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NARRATIVE LITERATURE REVIEW

Gluteal & Hip Stem Cell Enriched Fat Grafting (Brazilian Butt Lift): Optimizing Outcomes While Minimizing Complications

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ABSTRACT

Background: Gluteal & hip fat grafting (Brazilian Butt Lift) is the most common adjuvant procedure in body liposuction.

Aim: Using evidence-based medical information to optimize a surgical technique for awake body contouring with gluteal and hip augmentation using stem cell enriched fat grafting.

Methods: Retrospective, consecutive women (n=112) analysis from 2016 to 2022 electing awake, super-wet wetting solution, conscious sedation anesthesia in body contouring using VASER ultrasound liposuction in those requesting gluteal fat grafting. Fat grafting indications were for improved gluteal contour (85%, n=95) or size augmentation (15%). Fat grafts were placed solely in the subcutaneous plane and prepared by centrifugation-filtration fat processing combining platelet rich plasma and autologous adipose-derived stem cells enrichment. Women requesting general anesthesia or a gluteal or hip silastic implant were excluded.

Results: Using the GAIS revealed very much improved, very improved, and improved (97.6%) with 3.4% stating no change or worse (one patient). Patient subjective satisfaction with the overall procedure showed 92% (n=103) satisfied. Those dissatisfied were mainly from insufficient fat volume (n=7) or dissatisfied from the body contouring outcome (n=2). Those with insufficient fat volume were given the option of gluteal or hip silastic implant placement. There was a 14.6% (n=13) complication rate with seven (7.8%) experiencing minor contour irregularities and five (5.6%) seromas treated by needle aspiration. No patient experienced a serious adverse effect or oil cyst. No bacterial infections were diagnosed, however, there was one suspected atypical mycobacteria infection. Erythema and mild discomfort without fistula formation developed 6 weeks postoperatively, which resolved on 6 weeks of sulfamethoxazole-trimethoprim antibiotic treatment. The revision rate was 4.5% (4/112) for additional gluteal and/or hip fat grafting. Mean volume of purified, compacted, enriched fat grafted per buttock was 240 cc and per hip dip area was 45 cc. Overall total buttock fat grafting combining each buttock and each hip dip equaled 570 cc compacted, enriched fat, which corresponds to 950 cc of unprocessed, harvested fat.

Conclusion: Gluteal and hip fat grafting incorporated best practices harvesting, processing, enrichment, and administration techniques combined with VASER liposuction yielded superior patient satisfaction, aesthetic results, and no serious adverse effects.

Introduction

Body contouring by liposuction is the most requested cosmetic body surgical procedure requested in the United States[1]. Gluteal & hip fat grafting, commonly referred to as a Brazilian Butt Lift (BBL), is a common adjuvant procedure in body contouring and one of the fastest growing aesthetic procedures around the world[2,3]. The popularity of BBL revealed an 8-fold increase from 2011 to 2021 according to The Aesthetic Society for Aesthetic Plastic Surgery cosmetic surgery national data bank statistics[4,5]. Since their inception, both liposuction[6] and gluteal fat grafting[7] have seen incremental advancements directed at both improving aesthetic outcomes and lowering complications[8,9,10].

Subcutaneous gluteal fat grafting has gained popularity due to the advantage of its autologous nature, readily available, low risk after abandoning intramuscular injections, and low revision rate. Liposuction and gluteal fat grafting anesthesia in an awake state in an office-based operating room delivering conscious sedation (oral sedation with possible parenteral supplementation) along with the delivery of a wetting solution (lidocaine, epinephrine, and bicarbonate) by the tumescent or superwet techniques yields the highest safety, while rendering excellent patient comfort[10,11,12].

This papers author (RJT) highlighted caution of injecting fat into the gluteus maximus muscle throughout his career. This injection could injure the wall of large gluteal veins and posed an avoidable fatal risk from pulmonary fat emboli (PFE). Further, the large volume of fat administration performed by numerous gluteal surgeons adversely affects adipocyte survival. The main argument presented for intramuscular gluteal injections was greater fat volumes could be administered to augment the buttock to large sizes. And that the placement of fat into the muscular environment would improve adipocyte neovascularization.

Mendieta stated that gluteal fat grafting (GFG) ranging from 450 to 1100 cc per buttock side (900 to 2200 cc total) with intramuscular injections yields more precise augmentation, quicker recovery, and better patient satisfaction compared with gluteal silastic implants[13]. Beginning the publicized risks regarding BBL, the first reported fatality due to PFE microembolization was published in 2015 by Astarita et al.[14] This was soon followed by Shiffman describing fat tissue pulmonary embolism syndrome in 2016[15].

The pathophysiology of pulmonary fat embolism (PFE) is that a blunt cannula would injury the wall of a vein (most commonly either a superior or inferior gluteal vein), higher fat volumes increase the pressure in the muscular compartment, pressure gradient forces pushes fat into a vein lumen, transporting the micro or macro fat emboli through the inferior vena cava resulting in partial or complete obstruction of the pulmonary arteries culminating in acute right ventricular compromise or failure.

PFE is classified as microscopic (MIFE) or macroscopic (MAFE). Cardenas-Camerena et al. defines MIFE as microemboli forming from fat in liquid form, classically presenting within 1 to 3 days after surgery with a 10-30% mortality rate[16]. MAFE presents intraoperatively or within two hours of surgery with a 99% mortality rate[16].

The knowledge of a significant risk of mortality from a popular cosmetic surgery procedure prompted further study. The Aesthetic Surgery Education and Research Foundation (ASERF) Task Force survey in 2016 reported 198,857 gluteal fat grafting cases suffered nonfatal PFE (n=103) and fatal PFEs (n=32) for a career mortality rate of 1:6214 with an overall PFE stunning incidence of 1:1473. They concluded that variation in three methodologies to calculate risk of death yielded a low of 1:6214 to a high of 1:2351[2]. Surgeons reported injecting into the subcutaneous plane or superficial to mid-muscular area experienced 63% and 82% risk reduction[2]. Mofid et al showed that 3% of plastic surgeons experienced a fatality and 7% at least one pulmonary fat embolism in a patient over their careers performing BBLs[2].

The task force made recommendations to lower the PFE risk based on the clinical data (Table 1)[2]. Mofid et al identified risk factors that included deep muscle injections demonstrated the highest risk factor (4 times increase in fatal PFE, 6 times increase in nonfatal PFE) with all autopsies discovering fat within the gluteal musculature. The other risk factors they identified that increased the risk of PFE were the following: downward cannula angulation (3.8 times), < 4 mm injection cannula diameter (5 times), and multiple hole cannulas (2.4 times)[2]. Arguably, if one is injecting fat into muscle, the relevance of these other factors are difficult to calculate risk.

Table 1 ASERF Task Force Gluteal Fat Grafting Recommendations

Avoid injecting into the deep muscle
Use >4.1 mm diameter single hole injection canula
Avoid downward angulation of the cannula
Position patient & place incisions to create path avoiding deep muscle injections
Maintain constant 3-D awareness of cannula tip
Only inject when cannula is in motion
Consider PFE in unstable intra/postoperative patients
Review gluteal vascular anatomy
Include PFE & surgical alternatives in informed consent

ASERF- Aesthetic Surgery Education and Research Foundation

Cuzalina et al reviewed two surveys sent to board-certified surgeons from the American Board of Cosmetic Surgery in 2019 (procedure data from 2016-2019) and again in 2022 (procedure data from 2019-2021) regarding technical approaches and mortality in GFG[3]. A minority (39%) injected fat at least into superficial gluteal muscle during the earlier study time frame. The vast majority (96.5%) of surgeons administered fat exclusively in the subcutaneous plane in the second part of study. There was with an overall reasonable PFE incidence of 1:11,657. The mortality rate injecting fat into the superficial aspect of the gluteal musculature was of 1:11,400 (2 of 22,800 cases) with no fatalities (0 out of 12,800) injecting fat only into the subcutaneous plane. The ABCS authors used evidence-based medicine and the results of their two surveys to publish their GFG procedural recommendations (Table 2)[3].

Table 2 ABCS Current BBL Safety Recommendations

Inject SQ only (above investing muscular fascia)
Inject parallel to back, not a downward inclination
Use smooth 4 mm or larger blunt tip injection cannula
Use system preventing excess injection pressure
Use method to avoid large boluses of fat injection
Avoid injecting from inferior gluteal port if possible
Use meticulous cannula cleaning & sterilization methods
"No touch" injection cannula technique
Op site anal contamination prevention
Use method for no air contamination of injected fat
Use caution when combining BBL with other major procedures related to blood loss
Expert knowledge of peri-gluteal vascular anatomy
Written consent specifically informing of fat emboli
Consider closed drainage & chlorhexidine daily washes
Consider diagnostic ultrasound use during gluteal fat placement

ABCS- American Board of Cosmetic Surgery
BBL- Brazilian Butt Lift (Gluteal Fat Grafting)

Two additional studies confirm the validity of restricting the plane of fat graft placement to the subcutaneous space. The World Association of Gluteal Surgeons (WAGS), a mixture of cosmetic and plastic surgeons, promoting fat grafting guidelines highlighting only subcutaneous plane placement has an extremely low number of BBL fatalities (1:23,000) as of 2022 (Table 3)[3].

Table 3 WAGS BBL Safety Recommendations

1. Stay as far away from the gluteal veins and sciatic nerve as possible. Fat should only be grafted into the superficial planes, with the subcutaneous space considered safest. If the aesthetic goal requires more fat than can be placed in the subcutaneous layer, the surgeon should consider staging the procedure rather than injecting deep.
2. Concentrate on the position of the cannula tip throughout every stroke to ensure there is no unintended deeper pass, particularly in the medial half of the buttock overlying the critical structures.
3. Use access incisions that best allow a superficial trajectory for each part of the buttock; avoid deep angulation of the cannula; and palpate externally with the nondominant hand to assure the cannula tip remains superficial.
4. Use instrumentation that offers control of the cannula; avoid bendable cannulas and mobile luer connections. Vibrating injection cannulas may provide additional tactile feedback.
5. Injection should only be done while the cannula is in motion to avoid high-pressure bolus injections.
6. The risk of death should be discussed with every prospective BBL patient.

World Association of Gluteal Surgeons (WAGS)
BBL- Brazilian Butt Lift (Gluteal Fat Grafting)

The Multi-Society Task Force for Safety in Gluteal Fat Grafting representing board-certified plastic surgeons around the world (which included the Aesthetic Society, American Society of Plastic Surgeons [ASPS], International Society of Aesthetic Plastic Surgeons [ISAPS], International Federation of Adipose Tissue Science [IFATS], International Society of Plastic Regenerative Surgeons [ISPRES]) released a practice advisory on January 31, 2018 (Table 4). After introducing these GFG guidelines, the International Society of Aesthetic Plastic Surgeons observed only one fatal PFE[17,18].

Table 4 Multi-Society Task Force for Safety in Gluteal Fat Grafting Practice Advisory on GFG Recommendations

Fat transplantation to gluteal region restricted to Subcutaneous plane
For larger volume of fat > 200 cc per buttock, non-syringe methods employing roller pump fat propulsion device to reduce thenar fatigue
Do not use two hand syringe technique to inject fat
ULTRA BBL is a novel technique showing promise
No single technique is best suited for all patients
Intraoperative trans-thoracic ultrasound may show future promise for early detection of PFE
Post-discharge home-monitoring technology may show future promise
Ultrasound-guided BBL is recommended
No one cannula is best suited for all patients
Larger cannulas (>4 mm) are stronger, stiffer, & less likely to undergo “flexibility misguidance”
Avoid operator fatigue and minimize distractions
Maximum number of BBLs limited to 3 per day
A “single surgeon” approach, where one surgeon is present and actively performing entire procedure

GFG- Gluteal Fat Grafting, PFE- Pulmonary Fat Emboli
BBL- Brazilian Butt Lift

Even though multiple plastic surgery and cosmetic surgery societies have emphasized GFG *subcutaneous plane injection*, this has been expanded to both a medical board and state law. The Florida Board of Medicine in 2019 mandated all GFG be performed only in the subcutaneous plane. All fatal PFE's were found to have fat in the gluteal muscle's postmortem[19]. In 2022, the board limited the number of BBL's performed per surgeon to three per day and GFG must be performed with ultrasound guidance[19,20]. Limiting the number of GFG cases makes sense for two reasons: (1) most deaths (58%) were observed toward the end of the week, while only one-third occurred at the weeks onset[18], and (2) the orthopedic surgery literature has shown that increased fatigue diminishes proprioception that can increase the risk of deeper fat injection with less chance of a smooth, non-bolus fat grafting result[21].

Further legislature enacted in 2023 mandated prohibiting non-surgeons from harvesting or administering fat as well as prohibiting a surgeon from supervising BBL procedures in multiple operating rooms. Florida Governor DeSantis signed House Bill 1471 into law mandating ultrasound use in GFG[20]. One caveat, surgeons must use both hands for optimal proprioceptive control during both fat harvesting and fat placement. This critical feature is lost if the surgeon themselves must hold the ultrasound probe. A 1-handed surgeon is less likely to perceive of the specific plane of cannula placement and it's more difficult to administer fat in a multi-layer, subcutaneous plane, micro-aliquot technique. This predisposes to bolus fat injection, which results in decreased neovascularization within the central fat aliquot, culminating in fat necrosis[22]. Thus, it may be best for an assistant to hold and move the diagnostic ultrasound probe.

Although intramuscular GFG carries the highest risk, other potential risk factors have been studied. None of the above studies from plastic surgeons and cosmetic surgeons identified any association with surgeon experience (GFG case numbers) and PFE rate. In the South Florida BBL mortality experience, 88% were performed by well-trained board-certified plastic surgeons, which highlights being a plastic surgeon is not protective[19].

Cardenas-Camerena et al. postulated that PFE is independent of the volume of fat harvested or grafted[16]. Agullo et al survey by a multidisciplinary group of surgeons from the International Society of Aesthetic Plastic Surgeons from 2022 also concluded that the fatalities were not linked to particularly large volumes of injected fat[17]. International Society of Aesthetic Plastic Surgeons concluded that the use of a 4-mm cannula was unrelated to preventing intravascular fat injection. They also note that ultrasound guidance for fat injections is useful in determining cannula plane location, but there is no evidence that it limits risk[17].

Regarding improving aesthetic outcomes, scientific advances in fat harvesting, processing, enrichment, and administration have yielded improved fat viability, which translates to optimal aesthetic volume enhancement of any facial or body areas grafted. However, since there is not any universal acceptance of the "best" methodology, their continues to be significant variations in each step of fat grafting. Investigating the best practices for fat grafting and presenting clinical data on the use of this methodology is presented.

The clinical experience implementing the safest form of liposuction: awake, superwet or tumescent anesthesia with increased epinephrine dosing is presented. Additionally, superior body contouring techniques and technologies encompassing VASER third-generation ultrasound, high-definition sculpting, skin tightening technologies, such as radiofrequency helium-based plasma technology (HBT), and VASERSmooth cellulite subcision working synergistically with gluteal and hip subcutaneous fat grafting created desired buttock shaping and enhancement outcomes.

Methods

STUDY DESIGN

The objective of the clinical study was to assess patient satisfaction, note complication type and incidence, compare results to the medical literature, compile data of those electing skin tightening and/or cellulite subcision adjuvant therapy, present specific methodology of gluteal fat grafting in detail so others can duplicate superior aesthetic results.

This is a retrospective review evaluating consecutive adult women electing buttock and/or hip fat grafting during simultaneous "vibration amplification of sound energy at resonance"

(VASER) ultrasound liposuction (+/- HBT) with no other simultaneously carried out cosmetic procedures performed under awake, conscious sedation with either tumescent or superwet wetting solution delivery in an office-based operating room from 2016 through 2022. A chart review of those meeting inclusion criteria regarding identifying complications, volume of grafted fat, harvested fat volume, and patient PROM responses were tallied.

Those undergoing GFG under general anesthesia or with other cosmetic surgical procedures, such as breast aesthetic surgery (ie. implant augmentation, mastopexy, combined augmentation-mastopexy), body implant placement (ie. gluteal, hip, or calf implants), and skin excision procedures (abdominoplasty, brachioplasty, and thighplasty) were excluded.

The investigation was carried out following the rules of the Declaration of Helsinki of 1975, revised in 2013. This body contouring study was approved through the investigational review board of Touro University Nevada (TUNIRB000228).

SURGICAL INDICATIONS

Clinical indications for autologous gluteal and/or hip fat grafting fell mainly into two categories: (1) primary buttock and/or hip reshaping/ augmentation or (2) as an addition aesthetic procedure during liposuction body contouring. Because of the need for fat harvesting in fat grafting, simultaneously liposuction is always performed.

DECISION-MAKING PROCESS & ALTERNATIVE TREATMENTS

Desired buttock size was determined by both photographic morphing and/or patient presenting model photographs of target size. If the size was larger than can be achieved by one fat grafting session with sole subcutaneous plane placement, the following options were presented: (1) second session of fat grafting if sufficient body fat was available in areas not previously addressed by liposuction, or planned fat storage at a cell/tissue bank harvested from the primary liposuction procedure, (2) silastic gluteal implant placement (maximum size in one surgery was 350 cc and up to 700 by a second, staged procedure), or (3) composite gluteal augmentation with either a gluteal or custom hip silastic implant combined with fat grafting. No patients ever had "intramuscular" gluteal or hip fat grafting.

PREOPERATIVE CONSIDERATIONS

Patients underwent a comprehensive initial aesthetic consultation, medical clearance, and jointly arrived at a surgical plan with one's surgeon. All patients had a complete blood count (CBC), mainly to assess their hematocrit to calculate safe fat removal volume. All patients were inquired on medications, especially those inhibiting cytochrome P-450 (ie. antidepressants, benzodiazepines, macrolides, beta-blockers, calcium channel blockers, antifungals the most common) minimize their use during the perioperative period. Women were told to stop oral estradiol supplementation at least two weeks before, but preferably one month prior to surgery to minimize deep venous thrombosis risk.

PREOPERATIVE WEIGHT LOSS

Patients were recommended to be at their ideal body weight (IBW), or alternatively at least at the lowest weight possible given their weight loss history. Those above their IBW were recommend undergoing a weight loss trial, delaying their body contouring procedure. These strategies combined exercise, dietary changes, bioidentical hormone optimal supplementation, and referral to their primary care physician for consideration of adding a GLP-1 agonist. Any GLP-1 agonist medication needed to be stopped two weeks prior to surgery.

DAY OF SURGERY- PREOPERATIVE MEDICAL ASSESSMENT

The patient present without consuming clear liquids for 2-4 hours and no solid food for eight hours prior to surgery start time. History and examination confirmed lack of a recent upper respiratory infection and any medication allergies. Normal vital signs and a negative pregnancy test (emptying bladder) are confirmed. History of any medications that alter cytochrome P-450 is paramount along with their weight to calculate the maximum lidocaine dosing. The informed consent form was reviewed with the patient confirming the anatomical sites for liposuction and areas for fat grafting.

SURGICAL SKIN MARKING

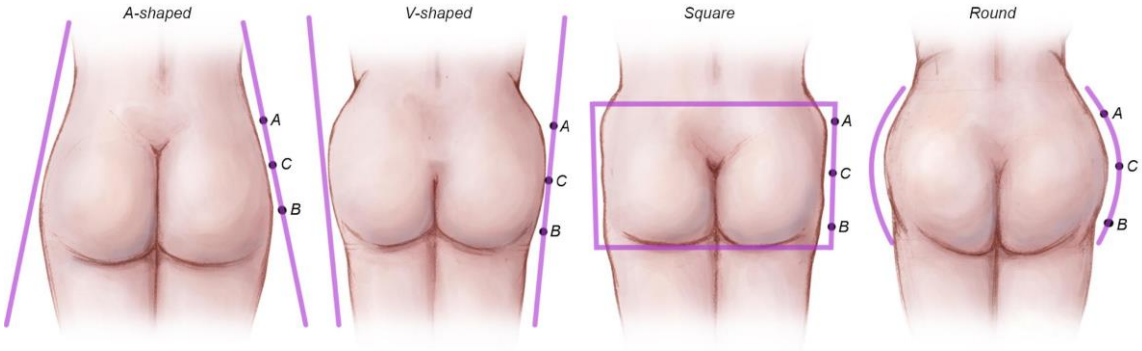
The patient was brought into the photography room. Before and after photographs in multiple views were obtained using an iPhone with two ring lights at a 45-degree angle to the patient and a

cobalt blue background. The photograph room has two 6-meter-tall mirrors across from each other for patients to observe the marking process. Patients are urged to be vigilant and specific with their verbal desires of her body contouring changes.

Marking was carried out prior to the patient receiving any oral sedation medications. In high-definition liposuction, the marking procedure can take 10-20 minutes in the standing position. Confirmation of a lack of umbilical hernia was paramount to prevent internal injury. The markings replicate the aesthetic goals of the patient influenced by the surgeon's expertise in artistry and body contouring technique implementing sexual dimorphism.

The patients desired gluteal frame appearance was confirmed of the three options: (1) A-shape (most common), (2) round, or (3) combination of A-shape and round shape (Figure 1). The three important points to optimize the gluteal shape in the "mid-axillary line" are: (A) upper lateral hip or Mendieta's superior aspect of zone 3, (C) mid-buttock, and (B) lateral (outer) thigh corresponding to zone 5 of Mendieta's classification.

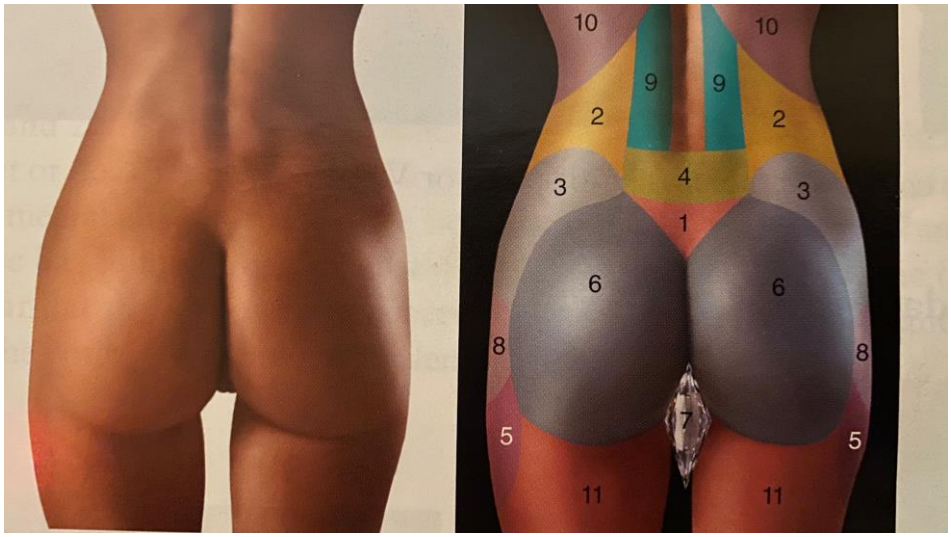
Figure 1 Gluteal Aesthetic Frames



Four main gluteal frames as originally described by Mendieta. The "A" frame is considered by most as the closest to ideal gluteal appearance. The three "mid-axillary line" important anatomic points to optimize the gluteal shape are: (A) upper lateral hip, (C) mid-buttock, and (B) lateral (outer) thigh. (Courtesy of Hoyos, AE, Prendergrast PM. High Definition Body Sculpting: Art and Advanced Lipoplasty Techniques. 1st Ed. Berlin: Springer-Verlag; 2014.)

Area "A" and "B" typically require fat removal and area "C" requires fat grafting. If one implements the eleven gluteal aesthetic zones of C Mendieta, zone 8 corresponds to "C" at the mid-lateral buttock and zone 6 represents the surface area of each buttock (Figure 2).[23] Each of these are the main sites for fat grafting along with the hip dips.

Figure 2 Art of Gluteal Sculpting



Anatomic zones to shape the gluteal frame include the lower back, flanks, buttock, hips, and both inner and outer thigh. Each requires a different approach with varying degrees of fat resection, fat grafting, and/or implant placement. Typically, fat removal is desired in all zones, except the augmentation of zones 6 and 8. Additionally, inferomedial buttock and the superior inner thigh may benefit from fat removal developing the negative space of zone 7. (Courtesy of Mendieta C. ed. The Art of Gluteal Sculpting. 1st ed. St. Louis, MO: Quality Medical Publishing, Inc; 2011 and copyright approval from Thieme Publishers, New York, New York).

During the body marking process, the surgeon describes each color marker's purpose, so patients understand the surgical plan. Marking includes the anatomic landmarks (costal margin, linea alba, linea semilunaris, Iliac crest, infragluteal folds), incision sites measuring about 6 mm in length (12 o'clock position of internal umbilicus, groin area inferior to panties maximum height along the vertical linea semilunaris, superior intergluteal fold, and most lateral aspect of infragluteal fold for 360° liposuction with gluteal and hip fat grafting), concentric circles noting areas for fat removal, sites for fat grafting, and inferior extent of liposuction on the abdomen extending along the junction of the hip and thigh are drawn with different color Sharpie pens (Figure 3 A, B, C).

Figure 3 Liposuction Surgical Markings in a Woman

Surgical markings begin with anatomic landmarks delineated with a **Green** Sharpie to include the abdomen the inferior aspect of the rib cage, the midline vertical linea alba and both linea semilunaris. **Black/Brown** is used for surgical incision locations (ex. superior umbilicus, inferior to linea semilunaris in mons pubis, lateral infragluteal fold, superior intergluteal crease, and if needed-inframammary crease). **Purple** identifies the PMI (Waist Point Maximum Indentation) and the extent or border of liposuction in each area (low abdomen, superior buttock area). **Blue** marks topographically the areas of excess fat for removal. **Red** notes topographically the fat grafting sites, often dividing the recipient area into quadrants (ie. breast, buttock).

Standard surgical marking pens too often are washed away during the procedure and were avoided. The waists point of maximum indentation (PMI) along the mid-axillary line of the flanks was noted When high-definition sculpting was to be performed in women, only the vertical borders of rectus muscle and external oblique (linea semilunaris) and linea alba above the umbilicus between the rectus abdominus muscle bellies are etched[24].

The female buttock optimal aesthetic appearance resembles an upside-down *heart* shape. Fat removal of the lower back and posterior flank frames the buttock shape being paramount in the planning, marking, and execution. There should be a *diamond shape of air* (zone 7) formed from the 45° angle of the inferomedial line of the buttock intersecting with the approximately 45° angle formed from the superior aspect of the inner thighs (Figure 2)[23]. Fat removal is often recommended in these two areas to optimize the buttock appearance, since there is often excess fat there (Video- Inferomedial Buttock VASER Liposuction). The patient looking in the two mirrors at different angles confirm all the marks and surgical plan. Another set of photographs are taken after marking is complete to document the surgical plan.

ANESTHESIA

Awake, oral sedation, superwet wetting solution anesthesia augmented by as needed titratable parenteral sedating or analgesia medications is the safest method of anesthesia delivery. After the marking was complete, the patient was given four preoperative medications. Oral antibiotic prophylaxis was given using a first-generation cephalosporin (clindamycin, if penicillin allergy) within one hour of surgical incision. Ondansetron 8 mg (Zofran®), lorazepam 1-2 mg (Ativan®) or alprazolam 1-2 mg (Xanax®), and hydrocodone 5-

10 mg with acetaminophen 325 mg or oxycodone 5-10 mg with acetaminophen 325 mg was taken orally by the patient.

She was escorted to the operating room wearing a robe and placed supine on the table covered by a sheet. A parenteral line is placed and blood taken with two special tubes for platelet rich plasma (PRP) centrifugation processing. A pulse oximeter was placed on the finger of the hand on the same side as the intravenous line. The cord was taped along the arm and immobilized near the shoulder not attached to the monitor. A blood pressure cuff was placed on the opposite arm with the cord directed to the shoulder. Electrocardiogram adhesive pads were placed on the chest. Patients are continually monitored of all vital signs with lactated ringers' (LR) solution at a keep-vein open (KVO) rate. Excess parenteral fluid administration is avoided, since patients are receiving tumescent fluid subcutaneously, where about 50-70% of volume is ultimately absorbed intravascularly. Medications are administered parenterally as needed to include midazolam (Versed®), diphenhydramine (Benedryl®), and/or fentanyl in 25 mcg aliquots.

WETTING SOLUTION PREPARATION

A LR 1000 ml or 3000 ml bag is warmed in the microwave. The amount of wetting solution estimated for each anatomic area is totaled (ml). The lidocaine maximum dose is calculated by multiplying the patient's weight (kg) by 50 mg/kg. The concentration per liter bag of lidocaine is then calculated with a minimum concentration of 800 mg/liter. If cytochrome P-450 inhibitors were being taken preoperatively, the maximum lidocaine does is lowered by 10 mg/kg to a maximum of 40 mg/kg. Bicarbonate 8.4% 10 cc is added to each liter and epinephrine 1:1,000 1.5 mg/liter (increased from 1.0 mg/l of Klein's solution) completes the wetting solution preparation.

SKIN PREPARATION

Once the parenteral line was placed, which was about 15 to 20 minutes after taking oral preoperative medications, Decadron 8-10 mg was administered parenterally before the skin preparation.

The patient stands adjacent to the operating table for skin preparation. A baby bottle warmer was used to warm chlorhexidine. All anatomical areas noted for liposuction and fat grafting are prepared, especially the anal area. Once completed, sterile orthopedic stockings are rolled over the hand and up the upper extremity. A sterile back table cover was placed on the operating room table. The sterile sleeves and sterile table cover make it easy for the patient to change body positions without contamination during the body contouring procedure.

VASER ULTRASOUND LIPOSUCTION & FAT HARVESTING

Body Positioning & Surgery Onset

The patient is initially situated in the supine position for abdominal, anterior flank, and possible mons pubis and inner thigh liposuction draped with sterile towels and drapes. Once supine liposuction was completed, the patient was rotated to the prone position for liposuction completion and gluteal and/or hip fat grafting. Sterile towels and half drape are again placed. A laparotomy pad soaked in chlorhexidine was placed in the intergluteal fold. Once in a pleasant anesthetic state, local anesthesia (1% lidocaine, 9 cc combined with bicarbonate 1cc) was injected with a 30 G needle to each incision. An 11 blade makes the incision with gentle skin pressure to avoid deep penetration. A short and long blunt infiltration cannula delivered the wetting solution in a superwet technique (Video- Superwet Technique for Wetting Solution Delivery).

VASER Ultrasound Energy Delivery

When fat grafting was planned, VASER ultrasound energy was delivered at 60% energy on pulsed mode with a 5-ring probe for the least amount of time to minimize adipocyte cellular injury. A technique called "compression coupling", invented by Dr John Millard, uses the surgeons nondominant hand to compress the tip of the ultrasound probe to sculpt the fat (Video- VASER Ultrasound Energy Delivery). More pressure results in more fat separation and one can remove most of the fat in an area (ie. linea alba and semilunaris) or feather with sequentially decreasing pressure such as along the gluteal transition areas around the buttock.

VASER energy delivery starts with abdominal etching, followed by treating the superficial layers, and culminating with the deep fat layer (below Scarpa's fascia) down to the rectus an external oblique muscle fascia. Since patients are awake yet sedated, if the muscle fascia is touched with the ultrasound probe, they respond with a painful verbal or "withdrawal" response. This response

minimizing the risk of intra-abdominal ultrasound probe or liposuction cannula penetration.

Liposuction & Fat Harvesting

Liposuction follows ultrasound delivery, starting with abdominal etching of the linea alba and semilunaris, followed by deep liposuction, then more superficial layers, and finalized with additional muscular etching (Video- Liposuction Fat Harvesting). Liposuction cannula sizes are 3.0, 3.7, and 4.6 with the smaller cannulas used closer to the skin surface. These liposuction cannulas are vented (small hole near the cannulas hand grip), known as VentX cannulas (Bausch Health, Laval, Canada), which lowers adipocyte cellular trauma during harvesting. The suction pressure is at ½ atmosphere to also minimize cellular trauma. Fat is harvested into a sterile fat collection container. Since patient was awake and cooperative, they can assist in changing body position to optimize body sculpting. The lower back, lumbar, and flank are the most important fat removal areas to frame the buttock and create maximum lordosis curvature (Video- Intraoperative Confirmed Lordosis Sculpting).

RENUVION- HELIUM-BASED PLASMA RADIOFREQUENCY TECHNOLOGY

If the addition of helium-based radiofrequency technology (HBT) was chosen by the patients with skin laxity for improved skin tightening, the procedure is performed after liposuction is complete. The HBT (Apyx Medical, Corp., Clearwater, FL) settings were 80% energy, 1.5 liter/minute helium flow, probe movement no greater than 3 cm/second, separating each plane of treatment by 1.5 cm using three probe movements both antegrade and retrograde in a fanning manner (6 passes) (Video- Renuvion Skin Tightening). This protocol achieved comprehensive plasma energy delivery to the entire surface area and depth of the anatomical treatment area.

VASERSMOOTH® CELLULITE SUBCISION

If patients have cellulite affecting the buttock, they are recommended to undergo ultrasound-assisted subcision. After infiltration of 75-125 cc of wetting solution to each buttock, a standard VASER probe treated the subcutaneous space around the cellulite area first at 60% energy on pulsed mode with a minimal amount of time, usually 30-60 seconds. Thereafter, a "V" shaped tip to the VASERSmooth handpiece ((Bausch Health, Laval, Canada) with continuous mode at 80% energy is placed subcutaneously. The "V" engages the fiber producing an indentation and the energy is pulsed, taking only 1-2 seconds to cut the fascia to skin fibers (Video- VASERSmooth Cellulite Subcision Technique). Caution is needed to minimize cutting these fibers if close together, because most have arterioles and venioles among them. One wants to avoid any vascular compromise to the overlying skin. After subcision was performed, any areas of indentations marked preoperatively were filled with fat.

FAT PROCESSING WITH STEM CELL & PRP FAT GRAFT ENRICHMENT

Once 500 cc of harvested fat is present in the closed fat collection container, the fat was transferred using Toomey large mouthed 60 cc syringes into luer lock 60 cc syringes (Video- Harvested Fat Transfer to Syringes). This allows the liposuction to continue without delay, while the fat is being processed by a medical assistant well trained in the fat purification and enrichment process.

The fat was then transferred into the TP-101 centrifugation syringes. A LipoKit or 416-centrifuge along with the manufacturers patented 100 μ filter, weighted TP-101 60 cc syringes (MediKan, Co. Ltd, Seoul, Korea) compact and purify the fat (Video- MediKhan Fat Processing by Centrifugation-Filtration). Centrifugation in this study ranged from 3000 to 4000 rpm for 3-5 minutes with the best settings for fat purification at 3000 rpms for 3 minutes. Fifty cc of harvested fat becomes 20-35 cc, average 30 cc of purified fat, or 60% of the harvested volume. It also concentrates adipose derived stem cells (ADSC) and stromal vascular fraction (SVF) support cells in the dependent 1 cc of fluid. The PRP (1 ml) and these ADSC/SVF admixtures (1 ml) are combined to every 25 ml of processed fat for enrichment.

FAT ADMINISTRATION

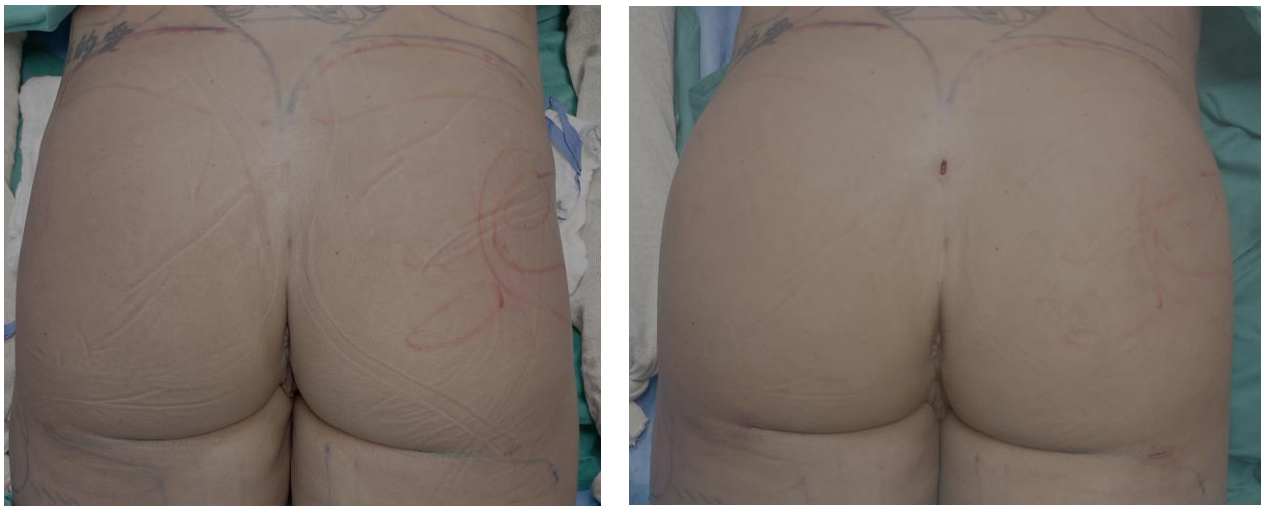
Immediately after completing the abdomen and anterior flank liposuction, the patient was rotated onto the prone position. The patient was already prepped, but additional chlorhexidine was applied to the skin, sterile towels along the surgical field periphery and a sterile half-drape placed. The superior intergluteal and lateral infragluteal incisions are injected with local anesthesia, incised, and undermined with tenotomy scissors. Wetting solution at 200 ml/minute was administered in the

subcutaneous plane (75 to 125 cc/ each buttock). The already processed, purified, compacted, and enriched fat is injected without delay.

The processed fat was transferred from 60 cc luer-lock syringes to 20 cc syringes. Fat injection employed 3.0 or 4.0 mm single hole fat administration cannulas (Video- Gluteal Fat Administration). Each 20-cc syringe total content was placed during the injection process into each buttock, making addition of volume delivery more accurate to count. Minimal torque force was used during fat injection, since the plane of placement was subcutaneous with lower fat volumes placed than most gluteal surgeons. Preferably using the superior intergluteal incision, fat was injected only in the subcutaneous plane. Since the patient was awake, if the gluteal maximus or medius muscle fascia was touched, the patient elicits am immediate noxious response. Surgeon proprioception allows for fat multi-layered, micro-aliquot placement with the cannula angled as flat as possible. Lateral gluteal fat placement and hip dip fat grafting utilizes the bilateral lateral infragluteal fold incisions. Only 2-5 ml of fat is injected with each retrograde hand movement using minimal injection force. Rarely was fat administered with an antegrade manner. Excess fat delivery was avoided to ensure best chance of neovascularization of fat grafts.

End point of gluteal and hip fat grafting was determined by three factors: (1) the grafted fat in the subcutaneous space was at its limit (ie. fat egressing out incisions), (2) all areas of depression or indentations had been treated (ie. fat augmentation or VASERSmooth cellulite fiber subcision), and (3) gluteal shape was optimized and symmetric (Figure 4 A, B). All patients receive the maximum volume possible based on the volume harvested or their limitation of the volume the gluteal subcutaneous space can accepted (ie. no egress of fat).

Figure 4 Intraoperative Before & After Gluteal Sculpting



28-year-old woman (5'3, 68.6 kg, BMI 25.9) who underwent VASER ultrasound high-definition liposuction with simultaneous breast, gluteal and hip centrifuge-filtered, stem cell and platelet rich plasma enriched fat grafting. Liposuction included abdomen, flanks, lower back, inferomedial buttock, inner thigh, superior posterior thigh, outer thigh and upper back. Supernatant fat totaled 2200 cc. Fat grafting breast totaled 475 cc purified fat (left 255 cc, right 220 cc), buttock totaled 465 cc purified fat (left 245 cc, right 220 cc), hip dip totaled 85 cc (left 45 cc, right 40 cc) for a subcutaneous total gluteal volume of compacted fat grafted at 550 cc. This corresponded to 917 cc of unprocessed, harvested fat. A- Intraoperative Before B- Intraoperative After

FAT STORAGE

A second staged fat grafting to the buttocks may be desired by the patient. If one desires a larger gluteal size than an estimated single fat grafting session can achieve and the patient has no interest in either gluteal or custom hip silastic implants, than an informed consent on further gluteal fat augmentation is required. One can limit the areas of liposuction to go back in the future to harvest the fat from the untreated areas and perform a second GFG procedure. Alternatively, the fat harvested from the primary liposuction procedure can be stored. The surgeon needs to plan for this and acquire the storage and transport supplies. The author in the past has used American Cryostem, Inc., which is no longer available. Currently, an excellent company for both fat storage and stem cell expansion is American Cell

Technologies (ACT, Sunrise, FL). ACT is one of the few GTP stem cell banks in the US. They require sterility testing, cell testing and counting, and their methodology maintains the highest standards.

PATIENT FOLLOW-UP

Patients were instructed to follow-up at postoperative day one, one and two weeks, 1, 2, 3, and 6 months, and every year thereafter. There estimate of final gluteal volume was first assessed at 3 months. Photographs, patient physical examination, weight measurement, and directly querying were used to assess final volume.

PATIENT AESTHETIC OUTCOME & COMPLICATION ASSESSMENT

The Global Aesthetic Improvement Scale Assessment (GAIS) was acquired from patients after the first 2 to 3 months after surgery. This five-point scale (0 to 5) is from worse, no change, improved, much improved, and very much improved. Additionally, patients were inquired if they were satisfied with both their body contouring and gluteal reshaping/augmentation outcome. Patient's verbal responses upon each visit and physical examination by the surgeon was performed to identify and treat any complications.

POSTOPERATIVE CARE

Pain Control

Most patients were prescribed gabapentin 300 mg three times daily and a COX-2 inhibitor (Celecoxib or Celebrex®, Pfizer, Inc, New York, NY) 200 mg twice daily for the first ten days after surgery to minimize necessity for narcotics. For breakthrough pain, acetaminophen 325 mg, hydrocodone 5 mg with acetaminophen, or oxycodone (5 or 10 mg) with acetaminophen was prescribed.

Dressings & Garment Use

All patients wore an appropriate size and fitted (at preoperative visit) compression garment (Contemporary Design, Inc., Palmer, PA) worn continuously for one month after surgery followed by one week only at night. The buttocks were not included in the compression. Superabsorbent pads are placed over the liposuction unclosed incision sites immediately after surgery and patients are told to replace until drainage ceases (1-3 days). Foam pads (Contemporary Design, Inc., Palmer, PA) were placed over the compression garment on the abdomen extending onto the flanks immobilized with an elastic abdominal binder was used for a minimum of two weeks but preferred for one month.

Home Body Position

Patients may sit on a chair, but not against the back of the chair to prevent fat gluteal compression for a minimum of two weeks but preferred 4-5 weeks. Recommendation to sleep on one's stomach or sides for the same duration.

Lymphatic Massage

Patients are recommended to perform massage using bimanual finger-tip technique for two minutes four times a day on the anatomic sites of liposuction to allow egress of fluid and improvement of lymphedema for two months postoperatively. Additionally, a medical assistant or trained specialist performed lymphatic massage starting after the fifth day after surgery. Some patients also elected to use external ultrasound device (VASERShape, General Projects, Inc., Florence, Italy) to facilitate lymphedema resolution.

Other Postoperative Concerns

No solid food for the first six hours after surgery until any nausea is resolved, then no restriction. First-generation cephalosporin antibiotic 500 mg four times a day for one week after surgery. Changed soiled absorbent pads as needed over liposuction incisions. Kept band aids over small incisions that were used for fat grafting administration (ie. superior intergluteal fold, and bilateral lateral infragluteal crease) for a minimum of 10-14 days. Patients are instructed to clean the toilet seat with antibacterial wipes prior to sitting down for at least two weeks after surgery to minimize bacterial contamination risk. No exercise for 3-5 weeks to decrease risk of seroma formation from the liposuction. Except for showering, no water exposure of incisions (ie, tub, pool, or body of water) until incisions are completely healed at 4-5 weeks after surgery.

Continuing weight reduction strategies postoperatively with a healthy, low fat, lower calorie diet, at least five days a week muscle strengthening and aerobic exercise for a minimum of 30 minutes and optimizing bioidentical hormone supplementation identified prior to surgery.

Consideration for Revision Surgery

Those requesting revision additional gluteal enhancement were presented the following

options: (1) no treatment, (2) repeat gluteal and/or hip fat grafting from fat harvesting of body areas not previously treated by liposuction, (3) acquiring stored fat form primary liposuction from fat and stem cell storage bank (American Cell Technologies) for reinjection, (4) silicone gluteal or custom (patient-specific) hip implant, or (5) composite implant and simultaneous or staged fat grafting. Revision fat grafting was not performed until after three months from the primary GFG procedure.

Those requesting revision liposuction were presented the following options: (1) no treatment, (2) noninvasive body contouring using either therapeutic ultrasound (VASERShape, General Projects, Florence Italy) or external radiofrequency (Venus Legacy, Venus Concept, Toronto, Canada), (3) revision VASER liposuction with or without HBT for additional skin tightening, and (4) open skin excision procedures (abdominoplasty, brachioplasty, thighplasty). In rare patients who only complain of creepy skin, skin resurfacing and tightening may be improve by 1-3 skin microneedling radiofrequency treatments (Venus VivaMD, Venus Concept, Toronto, Canada). Revision body contouring by liposuction was not performed for at least 6 months after the primary procedure and patients had to be at or below their day of surgery body weight.

Results

Women (age ranged from 22 to 60 years of age, mean 36, BMI range 22-31, mean 28) electing gluteal and/or hip fat grafting placed only in the subcutaneous plane under awake, conscious sedation anesthesia with superwet wetting solution technique (n=112) were analyzed. All patients (n=106) who elected buttock fat grafting had simultaneous hip dip fat grafting. Twelve patients (10.7%) elected simultaneous breast and gluteal fat grafting. Six patients (5.4%) elected only hip dip fat transfer.

Fat grafting indications were for improved gluteal contour (85%, n=95) or size augmentation (15%, n=17) yet refused gluteal or hip silastic implant placement. All patients had 360-degree VASER liposuction (abdomen, flanks, lower back).

The most common areas additional anatomic areas for liposuction were inner (52.7%) and/or outer thigh (46.4%), middle back (11.6%), axilla/upper back (8.9%), and inferomedial buttock (5.4%). Simultaneous HBT was performed in 34.8% (n=39) of patients and VASERSmooth ultrasound subcision in 6.25% (n=7).

Operative time for 360° liposuction with GFG averaged 1 hour 45 minutes to 2 hours. The time to complete each anatomic area combined the following: superwet fluid infiltration < 5 minutes, VASER energy delivery 4-8 minutes, liposuction/fat harvesting < 10 to 15 minutes with the variable being BMI, totally 25-30 minutes per anatomic area with GFG taking 10-20 minutes. The abdomen area time of procedure added another 5 to 10 minutes for high-definition etching.

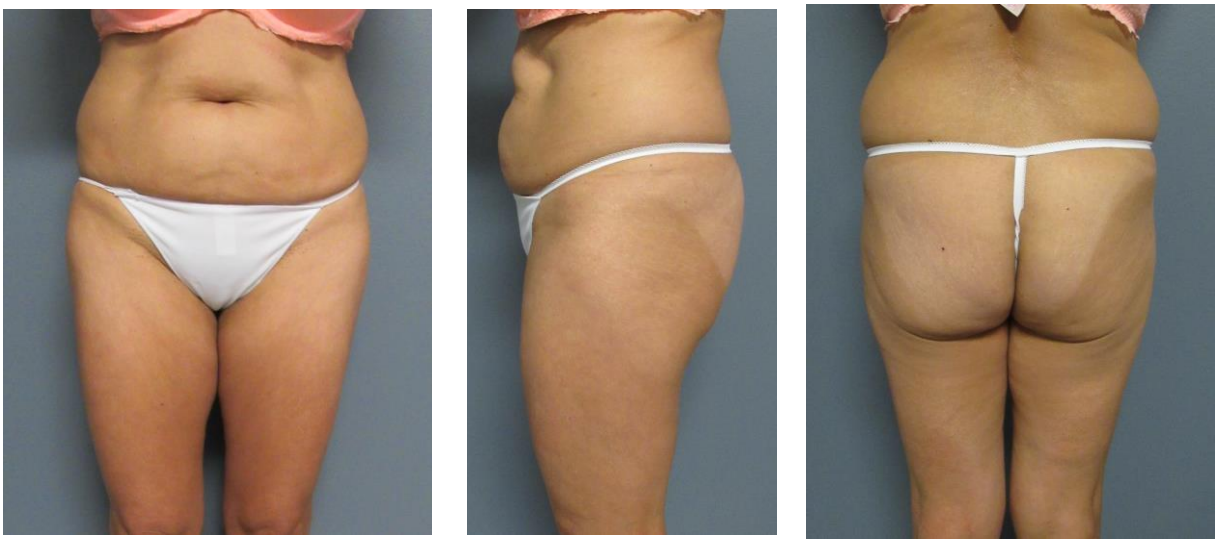
If VASERSmooth was added for cellulite treatment to the buttocks an extra 5 to 8 minutes was added. If HBT was performed for additional skin tightening, about 4 to 7 minutes for each anatomic area, and for typical 360° liposuction areas averaged 12 to 15 minutes. Fat centrifugation-filtration and preparation of syringes was carried out by trained operating room assistants simultaneously during the surgeon performed liposuction fat harvesting steps.

All fat grafts were prepared by centrifugation-filtration fat processing combining PRP and ADSC enrichment. Since 50 ml of harvested fat became an average volume of 30 cc (range 20 to 35 cc) of compacted, processed, and enriched fat, the average volume of purified fat grafted per buttock side was 240 cc (equals 400 cc unprocessed, harvested fat) and per each hip dip area was 45 cc (equals 75 cc unprocessed, harvested fat). *Overall total buttock fat grafting combined both buttocks and each hip dip averaged 570 cc compacted, enriched fat, which corresponded to 950 cc of unprocessed, harvested fat.*

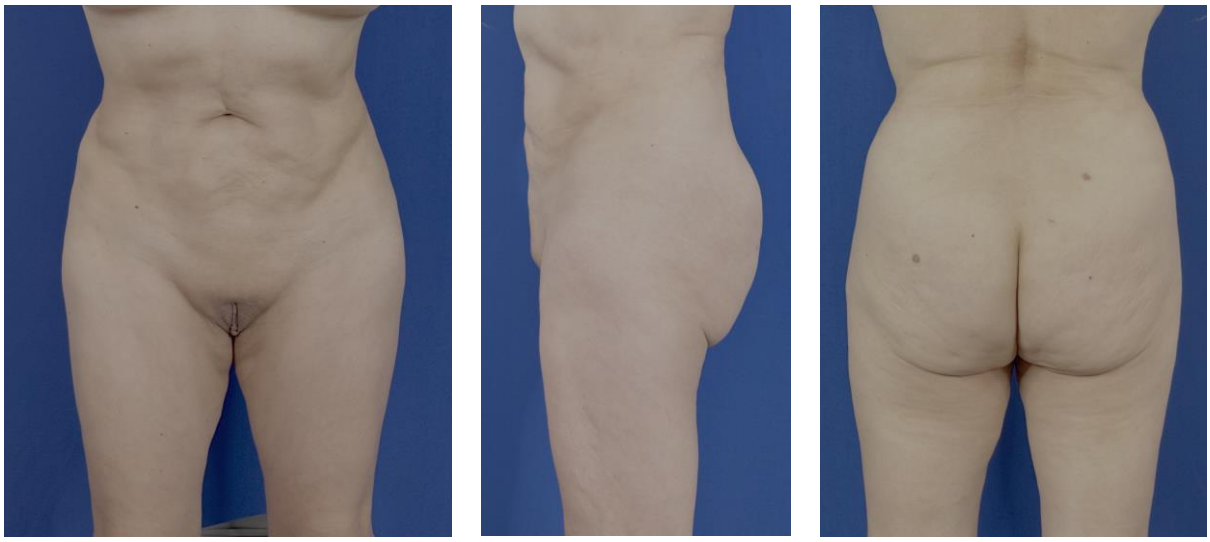
Using the GAIS revealed very much improved, very improved, and improved (97.6%) with 3.4% stating no change or worse (one patient). Patient subjective satisfaction with the overall procedure showed 92% (n=103) satisfied. Those dissatisfied were mainly from insufficient fat volume (n=7) or dissatisfied from the body contouring outcome (n=2). Mean follow-up was about one year; however, some patients have been followed for over ten years (Figure 5).

Figure 5 Long-Term Gluteal Sculpting Aesthetic Outcome

Before:



After at 8 years



55-year-old Asian woman (5'1, 53.6 kg Before, 54.5 kg After) who underwent VASER liposuction to abdomen, flanks, lower back, middle back (bra roll), inferomedial buttock, and inner thigh. Supernatant fat totaled 1200 cc. Gluteal subcutaneous fat grafting totaled 540 cc purified fat (left 240 cc, right 300 cc), buttock totaled 440 cc purified fat (left 200 cc, right 260 cc), hip dip totaled 100 cc (left 40 cc, right 60 cc). This corresponds to 917 cc of unprocessed, harvested fat. Before A. B. C. After 8 years postoperatively. D. E. F.

There was a 14.6% (n=13) complication rate with seven (7.8%) experiencing minor contour irregularities and five (5.6%) seromas treated by needle aspiration. No patient experienced a serious adverse effect or gluteal oil cyst. No anesthesia related complications occurred including airway obstruction, lidocaine toxicity, pneumonia, allergic reactions, PFE, or death.

No bacterial infections were diagnosed, however, there was one suspected atypical mycobacteria infection with no growth in culture. Erythema and mild discomfort without fistula formation developed 6 weeks postoperatively to left buttock, which resolved after 6 weeks of sulfamethoxazole-trimethoprim antibiotic therapy with complete resolution of the inflammation and suspected infection. No complications occurred due to HBT skin tightening treatments or VASERSmooth cellulite subcision including skin burns or vascular compromise.

The revision rate (second GFG procedure being performed) was 4.5% (4/112) for additional gluteal and/or hip fat grafting. One patient who requested a larger buttock appearance elected silastic implant placement.

Discussion

Gluteal and hip fat grafting during VASER high-definition liposuction is a valuable aesthetic tool harnessing autologous tissue to optimize the

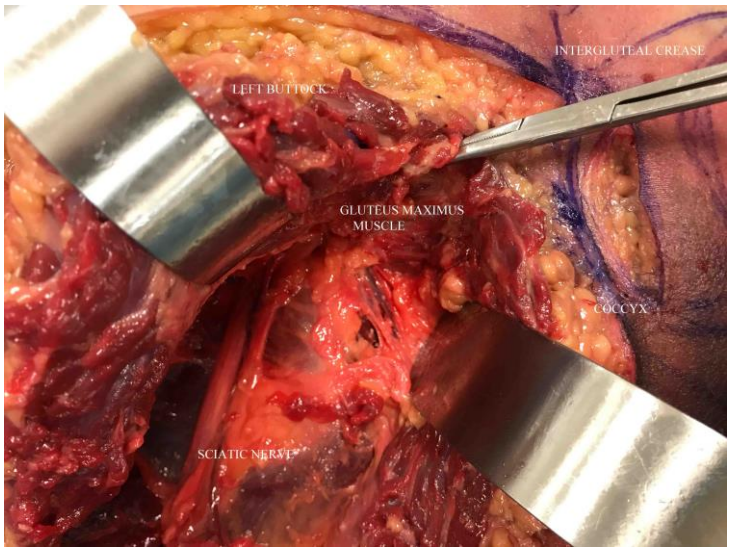
bodies shape in body contouring. Optimal body contouring or sculpting employs VASER third-generation ultrasound technology and high-definition sculpting techniques.[10,25,26] This study affirms the safety of awake, mainly oral supplemented sedation and analgesia using superwet wetting solution delivery resulted in no anesthesia related complications[10,11,12].

Although fat harvesting or removal is paramount in body contouring, the resultant skin tightening is more difficult to estimate and achieve. The literature has shown by Duncan that liposuction alone creates 8-10% skin retraction[27], VASER ultrasound energy an estimated 20% skin tightening[28], and when combined with Renuvion helium-based radiofrequency plasma technology (HBT) an estimated additional 20 to 30% more skin retraction[29,30,31]. This study employed both VASER and Renuvion to achieve superior liposuction sculpting and skin tightening results. VASER creates tightening by myofibroblast stimulation and the healing response in contrast to heat alone[28]. HBT uses heat-based collagen fiber contraction at 85° C for only 0.44 to 0.08 seconds to shrink collagen fibers by 65%[32,33,34]. Troell and Javaheri concluded that VASER combined with HBT can be performed safely, and can achieve superior subjective skin contraction to both face, neck, and body anatomic areas[35,36].

In concert with liposuction, fat grafting to a body area that may benefit from augmentation heightens aesthetic results. The most impactful change in gluteal fat grafting technique to significantly lower complications was reducing pulmonary fat embolism incidence by avoiding gluteal maximus and medius *intramuscular* fat injection. *The most important factor to prevent penetrating the gluteus muscle fascia resulting in intramuscular fat injection is an awake patient.* The awake and mild sedated patient will respond immediately (a fraction of one second) with a noxious response if the cannula (ie. infiltration, ultrasound probe, liposuction cannula or fat administration cannula) touches the muscles fascial surface. This was confirmed by Chia et al in 2018 of thirty-two women with an average of 359 cc of fat grafted per buttock under local anesthesia concluding that with patient's immediate feedback the surgeon would be acutely aware of any misguided cannula[37].

Understanding the gluteal "danger zones" vascular anatomy is essential, since venous wall injury results in PFE. The author is an instructor for Implantech Associates, Inc hands-on body implant cadaver course. Cadaver dissection during gluteal silastic implant placement identifies the superior and inferior gluteal veins located 4.5 to 5 cm from the sacral midline and 6 cm deep from the surface skin (Figure 6).

Figure 6 Cadaver Buttock Dissection



The thickness of the subcutaneous space (gluteal fat grafting plane) and the gluteus maximus muscle can be observed. The gluteal vasculature is situated 4.5 to 5 cm from midline at the lateral aspect of the sacrum and at a depth of 6 cm with the superior gluteal vessels superior to the piriformis muscle and inferior gluteal vessels inferior to this muscle (adjacent to medial Dever retractor at depth). The Sciatic nerve travels deep to the piriformis muscle, deep to the palpable sacrotuberous ligament. (Courtesy of Barry Eppley, MD, DMD, dissection during the Implantech Associates, Inc, Master's Class on Body Implants)

Pozza et al performed twenty dissections in ten vasculature latex-injected fresh cadavers[38]. Magnetic resonance angiograms (MRA) compared ex vivo findings. There was an average number of 25 vessels/cadaver (range of 16 to 32) in the subcutaneous plane, which were mainly vein comitantes of the perforating superior and inferior gluteal vessels. In the subcutaneous plane, the average caliber of the venules (1.05 ± 0.3 mm) enlarged traveling intramuscularly (1.3 + 0.3 mm)[38]. The main inferior gluteal veins (13.65 ± 6.55 mm) were significantly larger in diameter than the superior gluteal veins (7.61 ± 2.24 mm). Tributaries of these veins traveling on the deep surface of the gluteus maximus had reduced diameters (3.85 ± 1.9 mm). Although the subcutaneous plane has frequent smaller caliber veins, the vein caliber (7 to 13 times larger in diameter) at the medial aspect of the gluteus maximus muscle at depth drastically increases the risk of venous wall injury culminating in PFE[38].

Troell's liposuction technique adds a higher epinephrine dose (1.5 mg/l) in the wetting solution preparation instead of the standard Klien solution (1.0 mg/l). This increased epinephrine dose has been shown to minimize bruising without increasing intraoperative heart rate[10]. Theoretically, the higher epinephrine dose also minimizes the size of the venules through vasoconstriction, since subcutaneous gluteal fat administration typically occurs within one hour after tumescent fluid administration. Further, awake anesthesia increases sympathetic autonomic tone causing further lowering of blood vessel caliber, which also reduces risk of PFE[10].

Magnetic Resonance Imaging (MRI), the gold standard for evaluating muscle volume and three-dimensional shape, measured gluteus maximus muscle thickness in 104 sides of female buttock[39]. There were three anatomic points identified to measure thickness: A- lowest point of sacroiliac joint (SIJ), B- above femoral head (FH), and C- at ischial tuberosity (IT). Gluteus maximus thickness at point A (SIJ) was 16.0 ±4.2 mm, point B (FH) was 23.4 ±4.4 mm, point C (IT) was 24.7 ±7.6 mm. The lower half of the gluteus maximus muscle was thicker than the upper part. The average soft tissue thickness from the muscle to the skin (ie. subcutaneous space) at the muscle correlated points were point A 28.1 ±6.3, B 41.6 ±6.7 mm, and point C 49.2 ±8.9 mm. The subcutaneous plane was thicker than the gluteus maximus muscle thickness at all anatomical points by 57%, 55%, and 51%, respectively. The thickness of both sides was similar[39]. The subcutaneous space has a larger capacity for fat grafting volume than the gluteal muscle thickness with a dramatically reduced risk of causing PFE.

Most surgeons in meeting presentations and peer-reviewed papers placed large amounts of unprocessed and unenriched fat using pumps that result in higher adipocyte death[13,38]. More volume of grafted fat is less likely to receive neovascularization in the required time of 1-2 days before adipocyte death. Potentially staging fat grafting with two sessions will yield a higher adipocyte survival rate than the same volume administered in one session.

Overall average volume of fat injection to the buttocks per patient totaled 570 cc of centrifuge compacted, filter purified, and enriched fat, which corresponded to 950 cc of unprocessed or unpurified harvested fat. In comparison, Del Vecchio and Wall documented their average fat transplanted was 1003 cc with a range of 275 to 4400 cc in concert with the SAFELipo technique (Separation, Aspiration and Fat Equalization)[40,41]. Their method uses "expansion vibration lipofilling", a syringe-free technique where there is simultaneous disruption of liposuction area connective tissue, "exploded-tip" or enlarged tip cannula (two times the diameter of a standard 4-mm cannula) provides internal expansion of area, and backfilling fat with the roller-pump[40]. However, the fat grafts injected were unprocessed, unpurified, and not enriched with PRP or ADSC's.

The operative time for awake, superwet, VASER ultrasound-assisted liposuction with syringe, subcutaneous gluteal fat grafting was comparable to that of Del Vecchio and Wall (average 1 hour and 40 minutes) between 90 to 120 minutes[40]. However, the an advantage of the presented technique was the safest method of liposuction anesthesia (awake, tumescent compared to general anesthesia). Grazer (2000)[42] and another survey from the American Society of Plastic Surgery (1997)[43] documented a mortality rate from liposuction alone under general anesthesia from plastic surgeons between 1:5000 to 1:5225 compared to no deaths using awake, tumescent

anesthesia by dermatologists (2002)[44] with a theoretical risk of 1:500,000[45].

The awake state of anesthesia drastically lowers the risk of fascial penetration with resultant intramuscular fat injection. Additionally, the purification and enrichment process provided the best quality of fat graft. This allows the injection of smaller volumes yet corresponding to larger volumes of unprocessed fat lacking PRP and ADSC enrichment, which heightens fat neovascularization and ultimately adipocyte survival[46].

This study incorporated evidence-based medicine regarding fat harvesting, processing, enrichment, and administration to achieve best outcomes. Preparation of the gluteal fat grafts to optimize adipocyte survival is with ½ atmosphere suction pressure[10], centrifugation (3000 rpms for 3 minutes)-filtration (using100 µ filter)[46,47], enrichment with PRP and ADSCs[48,49,50], administration within two hours of harvesting[51], multilayering[52] in the subcutaneous plane only with fat micro-aliquots[53]. Centrifugation-filtration results in fat compaction containing less damaged adipocytes, red blood cells, oil, and wetting solution fluid[46,47]. PRP and ADSCs addition to fat grafts promotes neovascularization. Centrifugation protects the fragile adipocytes by removing protease and lipase enzymes, lipids and cellular toxins[47].

The fat purification method introduced in this study has been previously shown to have better predictability with 75-85% augmented final volumes of grafted fat[46,54]. Coleman concluded that there is minimal fat absorption after two to three months post-fat transfer with stable volume up to 12 years later[55,56]. Ultrasound energy delivery assists in separating adipocytes from the tissue matrix, this results in minimal cell membrane lysis and has no effect or minimal effect on graft viability at low energy delivery[57].

Three studies have shown that during fat harvesting using VASER ultrasound that there were preservation of adipocytes (87-92%) and ADSC (87-97%) cellular viability when decreasing the ultrasound energy to 60% for a limited duration[46,57,58]. Adipocyte survival revealed similar viability upon GMP laboratory cellular analysis with ultrasound-assisted mean fat viability of 91.5% with 7.9×10^5 cells/ml compared to 92.1% with 5.7×10^5 [46]. Fat graft volume thickness objectively measured employing a Terason 10-MgHz diagnostic ultrasound device (Teratech Corp, Burlington, MA) revealed 75-85% volume retention at 7 months post-injection[46].

Purified fat through centrifugation-filtration provides 60% of the volume of unprocessed fat, but with compacted at without excess saline, oil, and blood. Thus, much less is required for the same volume outcome and less fat grafted by this fact alone increases fat survival. The added growth factors from PRP and endogenous fat along with the ADSC and SVF support cells has been shown to be the best promoter of neovascularization. Volume of fat placement should not result in fat egressing out of the incision, which illustrates excess pressure on cells.

There were no bacterial infections noted, except one suspected Atypical Mycobacteria infection with onset over 6 weeks postoperatively. The most important factor to minimize infection risk was smoking or vaping cessation a minimum of 2-3 weeks prior and continuing 2-4 weeks postoperatively. Other factors included proper instrument cleaning and sterilization, chlorhexidine skin preparation instead of povidone-iodine (Betadine), diligent intraoperative sterile technique, allowing egress of fluid from liposuction areas by not closing incisions, antibacterial wipes of toilet seat prior to use until lateral infragluteal crease incisions are well healed, band aid application on fat grafting incision ports, perioperative antibiotics for 5-7 days, and avoid over-filling gluteal and hip fat grafted areas.

Patients who desire a larger size buttock or more augmentation of a hip dip have the option of soft, solid, silastic gluteal implants or custom hip implants[59,60]. Additionally, combined gluteal and or hip implants with additional fat grafting may be chosen by a patient. Optimal skin tightening can be achieved by the addition of Renuvion HBT after the liposuction step of the procedure, especially in weight loss and/or older patients with skin laxity. VASERSmooth ultrasound subcision of cellulite fibers followed by fat grafting into cellulite indentations resulted in optimal enhancement to a smoother buttock contour to yield superior overall aesthetic outcomes.

LIMITATIONS

The limitation of the retrospective clinical study was that it was not prospective, randomized or

blinded. The studies advantage was consecutive patients were analyzed. Higher numbers could provide more statistical power. Patient subjective satisfaction was the main outcome measure, although complications were objective observations.

Conclusion

Gluteal fat grafting during VASER high-definition liposuction body contouring implementing evidence-based medical literature has defined optimal surgical techniques and technologies to provide superior aesthetic outcomes, while maximizing safety to minimize complications.

The GFG methodology centers on heightened long-term fat volume by minimizing adipocyte trauma during harvesting, purification using centrifugation-filtration at 3000 rpms for 3 minutes with a 100 μ filter to both compact fat and remove toxins or contaminants, enrichment of fat grafts with both platelet rich plasma, stem cells, stromal vascular fraction support cells, and growth factors, culminating with multi-layering with fat micro-aliquots, while avoiding intramuscular fat placement by implementing awake anesthesia, higher epinephrine dosing in superwet wetting solution, and sole subcutaneous plane administration.

Incorporating a weight loss regime of superior low carbohydrate, low fat diet, nutritional supplements, daily exercise, bioidentical hormone replacement, and if required, glucagon-like protein-1 agonists both before and after body contouring can maintain excellent surgical outcomes. Other technologies maximize the body contouring aesthetic outcomes: helium-based plasma technology (Renuvion) to achieve additional skin tightening, especially in patients with more significant weight loss or increased age, and VASERSmooth to cut cellulite vertical fibers, achieving a smoother skin contour.

Conflict of Interest Statement:

The author has no conflicts of interest. The author does use in surgery and has taught accredited continuing medical education (CME) courses using VASER ultrasound liposuction equipment and instrumentation (VASER (Bausch Health Companies, Inc., Laval, QC, Canada), Renuvion helium-based plasma technology (Apyx Medical, Clearwater, Florida, USA), and a premier Centrifugation-Filtration system (MediKan Co. Ltd, Seoul, Republic of South Korea).

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The author received no financial support in the authorship of the manuscript. The author teachers for three medical schools, including as a Visiting Professor for the Plastic Surgery department of one. Only one institution gives financial restitution for fourth year medical students taught in monthly rotations. The author also teaches face and body implants in a cadaver and didactic Masters Education Class for Implantech Associates, Inc. since 2015, although does not receive financial compensation.

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Authors' contributions

Single author: The author contributed solely to the article.

Videos

1. Superwet Technique for Wetting Solution Delivery
2. VASER Ultrasound Energy Delivery
3. Liposuction Fat Harvesting
4. Renuvion Skin Tightening
5. Inferomedial Buttock VASER Liposuction
6. Intraoperative Confirmed Lordosis Sculpting
7. Harvested Fat Transfer to Syringes
8. MediKhan Fat Processing by Centrifugation-Filtration
9. VASERSmooth Cellulite Subcision Technique
10. Gluteal Fat Administration

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