The Volumetric Analysis of Fat Graft Survival in Breast Reconstruction

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Background: Fat grafting has emerged as a useful method for breast contouring in aesthetic and reconstructive patients. Advancements have been made in fat graft harvest and delivery, but the ability to judge the overall success of fat grafting remains limited. The authors applied three-dimensional imaging technology to assess volumetric fat graft survival following autologous fat transfer to the breast.

Methods: Fat grafting surgery was performed using a modified Coleman technique in breast reconstruction. Patients undergoing the procedure were entered into the study prospectively and followed. Three-dimensional imaging was performed using the Canfield Vectra system and analyzed using Geomagic software. Breasts were isolated as closed objects, and total breast volume was calculated on every scan.

Results: The data stratified patients into three groups with statistically significant parameters based on the volume of fat injected. The largest injected group (average volume, 151 cc) retained a volume of 86.9 percent (7 days postoperatively), 81.1 percent (16 days), 57.5 percent (49 days), and 52.3 percent (140 days). The smallest group (average, 51 cc) retained a volume of 87.9 percent (7 days postoperatively), 75.8 percent (16 days), 56.6 percent (49 days), and 27.1 percent (140 days). The intermediate group (average, 93 cc) retained 90.3 percent (7 days postoperatively), 74 percent (16 days), 45.7 percent (49 days), and 38.1 percent (140 days). Of note, irradiation or prior breast procedure type did not seem to affect the volume retention rate.

Conclusions: The authors' data suggest that fat retention is volume and time dependent. Patients receiving higher volumes of injected fat had slower volume loss and greater total volume retention. (*Plast. Reconstr. Surg.* 131: 185, 2013.)

The use of autologous fat grafting is not a new concept in the field of plastic and reconstructive surgery. Van der Meulen first documented the idea of harvesting and transplanting fat to correct soft-tissue defects in the late nineteenth century.[1,2] In 1895, Czerny first described fat grafting for breast reconstruction to improve lumpectomy defects.[3] However, fat grafting lacked widespread acceptance secondary to a high incidence of fat necrosis and cumbersome techniques for tissue transfer.

In recent years, Coleman and others have offered significant advancements in fat transfer to minimize the incidence of necrosis and improve aesthetic outcomes.[3–8] Thus, plastic surgeons have witnessed resurgence in the use of autologous fat as a tool for correcting primary and secondary breast deformities. Fat transfer not only offers a natural alternative to alloplastic implants but is unique in its ability to transfer small quantities of fat to localized areas of deficiency.

A wealth of literature has emerged focusing on issues such as ideal medium, harvesting and trans-

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ferring techniques, and postoperative complications in relation to breast cancer screening.[8–11] One area, however, that has yet to be studied well is the quantification of fat survival after transfer. The distribution patterns after fat injection remain entirely unknown. Spear and Coleman have reported the use of two-dimensional photography to evaluate the degree of improvement following fat grafting, but this approach has significant limitations. Specific morphometric values (breast volume, symmetry, breast shape, and contour) remain outside the scope of such analytic methods. Attempts to integrate more objective measuring tools such as water displacement, thermophilic casting, and magnetic resonance imaging–constructed three-dimensional models have been limited because of their cumbersome and time-consuming nature.[12–16] Thus, no accurate and reproducible tool exists with which to quantify the outcomes after fat transfer.

Three-dimensional photography has already been shown to be a valuable resource for the assessment of symmetry, shape, and contour. Our group has recently shown three-dimensional surface imaging as a useful device to accurately quantify the volumetric changes during the postoperative period following aesthetic and reconstructive breast surgery.[17] Based on this work, we introduced a novel analytical concept of mammometrics to quantify breast volume and shape.[17–19] This work serves as the foundation of the following article, which quantifies for the first time the amount of volume retention following autologous fat transfer to the breast. Thus, three-dimensional imaging may help achieve an objective approach for analyzing surgical outcomes of autologous fat transfer in terms of volumetric survival, shape preservation, and fat graft migration.

PATIENTS AND METHODS

Patients undergoing autologous fat injection surgery to the breast were offered enrollment into this study. Categories of patients included (1) revision of autologous breast reconstruction, (2) revision of implant-based breast reconstruction, and (3) revision after lumpectomy/partial mastectomy surgery. All patients were treated by one of the senior authors (N.S.K. or M.C.). Informed consent was obtained in accordance with the New York University Medical Center Institutional Review Board. All operations were performed using a modified Coleman technique in a closed system. Fat was harvested by suction-assisted lipectomy and transferred to a standard centrifuge at 3000 rpm for 3 minutes, and the middle layer of cells was injected into the recipient tissue.[8] The amount of fat injected and the injection sites were recorded intraoperatively for each revised breast.

Three-Dimensional Imaging and Volumetric Analysis

The imaging modality used was similar to that described in previous works by our group,[17] where the Canfield Vectra 3 pod system (Canfield Scientific, Fairfield, N.J.) captures the images (Fig. 1). Images were obtained preoperatively and at the standard subsequent postoperative visits routinely followed by the senior authors. On average, these visits were 7, 16, 49, and 140 days postoperatively. At those time points, three-dimensional measurements were calculated.

Constructed surface scans were imported into a secondary three-dimensional software program (Geomagic Studio 11; Geomagic, Inc., Research Triangle Park, N.C.) for all volumetric data analysis. Breast volumes were calculated using an established algorithm as described in previous work by our group.[17–19] All preoperative and postoperative breast images were aligned to reference x, y, and z coordinate axes, and total breast volume was computed for each breast. Breast volumes were recorded in cubic centimeter pixels (1 cm^3 = 1 cc). A sample timeline of breast images and associated volumes are shown in Figure 2.

RESULTS

In this study, 90 patients (123 breasts; average age, 49.6 years) underwent fat grafting. The body mass index for all patients did not have any statistically significant changes over the time period of this study. Of note, there were no complications (i.e., infections or hematomas) after fat grafting.

The patients were stratified into subgroups to analyze significant relationships between fat grafting and the recipient tissue. The first data breakdown divided the patients into three subgroups with statistically significant parameters based on the volume of fat injected. The first group (40 breasts) received the largest volume of fat (range, 111 to 216 cc), with an average injection volume of 151 cc, and retained 86.9 percent volume after 7 days, 81.1 percent at 16 days, 57.5 percent at 49 days, and 52.3 percent at 140 days. These findings contrast with the patients (42 breasts) who received a smaller fat volume, who had an average injection volume of 51 cc (range, 12 to 72 cc), and maintained 87.9 percent volume after 7 days, 75.8 percent by 16 days, 56.6 percent at 49 days, and 27.1 percent at 140 days. The third patient group

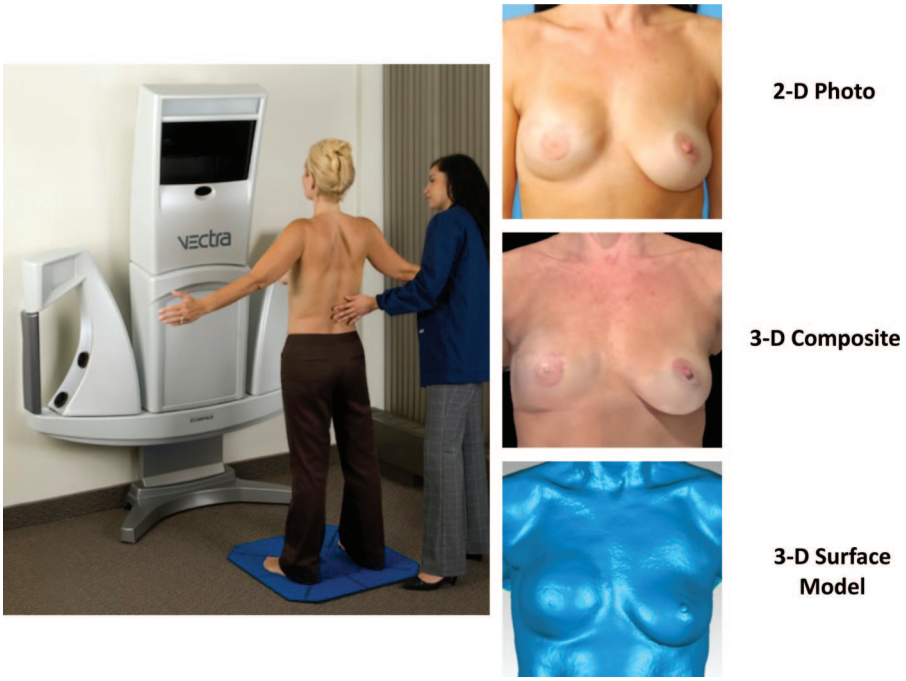


Fig. 1. Preoperative and postoperative two-dimensional (*2-D*) and three-dimensional (*3-D*) imaging was performed using the Canfield Vectra XT.

(41 breasts) received an intermediate volume (range, 75 to 108 cc) of fat grafting, with an average injected volume of 93 cc, and retained 90.3 percent volume after 7 days, 74.0 percent by 16 days, 45.7 percent at 49 days, and 38.1 percent at 140 days. At the last time point, the largest injection volume subset demonstrated a statistically significant higher volumetric retention in comparison with the other two groups; no other time points were statistically significant (Fig. 3).

The second patient stratification divided patients into those who received radiation therapy and those who did not. In the observed time period, there were 28 irradiated breasts and 95 breasts that were not irradiated. Average fat injected into the breast was 97.58 cc for the nonirradiated breasts and 105.04 cc for the irradiated breasts. In the irradiated subset, patients underwent fat grafting approximately 1.5 years after radiation treatment. For the nonirradiated breasts, at 7 days postoperatively, the breasts had 88.7 percent volume retention; at 16 days postoperatively, 75.5 percent volume retention; at 49 days postoperatively, 57.3 percent volume retention; and at 140 days, 43.3 percent volume retention. For the irradiated breasts, at 7 days postoperatively, the breasts had 86.7 percent volume retention; at 16 days postoperatively, 69.7 percent volume retention; at 49 days postoperatively, 59.8 percent volume retention; and at 140 days, 41.7 percent volume retention. No statistical difference was found between the two groups at any time point (Fig. 4).

The third patient classification divided patients into subgroups based on type of prior surgery: 12 lumpectomy breasts (11 patients), 32 autologous reconstruction breasts (19 patients), and 79 implant reconstruction breasts (51 patients). For the lumpectomy breast patients, at 7 days postoperatively, the breasts had 92.4 percent volume retention; at 16 days postoperatively, 73.2 percent volume retention; at 49 days postoperatively, 59.4 percent volume retention; and at 140 days, 56.3 percent volume retention. For the autologous reconstruction patients, at 7 days postoperatively, the breasts had 87.5 percent volume retention; at 16 days postoperatively, 81.5 percent volume retention; at 49 days postoperatively, 59.0 percent volume retention; and at 140 days, 31.4 percent volume retention. For the implant reconstruction patients, at 7 days postoperatively, the breasts had 87.7 percent volume retention; at 16 days postoperatively, 72.7 percent volume retention; at 49 days postoperatively, 58.5 percent volume retention; and at 140 days, 42.2 percent volume retention. At postoperative day 7, the lumpectomy reconstruction subset had statistically significant higher volume retention than the autologous reconstruction subset. At postoperative day 16, the

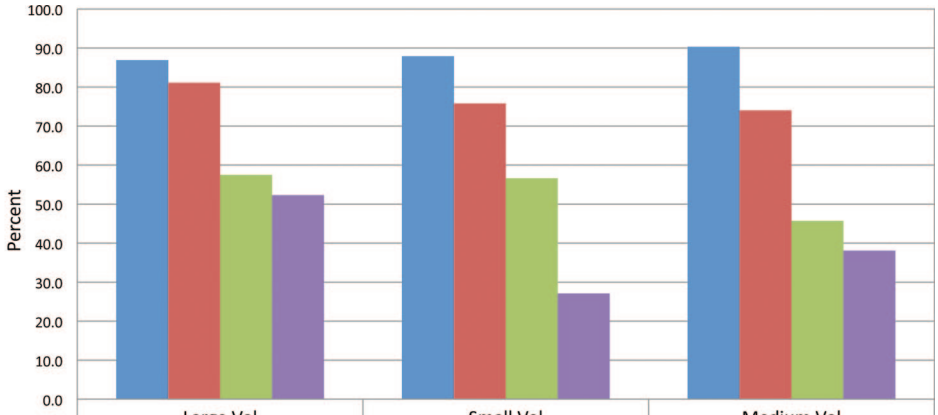
Fig. 2. A sample timeline of breast images and associated injection volumes are depicted for small-, medium-, and large-volume fat transfers. (*Above*) A 47-year-old patient following bilateral deep inferior epigastric perforator flap surgery with preoperative, 1-week, and 24-week postoperative images. Small fat volume injected (left breast, 54 cc). (*Center*) A 46-year-old patient following bilateral implant surgery and irradiation in her right breast with preoperative, 1-week postoperative, and 20-week postoperative images. Medium fat volume injected (right breast, 102 cc; left breast, 105 cc). (*Below*) A 42-year-old patient after left transverse rectus abdominis musculocutaneous flap surgery with preoperative, 1-week postoperative, and 12-week postoperative images. Large fat volume injected (left breast, 177.9 cc).

autologous reconstruction subset had statistically significant higher volume retention than the implant reconstruction subset. No other statistical difference was found among the three groups at the various time points (Fig. 5).

DISCUSSION

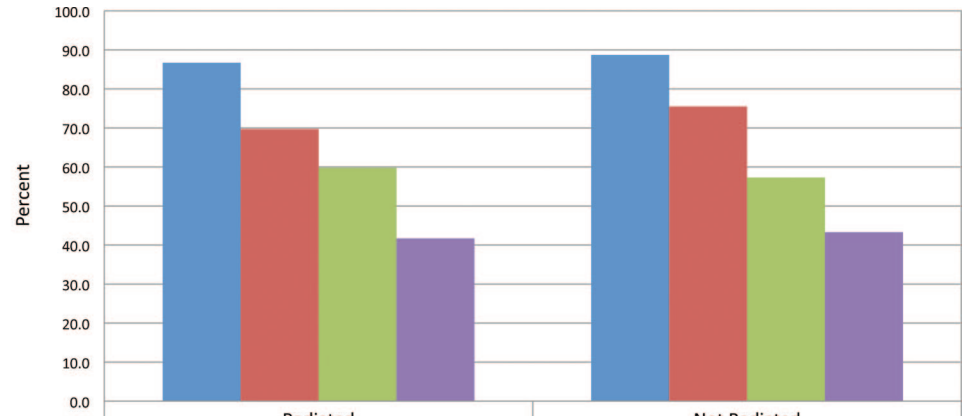
Various advancements have been made in the techniques of fat graft harvest and delivery, but our ability to judge the overall success of fat grafting objectively remains limited. Previously, we reported the use of three-dimensional imaging to assess breast morphology in patients undergoing reduction mammaplasty, breast augmentation, and breast reconstruction. This study applied similar three-dimensional imaging technology to quantify objectively the percentage of volume retention after fat grafting to the breast after lumpectomy, autologous breast reconstruction, and implant-based reconstruction.

Resorption of volume after autologous fat transfer to the breast is a well-documented phenomenon.[11] Our three-dimensional data affirm these subjective findings and quantify certain trends associ-



	Large Vol	Small Vol	Medium Vol
1st Week	86.9	87.9	90.3
16 Days	81.1	75.8	74.0
49 Days	57.5	56.6	45.7
140 Days	52.3	27.1	38.1

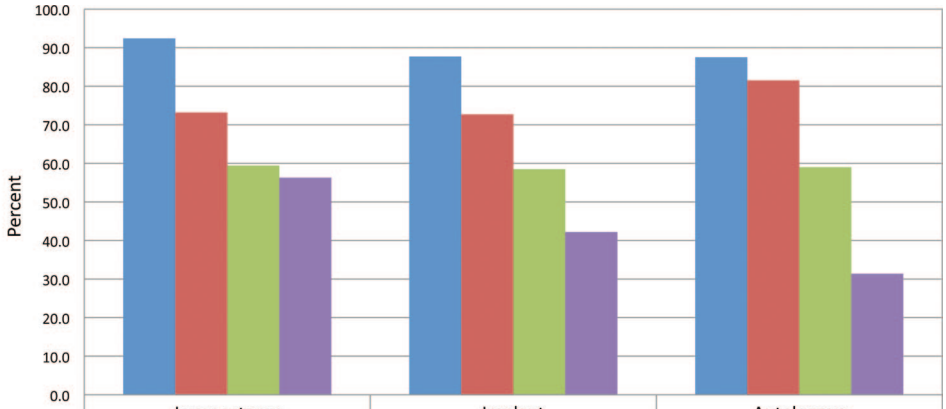
Fig. 3. Percentage volume retained over 140 days in three patient populations stratified by statistically significant differences in volumes of fat injected: large injection volume (average, 151 cc), intermediate injection volume (average, 93 cc), and small injection volume (average, 51 cc). At the last time point, the large injection volume subset has significantly higher percentage retention compared with the other two groups.



	Radiated	Not Radiated
1st Week	86.7	88.7
16 Days	69.7	75.5
49 Days	59.8	57.3
140 Days	41.7	43.3

Fig. 4. Percentage volume retained over 140 days in two patient populations divided by radiation therapy. The 28 irradiated breasts and 95 nonirradiated breasts demonstrate no statistical difference.

ated with autologous fat grafting. Evaluation of volume changes postoperatively revealed a distinct pattern of resorption percentage. Calculated volumes for all injected breasts demonstrated the largest volume percentage increase during the early postoperative period (postoperative days 5 through 23) and never dropped below the initial calculated preoperative breast volume. Of note, the difference in calculated volume between the preoperative image and first postoperative visit did not correlate with the actual fat injected. These findings are not surprising and are probably attributable to soft-tissue inflammation and edema after breast surgery. Based on the volumetric data over the observed time course, the breast tissue achieves resolution of soft-tissue edema with



	Lumpectomy	Implant	Autologous
1st Week	92.4	87.7	87.5
16 Days	73.2	72.7	81.5
49 Days	59.4	58.5	59.0
140 Days	56.3	42.2	31.4

Fig. 5. Percentage volume retained over 140 days in three patient populations stratified by surgical subtype: 12 lumpectomy breasts, 32 autologous reconstructed breasts, and 79 implant reconstruction breasts. The three groups demonstrate no long-term statistical difference.

subsequent volume retention of approximately 40 to 50 percent of injected fat by the end of 5 months postoperatively.

The analysis suggests that fat retention is volume and time dependent. Patients receiving more than 110 cc of fat graft lost the greatest percentage of volume during the first postoperative week and then the rate of volume loss tapered until volume retention stabilized to approximately half the total volume injected approximately 5 months postoperatively. Patients receiving smaller volumes of fat graft take longer to reach volume stability and have lower rates of volume retention. The curvilinear representation of the bar graph in Figure 3 reiterates these findings.

Quantitative preoperative breast dimensions may provide a blueprint with which to outline the amount of fat to be harvested, total volume to be infused, and location of injection to mimic the size and shape of the nonaffected opposite breast. For example, in patients with unilateral breast fat grafting, the average preoperative breast volume before fat grafting was 190.069 ± 64.285 cc, with the average contralateral noninjected breast volume of 261.357 ± 56.733 cc. Two months postoperatively, we found that the breast with fat injection had a volume of 286.199 ± 84.817 cc, an 8.68 percent difference in volume compared with the contralateral nonoperated side. These findings suggest that three-dimensional imaging may provide a resource to aid in presurgical planning and postoperative assessment to achieve symmetrical results.

Three-dimensional analysis provides a tool with which to monitor percentage retention associated with fat transfer and also to examine fat retention in different recipient sites. In this study, the patient population is subdivided into the following recipient sites: implant breast reconstruction, breast lumpectomy defects, and autologous breast reconstruction. We observe some statistically significant differences in volume retention in the early postoperative period, most likely secondary to acute inflammation and edema. However, these findings equalize at 49 days and 140 days; at these time points, the data identify an insignificant relationship between breast reconstruction type and percentage volume retention. Even though these recipient sites have varied composite tissues, they may behave similarly, as they all have some degree of autologous fat in the recipient subcutaneous plane. Long-term and larger studies are needed to affirm the presumed dynamics of the recipient tissue after autologous fat transfer.

Furthermore, three-dimensional analysis offers a method for examining trends associated with irradiated tissue and fat transfer. Radiation therapy for breast cancer alters underlying tissue perfusion and oxygenation, which can result in skin discoloration, subcutaneous tissue fibrosis, and associated capsular contracture of the reconstructed breast. In conjunction with these observed changes of irradiated tissue, our data identify intermittently smaller volume retention after fat transfer, but this finding is not statistically significant. Long-term and larger studies are needed

to affirm the presumed dynamics of the irradiated breast after autologous fat transfer.

The success of three-dimensional imaging to assess the viability of the breast after fat transfer provides a template with which to monitor postoperative changes of other surgical sites. Areas such as the face and the abdomen have discrete anatomical landmarks and thus could follow a similar protocol of image acquisition and data analysis to monitor postsurgical progression. Eventually, three-dimensional imaging and analysis will offer a detailed description of body asymmetry and provide a blueprint for surgical reconstruction with fat transfer.

This protocol allows for further evaluation of various donor sites. In this study, the senior authors harvested fat from various areas of the body for transfer to the breast; however, no study currently exists to delineate the ideal donor site of adipose tissue for breast reconstruction. Three-dimensional surface imaging now outlines a method to determine the outcome of fat grafting based on the viability of various anatomical sites and may eventually stipulate the ideal donor site.

Previous works have supported the validity of three-dimensional analysis, and in this study, the nonmodified breast provided an internal control reaffirming the accuracy of this technique. These findings confirm the success and precision of three-dimensional analysis as a useful tool to aid in preoperative planning and postsurgical outcomes.

CONCLUSIONS

This study applies three-dimensional imaging technology to analyze objective changes in breast shape following autologous fat transfer. Patients receiving larger volumes of fat injection retain more volume long term, and larger volume fat injection patients achieve volume stabilization faster. Across all groups, approximately 40 to 50 percent of the injected fat volume survives long term. Radiation therapy and recipient site appear to have no effect on the volume of fat that survives; however, longer term studies are needed to differentiate definitive trends.

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REFERENCES

1. Neuber F. Fetttransplantation. *Chir Kongr Verhandl Deutche Gesellsch Chir.* 1893;2:126.
2. Czerny V. Plastischer Ersatz der Brustdruse durch ein Lipom. *Chi Kong Verhandl.* 1895;2:126.
3. Rose JG Jr, Lucarelli MJ, Lemke BN, et al. Histologic comparison of autologous fat processing methods. *Ophthal Plast Reconstr Surg.* 2006;22:195–200.
4. Wan DC, Lim AT, Longaker MT. Craniofacial autologous fat transfer. *J Craniofac Surg.* 2009;20:273–274.
5. Pereira LH, Sterodimas A. Free fat transplantation for the aesthetic correction of mild pectus excavatum. *Aesthetic Plast Surg.* 2008;32:393–396.
6. Boyce RG, Nuss DW, Kluka EA. The use of autogenous fat, fascia, and nonvascularized muscle grafts in the head and neck. *Otolaryngol Clin North Am.* 1994;27:39–68.
7. Fournier PF. Facial recontouring with fat grafting. *Dermatol Clin.* 1990;8:523–537.
8. Coleman SR. Hand rejuvenation with structural fat grafting. *Plast Reconstr Surg.* 2002;110:1731–1744; discussion 1745–1747.
9. González de Garibay AS, Castillo Jimeno JM, Villanueva Pérez I, Figuerido Garmendía E, Vigata López MJ, Sebastían Borruel JL. Treatment of urinary stress incontinence using paraurethral injection of autologous fat (in Spanish). *Arch Esp Urol.* 1991;44:595–600.
10. Mikaelian DO, Lowry LD, Sataloff RT. Lipoinjection for unilateral vocal cord paralysis. *Laryngoscope* 1991;101:465–468.
11. Nguyen A, Pasyk KA, Bouvier TN, Hassett CA, Argenta LC. Comparative study of survival of autologous adipose tissue taken and transplanted by different techniques. *Plast Reconstr Surg.* 1990;85:378–386; discussion 387–389.
12. Rigotti G, Marchi A, Stringhini P, et al. Determining the oncological risk of autologous lipoaspirate grafting for post-mastectomy breast reconstruction. *Aesthetic Plast Surg.* 2010;34:475–480.
13. Montañana Vizcaino J, Baena Montilla P, Benito Ruiz J. Complications of autografting fat obtained by liposuction. *Plast Reconstr Surg.* 1990;85:638–639.
14. Cotrufo S, Mandal A, Mithoff EM. Fat grafting to the breast revisited: Safety and efficacy. *Plast Reconstr Surg.* 2008;121:701.
15. Gutowski KA. ASPS Fat Graft Task Force. Current applications and safety of autologous fat grafts: A report of the ASPS fat graft task force. *Plast Reconstr Surg.* 2009;124:272–280.
16. Carvajal J, Patiño JH. Mammographic findings after breast augmentation with autologous fat injection. *Aesthet Surg J.* 2008;28:153–162.
17. Tepper OM, Unger JG, Small KH, et al. Mammometrics: The standardization of aesthetic and reconstructive breast surgery. *Plast Reconstr Surg.* 2010;125:393–400.
18. Tepper OM, Small KH, Unger JG, et al. 3D analysis of breast augmentation defines operative changes and their relationship to implant dimensions. *Ann Plast Surg.* 2009;62:570–575.
19. Small KH, Tepper OM, Unger JG, et al. Re-defining pseudoptosis from a 3D perspective after short scar-medial pedicle reduction mammaplasty. *J Plast Reconstr Aesthet Surg.* 2010;63:346–353.