Current Applications and Safety of Autologous Fat Grafts: A Report of the ASPS Fat Graft Task Force

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Task Force Statement: In 2007, the American Society of Plastic Surgeons formed a task force to conduct an assessment regarding the safety and efficacy of autologous fat grafting, specifically to the breast, and to make recommendations for future research. The task force formulated specific issues regarding fat grafting and then compiled them to focus on five broad-based questions:

1. What are the current and potential applications of fat grafting (specifically breast indications, and if data are available, other cosmetic and reconstructive applications)?
2. What risks and complications are associated with fat grafting?
3. How does technique affect outcomes, including safety and efficacy, of fat grafting?
4. What risk factors need to be considered for patient selection at this level of invasiveness?
5. What advancements in bench research/molecular biology potentially impact current or future methods of fat grafting?

To answer these questions, the task force reviewed the scientific literature, critically appraised the information available, and developed evidence-based practice recommendations. Although the primary issue of interest was fat grafting to the breast, other aspects of fat grafting were evaluated. (*Plast. Reconstr. Surg.* 124: 272, 2009.)

A renewed clinical interest in fat grafting for both reconstructive and aesthetic purposes has prompted plastic surgeons and other medical practitioners to perform such procedures. While it appears that these procedures are being performed more frequently and for broader indications, there is a relative lack of information for physicians to guide them in choosing optimal techniques, appropriate patient selection, and offering realistic advice on outcomes and potential complications to their patients. By conducting an evidence-based review, we will offer a graded summary of the evidence to help optimize the clinical use of fat grafts.

DISCLAIMER

This task force statement provides strategies for patient management and was developed to assist physicians in clinical decision making. This task force statement, based on a thorough evaluation of the present

The members of the task force and their affiliations are listed in an Appendix at the end of this article.

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scientific literature and relevant clinical experience, describes a range of generally acceptable approaches to diagnosis, management, or prevention of specific diseases or conditions. This practice advisory attempts to define principles of practice that should generally meet the needs of most patients in most circumstances. This task force statement, however, should not be construed as a rule, nor should it be deemed inclusive of all proper methods of care or exclusive of other methods of care reasonably directed at obtaining the appropriate results. It is anticipated that it will be necessary to approach some patients' needs in different ways. The ultimate judgment regarding the care of a particular patient must be made by the physician in light of all the circumstances presented by the patient, the diagnostic and treatment options available, and available resources.

This task force statement is not intended to define or serve as the standard of medical care. Standards of medical care are determined on the basis of all the facts or circumstances involved in an individual case and are subject to change as scientific knowledge and technology advance, and as practice patterns evolve. This task force statement reflects the state of knowledge current at the conclusion of the task force's activities (March of 2008). Given the inevitable changes in the state of scientific information and technology, periodic review and revision will be necessary.

In addition, it is important to note that recommendations of the task force are based on evidence available in the published literature, which often reflects only positive findings; studies with negative findings are rarely published. In order for the task force to make a strong recommendation (grade A) for or against fat grafting for specific applications, high-quality randomized controlled trials would be needed to further evaluate safety and efficacy.

METHODS

Literature Search and Admission of Evidence

This review involved a prospective, systematic method for identifying and evaluating current literature on autologous fat grafting. A comprehensive search of PubMed and the Cochrane Database of Systematic Reviews was performed by using the following search terms: autologous fat grafting, autogenous fat grafting, autologous fat transfer, autogenous fat transfer, autologous fat filler, autogenous fat filler, fat harvest, adipocyte harvest, lipoaspirate, lipotransfer, lipoinjection, lipoinfiltration, fat augmentation, adipose augmentation, adipocyte augmentation, and adipocyte graft.

Search limits restricted results to English-language articles that were indexed as human studies, clinical trials, randomized controlled trials, systematic reviews, case series, or case reports. As a task force member was fluent in French, French-language manuscripts were included if they were relevant to the breast, which was the main focus of the task force. The original search resulted in 187 articles. Excluded from the literature selection were most articles addressing fat grafting with other types of grafts (i.e., dermal fat grafts) and fat grafting for non–plastic surgery applications. Articles of this nature were included only if deemed critical to the review (i.e., for review of complications). Also excluded were articles for which we were unable to access full text. Based on these final criteria, 110 articles were included in this review.

Critical Appraisal of the Literature

Relevant articles were categorized by study type: randomized controlled trial, systematic review, cohort study, case-control study, case series, or case report. Each article was critically appraised for study quality and assigned a corresponding level of evidence according to American Society of Plastic Surgeons Evidence Rating Scales (Table 1).

Development of Clinical Practice Recommendations

Practice recommendations were developed through critical appraisal of the literature and consensus of the American Society of Plastic Surgeons Fat Graft Task Force. Recommendations are based on the strength of supporting evidence and graded according to the society's Grades of Recommendation Scale (Table 2). Grade A and B recommendations were made if there were high-quality studies supporting a specific use or technique associated with fat grafting, while grade C or D recommendations were made if the level of evidence was low or inconsistent. Recommendations developed by the task force are provided throughout the document and also in Table 3.

Table 1. Evidence Rating Scale for Studies Reviewed

Level of Evidence	Qualifying Studies
I	High-quality, multicentered or single-centered, randomized controlled trial with adequate power; or systematic review of these studies
II	Lesser-quality, randomized controlled trial; prospective cohort study; or systematic review of these studies
III	Retrospective comparative study; case-control study; or systematic review of these studies
IV	Case series
V	Expert opinion; case report or clinical example; or evidence based on physiology, bench research or "first principles"

Table 2. Scale for Grading Recommendations

Grade	Descriptor	Qualifying Evidence	Implications for Practice
A	Strong recommendation	Level I evidence or consistent findings from multiple studies of levels II, III, or IV	Clinicians should follow a strong recommendation unless a clear and compelling rationale for an alternative approach is present
B	Recommendation	Levels II, III, or IV evidence and findings are generally consistent	Generally, clinicians should follow a recommendation but should remain alert to new information and sensitive to patient preferences
C	Option	Levels II, III, or IV evidence, but findings are inconsistent	Clinicians should be flexible in their decision-making regarding appropriate practice, although they may set bounds on alternatives; patient preference should have a substantial influencing role
D	Option	Level V: little or no systematic empirical evidence	Clinicians should consider all options in their decision-making and be alert to new published evidence that clarifies the balance of benefit versus harm; patient preference should have a substantial influencing role

Table 3. Task Force Recommendations Regarding Fat Grafts

Recommendation	Level of Evidence	Grade
Fat grafting may be considered for breast augmentation and correction of defects associated with medical conditions and previous breast surgeries; however, results are dependent on technique and surgeon expertise. *Because longevity of the graft is unknown, additional treatments may be necessary to obtain the desired effect. Additionally, fluctuations in body weight can affect graft volume over time.*	IV, V	B
Fat grafting can be considered a safe method of augmentation and correction of defects associated with various medical conditions. With infection being a primary concern, the need for sterile technique should be emphasized. Patients should be made aware of the potential complications and should provide written informed consent acknowledging their understanding of these risks.	I, II, III, IV	B
When determining whether or not a patient is an appropriate candidate for autologous fat grafting to the breast, physicians should exercise caution when considering high-risk patients (i.e., those with risk factors for breast cancer: BRCA-1, BRCA-2, and/or personal or familial history of breast cancer). Baseline mammography (within American College of Surgeons or American Cancer Society guidelines) is recommended.	V (expert opinion)	D

RESULTS

1. What are the current and potential applications of autologous fat grafting (specifically breast indications, and if data are available, other cosmetic and reconstructive applications)?

The evidence regarding fat grafting applications consists mostly of case series and case reports and a few small, lesser-quality experimental studies. Preliminary results are encouraging and warrant further study in the area of fat grafting for various applications.

Breast Indications

While there is at least one registered prospective clinical trial (BRAVA, clinicaltrials.gov ID: NCT00466765) and other nonregistered prospective trials involving fat grafting to the breast, no randomized controlled trials were identified during the literature search. The available literature consists mostly of case series, case reports, and expert opinion and describes fat grafting for various breast indications, both cosmetic and reconstructive[1–10] (evidence level: IV, V).

Several small case series and a case report describe fat grafting to the breast for augmentation and/or correction of defects due to medical conditions or previous breast surgeries. Combined, 283 patients had fat grafting procedures; approximate age range was 21 to 73 years.

In these reports, indications for fat grafting included:

- Micromastia
- Postaugmentation deformity, with and without removal of implant
- Tuberous breasts

- Poland's syndrome
- Postlumpectomy deformity
- Postmastectomy deformity
- Deficits caused by conservative treatment or reconstruction with implants and/or flaps (latissimus dorsi or transverse rectus abdominis muscle)
- Damaged tissue resulting from radiotherapy
- Nipple reconstruction

In most cases, fat grafting was accomplished by lipoinjection of autologous adipose tissue directly into breast tissue. Lipoinjection was performed in one to three stages, as needed. The amount of fat injected per operation per breast ranged 1.5 to 2.5 cc for nipple reconstruction, and 30 to 460 cc for augmentation and correction of defects. In contrast, one study injected fat into leaf-valve breast implants, thereby using fat as filler material instead of saline.

Of the 283 patients, most had satisfactory results, as reported by the patients and/or independent panels of surgeons. Follow-up ranged from 1 month to 10 years. Eight procedures (2.8 percent) were deemed unsuccessful (one failure in a patient receiving fat grafting to improve symptoms associated with radiotherapy damage; seven breasts (2.5 percent) showed no improvement from recontouring after reconstruction). Thirty-six complications (12.7 percent) or unfavorable sequelae were reported: three (1.1 percent) infections, 14 (4.9 percent) calcifications, 16 (5.7 percent) fat necroses, and three (1.1 percent) unspecified superficial lumps. In one study, two cases of breast cancer were diagnosed after augmentation (one in a nongrafted area; one in a potentially grafted area), but the investigators reported no delay in detection or treatment.

An additional case series, involving 30 patients who had undergone reconstruction and fat grafting for breast cancer, investigated the ability of imaging technologies to detect suspicious lesions. No interference with breast cancer detection was noted. The authors emphasize the need for biopsy in cases where imaging cannot provide definitive diagnosis.[11]

Other case reports describe complications associated with fat grafting to the breast (e.g., inflammation, calcifications, fat necrosis, and life-threatening sepsis)[12–16]; however, because most involve patients presenting to a surgeon who did not perform the procedure, details regarding the operating surgeon's technique and expertise are mostly unavailable. These reports were not included in the description of cases above.

Fat grafting may be considered for breast augmentation and correction of defects associated with medical conditions and previous breast surgeries; however, results are dependent on technique and surgeon expertise. *Because longevity of the graft is unknown, additional treatments may be necessary to obtain the desired effect. In addition, fluctuations in body weight can affect graft volume over time* (recommendation grade: B).

Other Indications

Fat grafting has also been used for the following applications; however, the task force is unable to make recommendations regarding these applications without further research and analysis:

- Gluteal augmentation and repair of contour deformities[17–21] (evidence level: IV, V)
- Facial augmentation and correction of defects[19,22–46] (evidence level: III, IV, V)
- Hand rejuvenation[47–49](evidence level: II, IV)
- Lip augmentation[50–54] (evidence level: II, IV)
- Penile enlargement and aesthetic improvement[55,56] (evidence level: IV, V)

2. What risks and complications are associated with fat grafting?

The evidence for associated risks and complications consists mainly of case series and case reports documenting complications associated with fat grafting for various plastic surgery applications.

Potential complications/risks are described below.

Anesthesia-related complications: No cases of anesthetic complications were reported. These complications are uncommon, and considering this procedure is typically done under local anesthesia, with or without sedation, the risk is considered low.

Infection [9,14,20,36,54]: Cases of prolonged inflammation, septic shock, and *Staph* infections have been documented with these procedures. Most cases resolved with antibiotic therapy (evidence level: IV, V).

Bleeding [9,21,37,46]: Cases of seroma or hematoma have been documented with these procedures. No cases, however, of unusual or severe bleeding have been presented (evidence level: IV).

Less than expected beneficial outcome [2,11,12,23,57–59]: Results from these procedures are typically reported as excellent or good; however, no standardized rating scales are available to evaluate outcome. Overall, graft volume loss, via reabsorption or necrosis, is the primary cause of poor results. Initial overcorrection, performed by an experience surgeon, can often compensate for this outcome. Instances of graft hypertrophy or over-

growth have been documented; however, they appear to be rare. Other complications affecting aesthetic results include the formation of calcified and noncalcified masses (evidence level: IV, V).

Interference with breast cancer detection [2,3,9,11–13]: Fat grafting to the breast could potentially interfere with breast cancer detection; however, no evidence was found that strongly suggests this interference. Two cases of breast cancer were reported after fat grafting to the breast, but there was no delay in detection or treatment. Radiological studies suggest that imaging technologies (ultrasound, mammography, and magnetic resonance imaging) can identify the grafted fat tissue, microcalcifications, and suspicious lesions; biopsies may be performed if needed for additional clarification. *Based on a limited number of studies with few cases, there appears to be no interference with breast cancer detection; however, more studies are needed to confirm these preliminary findings* (evidence level: IV, V).

Other risks [9,14,20,36,54,60–63]: Considering the level of invasiveness during this procedure, the occurrence of unexpected, life-threatening complications should be measured. The available literature documents a low case number of fat embolism (including one pulmonary fat embolism resulting in the death of the patient), strokes, a single case of lipoid meningitis, as well as serious cases of infection including septic shock (evidence level: I, IV, V).

Overall, complication rates associated with fat grafting are not unduly high, considering the level of invasiveness of the procedure. Cases of severe complications and death appear to be extremely rare, and causation in these cases could not be fully determined. Therefore, the task force found no compelling evidence that would warrant a strong recommendation against autologous fat grafting. The risks associated with fat grafting procedures may actually be lower than for other types of surgery; however, no high-level studies comparing fat grafting to other procedures are available, and as such, surgeons should exercise appropriate caution. Fat grafting can be considered a safe method of augmentation and correction of defects associated with various medical conditions. With infection being a primary concern, the need for sterile technique should be emphasized. Patients should be made aware of the potential complications and should provide written informed consent acknowledging their understanding of these risks. See **Figure, Supplement Digital Content 1**, for a sample consent form, ***http://links.lww.com/A1379*** (recommendation grade: B).

3. How does technique affect outcomes (safety and efficacy)?

The evidence consists mainly of case series, case reports, and animal studies describing specific techniques for several aspects of fat grafting. Evidence summaries for each aspect of fat grafting technique are presented below; however, the task force is unable to make recommendations without further research and analysis.

Harvest technique [3,24,28,49,64–73]: The primary concerns to be addressed during tissue harvest are level of invasiveness (patient safety) and tissue viability (efficacy). With this in mind, exposure to air and mechanical damage should be minimized at this step. It is suggested that tissue harvest be performed using a 3- to 4-mm blunt cannula or similar needle, while utilizing minimal amounts of suction required for tissue extraction (evidence level: IV, V).

Harvest site [74]: The primary concerns to be addressed during choice of harvest site are adequate tissue volume, which is patient specific, and patient/physician preference. There is no compelling evidence regarding harvest site and efficacy of fat grafting (evidence level: V).

Graft preparation[2,3,8,25,28,44,48,49,52,65,68,70,74–77]: To avoid contamination and maximize tissue viability, exposure to air and mechanical damage should be minimized. Many studies suggest that viable adipocytes should be separated from blood, serum, and damaged adipocytes via centrifugation (3000 rpm for 3 minutes) while still within the harvest syringe. Note, however, that centrifugation is typically described in revolutions per minute, not in terms of relative centrifugal force expressed in units of gravity. Because many microcentrifuges have settings only for speed, a formula for conversion is required to ensure that the appropriate setting is used. The relationship between revolutions per minute and relative centrifugal force is as follows: $g = (1.118 \times 10^{-5})\ R\ S^2$, where R = radius of rotor (center of rotor to sample), in centimeters, and S = speed, rpm[78] (evidence level: IV, V).

Injection technique [3,19,24,28,49,66,77]: To optimize fat graft viability, mechanical damage of the tissue to be injected should be minimized. Graft injection should be performed using a 2- to 2.5-mm blunt-tipped infusion cannula or a similar blunt needle, and with injection occurring in multiple passes in the area of augmentation, resulting in small fat deposited with each pass (evidence level: IV, V).

Injection site [7,43,69,79–83]: The primary concern to be addressed during choice of injection site in-

volves the desired outcome of the procedure, which is patient specific. The evidence does not indicate whether or not injection site significantly effects graft viability (evidence level: IV, V).

Graft storage[51,84–90]: Overall, tissue viability tends to drop significantly upon storage, which in turn may decrease fat graft efficacy. It is suggested that fat tissue be used fresh (evidence level: IV, V).

Use of epinephrine and lidocaine at the donor site[91]: The use of either epinephrine or lidocaine has not been shown to affect graft viability, though thorough investigations have not been performed. It is suggested that use of anesthetics at the injection site be minimally applied (evidence level: V).

4. What risk factors need to be considered for patient selection at this level of invasiveness?

No evidence was found that specifically addressed patient selection. Therefore, the recommendation was developed by consensus of the task force and is considered expert opinion. When determining whether or not a patient is an appropriate candidate for autologous fat grafting to the breast, physicians should exercise caution when considering high-risk patients (i.e., those with risk factors for breast cancer: BRCA-1, BRCA-2, and/or personal or familial history of breast cancer). Baseline mammography (within American College of Surgeons or American Cancer Society guidelines) is recommended (recommendation grade: D).

5. What advancements in bench research/molecular biology potentially impact current or future methods of autologous fat grafting?

The current evidence consists primarily of in vitro and animal studies describing cell/tissue manipulation to improve viability.[41,80,84,86–89,92–111] These studies include variations in co-injection additives, pretreatment of graft site, and/or adipose tissue studies addressing compensatory increase fat response, oxygen requirements for graft viability, cell-culture techniques, graft storage and cryopreservation, and assays for graft survival. No randomized controlled trials were identified during the literature search. The nature of this question and lack of human data limit our ability to make recommendations; however, many of the studies indicate potential efficacy, justifying further research in these areas (evidence level: V).

CONCLUSIONS

Clinical Applications

Based on a review of the current literature and a lack of strong data, the task force cannot make specific recommendations for the clinical use of fat grafts. Although fat grafts may be considered for use in the breast and other sites, the specific techniques of graft harvesting, preparation, and injection are not standardized. The results, therefore, may vary depending on the surgeon's technique and experience with the procedure. Although there are few data to provide evidence for long-term safety and efficacy of fat grafting, the reported complications suggest that there are associated risks. Regarding fat grafting to the breast, there are no reports suggesting an increased risk of malignancy associated with fat grafting. There is a potential risk of fat grafts interfering with breast physical examination or breast cancer detection; however, the limited data available suggest that fat grafts may not interfere with radiologic imaging in detecting breast cancer.

Future Research

The task force believes autologous fat grafting is a promising and clinically relevant research topic. The current fat grafting literature is limited primarily to case studies, leaving a tremendous need for high-quality clinical studies. While this evidence-based review resulted in few, if any, new data that would prompt a substantial change in the current state of fat grafting, the lack of new information poses two important questions: (1) are current methods of fat grafting still the accepted standard, or (2) is more research needed and should funding be directed toward new studies? For many aspects of fat grafting, the task force found the latter to be true and has suggested the following areas for future research:

- Randomized controlled trials to assess safety and efficacy of fat grafting for different indications
- Randomized controlled trials to assess safety and efficacy of specific fat grafting techniques
- Studies to further assess the effect of fat grafting on breast cancer detection and treatment
- Studies to identify risk factors and improve patient selection for procedures involving fat grafting
- Studies to investigate aspects of cell/tissue viability and graft survival, as well as long-term storage and banking of fat grafts.

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APPENDIX

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REFERENCES

1. Amar O, Bruant-Rodier C, Lehmann S, et al. [Fat tissue transplant: Restoration of the mammary volume after conservative treatment of breast cancers, clinical and radiological considerations.] *Ann Chir Plast Esthet.* 2007;53:169.
2. Yoshimura K, Sato K, Aoi N, et al. Cell-assisted lipotransfer for cosmetic breast augmentation: Supportive use of adipose-derived stem/stromal cells. *Aesthet Plast Surg.* 2008;32:48.
3. Coleman SR, Saboeiro AP. Fat grafting to the breast revisited: Safety and efficacy. *Plast Reconstr Surg.* 2007;119:775.
4. Rigotti G, Marchi A, Galie M, et al. Clinical treatment of radiotherapy tissue damage by lipoaspirate transplant: A healing process mediated by adipose-derived adult stem cells. *Plast Reconstr Surg.* 2007;119:1409.
5. Missana MC, Laurent I, Barreau L, et al. Autologous fat transfer in reconstructive breast surgery: Indications, technique and results. *Eur J Surg Oncol.* 2007;33:685.
6. Spear SL, Wilson HB, Lockwood MD. Fat injection to correct contour deformities in the reconstructed breast. *Plast Reconstr Surg.* 2005;116:1300.
7. Bernard RW, Beran SJ. Autologous fat graft in nipple reconstruction. *Plast Reconstr Surg.* 2003;112:964.
8. Fulton JE. Breast contouring with "gelled" autologous fat: A 10-year update. *Int J Cosmet Surg Aesthet Dermatol.* 2003;5:155.
9. Hang-Fu L, Marmolya G, Feiglin DH. Liposuction fat-fillant implant for breast augmentation and reconstruction. *Aesthet Plast Surg.* 1995;19:427.
10. Bircoll M. Cosmetic breast augmentation utilizing autologous fat and liposuction techniques. *Plast Reconstr Surg.* 1987;79:267.
11. Pierrefeu-Lagrange AC, Delay E, Guerin N, et al. [Radiological evaluation of breasts reconstructed with lipomodeling.] *Ann Chir Plast Esthet.* 2006;51:18.
12. Pulagam SR, Poulton T, Mamounas EP. Long-term clinical and radiologic results with autologous fat transplantation for breast augmentation: Case reports and review of the literature. *Breast J.* 2006;12:63.
13. Kwak JY, Lee SH, Park H, et al. Sonographic findings in complications of cosmetic breast augmentation with autologous fat obtained by liposuction. *J Clin Ultrasound* 2004; 32:299.
14. Valdatta L, Thione A, Buoro M, et al. A case of life-threatening sepsis after breast augmentation by fat injection. *Aesthet Plast Surg.* 2001;25:347.
15. Haik J, Talisman R, Tamir J, et al. Breast augmentation with fresh-frozen homologous fat grafts. *Aesthet Plast Surg.* 2001; 25:292.
16. Castello JR, Barros J, Vazquez R. Giant liponecrotic pseudocyst after breast augmentation by fat injection. *Plast Reconstr Surg.* 1999;103:291.
17. Harrison D, Selvaggi G. Gluteal augmentation surgery: Indications and surgical management. *J Plast Reconstr Aesthet Surg.* 2007;60:922.
18. Murillo WL. Buttock augmentation: Case studies of fat injection monitored by magnetic resonance imaging. *Plast Reconstr Surg.* 2004;114:1606.
19. Monreal J. Fat tissue as a permanent implant: New instruments and refinements. *Aesthet Surg J.* 2003;23:213.
20. Restrepo JCC, Ahmed JAM. Large-volume lipoinjection for gluteal augmentation. *Aesthet Surg J.* 2002;22:33.
21. Roberts TL, Toledo LS, Badin AZ. Augmentation of the buttocks by micro fat grafting. *Aesthet Surg J.* 2001;21:311.
22. Cardenas JC, Carvajal J. Refinement of rhinoplasty with lipoinjection. *Aesthet Plast Surg.* 2007;31:501.
23. Coleman SR. Lower lid deformity secondary to autogenous fat transfer: A cautionary tale. *Aesthet Plast Surg.* 2008; 32: 415.
24. Guyuron B, Majzoub RK. Facial augmentation with core fat graft: A preliminary report. *Plast Reconstr Surg.* 2007;120: 295.
25. Hu S, Zhang H, Feng Y, et al. Introduction of an easy technique for purification and injection of autogenous free fat parcels in correcting of facial contour deformities. *Ann Plast Surg.* 2007;58:602.
26. Kaufman MR, Bradley JP, Dickinson B, et al. Autologous fat transfer national consensus survey: Trends in techniques for harvest, preparation, and application, and perception of short- and long-term results. *Plast Reconstr Surg.* 2007;119: 323.
27. Sardesai MG, Moore CC. Quantitative and qualitative dermal change with microfat grafting of facial scars. *Otolaryngol Head Neck Surg.* 2007;137:868.
28. Coleman SR. Structural fat grafting: More than a permanent filler. *Plast Reconstr Surg.* 2006;118:108S.

29. Domergue S, Psomas C, Yachouh J, et al. Fat microinfiltration autografting for facial restructuring in HIV patients. *J Craniomaxillofac Surg.* 2006;34:484.
30. Narins RS, Tope WD, Pope K, et al. Overtreatment effects associated with a radiofrequency tissue-tightening device: Rare, preventable, and correctable with subcision and autologous fat transfer. *Dermatol Surg.* 2006;32:115.
31. Pontius AT, Williams EF III. The evolution of midface rejuvenation: Combining the midface-lift and fat transfer. *Arch Facial Plast Surg.* 2006;8:300.
32. Burnouf M, Buffet M, Schwarzinger M, et al. Evaluation of Coleman lipostructure for treatment of facial lipoatrophy in patients with human immunodeficiency virus and parameters associated with the efficiency of this technique. *Arch Dermatol.* 2005;141:1220.
33. Ellenbogen R, Motykie G, Youn A, et al. Facial reshaping using less invasive methods. *Aesthet Surg J.* 2005;25:144.
34. Guaraldi G, Orlando G, De Fazio D, et al. Comparison of three different interventions for the correction of HIV-associated facial lipoatrophy: A prospective study. *Antivir Ther.* 2005;10:753.
35. Kanchwala SK, Holloway L, Bucky LP. Reliable soft tissue augmentation: A clinical comparison of injectable soft-tissue fillers for facial-volume augmentation. *Ann Plast Surg.* 2005;55:30.
36. Kuran I, Tumerdem B. A new simple method used to prepare fat for injection. *Aesthet Plast Surg.* 2005;29:18.
37. Ellenbogen R, Youn A, Yamini D, et al. The volumetric face lift. *Aesthet Surg J.* 2004;24:514.
38. Karabulut AB, Tumerdem B. Obtaining predictable results in malar augmentation with preimplant fat injection. *Plast Reconstr Surg.* 2004;114:1974.
39. Serra-Renom JM, Fontdevila J. Treatment of facial fat atrophy related to treatment with protease inhibitors by autologous fat injection in patients with human immunodeficiency virus infection. *Plast Reconstr Surg.* 2004;114:551.
40. Dasiou-Plakida D. Fat injections for facial rejuvenation: 17 years experience in 1720 patients. *J Cosmet Dermatol.* 2003;2:119.
41. Sadick NS, Hudgins LC. Fatty acid analysis of transplanted adipose tissue. *Arch Dermatol.* 2001;137:723.
42. Berman M. Rejuvenation of the upper eyelid complex with autologous fat transplantation. *Dermatol Surg.* 2000;26:1113.
43. Cortese A, Savastano G, Felicetta L. Free fat transplantation for facial tissue augmentation. *J Oral Maxillofac Surg.* 2000;58:164.
44. Erol OO. Facial autologous soft-tissue contouring by adjunction of tissue cocktail injection (micrograft and minigraft mixture of dermis, fascia, and fat). *Plast Reconstr Surg.* 2000;106:1375.
45. Reiche-Fischel O, Wolford LM, Pitta M. Facial contour reconstruction using an autologous free fat graft: A case report with 18-year follow-up. *J Oral Maxillofac Surg.* 2000;58:103.
46. Guerrerosantos J. Simultaneous rhytidoplasty and lipoinjection: A comprehensive aesthetic surgical strategy. *Plast Reconstr Surg.* 1998;102:191.
47. Butterwick KJ, Bevin AA, Iyer S. Fat transplantation using fresh versus frozen fat: A side-by-side two-hand comparison pilot study. *Dermatol Surg.* 2006;32:640.
48. Butterwick KJ. Lipoaugmentation for aging hands: A comparison of the longevity and aesthetic results of centrifuged versus noncentrifuged fat. *Dermatol Surg.* 2002;28:987.
49. Coleman SR. Hand rejuvenation with structural fat grafting. *Plast Reconstr Surg.* 2002;110:1731.
50. Duskova M, Kristen M. Augmentation by autologous adipose tissue in cleft lip and nose: Final esthetic touches in clefts. Part I. *J Craniofac Surg.* 2004;15:478.
51. Bertossi D, Zancanaro C, Trevisiol L, et al. Lipofilling of the lips. *Arch Facial Plastic Surg.* 2003;5:392.
52. To WC, Seeley BM, Castor S, et al. One-year survival of AlloDerm allogenic sermal graft and fat autograft in lip augmentation. *Aesthet Surg J.* 2002;22:349.
53. Fulton JE Jr, Rahimi AD, Helton P, et al. Lip rejuvenation. *Dermatol Surg.* 2000;26:470.
54. Niechajev I. Lip enhancement: Surgical alternatives and histologic aspects. *Plast Reconstr Surg.* 2000;105:1173.
55. Panfilov DE. Augmentative phalloplasty. *Aesthet Plast Surg.* 2006;30:183.
56. Spyropoulos E, Christoforidis C, Borousas D, et al. Augmentation phalloplasty surgery for penile dysmorphophobia in young adults: Considerations regarding patient selection, outcome evaluation and techniques applied. *Eur Urol.* 2005;48:121.
57. Guaraldi G, De Fazio D, Orlando G, et al. Facial lipohypertrophy in HIV-infected subjects who underwent autologous fat tissue transplantation. *Clin Infect Dis.* 2005;40:e13–e15.
58. Miller JJ, Popp JC. Fat hypertrophy after autologous fat transfer. *Ophthal Plast Reconstr Surg.* 2002;18:228.
59. Latoni JD, Marshall DM, Wolfe SA. Overgrowth of fat autotransplanted for correction of localized steroid-induced atrophy. *Plast Reconstr Surg.* 2000;106:1566.
60. Yoon SS, Chang DI, Chung KC. Acute fatal stroke immediately following autologous fat injection into the face. *Neurology* 2003;61:1151.
61. Lee PE, Kung RC, Drutz HP. Periurethral autologous fat injection as treatment for female stress urinary incontinence: A randomized double-blind controlled trial. *J Urol.* 2001;165:153.
62. Ricaurte JC, Murali R, Mandell W. Uncomplicated postoperative lipoid meningitis secondary to autologous fat graft necrosis. *Clin Infect Dis.* 2000;30:613.
63. Feinendegen DL, Baumgartner RW, Schroth G, et al. Middle cerebral artery occlusion and ocular fat embolism after autologous fat injection in the face. *J Neurol.* 1998;245:53.
64. Gonzalez AM, Lobocki C, Kelly C, et al. An alternative method for harvest and processing fat grafts: An in vitro study of cell viability and survival. *Plast Reconstr Surg.* 2007;120:285.
65. Piasecki JH, Gutowski KA, Lahvis G, et al. An experimental model for improving fat graft viability and purity. *Plast Reconstr Surg.* 2007;119:1571.
66. Özsoy Z, Kul Z, Bilir A. The role of cannula diameter in improved adipocyte viability: A quantitative analysis. *Aesthet Surg J.* 2006;26:287.
67. Pu LL, Cui X, Fink B, et al. The viability of fatty tissues within adipose aspirates after conventional liposuction: A comprehensive study. *Ann Plast Surg.* 2005;54:288.
68. Karacalar A, Orak I, Kaplan S, et al. No-touch technique for autologous fat harvesting. *Aesthet Plast Surg.* 2004;28:158.
69. Baran CN, Celebioglu S, Sensoz O, et al. The behavior of fat grafts in recipient areas with enhanced vascularity. *Plast Reconstr Surg.* 2002;109:1646.
70. Jackson IT, Simman R, Tholen R, et al. A successful long-term method of fat grafting: Recontouring of a large subcutaneous postradiation thigh defect with autologous fat transplantation. *Aesthet Plast Surg.* 2001;25:165.
71. Shiffman MA, Mirrafati S. Fat transfer techniques: The effect of harvest and transfer methods on adipocyte viability and review of the literature. *Dermatol Surg.* 2001;27:819.

72. Lalikos JF, Li YQ, Roth T, et al. Biochemical assessment of cellular damage after adipocyte harvest. *J Surg Res.* 1997; 70:95.
73. Fagrell D, Eneström S, Berggren A, Kniola B. Fat cylinder transplantation: An experimental comparative study of three different kinds of fat transplants. *Plast Reconstr Surg.* 1996;98:90.
74. Rohrich RJ, Sorokin ES, Brown SA. In search of improved fat transfer viability: A quantitative analysis of the role of centrifugation and harvest site. *Plast Reconstr Surg.* 2004; 113:391.
75. Rose JG Jr, Lucarelli MJ, Lemke B, et al. Histologic comparison of autologous fat processing methods. *Ophthal Plast Reconstr Surg.* 2006;22:195.
76. Smith P, Adams WP Jr, Lipschitz A, et al. Autologous human fat grafting: Effect of harvesting and preparation techniques on adipocyte graft survival. *Plast Reconstr Surg.* 2006; 117:1836.
77. Ersek RA, Chang P, Salisbury MA. Lipo layering of autologous fat: An improved technique with promising results. *Plast Reconstr Surg.* 1998;101:820.
78. Bishop ML, Fody EP, Schoeff L. *Clinical Chemistry: Principles, Procedures, Correlations.* Baltimore: Lippincott, Williams & Wilkins; 2004.
79. Karacaoglu E, Kizilkaya E, Cermik H, et al. The role of recipient sites in fat-graft survival: Experimental study. *Ann Plast Surg.* 2005;55:63.
80. Lacy EL, Bartness TJ. Effects of white adipose tissue grafts on total body fat and cellularity are dependent on graft type and location. *Am J Physiol Regul Integr Comp Physiol.* 2005; 289:R380–R388.
81. Aygit AC, Sarikaya A, Doganay L, et al. The fate of intramuscularly injected fat autografts: An experimental study in rabbits. *Aesthet Plast Surg.* 2004;28:334.
82. Guerrerosantos J, Gonzalez-Mendoza A, Masmela Y, et al. Long-term survival of free fat grafts in muscle: An experimental study in rats. *Aesthet Plast Surg.* 1996;20:403.
83. Samdal F Skolleborg KC, Berthelsen B. The effect of preoperative needle abrasion of the recipient site on survival of autologous free fat grafts in rats. *Scand J Plast Reconstr Surg Hand Surg.* 1992;26:33.
84. Atik B, Ozturk G, Erdogan E, et al. Comparison of techniques for long-term storage of fat grafts: An experimental study. *Plast Reconstr Surg.* 2006;118:1533.
85. Pu LLQ, Cui X, Li J, et al. The fate of cryopreserved adipose aspirates after in vivo transplantation. *Aesthet Surg J.* 2006; 26:653.
86. Moscatello DK, Dougherty M, Narins R, et al. Cryopreservation of human fat for soft tissue augmentation: Viability requires use of cryoprotectant and controlled freezing and storage. *Dermatol Surg.* 2005;31:1506.
87. Wolter TP, von Heimburg D, Stoffels I, et al. Cryopreservation of mature human adipocytes: In vitro measurement of viability. *Ann Plast Surg.* 2005;55:408.
88. MacRae JW, Tholpady SS, Ogle R, et al. Ex vivo fat graft preservation: Effects and implications of cryopreservation. *Ann Plast Surg.* 2004;52:281.
89. Shoshani O, Ullmann Y, Shupak A, et al. The role of frozen storage in preserving adipose tissue obtained by suction-assisted lipectomy for repeated fat injection procedures. *Dermatol Surg.* 2001;27:645.
90. Lidagoster MI, Cinelli PB, Levee E, et al. Comparison of autologous fat transfer in fresh, refrigerated, and frozen specimens: An animal model. *Ann Plast Surg.* 2000;44:512.
91. Shoshani O, Berger J, Fodor L, et al. The effect of lidocaine and adrenaline on the viability of injected adipose tissue: An experimental study in nude mice. *J Drugs Dermatol.* 2005;4: 311.
92. Karacal N, Cobanoglu U, Ambarcioglu O, et al. The effect of fibrin glue on fat graft survival. *J Plast Reconstr Aesthet Surg.* 2007;60:300.
93. Rubin JP, Bennett JM, Doctor J, et al. Collagenous microbeads as a scaffold for tissue engineering with adipose-derived stem cells. *Plast Reconstr Surg.* 2007;120:414.
94. Torio-Padron N, Baerlecken N, Momeni A, et al. Engineering of adipose tissue by injection of human preadipocytes in fibrin. *Aesthet Plast Surg.* 2007;31:285.
95. Witort EJ, Pattarino J, Papucci L, et al. Autologous lipofilling: Coenzyme Q10 can rescue adipocytes from stress-induced apoptotic death. *Plast Reconstr Surg.* 2007;119:1191.
96. Clavijo-Alvarez JA, Rubin JP, Bennett J, et al. A novel perfluoroelastomer seeded with adipose-derived stem cells for soft-tissue repair. *Plast Reconstr Surg.* 2006;118:1132.
97. Pu LL, Cui X, Fink B, et al. Adipose aspirates as a source for human processed lipoaspirate cells after optimal cryopreservation. *Plast Reconstr Surg.* 2006;117:1845.
98. Yazawa M, Mori T, Tuchiya K, et al. Influence of vascularized transplant bed on fat grafting. *Wound Repair Regen.* 2006; 14:586.
99. Yi CG, Xia W, Zhang L, et al. VEGF gene therapy for the survival of transplanted fat tissue in nude mice. *J Plast Reconstr Aesthet Surg.* 2007;60:272.
100. Yi C, Pan Y, Zhen Y, et al. Enhancement of viability of fat grafts in nude mice by endothelial progenitor cells. *Dermatol Surg.* 2006;32:1437.
101. Goehde SC, Kuehl H, Ladd ME. Magnetic resonance imaging of autologous fat grafting. *Eur Radiol.* 2005;15:2423.
102. Yamaguchi M, Matsumoto F, Bujo H, et al. Revascularization determines volume retention and gene expression by fat grafts in mice. *Exp Biol Med (Maywood)* 2005;230:742.
103. Lacy EL, Bartness TJ. Autologous fat transplants influence compensatory white adipose tissue mass increases after lipectomy. *Am J Physiol Regul Integr Comp Physiol.* 2004;286: R61–R70.
104. Rehman J, Traktuev D, Li J, et al. Secretion of angiogenic and antiapoptotic factors by human adipose stromal cells. *Circulation* 2004;109:1292.
105. Rieck B, Schlaak S. Measurement in vivo of the survival rate in autologous adipocyte transplantation. *Plast Reconstr Surg.* 2003;111:2315.
106. Rieck B, Schlaak S. In vivo tracking of rat preadipocytes after autologous transplantation. *Ann Plast Surg.* 2003;51:294.
107. Huss FR, Kratz G. Adipose tissue processed for lipoinjection shows increased cellular survival in vitro when tissue engineering principles are applied. *Scand J Plast Reconstr Surg Hand Surg.* 2002;36:166.
108. Nishimura T, Hashimoto H, Nakanishi I, et al. Microvascular angiogenesis and apoptosis in the survival of free fat grafts. *Laryngoscope* 2000;110:1333.
109. Shoshani O, Shupak A, Ullmann Y, et al. The effect of hyperbaric oxygenation on the viability of human fat injected into nude mice. *Plast Reconstr Surg.* 2000;106:1390.
110. Stashower M, Smith K, Williams J, et al. Stromal progenitor cells present within liposuction and reduction abdominoplasty fat for autologous transfer to aged skin. *Dermatol Surg.* 1999;25:945.
111. Canady JW, Thompson SA, Moon J, et al. Augmentation of oral tissues in rabbit using autogenous fat. *Cleft Palate Craniofac J.* 1995;32:1.