3D Analysis of Breast Augmentation Defines Operative Changes and Their Relationship to Implant Dimensions

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Abstract: Breast augmentation is one of the most common plastic surgery procedures performed in the United States today. Evaluation of postoperative results lacks true objective measurements. The following study reports the application of 3-dimensional (3D) photography to document changes that occur in breast morphology after breast augmentation.

Patients undergoing augmentation mammaplasty with a periareolar incision were offered pre- and postoperative 3D photographs. 3D models were constructed and the following parameters were assessed: maximum anterior-posterior projection from the chest wall, angle of breast projection, total breast volume, volumetric tissue distribution in the superior and inferior poles, and surface and vector distance measurements to key landmarks.

A completed series of 3D images were obtained from 14 augmentation patients (28 breasts) at an average postoperative day of 143. Saline and silicone implants were used equally (n = 14 for each). Total volume of the breast changed in correlation with the implant size (1.9% difference, $P = 0.83$). There were no significant changes in the volumetric distribution within the upper and lower poles of the breasts noted between pre- and postoperative scans ($P = 0.81$). The internal angle of breast projection was found to increase (13.6 degrees, $P < 0.01$), as did the sternal notch to nipple distance (11 mm, $P = 0.018$). Anterior-posterior projection significantly increased by 23.3 mm. However, this increase in projection was 20.9% less than expected based on implant dimensions (72.7–58.7 mm, respectively, $P < 0.01$).

This study documents objective changes in breast morphology after augmentation mammaplasty. 3D imaging scans were able to document true changes that occur with breast augmentation including breast volume, the increase in the internal angle of the breast projection, and the sternal notch to nipple distance. 3D photography further highlighted that breast augmentation results in less than expected anterior-posterior projection, possibly due to tissue attenuation occurring anterior to the implant.

Key Words: 3D photography, 3D imaging, breast augmentation, breast implant, silicone implant, saline implant, mammometrics

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Breast augmentation techniques have continued to evolve since the first report of adipose delivery to the breast in 1895 by Czerny.[1] Early techniques for breast augmentation, such as paraffin and liquid silicone injections showed variable success but were limited by the inability to reliably predict changes in volume and shape. In 1962, breast implants were introduced and soon thereafter became the predominant approach to breast augmentation. According to the American Society of Plastic Surgery, 347,500 breast augmentations were performed in the United States in 2008, a 64% increase from 2000. Currently, a variety of different surgical techniques as well as implant subtypes are available. Traditionally, saline implants were used primarily for breast augmentation but this paradigm has changed in the United States since the recent FDA approval of silicone implants in 2006.

To aid in implant selection, various algorithms have been proposed based on implant characteristics, such as size, type (saline versus silicone, textured versus smooth, and round versus anatomic), projection profile, and width.[2] While these factors aid in preoperative planning, surgeons lack a complete 3-dimensional (3D) preoperative blueprint of the breast and thus still rely on linear measurements and some subjective approaches for operative planning. Correct implant selection is critical to a successful breast augmentation to avoid the pitfalls of ptosis, shell visibility, palpability, and lateral displacement.

Not only are current techniques for preoperative evaluation limited, but the assessment of postoperative results also lacks a systematic and objective system. Currently, augmentation mammaplasty results are generally assessed by visual inspection. 2D imaging can be used to perform some surface measurements and assess symmetry, but they are limited in scope and depth. Patient surveys may also be used to determine success, but the outcome measured under these circumstances may include inherent subjectivity that poses obvious limitations.[3] Other studies may record the success of the procedure as defined by the willingness of a patient to recommend the surgery to a friend or family member.[4] Unfortunately these study protocols fail to objectively define postoperative results or document the changes to breast morphology after implant insertion.[5]

Given the 3D nature of the breast, an optimal tool for assessing breast augmentation surgery would provide objective breast data in multiple dimensions, including shape, volume, and contour. We, and others, have recently demonstrated that 3D imaging may be a valuable resource for the assessment of breast symmetry and other clinical measurements that 2D photography does not provide.[6,7,8] The following study applies 3D imaging technology to breast augmentation and represents the first report, to our knowledge, that documents true anatomic changes that occur with augmentation mammaplasty.

METHODS

Patient Enrollment and 3D Scans

Patients undergoing augmentation mammaplasty were offered enrollment into the study. All procedures were performed using a periareolar approach by one of 2 senior authors (M.C., N.S.K.). Informed consent was obtained in accordance with the guidelines set forth by the New York University Medical Center Institutional Review Board. 3D scans were obtained as previously reported.[9] The customized chest-wall template was constructed for each patient. Breasts were isolated as closed polygon models and 3D data analysis was performed as outlined.

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Breast Volume Analysis and Volumetric Distribution

Total breast volume was calculated for each pre- and postoperative 3D model. A horizontal-split plane (*XZ plane*) was placed through the lateral border of the inframammary fold (IMF) to divide the breast into upper and lower poles. To ensure accuracy and reproducibility, this individualized horizontal-split plane was applied to all postoperative images as well. Tissue distribution in the upper and lower poles was determined by calculating the percent of volume above and below this plane.

Breast Projection and Internal Angle

Sagittal sections were taken through the nipple on each breast to identify the point of maximal breast projection. The computer software identified the maximum distance from the chest wall to the breast surface. The maximum anterior-posterior (AP) distance of the breast relative to the chest wall was determined for each pre- and postoperative image. The angle of the upper pole of the breast at the chest wall was also measured and was termed the internal angle of the projection of the breast.

Surface and Vector Distances

The following surface distance measurements were performed: sternal notch to the nipple, and nipple to the IMF. Concurrently, vector measurements were taken from the nipple to the level of the sternal notch on the y-axis.

Statistical Analysis

All data are presented as the mean ± SD. Pre- and postoperative values were compared using a paired *t* test and a $P < 0.05$ was determined to represent statistical significance.

RESULTS

Patient and Implant Characteristics

The average age of the patients was 32 years old (range: 20–51) with a preoperative breast volume that was 184.8 ± 75.0 mL. Round smooth saline and silicone implants were used equally (14 each) with an average implant size of 304.3 ± 39.1 mL. The average AP projection of the implant documented by the manufacturer was 37.3 ± 2.3 mm (Fig. 1).

Demographics

Age	32 yrs (range 20–51 yrs)
Patients	14
Implant type	Saline –14 Silicone –14 (submuscular)
Average preoperative breast volume	184 +/- 75cc (range: 96–394cc)
Average day post op	143 (range: 19–588)
Average implant size	304.3 +/- 39.1cc
Implant AP projection	37.3 +/- 2.3 mm

FIGURE 1. The table shows the demographics of the patients in the study group.

Volumetric Analysis After Augmentation Mammaplasty

The volume of the breast significantly increased in size from an average of 184.8 mL to 486.3 mL. This change of 301.5 ± 57.7 mL was consistent with the implant size 304.3 ± 39.1 mL ($P <$ 0.01) (Fig. 2). Preoperatively, the average percentage of tissue in the superior and inferior poles was 51.6% ± 9.9% and 48.4% ± 9.7%, respectively. Volumetric distribution of the breast did not change with augmentation (superior pole 52.5% ± 14.7%, inferior pole 47.5% ± 14.7%, $P = 0.81$) (Fig. 3).

Anterior-Posterior Projection and Internal Angle

The average preoperative anterior-posterior projection was 35.4 ± 10.5 mm. The average implant AP projection documented by the manufacturer was 37.3 ± 2.3 mm. After breast implant insertion, AP projection significantly increased to 58.7 ± 7.9 mm ($P < 0.01$) (Fig. 4). Interestingly, the average expected postoperative projection was larger than the actual projection. (Average preoperative AP projection + average implant dimension = 72.7 ± 9.73 mm). This change between actual (58.7 ± 7.9 mm) and expected (72.7 ± 9.73 mm) represents a 20.9% decrease from the expected anterior-posterior projection ($P < 0.01$) (Fig. 5). This observation occurred in both saline and silicone groups to a similar extent (saline: 20.1% ± 5.0%; silicone: 21.7% ± 7.4%; $P = 0.535$) (Fig. 6). Increased

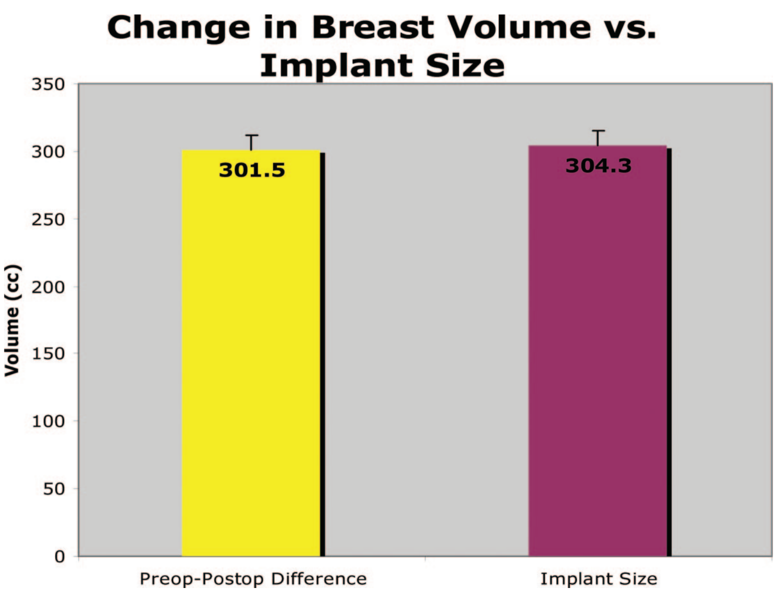

FIGURE 2. Three-dimensional generated breast volumes were calculated preoperatively and postoperatively. The average change in these total volumes after augmentation was 301.5 ± 57.7 mL (postoperative volume – preoperative volume), which was comparable to the average size of the implant, 304.3 ± 39.1 mL ($P = 0.83$).

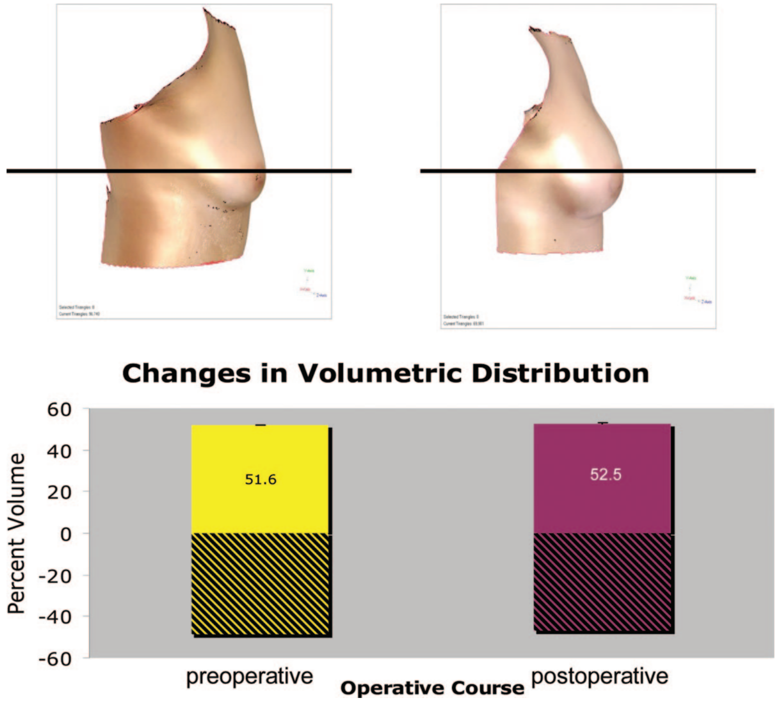

FIGURE 3. A horizontal-split plane was created through the lateral border of the IMF and applied to both preoperative and postoperative images. The total volumes in the superior and inferior poles of each image were calculated. The graph shows a preoperative volumetric distribution of 51.6% ± 9.9% of breast tissue in the superior pole and 48.4% ± 9.7% of breast tissue in the inferior pole and postoperative values of 52.5% ± 14.7% and 47.5% ± 14.7% ($P = 0.81$).

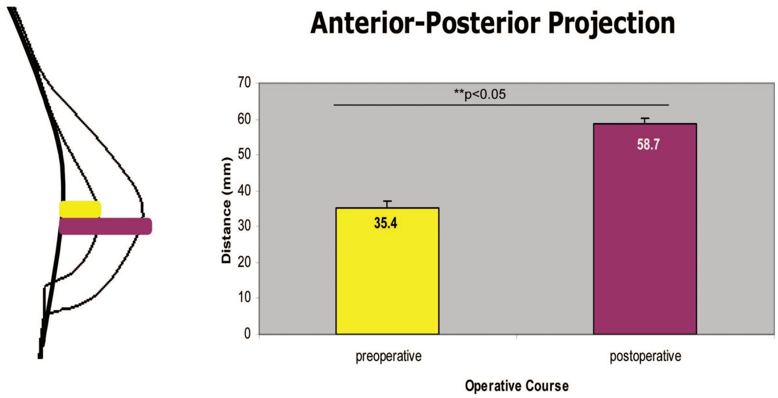

FIGURE 4. Sagittal sections were taken through the nipple for each breast image preoperatively (yellow) and postoperatively (purple), which represented the maximal point of breast projection. The maximum anterior-posterior projection (AP projection) was calculated as the distance between this plane and the chest wall. The graph shows that the average preoperative AP projection was 35.4 ± 10.5 mm, which increased significantly to 58.7 ± 7.9 mm postoperatively ($P < 0.01$).

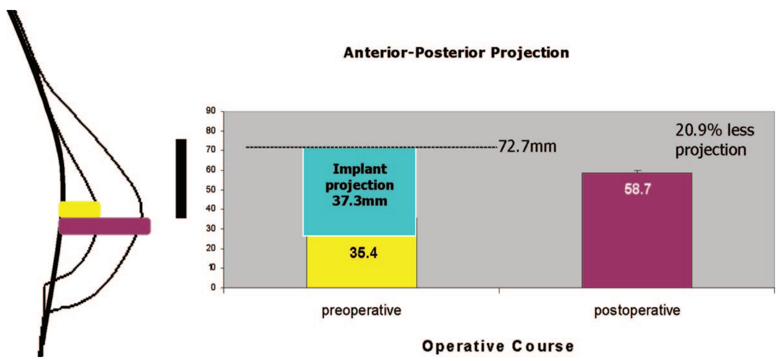

FIGURE 5. The graph shows that the average expected postoperative projection (preoperative AP projection plus the implant dimension) was 72.7 ± 9.73 mm. The actual postoperative AP projection was 58.7 ± 7.9 mm. This represents a 20.9% less-than-expected anterior-posterior projection of the implant ($P < 0.001$).

projection of the breast was associated with a 13.6-degree increase in the internal angle of the breast (8.8 ± 2.2 degrees preoperatively to 22.4 ± 6.4 degrees postoperatively; $P < 0.01$) (Figs. 7, 8).

Surface and Vector Measurements

Sternal notch to nipple surface distance significantly increased by 11.0 ± 9.7 mm (185.3 ± 18.6 mm to 196.3 ± 14.8 mm;

$P < 0.01$). The vector measurement of nipple height was 145.5 ± 17.1 mm versus 146.3 ± 16.3 mm ($P = 0.86$), thus demonstrating a stable nipple height. Nipple to IMF surface distance significantly increased from 58.31 ± 10.77 mm to 85.88 ± 11.30 mm ($P < 0.01$) (Fig. 8).

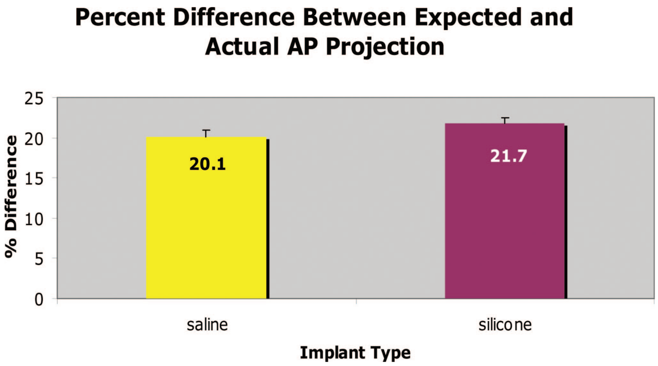

FIGURE 6. No significant differences in AP projection were noted between the saline and silicone groups (saline: 20.1% ± 5.0%, silicone: 21.7% ± 7.4%, $P = 0.535$).

DISCUSSION

The following study demonstrates the clinical utility of 3D photography for assessing changes in breast morphology that occur with augmentation mammaplasty. New breast parameters are introduced (AP projection, volumetric distribution, and internal angle) that provide significant improvement from previous studies, which are limited to 2D images, surface measurements, and patient evaluations. We believe these techniques are of clinical value and represent an important step toward a more standardized approach to aesthetic breast surgery.

Our initial comparison between preoperative and postoperative volumetric measurements confirmed our techniques and served as an internal control. 3D volume measurements showed no significant difference between the implant size and 3D volumetric change (postoperative volume – preoperative volume). No recognizable changes occurred in the percentage of tissue above and below the horizontal-split plane. This later finding was expected as breast

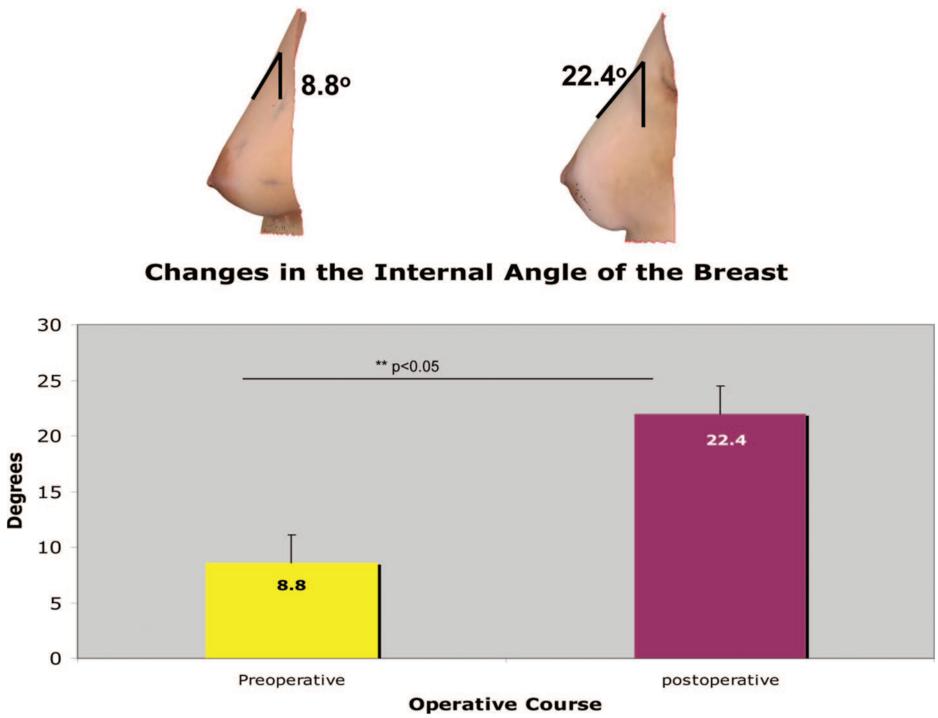

FIGURE 7. Sagittal sections were taken through the nipple and the angle that the superior pole of the breast made with the chest wall was measured. The graph shows that breast augmentation created a 13.6-degree increase in the internal angle of the breast (8.8 degrees ± 2.2 degrees preoperatively to 22.4 degrees ± 6.4 degrees postoperatively ($P < 0.01$).

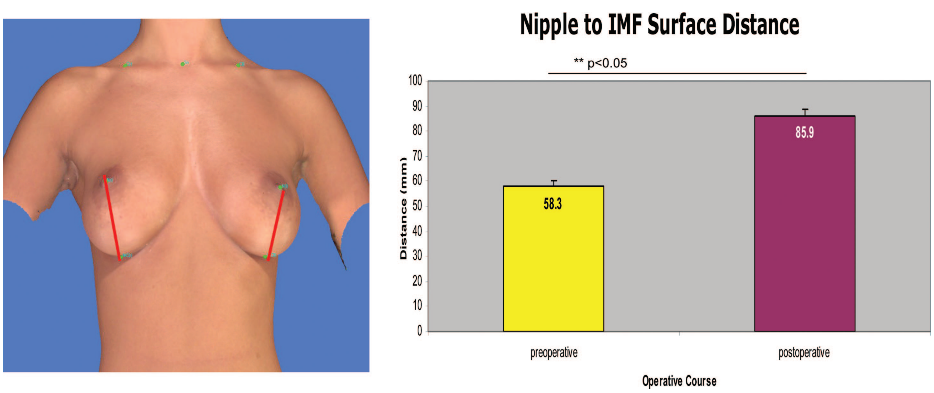

FIGURE 8. The surface distance from the nipple to the IMF, following the contour of the breast was measured. The graph shows this distance significantly increased from 58.3 ± 10.77 mm to 85.9 ± 11.30 mm ($P < 0.001$).

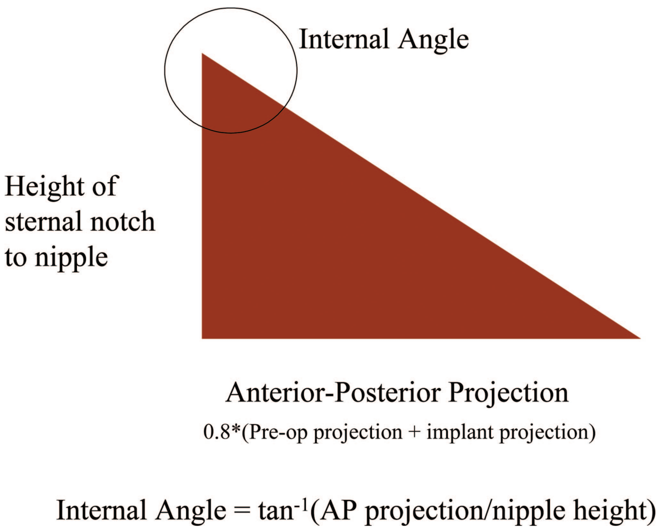

FIGURE 9. The predicted postoperative internal angle can be predicted using 3D imaging and basic trigonometric analysis. We can determine the postoperative nipple height (unchanged by surgery) and postoperative AP projection (80% of the sum of preoperative projection and the manufacturer-stated implant projection) with preoperative 3D imaging. Therefore, since we know both the postoperative AP projection and the nipple height, we can calculate the postoperative internal angle using an inverse tangent function.

augmentation with round implants should increase the fullness of the upper and lower poles proportionately if placed centrally within the breast.

To further assess morphologic changes, we measured the changes in AP projection after implant insertion. Interestingly, the actual AP projection of the breast was found to be 20% less than predicted based on manufacturer implant dimensions. A likely explanation for this observation may be tissue attenuation of the overlying pocket. Posterior displacement of the chest wall after insertion of the implant in a submuscular pocket may also play a role. This finding has been described in other alloplastic implants, such as in the chin, but has yet to be reported for breast augmentation.[10] The effects of capsule formation in relationship to the projection of the implant remains unknown, but is unlikely to play a significant role in this study due to the relatively short postoperative follow up. Furthermore, whether these findings are less prevalent with subglandular implants remains unknown.

Also, our data revealed an increased fullness in the superior pole of the breast associated with a 13.6-degree increase in the internal angle. This measurement is unique to 3D imaging and suggests the possibility of predicting the operative changes as well as providing a guide for the implant selection. One useful tool of 3D imaging is the ability to calculate, using basic trigonometric analysis, the predicted postoperative internal angle. From a preoperative 3D scan, we can determine the postoperative nipple height (unchanged by surgery) and postoperative AP projection (80% of the sum of preoperative projection and the manufacturer-stated implant projection). Therefore, since we know both the postoperative AP projection and the nipple height, we can calculate the postoperative internal angle using an inverse tangent function (Fig. 9). Data-based predicted changes such as these (projecting angle of the superior pole and the expected projection of the breast) would allow simulation software to indicate the expected postoperative shape of the breast, thus creating a scientifically based model.

3D data measurements could offer a useful compliment to some of the existing systems for implant selection including the TEPID system, the High Five System, and the Body Logic system. The TEPID system, based on patient's tissue characteristics, addresses tissue (T), tissue envelope (E), parenchyma (P), implant (I), and tissue dynamics (D).[11] The High Five system assesses implant coverage/pocket planning, implant size/volume, implant type, inframammary fold position, and incision.[12] The BodyLogic System, developed by Mentor (Santa Barbara, CA), includes base diameter, projection, and volume measurements for determining the correct implant. Although these systems are simple and practical methods to evaluate the preoperative breast, they lack in their ability to create a complete objective evaluation of the preoperative breast. 3D measurements provide not only new relevant parameters such as internal angle and volumetric distribution but also provide a computer-based approach for existing measurements (ie, base width) that are currently operator dependent.

The present study also establishes a foundation for utilizing 3-dimensional analysis to compare various surgical approaches. While our study is limited to submuscular, periareolar implant augmentation, these imaging tools can easily be applied to studying results of other surgical techniques. Based on our findings, a surgeon may want to select implants with 20.9% greater projection than desired because of postoperative morphologic changes. However, long-term studies (5 years) should be conducted to highlight definitive postoperative changes following augmentation mammaplasty with varied surgical techniques. Evaluation of long-term results would determine the extent of implant migration, changes in nipple position, or the redistribution of soft tissue. Potential practical applications of long-term analysis include choice of pocket, incision techniques, implant selection to optimize postoperative breast projection, and contour.

To this point, the authors propose 3D photography as a way of creating a new set of objective measurements to document the changes of breast topography over time. The authors believe that by compiling a true series of changes to the breast, surgeons will be able to better assess surgical outcomes.

CONCLUSION

3D imaging provides an objective approach to obtaining various breast parameters, some of which have previously not been possible to determine. This technology affords the ability to assess immediate and long-term operative results, and correlate these changes with implant dimensions. While large scale studies are needed to truly incorporate 3D imaging into surgical preoperative planning in breast augmentation, the authors believe this technology will play an important role in the future of breast augmentation.

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