28 Autologous Fat Transfer: Evolving Concepts and Techniques

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Summary box

- There is increasing demand for fat transfer as a means of facial volume restoration in cosmetic rejuvenation, where it not only is a corrective technique for soft tissue defects and rhytides but also it corrects the atrophy due to the aging process.
- Because of improved understanding of the process of neovascularization and fat as a living graft, the emphasis has shifted from overcorrection to transfer of small volumes of fat.
- Autologous fat is usually harvested by gentle syringe aspiration and concentrated by centrifugation prior to reinjection into subcutaneous fat or muscle.
- Fat autograft muscle injection follows the patient's anatomic landmarks by placing fat within or adjacent to facial muscles.
- Potential complications of all fat transfer techniques include nodule formation due to overcorrection, fat necrosis, infection, and vascular occlusion, most of which can be avoided by careful, sterile technique.
- Data on long-term outcomes are scarce and largely based on two-dimensional photography. Further research on outcomes and factors affecting survival of adipocytes is needed and will necessitate finding an improved means of objective measurement.

INTRODUCTION

Fat augmentation is a popular and effective method for restoring volume to facial and body defects utilizing a variety of techniques. In many regards, fat fulfills the criteria as the ideal filling substance. It is readily available in most patients, inexpensive, non-allergenic, has no potential for infectious disease transmission, and has high patient acceptance. How well fat fulfills other key criteria of an ideal filler, such as predictability and persistence of correction over time, is controversial. This chapter will examine the evolving concepts in fat transplantation and the debates regarding the optimal techniques for achieving long-term results.

Historical vignette

The history of fat transfer dates back to 1893 in an oft-quoted report by Neuber involving transfer of 1-cm pieces of fat from the arm to facial depressions caused by tuberculosis.[1] Lexer utilized fat for facial hemiatrophy and malar augmentation in 1910.[2] Bruning was the first to report injecting fat through a needle in 1919.[3] In the 1950s, Peer noted a 40–50% retention of transplanted fat at 1 year.[4] In the late 1970s and early 1980s, increasing interest in fat transplantation techniques was stimulated by advancements in liposuction by Illouz.[5] Fat could now be extracted by suction rather than the older excision method. Fat grafting was still an open or semi-open procedure until Fournier's discovery in 1985 that fat could be extracted with a syringe and needle.[6] The popularity of fat transfer subsequently grew and provoked further inquiry into optimal techniques for harvesting, processing, and injection of fat for achieving adipocyte survival and longevity of results. The literature of the 1980s abounds with anecdotal and empirical reports regarding fat cell viability but few, if any, controlled studies. Some reported dissatisfaction with transient results.[7]

The 1990s brought a second, even more explosive surge of interest in liposuction, with an 8-fold rise in the number of procedures performed in the United States from 1990 to 1999.[8] This growth was due in large part to Klein's introduction of the tumescent technique, allowing liposuction to be performed less invasively under local anesthesia with minimal postoperative downtime and unparalleled patient safety.[9] The increase in liposuction procedures fueled an increased interest in using fat for correction of soft tissue defects and furrows. The 1990s also gave rise to an aging 'baby boomer' population with an increased demand for non-surgical rejuvenating procedures, including fat augmentation.[10]

New trends

Concepts and techniques regarding fat transfer changed during this period. One of the most significant changes in technique has been a shift from overcorrecting to transferring small volumes of fat.[11] This reflects a transition in the concept of fat as a temporary reabsorbed filler to fat as a living graft. In the 1980s and early 1990s, it was not uncommon for large volumes of fat to be placed with deforming overcorrection of 50% or more.[12–14] It was reasoned that all the fat was absorbed and that overcorrection would result in more fibrosis. The rate of resorption of these volumes was often variable, unpredictable, and asymmetric.

The theory of fat survival postulates that following transfer to the recipient site, the transplanted fat becomes ischemic. Some cells die and others survive as intact adipocytes or

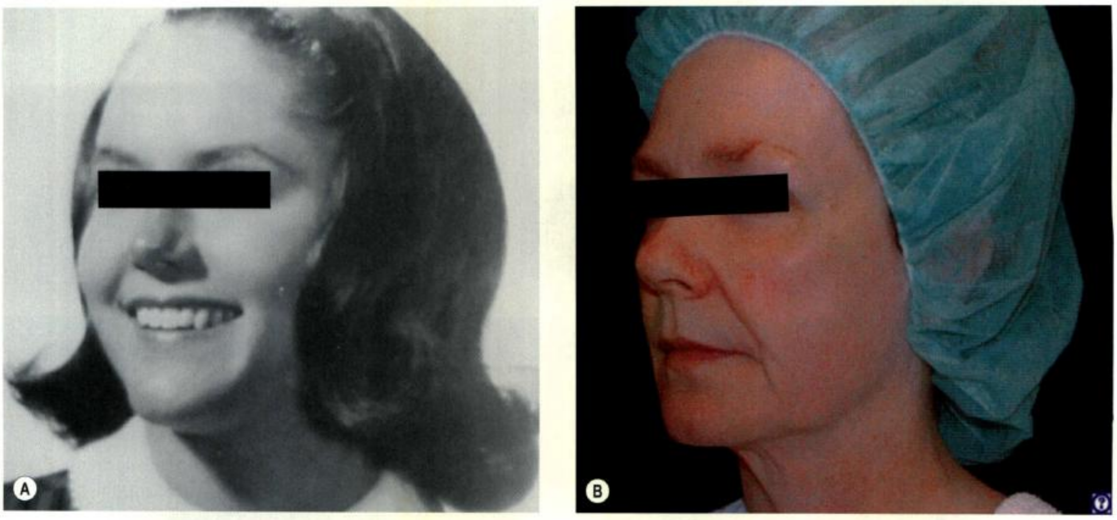

Figure 28.1 30-year facial volume loss.

preadipocytes until a blood supply is established from the periphery. In the late 1980s, Coleman championed the survival theory of fat grafting and developed a method he called Lipostructure™.[15] He advocated placing small parcels of fat with repetitive passes into multiple tissue planes, reasoning that a blood supply was more easily established. Gentle atraumatic handling of the fat cells was required for survival of the cells. Others reported improved longevity with smaller injection volumes and less traumatic harvesting and processing.[16] In 1993, Carpaneda & Ribeiro[17] validated these empiric findings when they compared viability of fat cylinders of different diameters. They found that smaller injected volumes, less than 3 mm in diameter, had optimal viability. At 2 months, viable fat cells were noted only in the peripheral zone of larger grafts having diameters of 3.5 mm or more.[17] The core of larger grafts had undergone necrosis due to lack of vascularization. In a recent review of the literature, small-volume transfer was the common denominator in studies reporting good longevity of fat.[18]

During the 1990s and into the 21st century we have also seen an expansion in the indications for fat transfer. In the 1980s, fat was typically injected directly under rhytides or soft tissue defects. A relatively new concept in rejuvenation of the aging face is replacement of volume loss; not simply injecting fat under specific rhytides and furrows, but rather full-face volume restoration.

It has been increasingly recognized among aesthetic surgeons that rhytidectomy alone does not necessarily rejuvenate a patient's appearance. Berman thoughtfully challenges the traditional concepts of rejuvenation, stating that the taut skin achieved through rhytidectomy may not equate with a youthful appearance.[19] He and others recognize the need to correct the atrophy of hard and soft tissues that occurs with age to achieve a truly rejuvenated appearance (Fig. 28.1).[19–22] It has also been pointed out that rhytidectomy may cause soft tissues to thin out even more, resulting in accelerated aging and a skeletonized appearance.[20]

In addition to atrophic changes in soft tissues, remodeling of the craniofacial skeleton is now recognized to occur throughout life and impart further changes to the overlying soft tissue.[22–27] These concepts of aging diverge from the traditional view, that facial aging is a result of gravity-induced ptosis. Restoring volume to the aged face is now becoming an integral part of facial rejuvenation in addition to – or in some cases instead of – more conventional methods. In order to restore full facial volume, larger quantities in the range of 20–100 mL or more are required. Such quantities are not currently feasible with synthetic fillers primarily due to expense of numerous syringes and the temporary nature of most synthetic fillers. Autologous fat is the natural choice for volume correction of this degree. The challenge is the same, whether filling a furrow with fat or replacing full facial volume. How do we achieve optimal longevity of transferred fat?

Controversies in performing the procedure

Autologous fat transfer is a multistep procedure. A review of the literature reveals that the proper method of performing every step of the procedure has been the subject of debate. At issue is the survival of the adipocyte and what factors have a positive or negative impact on survival (Box 28.1).

Each of these factors has been examined to some degree but definitive answers are lacking. Although the literature is replete with anecdotal reports, there are few objective studies. The difficulty in establishing consensus is a reflection of the difficulty in measuring outcome. There is no practical method to objectively document results. Transferred fat cannot be labeled or distinguished from recipient site fat cells with a distinct histologic marker. Successive imaging with magnetic resonance or ultrasonography is expensive and exposes the patient to unnecessary radiation. Measuring outcome is further complicated by variable rates of aging over time and changes in weight over time. We must therefore rely on photographic results until a better means of assessing outcome is available.

PREOPERATIVE PREPARATION

A preoperative history and physical examination are performed to screen for serious medical conditions, concomitant

Box 28.1 Controversial factors in fat cell survival

- *Choice of harvesting site.*
- Degree of negative pressure during harvesting.
- Diameter and type of harvesting cannula.
- Exposure of fat cells to air, blood, or lidocaine.
- Centrifugation of the fat.
- Rinsing the fat.
- Vascularity and mobility of the recipient site.
- Diameter and type of injecting cannula or needle.
- Freezing fat for later use.

infections, bleeding diatheses, medications, and allergies. Medications containing aspirin and non-steroidal anti-inflammatory agents are discontinued 2 weeks before surgery. Vitamin E and certain herbal formulations should be discontinued before surgery. Prophylactic oral antibiotic therapy may be started the night before the procedure: cephalexin 500 mg orally twice daily for 7 days, or minocycline 100 mg orally once or twice daily for penicillin-allergic patients. To minimize potential bruising, mephyton may be prescribed. The choice for the donor site is discussed with patients in advance. Benefits and risks are reviewed, as well as the post-operative sequelae. It is important to inform patients of expected downtime in advance.

TECHNICAL ASPECTS

Harvesting

Donor site

The optimal donor site has not been unequivocally established. Many choose the outer thigh as the ideal site due to its non-fibrous nature and relative avascularity. The rationale is that the least vascularized tissue will best survive the initial hypoxic period after transfer. Hudson et al.[28] found that adipocytes from the buttock and outer thigh areas are the largest and have the greatest lipogenic activity. Ullman et al.[29] injected fat from various sites into nude mice and found the outer thigh fat to have the lowest resorption rate. In any given patient, availability of fat is certainly a factor. Indeed, many patients desiring improvement of a gaunt facial appearance have very little body fat and one must obtain fat wherever possible. Areas that are diet resistant such as the knee are often recommended in that, theoretically at least, the transplanted cells will be stable whether the patient gains or loses weight over time.

Use of lidocaine

Some studies indicate that lidocaine has a negative effect on fat cell viability. This has been shown both with lidocaine 1% and diluted lidocaine 0.1%.[30,31] The effect could be removed by rinsing with saline. In contrast to these earlier studies, Keck et al.[32] examined the effect of various local anesthetic solutions on the viability of preadipocytes in vitro and found the opposite to be true. After incubation for 30 minutes, simulating the time of clinical exposure, cell viability was found to be highest with lidocaine 1% at over 80% viability versus articaine 1% at 55%, ropivacaine at 51%, and prilocaine at 26%.[32] Of interest, when the articaine was diluted in 1 liter

Figure 28.2 Gentle harvesting with a 10-mL syringe held back with 1–2 mL pressure.

of saline for tumescent anesthesia, the viability increased to 85%. This study of preadipocytes and other studies of adipocytes[33] may help to explain why lidocaine has been used for decades with apparent success for donor site anesthesia. Differing dilutions of tumescent anesthesia have been recommended with or without epinephrine. Amar[21] recommends infiltrating Klein's solution much like a ring block around the core of fat to be harvested in order to minimize contact with lidocaine. A few authors recommend the use of Ringer's lactate rather than normal saline, reasoning that glucose-containing solution may enhance fat cell viability.[11]

Harvesting technique

Utilizing an enzymatic assay of fat cell damage, Lalikos et al.[34] showed that harvesting by suction versus direct excision of fat did not increase apparent damage to the fat cell. Other studies have also indicated that fat cells harvested by syringe, machine aspiration, or direct excision all appear to have similar viability. Suction aspiration at low-level negative pressure did not appear to rupture cells in two studies, although partial breakage was seen at negative pressures of 700 mmHg and higher.

Syringe aspiration with low negative pressures is most often recommended (Fig. 28.2). Those advocating the gentlest handling suggest 10-mL syringes to minimize vacuum pressures with the plunger held back no more than 2–3 mL.[11,12,15] Other experienced surgeons report harvesting with larger 20–60-mL syringes without harming the fat cells, as documented with cell culture for up to 2 months.[35] Although various cannulae and needles have been recommended, Shiffman & Mirrafati[36] compared harvesting and reinjection with 2.5–3.0-mm cannulae or an 18-gauge needle. None of these caused disruption of fat cells histologically.

Processing the fat

Once the fat is harvested, the next issue is whether or not it requires further processing before injection. All would agree on the first step, which is to stand the syringes upright for a period of 15–60 minutes to allow separation into supranatant and infranatant fractions (Fig. 28.3). The infranatant fluid is then drained off the bottom and the oil fraction on top is

Figure 28.3 Syringes held upright for 10 minutes separate into supranatant and infranatant fractions.

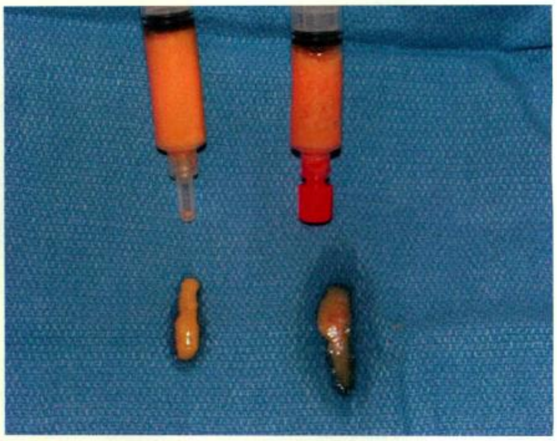

Figure 28.4 Centrifuged fat on left appears more concentrated and cohesive on injection than non-centrifuged fat.

often decanted off. In Griffin's survey of experienced cosmetic surgeons, 62% wash the fat with saline or Ringer's lactate to remove lidocaine or blood.[37] Lidocaine has been shown to affect fat cell growth in culture and blood is thought to stimulate phagocytosis of fat cells.[38] In Sommer & Sattler's review, all authors agreed that blood in transplanted fat accelerates degradation of transplanted fat.[18]

Rather than rinse, many surgeons prefer to centrifuge the fat. A survey of 508 plastic surgeons revealed that 47% centrifuge, 29% rinse fat, and 12% transfer directly without any processing.[39] Centrifugation has been shown to separate fat cells from blood products, proteases, free lipids, and lipases which may degrade freshly grafted adipocytes.[40] Various speeds and time intervals for centrifugation have been recommended. Histologically, fat cells centrifuged for 10–60 seconds at 3600 rpm show no evidence of cell damage although cells centrifuged for 15 minutes have been shown to have distorted morphology.[36,41] Whether or not centrifugation removes lidocaine has not been demonstrated. Centrifugation does concentrate fat cells, resulting in a larger number of cells per mL of volume transferred (Fig. 28.4). When 10 mL of fat is centrifuged at 3600 rpm for 1–3 minutes, there is approximately 30–40% of the volume separated at the bottom as a bloody fluid (Fig. 28.5). In one of the few controlled studies, a double-blind comparison of fat transfer to the dorsum of the hands with centrifuged versus non-centrifuged fat, improved longevity and aesthetic results were observed with the centrifuged fat at the 3-month and 5-month follow-up visits in 100% of patients (Fig. 28.6).[42] The author now routinely utilizes centrifuged fat in essentially all cases. Fulton et al.[11] use centrifuged fat for facial correction, but prefer non-centrifuged fat for larger-volume transfers into breasts, biceps, or buttocks – areas in which lumpiness has been noted with centrifuged fat. One must use sterilized canisters or sleeves within the centrifuge, as *Pseudomonas* and other pathogens have been cultured from the centrifuge.[43]

Another method of fat processing has been examined by Moscatello et al.[44] involving the addition of collagenase in order to dissociate the fat graft into smaller cellular packets. In-vitro ceiling culture showed a greater than 80% viability compared to 17% without the rather lengthy processing procedure. Others have looked at the addition of human albumin,

Figure 28.5 Before and after centrifugation at 3600 rpm for 3 minutes. Note 30–40% volume loss.

glycogen, or growth factors but definite benefit has yet to be demonstrated.

Injection techniques

The most common placement for transplanted fat is within the subcutaneous fat.[16,45,46] The suggested degree of overcorrection has decreased from originally 50% to 30% to now with minimal or no overcorrection.[4,11,44,45] Smaller volumes of fat are thought to improve graft survival as previously mentioned. Small volumes also reduce downtime for patients because postoperative edema, as a general rule, is directly proportional to the amount transferred.[47,48] Retrograde injection with gentle pressure is performed to minimize injecting a large bolus of fat and to reduce the rare risk of intravascular injection. The cannula is inserted and advanced to the most distal site. Fat is then injected as the cannula is withdrawn and small parcels of fat are placed. The recommended syringe size for transfer varies from 10 mL[36,48] to 3 mL[11,45] to 1 mL.[15,40,49] The author prefers the 1-mL syringe as less pres-

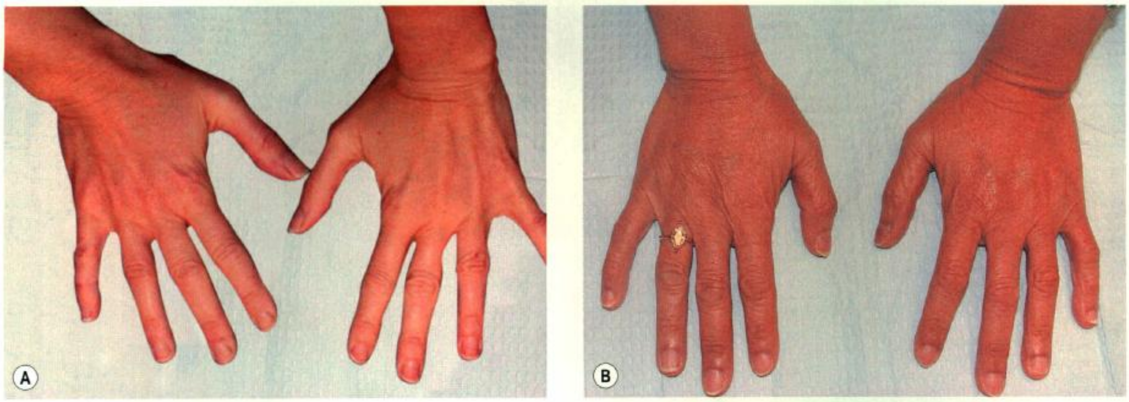

Figure 28.6 (A) Before and (B) 12 months after long-term survival of the fat in the dorsum of the hands. Note improved result on patient's left hand with centrifuged versus non-centrifuged fat.

Figure 28.7 Fat particles are smaller when injected through a 1-mL syringe versus a 10-mL syringe with similar injection pressures.

sure is required to empty it and the size of the fat particles is smaller (Fig. 28.7). When transferring to smaller syringes, a female-to-female adapter is available and allows transfer without exposure to air. Prolonged air exposure has been demonstrated to negatively impact fat cell viability.[50] A 10-mL syringe rack is useful for placing and securing the upright syringes (Fig. 28.8).

Both blunt-tipped cannulae and 14–25-gauge needles have been advocated for transfer.[51] Some studies have suggested the minimum diameter size of the injection instrument be no smaller than 18-gauge to prevent damage to the fat cell.[52,53] In Shiffman & Mirrafati's study, injection with smaller-diameter 20-gauge and 22-gauge needles caused damage to adipocytes as evidenced by histologic changes in cellular and nuclear morphology.[36] Blunt-tipped cannulae reduce the risk of bleeding and the rare risk of intravascular injection. However, it is argued they pass through tissue with more friction and trauma, which may cause increased bleeding and inflammation in the recipient site.

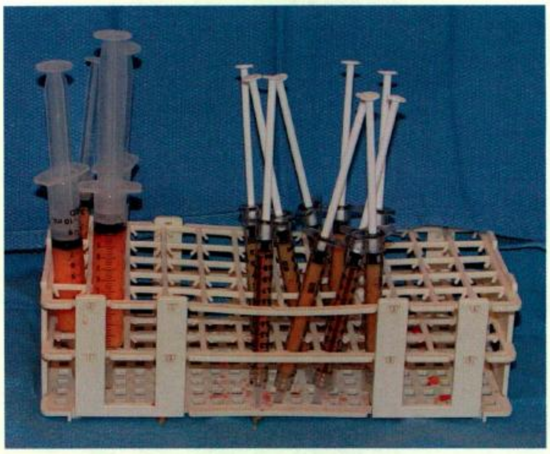

Figure 28.8 Syringe rack for securing upright 1-mL and 10-mL syringes.

Indications for fat augmentation

The most common indications for fat augmentation of the face include the nasolabial fold and the marionette fold. Other indications for fat transfer of the face include augmentation of the cheeks, malar area, and chin. In the past decade, cosmetic surgeons have begun to restore soft tissue volume, not simply under the rhytide or defect, but for full-face volume correction. Newer approaches for restructuring the face include Lipostructure™,[15] panfacial rebalancing,[37] and fat autograft muscle injection (FAMI).[21]

Body areas which are sometimes augmented with fat are the buttocks, biceps, calf, and breast. Fat augmentation of the breast is a controversial area given that calcifications may develop postoperatively.[54–56] Although these calcifications have been shown to differ radiographically from those caused by breast cancer, the areas could require biopsy, causing undue morbidity for the patient.[55] Rejuvenation of the dorsum of the hands is another indication for fat augmentation. Generally, 10 mL or less is placed in each hand, although Coleman recommends 20–30 mL per hand.[57] Other common indications for fat augmentation are defects from

Figure 28.9 (A) Before and (B) after facial rebalancing. (Courtesy of L Donofrio.)

disease or trauma, for example acne scars, linear morphea, lupus profundus or erythematosus, and cellulite.

Lipostructure™

Sidney Coleman was one of the first to champion the placement of small 'parcels' of fat in order to facilitate neovascularization. He was also one of the first to advocate full-face three-dimensional enhancement of youthful contours, which he termed Lipostructure™. His method involves an intricate layering of minute quantities of fat within multiple tissue planes, not only in the subcutaneous plane but also adjacent to bone, fascia, and muscle. Each droplet of fat is placed 'within 1.5 mm of living vascularized tissue.' Typically, 30 or 40 passes are required to empty a 1-mL syringe with a blunt-tipped 17-gauge or 18-gauge cannula. Quantities injected for a full face often exceed 100 mL. Because the fat is viewed as a living graft, it is handled gently with atraumatic harvesting, no rinsing, and brief centrifugation for 30 seconds.

Coleman[15] reports long-term results with his method in the order of years. 'Before and after' photographs suggest that Lipostructure™ may replace the need for rhytidectomy. The single most significant drawback to this method is the marked edema seen for weeks or months postoperatively. The benefit of dramatic panfacial correction must be weighed against the extended recovery period for the patient.

Facial rebalancing

In order to circumvent prolonged edema for the patient, Donofrio modified Coleman's procedure with a method of 'fat rebalancing,' also involving the entire face but with repeated smaller procedures (6–12) over a 1–2-year period.[40] Fresh fat is utilized the first time, but in most patients, frozen fat is injected on subsequent visits. The entire face is treated with smaller total quantities (approximately 20–30 mL), which reduces the downtime for patients to 1–10 days, depending on the extent of the procedure. Fat is processed atraumatically and injected with blunt-tipped cannulae with the intricate, repetitive pass, layered method recommended by Coleman. Fat is placed exclusively in the subcutaneous space. Donofrio focuses not only on replacing fat but also addresses areas of fat hypertrophy that are found in the aging face.[22] Microliposuction of the jowls and other areas is typically performed during the fat transfer procedure for aesthetic rebalancing (Fig. 28.9).

Fat autograft muscle injection

Most cosmetic surgeons agree that an abundantly vascularized recipient site for transplanted fat will result in optimal survival of the fat, an opinion confirmed by several histologic studies.[12,17,37,58] French anatomist and plastic surgeon, Roger Amar, has incorporated this principle into a technique, in which fat is injected into or immediately adjacent to the muscles of facial expression, and which he coined FAMI. The concept of FAMI was inspired by a study in 1996 by Guerrerosantos et al., in which they demonstrated 5-year survival of fat in rat muscle.[59] Muscle thickness continued to increase for 6 months following fat grafting. The FAMI technique involves full-face volume correction following the landmarks of the patient's own anatomy, namely the origin and insertion of various muscle groups. Volumes placed range from approximately 20 mL to 70 mL, utilizing a set of blunt-tipped cannulae which are curved and angled to conform to the skeletal contours of the face (Fig. 28.10). There is less apparent trauma than methods by Coleman and others using over 30 repetitive passes per syringe: with FAMI a 1-mL syringe is emptied in one to three passes The fat is placed along vectors which parallel blood supply, minimizing trauma to the vessels. Patients are able to return to work in 3–7 days depending on volumes placed. Amar has reported longevity of 3–5 years with this method.[60]

FAMI can be performed as a full-face volume correction or for localized volume loss such as the lips, tear-trough deformity, chin, or perioral regions; however, a filler such as hyaluronic acid should be favored to be used for the lips. FAMI is ideal after rhytidectomy in patients with thin, overly taut skin. It is also indicated in conjunction with liposuction of the neck for replacing volume of the chin, mandibular border, pre-jowl notching, and lower perioral regions[61] (Fig. 28.11). Patients are asked to bring a photograph of themselves taken 10–20 years before the consultation in order to appreciate the volumes that have been lost. In restoring the muscle sling of the face, the overlying skin drapes in the smooth, uninterrupted contours of youth.

Amar's harvesting and processing techniques include utilizing the medial knee as his preferred donor site, and processing of the fat with centrifugation at 3600 rpm for 3 minutes. Injection into the muscles is based on knowledge of the origin, insertion, and plane of each muscle to be injected as well as familiarity with the bony landmarks of the skull[62–64] (Table 28.1 and Fig. 28.12). Specific injection cannulae have been developed for various muscle groups, allowing for smooth passage of the cannula. The cannula is directed to the origin or insertion of the muscle and the fat is injected in a retrograde fashion with low injection pressure (Figs 28.13 and 28.14). There are three ways the surgeon determines that he/she is injecting in the muscle. For certain muscles, the bundle can be palpated as the enveloping fascia is filled. Other muscles are very thin, not palpable, and the surgeon must rely on bony anatomic landmarks to guide the injection as close as possible to the muscle. With some muscle groups, a loss of resistance is the clue that the cannula has penetrated the fascia and is within the muscle. Anesthesia for this procedure is achieved with nerve blocks, supplemented with oral or intravenous sedation depending on individual patient requirements. Amar's technique, which evolved over the past 7 years, now has a second step after muscle injection consisting of supraperiosteal injections of highly centrifuged fat which he believes consists of more stem cells. These injections would theorectically compensate for bone loss if these cells could be shown to differentiate into bone in vivo.

The postoperative course of FAMI is unremarkable. There is essentially no pain and little bruising, which appears on the second or third day. Edema is the most significant symptom and patients need to be warned in advance or they will be concerned that too much fat has been placed (Fig. 28.15). The recovery period will depend on the quantities placed. With a full-face correction of 70 mL, the patient may require 7–10 days of downtime. In a preliminary report, the author utilized 20–30 mL on average for partial-face corrections with good results[65] (Fig. 28.16). This lower total volume replacement reduces the downtime to 3–5 days. Complications of this technique have not been reported except for the usual postoperative sequelae of bruising, edema, and temporary palpable lumpiness, which is not generally visible. Potential complications are discussed below.

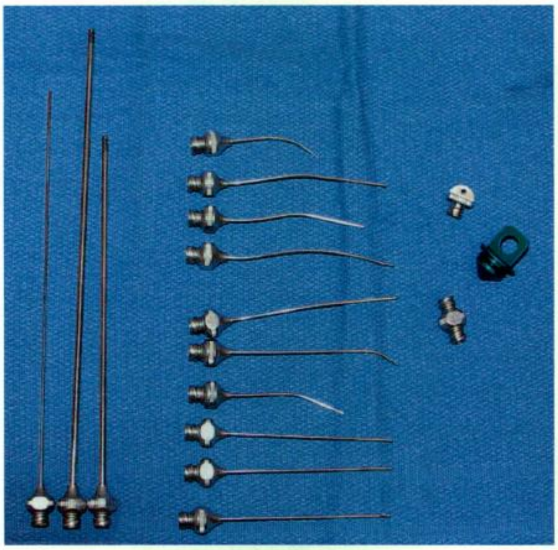

Figure 28.10 FAMI injection cannulae are curved and angled to conform to musculoskeletal contours.

Table 28.1 Facial muscles commonly injected in FAMI

MUSCLE	PLANE
Frontalis	Superficial
Procerus	Superficial
Corrugator	Deep
Orbicularis oculi	Superficial
Zygomaticus minor	Superficial
Levator labii superioris alaeque nasi	Mid
Levator labii superioris	Mid
Levator anguli oris	Deep
Zygomaticus major	Mid
Depressor labii inferioris	Mid
Depressor anguli oris	Mid
Mentalis	Deep
Buccinator	Deep
Risorius	Mid
Platysma	Mid
Orbicularis oris	Mid

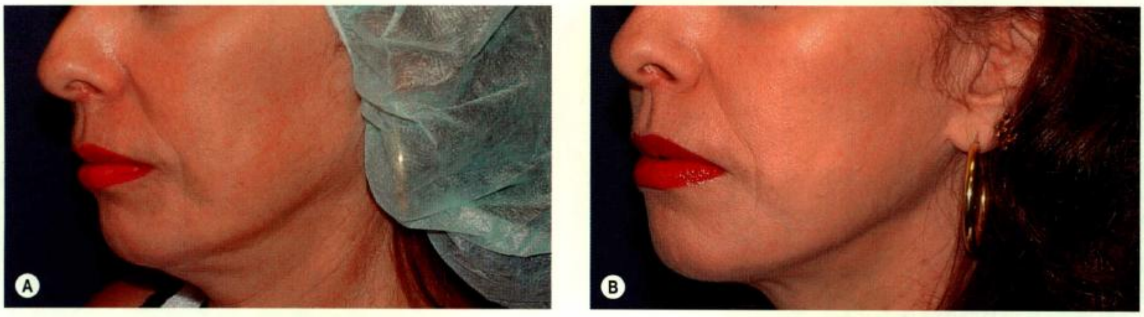

Figure 28.11 (A) Before and (B) after lower face FAMI with 9.7 mL injected and concomitant liposuction of the neck. Note improved chin height and mandibular border.

OPTIMIZING OUTCOMES

The optimal results will be determined by proper placement and by survival of the fat cells.

Longevity

The literature contains few objective studies regarding the longevity of transplanted fat. Horl et al.[66] demonstrated a 49% volume loss at 3 months, 55% loss at 6 months, and negligible loss between 9 and 12 months utilizing magnetic resonance imaging of fat transplants. Ultrasound imaging has been utilized to demonstrate long-term correction up to 1 year in patients with defects due to disease processes.[67,68] Another prospective study analyzed longevity via computed tomography scanning with three-dimensional volume analysis in HIV patients treated with the Coleman method.[69] Not only did fat endure at 1 year, but for unknown reasons, there was a tendency for the volume to increase from the 2nd to 12th month. Saddick & Hudgins[70] used a marker of fatty acid

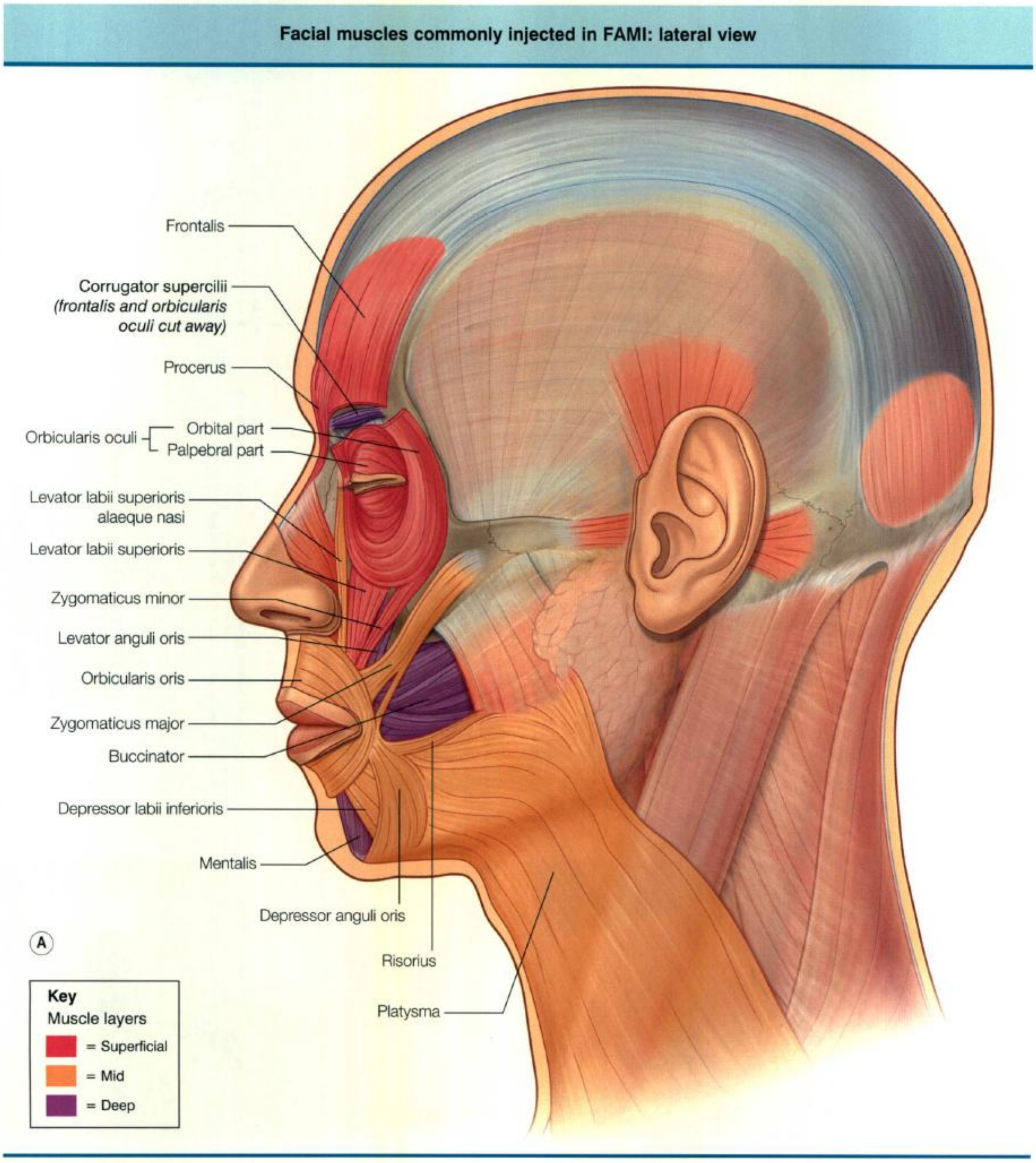

Figure 28.12 Muscles of facial expression. (A) Side view. (B) Front view.

Facial muscles commonly injected in FAMI: anterior view

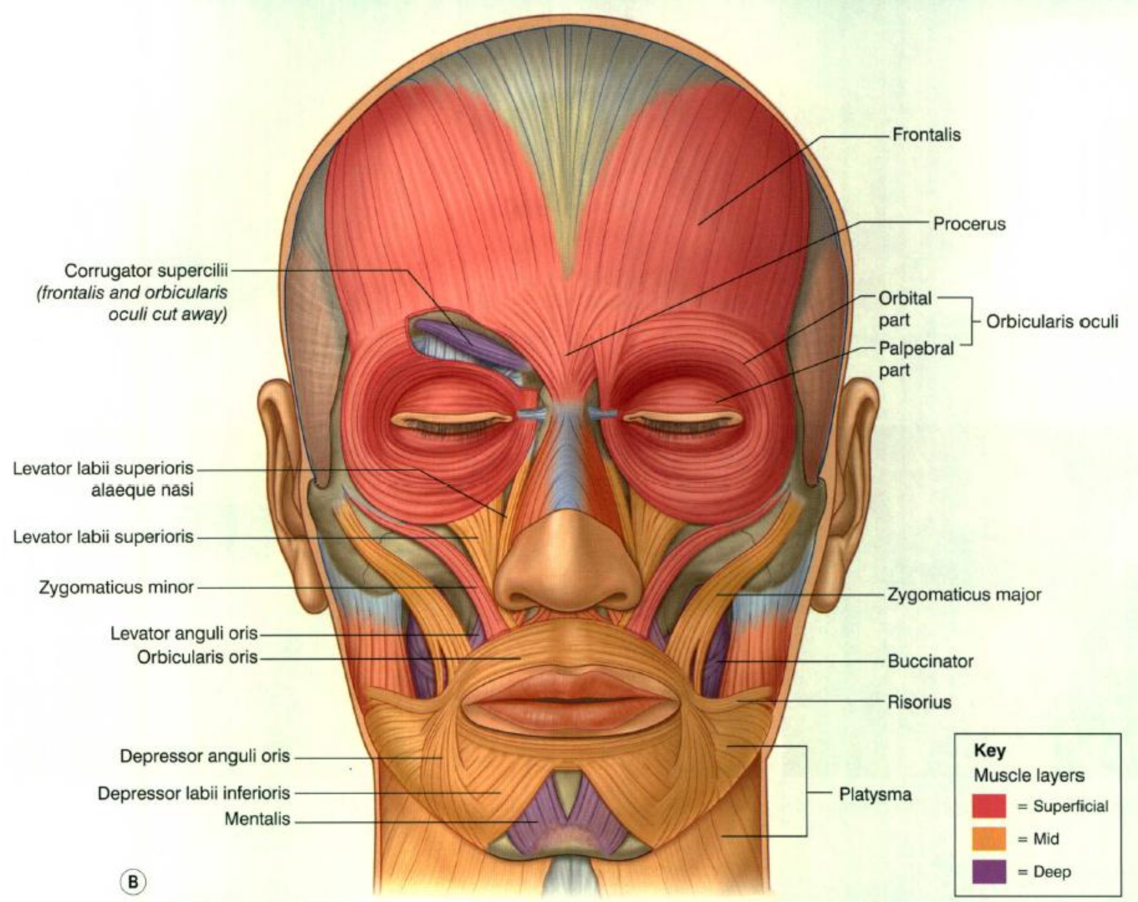

Figure 28.12, cont'd

Figure 28.13 Injection of the zygomaticus minor with cannula #4.

Figure 28.14 Injection of the depressor anguli oris with cannula #5.

Figure 28.15 Postoperative edema on day 3 after FAMI of lower face with 30.3 mL injected.

Figure 28.16 (A) Before; (B) 5 weeks after; and (C) 8 months after partial-face FAMI with 24.7 mL.

composition that was specific to the donor site. They were able to demonstrate a 1-year persistence of that marker in the recipient site in one of six patients. In the other five, the donor site marker was undetectable. They speculated that perhaps recipient site factors caused conversion of the donor site marker to the fatty acid composition of the recipient site.

Animal studies have shown long-term survival of autologous fat. Nguyen et al.[71] found persistence of transplanted fat in rats at 9 months when fat was injected into the muscle. Fat injected into the subcutaneous plane was completely absorbed. Guerrerosantos reported 5-year survival of fat when injected into rat muscle.[59]

Studies based on photographic results and physician assessment have reported long-term results varying from 'disappointing' to many years.[7,11,45,46,48,72–75] Some have noted the longest survival when the recipient site is relatively immobile, such as the fixed scars of linear morphea,[13] the forehead,[16] the infraorbital area,[11] or the backs of the hands[76,77] (see Fig. 28.6). In a study of scleroderma-induced facial scars, these results were corroborated: the forehead had the greatest retention with 51–75% of correction remaining at 1 year, while scars of the chin and nose showed poor retention of correction with less than 25%.[78] The most mobile area of the face – the lips – has been least responsive to long-term correction.[11,53] Eremia & Newman found that longevity was related to recipient site.[53] Good to excellent results were seen at 5–8 months for the nasolabial and melolabial folds and poor results were observed in the lip and glabella. Perez notes more permanent results in younger patients.[74] Based on the limited objective data, animal studies, and empirical results from experienced cosmetic surgeons, one can conclude that long-term fat survival is achievable. Further studies are ongoing to define the factors resulting in optimal survival.

Touch-up procedures

Many recommend touch-up procedures for optimal results. There are several reasons that touch-up procedures are performed. With the use of small volumes for fat transfer, one treatment session may not be adequate to achieve optimal volume restoration. In addition, the patient may not have enough downtime to undergo placement of more than 30 mL, yet have a deficit of 100 mL or more. There is also variable longevity of transplanted fat from months to years due to incompletely understood factors. Ongoing aging and/or weight loss of patients further contribute to the need to replace additional fat after the initial session (Fig. 28.17). Lastly, patients are often reluctant to have too much volume

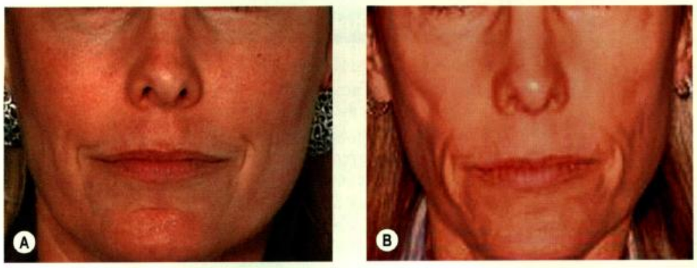

Figure 28.17 Dramatic facial volume changes due to weight loss of only 10–15 pounds (4.54–6.81 kg) such as this will significantly affect longevity of fat augmentation.

placed, particularly in the lips, but when they see the initial results, they realize they would like an even fuller look.

Use of frozen fat

Frozen fat is commonly utilized in clinical practice for augmentations and touch-up procedures with apparently pleasing results.[40,48,75] However, it is argued that freezing fat affects its viability. It is certainly efficacious to use frozen fat for touch-up procedures rather than reharvest in a sterile fashion. Few studies have addressed this question. Histologic studies have shown frozen and thawed adipocytes that are identical to those of normal tissue.[79] Takasu & Takasu[79] reported long-term retention of fat that had been frozen for up to 7 years. Shoshani et al.[80] compared frozen fat versus fresh fat injected into nude mice. Assessments by clinical observation, weight and volume measurement, and histologic parameters demonstrated successful take at 15 weeks in both groups with no statistically significant difference in volume at 15 weeks. In a side-by-side comparison study of fresh versus frozen fat injected to the dorsum of the hands, it was found that frozen fat lasted as long or longer at 3-month and 5-month intervals.[81] Indeed, aesthetically, the hand with the frozen fat was preferred at the 3-month and 5-month follow up (Fig. 28.18). The frozen fat was preferred initially as well in a majority of patients because there was less postoperative edema of the hand. Another study compared the viability of adipocytes frozen with four different methods: snap frozen in liquid nitrogen without media; frozen at –20°C without media; incubated at 37°C with 10% bovine serum; or incubated without media.[82] The fat simply frozen at –20°C showed only a slight drop in mitochondrial activity at 8 days, and all other methods had a >60% drop in mitochondrial activity. However, other studies reject the use of frozen fat. Lawrence found no viable adipocytes in frozen aspirates measured by cell culture.[83] Research regarding the viability of frozen fat is ongoing and clearly needed. In some countries, the legal requirement is that fat is stored in a freezer for later use and must fulfill the requirements for organ transplantation. These regulations limit the use of frozen fat in transplantation.

Protocol for FAMI technique

With so many techniques and opinions, it may be confusing for the novice in fat augmentation to know how to begin.

Figure 28.18 Fresh fat (patient's left) versus frozen fat (patient's right) in dorsum of hands. Equal or better results seen with frozen fat at 5 months.

Data have been presented in this chapter to help the new surgeon weigh the merits of the various methods. The author has experience in many different techniques and has found the FAMI technique a logical, learnable procedure with predictable results.

A typical protocol in the author's practice is to have one larger session of FAMI with 30–40 mL of fresh fat and expecting a downtime of 5–7 days. This is followed by one to three touch-up sessions, at intervals of 4–6 months, of less than 10 mL of frozen fat. These smaller sessions heal over a weekend (Box 28.2). Variations from this protocol include injection sessions monthly or every other month for 1–2 years with frozen fat for gradual sequential augmentation.[40] Others repeat the entire initial session every few years as needed with fresh fat.[15] Fournier advocates periodic injections every few years to keep pace with the aging process.[75] He also regularly uses frozen fat as needed for touch-up procedures.

PITFALLS AND THEIR MANAGEMENT

The complication rate is low with all fat augmentation techniques.

Box 28.2 Author's protocol for FAMI

- Sterile prep and drape.
- Donor site anesthesia with Klein's tumescent formula.
- Nerve blocks of the face.
- Gentle harvesting with 10-mL syringes.
- Syringes held upright and infranatant fluid discarded.
- Full 10-mL syringe centrifuged at 3600 rpm for 3 minutes.
- Oil and infranatant fractions discarded.
- Transfer to 1-mL syringes.
- Inject cephalad to caudad each muscle group, bilaterally.
- Postoperative checks at 24 hours and 1 week.
- Evaluate for touch-up session at 4–6 and 8–10 months postoperatively.
- Touch up injections with <10 mL of frozen fat p.r.n.

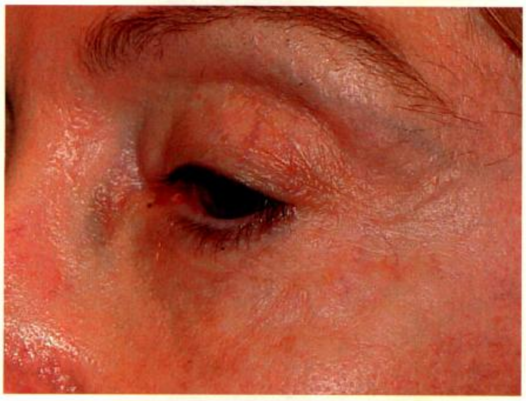

Figure 28.19 Overcorrection in infraorbital region with numerous small visible nodules.

Pitfalls and their management

- Avoid overcorrection due to injection of a large bolus of fat; as the infraorbital area is most prone to overcorrection, this area is best done by the experienced surgeon using only minute quantities with low injection pressure.
- Screen patients preoperatively for infection, especially in facial areas, and treat prior to surgery. Use antibiotic prophylaxis in all patients and use sterile technique in all steps of the procedure.
- Avoid intravascular penetration by using blunt-tipped cannulae, retrograde injection after withdrawal to assure one is not intravascular, and minimal injection pressure with 1-mL syringes.

Overcorrection is probably the most common complication, particularly in the infraorbital area. Visible, superficial nodules may develop with overcorrection of this area, or from injecting too large a bolus of fat too superficially (Fig. 28.19). Caution is advised in this area if it is to be injected at all. Experienced surgeons recommend that very minute quantities are injected in the periorbital area with each pass of a 1-mL syringe.[49,84] Overcorrection may be difficult to treat. Low-dose steroid injection, repeated massage, and excision have been suggested treatments.[49,84]

Other complications are sometimes seen after fat augmentation. Fat hypertrophy may follow weight gain after fat augmentation, and may require surgical revision.[85] The symmetry with the FAMI technique appears to mitigate this problem (Fig. 28.20). Fat necrosis may occur on occasion, resulting in extrusion of fat. Infection is another potential complication. Patients need to be screened adequately for concomitant, recurrent, or chronic infections, particularly of adjacent facial areas such as sinus, dental, or ocular regions.[86] These infections need to be adequately treated before undergoing the procedure. The use of prophylactic antibiotics is

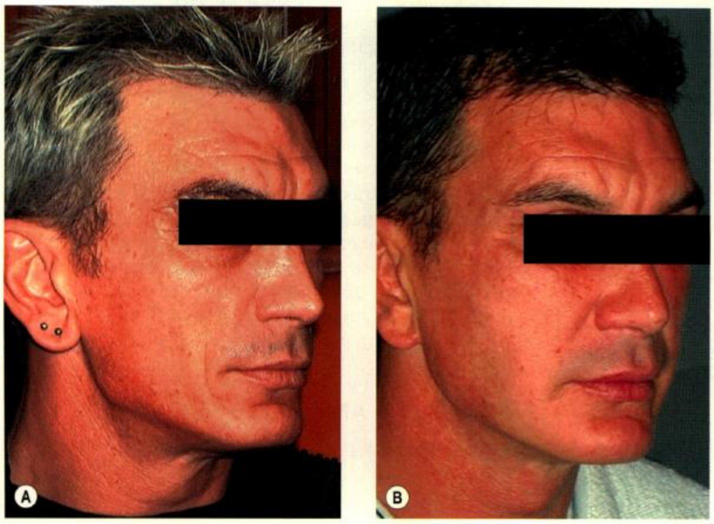

Figure 28.20 (A) Before and (B) 2 years after full-face FAMI in a 39-year-old man. The patient's face is symmetric despite a 10 lb (4.5 kg) weight gain. (Courtesy of R Amar.)

Figure 28.21 Removable centrifuge sleeves should be sterilized for each case.

generally recommended in all patients. Fat augmentation should be carried out as a sterile procedure. The centrifuge has been the source of infection with *Pseudomonas*.[43] Sterile centrifuge sleeves should be utilized, as well as sterile instruments (Fig. 28.21). There have also been reports of infection with *Staphylococcus*, *Streptococcus*, and *Mycobacterium*.[43,45,49,86]

The most serious potential complication of fat augmentation is vascular occlusion caused by inadvertent intravascular injection. Blindness has been reported following fat injections of the glabellar lines[87,88] and also from injection of the nasolabial fold.[89] Middle cerebral artery occlusion and ocular fat embolism have also been reported following fat injection of the face.[90,91] Occlusion or emboli are rare complications Reports have indicated sharp instrumentation and 10-mL syringes with high injection pressures were utilized.[91] Use of blunt-tipped cannulae will minimize the risk of vascular penetration as well as initial withdrawal of the plunger to assure one is not intravascular. Retrograde fill, 1-mL syringes, and low injection pressures further reduce the risk of intravascular injection. When evidence of vascular compromise is seen on the skin with dramatic blanching, Wexler advises placing the patient in Trendelenburg, applying nitroglycerin paste, and massaging the area until the flush returns to the skin.[92] A potential complication of intramuscular injection is dysfunction of facial muscles. Although not reported by Amar, weakness of facial muscles of mastication has been observed when fat is injected intramuscularly.[93] The masseter muscle is not injected in the FAMI procedure. In addition, the curved and angled cannulae of FAMI most likely minimize injury to the muscle.

FRONTIERS

The future of fat transplantation may lie not in the adipocyte itself but in the injection of preadipocytes or stem cells. These cells are fibroblast-like fat cell precursors that are present in adipose tissue. They can be grown and differentiated into mature fat cells in culture.[94–96] Initial research indicates that stromal cells from adipose tissue are smaller and more resilient. Indeed, they have been found to survive ischemia better than mature adipocytes and have the potential to differentiate into fat cells after transplantation. In addition, adipocyte stem cells are known to release angiogenic growth factors, which may facilitate neovascularization. The isolation of these cells has been expensive and time consuming and only a few studies have examined their use.[97,98] In one clinical study, adipose-derived stem cells were injected into three patients with defects from Perry Rhomberg disease or lupus profundus.[99] Duration and clinical improvement were rated higher than three control patients receiving traditional fat transfer although statistical improvement was not demonstrated. The isolating process took 90 additional minutes in this study and involved centrifugation and digestion with collagenase. Such processes may be applied in the clinical setting more commonly if a clear benefit in outcome or duration from the addition of progenitor stem cells can be demonstrated.

Fratila[100] suggested that lymph drainage 1 day after surgery may reduce postoperative edema. Lymph drainage is a very gently performed superficial massage, which will not affect the viability of the transplanted fat cells, but reduces postoperative edema. The reduction in edema lowers the surrounding pressure on the transplanted fat, which will maximize the result of the fat transplantation.[100]

SUMMARY

Fat augmentation has been practiced for decades with good reason. It is safe, relatively inexpensive, and readily available. Now that cosmetic surgeons are recognizing that facial aging is not simply due to gravity but rather to atrophy of tissues, the use of fat for volume restoration is becoming even more popular. Newer techniques of Lipostructure™, facial fat rebalancing, and FAMI, are targeted to achieve true full-face three-dimensional rejuvenation.

We are lacking an effective, practical means of objectively measuring outcome. Without this, we will not be able to answer basic questions of optimal harvesting site, processing technique, and most effective injection technique. Histologic and animal studies suggest there is greater potential for revascularization with small volumes of fat thereby enhancing survival. Limited data suggest centrifugation contributes to long-term results. Gentle handling and cannula size of 18-gauge or larger seem to be important to survival. Scientific research is emerging to address these issues. Further research will also elucidate the role of preadipocytes or stem cells in adipose tissue.

These are exciting times to be performing fat augmentation. It is a dynamic, expanding field offering the cosmetic surgeon a creative outlet and the patient gratifying results.

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