treatment journey to provide advantageous results. We often discuss and offer a staged approach to treatment of these patients beginning with VASER liposuction of the deep layer to debulk the arm and RF treatment of the subdermis. At the second stage, brachioplasty is performed. With this two-stage approach, some improvement in the skin laxity is achieved by recruiting the patient's own skin tightening and the length of the excisional scar is more shortened, particularly at the elbow, axilla, and the lateral chest wall. In some cases, additional treatments with subdermal RF may also be performed.

9.4 Burns and tissue necrosis

All energy-based devices, whether utilizing ultrasound, RF, or laser, generate heat that results in soft tissue skin tightening as a primary or secondary treatment goal. Skin burns and tissue necrosis, however, can result from too much energy and heat application. In order to avoid excess energy accumulation in any treatment area, the device is kept in smooth motion, end-hits are avoided, tissues are well-hydrated, and the incision and immediate surrounding skin are protected with use of a port and energy application is avoided in a 2-5 cm radius around the entry site.

Along with more skilled application of technology, energy-based devices themselves have evolved to provide more tissue protection and safety. The earlier generations of UAL devices generated high levels of ultrasound energy, thought to underlie most UAL complications such as burns and seroma formation. The current generation of VASER device delivers notably lower amounts of ultrasound energy to the soft tissues, especially when using the pulsed (VASER) mode, while still efficiently and effectively emulsifying fat and supporting skin tightening [5].

RF devices have undergone improvement as well. As described earlier, bipolar devices have developed to better manage direction of heat and energy application than monopolar devices. Bodytite incorporates internal and external temperature monitors with safety shut-offs if the tissue heats beyond temperature boundaries set by the surgeon. Perfusion imaging assessment using indocyanine green imaging and optical coherence tomography demonstrated no compromise of subdermal perfusion following treatment with a bipolar RF device [12].

We use Renuvion as our preferred subdermal RF device in the arm for its efficacy and safety features. Renuvion generates a low-current RF energy, the depth of heating is minimal, and overheating of the tissues with multiple passes is less likely. As tissues are treated, the fibroseptal bands coagulate, contract, and increase in impedance. The plasma beam thereby quickly alternates to target different tissues adjacent to the device tip in a 360° fashion, as untreated tissues present lower impedance. Surrounding untreated tissue remains cool, allowing for heat to dissipate quickly post treatment by heat conduction. Energy flow is thereby fractional resulting in effective FSN contraction without excessive heating of the tissue field and, in particular, the dermis. The difference in subdermal and skin surface temperatures is much larger with Renuvion, allowing for safe skin temperatures to be maintained without the need for temperature monitoring. With subsequent passes in the same region, the energy continues to follow the path of least resistance (lower impedance) and therefore preferentially treats previously untreated tissue. With multiple passes, untreated tissues are optimally targeted, and over-treatment of any single area is avoided [14].

Regardless of the device used, the risk of burn is not entirely eliminated. Should there be any concern about too much heat application and burn potential, the area should be cooled with a cold moist dressing immediately. We apply topical dimethyl sulfoxide (DMSO) for any areas of potential skin compromise beginning immediately postoperatively and continued at home by the patient as long as required.

DMSO is a topical anti-inflammatory agent that has been shown to be beneficial to wound healing and analgesia [31]. Any areas of skin or tissue necrosis must be cared for in accordance with principles of burn and wound healing.

9.5 Seroma

The lymphatic system in the arm courses alongside the venous system and is enveloped by the deep fascial system. With any excisional surgical approaches, superficial dissection is essential to preserve the lymphatic network and prevent issues with seroma formation. Although energy-based minimally invasive devices tend to produce more postoperative serous drainage, the lymphatic system is not compromised. Dayan et al. [12] demonstrated the safety profile of subdermal RF application using indocyanine green lymphatic imaging, which demonstrated no compromise of lymphatic channels, peristaltic function, or subclinical lymphedema post-treatment. Instead of circumferential treatment of the arm (360-degree liposuction with or without skin tightening), we advocate leaving behind a bridge of undisturbed skin and subcutaneous tissues at least 5 cm wide along the lateral border of the arm to decrease postoperative swelling. Gravity-based drainage of fluid from the elbow incision is sufficient, although drains are occasionally used.

9.6 Nerve injury

9.6.1 Ulnar nerve

The ulnar nerve arises from the medial cord of the brachial plexus and travels deep to the fascia in the upper portion of the arm. It becomes more superficial when it pierces the intramuscular septum 8 cm superior to the medial epicondyle at the arcade of Struthers and travels medial to the triceps before passing through the cubital tunnel posterior to the medial epicondyle. Surgical incisions must be placed away from the ulnar nerve and placed either on the radial side of the elbow or anterior to the medial epicondyle if more ulnar-sided access is necessary. The path of the ulnar nerve at the elbow is marked and liposuction or energy application is avoided in this critical region.

9.6.2 Sensory nerves

The medial brachial and medial antebrachial sensory nerves arise from the medial cord of the brachial plexus and travel just superficial to the deep fascia along with the basilic vein. In the distal 1/3 of the arm, sensory branches can be encountered (often 7-14 cm proximal to the medial epicondyle) [2]. The nerves can be injured during dissection of the distal 1/3 of the arm in brachioplasty procedures. Direct nerve damage or transection is less likely with minimally invasive approaches.

9.7 Infection

Less invasive approaches to arm contouring tend to be associated with less postoperative major complications than excisional approaches with brachioplasty. Although no studies that directly compare the two approaches in comparable groups have been conducted to date, trends can be drawn from available large population databases. Studies of patients enrolled in the CosmetAssure database from 2008 to 2013 [32, 33] revealed that major complications occurred in 0.7% of patients undergoing liposuction alone and in 1.3% of brachioplasties alone. When brachioplasty was combined with liposuction, overall rate of major complications increased to 3.6% although the study was limited to liposuction as a procedure and not necessarily specific to liposuction of the arms per se. BMI equal or higher than 30 kg/m^2 was found to be an independent risk factor for infection. To minimize risk of infection with arm contouring procedures, complete sterile preparation and draping is required, even if a less-invasive approach is taken. Patients are encouraged to achieve a healthy BMI as lipocontouring is not a replacement for healthy lifestyle, and a normal BMI can optimize patients for better recovery as well as better results. Patients who are PDWL are at higher risk of nutritional deficiencies and are encouraged to undertake a complete healthy protein-rich diet prior to surgery [34].

9.8 Learning curve and management of surgeon/patient expectations

As with the adoption of any new surgical technique or technology into one's practice, it is of paramount importance to recognize the learning curves associated with novel approaches and to proceed cautiously. Following mastery of the device itself—learning how to operate safely with balance of tumescence, zones of treatment, energy settings, depth of device placement and direction and speed of device manipulation—patient selection and management of expectations are key to success. Younger surgeons are encouraged to establish comfort with location and planes of deep versus superficial fat pockets in the arms and gain success with debulking of excess deep fat of the posterior region of the arm before attempting superficial liposuction and muscular etching to avoid unwanted irregularities and contours. Similarly, when implementing RF skin tightening, it is best to select cases of mild skin laxity and ptosis in which treatment response is likely to be in keeping with both patient and surgeon expectations. It is always the gold standard to offer excisional surgery to patients with significant skin laxity, striae, and/or severe photoaging, where the damaged dermis can be less reliable in terms of contraction and neo-collagenesis upon which RF depends. Depending on location of skin excess, whether it is mostly involving the axilla region, the entire dependent portion of the arm, extending to the elbow, or extending to the chest wall, the patient may be best treated with axillary short scar brachioplasty, traditional brachioplasty, extended brachioplasty to below elbow, or extended brachioplasty to lateral chest as indicated [25]. While patients may be deterred by the conspicuous brachioplasty scar, it is important to emphasize trade-off between scar and amount of arm contouring and skin tightness desired by the patient. A patient with significant skin excess who wants ideal arm contour and as much skin tightness as possible will never be satisfied with results achieved with RF skin tightening alone. Conversely, a patient who is completely intolerant of scars but is satisfied with even mild to moderate improvement of skin laxity, will be well-served with RF skin tightening. Although RF skin tightening can be safely combined with excisional surgery concurrently, we again advocate that the surgeon establishes comfort with the technology first. Furthermore, we recommend utilizing lower energy settings and avoiding application of energy within a 2-5 cm margin of incision edge to ensure skin viability and uncompromised wound healing.

10. Alternative treatment options and their limitations

10.1 RF-assisted liposuction (RFAL)

RF-assisted liposuction is an alternative means of utilizing RF energy to emulsify fat and tighten soft tissues as an adjunct to correction of lipodystrophy with liposuction. Utilizing the RFAL technique, RF is applied to the subcutaneous tissues following infiltration with tumescence. Thereafter, excess fat and fluid is removed with SAL or PAL [35]. RFAL is a useful alternative technique that achieves many of the same goals as contouring with VASER liposuction and skin tightening with RF. There are two advantages to separating the process of lipocontouring and soft tissue tightening: one lies in the flexibility to harvest viable adipocytes with VASER liposuction that can then be utilized for fat grafting if needed [7, 8], and the second is the reduced disposable cost of utilizing the single-use RF handpiece only for patients that truly need additional skin tightening. Additionally, by performing liposuction prior to RF energy application, tissue heating is optimized as the volume of intervening heat-resistant fatty layer will be decreased, and the subdermis and FSN better exposed as desired targets of energy application [14].

10.2 Laser-assisted liposuction

In addition to VASER and RFAL, another modality that utilizes energy for adipocyte lysis prior to aspiration and offers a degree of skin tightening is Laser-assisted liposuction (LAL). Multiple systems are marketed that utilize 1064 nm Nd:YAG, 1320 nm Nd:YAG, and 980 nm diode lasers conducted via an optical fiber within a cannula and placed in direct contact with adipose tissue. The laser produces photomechanical and photothermal effects that result in adipocyte lysis, small vessel coagulation, dermal coagulation, and subsequent neocollagenesis [36, 37]. While to our knowledge there are no published reports that directly compare VASER to LAL, a similar amount of skin retraction could be achieved with LAL (between 11 and 17%) [36, 37]. There are some limitations to the use of LAL: Since absorption of laser energy results in adipocyte rupture and death, this technique eliminates potential harvest of viable fat cells that can be utilized for fat grafting [36]. There is also a steep learning curve associated with LAL. Duration of laser activity in tissues is variable and affected by tissue thickness and volume as well as overall treatment size, previous scarring and fibrosis, and skin laxity. Loss of resistance denotes adipocyte lysis and is utilized as an endpoint. Surgeons must be vigilant to avoid excessive energy build up at the fiber tip that can rapidly build up and result in tissue necrosis [36].

10.3 Water jet-assisted liposuction

Water jet-assisted liposuction (WAL) targets a thin fan-shaped water stream into soft tissues to release fat lobules from the matrix. WAL can yield lipoaspirates well-suited for fat grafting but does not improve overall liposuction results or skin retraction after treatment [38, 39]. Although the aspirated fat is of excellent quality with minimal bleeding, the time required to aspirate even one area was found to be inefficient in our hands and excessively prolonged operative time in combined procedures. This, and the lack of improved outcome in liposuction or skin quality, made WAL a nonviable option in our practice.

10.4 Cryolipolysis

Cryolipolysis is a useful non-invasive adjunct for reduction of fullness in patients with spot or localized fat excess and otherwise good skin quality. Applications of cryolipolysis in the extremities is generally limited as most patients require contouring of the entire upper length of the extremities with skin quality frequently also needing to be addressed. Rivers [23] has described the use of multiple coupled cryolipolysis applicators to broaden inclusivity of patients to those with more fatty excess, but this technique can be costly for patients. We reserve cryolipolysis for treatment of patients who seek only non-invasive treatments, are young with good skin quality and elasticity, and have mild localized areas of adipose excess in the upper arm or anterior axillary region. Remaining patients are treated according to our proposed arm contouring treatment algorithm.

10.5 Deoxycholic acid

Deoxycholic acid (Kybella (USA) or Belkyra (Canada) Allergan Pharmaceuticals, Markham, ON, Canada) is an injectable treatment for subcutaneous fat excess, currently approved for improvement of submental fat. Deoxycholic acid induces adipocytosis and local inflammatory response to result in improved neck contour [24]. Off-label treatment of the upper arms with deoxycholic acid has been described [24], although to our knowledge no studies of large patient sizes, long-term results, and potential complications have been published. As one of the clinical trial centers for use of deoxycholic acid in the submental region, we have extensive experience with the product and its method of action. Given its localized treatment area, need for multiple treatments, significant post-treatment swelling, lack of improvement of skin quality, need for high volumes of product and corresponding cost, and residual subcutaneous fibrosis that can impair future surgical treatments (such as with liposuction), we do not recommend use of deoxycholic acid for arm contouring. Adverse neurotoxic effects of deoxycholic acid resulting in demyelination of nearby nerves with resultant anesthesia/hypesthesia of sensory nerves and weakness of motor nerves, is another limiting factor in broadened use of this drug in body contouring [24].

11. Conclusion

Arm liposuction is a very rewarding procedure for both patients and surgeons that can be easily performed under local anesthetic or in combination with other procedures under general anesthetic. The addition of energy-based devices has expanded treatment options for patients with arm contouring concerns who either do not desire significant brachioplasty excisional surgery or who do not have enough excess skin to warrant the large incisions. These technologies can also be used to enhance the results even in our more traditional brachioplasty patients.

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Conflict of interest

Dr. Julie Khanna is a consultant for VASER, Inmode, Renuvion, and Allergan. Dr. Maryam Saheb-Al-Zamani has no interests to disclose. There were no financial conflicts of interest in preparation of this chapter.

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Chapter 17

Enhanced Liposuction for Arms

Engin Selamioglu and Ercan Karacaoglu

Abstract

Arm contouring is a desired goal of the arm esthetics. Brachioplasty is a developing and safe surgery to improve the arm silhouette but scar is a one of the most distracting factor for both patients and surgeons. In this chapter conventional liposuction with laser assisted liposuction (LAL) is proposed to yield satisfactory results in selected group of patients. Classification systems are helpful to decide for proper patient selection for this technique. It includes assessment of fat excess, skin excess, and location of the deformity (proximal, entire arm, arm and chest). Patients with minimal to extensive fat deposits plus minimal to moderate skin laxity are the best candidates for this approach. When properly performed, with realistic expectations, liposuction and LAL combination is considerably a procedure of choice for arm contouring in these selected cases. The contraction of arm skin is considerably consistent. Our approach, except in the most extreme cases, is to initially recommend liposuction and possibly even a second liposuction prior to recommending brachioplasty. An esthetically pleasant result can be obtained even in massive arms with good skin tone. Massive arms with poor skin tone, however, may not. Patient selection and preoperative planning are discussed in detail. A thorough description for patient positioning and anesthesia options are studied. The technique of the liposuction is widely described including specific regional contour goals with artistic attention to enhance the contour. Refinement regarding skin tightening and skin surface smoothness are also discussed. Arm contouring is a growing field of body contouring and can be practiced with low complication rates and high patient satisfaction. Available classification systems help to select proper patient group. Laser assisted fat removal combined with conventional liposuction are promising procedures for selected patients.

Keywords: arm contouring, arm shaping, brachioplasty, laser lipolysis, arm laser, lipolysis

1. Introduction

Arm contouring is one of the most emerging topic in body contouring. In this chapter conventional liposuction with laser assisted liposuction (LAL) is proposed to yield satisfactory results in selected group of patients. Classification systems are helpful to decide for proper patient selection for this technique. It includes assessment of fat excess, skin excess, and location of the deformity (proximal, entire arm, arm and chest). Patients with minimal to extensive fat deposits plus minimal to moderate skin laxity are the best candidates for this approach. When properly performed, with realistic expectations, liposuction and LAL combination is considerably a procedure of choice for arm contouring in these selected cases. The contraction of arm skin is considerably consistent. Our approach, except in the most extreme cases, is to initially recommend liposuction and possibly even a second liposuction prior to recommending brachioplasty. An esthetically pleasant result can be obtained even in massive arms with good skin tone. Massive arms with poor skin tone, however, may not.

This chapter reviews the relevant literature in arm contouring including surgical and minimal invasive procedures used to esthetically improve the arm. Patient selection and preoperative planning are discussed in detail. A thorough description for patient positioning and anesthesia options are studied. The technique of the liposuction is widely described including specific regional contour goals with artistic attention to enhance the contour. Refinement regarding skin tightening and skin surface smoothness are also discussed.

1.1 Overview

1. Selection of Candidates, Preoperative Planning, Preoperative Photo documentation

2. Patient Positioning, Anesthesia Options

3. Infusion, Traditional Liposuction, Selection of Liposuction Cannulas, PAL (Power-Assisted Liposuction), Water-Jet asisted liposuction

4. Toning and Smoothing of the skin

5. Art of Arm Contouring (regional boundary goals, and how to achieve them)

6. Postoperative Care (compression garments, activity restrictions)

7. Prevention of Complication and Complication Management

2. Selection of candidates, preoperative planning, preoperative photo documentation

2.1 Selection of candidates

- One of the most crucial steps in body and arm shaping operations is the selection of candidates. In order to have the best result after a liposuction procedure, patient selection has to be done very carefully. Correct selection of the patient is one of the most important determinants in obtaining the desired result after the liposuction procedure. Thus detailed physical examination during the assessment of a patient has a great importance.

- There is not only one reason behind the upper arm deformities. It may occur due to the accumulation of an excess fatty tissue,which is called lipodystrophy, or in some cases skin laxity might be the only reason for upper arm deformities. However, coexistence of both causes may result in upper arm deformities.

- Patients who will be selected for a liposuction procedure, should have a good skin elasticity with little skin laxity and there should be no or limited excess skin. In patients with excessive skin laxity, it is not possible to reach the ideal result solely with liposuction. Skin resection might be required in patients who have severe skin laxity or extreme excess skin.

- Various algorithms and classifications have been described to decide the surgical procedure that is going to be applied [1–3]. In 1998, Teimourian and Malekzadeth have defined the first classification system by diving the patients into 4 groups. Patients who have mild or moderate fatty tissue and mild skin laxity are defined as group1 and liposuction procedure alone is preferred option. However, depending on the degree of fatty tissue a combination of liposuction or only resection is recommended for patients in other groups with more skin laxity [1]. Applelt et al. expanded the classification system to include the location of excess skin and severe deformities involving the arm and lateral chest wall, were added into the indications for brachioplasty [2, 4]. Although, El Khatib's classification of brachial ptosis is similar to these classifications, it includes the measurement of the amount of skin ptosis under the brachial sulcus.

2.2 Preoperative planning

- In body shaping procedures, preoperative surgical marking during preoperative planning has a great importance for an optimum result. Preoperative surgical marking has to be done with detailed physical exam while the asymmetries are also need to be addressed as well. In the presence of assymetry, patient should be informed regarding the postoperative result. As a result of physical exam, the concavity and convexity should be determined and marked. These markings will be guideing the surgeon during the surhery and will also decrease the risk of contour deformities by applying the liposuction to the appropriate areas as needed. Preoperative marking should be done in standing position. Patient's shoulders must be placed in 90 degrees of abduction and elbows should be positioned at 90 degrees of flexion. This position will help to assess the skin laxity, skin excess and the degree of ptosis. Surgeon will able to evaluate the contour deformities while the patient's arm are in full extension. Preoperative surgical markings should be checked one more time after the patient is placed on the operation table.

3. Patient positioning, anesthesia options

3.1 Patient positioning

- Patient should be placed in supine position on the operation table. After the patient is taken to the surgery room, the preoperative surgical marking should be checked one more time. Arms should be freely positioned to facilitate arm movement during liposuction procedure. If circumferential liposuction is planned, the arm should be considered into 3 units as medial, lateral and posterior and liposuction needs to be performed in a sequential order.

3.2 Anesthesia options

- The type of anesthesia can be decided based on the preference of the patient and the surgeon, the amount of fat and the necessity of ancillary surgical procedures to be applied. If it is a limited volume liposuction and no additional surgical procedures is planned then, local and regional anesthesia may be the type of anesthesia chosen. If it is going to be a large volume liposuction and h additional surgical procedures will be added then, general anesthesia may be preferred. The importance of fluid replacement should be kept in mind throughout surgery. And it is crucial especially for mega volume liposuction.

4. Infiltration, traditional liposuction, LAL, PAL, selection of liposuction cannulas

4.1 Infiltration

- It is of great importance and practice to apply infiltration solution before starting the liposuction procedure. The tumescent technique containing diluted epinephrine and lidocaine, which is frequently used in liposuction practice today, was described by Jeffrey Klein [5]. Reasons and advantages beyond application of infiltration solutions are a few. Epinephrine and lidocaine in the solution have two basic roles: anesthesia and vasoconstriction. Thanks to the vasoconstrictor effect, bleeding during the procedure and bruising in the post-operative period are reduced considerably. For patients whom general anesthesia is not preferred, liposuction can be performed with infiltration thanks to its anesthetic effect. For patients undergoing general anesthesia, intraoperative anesthesia is supported and patient comfort is increased in the post-operative period thanks to this anesthetic effect. It is not an obligation to use lidocaine in the infiltration solution in patients undergoing general anesthesia. However it is generally preferred because of these secondary effects. In order to reduce the risk of toxicity, the amount of lidocaine dosage should not exceed 35 mg/kg [6]. The infiltration solution commonly used today is a mixture of 1 ml of epinephrin (1:1000) and 50 ml of 1% lidocaine for 1 liter of Ringer lactate solution [7]. While the ratio of infiltration solution to aspirate volume is approximately 2–3:1 in the tumescent technique, which is one of the most widely used infitration technique, this ratio is approximately 1:1 in the super wet technique. Application of infiltration solution facilitates the movement of the cannula by providing tissue expansion and decreasing friction forces during the liposuction procedure. The infiltration solution should be evenly distributed to the area of liposuction. Over-infiltration (more than 3:1 ratio) should be avoided as it may cause the surgeon to judge falsely.

4.2 Traditional liposuction

- In the traditional suction-assisted liposuction (SAL) method, the liposuction process is performed by suctioning the deep fatty tissues with a vacuum driven source providing negative pressure [8, 9]. This method is usually carried out with a device that provides negative pressure with aspiration [10]. Ultrasound-assisted liposuction (UAL) is another technique available. UAL may cause a higher rate of seroma formation compared to the traditional (SAL) method. Furthermore, care should be taken to avoid thermal injuries that may occur due to its thermal effect. SAL can be combined with power-assisted liposuction (PAL). A forward moving cannula is used in the power-assisted liposuction (PAL) method. This method can be preferred for patients who have dense soft tissues or secondary cases. One of the greatest advantages is that the surgeon gives less effort and provides suction in more dense areas of fibrous tissue. In laser-assisted liposuction (LAL) method, it is estimated that the laser energy causes the destruction of fatty tissue. One of the most advantage of LAL is its capability for a better skin retraction compared to the traditional method. This is a great value for patients with severe skin laxity. LAL is our preferred method for arm liposuction for this high potential skin contraction feature. Radiofrequency-assisted liposuction (RFAL) method can also be preferred in patients with severe skin laxity to provide a skin contraction and retraction. Care should be taken against thermal injuries that may occur on the skin due to thermal energy during the radiofrequency-assisted liposuction (RFAL) process.

4.3 Selection of liposuction cannulas

- Cannula options are available in various lengths from 2 mm to 4 mm depending on the amount of fatty tissue in the area to be applied during the liposuction procedure. Cannulas which are small in diameter are used to eliminate surface irregularities and minimize the risk of contour deformity. Care should be taken not to loose the skin tissue during liposuction procedure. Hence, the risk of contour deformity can be minimized by directing the sucking holes apart from the skin surface. Arm shaping procedure with the LAL method, begins with infiltration through two stab incisions near the elbow area. These two stab incisions are desired to be located on the posterior half of the arm and to be at a certain distance from each other to allow cris-cros. Although cris-cros is aimed, it is mainly planned to aspirate regional fat accumulation located along the vertical axis of the arm. In other words, during liposuction, fat aspiration is requested in a single direction, not homogenous and versatile as in abdominal or back region. As the initial step, the process starts as traditional SAL and after the targeted area is aspirated, the laser component is applied alone. According to the tissue elasticity, laser component is applied in certain watts (Orbeam Diode Laser, in a 60-watt laser device, 1000 nm fiber with a 25-watt output and 4500–6500 joules preferred per one arm.).

5. Toning and smoothing of the skin

- Again, we cannot emphasize enough the importance of selection the appropriate candidates. Liposuction can achieve good results in patients who have mild or moderate fatty tissue, good skin tone, and mild skin laxity. In patients who have severe skin laxity or extreme excess skin, resection based procedures might be applied alone or in combination with liposuction procedure. The biggest downside of resection based surgeries in brachioplasty is the resulted scar tissue in the long axis of the arm. In patients without severe skin laxity and skin excess, energy-based systems might be used to provide a skin contraction of the targeted area. LAL or RFAL methods may be preferred in these patients [11]. In addition, radiofrequency energy-based skin tightening technique can be combined with the liposuction procedure. It is possible to obtain a more satisfactory result by applying the second LAL session for patients with severe skin laxity or whom desired skin contraction could not be achieved in the first session. It is recommended that a gap of at least 6 months between two sessions would be feasible (**Figures 1**–**8**). All patients are undergone only the LAL. No ancillary modalities were applied. We believe patients would benefit from RFAL as well.

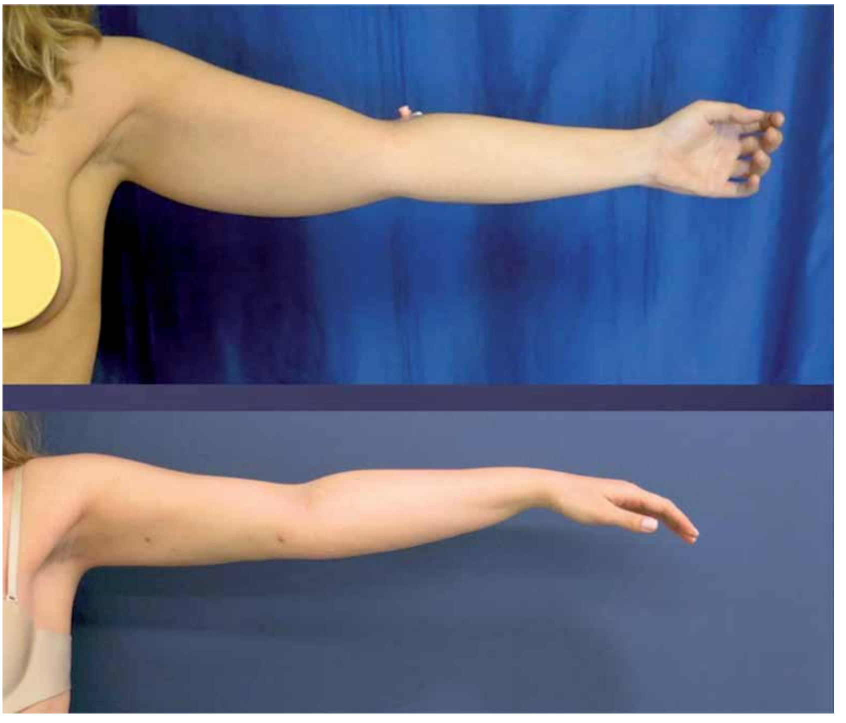

Figure 1.
28 years old patient with local fat depositions in both arm. Left arm anterior view before and 2 months after laser assisted liposuction (LAL).

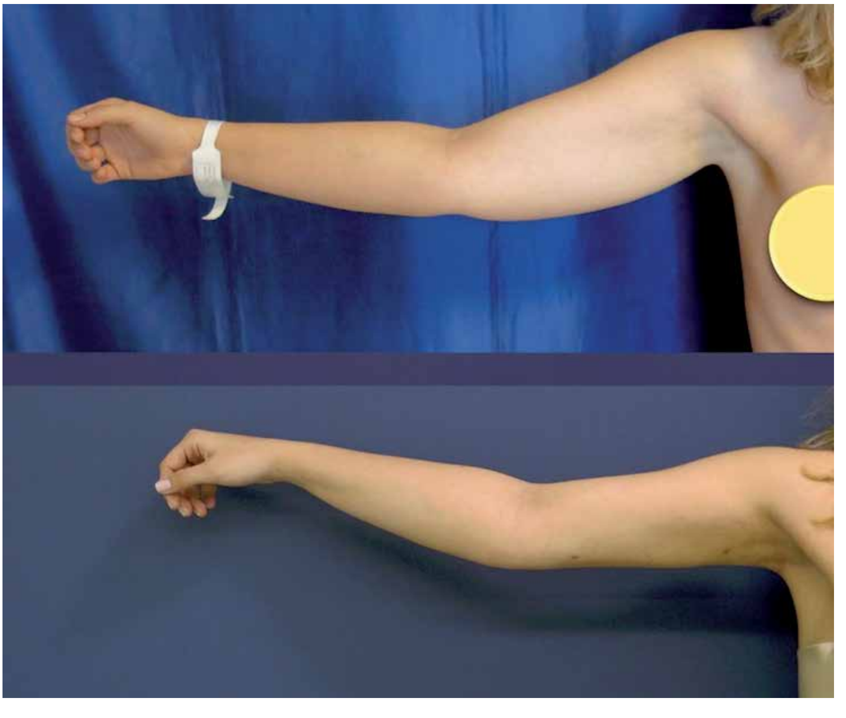

Figure 2.
28 years old patient with local fat depositions in both arm. Right arm anterior view before and 2 months after LAL.

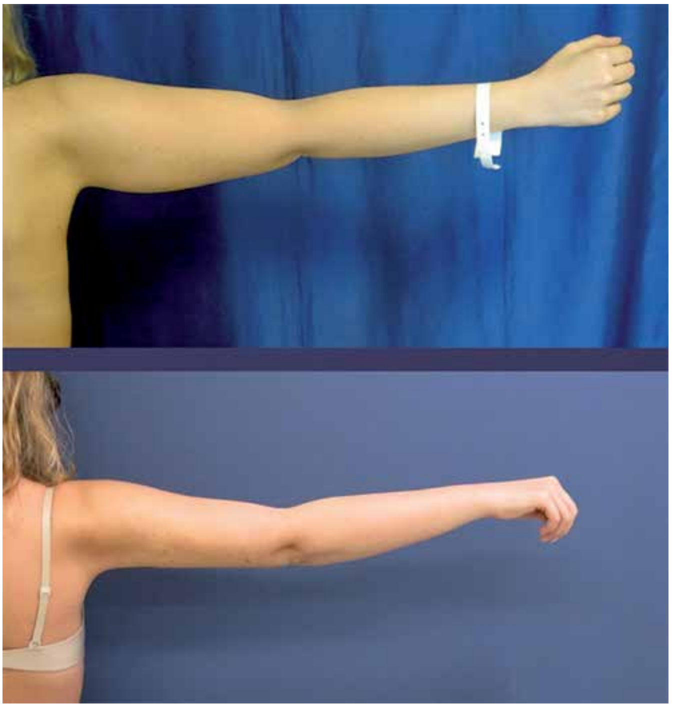

Figure 3.
28 years old patient with local fat depositions in both arm. Right arm posterior view before and 2 months after LAL.

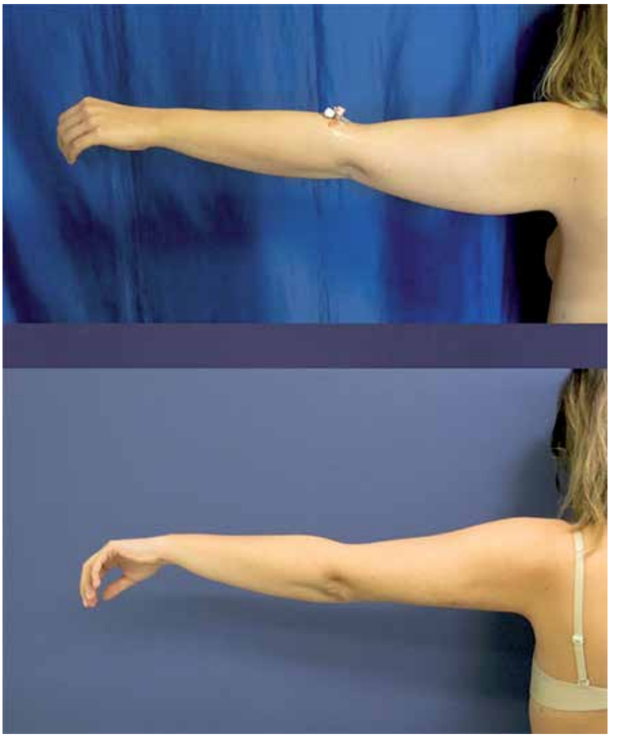

Figure 4.
28 years old patient with local fat depositions in both arm. Left arm posterior view before and 2 months after LAL.

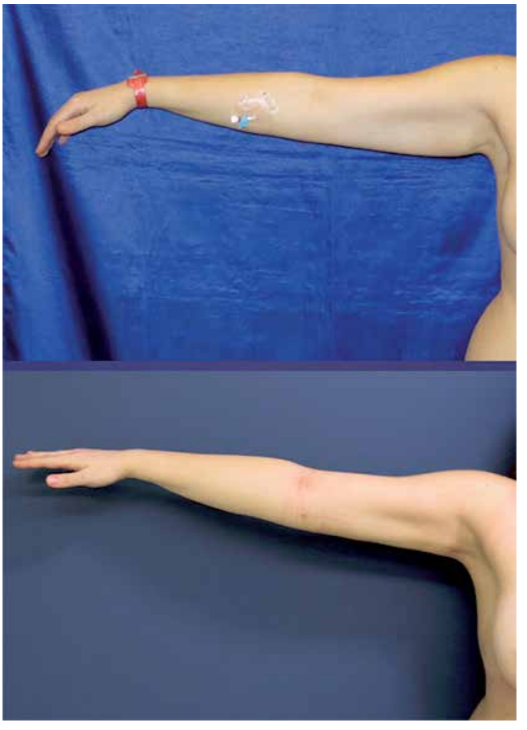

Figure 5.
45 years old patient with local fat depositions in both arm. Right arm anterior view before and 1 year after LAL.

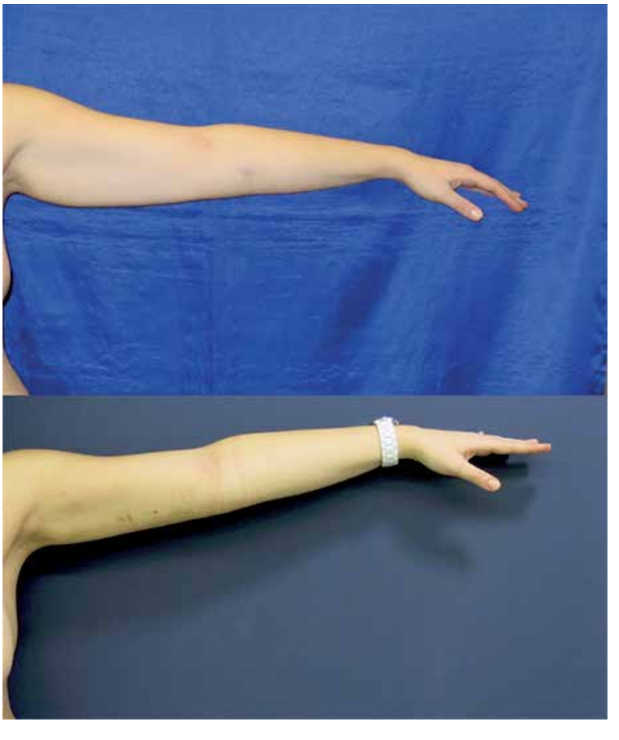

Figure 6.
45 years old patient with local fat depositions in both arm. Left arm posterior view before and 1 year after LAL.

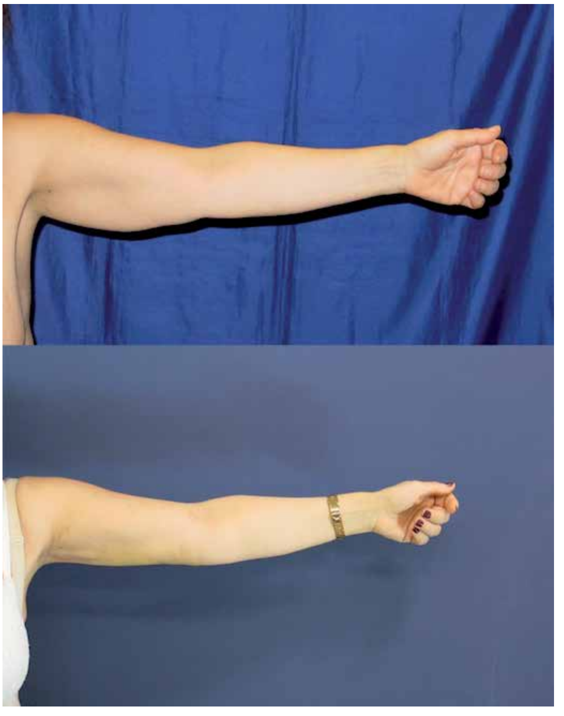

Figure 7.
54 years old female patient with local fat depositions in both arm. Right arm anterior view before and 6 months after LAL.

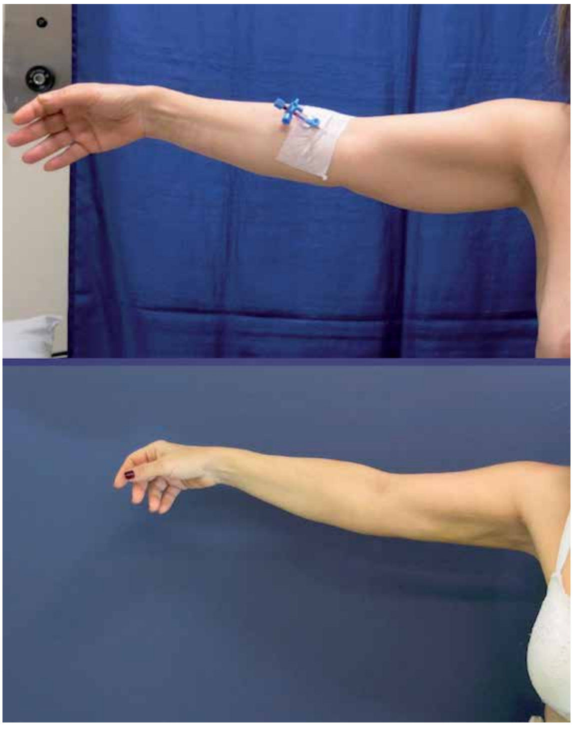

Figure 8.
54 years old female patient with local fat depositions in both arm. Left arm posterior view before and 6 months after LAL.

6. Art of arm contouring

- Extreme care should be taken for contour deformities that might occur after liposuction. Considering the convex and concave surfaces of the arm, besides the LAL method, the establishment of concave areas with fat grafting should be considered principally in primary liposuction. Liposuction procedure and fat grafting can be combined to reduce the risk of contour deformity. This will give a more pleasant cosmetic looking and will provide skin quality in selected patients. The fat aspirated from redundant areas of the arm can be used for grafting the fat. This can be of paramount importance specifically while shaping the bicipital groove area with fat grafting [12].

7. Postoperative care, compression garments, activity restrictions

- Patients should be informed about the post-operative period. In the early phase of post-operative period, patient should be informed about bruising and edema. Especially in the first 2–3 days, the patient should be informed that there might be serious leakage from the incisions. It is completely surgeon's choice to suture the incision area or not.

- It is suggested to use compression garments or compression bandages in order to reduce the formation of edema and bruising in the post-operative period. It is believed that this approach accelerates the healing as well. Although applying of compression garments is suggested for an average of 4 weeks, more might be needed depending on individual requirements.

- Patients are mobilized 3 to 4 hours after the surgery. In the early phase of post-operative period, mobilization should be encouraged but patients should also be informed for avoiding excessive and strenuous physical activity. Patient should be followed up after the first week. If there is not any problem during this one week period, the amount of physical activity can be gradually increased from the first week on. Patients are recommended to perform normal daily activities by avoiding excessive physical activity. Patients who do not have any problems in their follow-up can be allowed for full physical activity, 3–4 weeks after the surgery.

8. Summary

Contouring of the arms is the desired goal of the arm esthetics. Arm lifting is a developing and safe surgery to improve the arm silhouette but scar, all the way along the arm, is one of the most distracting factor for both patients and surgeons.

In this chapter conventional liposuction with laser assisted liposuction (LAL) is proposed to yield satisfactory results in selected group of patients.

Patients with minimal to extensive fat deposits plus minimal to moderate skin laxity are the best candidates for this approach. When properly performed liposuction and LAL combination is considerably a procedure of choice for arm contouring in these selected cases. The contraction of arm skin is considerably consistent for certain ages and people. Our approach, except in the most extreme cases, is to initially recommend liposuction and possibly even a second liposuction prior to recommending brachioplasty. An esthetically pleasant result can be obtained even in massive arms with good skin tone.

Patient selection and preoperative planning are discussed in detail. A thorough description for patient positioning and anesthesia options are studied. The technique of the liposuction is widely described including specific regional contour goals with artistic attention to enhance the contour. Refinement regarding skin tightening and skin surface smoothness are also discussed.

Arm contouring is a growing field of body contouring and can be practiced with low complication rates and high patient satisfaction. Available classification systems helps to select proper patient group. Laser assisted fat removal combined with conventional liposuction is an effective combination to provide satisfactory results for selected patients.

Conflict of interest

There is no conflict of interest to declare.

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Chapter 18

Enhanced Abdominal Contouring

Shawna R. Kleban, Gaurav Bharti and Bill G. Kortesis

Abstract

This chapter will discuss the various energy-based modalities that are available to optimize circumferential trunk liposuction to enhance patient results. We will discuss multimodal liposuction using power assisted liposuction, ultrasonic energy addition, as well as radiofrequency assisted modalities to achieve adipose reduction and concurrent skin and soft tissue contraction. An in-depth look at patient selection and intraoperative technique will be presented. The postoperative management for each modality will be discussed in detail, including expected results from each modality and potential complications and their ensuing management. We will also discuss the application of different modalities alone and in combination to achieve superior results.

Keywords: ultrasound-assisted liposuction, radiofrequency assisted lipolysis, helium plasma focused radiofrequency liposuction, abdominal liposuction, energy-based liposuction

1. Introduction

The use of liposuction to contour the abdomen and trunk has been employed for almost 40 years [1]. Since its widespread adoption, there has been a continual evolution in technique and the addition of various complementary technologic adjuncts. Energy-based devices have been created to enhance the results of traditional liposuction. The currently available energy-based devices include ultrasound, laser, and radiofrequency. The primary goal of the majority of energy-based devices is to create skin and fibroseptal contraction to improve postoperative skin laxity. Power-assisted liposuction is often utilized in combination with these energy-based technologies to aid in surgeon comfort and efficiency. Several techniques and modalities may be combined to improve patient results.

1.1 SAFE (separation, aspiration, and fat equalization) liposuction

We believe that incorporating the SAFE (Separation, Aspiration, and Fat Equalization) technique, as described by Simeon Wall, Jr., leads to superior liposuction results [2, 3]. As originally described, this technique involves three key steps: (1) separation of the fat using an exploded-tip or basket-tip cannula without suction, (2) aspiration of the fat, and (3) fat equalization again with an exploded-tip cannula off suction. Separation leads to mechanically emulsified fat while preserving vascular structures. Approximately 40% of the operative time is spent "separating" and the surgical endpoint is loss of resistance. Aspiration is then performed using less aggressive cannulas for 40% of the operative time. Finally, fat equalization is performed with a basket-tip cannula without suction. Any irregularities can be smoothed out during this step and the fat is again emulsified resulting in a bed of "local" fat grafts. These "local" grafts prevent adherence of the dermis down to the underlying fascia. The surgical endpoint is a smooth rolling pinch test and a visibly smooth contour which translates to 20% of the total operative time.

1.2 Power-assisted liposuction (PAL)

Power-assisted liposuction (PAL) was introduced in 1998 by MicroAire Surgical Instruments (Charlottesville, VA, USA). The original handpiece utilized compressed air to power the device with later generations powered by electricity [4]. PAL is advantageous in fibrous areas and for secondary liposuction cases and has been noted to decrease surgeon fatigue with less plugging of the cannula and shorter operative times [5–7]. Some disadvantages of PAL are cost, learning curve, potential vibratory injury, and noise [4].

1.3 Ultrasound-assisted liposuction (UAL)

Ultrasound-assisted Liposuction (UAL) was first described by Zocchi nearly 30 years ago [8]. The ultrasonic probe transforms electrical energy into mechanical energy leading to cavitation and cellular disruption. The emulsified fat is then aspirated via traditional suction-assisted lipectomy (SAL). The third-generation UAL devices such as VASER™ (Solta Medical, Hayward, CA, USA), use pulsed rather than continuous energy allowing for greater fragmentation of adipocytes at a lower energy setting [9].

Proponents of UAL have found that the addition of UAL leads to decreased intraoperative blood loss, decreased postoperative ecchymoses and discomfort, decreased operative time, and enhanced skin contraction [9–15].

The drawbacks of UAL include increased expense, larger incisions, technical difficulty with a steep learning curve, and the risk of thermal burns [16–19].

The addition of VASER should be considered for patients undergoing large-volume liposuction or liposuction of fibrous areas such as the back and hip rolls (posterior flanks) where increased blood loss is expected [11]. VASER may also be considered in patients where additional skin tightening is desired [13].

We have combined the techniques of SAFE and ultrasound-assisted liposuction by utilizing the VASER to separate and emulsify the fat prior to suctioning. Fat equalization is still performed using the basket-tip cannula.

1.4 Laser-assisted liposuction (LAL)

Laser-assisted liposuction (LAL) relies on selective photothermolysis to target and lyse adipocytes [20] and interest in LAL began after studies conducted by Apfelberg [21] and Apfelberg et al. [22, 23] in 1992.

The wavelengths utilized in LAL target fat, collagen, vascular structures, hemoglobin, and water to varying degrees. Obliteration of these targets leads to photolysis of adipocytes, release of adipocyte lipases, dermal collagen contraction, and photocoagulation of small vessels [24–26].

The three main lasers utilized for LAL are the 1064 nm Nd:YAG, the 980 nm diode, and the 1064/1320 nm Nd:YAG lasers [27]. The most studied wavelength is 1064 nm Nd:YAG which has hemoglobin as its target [28]. Both SmartLipo™ (Cynosure Inc., Westford, MA, USA) and ProLipo PLUS™ (Sciton, Inc., Palo Alto, CA, USA) utilize 1064 nm wavelengths. ProLipo PLUS combines 1064 nm with 1319 nm in hopes of providing additional dermal contraction [29].

LAL can either be performed at the same procedure as SAL or in a two-stage procedure with SAL performed at the second stage.

Initial studies showed minimal cosmetic benefit with the addition of LAL to traditional SAL [22] The disadvantages of LAL include increased cost, increased operative time, and potential for thermal burns [30].

1.5 Radiofrequency-assisted liposuction (RFAL)

Radiofrequency-Assisted Liposuction (RFAL) takes advantage of a high frequency oscillating electrical current to create a thermal effect which dissolves fat cells and causes dermal contraction. RF devices lead to contraction of the fibroseptal network (FSN) through immediate contraction of collagen fibers, subdermal remodeling, and neocollagen formation [31–34]. The devices that we currently use for the abdomen and trunk are BodyTite and Renuvion (formerly J-Plasma).

1.5.1 BodyTite radiofrequency (InMode)

The InMode devices (Invasix, Yokneam, Israel) are bipolar radiofrequency devices that contain both an internal and external temperature monitor. The tip of the handpiece delivers RF energy which travels to an external electrode that slides on the surface of the skin in line with the internal electrode. The RF energy creates a zone of thermal coagulative necrosis leading to adipocyte injury and FSN contraction [34]. BodyTite has been shown to lead to improved skin and soft tissue contraction when compared with traditional SAL (35% versus 8%) [35]. Complications after BodyTite include bruising, contour irregularities, pain, and thermal burns [36–38].

1.5.2 Renuvion helium plasma-driven radiofrequency (Apyx)

Renuvion was originally developed as a laparoscopic cautery device for general, gynecologic, and urologic surgeries [39]. Renuvion (Apyx Medical, Clearwater, FL, USA) combines radiofrequency energy and helium plasma to create subdermal tissue contraction. The device reaches the optimal temperature for subdermal tissue contraction (85°C) quickly with minimal thermal spread and cools to baseline temperatures in less than a second [40–45].

Helium plasma is created when helium gas is passed over the energized electrode at the tip of the handpiece. Heat is generated by the plasma beam itself and through the RF energy that passes from the handpiece to the patient's tissues [5].

The device is used after liposuction but can also be used alone to create skin tightening. The handpiece is passed through the subdermal plane and deeper subcutaneous tissues while slowly withdrawing the device. The amount of energy applied is recorded. In our experience, applying at least 10 kJ to the anterior abdomen is necessary.

Immediate results can be seen when using this device with visible improvement at 24 hours postoperatively and continued improvement for up to 12 months [5].

The advantages of the Renuvion system are decreased procedure times, decreased pain, and decreased risk of complications [39, 45–49]. The measured skin temperature rarely exceeds 38°C, leading to its increased safety profile. The risks associated with this device include helium embolism, thermal burns, pneumothorax, transient or permanent nerve injury, and helium gas buildup and crepitus.

1.6 Cannula selection

1.6.1 Cannula size

The larger the diameter of the cannula, the more rapidly the fat is removed. Larger diameter cannulas may be prone to creating contour irregularities from oversuctioning. Therefore, a balance exists between efficiency and postoperative complications. For abdominal and trunk contouring, we typically utilize 4 mm cannulas. The exception is for patients with extreme adiposity or minimal adiposity. A 5 mm cannula may be used during the initial debulking of the deeper fat compartments in patients with large adipose stores. In contrast, 3 mm cannulas may be appropriate for patients who are extremely thin to help prevent postoperative contour irregularities.

1.6.2 Cannula type

Caution has been placed on using basket cannulas for suctioning [2, 3], but we have not noted any untoward effects. On the contrary, we have found that suctioning with a 4 mm basket-tip cannula is more efficient than suctioning with the same diameter Mercedes-tip cannula. We utilize basket-tip cannulas for fat separation and fat equalization. Multi-holed cannulas are used for abdominal etching to remove all the fat between the fascia and dermis.

2. Evolution of technique

We have gone through multiple iterations to arrive at our current method of abdominal contouring.

Regardless of the technology used, liposuction technique is of paramount importance. The end point of liposuction should not be viewed as what has been taken away, but what remains. While it is important to note the total volume of fat aspirated from each site, the resulting contour is of greater importance.

Our current method of abdominal contouring combines the SAFE (Separation, Aspiration, and Fat Equalization) technique with VASER for fibrotic areas and Renuvion or BodyTite to assist in skin contraction in patients with more significant skin laxity. In our experience, VASER leads to mild skin contraction, but its main advantage is easier fat removal by facilitating adipose disaggregation in fibrotic areas. We use vaser in almost every liposuction case with the exception of cases where the aspirated fat would be used for fat grafting the breasts and when we are elevating an abdominoplasty flap.

When more profound skin contraction is required, we turn to the Renuvion or InMode devices. The decision for using Renuvion over the InMode devices is based on the surgical area treated. The design and ease of use of the Renuvion device makes it better suited for larger treatment areas. Bodytite can typically target more superficial soft tissue contraction needs while Renuvion can be helpful for large surface area fibroseptal contraction. There are instances where we will combine both Renuvion and Bodytite to achieve maximal contractions. In addition we will often add percutaneous treatment using RF microneedling treatments to improve skin quality and further increase contraction. We prefer the Morpheus 8 devide by InMode. We will typically perform 3 serial treatments separated by 4–6 weeks. We no longer utilize laser-assisted liposuction as we have had superior results with radiofrequency-assisted liposuction.

3. Patient evaluation and marking

Ideal candidates for abdominal and trunk liposuction are patients who present with localized areas of adiposity with minimal to moderate skin laxity. Patients with significant skin excess or those with minimal adiposity are better suited to excisional procedures. A pinch test should be performed to delineate subcutaneous versus intraabdominal fat. Patients should be counseled that intraabdominal fat will not be addressed or improved by liposuction. A history of any intraabdominal procedures should be elicited and the patient should be examined for any abdominal scars or hernias. Imaging is typically reserved for patients with questionable abdominal wall defects or hernias. In these cases, a computed tomographic scan of the abdomen and pelvis with oral contrast should be performed prior to surgical intervention.

Figure 1.
Standard abdominal series. Includes anterior and posterior trunk.

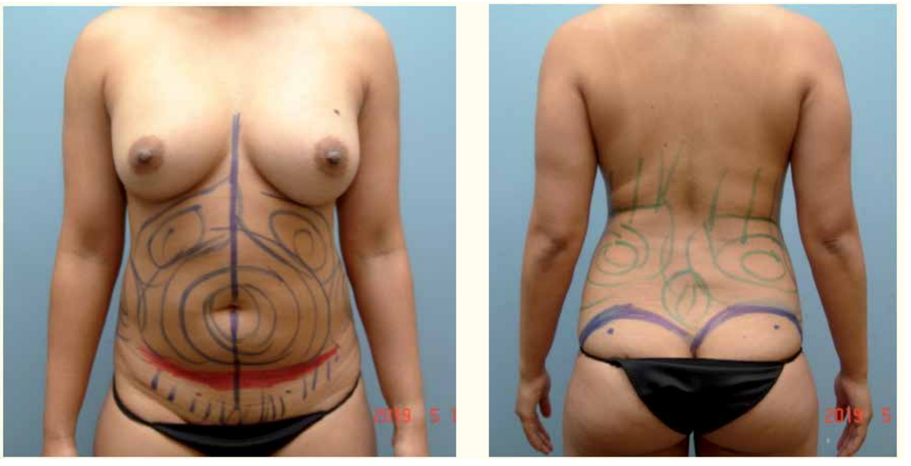

Figure 2.
Example of topographic marking for circumferential trunk liposuction. Thin areas are marked in red.

A standard series of photographs are taken prior to marking the patient (**Figure 1**).

The areas for liposuction are then marked topographically with care to delineate zones of adherence and other areas where liposuction should be minimized. The areas where fat removal should be avoided are typically marked in red (**Figure 2**). For patients undergoing abdominal etching, the muscular anatomy of the rectus abdominis muscle and external obliques are palpated with the patient flexing his or her abdominal muscles. The linea alba, linea semilunaris, and transverse rectus abdominis muscle inscriptions are marked. The rectus abdominis muscle inscriptions typically begin at the level of the umbilicus and continue with two or more inscriptions superiorly. Any excessive flank adiposity is marked topographically as well.

4. Operative technique

Following preoperative photographs and markings, the patient is brought to the operating room and placed in the supine position. Sequential compression devices are placed and activated prior to induction of general anesthesia. A warming blanket is used throughout the procedure to maintain optimal body temperature. For moderate to large volume liposuction, 1 gram of tranexamic acid (TXA) is administered intravenously at the start of the procedure.

The areas to be liposuction are infiltrated with tumescent solution prior to formal prepping and draping. The liposuction entry sites are cleansed with Betadine prior to incision and the cannula is frequently wiped with Betadine. In moderate to large volume liposuction, lower concentrations of lidocaine are used and 1 gram of TXA is added to each 1 liter bag of tumescent solution. The tumescent formula typically utilized is 12.5 mL 1% lidocaine, 1 mL 1:1000 epinephrine, and 1 gram TXA in 1,000 mL of warm Lactated Ringer's solution. The total amount of tumescent solution used depends on the planned amount of aspirate. The ideal ratio of infiltration fluid to aspirate volume is 1:1 for moderate and large-volume liposuction. A higher ratio of tumescent solution is typically utilized for small volume liposuction.

Small Volume Liposuction: <2,000 mL.

Moderate Volume Liposuction: 2,000 mL to 5,000 mL.

Large Volume Liposuction: >5,000 mL.

The patient is then fully prepped and draped. Skin protector ports are then placed at the access sites. Ultrasound-assisted liposuction (UAL) with VASER™ (Solta Medical, Hayward, CA, USA) is then performed to all areas of planned liposuction unless concomitant abdominoplasty is being performed. For these patients, VASER is only utilized posteriorly on the trunk. For the abdomen and posterior trunk, the VASER is set to 80% power. End hits of the cannula are avoided to prevent thermal injury to the dermis. Treatment is performed in both the deep and superficial fat layers until resistance is lost. Special attention is paid to zones of adherence to break up the dense fibrous attachments in these areas.

The typical treatment time is 5–10 minutes for the anterior trunk and 5–15 minutes for the posterior trunk.

The SAFE technique (Separation, Aspiration, Fat Equalization) described by Simeon Wall, Jr. [2, 3] is utilized for all trunk liposuction cases, but is avoided when performing liposuction to the anterior portion of the abdominoplasty flap.

Power-assisted liposuction (PAL) using MicroAire (Charlottesville, VA, USA) handpiece with 4 mm Mercedes tip and Basket tip cannulas is performed until even contour is achieved. The majority of the liposuction is focused on the deeper fat layers, leaving a thin, even blanket of fat in the superficial layer to prevent contour irregularities.

Fat equalization with a 4 mm basket tip cannula on the PAL handpiece is then performed. This equalization should be performed outside the areas of liposuction to blend and feather the liposuctioned area into the non-liposuctioned area.

4.1 Circumferential trunk liposuction

Patient positioning for circumferential trunk liposuction can be performed in the supine, prone and lateral positions. Our preferred technique for circumferential trunk liposuction positions the patient prone and then supine. We do not routinely utilize lateral positioning. When the patient arrives in the operating room, they are initially placed supine on a stretcher and tumescent fluid is infiltrated anteriorly. The patient is then placed prone on the operating room table and the posterior trunk is similarly infiltrated. The patient is then prepped and draped in the usual sterile fashion and suctioning begins in the prone position. The patient is transferred back to the stretcher in the supine fashion and placed on the operating room table in the supine position. The patient is again prepped and draped and suctioning is performed to the anterior abdomen.

4.2 Abdominoplasty with liposuction

A majority of our patients undergoing full abdominoplasty also receive abdominal liposuction to improve postoperative abdominal contour. Liposuction is performed prior to resection of the abdominal skin flaps. Access incisions are created within the area of planned resection and at the superior umbilicus.

A 4 mm Mercedes tip cannula is used with the Microaire PAL system to perform liposuction to the entire abdominal flap. The use of basket cannulas and fat equalization is minimized to prevent trauma to the vessels supplying the abdominoplasty skin flap. After the abdominal skin and fat is resected, the subscarpal fat is further trimmed to improve the contour and match the thickness of the mons.

4.3 Abdominal etching

Candidates for abdominal etching include patients who desire muscular definition in addition to fat reduction.

Patients with poorly defined muscular anatomy are candidates for modified abdominal etching, while patients with well-defined muscular anatomy are candidates for full abdominal etching [50].

Modified abdominal etching involves moderate fat preservation over the rectus abdominis muscles with thinning of the subcutaneous fat layer over the external obliques. Increased definition is performed at the linea alba and linea semilunaris.

Full abdominal etching adds liposuction of the rectus muscle inscriptions to the areas of liposuction performed in modified abdominal etching.

4.4 Drain vs. No drain

Incisions are either left open for drainage or closed with simple interrupted sutures when small volume liposuction is performed. Drain placement is considered for larger areas of liposuction. A 7 mm flat JP drain is placed to facilitate fluid egress and seroma prevention when larger volume liposuction is performed. The lumbar (hip roll) area is often drained especially in the setting of concomitant abdominoplasty. In these cases, the liposuction cannula can be advanced through the subcutaneous tissue from one liposuction entry site to another, the external portion of the drain is placed over the cannula and the drain is pulled through the entry site. When Renuvion is performed, the access sites are left open to allow for helium gas and fluid escape.

5. Outcomes and results

With the combination of sound liposuction technique and energy-based technologies we have seen excellent results with improvement in skin laxity. Whenever possible, we treat the trunk circumferentially. Below we demonstrate our abdominal contouring results with and without energy-based technologies, with the addition of an abdominoplasty, and with the addition of abdominal etching.

5.1 Case 1: circumferential trunk liposuction with SAFE technique

This is a 33-year-old female who desired circumferential trunk contouring. We performed circumferential trunk liposuction with the SAFE technique using the MicroAire PAL handle and 4 mm Mercedes tip and basket tip cannulas. In addition, she received breast and buttock fat grafting to enhance her result. Each buttocks was grafted with 250 cc and the breasts were grafted with 250 cc and 200 cc. A total of 1660 cc of excess fat was removed (**Figure 3**).

5.2 Case 2: circumferential trunk liposuction with VASER and Renuvion

Case 2 is a 36-year-old female who desired trunk contouring. Circumferential trunk liposuction with VASER and Renuvion was performed. She also received fat grafting to her breasts. The total VASER time was 5 minutes and 53 seconds to the posterior trunk. Renuvion was performed in 4–5 passes per treatment area. The total excess fat removed was 1360 cc (**Figure 4**).

5.3 Case 3: full abdominoplasty with circumferential trunk liposuction

This 42-year-old patient desired trunk contouring. She presented with rectus diastasis, excess abdominal skin, and abdominal striae; necessitating skin removal

Figure 3.
Preoperative photographs. Patient is shown 3 months postoperatively with significant improvement in abdominal contour.

and repair of her diastasis. She underwent circumferential trunk liposuction and full abdominoplasty with rectus muscle plication. VASER was used to treat the posterior trunk (**Figure 5**).

5.4 Case 4: abdominal etching with VASER

Case 4 is an example of full abdominal etching on a 44-year-old male. He also underwent chest contouring with VASER liposuction and gynecomastia gland excision. A total of 950 cc of fat was removed from the abdomen and chest (**Figure 6**).

5.5 Postoperative care

All patients are placed in compression garments at the conclusion of the procedure. When combined with abdominoplasty, an abdominal binder is placed for ease of evaluating the abdominal flap postoperatively. For circumferential trunk liposuction, either an abdominal binder or compression garment is placed. A layer of foam is placed beneath the garment to ensure even compression and reduce indentations from the garment.

If the patient is staying overnight for monitoring, the drains are hooked up to wall suction to allow for rapid fluid egress and removal of residual tumescent fluid. The drains are placed back to bulb suction when the drainage slows down.

Patients are prescribed oral antibiotics, pain medication, and vitamins. Patients are instructed to drink plenty of fluids with a goal of 1 gallon per day. The abdominal binder or compression garment is worn at all times, except when

Figure 4.
Preoperative photographs and markings. Patient shown 5 months postoperatively with excellent contour and skin contraction.

showering, which is permitted on postoperative day 2. It is recommended that patients wear some form of compression for at least 6 weeks postoperatively. Drains are removed once the output is less than 25 cc per day for at least two consecutive days.

Three Endermologie® (LPG Endermologie USA, Fort Lauderdale, FL) treatments are recommended to all patients to improve postoperative edema, with the option to add further treatments for continued areas of swelling or firmness. The Endermologie machine employs a suction-assisted massage technique that improves lymphatic drainage [51].

5.6 Management of postoperative complications

Seromas are a known complication of liposuction and may occur even in the setting of drain use. When patients present with a seroma, they are treated aggressively with repeated aspirations every day or every other day until the collection resolves.

Figure 5.
Preoperative photographs demonstrating skin excess and abdominal striae. Postoperative result at 6 months with improved contour.

Contour irregularities may be treated with manual lymphatic drainage (MLD) or Endermologie when mild. Endermologie and MLD help reduce postoperative edema and soften areas of firmness. More significant irregularities may be addressed with Kybella or touch up liposuction.

When patients present postoperatively with residual skin laxity that is minimal, external percutaneous radiofrequency microneedling devices (InMode Morpheus) may be used to aid in further skin contraction.

Potential complications from energy-based devices include thermal injury. Areas of full-thickness burns are treated conservatively with local wound care. Once healed, these small areas are often amenable to scar revisions.

Figure 6.
Preoperative photographs and 3 month postoperative photographs are shown.

6. Future directions

Continual improvement of energy-based technologies has led to enhanced patient outcomes for body contouring. The currently available technologies are suitable for minimal to moderate skin laxity, but no device is able to provide surgical results for patients with severe excess skin and laxity. Furthermore, few therapies have proved useful for the treatment of skin rippling and dimpling associated with cellulite. Future directions should focus on maximizing fibroseptal network and skin contraction, addressing rippling cellulite, and preventing postoperative liposuction deformities.

Furthermore, our patients yearn for less invasive options as well as less stigmata of having had a surgical procedure. Technology will continue to evolve to achieve further skin and soft tissue contraction in combination with fat reduction. Eventual advances will ideally allow these changes to occur percutaneously without the need for any incisions or downtime.

7. Conclusion

Enhanced abdominal contouring involves the addition of energy-based devices to traditional abdominal liposuction. We recommend performing SAFE liposuction in all patients (excluding abdominoplasty flaps). VASER can be utilized as the initial step in SAFE liposuction instead of separation by basket tip cannulas. VASER may also assist in some skin contraction and is helpful for fibrous areas. Power-assisted liposuction allows for decreased surgeon fatigue and increased efficiency. Radiofrequency devices (BodyTite and Renuvion) are considered for patients with more severe skin laxity. These treatments can be safely combined to provide optimal patient results.

Conflict of interest

Dr. Bharti and Dr. Kortesis are consultants for Allergan, Apyx Medical, and InMode. Dr. Kleban has no conflicts of interest to disclose.

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Chapter 19

Posterior Torso and Buttocks Contour Enhancement

Edward M. Zimmerman

Abstract

The harmonious contour and movement of the dorsal human form--male and female, youthful through senescent--has been observed, critiqued, and physically and surgically sculpted throughout human existence with the goal of producing a more functional, balanced and beautiful body. This chapter will explore variations and pendulum swings of desirable/beautiful/athletic posterior contours and how the cosmetic units of the upper back, bra roll, axilla, waist, low back, upper buttocks, vertical and horizontal buttocks folds, lateral hips and banana rolls are both independent and interdependent. The evaluation of the topography of the posterior torso and buttocks, at rest and in movement, will be reviewed, Invasive and non-invasive technologies, utilized alone and bundled together for sculpting and refining optimal outcomes with reduced risks will be discussed. Improving the elasticity and tightness of the tissues and enveloping skin will be considered.

Keywords: Buttocks, waist, posterior torso, bra roll, liposuction, tissue tightening, cellulite

1. Introduction

1.1 Overview

Humankind has observed and drawn, sculpted media and their own physique since earliest recorded history. Pictograms of fertility and barren, conquerors and down-trodden, leaders and protectors, deities and devils, and young and old, are some of our earliest shared memories. Whether thin or thick, young, or old, athletic, or sedentary, fertile, or fragile, we carry with us preconceived visions of what each of these descriptors means to us. We critically evaluate each human we encounter against these standards which predate spoken word and have been genetically embedded in every member of the *Homo Sapiens* family. In fact, we often respond and are responded to initially based solely on our physicality. Since appearance is often evaluated before function or cognition, it is of great importance, often playing a pivotal role in our life opportunities, paths, health, and happiness.

1.2 Patient assessment

Each cosmetic patient who shares their time, goals, and dreams with us is concerned about the appearance they present to their family, spouse, peers, and the world in general. Often, there is adipose between the skin and the muscles that we may be able to sculpt and reveal by selective reduction, addition, tightening of the enveloping cutaneous shell and beyond what has been genetically predetermined. Diet, supplements, exercise, lifestyle, and genes amalgam to create the ultimate exterior expression possible to achieve, short of surgically implanted prosthetic contours.

Our task is to sieve through the unrealistic options and present the possible. Balance risk with reward, outcome with economy and counsel our patients appropriately and patiently, perform our tasks skillfully, and rejoice in our patient's success.

After a thorough discussion of the patient's medical history, physical exam and desires we must counsel them on the possible avenues of intervention. Liposculpting, fat shifting and grafting, and tissue tightening are the major tools of rejuvenating the appearance of the dorsal aspects of a human to help them appear more youthful, healthy and powerful.

1.3 Pertinent anatomy

Specifically, we evaluate the looseness and elasticity of the skin, the contour and definition of the deltoids, trapezius, latissimus dorsi, rhomboids, gluteal muscles, shoulder blades, posterior rib cage, spine, and hip bones as well as the curves, symmetry, and proportions that we aspire to emulate in athletic, vigorous, hormonally optimized men and women considering age and ethnic heritage.

2. Technique

2.1 Markings

Once standardized digital pictures are obtained (standing, 6 views with arms out to sides or relaxed behind and additional flexing and extending views if the procedure will be "Hi Def") the skin is cleaned (Hypochlorous Acid works well) and dried. Surgical markers, or "Sharpie Permanent markers" can be used to outline the effects of gravity on the standing form. A topography map is developed that shows elevations, depressions, adhesions, dimples, cellulite, transition areas and extent of tumescent anesthesia to be instilled. In my office we often use Green Sharpie for elevations and extent of tumescence, cross-hatched areas for divots and cellulite that may be addressed, blue for areas to have fat shifting or fill. Red means be careful or needs more attention/precision) for insertion sites and areas to maximally thinned for desired definition or energy application or both.

In general, we seek to emphasize sinuous muscle and bone contours, debulk horizontal planes to supply "snatched" female waists and celebrate the transitions between the horizontal dimensions of the posterior rib cage framed by the shoulders, traps, lats and rhomboids; waist including the obliques and expansion of the hips and buttocks, where the ideal female waist may be significantly smaller than its borders. Male measurement comparisons may be less dramatic but endeavor to show off muscle contour, sometimes to the extreme in HiDef cases.

Phi (the "Golden Ratio of measure) can be loosely applied to the torse in that the maximal chest and buttocks circumference is roughly 1.618 times the desired waist measurement. The vertical fold of the buttocks is roughly 1.618 as high as the desired horizontal intragluteal fold (tethering of tissue to the ischial tuberosity) under each cheek and the height of the buttocks, measured from the infra-gluteal fold is 1.618 as high as the desired perpendicular projection of the buttocks (depending on ethnic background and the current esthetic swings of the pendulum). The low back and lateral waist generally have a gentle rather than abrupt transition into the hip and buttocks projection.

Buttocks projection, starting somewhat below the height of the superior iliac spine, may be maximized based on desired ethnic appearance: Patients of Latin heritage sometimes want a lower point of maximal projection with blending into the lateral hip, a Caucasian "bubble butt" has maximal projection about mid buttocks height, around the level of the greater trochanter and patients of African American heritage may desire their maximal buttocks projection at the level of the upper pole and prefer somewhat more global volume.

The lateral hip depression, sometimes referred to as "Hip Dip" is formed from a condensation of the gluteus medius and maximus, vastus lateralis, quadratus femorus and greater trochanter. It is more apparent in thinner, athletic, and older/deflated patients and may be accentuated or filled as desired, consistent with the overall esthetic goal.

There is a "V" shaped contour arising from the superior pole of the vertical gluteal crease that outlines the superior-medial aspect of the upper buttocks adjacent to the sacrum which can be emphasized or not, again depending upon esthetic goals. Similarly, the posterior dimples (of "Venus") presented by where the spine amalgams with the bones of the pelvis, align with the vectors of the posterior superior iliac spines, help outline the superior medial buttocks should probably be left intact [1].

2.2 Anesthesia

A key to allowing these procedures to be safely performed in the office as an elective procedure is great tumescent (to fill and make firm) anesthesia. Physicians from Gynecology, Dermatology and Plastic Surgery all take credit for this advancement at about the same time in history (late 1980's). Because lidocaine is so tightly bound in external fat compartments, profound anesthesia lasting hours can be derived from very dilute concentrations compared to typical derm and dental procedures. We all learned the 5 mg/kg body weight limit of Lidocaine without epinepherine and 7 mg/kg body weight limit for Lidocaine mixed with Epi, to avoid side effects including bradycardia. Interestingly, dilute solutions (0.05% lido with 1:1 M Epi and 12 mEq/L Sodium Bicarbonate mixed in Normal Saline or Lactated Ringers solution, works well below the waist; 0.1% lido etc. works fine for most torso lipo procedures; 0.15% lido for abdominoplasties, breast, male chest, axilla and upper arm procedures and 0.2% lido allows for pain free face and neck lipo and surgeries). A total of 35-50mgLido/kg body weight is generally considered safe. Comfort continues for 10–15 hours after the procedure, but that allows for peak levels and possible toxicity at 12 to 15 hours after your case started and the patient is at home otherwise oblivious to the cause of their peri-oral numbness, restlessness, nausea, tinnitus, seizures and even cardiac arrest. So these are discussed with the patient and in the after-surgery care-taker instructions to call the treating physician or facility if these symptoms occur. With conservative adherence to limiting lidocaine to 35-50 mg/kg body weight this should rarely be a problem. The treatment for lidocaine toxicity is IV 20% lipid emulsion solutions like IntraLipid with a loading dose of 1.5 ml/kg over 1 minute followed by and infusion of 15 ml/kg/hour while CPR is being performed throughout. An additional 2–3 boluses may be supplied every 5 minutes if needed for return of spontaneous circulation and the drip can be doubled up to 30 mg/kg/hour up to total dose of 10-12 ml/kg depending on the guidelines utilized for relief of symptoms. The IV lipids competitively bind the free lidocaine and pull it out of the neurologic, cardiac and GI systems [2].

Isotonic tumescent fluid volume should be limited to roughly 1.2 times the healthy patient's daily fluid requirements of 3–4 Liters/day for most men and women thereby avoiding cardio-pulmonary and renal issues. No additional IV fluids are desired, although IV access via saline lock is recommended for safety and to administer certain meds. This is based on understanding that a variable portion of the tumescent fluid will be suctioned out during the procedure, some will ooze out, and the patient will gradually utilize the rest.

Tranexamic Acid is often mixed into tumescent fluids (and even given IV) at 500-1000 mg/liter NS or RL to assist in hemostasis.

Injection of the tumescent fluid in small areas may simply be by 20 cc syringe and a spinal needle, but larger areas are more easily instilled with a pressure bag or peristaltic infusion pump with a foot pedal and 12–16-gauge, blunt, multi-holed (Rainbird or similar configuration) cannula. Generally, keep the cannula parallel to the skin. It should slide through the fat compartment easily. If the tip end hits or snags, change the vector and depth of deployment and try again. Fluid may be infused on both antegrade and retrograde strokes. Start with deeper infusions in radial fashion and work towards the skin in with gentle deployment and retrograde strokes and a slow infusion rate for comfort and precision. Once the tissue is firm, move on to another insertion site and cross hatch the area for better anesthesia. Massage the tissue to spread the fluid evenly through the fat and allow 20–60 minutes for anesthetic effect to set up. Blanching of the skin is often observed from the epinephrine component and the tissue will soften and become more moldable.

2.3 Sedation

Small areas of adiposity can be lipo-sculpted comfortably after tumescent anesthesia is instilled. Fat for facial fat grafting, cellular medicine and research can be obtained in this fashion. Oral sedation with sedative-hypnotics or antihistamine (eg: diazepam or hydroxyzine) and opiates have been used safely for decades and are easily reversible. ProNox and other patient administered analgesia can assist in "awake" procedures.

If larger (1 to 4 Liters of supernatant fat, depending on state regulations) procedures are planned, they are safer when performed in an accredited office-based facility or ASC equipped to handle the potential adverse side effects of deeper sedation.

IV and IM sedation with continual monitoring and IV access are generally preferred over intubation, so the patient can assist in repositioning and flexing during the procedure and sitting or standing up in order to judge effect of procedure, symmetry and re-mark the patient to fine tune the result periodically [3–5].

2.4 Placement of insertion sites

3-5 mm insertion sites can be places surreptitiously in axillary, infra-mammary, gluteal and even flank folds after local wheals of 1% Lido with epi and bicarb have been raised at the point that a cross clamped 11 blade or 2 mm punch adits are intended. Inside the umbilicus is another useful insertion area for shaving down the lateral waist with a longer cannula. Insertion sites should be parallel to Langer's lines and made just large enough to admit the tips of a sharpened hemostat or small scissors which are used to stretch the opening (along lines of tension) slightly larger than any intended cannula. Doing so allows the skin edges to be less traumatized during the procedure. Have the patient put on typical bathing suits or underwear and outline their design. Hide lateral hip, lower waist and back insertion sites where they will at least be covered most of the time. Alternatively, freckles, moles and tattoos can be used to hide insertion sites.

Insertion sites may be placed symmetrically for ease of sculpting symmetrically or placed irregularly in attempt to mask the procedure. However, most insertion sites heal so well in a year as to barely be visible, so this author generally prefers symmetric placement.

Insertion sites in more friable (older) skin or darker skin types prone to produce pigment after trauma can be protected with a coating of mastic and Duoderm against the skin and Tegaderm on top of that to hold the dressing in place during suctioning. Insertion sites should be closed with a stitch if they get too irritated during the procedure. Remove the stitch in about a week so it does not leave a scar of its own [3–5].

2.5 Liposculpting

Historically, early liposuction was little more than large bore tubes used to remove conduits of fat. Because tumescent anesthesia had not been discovered yet, some of those patients exsanguinated from blood loss, had significant contour irregularities and skin sloughs. While these are all possible risks of modern liposculpting, they are very rare because of the techniques and technologies currently employed.

LipoSculpting is both an art and a science. After the tumescent anesthesia has taken effect, and lack of sensation to painful stimuli removed, it is helpful to establish a surgical plane through the fat for suction cannula passage using a cannula without suction or a multi-holed, non-suction, fat shifting/emulsifying cannula (Blugerman or cheese grater style). This 3-5 mm blunt tipped cannula should be introduced through the same insertion sites and pushed parallel to the skin surface. The "dumb" hand pushes and pulls the cannula through the compartment. It should travel easily through the fatty layers and not pushed with enough force to penetrate through the skin or fascia. The "smart" hand feels and directs the cannula through the tissue and monitors the thinning of the fat compartment. A thumb slot in a cannula handle indicates that the majority of openings at the tip are on the other side. This helps orient the cannula so as to not overly rasp the undersurface of the skin and cause unnecessary scaring, slough or erythema ab igne.

Cannulas come in every configuration and size desired. They are generally attached via a disposable suction tube, to glass or disposable canister which is attached to a vacuum pump that generates 15-25 mm Hg vacuum. There are both manual cannulas and power assisted oscillating, rotary or vibrating cannulas. Decreasing the cannula size, number of openings in the tip and decreasing the suction, all decrease effect and vice versa. Once the treatment areas are tunneled and a surgical plane designed, suction cannula(s) are used to sculpt the underlying fat to reveal the desired anatomic contours available. The aspirate should generally be yellow to orange, indicating that there is hemostasis in that area. Presuming one has stayed in the plane of subdermal adiposity, excessive aspirated blood noted would be a reason to stop rasping that area, potentially infuse more tumescent fluid into the area to help with hemostasis and discomfort and hold direct pressure on the area briefly to assure hemostasis ensues.

Viewing the sculpted form from the head and feet, overhead, at table level and sitting or standing the patient up to see how the tissue contours due to gravity is helpful to assure desired contours and symmetry.

Once sculpting is completed, the patient is cleaned and dried, any overly traumatized insertion sites are loosely closed (leaving some open to drain by gravity or any drains placed).

A compression garment of 10-20 mm Hg that covers both the sculpted and immediately adjacent areas to help blend their contours rather than tourniquet or indent the treated tissue is applied. It has an opening that can be pulled forward or back in the crotch area for hygiene, rather than grommets to release and has side zippers to allow easy changing or the absorbent pads applied over the insertion sites without taking the garment fully off or down. The garment is left in place and supports the patients blood pressure by preventing rapid third spacing until the tissues start to reattach in the first few days. Thereafter, the garment can be worn primarily when the patient is awake and removed during sleep for 4–6 weeks, at which point the tissues should have reattached well, softened and seromas resolved or drained early on (sometimes with ultrasound guidance and sometimes just by palpation when the patient is standing). The patient is offered fluids, and they are observed until they meet discharge criteria-alert enough to cooperate, minimal nausea, good hemostasis, no orthostatic vital signs and an adult to drive them home and supervise them as any sedation wears off. Contact information and instructions including medication use and pad changes are verified and follow up visit time and date is reviewed with the responsible person who is picking the patient up and staying with them that night. A call in a few hours to verify patient comfort and review instructions and medications is helpful. Many physicians put patients on broad spectrum anti-biotics starting 1–3 days pre-op and continuing for 5–10 days post op. Others give just a gram of Ancef or similar at the start of the case. Lipo-sculpting is at best a clean, rather than sterile procedure because of all the movements the patient makes during the procedure. That said, the use of oral antibiotics, anti-microbial soap use at home for several days pre-op, surgical prep of the treatment areas, use of bacteriostatic tumescent fluid, sterile instruments etc., and dedicated OR or procedure rooms, make infection quite rare. An inexpensive single (parting) dose of Gentamicin 5 mg/kg IM in an ASA 1–2 patient with normal kidney and ear function is performed by some physicians as well [3–5].

2.6 Drains

Drains are not usually required in straight lipo cases but may be utilized when combined with skin excision or abdominoplasty cases, even small Penrose drains that only stay in for a few days may decrease the risk of seromas and the resulting "woody" areas of healing.

2.7 Ancillary procedures

2.7.1 Fat shifting

Guillermo Blugerman, MD designed a multi holed tip on a solid cannula that is used in cheese grater fashion to blend and shift fat under the skin. Useful diameters range from 3 mm for fine tuning HiDef procedures and sculpting faces and necks, to 4 to 6 mm cannulas used for the rest of the body. This cannula can be used to grossly define a surgical/suction-able plane and elegantly adjust variations in skin pinch to improve surface contours. The fat morsels liberated by the distal holes are release from the proximal holes and vice versa, with each stroke, literally leveling the "playing field" and allowing the skin to drape more smoothly. I use this cannula to define the thickness of the fat and make a plane that is easy for the suctioning cannula to pass when starting the procedure, adjust for fine symmetry during a case, and fine tune every liposculpting case after sitting the patient up and marking remaining contour and symmetry issues. Depending on the tightness or pressure of the "smart" hand pressing the tissue into the holes of the cannula as the cannula is moved by the "dumb" hand, macro or micro effects can be achieved. Manual skin manipulation is useful for massaging and blending the emulsified fat to the desired locations.

2.7.2 Fat grafting

Volumes have been written about fat grafting. For the sake of completeness, it will be described.

Fat is the most convenient and likely inexpensive autologous, homologous volumizer available today. It is a natural product of liposculpting and contains thousands of times for regenerative cells and the accompanying milieu than bone marrow. Fat is a complex organ of metabolism and endocrine function as well as a physical and thermally protective tissue that makes our exterior contours more (or less) esthetically pleasing. The basics of fat grafting involve collection of Macro (structural) fat (1-3 mm) is collected via a small-holed suction cannula at lower pressures.

(12-20 mm Hg vacuum) into a sterile container. The fat is allowed to separate (it floats above the infranatant tumescent fluid and blood) from via sitting or sitting on a vibrating platform and/or some centrifuge fat. Many prefer to strain or wash lidocaine containing fluid and fibrous material out in some fashion. (Consider PureGraft and Wells Johnson systems or variations as "closed" to the air vs. open straining techniques). Oil (fractured fat cells and other inflammatory substances) should be removed from the top of the mix as well. Once macro fat is gently collected and processed, it is important to weave it into the subcutaneous space with as little trauma as possible to preserve as much viability as possible. Weaving of the fat can be performed in basketweave fashion with a larger (3-4 mm), single holed, blunt cannula, with the least effective injection pressure used, on the retrograde portion of the pass ONLY, to decrease the risk of fat embolization into an arterial vessel. Injecting fat into muscle is not recommended, despite the possible higher fat survival rate and greater effect on contour, it is not justified considering the increased and unpredictable risk of arterial injection and fat emboli causing pulmonary blockage and death from an elective esthetic procedure. Fat grafting is more successful if performed from several different insertion sites and not creating lakes or puddles of fat which may become a hypoxic, necrotic source of inflammation and fibrous induration.

After macro fat is placed in the subcutaneous plane to contour the buttocks and hips into the desired shape, it can be further infiltrated and smoothed with micro and nano (supportive) fat (less than 400 micron cells) obtained by sieving the fat through smaller holes (Hogue Surgical) of pushing through various sized screens or ball bearing (Tulip, NanoCube and others) and then metabolically supported with the patients' own platelet rich plasma in as nearly a 1:1 ratio as possible (it may go up to 1:20) injected into the same area. While it is likely that few of the initial fat cells injected survive (Yoshimora et al), it is estimated that 50–70 percent of the volume deposited may survive at a year. Recognize that the fat cells are disconnected from both their nutrient and waste removal systems when they are grafted. It is theorized that some cells "hibernate" until they are reconnected in their new location and then enlarge further as they thrive once again. Larger clumps of transferred fat cells die as they are poisoned by hypoxic inner core saponification leading to inflammation of the surrounding fat cells which are then more prone to macrophage attack. Tender, palpable "oil" pockets that can be found for o = months after a procedure should be removed when possible (Ultrasound directed I and D) or an area of fibrous scar tissue can result. It is more successful to plan for several sessions of fat grafting over the course of a year than to attempt ambitious volumes in one procedure that are prone to issues.

Fat grafted areas require some compression and support to help the fat "gel" and stay in position as it evolves into a long lasting volumizer. Compression garments generally supply 10-15 mm of compression to grafted areas and more to lipo'd areas. They are generally worn 23/7 for 2–3 weeks and when up afterwards, for a total of 4 to 10 weeks. We sit on our ischial tuberosities and move throughout our sleep cycle, so it is dubious that most fat grafted buttocks require the patient to purchase special foam wedges to sit on or adhere to caveats about excessive supine sleeping preventing circulation to most if not all the grafted areas.

Fat grafting should not be offered to current smokers, patients who are avid exercisers or who are or plan to actively diet. The original grafted fat does may not survive to any great extent anyway according to Yoshimura et al. [6, 7].

2.7.3 Tissue tightening

Over the last 2 decades, subdermal tissue tightening via bulk heating, (after debulking the fat compartment with lipo), has evolved from various 0.5 to 1.5 mm laser fibers of different infrared wavelengths that were run inside of cannulas and projected in non-columnated beams out the tip or side of the cannula, to monopolar 15 cm x 2 mm tubes (ThermiTight) that allowed for bulk heating with a tip the size of several grains of rice. None of these technologies were particularly successful for larger body areas because they produced too small an effect to cover the volume and surface presented. Further, they were fraught with risk of end hits, skin burns and uneven distribution of thermal effect. Lack of homogeneous effect resulted in adding undulations to the skin and tissue they were trying to smooth.

A newer technology available in the US for about 4 years, utilizing an RF generated helium plasma field (Renuvion by Apyx Medical) is proving itself to be a more useful and predictable tool for subdermal tissue tightening of the body as well as the face and neck. The plasma field influences tissue for several centimeters around its either in-line or side-firing tip and uses the interaction with and contraction of the fibro-septal network to tighten the tissue without bulk heating. The risk of burn-throughs caused by end hits is substantially reduced. The technology can be utilized to tighten skin envelopes that does not exhibit stria by 10–20 percent with a single treatment and treatments can be repeated over time. It can be used deeper in the tissue before fat grafting is performed more superficially.

A key to success with this technology is assuring that the helium flow, generally 1–3 liters/minute has adequate exit ports that are connected with the treatment area(s) and that periodic milking of the treatment area pushes excess gas out of those ports. Gentle suctioning of the treatment area(s) at the conclusion of Helium Plasma application removes additional gas, residual tissue and oil generated during the procedure, decreasing risk of sub-cutaneous crepitus which can take 3–10 days to resolve or inflammatory healing. Some physicians advocate external infrared thermal monitoring to maximize safety and homogeneous effect.

Another key to success with this technology is *not* over-treating an area. This technology is sometimes combined with ultrasonic fat sculpting (VASER) and or other RF skin technologies. The initial appreciated tissue tightening will generally continue to improve over several months. Excessive treatment with Renuvion alone or in concert with other Energy Based technologies, especially in thinner tissue areas like necks, can cause irregular contraction and fibrosis requiring steroid injection, massage, undermining and even redraping procedures. Grade 1 to 2 compression of treatment areas and weekly or more lymphatic drainage massage both improve the rate of return to full activities and esthetic outcome.

The current flexible, carbon fiber, single use handpiece is available in 15 and nearly 30 cm lengths and is only 3 mm in diameter. There is an original 5 mm diameter (stiffer) in-line port, single use handpiece available in various lengths as well. The results of this technology have generally been predictable and sustainable, and they offer an alternative to surgical skin excision in appropriate cases with and without liposculpting and/or fat grafting.

Renuvion allows the clinician to offer less invasive procedures in select patients, that previously would have required more invasive surgery (Eg: J plazty® vs. a surgical neck lift). The company supports the exchange of information between providers with User Meetings and on-line forums. This has allowed the technology to be utilized more rapidly and more safely, worldwide [8, 9].

2.8 Pre- and post-operative protocols and considerations

ASA 1–2 patients who have maintained their current body weight, have BMIs under 35, are not stressed, have enough time, support, and appropriate nutrition to survive and prosper from this elective surgery are candidates. The pre and post op protocols and considerations are like traditional lipo-sculpting. The use of appropriate wound drainage, tissue support and compression of tunneled tissue without over compression of fat grafted or skin excision areas, and weekly or more often lymphatic drainage massage assures the best possible outcome long-term for these patients. Practices that do not supply all aspects of care to their posterior torso and buttocks contour patients may not enjoy as successful and trouble-free outcomes.

2.9 Complications

Issues are prevented by scrupulous planning, attention to detail, micro-management of the patient and team members involved in their care and personally seeing the patient whenever there is any concern. We cannot control or even imagine what patients do outside of our offices, so our duty to "first do no harm" is challenging to fulfill.

Caveats learned through the years are repetitive but true: anything that can go wrong, will; be extra careful operating on family and friends, they are both hard to come by and sometimes less understanding if there is an issue; frame expectations well, ahead of time (consider your consultation like speed dating and your consent is a pre-nuptial agreement); beware of pet owners, they will cuddle their pets and may get atypical infections weeks and months after their procedures.

3. Summary

3.1 Pearls and pitfalls

Doctors Robert Yoho and Jeff Klein gave me sage advice to start with manual techniques for more forgiving areas like torso lipo on more slim patient without skin laxity using a spinal needle for comfortable, though time consuming, tumescing and careful suctioning with smaller cannulas for my first 50 patients. Torsos are directly connected to axilla, pubic, hip and upper buttocks areas, so they were attempted next. Then move on to more complex and potentially challenging areas like neck and extremities. Gradually I mastered effective tumescense from deep to superficial planes with 12–16 gauge cannulas that did not overfill the tissue (prolonging recovery and masking the actual fat thickness) as well as the art of comparing the subdermal fat by palpation and skin pinch to achieve fairly symmetric results. Suctioning should be deployed from several insertion sites or adits to cancel out the grooves and irregularities that suctioning aggressively from one insertion site almost always yields. When you get comfortable with manual techniques, consider adding Power Assisted technologies. I prefer rotary versus reciprocating power cannulas which seem smoother, more forgiving and faster, but perhaps best to try each technology for yourself. This journey is harder than it looks. It's time consuming and there are no shortcuts to sculpting the living human and developing your tactile skills and endpoints-much like learning a new instrument or competitive sport. Frequent sitting up, standing and positioning the treatment area(s) as they hang when standing, marking persistent elevations, divots and other contour asymmetries and progressively enhancing these contours will always give a better long term result than sculpting performed under deeper sedation in just a supine or prone position. Detailed op notes and critical examination of before, 6 week and 3 month or more photos will help perfect your skills and allow you to accomplish more precise contours in less time. Each patient is a new challenge of art, science and skill. Each one leads to better success, finesse and allows you to achieve the subtle nuances of depth and shadow, youth and age, masculine and feminine, and an appreciation that what you leave intact is at least as important as what you remove. The mature sculpture has insight of when to struggle and strive for further definition, contour and tightness and when the work is "done"-to walk away before the result is corrupted.

Suggestions and considerations are strewn and densely packed in this chapter. Use and modify them in your unique fashion. Perhaps the best advice is "life is short, learn from the mistakes of others". I have tried to openly share many of my most time consuming, brain-damaging and painful-for both patient and practitioner-lessons. I wish you luck, fulfillment and great success. Enjoy the journey!

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Chapter 20

Applications and Limitations of Suction Assisted Transverse Medial Thigh Lift

Umar Daraz Khan

Abstract

Aims and objectives: Skin laxity or excess can be a part of ageing process and weight loss. Skin laxity or excess is commonly experienced following weight loss around arms, thighs, face and neck, breast and abdomen. Various methods and techniques are described to address these excess skin issues. Liposuction assisted abdominoplasty has been described by Saldanha along with Colour Doppler studies of the superior and inferior epigastric arteries. Similarly DJ Hurwitz has described liposuction assisted brachioplasty. The process allows honeycombing of the subcutaneous tissue when suction lipectomy is performed using blunt tipped cannulas. Process allows creation of a safe plane superior to the deep fascial layer with preservation of the important nerves and vessels. Skin excess is removed without the need of sharp dissection or risks to the underlying structures. Postoperative bleeding and bruising is minimal and most of the instances the procedure is performed as a day case without drains. Patient postoperative analgesia requirements are minimal and allows patient to ambulate early with a quick recovery. Methods: Between 2009 and 2018, 153 suction assisted procedure were performed on various parts of the body. Of the 153 procedures 22 patients had thigh lifts as an outpatient. Results: There was no skin loss, DVT, PE or motor nerve damage. All patients retained sensation of the distal limbs.

Keywords: medial thigh lift, superficial fascial suspensory system, body contouring following massive weight loss

1. Introduction

With the change of lifestyle, easy availability of fast food and takeaways of rich food, acquired obesity is seen in all sections of life regardless of an individual socioeconomic background. For these reasons, obesity has been steadily on the rise along with its associated comorbidities causing an increased burden on health care delivery systems. However a rise in awareness related to the risks associated with obesity and introduction of safe procedures for bariatric surgery has resulted in an increased number of people with massive weight loss. Unfortunately, one of the undesirable side effects following massive weight loss is the redundant skin excess. Skin laxity or excess can also be, hereditary, hormonal, drug induced, part of ageing process, weight loss following conservative measures, drastic weight fluctuations or following childbirths etc. Common sites of skin laxity or excess following weight loss are seen around arms, thighs, buttocks, face, neck, breast and abdomen. These areas of skin laxity or excess can be extremely distressing, unmanageable hygienically and often affect social, personal aspects of life. Weight loss following bariatric surgery or by any other means is only half the job done and the objectives are not fully achieved until skin laxity issues related to weight loss are dealt with using appropriate surgical procedures. The real goals of body weight loss are not complete until self-esteem, self-confidence and body image is not restored using surgical methods. Various techniques have been described time to time and to address the excess skin or skin laxity issues following significant weight loss, which in some individual, affect nearly their entire body.

To device a procedure, mastery of the underlying anatomy and the role of these anatomical structures is paramount. The understanding, presence and introduction of the superficial fascial system by Lockwood in 1990 added anatomical sense to the procedures and longevity of the results [1]. However, reproducibility of a result is not with out adding simplicity and safety to the procedure. Great advancements to body contouring surgeries following massive weight loss came after the introduction of liposuction without undermining prior to skin excision. Liposuction assisted abdominoplasty has been described by Saldanha which has added safety, simplicity and reproducibility to the procedure [2]. The procedure is widely used and reported by many other surgeons [3, 4]. Hurwitz has described liposuction assisted brachioplasty with a similar concept that has added simplicity, safety and reproducibility to the procedure [5]. Similarly, liposuction assisted medial thigh lift using transverse incision with or without vertical excision of medial thigh skin has added safety to the procedure and has also been reported with acceptable results and fewer complications [6–8]. Addition of liposuction prior to skin excision allows honeycombing of the subcutaneous tissue following the use of blunt tipped cannulas for lipectomy. Process allows creation of a safe plane superior to the deep fascial layer with preservation of the important nerves and vessels. Skin excess is removed without the need of undermining or dissection of adjacent skin. Postoperative bleeding and bruising are minimal and in most of the instances, the procedure is performed as a day case without drains. Postoperative analgesia requirements are minimal and allows patient to ambulate early with a quick recovery. When transverse resection is done without excision of vertical segment of skin, improvement is only limited to upper 3rd of the inside. Transverse resection alone may give very well concealed scars but is not suitable for massive weight loss patients where skin resection in vertical axis is mandatory for adequate results.

2. Material and methods

A retrospective chart review of 153 consecutive suction-assisted procedure was performed on various parts of the body. Of the 153 procedures 22 patients had suction assisted transverse medial thigh lifts as an outpatient procedure.

2.1 Inclusion and exclusion criteria

All patients in the series belonged to ASA class 1 or 2 with skin excess predominantly limited to upper medial compartment of thigh. Contraindications to this procedure include, lymphodema, smoking, diabetes or patients with history of vasculopathies. Those with a history of deep venous thrombosis (DVT) or other venous abnormalities of lower limb should be investigated and appropriate prophylaxis given.

Those patients who strongly expect or request circumferential results in upper, middle and lower thigh were excluded and not considered suitable for medial thigh lift.

3. Marking

All patients are marked in standing position. Two points are marked to delineate the limits of incision line incorporating the extent of medial thigh excision. Anterior limit and extent of the line is marked usually on the mid-inguinal point while posterior extent line is limited by the medial limit of the gluteal crease. Anteriorly, the extent of incision can be extended up and laterally to the anterior superior iliac spine if needed. From the anterior point, a line is drawn down and medially and 1–2 cm caudal and parallel to the inguinal ligament, groin and perineal fold. The line is extended posteriorly into the medial part of gluteal crease. It is extremely important in the medial groin and perineal area to draw the line 2 cm caudal to crease to prevent labial distortion. Proposed inferior incision line is drawn as a crescent, width of the crescent at its middle does not generally exceed 10–12 cm. Once the lower limit of the line is drawn, proposed excision lines are pinched together to ensure tension free closure and are checked with thighs in adduction, external rotation and gentle abduction for a tension free closure.

4. Anaesthesia, positioning, infiltration and technique

All procedures are performed under full general anaesthesia. All patients have endotracheal intubation for a secured airway. All patients receive intravenous antibiotics and intermittent pneumatic decompression device for DVT prophylaxis. Catheterisation of patients is not required due to short nature of the procedure unless the procedure is carried out simultaneously with another procedure. Low molecular weight heparin is given in selected cases of medial thigh lift unless the procedure is combined with other procedures. For a better intraoperative position and patient handling, procedure is performed in two separate positions. This allows access to the upper medial thigh without abducting or spreading the legs and I prefer to operate first in a prone position. Steps involve infiltration, liposuction and excision of the posterior half of crescenetric markings before turning them to supine position to complete the surgery. Infiltration fluid is prepared using 1,000 cc of normal saline, 30 ml of 1% lidocaine plain and 1 mg of adrenaline (1:1,000). Measured and equal infiltration is performed using Luer Lock 50 cc syringes with 2 mm blunt tipped infiltration needles. On average 250 to 300 cc fluid is used on each side. Suction assisted lipectomy (SAL) is performed first using 4 mm suction cannula with patient in prone position. Agrresive liposuction is predominantly limited to the marked area to ensure viability of adjacent skin (**Figure 1a**). A conservative liposuction is also performed to an adjacent area on the thigh just below the proposed line of excision. This allows flexibility, thinning and, honeycombing of the skin flap. Honeycombing allows a better mobilisation of skin flaps and harmony in tissue thickness when approximated. Usually the skin flaps thickness up to 1.5–2 cm is ideal to keep lymphatic system secured. The liposuction plane is superficial to deep fascia that prevents injury to all important neurovascular bundles tucked well under the deep fascial layer. Starting from the lateral to medial from gluteal crease, skin is incised along the upper marked margin and up to midpoint of the marked crescent. The honeycombing allows risk free dissection of skin and defatted subcutaneous layer in downward direction and under direct vision. An inferiorly based flap is raised and once the dissection has reached to the lower

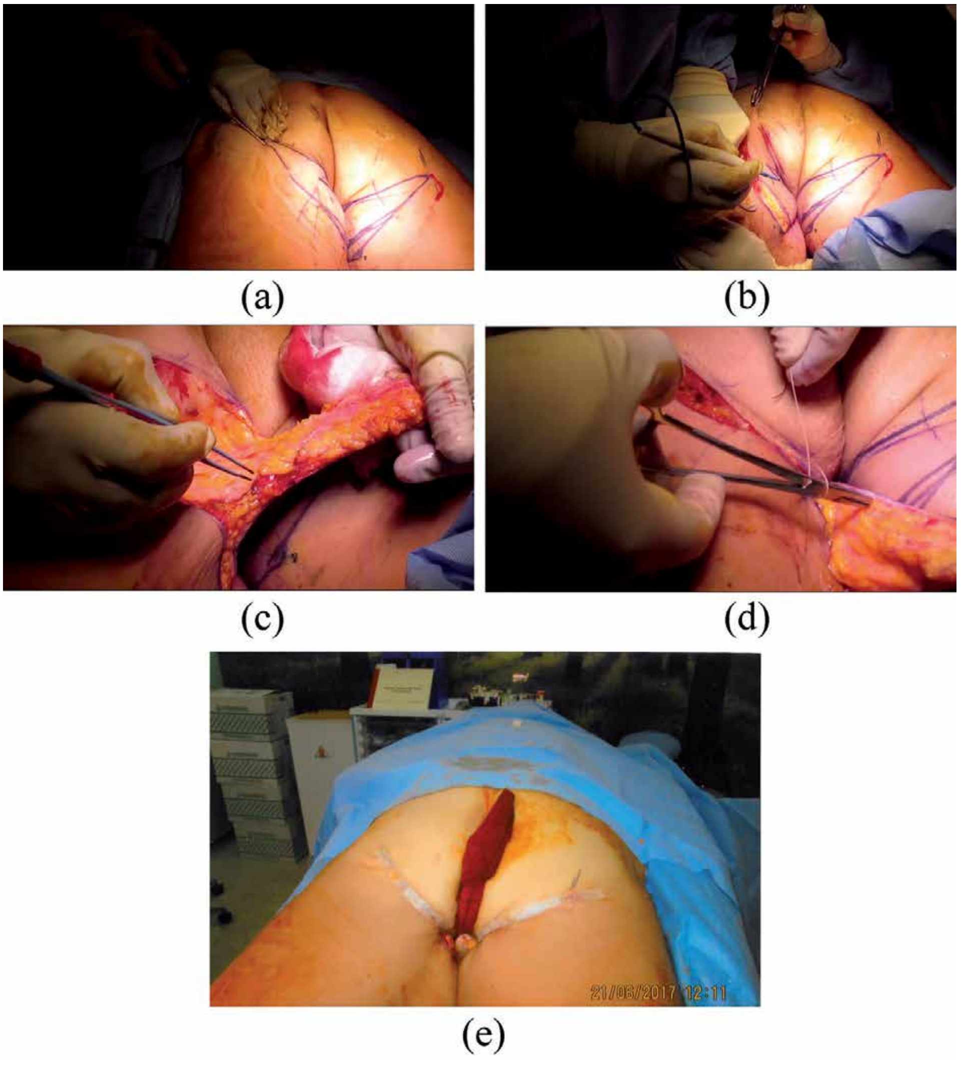

Figure 1.
Intraoperative pictures showing resection of the posterior half of the skin of left medial thigh, in prone position. (a) Liposuction of the posterior thigh. (b) Incision of the upper and lower margins of the posterior crescenteric markings. (c) Lateral to medial dissection of the flap above deep fascia using finger-switch point diathermy on cutting mode. (d) Deep closure along with restoration of superficial suspensory ligament. (e) Posterior half of the medial thigh skin closure completed on both sides with an inch wide adhesive dressing.

margin of the marked crescent, proposed excision margin is approximated for a tension free closure. Adjustments are made if necessary. Skin is now incised along the lower margin and extended medially to the midpoint of the crescent (**Figure 1b**). The dissection and the separation of skin is performed using finger-switch point diathermy, closer to the skin flap and under direct vision which facilitates prospective haemostasis in a more secured way without disruption of lymphatic network (**Figure 1c**). Once excision of the posterior half of skin crescent is completed, superficial fascial system is restored using 2–0 vicryl sutures from dermis of the upper and lower skin margins and sutured to Colle's fascia [9], fascia over the adductor muscle and periosteum of the pubic bone (**Figure 1d**). Skin closure is performed using 3–0 vicryl subcutaneous and 4–0 monocryl intradermal sutures and self-adhesive dressing (**Figure 1e**). Wound is dressed and patient is turned into supine position and the procedure is repeated on the anterior aspect to complete the medial

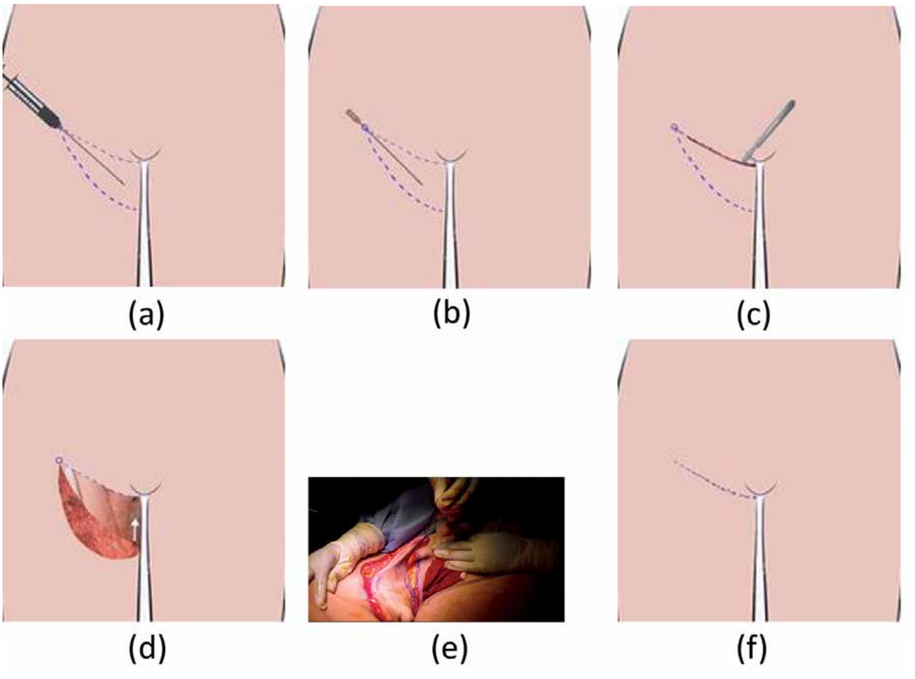

Figure 2.
Stages of anterior part of the suction assisted liposuction and medial thigh lift on the anterior aspect of right side. (a) Measured infiltration of fluid using 50cc Luer lock Syringe mounted with 2 mm infiltration blunt needle. (b) Suction assisted lipectomy using 4 mm cannula. (c) Skin incision in perineal thigh junction. (d) Inferiorly based flap with underlying muscle neurovascular bundle protected by deep fascia. Flap is pulled up to check and ensure a tension free closure before the skin belt is excised. (e) Lateral to medial skin flap dissection on the anterior aspect of right upper medial thigh. (f) Skin closure in layers.

thigh lift (**Figure 2a**–**f**). Dissection in the anterior part has to be done carefully to avoid injury to great saphenous vein and lymphatic system. Skin and fascial system closure is achieved as above. A single drain is used on each side and subsequently removed next day. Sutured area is wiped with Povidone Iodine, sprayed with an adhesive aerosol and an inch wide adhesive linear paper dressing applied. Light absorbent gauze dressing is placed and a surgical pressure garment applied.

4.1 Postoperative instructions

Patients stay in the clinic for at least 6–8 hours. Early postoperative ambulation is encouraged and elasticated compression stockings are applied until patient is well mobilised. Once they have passed urine, pain free and able to eat and drink without nausea or vomiting, they are allowed home with a supply of oral antibiotics and oral analgesia. Soft dressings can be taken down after two or three days and patients are encouraged to have sitz bath for localised cleansing and hygiene.

5. Results

All patients were females in the series and mostly done as day cases (**Figures 3**–7). There was no skin loss, wound breakdown, labial distortion, deep venous thrombosis, seroma, pulmonary embolism or motor nerve damage. Postoperatively all patients retained sensation of the distal limbs and there was no lymphedema noticed in any of the patient in the group.

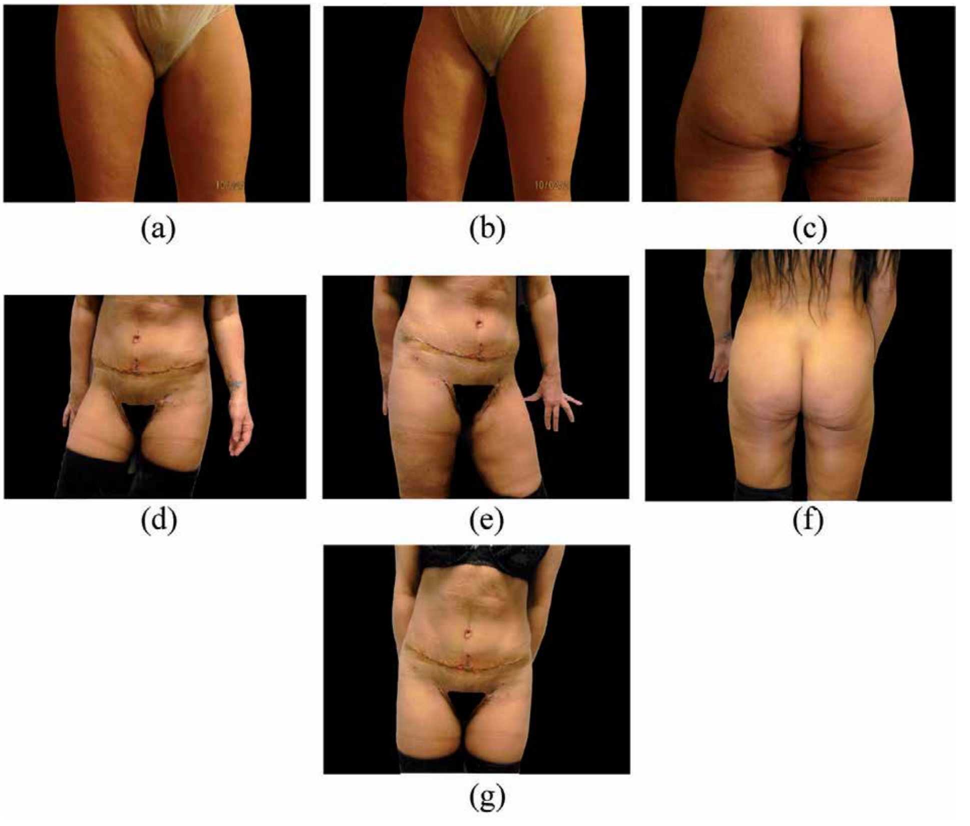

Figure 3.
(a–c) Preoperative views of a 38 year female model with minor skin excess of upper medial thigh (Pittsburgh Rating Scale 1). (d–g) Postoperative views two weeks following abdominoplasty and suction assisted medial thigh lift.

6. Discussion

Massive weight loss, either achieved using conservative measures or following bariatric surgery, is not without its noticeable side effects (**Figure 6a**–**f**). These patients are left with deflated chest/breast accompanied with redundant, loose and excess skin on face, neck, arms, abdomen, back, knees, upper and lower thighs and often circumferentially. On the other hand, the skin excess on the upper medial thigh can also be associated with generalised ageing process, weight fluctuations or changes seen following pregnancies (**Figures 3** and **4**) or moderate weight loss following conservative measures (**Figure 5a** and **b**). The skin excess or skin fold in upper medial thigh area may also result from overzealous liposuction or liposuction in poorly selected patients (**Figure 7a** and **b**). These iatrogenic deformities also benefit from medial thigh lift for skin excision.

A classification system for the deformities associated with massive weight loss for each area has been devised to grade the scale of these deformities. The system known as Pittsburgh Rating Scale (PRS) divides all these presentations from 0 to 3, zero being normal and 3 being most severe. The grading scale also suggests best operative approach for each grade [10].

The idea and need for rejuvenation of upper medial thigh is not new and with the safety of anaesthesia and postoperative management, techniques have been described in the past [11–13]. However the techniques described were unable to gain popularity among patients and surgeons alike. Inferior scar migration, scar

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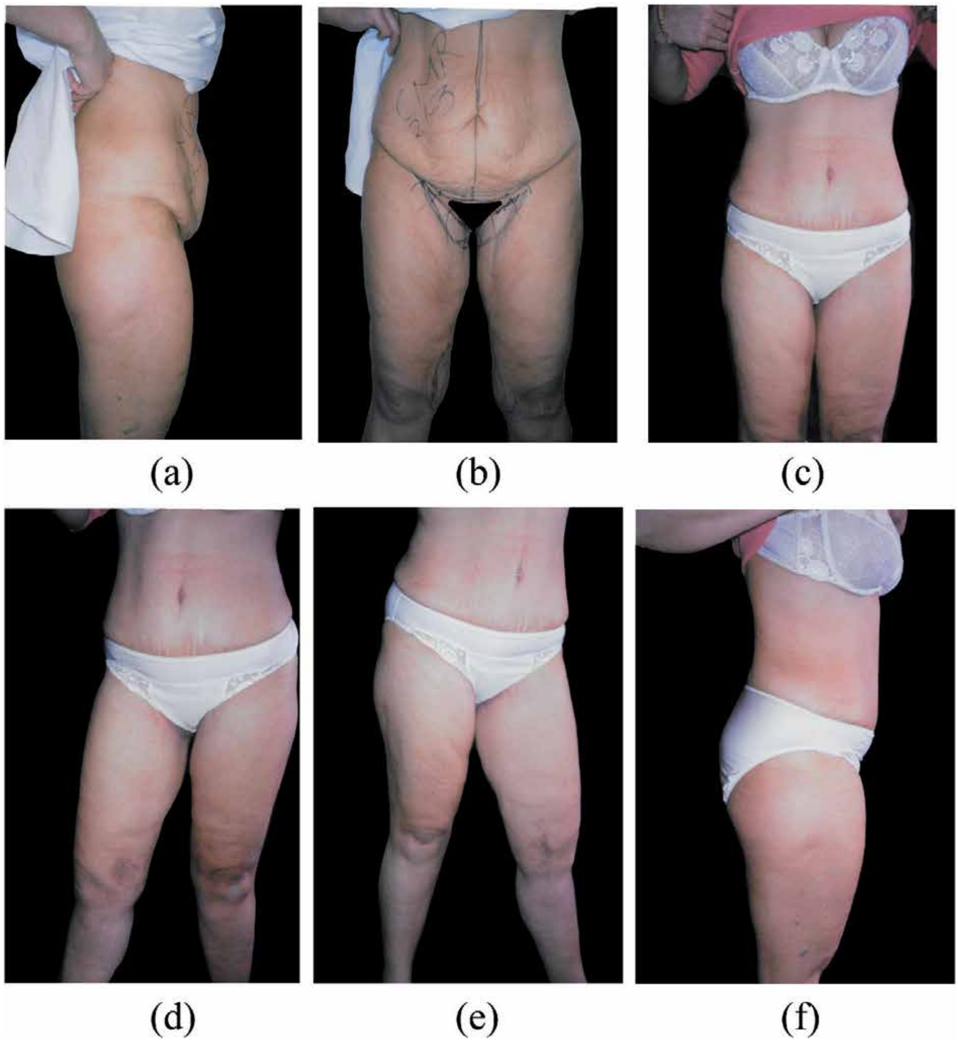

Figure 4.
(a and b). A 45 year old lady who presented with moderate skin laxity on anterior abdominal wall and upper medial thigh (Pittsburgh Rating Scale 2) following pregnancy and age related changes. (c–f) Postoperative views showing results following suction assisted lipo-abdominoplasty and medial thigh lift.

Figure 5.
(a) A 35-year-old female presenting with major upper medial thigh skin excess following considerable weight loss (Pittsburgh Rating Scale 2). She also was not happy from inadequate results following her abdominoplasty elsewhere. (b) Post-operative view following suction assisted medial thigh lift and revision of abdominoplasty and liposuction of flanks.

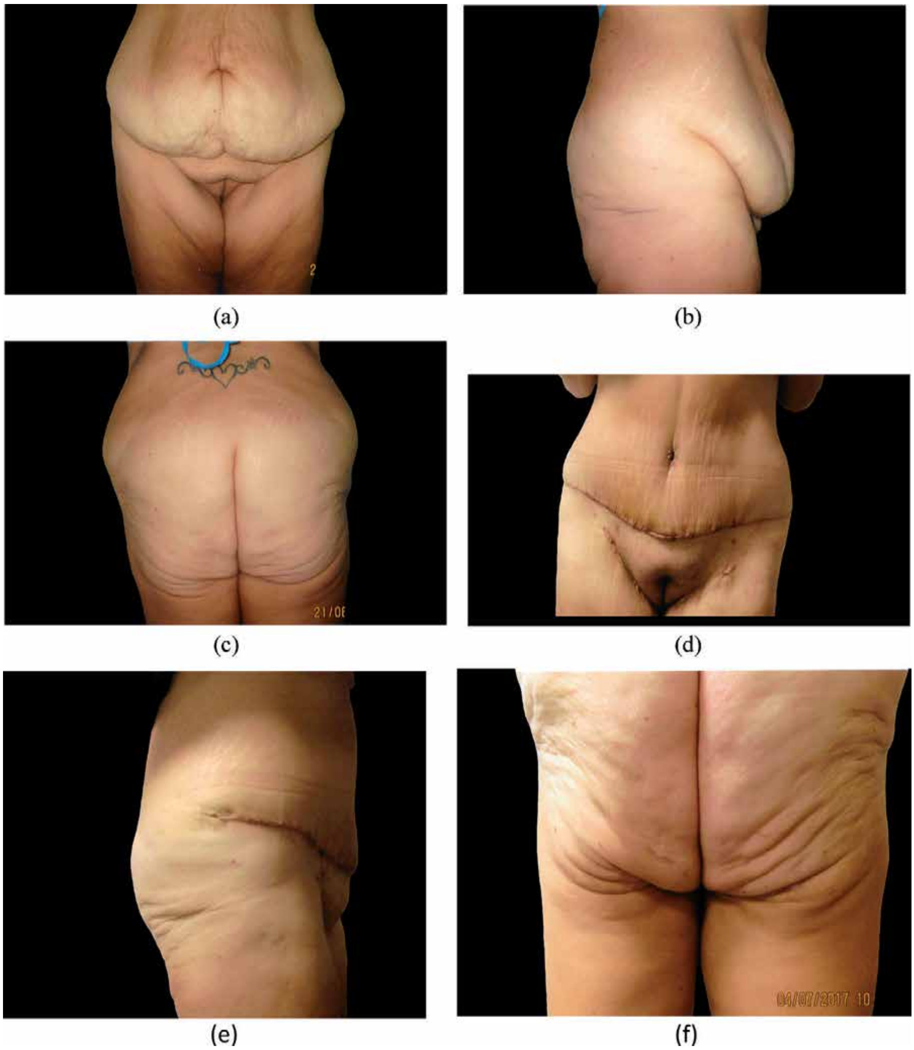

Figure 6.
(a–c) Preoperative views of a lady following massive weight loss. She was unhappy with the abdominal skin excess and contouring along with skin laxity on upper medial thigh (Pittsburgh Rating Scale 3). (d and e) Postoperative views showing results following suction assisted lipo-abdominoplasty and medial thigh lift as a day case. The improvement was limited to upper medial third only (f).

stretching, labial distortion or widening exposing labia-minora and recurrence of ptosis were to name the few. The precise anatomical description and introduction of superficial fascial system suspension by Lockwood provided a new impetus and vigour to perform these surgeries. The renewed knowledge and detailed anatomy of the superficial fascial system helps to restore trunk and limb anatomy resulting in its rejuvenation following massive weight. Lockwood technique of restoring this system has given remarkably improved and longer lasting results with elimination of the drawbacks attached with thigh lifts procedures described earlier [1, 14, 15].

Recent colour Doppler studies following liposuction to the abdominal wall has changed the concepts, horizon, and application of the procedure to various body contouring procedures including medial thigh lift. Doppler Flowmetry studies, performed by Dr. Graf, showed that there was no damage to the abdominal skin perforator system arising from the deep epigastric system and on the contrary, there was an increase of

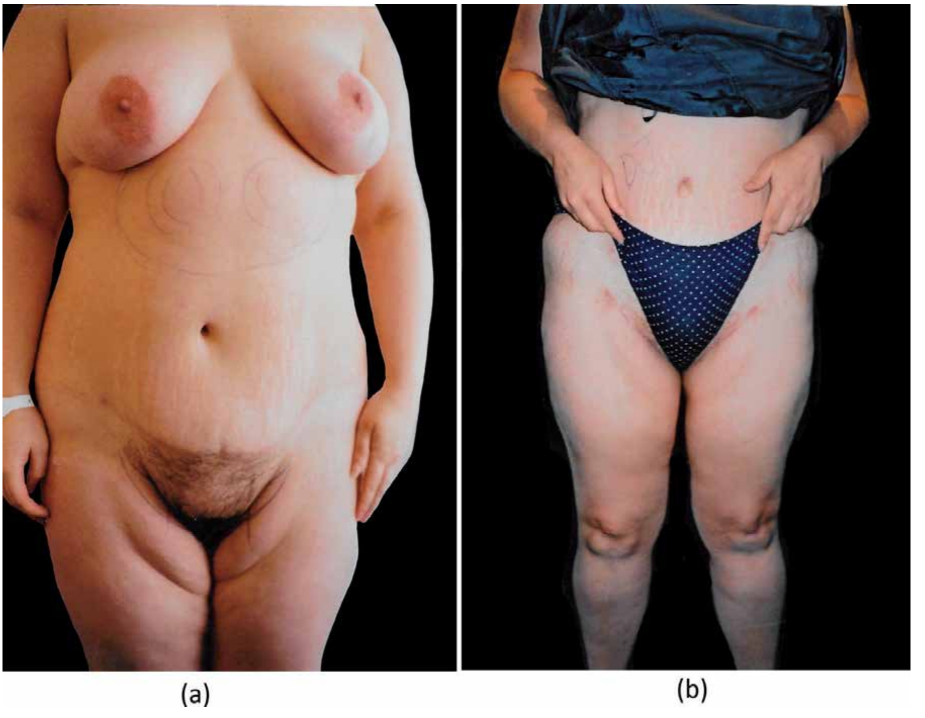

Figure 7.
(a) A 29-year young lay who presented with medial thigh skin excess and laxity following aggressive suction assisted liposuction. (b) Three months following suction assisted medial thigh lift as a day case.

56% blood flow through these perfortaors [16]. The report of the results have changed previously held concepts of abdominal blood supply that discouraged anterior abdominal wall liposuction combined with abdominoplasty [17, 18]. Honeycombing of the subcutaneous layer of fat resulting from suction assisted liposuction allows anterior abdominal wall to get pulled down without the need of extensive undermining of abdominal wall skin or dissection and preserving anterior wall vascularity at the same time [2, 4, 16]. The concept was extended to liposuction assisted brachioplasty and medial thigh lift with safety, reproducibility and acceptable results [5–8].

Suction assisted medial thigh lift can be performed using a transverse incision with or without vertical element. The procedure can also be performed on its own, or it can be combined with other procedures. When performed on its own, it can be performed as a single stage day case procedure. Some surgeon still prefers to do the liposuction first and skin resection as a second stage procedure, about six months or so later. By staging the procedure, the idea is to add safety to the skin flap, as it is generally believed that liposuction combined with medial thigh lift may result in higher local complication rate including skin flap necrosis. However, staging the procedure needs two hospitalisations each at an extra cost, with two sets of recovery periods and each procedure may have its own complications. Additionally, liposuction does result in subcutaneous scarring and quite often makes the tissue dissection and resection difficult, which may increase the incidence of local complication rate on its own [6]. On the contrary, complications rates following liposuction assisted medial thigh lifts are few and gives an added benefit of performing it as a day case. Vascularity of the skin flaps, due to undisturbed perforators, prevents skin necrosis or wound dehiscence secondary to ischemia. Honeycombing of the underlying tissue allows skin approximation without creating a dead space or putting any pressure on the skin edges resulting in good healing. Absence of dead space complemented by intact venous and lymphatic system prevent seroma formation and surgery can be performed without drains [6, 8]. Liposuction assisted transverse medial thigh lift have shown no skin flap necrosis, wound dehiscence or other major complications when compared with en bloc excision [8].

In personal experience of the author, all patients have shown a good and early recovery with no wound breakdown or skin flap necrosis. However and for adequate results, patient selection is extremely important. The transverse resection procedure should ideally be limited to PRS Scale 1–2 [10]. Drawback or disadvantage of suction assisted transverse medial thigh lift is the extent of improvement expected. This improvement is normally limited to upper medial third mostly (**Figure 6a**–**f**). When a patient presents with massive weight loss (PRS Scale 3), a vertical component must be added to transverse resection for an adequate circumferential results unless patient is not prepared to have an extensive scars on the inside of the thigh. Patient must be informed that, when transverse skin excision is performed, improvements are limited to upper third of the inside of the thigh only and no change is expected to lower two thirds of the inner aspect of the thigh or to other parts of the thigh including buttock area (**Figure 6a**–**f**). Last but not least, a proper history and physical examination, thorough informed consent and appropriate selection of patient is mandatory for a beneficial outcome and is the key to a happy patient.

7. Conclusion

Restoration of superficial fascial system suspension combined with suction assisted lipectomy for transverse medial thigh lift is safe, swift and minimises surgical morbidity and associated with quicker recovery. Neurovascular bundles are preserved, as the plane of dissection created is superficial to deep fascia with neurovascular bundles safely encased underneath. When performed alone, improvement and rejuvenation is limited to upper medial third of the thigh alone.

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Conflict of interest

The author declares that they have no conflict of interests.

Informed consent

Informed consent was obtained from all individuals participants included in the study.

Ethical standards

All procedures performed in the studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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Section 6

Complications

Chapter 21

Complications and Solutions for Post-Operative Liposuction Deformities

Chris W. Robb and Michael H. Gold

Abstract

In this chapter, the authors will review the complications associated with liposuction and laser liposuction procedures, using published reports as the guide to document these complications and deformities to the readers. In addition, the authors will also report on the use of tumescent anesthesia and the published documentation regarding safety concerns that have been presented via the use of tumescence versus general anesthesia when performing liposuction or laser liposuction. Real-world discussions also will take place in which the authors describe best treatment practices as solutions to those complications described. Liposuction and laser liposuction are wonderful procedures that have been performed for many years. Understanding and being able to identify and treat any untoward complications is extremely important to make everyone a better surgeon and a better physician.

Keywords: complications, liposuction complications, liposuction deformities, solutions for complications

1. Introduction

One of the most challenging aspects of liposuction is patient satisfaction. Patients undergoing liposuction, fat grafting or other forms of fat sculpting are present primarily for cosmetic reasons. Whether removing fat or adding it, contour correction is the goal. As such a very scientific and clinically complex procedure must have an esthetic outcome and the surgeon is truly acting as physician and artist.

G. Neuber is commonly called the father of fat grafting for his innovative 1893 transfer of fat from the arm to the orbital rim to correct an osteomyelitis deformity. Dr. Neuber is also the grandfather of the modern surgical suite and other than Ambroise Paré did more to revolutionize the aseptic technique than any predecessor [1].

Contour deformities have been the bane of our existence as practitioners since the dawn of the procedure. Khanna et. al. review a case by Dujarrier of a ballerina from whom fat was removed from the knee. Unfortunately, the femoral artery was damaged necessitating a below-the-knee amputation. Certainly, an unfortunate contour deformity [2].

The introduction of cannula in 1975 by the Fischer's, a father and son physician team, dramatically altered the landscape of liposuction. While still performed under general anesthesia, three small incisions were made allowing the introduction of blunt cannulas with suction. This allowed a more uniform, less invasive procedure [3]. The technique was further adapted until late 1987 when Klein reported the first use of the tumescent technique for performing liposuction under localized anesthesia. These solutions used very dilute lidocaine and epinephrine. This technique significantly improved outcomes via several mechanisms, as discussed below, and decreased the rate of serious complications. Before this liposuction was predominantly an inpatient procedure. The tumescent technique resulted in a shift of the procedure to outpatient clinics and day surgery centers. Klein continued to perfect the procedure and elucidate the metabolism of lidocaine and the maximum safe doses of lidocaine allowed [4, 5].

This chapter is dedicated to the discussion of post-procedure deformities resulting from liposuction, and an up-to-date review of their prevention and correction.

Of course, to the novice, the term deformity might only suggest areas of over or under treatment, but the term, in this case, is broad and must also include defects of the superficial layer (peau de orange, ulcerations, etc.), deformities of the intermediate and deep layers (over-correction, under-correction, hematomas, seromas) and those arising from damage to deeper structures (ablation of the gluteal sulcus, damage to the marginal mandibular nerve, etc.). More serious complications such as pulmonary embolism, the obese patient, volume overload and perforation of deeper structures are reviewed elsewhere [6].

2. Prevention

Iatrogenic deformities should be avoided. Technique and surgical environment each play a significant role in reducing the chance of clinical error. The facility in which liposuction is performed historically played a greater role in avoiding complications than it does today. The safety of outpatient surgical procedures improved after the formation of the American Association for Accreditation of Ambulatory Surgical Facilities (AAAASF) in 1980 [7]. The number of ambulatory care centers increased 20-fold from 275 in 1980 to 5500 in 2014. The first quality control measure implemented was a limitation on the total volume of fat aspiration. Centers using office-based anesthesia experienced a decrease in severe complications as safety protocols and standards were implemented. Most complications, however, were due to surgical technique rather than anesthesia or facility regulations.

The lowest fatality rates are reported with "true" tumescent liposuction in which general anesthesia is not used. Complication rates are decreasing as new technologies emerge, for example, laser liposuction [8]. Gupta et al. reviewed procedures across several accredited facilities and found evidence that in-office procedures are a very safe alternative when adequate patient selection is used. Overall complication rates for these procedures were estimated at 1.3%, lower than that for other larger facilities [9].

Fatality rates for liposuction appear to be very low overall, and exceedingly rare with pure tumescent anesthesia. Hanke et al. surveyed Fellows of the American Society of Dermatologic Surgery. 15,336 respondents reported complications. Of those, none reported a fatality. Skin irregularity (dimpling, retraction) occurred at a rate of 0.34% and was the third most frequently reported complication. Other reported contour deformities included hematomas/seromas (0.17%), patient dissatisfaction with appearance (0.08%) and ulceration (0.01%) [10]. These results are comparable to a review of 9002 patients by Boeni and Waechter-Gniadek of which 0.1% had hematoma/seroma and 0.01% had skin necrosis [6].

3. Technique

A good medical history should be taken as part of preventing complications including contour deformities. A well-informed patient who understands every step of the process suffers less anxiety and tolerates mild discomfort more easily. Discomfort limits access to deeper fat compartments makes fibrous areas harder to treat and often leads to a partial treatment or hurried treatment.

There are no formalized standards for preoperative assessment. However, there is consensus in the literature. Araco et al. exclude patients with a body mass index (BMI) > 30, patients with "severe" cardiovascular or pulmonary disease and patients with altered liver function, platelet function or vascular instability (Raynaud's) [11]. In a review, Wells and Hurvitz restricted patients to anesthesia classes 1 or 2 [12]. Smokers should be advised that they may have poor wound healing. Patients with diabetes should be advised of an increased risk for infection as well as delayed wound healing. A hemoglobin A1C of 6.5 or less indicates a decreased risk of adverse events. Skin laxity post-liposuction may not tighten as well in smokers, diabetics or post-menopausal women [13].

A thorough physical examination should be performed. Surgical scars in the treatment area, abdominal herniations, areas of contour deformity and the grade of skin laxity should be noted. After liposuction, previous surgical scars that are not released (e.g. caesarian section, appendectomy) may act as shelves and dramatically change the overall contour. Similarly, severe skin laxity will not significantly correct and will remain a deformity. Likewise, excessive fat removal may leave lax skin that was not obvious before the volume was removed. Unfortunately, it is difficult to predict how a patient's skin will tighten. Several factors play a role, including environment and genetics. Premenopausal women and women on estrogen supplementation may have the best improvement in post-liposuction laxity. This may be because estrogen directly increases fibroblast activity and contributes to collagen and elastin synthesis [14].

The patient's expectations are of course just as important as our own. Excellent communication must exist between the provider and patient at every step. The patient must be well versed in the entire procedure they have elected to undergo. Realistic expectations are very important, as the patient may have an idealized image of themselves post-liposuction that exceeds the parameters of the treatment or may even necessitate a more advanced procedure (abdominoplasty). Photographs that depict realistic results should be reviewed.

After consent, photographs should be taken of the patient in a normal anatomic position. Afterwards, using either a mirror or photographs, the provider should personally discuss with the patient the areas to be treated and give a detailed expectation of results. Proper consideration should be given to the body site being treated. The body should be placed in an anatomic position when considering your approach and mapping. Tensing of musculature may reveal adhesions, herniations, diastasis or asymmetries not otherwise evident. Cellulite, scars, skin textural differences and asymmetry should be carefully noted.

Contour markings should be drawn topographically using a permanent marker and photographs retaken. Care should be taken to mark areas to avoid or that need excess caution (subcostal margin, iliac crest, gluteal crease). Some providers also mark areas where more extensive liposuction might be desired, such as the border of the rectus abdominus. Asymmetry should be noted. Scars and previous surgical sites should be demarcated.

The safe tumescent technique is discussed elsewhere. During tumescence, pre-tunneling is beneficial. Passing the infusion cannula through deep and superficial fat layers distributes tumescence more uniformly, preventing "hot spots" of patient discomfort. Using a fanning pattern prepares the tissue for larger cannulas during suction and helps with uniformity. Once liposuction begins, gradually larger bore cannulas can be used, starting with smaller cannulas. Fanning patterns should overlap in minimally two areas and preferably three. The use of gradually larger bored microcannulas is unique to in-office tumescent liposuction. Patients experience more pain when larger cannulas are used immediately, effecting the physician's ability to take their time uniformly suctioning the treatment area. This will result in poor liposuction techniques and possibly significant contour irregularities. This is especially true around the umbilicus, where fat compartments are isolated from the rest of the abdomen and anesthesia is harder to obtain if tumescence is insufficient. This may lead to under-correction around the umbilicus (**Figure 1**). Larger bore cannulas can be used under general anesthesia by an experienced physician. However, they run the risk of contour deformity because large volumes are removed with each pass. Microcannulas pass easily through septae even in superficial layers and allow a "fine tuning" approach without causing irregularities of the skin surface. They also cause less trauma to fibrous bands connecting the skin to the deeper fascia layers, allowing the skin to remain in its normal position during the natural skin tightening that occurs over the following months. Large bore cannulas should be restricted to use by experienced providers who are very adept with tumescence and volume management. Microcannulas also decrease the risk of bleeding and hematoma formation. An 8 mm cannula transects fewer vascular components than a 2 mm cannula. Similarly, the probability of leaving a large potential space is decreased using the microcannula technique thus decreasing the risk of seroma.

Fat should be suctioned sequentially first from deeper layers then superficial layers. If the original layer suctioned is too superficial, there is a tendency on behalf of new practitioners to assume the tissue, they are grasping is the only area that needs treatment and deeper layers of fat are overlooked. Power-assisted liposuction and laser-assisted liposuction are also rapid and may increase contour irregularities. In an analysis of 2398 patients, contour deformities occurred at a rate of 5.9% when only power-assisted liposuction was used [15].

Figure 1.
Periumbilical under-correction.

4. Under correction

Under correction occurs when an area of fat is not adequately removed. In almost all instances, this contour deformity is entirely technique-based. The most common areas are the arms, flanks, the periumbilical region and above the knee [16].

The primary cause of under-correction is patient discomfort. Inadequate tumescent volume, poor deep tumescence and incorrect lidocaine concentrations lead to intraoperative pain or systemic side effects. As discussed above, care should be taken to tumesce deeper layers adequately and then suction should be started in these layers first. Pitman et al. recommend the total fluid administered should be approximately double the volume of expected aspirate, meaning an approximate 1:1 ratio of tumescence to fat if all tumescence was aspirated [17]. This is a reasonable rule of thumb keeping in mind the maximum dose of 55 mg/kg lidocaine. Typically, 21–22% of injected fluid is not absorbed, making the ratio of fat removed to fluid absorbed 11:1. Matarasso recommended that this should be kept in mind during longer or more complicated large volume procedures when calculating fluid replacement and to achieve "consistency in reporting" authors should standardize comments on volumes of injectate, aspirate, and infranatant fluid fractionation [18].

More fibrous areas, such as the male chest, the outer hip or the submentum may require a higher concentration of lidocaine in the tumescent fluid. In the authors' opinion, the 1:1 recommendation still applies. Taking too long to perform the procedure can lead to patient discomfort and incomplete liposuction. Smaller cases should be selected first until the technique is comfortable and familiar.

Under corrected areas can typically be corrected with repeat liposuction. There is no consensus as to when second liposuction can be performed. It is inadvisable to perform a second procedure during the healing process when inflammation, edema and fluid retention are still present. Most physicians are comfortable waiting 3–4 weeks if the intent is in correct volume. Tissue laxity and lymphedema must be excluded as causes. Pinch testing and sweep testing, as described by Toledo and Mauad, help to identify residual fat deposits [19].

When the volume to be corrected is relatively small, cryolipolysis may be a reasonable consideration. Coolsculpting has been Food and Drug Administration (FDA) approved for fat reduction of the chin, abdomen, thighs, flanks, bra fat and buttocks. The results have been reviewed in several publications. Submental fat reduction can be as much as 2 mm, with 83% satisfaction [20]. Fat reduction in the abdomen was as much as 27%, the bra area 20%, the flanks 25%, the inner thigh 20% and the outer hip 29% [21]. The technique remains safe, and erythema occurs in almost all patients. The incidence of post-treatment sensitivity treatment ranged dramatically from 0.6% in one study to 73% in another, with gradual improvement over 2 months. 29–96% of patients reported at least mild pain during the procedure, but this resolved and 1 week later only 2.5% reported pain [22].

External ultrasound devices can also be used to decrease small areas under correction. Several devices exist. External ultrasound devices heat fat via a photo-acoustic effect. Specific frequencies heat fat faster and more selectively. Free lipids can be detected in lymphatic fluid post-treatment, verifying cell membrane permeability and/or cell death [23]. There is no consensus on the best intensity settings, frequency of ultrasound, or frequency of treatment. A few reviews of larger patient populations do exist, indicating improvement in volume [24]. High-intensity focused ultrasound (HIFU) focused at a depth of 1.1–1.6 cm, results in almost immediate adipocyte death primary via acoustic cavitation and heating. Apoptosis may also play a role. An excellent review by Atiyeh and Chahine of several studies reported a mean waist circumference reduction of 2–5 cm. Overall, HIFU resulted in a "modest" reduction in fat, but most studies had inaccurate and inconsistent measuring tools. These authors recommended HIFU for non-obese patients seeking a minimal reduction in volume [25]. This makes HIFU reasonable for small areas remaining after liposuction. Anecdotally, our clinic uses HIFU for exactly this purpose, often combined with radiofrequency to promote dermal heating and subsequent tightening.

Radiofrequency non-invasive body contouring may also be of some benefit for contour irregularities. Radiofrequency heats fat indirectly by orienting water molecules in an electric field. Subsequent spinning results in heat and eventually adipocyte death. The frequency of devices ranges from 3 kHz to 24 GHz and may be unipolar, monopolar, or bipolar. These treatments typically involve heating the skin above 42°C for a 15–45 min period. Higher intensities may destroy fat more quickly but are typically not tolerated by the patient. Most studies demonstrate improvement in skin tightening but a few studies demonstrate volume reduction as high as 20% [26]. Radiofrequency is safe to use for small areas but should be avoided directly over bony structures, in patients with metal implants or defibrillators or those with metallic intrauterine devices.

Diode lasers emitting 1060 nm infrared light have recently been introduced. With these devices, abdominal fat may be reduced by as much as 19% and submental fat by 26.4% after a single treatment. The devices are relatively new, and we await larger studies [27]. Likewise, low-level laser light therapy (LLLT) devices may have some effect on localized adiposity. However, these devices vary wildly in efficacy, treatment intensity, treatment time and treatment endpoint. Typically, these results are experienced more slowly and maybe less than ideal for correcting contour deformities post-liposuction. Some evidence exists demonstrating LLLT plus liposuction may be beneficial, but that LLLT as a stand-alone procedure is not sufficiently effective [28–30].

In the last 2–3 years high-intensity focused electromagnetic (HIFEM) field treatment has shown efficacy in inducing muscle hypertrophy and fat reduction [31]. Katz et al. demonstrated an average reduction in abdominal fat of 19% from 1 month after treatment and 23.3% from 3 months after treatment using HIFEM in patients BMI 20–30 kg/m^2. Each patient received for 30-minute treatment spaced 2 days apart over 2 weeks. The treatments were highly tolerated. Cellular controlled apoptosis appears to be the predominant mechanism [31]. The procedure is also an option for treatment of other sites, such as the calves or arms [32].

Finally, liposhifting may be appropriate for small under corrected areas. This technique involves anesthetizing the area, then gently loosening fat with a cannula (without suction). The loosened fat is gently rolled out to the desired contour and a garment placed to fix the tissue in place. Several patients in our practice have had excellent results with this technique [33].

5. Overcorrection

In the case of overcorrection, excess fat has been removed from the subject such that the desired contour is depressed. These occur in every possible anatomic site but are most evident where the esthetic result is visible ventrally. The abdomen is the most common site, primarily because of the larger area, although it is the least technically difficult. However, more technically difficult sites include the outer and inner thighs and the posterior upper leg [16]. Treatments for overcorrection include reinjection of aspirated and prepared fat (see below), the release of fibrous bands using either mechanical or enzymatic release (e.g. as seen in areas of bound down skin or cellulite), and various fillers, specifically poly-L-lactic acid (PLLA).

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It can be very helpful to annotate the expected amounts of aspirate on a photograph or body map. Then during the procedure documentation can be made as to actual volumes extracted. Toledo and Mauad recommend collecting several syringes of fat initially so that overcorrected areas can be grafted immediately [19]. We find it helpful to have the patient stand at the end of the procedure so that contour irregularities can be assessed. In a supine patient, contour irregularities can be observed by stretching the skin and looking for subtle changes in contour. These areas can then be further assessed with a pinch test. Care must be taken not to overcorrect and undercorrected area causing the provider to go back and forth between sites. While it is often helpful to blend the hills surrounding under corrected sites into the normal contour, this can be an easy pitfall and reinjection may be a better option. Overcorrection can also occur in what Klein refers to as a "spoke and wheel deformity". This occurs when suctioning occurs repeatedly at the base of a fanning pattern where more passes occur. Avoid this by stopping suction on entry and exit and during changes in direction.

Overcorrection also occurs in the mons pubis, where vulvar edema can be problematic. This area should be approached very conservatively. Even a mons pubis that appears to have significant volume may be deceptive because the fibrous borders of this area make small amounts of fat seem larger. Overcorrection of this area can result in painful intercourse.

By collecting several syringes at the beginning of the procedure fat can be saved for same-day reinjection. Fat graft survival is based on several factors. Larger cannulas decrease the sheer force of adipocytes against the cannula wall. Adipocytes exposed to higher vacuums can also suffer damage. Larger and shorter cannulas have better adipocyte viability based on Poiseuille's law because pressure drop is directly related to the length of the cannula and inversely related to the 4th power of the radius. A larger bore dramatically decreases the change in pressure an adipocyte must undergo. Fat should be cleaned of blood and tumescent fluid, but centrifuging may be damaging [34]. There is a 1470 diode laser powered to disrupt septa but not destroy adipocytes. This works because water-containing septae preferentially absorb 1470 nm infrared energy over adipocytes. Adipocytes are then collected in a mesh basket within the container and excess tumescence, blood and oil are suctioned out in a two-step process. This fat is reported to be over 90% viable [35]. The addition of platelet-rich plasma may nearly double fat graft survival (55–89%) [36]. Platelet-rich fibrin may be beneficial as well, as it releases growth factors more quickly to adipocytes at risk of death (greater than 300 μm away from the periphery of the transfer) [37]. Reinjection should be performed in small aliquots using only gentle pressure. Distribute it in a fanning pattern to increase vascular exposure. Depending on the method of collection and fat preparation, the problematic area should be injected with an additional 50–100% over baseline to allow for resorption. Liposhiftng is beneficial if the over-corrected area is adjacent to a larger volume of fat.

Cellulite and scar depressions can be released using a forked cannula. These release fibrous bands in a technique called subsicion [38]. After release, cellulite and scars may be fully corrected and no further treatment is needed, otherwise fat grafting or poly-L-lactic acid may also be used.

Collagenase may be an additional off-label consideration to improve bound-down scarring or cellulite. Collagenase derived from *Clostridium histolyticum* has recently been FDA approved for treating cellulite and has been used for Dupuytren's contracture and Peyronie's disease as early as 2013 [39]. The most common side effects have been ecchymosis and pain at the injection site but reports of edema and hematoma exist [40].

Poly-L-lactic acid (PLLA) is a deep dermal filler that stimulates collagen formation by activating fibroblasts. Volume correction can persist for 2 years or more. Results may not be seen for 4–8 weeks, and injections typically are placed 4–6 weeks apart. Correction of depressed areas is temporary, and results may not be visible for several weeks after injection. Unlike autologous fat transfer, overcorrection is not recommended here. Several sessions are needed. The technique can be cost-prohibitive for larger areas. Each syringe provides only 5–12 ml of fluid depending on dilution. Fillers should not be used on the day of liposuction. Time should be allowed for swelling and edema to subside. Also, 1% lidocaine with epinephrine is often used in reconstituting ploy-L-lactic acid and this complicates calculations of maximum lidocaine dose after tumescence when numerous syringes are used. We have had success with the correction of gluteal cellulite and volume using PLLA (**Figure 2**) but found no case reports using PLLA specifically for overcorrection.

Recently allograft adipose matrix (AAM) has been introduced for volume correction. An AAM was developed by the processing of recovered adipose tissue as a human cell and tissue products (HCT/P) allograft [41]. It is stored at room temperature and as such can quickly be reconstituted if overcorrection is observed. Injection of an adipose-specific matrix promotes adipocyte differentiation, proliferation, and neovascularization. Patients generally tolerate injection very well. Biopsy of treated temporal tissue revealed an increase in adipocytes and blood vessels at 8 weeks. Gold et al. observed that AAM generally appears to follow the same trend as autologous fat grafting and may reach final volume more quickly. Thus, the underlying mechanisms of fat grafting and AAM may be similar [42]. More experience is needed with this product, but it seems to have great potential.

Millifat (2–2.5 mm "parcels" of fat) may be an alternative solution to mild superficial contour deformities, probably by the same mechanisms as AAM and grafting. Nanofat (500 μm particles) can similarly be used to improve skin texture and assist in volume support [43]. This is typically introduced via microneedling or a 25 gauge cannula.

Figure 2.
Correction of cellulite and volume using PLLA. Photo courtesy: Jamie Wilson PA-C.

6. Other contour deformities

Seromas account for 2–5% of complications from liposuction [44]. Seromas are a result of excessive fat removal and destruction of fibrous bands using either larger cannulas or aggressive techniques. They occur when a potential space is created and fills with fluid. They usually occur within 2 weeks post-operatively. Proper garment fitting is essential in avoiding seromas. Scrotal and vulvar swelling is a frequent complication especially when the suprapubic is suctioned. This is primarily due to edema from fluid movement due to gravity and rarely a hematoma or seroma. Bodysuits are available that put pressure on the suprapubic, but care must be taken that the garment is not so tight that edema in the vulva or scrotum results in cyanosis or numbness. Needle aspiration is the primary treatment, followed by compression. The seroma may need to be drained several times until it stops forming. It is important to manage seromas so that a permanent cavity is not created.

Hematomas form via a similar mechanism when vascular damage is sufficient for blood to fill a potential space (**Figure 3**). Larger cannulas, muscle trauma and aggressive liposuction increase the risk of hematomas. After tumescence Klein recommends a period of detumescence to allow vasoconstriction and so that tissue is more easily pinched and manipulated. A good medical history should include the use of blood thinners, including over-the-counter non-steroidal anti-inflammatory drugs (NSAIDS) and herbal supplements such as garlic, ginseng, and *Gingko biloba*.

Prevention of hematomas, bleeding and ecchymosis may be achieved by adding tranexamic acid (TXA) to the tumescent fluid. Rodriguez-Garcia et al. report a decrease in blood loss as measured by hematocrit [45]. Adding TXA to lipoaspiration sites post-liposuction also has decreased bruising [46].

Drainage of hematomas followed by compression is essential and may require several treatments. Rapidly developing hematomas may indicate a significant vascular bleed and require direct compression. In severe cases, a drain may be required. A chronic hematoma can form a fibrotic mass, and some have demonstrated calcification. If left untreated, hematomas can take months to resolve. It has been postulated that laser-assisted liposuction may have a lower rate of bleeding and ecchymosis because of cauterization. The 1064/1319 nm devices may improve skin tightening slightly better than others. The risks of thermal injury and ulceration are increased using lasers. Radiofrequency assisted liposuction (RFAL) devices demonstrate a very safe profile. The rate of minor complications including hematomas

Figure 3.
Post-liposuction hematoma of the right lower abdomen at 1 week.

is significantly reduced with second-generation RFAL devices as reviewed and discussed by Chia et al. [47].

Normally temporary hyperpigmentation is the only residual evidence of an access port after healing. Keloids and hypertrophic scars can occasionally occur at these sites. They can also occur where ulceration or necrosis occurred. A patient with a history of keloids should be warned about the increased risk. The risk of scarring is increased if an undersized port undergoes significant friction. The treatment of hypertrophic scars and keloids is generally the same. Intralesional triamcinolone 5–10 mg/cc injected once every 4–6 weeks is usually sufficient to flatten the scar. Silicone sheets, gels and gentle massage are very helpful but are much slower. Transcutaneous delivery of triamcinolone or 5-flourouracil has been reported as beneficial. Laser-assisted delivery of medications via fractional ablated channels may prove promising, but the FDA has warned against using products not designed to be used systemically or subcutaneously. Botulinum toxin may also act via myofibroblasts. Hypertrophic scars respond to fractionated ablative lasers via a remodeling mechanism and this may be appropriate as sole therapy.

Superficial skin irregularities are very common. Illouz reports 8.2% of patients experienced skin irregularity post-procedure [48]. Superficial aspiration can result in a bound down or peau d'orange appearance with dermal scarring and fibrosis. Avoid this by always keeping the cannula window faced downward away from the dermis. Illouz as well as Dixit and Wagh recommend leaving 5 mm of fat beneath the dermis and over the fascia to prevent scarring and waviness [16, 48]. Lax skin may tighten better by traumatizing the subdermis either mechanically or with heat. Devices using ultrasound, radiofrequency, lasers, and helium plasma are marketed for this purpose. Care must be taken not to damage the fragile superficial vascular plexus and lymphatics. Being too aggressive near the dermis can result in dimpling, ecchymosis, ulceration and permanent reticular erythema referred to as erythema ab lipoaspiration (**Figure 4**). Correcting peau d'orange skin and erythema ab lipoaspiration is incredibly difficult. Mesoglycan-based therapy orally at a dose of 50 mg twice daily worked in one case report of erythema ab igne, which is similar. Treatment lased 1 month at twice a day and 2 months at daily dosing [49]. Cho et al. report a case of a 23-year-old woman with erythema ab igne treated with a 1064 nm ND:YAG using low fluences (1.8–2.5 J/cm^2, 2 passes). She was treated with three treatments separated by 2 weeks [50].

Post-inflammatory erythema and ecchymoses may be improved with intense pulsed light (IPL). In the authors' opinion, IPL is beneficial for post-liposuction erythema generally. Using a broadband light device, a 560 nm filter and a 4.5 cm spot size (12 J cm, 30 ms and 20° cooling; two passes) every 2 days resulted in improvement of ecchymoses and erythema after 2 weeks.

Permanent skin creases frequently occur after liposuction when redundant skin folds onto itself. Properly fitted garments that do not pinch or fold the skin are essential. The patient should be made aware that folds of the skin should be flattened when the garment is adorned. Even when a garment is in place, sitting in certain positions can fold the skin. Folded skin can make permanent creases with resulting shelves of redundant tissue that persist indefinitely (**Figure 5**). Treatment can be challenging and includes lymphatic massage to assist in scar release and fluid drainage from the area superior to the crease. Subcision using a forked cannula may be required. If this is performed the area can scar again, which may be alleviated with fat grafting below the site or collagenase as discussed elsewhere. Collagenase may also be considered, especially if followed with radiofrequency and targeted pressure energy. This has been demonstrated clinically with cellulite as a model [51].

Figure 4.
Scar from dermal necrosis from laser-liposuction.

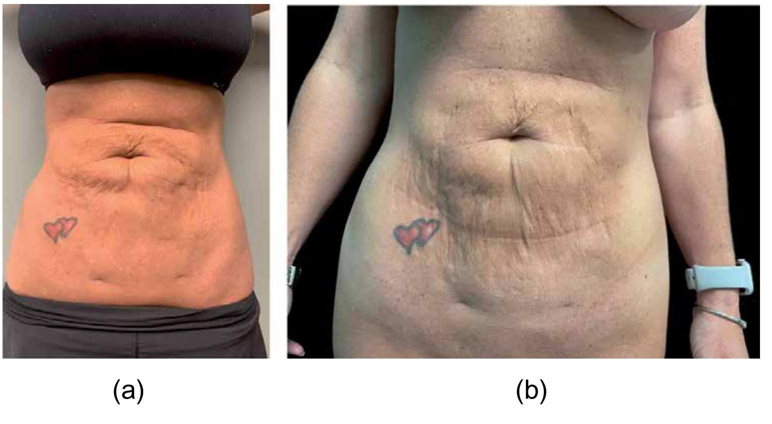

Figure 5.
(a) Post-liposuction creases from the inappropriately worn garments. (b) The same patient after massage for a month.

Liposhifting may also be beneficial [33]. Bound-down skin that moves with muscle contraction is attached to the fascia. This should be carefully subcised. An alternative is triamcinolone injection and/or 5-flourouracil injectable solution. (Illouz) Chacur et al. reported a case of liposuction fibrosis and dermal scarring treated with a combination of subcision, injected polymethyl methacrylate and fractionated CO_2 (epidermal). A single session resulted in notable improvement extending to 4 years [52]. It should be remembered that triamcinolone can also cause fat atrophy and in some cases fat atrophy may exacerbate the problem.

7. Specific sites

The gluteal sulcus is a problematic area. This area must be strictly avoided and there should never be an attempt to create an artificial gluteal sulcus using liposuction in patients. Disruption of the fibrous septae that create the inferior gluteal sulcus can lead to gluteal ptosis. Correction of this deformity is almost entirely surgical, although autologous fat grafting has shown some benefit in rebuilding the curvature of the buttock. Sozer and Eryilmaz described a successful split gluteal flap for this repair [53]. Others have described using anchoring de-epithelialized skin flaps. Subcutaneous threading improved to grade 2–5 gluteal ptosis to grade 2 or better. More severe ptosis improved in only 14% of cases [54].

The banana fold represents redundant fat and skin below the gluteal sulcus. Most authors recommend superficial liposuction of this area. This procedure should be reserved for the most experienced practitioners. Deeper or more aggressive liposuction can cause a double banana fold. Autologous fat transfer can improve double folds [55]. Gonzalez reported a dermotuberal anchorage buttock-lifting technique which must be performed surgically [56].

Liposuction of the submentum is straightforward and takes very little time. Overcorrection is common in this area and bound down skin is the result. Small areas can be injected with triamcinolone and only rare cases may need subcision. Massage can make a dramatic difference if tissue is bound down to the platysmal fascia. The laxity common in this area may tempt a clinician into over-treating the subdermis. However, the normal inflammation occurring in the subdermal layer has a profound effect on neck laxity, as can also be seen with cryolipolysis and mesotherapy. The marginal mandibular nerve traverses the jawline within 2 cm of the area below the melolabial fold. The nerve is superficial but beneath the platysmal muscle. The clinician can easily penetrate the plastymal muscle without realizing it, although the patient usually describes some discomfort. When this happens, suctioned fat is noticeably blood-tinged and bleeding often occurs from the port. Likewise, it is not wise to suction on the superficial surface of the platysma because inflammation can cause a paralysis of the marginal mandibular and the corner of the mouth will drop. Over 90% of marginal nerve injuries recover over several months without treatment. In severe cases, a platsymal motor nerve transfer can restore nerve palsy [57].

Breast deformities include depressions and dimpling, especially in the upper pole. This area rarely needs to be liposuctioned. Most problems occur during fat grafting. If fat is injected in a fan-like pattern from the axillary fold a potential space is created and unsightly fat collects in the axillary fold. It is common for liposuction to result in temporary lumpiness that persists for several weeks. That said, mammography is recommended if a new lump appears greater than a month after liposuction [58].

The calves and ankles can be difficult when trying to maintain a natural curvature. In women, overcorrection in this area results in a markedly masculine appearance. Liposuction should not be performed on the calf if the pinch test is less than 2 cm of fat. The calves should be assessed when standing normally, standing on the toes, and supine [59]. The ankle is at special risk of ulceration, as well as nerve damage and varicosities. Fat transfer to over corrected areas of the calf and ankle suffers from lack of vascularity for the graft, and results are disappointing. While there are no case reports, dermal fillers may be preferred.

In summation, the physician is faced with a canvas of options for body contour correction. When in capable hands, liposuction has evolved to be an extremely safe and gratifying option. As with any surgical procedure, the complications are many. But with the advent of new energy technologies, new research of combination treatments, and a more mature understanding of older options (e.g. fat grafting) the options available for correcting the inevitable rare complication are better than they have ever been. In addition to energy devices, new injectables, such as nanofat, collagenase, deoxycholic acid and PLLA to name, a few have given the surgeon a palette of options never before available. Armed with these, we can provide our patients with the absolute best outcomes available to modern medicine.

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Liposuction began as a simple, minimally invasive method of reducing the amount of localized fat in a region. Today it is a sophisticated and complex process, with many variations in purpose and technique. In this book, a global slate of expert surgeons offers a detailed description of various minimally invasive and non-invasive options for contouring the face, neck, and body. Chapters detail the evolution and utilization of various energy-based devices and combination treatments. They also describe procedure limitations and treatment of complications. Finally, they discuss indications for various approaches with case study descriptions so readers might be assisted with treating patients in their everyday practice.

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