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Re-defining pseudoptosis from a 3D perspective after short scar-medial pedicle reduction mammaplasty

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Summary *Background:* Bottoming out is a well-known phenomenon described with reduction mammaplasty (RM). To date, the evaluation of post-operative bottoming out remains an imprecise science. The following study reports the application of three-dimensional (3D) photography to objectively investigate changes in breast morphology.
Methods: Patients undergoing medial pedicle RM had 3D photographs (Konica Minolta V910) taken during the early and late post-operative period (early = 60–120 days; late = 400–500 days). 3D images were compared and bottoming out was assessed with 3D parameters and vectors including total breast volume, volumetric tissue distribution above and below the Central (C) plane, distance of the C-plane to the lowest point of the breast, and maximum anterior-posterior projection from the chest wall.
Results: Post-operative images from 15 consecutive RM patients showed an average volume of 556 +/− 144cm3 (early) and 441 +/− 183cm3 (late). The percent of tissue in the upper pole of the breast changed from the early to late post-operative period (76% vs. 69%, respectively; $p < 0.01$). The distance from a fixed C-plane to the inferior pole significantly increased (42 +/− 15 mm early vs. 51 +/− 18 mm late; $p < 0.01$). AP projection decreased by an average of 6.23 mm ($p < 0.01$). The lateral border of the IMF significantly dropped by 6.27 mm.
Conclusions: This study objectively describes both the occurrence of bottoming out and the quantitative amount in terms of changes in volumetric distribution, surface topography and breast projection. With 3D photography, plastic surgeons can perform objective evaluation of breast transformation over time, which ultimately will aid in planning to allow for better surgical outcomes.

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Background

Reduction mammaplasty (RM) is one of the most commonly performed procedures in plastic surgery. Despite a significant degree of patient satisfaction with RM, pseudoptosis, or 'bottoming out,' seems to be an inevitable consequence of such procedures.[1] Although the exact etiology of bottoming out is unknown, most surgeons believe that the remaining breast tissue causes pressure on the inferior pole with subsequent scaphoid appearance in the upper pole and lengthening of the inferior scar.[2]

As breast reduction procedures continue to evolve, a number of surgeons have modified their surgeries in hopes of preventing or minimizing pseudoptosis. In 1975, Orlando and Guthrie proposed that a superiomedial pedicle reduces bottoming out by deferring volume to the upper pole of the breast.[3] Lejour later modified the superior pedicle approach to initially exaggerate breast projection in order to further improve the aesthetic outcome.[4] While other techniques such as the short-scar periareolar inferior pedicle mammaplasty aimed to prevent pseudoptosis, many believe this technique maintains significant breast tissue in the lower pole of the breast thereby leading to excessive inferior breast fullness and lengthening of the scar.[4] Recently, Hall-Findlay's description of a vertical scar superiomedial dermoglandular pedicle claims to reduce the incidence of bottoming out with its superior attachments and superiomedial fullness.[4] Based on these claims, the senior author has adopted the short-scar medial pedical technique in breast reduction surgery to both limit the amount of pseudoptosis that occur, and create the most aesthetic scarring pattern possible. However, the ability of this technique to limit pseudoptosis has not been quantitatively assessed.

Bottoming out is an important factor to consider in all types of reduction mammaplasty procedures. However, as previously mentioned, there are few studies to date which have objectively assessed this phenomenon. Reus and Mathes utilized surface measurements to analyze bottoming out with inferior pedicle RM. The authors report that pseudoptosis correlates to breast size: a 48% increase in the length of the vertical limb after inferior pedicle RM with resection weights between 500 and 1200 grams, versus vertical limb lengthening of 72% in those patients with resection weights greater than 1200 grams.[5] Ergdogan and others reported similar findings documenting an average increase in the areola-to-inframammary fold distance by 52%.[6] Others have evaluated 'bottoming out' with measurements including the distance from the sternal notch to nipple or sternal notch to visual inferior pole.[7] Unfortunately, surface measurements that document pseudoptosis are limited to two dimensions and fail to delineate the corresponding changes in volume and shape of the breast. An innovative approach and potential solution to documenting post-operative changes may be the application of three-dimensional (3D) photography, which recently was shown by our group and others to be a practical tool for breast analysis.[8–11] Our earlier work in American Journal of Surgery demonstrates the technical feasibility of 3D photography and validates the data obtained with this technology (i.e. volume, tissue distributions, and breast projection).[11] Subsequent works in Plastic and Reconstructive Surgery uses these techniques to objectively define the short term post-operative changes following reduction mammaplasty.[12] In the following unique study, we apply 3D imaging technology to objectively assess long-term post-operative changes such as bottoming out of the breast following medial pedicle reduction mammaplasty.

Methods

Patient enrollment

Patients undergoing reduction mammaplasty (RM) with a short-scar medial pedicle technique between July 2006 to December 2006 were offered enrollment into the study. The short-scar, medial pedicle technique was performed as previously described by the senior author.[13] These patients received breast scans pre-operatively, during the early post-operative period (60–120 days post-operatively), and the late post-operative period (400–500 days post-operatively). Informed consent was obtained in accordance with the guidelines set forth by the New York University Medical Center Institutional Review Board.

3D photographs

3D scans were obtained on pre- and post-operative visits using a non-contact laser scanner (*Konica Minolta – V910*) as previously described.[11] The scanner captures the entire area in approximately 2 seconds and then converts the surface shape to a polygon lattice of roughly 300,000 points. The camera is placed 3 feet from the subject at the level of the breasts at the Nipple Areola Complex (NAC) and scans were obtained with the subject facing +90, +45, 0, −45, and −90° relative to the lens. Multiple angles are needed to capture 360-degree view of the torso. Additional inferior views were obtained by placing the camera at knee-level and tilting it upward towards the Inframammary Fold (IMF). For the inferior views, scans are obtained with the subject facing +90, +45, 0, −45, and −90 relative to the lens. This technique of obtaining inferior views has proven useful for large ptotic breasts that tend to create shadowing and thus leaves hole in the three-dimensional model.[11] The individual images were then merged into a single 3D model using computer software that identifies pairs of corresponding points in overlapping regions (*Geomagic Studio 9*). To isolate the breast, a customized chest wall template was utilized for each patient based on the pre-operative image. This template is achieved by removing the breast (boundaries defined superiorly at the level at which the breast projects off the chest, and inferiorly, medially, and laterally by the borders of the inframammary fold) and performing a computerized curvature based fill. Subsequently, a Boolean operation of the chest wall template and the surface image was performed in order to establish a closed object.

Breast volume analysis

All breast images were aligned to a reference X, Y, and Z coordinate axis. Total breast volume was determined for each breast. For every preoperative image, a transverse, central plane (C plane) was created in the XY coordinate axis that intersects the lateral borders of the inframammary fold of the pre-operative image to divide the breast into superior and inferior poles. The pre-operative image and the chest wall template share a set of fixed coordinates; thus the Geomagic software copies the C plane from the pre-operative image to the chest wall template while maintaining the same position in space. The lateral border of the IMF was chosen due to its anatomic specificity and its consistency of identification, independent of patient posture or position. To ensure reproducibility throughout the study, the initial C plane and chest wall template were applied to all post-operative images for volumetric distribution analysis.

3D compare color mapping

3D comparisons of early and late postoperative images (reference object and test object, respectively) were used to generate color maps. Maximum and minimum distance deviations were +25 and −40 mm, respectively. Color scales were divided into 40 segments. The software generates an asymmetry score that indicates the average deviation found in the comparison.

Breast projection

Sagittal sections were taken through the nipple on each breast in order to identify the point of maximal breast projection. With the saggital cross section of the breast model over the chest wall template, the software generates two parallel tangential lines: a line tangential to the NAC and a line tangential to the chest wall template. The perpendicular distance between the two parallel tangential lines is the maximum anterior-posterior projection (AP distance). The maximum anterior-posterior (AP) distance of the breast relative to the chest wall was determined for each image. The vector distance from the initial C plane to the post-operative lateral border of the IMF and to the lowest point of the breast were recorded. Distance measurements between critical landmarks were also determined including the sternal notch-nipple surface distance and the inter-nipple surface distance.

Statistical analysis

All data are presented as the mean ± standard error of the mean. A paired *t*-test was used to compare early and late post-operative values, and a $p < 0.05$ was determined to represent statistical significance.

Results

Patient demographics

The patient population for this study consisted of 15 women aged 25 to 60 years old, with an average age of 36 +/− 9.9 years. The patients' weights varied from 117 to 165 pounds, with an average of 139.7 +/− 16.5 pounds. The pre-operative bra sizes ranged from 32–38 inches in circumference and C to F in cup size.

Volumetric changes and redistribution

Post-operative analysis was performed in fifteen patients at post-operative day of 78 +/− 39 (early) and day of 468 +/− 76 (late), respectively. The average early and late volumes were 556.79 +/− 144.41 cm^3 and 481 +/− 183.95 cm^3, respectively (Figure 1). This difference represents a 13.61% reduction in breast volume suggesting settling of the breast

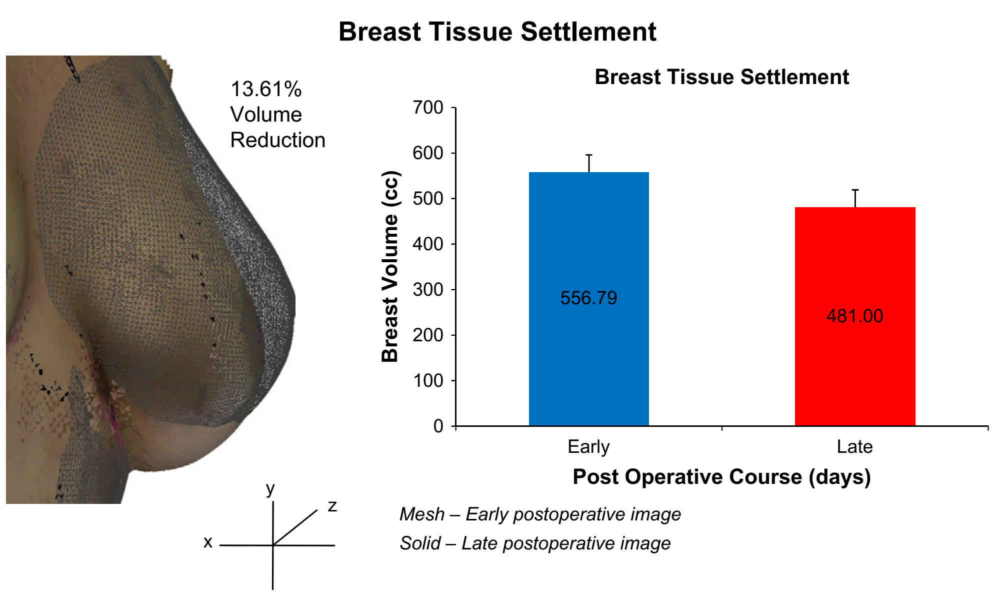

Figure 1 3D generated breast volumes were created for fifteen patients 78 +/− 39 days and 469 +/− 76 days post-operatively. The table shows a settling in the average breast volume of the patient population of 75.79 cc, which is 13.61%. The overlay of early (mesh) and late (solid) post-operative images for a typical patient gives a visual representation of the breast tissue settlement.

($p<.01$). Subdivision of the early post-operative breast into upper and lower poles demonstrated the following distribution: 75.96% of volume above the IMF and 24.04% below the IMF. Identical analysis of the late post-operative images revealed that 69.46% of the tissue was in the upper pole and 30.54% in the lower pole. Thus, breast tissue underwent an average redistribution of 6.5% tissue to the inferior pole of the breast ($p < 0.01$) (Figure 2).

3D comparisons

3D comparison images identified a redistribution of tissue with a predominately negative deviation of points in the central portion of the breast and a positive deviation of points in the inferior pole of the breast. The average asymmetry score between the reference object and test object for all patients was 5.11 +/− 1.75 mm. A representative image is shown in (Figure 3).

Vector analysis of breast shape

Vector measurements from the initial C plane to the inferior pole of the post-operative breast revealed a significant increase in distance during the post-operative period (42.03 +/− 15.71 mm early versus 51.61 +/− 18.83 mm late, $p < 0.01$). The anterior-posterior (AP) distance from the chest wall significantly decreased by an average of 6.23 mm from early to late post-operative period (from 58.05 +/− 13.76 mm early to 51.82 +/− 13.61 late; $p < 0.01$) (Figure 4).

Additional surface measurements revealed a significant decrease in the inter-nipple distance (249.25 +/− 16.36 mm early post-operatively versus 217.18 +/− 18.91 mm; $p < 0.01$) and sternal notch-nipple distance (217.68 +/− 15.74 mm early post-operatively versus 206.60 +/− 17.45 mm; $p < 0.01$). Vector measurements of the same distances revealed an insignificant decrease in the inter-nipple distance (218.45 +/− 43.90 early post-operatively versus 216.54 +/− 40.10, $p = 0.80$) and sternal notch-nipple distance (225.40 +/− 40.10 early post-operatively versus 220.25 +/− 28.31, $p = 0.22$).

During the early post-operative period, vector measurements from the initial transverse plane to the lateral border of the IMF revealed a significant rise in distance of 16.67 +/ − 10.30 mm. Late post-operative analysis identified the distance between the parameters decreased significantly (6.27 mm), thus placing the lateral border of the IMF 10.40 +/− 8.71 mm above the initial transverse plane.

Discussion

The following study uses three dimensional photography and novel analytical tools to define bottoming out after short scar medial pedicle RM. With the introduction of new parameters such as 3D comparison, AP projection, and volumetric distribution, this study represents significant advancements from previous work, which is limited to only two-dimensional images, surface measurements, and patient evaluations identifying post-operative changes.

Our comparison between early and late post-operative volumes demonstrated a significant degree of breast

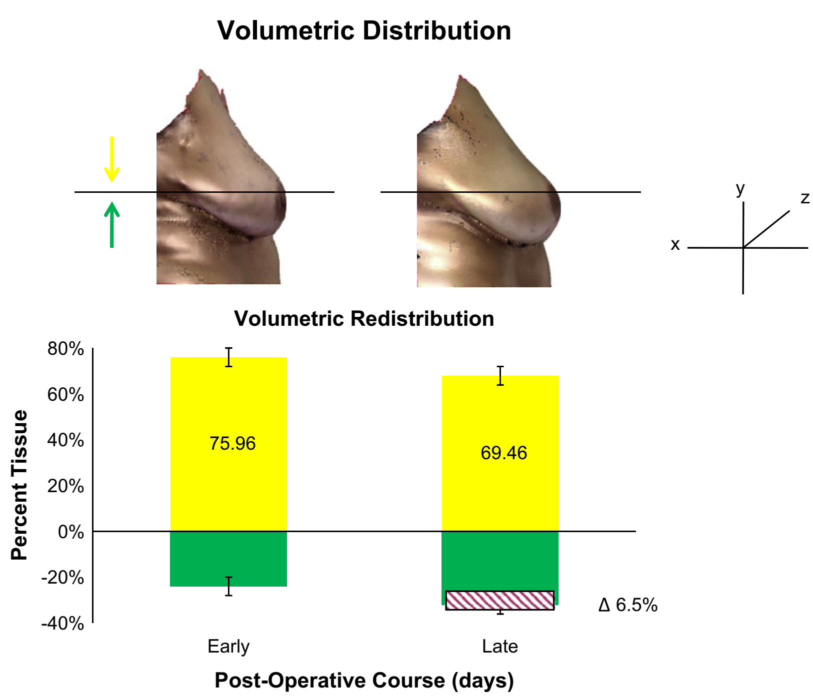

Figure 2 A horizontal plane intersecting the lateral border of the inframammary fold was generated for each patient and was then applied to both the early and late post-operative images. The volume in the upper and lower pole was calculated in for each breast. The table shows a change in volumetric distribution from 76% superior pole and 24% inferior pole in the early post-op state, to 69.5% superiorly and 30.5% inferiorly in the late post-op state, which is a net redistribution of 6.5% of the volume to the inferior pole ($p < 0.01$).

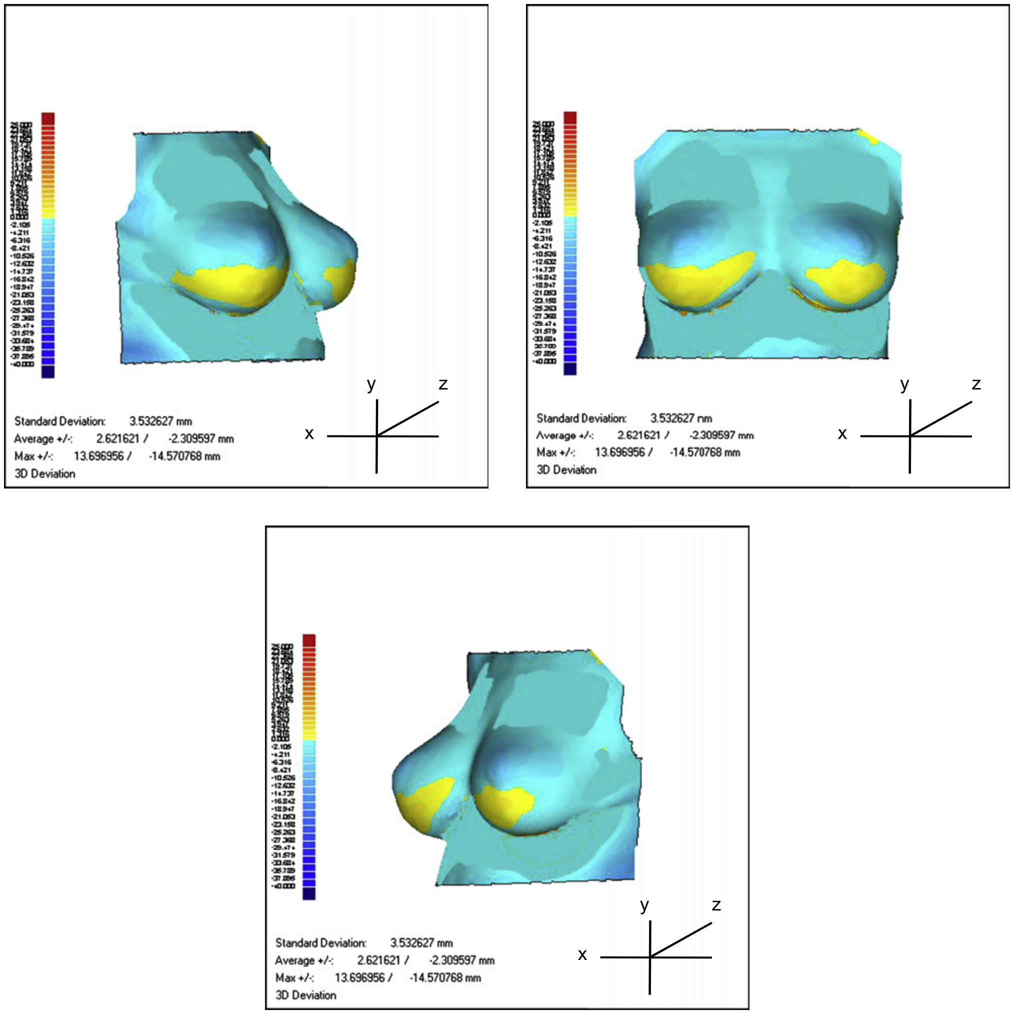

Figure 3 3D comparison studies were performed for each patient by overlaying the early and late post-operative images. By using a multi-point vector sum analysis, color maps were created comparing early (set as reference) and late post operative images (set as test). Darker blue correlates to negative deflections in volume, and yellow correlates to positive deflections. There was an average asymmetry score between reference and test objects of 5.11 mm $+/-$ 1.75 mm.

settling over the post-operative year. While previous studies demonstrate that the majority of post-operative changes take place during the first three months after surgery[14]; our 3D data demonstrates that significant volumetric changes continue to occur well into the first year following surgery. We attribute this finding to the breast tissue settling into the breast envelope as well as the resolution of post-operative edema.

The changes in anatomical surface measurements support the significant volumetric changes seen in the first year. We attribute the reduction in the sternal notch to nipple surface distance and inter-nipple surface distance to the reduction in total breast volume from the early to late post-operative period. Of note, we recognize the discrepancy between the surface measurements and vector measurements. The surface measurements between the early and late post-operative period are statistically significant while the vector measurements remain constant. As total breast volume decreases, breast surface measurements should concurrently decrease while vector distances are stagnant.

The present study is the first to quantify the volume of tissue redistributed to the inferior pole of the breasts. Three-dimensional long-term volumetric evaluation of the inferior and superior poles of the breast emphasized post-operative pseudoptosis with a 7% redistribution of tissue to the inferior pole of the breast. Chalekson and others grossly evaluated post-operative pseudoptosis with two dimensional measurements by comparing aesthetically optimal breasts and breast having undergone the Robertson technique using the visual inferior pole ratio, quotient of the two lines: sternal notch to nipple and sternal notch to visual inferior pole.[7] However,these previous studies never incorporated volumetric measurements into evaluation of pseudoptosis.

To further assess morphologic changes, 3D comparison overlays the early and late post-operative images constructing a color coded topographical map of the two objects highlighting the maximum and minimum points of deviations (Figure 3). The asymmetry score quantified a significant difference between the early and late post-operative data sets; a review of the 15 images identified

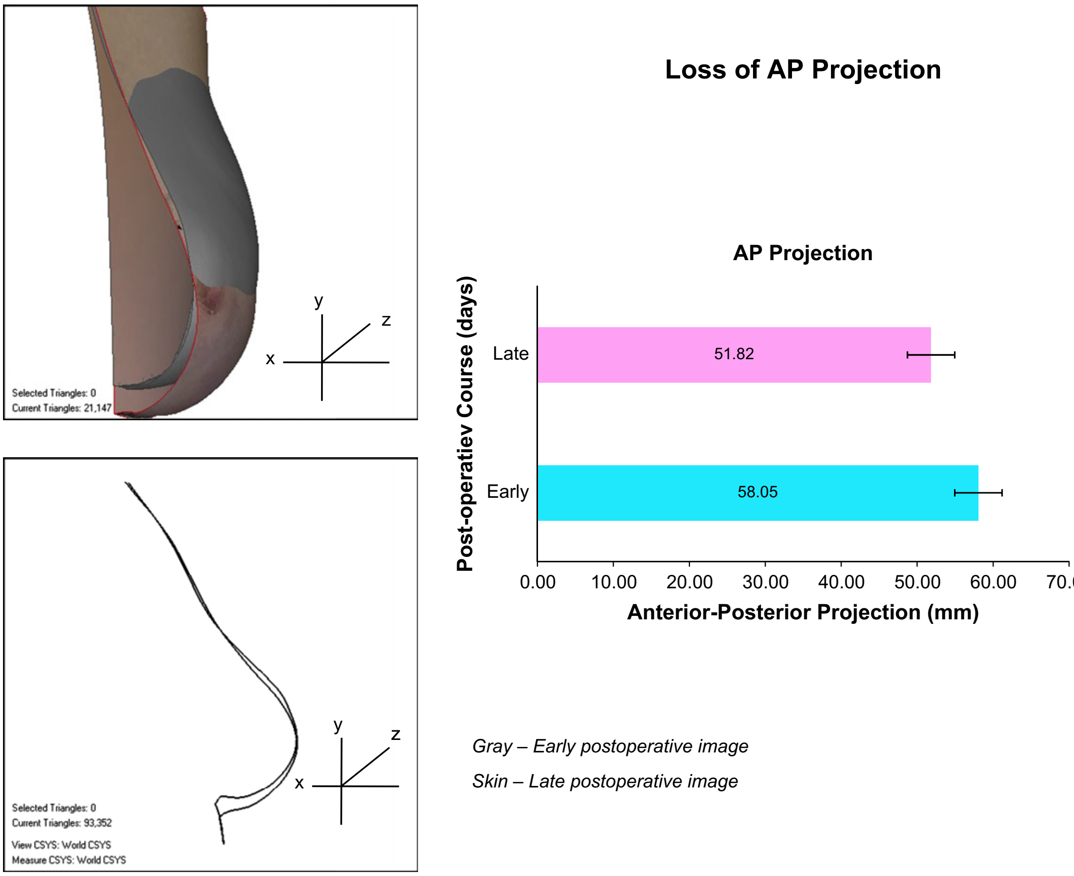

Figure 4 The sagittal cross section at the nipple demonstrates the distance between the chest wall and the most anterior point of the breast in the early (gray) and in the late (skin) post operative period. The table shows that the anterior posterior projection (AP Projection) decreases significantly over the post-operative course from 58.05 +/− 13.76 mm early to 51.82 +/− 13.61 late, an average decrease in AP Projection of 6.23 mm ($p < 0.01$).

a redistribution of tissue with a negative deviation of points in the central portion of the breast and a positive deviation of points in the inferior pole of the breast. We attributed the negative deviation in the central portion of the breast to a loss of anterior-posterior projection with the resolution of post-operative swelling and the redistribution of tissue to the inferior pole of the breast. The positive deviation of points in the inferior pole reinforces the redistribution of tissue. Analysis of the sagittal cross sections supported this observation by determining a decrease in the central portion of the breast and inferior displacement of tissue at the lower pole of the breast.

The post-operative redistribution of tissue correlates to the change in position of the lateral border of the IMF. The IMF is a zone of adherence of the superficial fascial system to the underlying chest wall and is anatomically defined as the area where the skin of the lower pole of glandular breast tissue meets the chest wall forming a groove referred to as the inframammary crease.[15] The IMF has considerable impact on the appearance of the breast. From the onset of breast development, the IMF anchors the inferior pole of the breast to the chest wall, and with age, the breast becomes ptotic relative to this point. The concept of surgical changes to the IMF has therefore been documented in augmentation mammaplasty and reconstruction mammaplasty, but to our knowledge, there is no account to date in the literature of the affect of reduction mammaplasty on the IMF.[16–20] In evaluating short scar medial pedicle reduction mammaplasty, the superior rotation of the pedicle elevates the lateral border of the IMF as seen during the early postoperative assessment. As the breast tissue settles post-operatively, the lateral border of the IMF progresses inferiorly but never reaches its initial pre-operative boundary.

Notably, lifestyle changes and/or personal characteristics may influence the various measurements that were taken. Previous studies demonstrate that breast reduction improves patient overall body image and may lead to post-operative weight loss.[21] Furthermore, breast volume may increase in the second half of both normal and contraceptive-controlled menstrual cycles and skin may become thinner, less tense, and elastic as one ages.[22,23] These factors may represent minor limitations to this study as skin quality, hormonal status, and weight were not documented at the different screening points.

Qualitative reviews of varying surgical techniques document optimal post-operative surgical results based on pedicle selection, intra-operative tissue resection, closure techniques, or incision selection.[3–7] Hall-Findley and others have subjectively argued that vertical scar medial pedicle reduction mammaplasty improves long-term breast contour (decreases post-operative pseudoptosis) in comparison to inferior pedicle techniques.[24] Andrades and Prado et al. argued that breast base reduction, projection-to-base ratio maintenance and nipple areola complex repositioning are the foundation of breast reduction techniques.[25] Our study demonstrates the application of 3D photography to obtain these previously unattainable measurements and to supplement the geometric principles of breast reduction techniques previously set forth by Andrades and Prado.

The present study establishes a foundation for utilizing three-dimensional analysis to compare various surgical approaches to ultimately provide guidelines for pre-operative surgical planning and intra-operative surgical decision to optimize post-operative results. For instance, the medial and lateral pillars can be brought together in a way to create more projection of the breast than is actually desired, as the study indicates that loss of projection is to be expected. In fact, with the loss in AP projection quantified at 6.23 mm on average, one can have an objective goal of the amount of over-projection desired. However, long term studies (5-10 years) should be conducted to highlight definitive post-operative changes following medial pedicle reduction mammaplasty. Potential practical applications of long term analysis include choice of pedicle techniques, incision techniques, or intra-operative tissue resection to optimize post-operative breast projection and contour. We are currently carrying out long-term studies (2–3 years) and our preliminary findings suggest no significant post-operative changes in breast morphology in the second year.

We recognize that the screening protocol and surgical technique may be a minor limitation to the study. Approximately 70% of the breast reduction patients in the surgical practice of the senior author undergo medial pedicle reduction mammaplasty based on the preoperative surgical assessment of the surgeon. In the senior authors' experience, medial pedicle reduction is typically reserved for patients with less than 1000 gm of tissue resection in each breast. Of note, our screening schedule correlates with the typical post-operative schedule of the senior author. The patient population and the nature of the procedure (elective cases) limit frequent post-operative screenings for all of the enrolled subjects. Although the surgical practice of the senior author is predominantly dedicated to short scar medial pedicle RM, these imaging tools can easily be applied to studying long term results of other surgical techniques.

3D imaging holds future promises as a method of standardizing breast surgery analysis, much the same way craniofacial surgery has been influenced by cephalometrics. By creating markers on the chest wall and corresponding points on the breast such as AP projection, nipple placement, and inferior pole fullness, three-dimensional photography could formulate a system to study the movement of the breast. To this concept, we propose 3D photography as a way of creating a new set of objective measurements to document the changes of breast topography over time. Further, we aim to use this new system to correlate various changes in breast parameters to specific surgical techniques and ultimately improve aesthetic outcomes. For example, a three dimensional database could influence the choice of pedicle techniques, incision techniques, or intra-operative tissue resection to optimize post-operative breast projection and contour. We feel that by using a realistic imaging system designed to create perfect scale models of each patient's individual anatomy, this new system can be expanded to allow for accurate prediction of surgical results.

Our ability to analyze the breast quantitatively and reproducibly with 3D imaging may lead to its use in simulation software programs. By compiling a series of previously recorded actual changes to the breast in various dimensions, these validated changes can be applied to a patient's 3D image to create a realistic model of what the likely result will be. The ultimate goal of three-dimensional analysis is to provide a guideline for pre-operative planning based on a database of post-operative results.

This study is the first to quantify long-term post-operative changes following vertical scar medial pedicle reduction mammaplasty and identifies preservation of breast shape with minimal loss of anterior posterior projection and redistribution of tissue to the inferior pole of the breast. This unique data set lays the foundation for comparison with other pedicle techniques or incision techniques whereby 3D imaging may ultimately provide guidelines for pre-operative surgical planning. We feel that this study can represent the sentinel report to be used in creating a database identifying the quantitative changes that occur in a set of aesthetically important parameters. By identifying these changes in a clinically applicable manner, we hope that the future will allow precise surgical planning to account not only for initial outcomes, but these long-term changes as well. We believe 3D photography offers a considerable advance in plastic surgery and hope that this technology will lead to improved objectivity and consistency in mammaplasty procedures.

Conflict of interest/funding

None.

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