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A Comparison of Superomedial Versus Inferior Pedicle Reduction Mammoplasty Using Three-Dimensional Analysis

A Thesis Submitted to the

Yale University School of Medicine

in Partial Fulfillment of the Requirements for the

Degree of Doctor of Medicine

by

Victor Zhang Zhu

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ABSTRACT

A COMPARISON OF SUPEROMEDIAL VERSUS INFERIOR PEDICLE REDUCTION MAMMOPLASTY USING THREE-DIMENSIONAL ANALYSIS.

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Reduction mammoplasty using the inferior pedicle (IP) technique continues to be more commonly performed than the superomedial pedicle (SMP). This study uses three-dimensional (3D) imaging to compare postoperative linear and volumetric changes in SMP and IP breast reductions.

Reduction mammoplasty was performed using either a SMP or IP, with a Wise-pattern skin incision. Patients in each cohort were matched based on total postoperative breast size, BMI, and age. Postoperative 3D photographs were taken at 1-3 months and 6-12 months. Measurements included: sternal notch to nipple distance, areola surface area, total breast volume, breast projection, proportion superior pole volume, proportion medial pole volume, and tissue shifting over time.

There were 13 SMP patients (26 breasts) and 14 IP patients (28 breasts). There were significant differences at 1-3 months between the cohorts in sternal notch to nipple distance (21.6±0.4cm SMP vs. 24.1±0.3cm IP, p<0.01), and proportion superior pole volume (53.9±1.2% SMP vs. 57.3±1.1% IP, p=0.04). The sternal notch to nipple distance (21.6±0.4cm SMP vs. 24.6±0.4cm IP, p<0.01) remained different between the two cohorts at 6-12 months; however, there was no difference in superior pole fullness at this time point. There was a significant difference in proportion medial pole volume (38.1±2.0% SMP vs. 45.8±1.4% IP, p<0.01). There were changes in volumetric distribution over time in both cohorts, with decreased proportion medial pole volume in the SMP cohort, and increased proportion medial pole volume in the IP cohort (p<0.01) over time. Areola surface area increased significantly more over time in the IP cohort than the SMP cohort (2.87±0.77cm^2 IP vs. 0.01±0.57cm^2 SMP, p<0.01).

There is no difference between the SMP and IP technique in proportion superior pole volume or breast projection within the 12-month postoperative period; however, the IP technique demonstrated greater proportion medial pole volume and increased areolar surface area over time.

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TABLE OF CONTENTS

INTRODUCTION

Reduction Mammoplasty and its Benefits

Reduction mammoplasty, or breast reduction, is one of the most commonly performed procedures by plastic surgeons, with over 100,000 reductions performed in 2013.[1] It is usually considered a reconstructive procedure in the United States and is oftentimes covered by health insurance. Some patients also receive reduction mammoplasty for cosmetic reasons to improve the shape of the breasts, where the procedure is frequently combined with mastopexy techniques. There are multiple benefits to the procedure including alleviation of back and other musculoskeletal pain, prevention of skin irritation from excess tissue, indentation of brassiere straps, and mitigation of psychological depression and social anxiety. Patients generally report high levels of satisfaction with the procedure, citing improvements in physical health, psychological wellbeing, and social functioning, even with relatively small reductions.[2,3,4,5]

Musculoskeletal pain is perhaps one of the most physically debilitating effects of macromastia. One study sought to evaluate pain symptomology using a battery of questionnaires and assessments. They found that prior to surgery, half of breast reduction patients reported breast related pain, whereas 6-9 months after surgery, only 10% did. Using the McGill Pain Questionnaire, a survey designed to measure severity and quality of pain, operative patients realized a decrease in pain scores from 26.6 to 11.7 ($p<0.01$). This study also used the EuroQol and SF-36 surveys which evaluated general physical and mental health status. Operative patients had an increase in EuroQol from 0.67 to 0.86 ($p<0.01$) as well as increases in all eight domains of the SF 36 ($p<0.01$). To measure self-esteem, this study used the Multidimensional Body-Self Relations Questionnaire and similarly found statistically significant ($p \leq 0.05$) improvements in appearance evaluation, appearance orientation, fitness evaluation, overweight preoccupation, and self-classified weight. By evaluating a variety of different health indicators using several survey instruments, this study was able to evaluate multiple domains of health functioning in addition to pain in the breast reduction patient. Furthermore, this study used two separate control groups (persons with macromastia and persons without) that did not receive breast reduction in order to improve the validity of the results.[4]

Despite already high patient satisfaction rates with the procedure, surgeon led improvements in aesthetic result can lead to even higher rates of patient satisfaction. A study by Godwin et al. (2014)[6] demonstrated that over 15 years, a group of surgeons that self-criticized and improved their surgical technique developed greatly improved patient satisfaction in a variety of measures. In this study, there was a 79% increase in "Excellent" responses in Overall Body Harmony, 72% increase in "Excellent" responses in Appearance in Clothes, a 69% increase in "Excellent" responses in Appearance out of Clothes, and a 76% increase in "Excellent" responses in Overall Breast Symmetry. As such, it is critical for plastic surgeons to continue efforts to improve surgical technique and aesthetic result in order to improve patient satisfaction with breast reduction.

There is even evidence that reduction mammoplasty may reduce breast cancer incidence. A study in Sweden that followed over 30,000 women who had received breast reductions using nationwide healthcare registers found that there was a 29% (95% confidence interval: 22-35%) reduction in breast cancer incidence among women who had received breast reductions as compared to a similar cohort of Swedish patients of the same age that did not.[7] While it is true that highly powered database studies like this one can often lead to statistically significant findings due to the immense sample sizes, this particular finding is likely clinically meaningful due to the magnitude of reduction. Furthermore, previous studies have also indicated a decrease in breast cancer incidence following reduction mammoplasty.[8] Finally, this reduction in breast cancer risk makes logical sense, as the removal of excess breast tissue can reduce the amount of breast tissue that can undergo malignant transformation.

Measuring the Aesthetically Ideal Breast

Many previous studies have attempted to characterize specific measurements to define an aesthetically appealing breast.[9,10,11,12,13] These parameters include greater projection of the breast from the chest wall, increased upper pole fullness (proportion superior pole volume), increased medial pole fullness/cleavage (proportion medial pole volume, nipple position, and breast symmetry. Important surgical parameters also include a reduction in scarring and prevention of tissue shifts over time, especially from the superior pole to the inferior pole.

Liu and Thomson (2011) sought to identify ideal linear measurements for the breast. In a study that solicited evaluations of 109 pairs of breast images from 252 plastic surgeons, 15 cosmetic patients, and 25 reconstructive patients, they found ideal sternal notch to nipple distance of 21 – 21.5 cm, inter-nipple distance of 21 cm, nipple to inframammary fold distance of 8 cm, anterior axillary line to nipple distance of 13cm, and areola diameter distance of 4 – 4.5cm. In most cases, surgeons and patients had statistically similar measurements; however, in some cases patients had a 0.5 cm higher measurement than surgeons. This difference is reflected in the measurement ranges above. When separating the breast image volunteers by BMI and height, several differences were noted. Higher BMI patients had increased measurements in all parameters as would be expected. Taller patients on the other hand, surprisingly had reduced ideal measurements in almost all parameters. Of note, cosmetic patients strongly valued greater superomedial fullness (cleavage) whereas reconstructive patients strongly valued symmetry between breasts.[10] Despite the lower number (and power) of patient responses compared with surgeon responses, the incorporation of patient responses improves the generalizability of the study and allows for the understanding of patient opinions on ideal aesthetic breast measurements. While it appears that generally surgeons and patients had similar opinions on ideal measurements, there are also important differences to take note in planning surgeries for cosmetic and/or reconstructive patients.

These differences between patients and surgeons were further elaborated in a study by Hsia and Thomson (2002), which presented images of breast shapes with differing upper pole contours to three different cohorts: plastic surgeons, patients seeking breast augmentation, and lay people. The study participants were to rate the images for attractiveness, naturalness, how consistent the shape was to their personal ideal, and how consistent the shape was to their perceived societal ideal. In general, the breast images with flat upper-pole contours received the highest scores among all groups; however, it was interesting to note that plastic surgeons generally rated concave upper-pole contours more favorably than surgeons ($p < 0.01$). Lay people had responses in between those of plastic surgeons and patients.[9] While sample sizes were relatively low in the plastic surgeon (11) and patient (13) cohorts, these results remind us that, regardless of what experts consider an aesthetically “ideal” breast, personal preference still plays a large role when it comes to preferred breast shapes.

Mallucci and Branford (2012,2014) in the United Kingdom published two papers regarding ideal breast morphology. In the first paper, they studied the breasts of 100 models from the Sun newspaper website and found an ideal nipple position in the 45:55 ratio, where the nipple is placed on a vertical line with 45% of the breast above the nipple and 55% of the breast below. All models were within 3 percentage points of this ideal proportion. They also discovered that all nipples pointed upward at an angle of 20 degrees ($\pm$ 7 degrees) above a horizontal line through the nipple. As for upper pole shape, the authors found 61 breasts with a concave contour, 33 with a straight contour, and 6 with a convex contour.[11] This study was unique in that newspaper publishers, who presumably wished to reflect the supposed preferences of British society, selected the model breasts.

In the second study by Mallucci and Branford (2014), the authors confirmed the 45:55 ratio finding by taking images of the breasts of four women, and morphing the images with the following rations 35:65, 45:55, 50:50, and 55:45. 1315 respondents (including 53 plastic surgeons) were then asked to rate the morphed images in terms of attractiveness. The vast majority of the respondents marked the 45:55 ratio highest, with the 50:50 ratio second highest. Plastic surgeons, in particular, had some of the highest proportions (94%) that rated the 45:55 highly.[12] This is in agreement with the studies by

Liu and Thomson (2011) and Hsia and Thomson (2014) which found plastic surgeons generally preferring concave upper pole slopes and more natural appearing breasts.

Mallucci and Branford (2014) then broke the respondents down into groups based on age, sex, continent of origin, and ethnicity, which revealed interesting deviations. Women younger than 40 were more apt to rate the 45:55 ratio higher than women older than 40 (85% vs. 76%, $p < 0.05$). Instead of the 45:55 ratio, older women were generally more accepting of the 50:50 ratio (lower nipple and greater proportion in the upper pole). Men also were more likely than women to prefer the 45:55 ratio (90% vs. 82%, $p < 0.01$) to the 50:50 ratio. North Americans (92%) were more likely to rate the 45:55 ratio higher than Europeans (86%). The fact that men and North Americans rated the "natural" (45:55) ratio higher than the "fake/augmented" (50:50) ratio was surprising to the authors given cultural stereotypes that state men prefer an augmented shape and patterns of augmentation in the US vs. Europe. Compared to other ethnic groups/continents of origin, Black/African respondents had the lowest proportion rate the 45:55 ratio highest at 75-76%, with a significant minority rating the 50:50 ratio as their first choice 18%.[12] While the authors emphasize that the 45:55 ideal ratio generally held across all populations reflecting similar breast ideals across all societies and cultures, it could be argued that the small differences in percentage rating the 45:55 ratio highest across varied populations may reflect differing cultural preferences when it comes to breast shape. These cultural differences are especially important with regards to this research since it was primarily conducted in the United Kingdom, which may have differing views on what an ideal breast shape constitutes than in the United States. Additionally, the use of photoshop morphing of the images and the lack of a 40:60 image may be seen as potential limitations of this research.

In summary, previous studies on breast aesthetics have managed to uncover certain ideal linear measurements, including sternal notch to nipple distance, inter-nipple distance, and nipple to inframammary fold distance. These studies have also found ideal ratios of superior pole to inferior pole volume, based on the location of the nipple and using linear measurements. While preferences are similar across all cultures and populations, there are minute but important differences in certain subgroups. For example, cosmetic surgery patients seem to prefer more convex upper pole contours and greater proportion of superior pole to inferior pole, whereas plastic surgeons and those from the Americas seem to prefer flatter/concave upper pole contours with a reduced proportion of superior pole to inferior pole.

In summary, previous studies on breast aesthetics have been confined to various surface linear measurements that are considered ideal, including sternal notch to nipple distance, inter-nipple distance, and nipple to inframammary fold distance. In cases where internal linear measurements could not be taken, alternative surface measurements were made. For example, anterior axillary line to nipple distance was used in place of breast projection. Linear measurements (45:55 ratio for breast distribution in the superior and inferior poles) and linear forms (convexity/concavity of the superior breast slope) were also used as alternatives to measuring proportion superior pole to inferior pole volume and shape of the superior breast curve, respectively.

Breast Reduction Techniques

In breast reduction, it is important to differentiate between the skin resection pattern and the pedicle type. The skin resection pattern refers to the technique of removing excess skin, and the result is the remaining scar pattern on the breast skin. There are a variety of different skin resection patterns, including the periareolar pattern, the vertical skin pattern, and the Wise (inverted T) skin pattern. The remaining scar with a periareolar pattern skin resection is a periareolar scar. With the vertical skin pattern, a verticle scar from the areola to the inframammary fold is added to the periareolar scar, forming a "lollipop" shape. Finally, with the Wise (inverted T) skin pattern, a horizontal scar on the inframammary fold is added to the vertical skin pattern scar, ultimately forming an "inverted T" shape or an "anchor" shape. While larger scar skin resection patterns are aesthetically unpleasing, they also allow the surgeon greater ability to manipulate tissues and create a more pleasing breast shape.[14,15,16,17]

Pedicle type refers to which portion (or "pedicle") of the breast is retained during the breast reduction process. Commonly used pedicle types include the inferior pedicle, medial pedicle, superior pedicle, and lateral pedicle. The inferior and medial pedicle blood supply is based on perforating branches of the internal mammary artery. The lateral pedicle blood supply is based on branches of the lateral thoracic artery. Finally, the superior pedicle is based on branches from both the internal mammary artery and the lateral thoracic artery. The skin resection pattern can usually be an independent choice from the pedicle type; however, commonly employed combinations for breast reduction include the inferior pedicle, Wise-pattern breast reduction and the medial pedicle, vertical skin pattern breast reduction.[15,16,17]

The inferior pedicle, Wise-pattern breast reduction technique is often considered the gold standard for its reproducibility and reliable outcomes in a large variety of reductions.[2,18] Wise first described his skin resection pattern in 1956[19] and Ribeiro first described the use of the inferior pedicle in 1975.[20,21] The two were combined into the inferior pedicle, Wise-pattern breast reduction that was first described by Robbins in 1977.[22,23] Critics of the inferior pedicle technique describe that the result is an aesthetically “boxy” breast that is wide, flat, and lacks upper pole fullness. This is due to the technique’s use of the inferior pedicle, and the excision of tissue from the superior pole. Furthermore, the inferior pedicle technique undergoes tissue shifting from the superior pole to the inferior pole postoperatively (also called “bottoming out” or “pseudoptosis”), further exacerbating the lack of upper pole fullness.[2,24,25,26,27,28]

To correct some of the shortcomings of the inferior pedicle technique, Hall-Findlay described the medial pedicle technique in the 1990s, building on earlier work from Lejour and Lassus.[29,30,31,32,33,34,35,36,37,38,39] Hall-Findlay’s medial pedicle technique is oftentimes referred to as the superomedial pedicle technique since when the patient is in the standing position, the medial pedicle appears to originate from the superomedial corner due to the effects of gravity. Proponents of the superomedial pedicle claim that the technique provides increased upper and medial pole fullness, prevents tissue shifting from the superior pole to the inferior pole, and is able to better maintain breast projection. This is due to the technique’s preservation of the superior and medial breast tissue and removal of the inferior and lateral breast tissue. Proponents have used this technique even in very large reductions.[40,41,42,43,44] Despite these benefits, 75% of plastic surgeons still prefer the inferior pedicle technique.[37,45] This is attributed to training barriers and discomfort with a novel technique in the context of the well-established inferior pedicle technique.

Comparing Inferior Pedicle and Superomedial Pedicle Techniques

Despite the stated advantages of the superomedial pedicle technique, there have been no quantitative studies that have directly compared the two techniques' volumetric and morphologic outcomes. Previous studies that have directly compared the two techniques have focused primarily on complication rates and postoperative patient satisfaction surveys.[46,47] In a retrospective review of 100 inferior pedicle, Wise-pattern breasts and 100 superomedial, vertical skin pattern breasts, Antony et al. (2013) found no significant difference in total complications (23 vs. 23, $p = 1.00$) between the two techniques. Patients in the two cohorts were matched based on age and weight of breast tissue resected. Four separate surgeons did the breast reduction procedures. Complications measured include nipple sensation loss, seroma, minor skin breakdown, return to operating room, nipple areola complex necrosis, hematoma, and wound infection.[46] The authors had a relatively high sample size; however, some of the measured complications such as nipple areola complex necrosis are relatively rare phenomenon that would not be expected to have more than a few, if any cases. As such, the statistical analysis of complications separated by type would likely require higher sample sizes.

Another study by Cruz-Korchin and Korchin (2003) compared postoperative patient satisfaction surveys following either inferior pedicle, Wise-pattern breast reductions or superomedial pedicle, vertical skin pattern breast reductions. In this randomized controlled study, 105 patients received inferior pedicle, Wise pattern breast reductions and 103 patients received superomedial pedicle, vertical skin pattern breast reductions, all from the same surgeon. Patients were then given postoperative questionnaires at six months assessing their satisfaction with the surgical outcome on a variety of measures. There were no differences between the two groups' survey responses in breast size, shape, symmetry, nipple sensation, symptom relief, ease of bra/clothes fitting, and overall satisfaction; however, patients who received the superomedial pedicle, vertical skin pattern reductions did note higher scores in scar minimization and overall aesthetic results. This group also had a higher rate of needing secondary revisions.[47]

In summary, these studies comparing inferior pedicle, wise-pattern breast reductions with superomedial pedicle, vertical skin pattern breast reductions indicate that complication rates tended to be similar among the two groups, although patients with superomedial pedicle, vertical skin pattern reductions may require additional revisions. Satisfaction rates with scar minimization and overall aesthetic results were higher with the superomedial pedicle, vertical skin pattern reduction, although this may be a reflection of the differing skin resection patterns, and less so due to the pedicle type. Additional studies would be needed to isolate pedicle type from skin resection pattern, unfortunately, there are no studies that compared two groups with a different pedicle but the same skin resection pattern. Furthermore, none of the above studies analyzed morphologic and volumetric outcomes between the two techniques. While patient satisfaction scores for breast size/shape on postoperative surveys can be viewed as a proxy for volumetric/morphologic outcomes between the two types of breast reduction, a direct quantitative comparison would clearly be more accurate.

Mammometrics

Mammometrics refers to the use of three-dimensional (3D) breast measurements to guide operative planning, quantitatively analyze surgical outcomes, and track changes over time.[48] Simply put, "mammometrics" means measurements of the breast. The original definition of mammometrics only includes 3D measurements; however, the term is applicable to two-dimensional (linear) measurements as well. It is important to understand the history of mammometrics in order to appreciate the advances make possible through 3D photography and digital image analysis. As such, historical methods of mammometrics will first be enumerated in the section.

As is evident in research presented within this manuscript, linear breast measurements were the first to receive standardization, due to the simplicity of conducting linear measurements with a measuring tape. Measurements such as the sternal notch to nipple distance, inter-nipple distance, and nipple to inframammary fold distance are examples of linear measurements especially important for the breast. Volumetric (3D) measurements on the other hand have been difficult to develop due to the uniquely variable and complex breast form.

Attempts were first made using complex mathematical formulas to approximate volume.[48] Other methods used for volume measurements include Archimedes' principle of water displacement, where the breast is placed in a bowl of water, and the volume of water displaced is measured. Plaster molding and casting has also been employed as a method for volume measurements of the breast. While the methods of water displacement and plaster molding/casting can be relatively accurate when done carefully and correctly, both methods tend to be labor intensive and cumbersome to enact. A simpler method has been developed based on the Grossman-Roudner device, a conical measuring device in which the breast is placed in the device to retrieve a volume.[49] This method has been criticized, however, due to its inability to measure lateral breast volume and large/small breast volumes.[48] Even when any of these historical methods can create an accurate and reliable total breast volume measurement, none of these techniques can measure volume distributions in the breast (for example, proportion volume in the superior/inferior pole or medial/lateral pole) or other more advanced 3D measurements.

Technological advancements in 3D photography and photoimaging software has allowed for more accurate mammometrics. This technique, also called stereophotogrammetry, involves taking a photograph of the breasts from three different angles. These images are then digitally reconstructed into a 3D object, which is then subject to total volume measurements or partial measurements of a portion of the object. Linear measurements as well as surface area measurements can also be conducted. The 3D stereophotogrammetry method has been validated over the last decade as a novel method for mammometrics that is superior to previous measuring techniques.[49,50,51,52,53,54,55]

Previous studies have used 3D stereophotogrammetry in comparing preoperative and postoperative changes following augmentation mammoplasty[56,57,58] and breast reconstruction[59,60]. In breast reduction, there have been two studies that have used 3D stereophotogrammetry. Small et al. (2010) used the technique to follow 15 patients undergoing medial pedicle, vertical pattern skin incision. Photographs and measurements were made in the early postoperative period (60-120 days) and the late postoperative period (400-500 days). The authors' aim was to quantify, using 3D stereophotogrammetry, changes in the postoperative breast shape, with a focus on the phenomenon of tissue redistribution to the inferior pole over time (bottoming out/pseudoptosis). This focus was based on the idea that the medial pedicle is purported to reduce bottoming out. They found that total volume decreased from an average of 556 cc to 441 cc ($p<0.01$) over the two time periods. Upper pole proportion reduced on average from 76% to 69% ($p<0.01$) and breast projection decreased on average by 0.6cm ($p<0.01$). Sternal notch to nipple distance also decreased from 21.8cm to 20.7cm ($p<0.01$) over the study period. There were no significant changes, however, in inter-nipple distance measurements (21.8cm early vs. 21.7cm late, $p=0.80$). As such, this study found that tissue does redistribute to the lower poles over the course of 400-500 days in medial pedicle, vertical skin pattern breast reductions.[61] Unfortunately, this study did not have a second cohort of inferior pedicle breast reduction patients, as it would be interesting to compare if the medial/superomedial pedicle reduction indeed has less tissue redistribution to the lower poles over time.

In a subsequent study, Quan et al (2011) followed this cohort beyond one year to a second and third year. Ten patients remained in the study over the course of the three-year period. The authors found no subsequent change in volume, tissue redistribution from the upper to lower pole, breast projection, sternal notch to nipple distance, and inter-nipple distance (all $p > 0.05$). The authors thus concluded that no statistically significant change occurs after one year for medial pedicle, vertical skin resection breast reduction.[62]

Once again, this study did not study inferior pedicle breast reductions and as such it is unclear if postoperative changes occur in inferior pedicle breast reduction patients, and, if so, how these changes would compare to medial pedicle breast reduction patients.

PURPOSE

The specific aims of this study are to use 3D stereophotogrammetry to quantify and compare postoperative volumetric and morphologic outcomes between superomedial (SMP) and inferior pedicle (IP) breast reductions. Since the purpose of this study is to isolate the effect of pedicle type on tissue redistribution, both the inferior pedicle and superomedial pedicle reductions used the same skin incision pattern – the Wise-pattern incision. Mammometric parameters measured include total breast volume, breast projection, upper (lower) pole fullness, medial (lateral) pole fullness, and tissue shifting over time. Sternal notch to nipple distance, inter-nipple distance, nipple to inframammary fold distance, and areola surface area measurements also were conducted.

The hypothesis is that superomedial pedicle reduction will have greater upper pole fullness and medial pole fullness as well as reduced tissue shifting over time. This is based on the purported benefits of the superomedial pedicle. If this is found to be true, then this study would influence the continued adoption of the superomedial technique to create improved patient outcomes in breast reduction. Total breast volume is expected to diminish over the study period in both cohorts as postoperative edema resolves and as the breast settles into its final postoperative state. There is no evidence that either the superomedial or inferior pedicle will have differing rates of edema resolution so it is likely that there is no difference in total breast volume reduction between the two cohorts.

As for linear measurements, due to the reduction in pseudoptosis purported with the superomedial pedicle reduction as compared to the inferior pedicle reduction, it is expected that changes in sternal notch to nipple distance and nipple to inframammary fold distance will be reduced in the superomedial cohort as compared to the inferior pedicle cohort. There is no evidence that inter-nipple distance or areola surface area measurements will be different between the two cohorts.

This is the first objective quantitative analysis comparing these different breast reduction techniques. Additionally, this is the first quantitative mammometric analysis conducted on inferior pedicle, wise-pattern breast reduction patients.

METHODS

Patient Selection

After obtaining approval by the Yale University Institutional Review Board, all female patients 16 years or older presenting to the Yale Section of Plastic Surgery from 2012-2014 for reduction mammoplasty were given the opportunity to participate in this study. Exclusion criteria for the study included any previous breast surgery, age under 16 years, and any history of breast malignancy. Patients were prospectively and randomly assigned by the scheduling department to one of the two senior authors. Patients were not told of the different breast reduction techniques prior to surgeon assignment. Surgeon A performed superomedial pedicle reductions, and Surgeon B performed inferior pedicle reductions; both used a Wise pattern skin incision. The new nipple position for both surgeons was marked pre-operatively using transposition of the inframammary fold, approximation of the mid-humeral level, and notch to nipple measurement for symmetry.

Following a detailed explanation of the study design, as well as the risks and benefits of study participation, informed consent was obtained. Patients in each group were then matched based on age, BMI, and total postoperative breast volume in the early postoperative period. Matching in each group was done based on the following parameters: Age >18 and <70, BMI <45, and postoperative breast volume <500 or >1300cc. All patients in each group fit within these matching parameters. Patients who had significant weight loss that affected breast volume during the course of the study were excluded.

<u>3D Photography</u>

Following reduction mammoplasty, all patients were asked to return during the early postoperative period (1-3 months postoperatively) and the late postoperative period (6-12 months postoperatively). During these visits, 3D photographs of the breasts were taken using the Canfield Vectra 3D camera (Fairfield, NJ). Complications, such as wound dehiscence, painful scars, infection requiring antibiotics, and surgical revision, were also noted during these visits. Patients who failed to return for the requisite two postoperative pictures were removed from the study.

<u>Mammometric Analysis</u>

Geomagic software (3D Systems, North Carolina) was used for mammometric and volumetric breast analyses. All measurements were taken three times and averaged to improve the accuracy of the results. The same researcher completed all measurements in order to improve the precision of the results. Important landmarks were identified and held constant for all measurements: sternal notch, nipple, and the point of maximum projection. The point of maximum projection was found by rotating to the perpendicular profile image. The maximum point on the Z-axis on each breast was labeled the point of maximum projection for that breast. The point of maximum projection was oftentimes the nipple of the breast; however, this was not always the case. The following linear measurements were made: sternal notch to nipple surface distance, nipple to inframammary fold surface distance (the point on the inframammary fold was chosen as that point which is directly below the nipple on the Y-axis), inter-nipple vector distance, projection of the breast from the chest wall to the nipple, and projection of the breast from the chest wall to the point of maximum projection (sometimes these last two measurements would be the same if the point of maximum projection was the nipple). Vector measurements refer to the distance of a direct line between two points. Surface measurements refer to the distance of a line following the curvature of the skin from the first point to the second point. Surface area measurements included the areola and the whole breast.

The following volumetric measurements were made: total breast volume, proportion superior pole volume, and proportion medial pole volume. Total breast volume was calculated by measuring the total breast tissue volume with the chest wall as the dorsal boundary, the inframammary fold as the inferior boundary, the anterior axillary line as the lateral boundary, and the sternal midline as the medial boundary. The proportion superior pole volume was measured by creating an YZ plane (axial plane) intersecting the point of maximum projection, parallel to the ground. The volume of breast above this plane was considered the superior pole volume and the volume below the plane was considered the inferior pole volume. To obtain proportion superior pole volume, the superior pole volume was divided by the total breast volume. The proportion medial pole volume was obtained by creating a XZ plane (sagittal plane) through the point of maximum projection, perpendicular to the YZ plane. The volume of the breast medial to this plane was considered the medial pole volume and the volume lateral to this plane was considered the lateral pole volume. To calculate the proportion medial pole volume, the medial pole volume was divided by the total breast volume.

Tissue shifting from the superior to the inferior pole over time was also calculated by determining the difference between the proportion superior pole volumes of the late and early postoperative periods. Tissues shifting from the medial to lateral poles was measured by determining the difference between the proportion medial pole volumes of the late and early postoperative periods. Changes in other measurements were also evaluated by taking the difference of late and early postoperative period measurements.

Statistical Analysis

Statistical analysis was conducted using SPSS software (Version 21, IBM, New York). Independent samples T-tests were used for analyses and significance was determined to be at $p \leq 0.05$. With an estimated effect size of 3% in the superomedial pedicle group and 6% in the inferior pedicle group, a common standard deviation of 2, a level of significance of 0.5, and a power level of 0.8, the calculated sample size would be 7 for each group.

RESULTS

Data is presented as mean ± standard error of the mean. There were 32 patients who consented for the study and completed all required components of the study. Five patients were excluded due to significant weight loss during the course of the study (1), and excessive BMI or extreme volumes (4). The final tally included 27 patients, with 13 patients in the superomedial pedicle (SMP) cohort and 14 patients in the inferior pedicle (IP) cohort. Taking each breast as a separate sample, there were thus 26 SMP breasts and 28 IP breasts available for mammometric analysis.

There were no statistically significant differences between the two cohorts regarding age, BMI, or total postoperative breast volume at the early postoperative period. Demographic data is presented in Table 1. The average age in the SMP cohort was 36.7 ± 3.0 and 37.5 ± 3.0 in the IP cohort ($p = 0.84$). The average BMI in the SMP cohort was 30.9 ± 1.3 versus 32.5 ± 1.4 in the IP cohort ($p = 0.39$). Total postoperative breast volume in the early postoperative period in the SMP cohort was 801 ± 31 cc and 779 ± 42 cc in the IP cohort ($p=0.68$). The average weight of breast tissue resected in the SMP cohort was 417 ± 30 cc and 846 ± 78 cc in the IP cohort ($p<0.01$). This was due to surgeon A's preference to remove smaller amounts of breast tissue than surgeon B.

There were minimal complication rates requiring surgical revision in both groups (2/16 SMP vs. 0/17 IP, $p=0.17$). In the SMP group one patient developed a 1cm dehiscence of the L breast as well as scar hypertrophy. Another patient developed a cyst that was excised and an area of fat necrosis that was biopsied between the early and late postoperative periods. One patient felt her breasts remained too large and requested further revision, which was performed after the late postoperative analysis (not counted as a surgical complication for statistical purposes). The area of fat necrosis was subsequently excised following the late postoperative analysis. In the IP group, one patient had fat necrosis, and another patient had a small dog-ear at 1 month, neither of which required surgical intervention.

Change Over Time for the Superomedial Cohort (Table 2)

Analyzing the change over time from the early to late postoperative period within the superomedial pedicle cohort, the sternal notch to nipple distance (21.6 ± 0.4 cm early vs. 21.6 ± 0.4 cm late, $p=0.93$), nipple to inframammary fold distance (12.6 ± 0.3 cm early vs. 12.3 ± 0.3 cm late, $p=0.13$), and inter-nipple distance (21.9 ± 0.8 cm early vs. 22.4 ± 0.8 cm late, $p=0.15$) did not significantly change from the early to late postoperative measurement. The nipple projection distance (6.6 ± 0.3 cm early vs. 6.3 ± 0.3 cm late, $p=0.01$) and maximum projection distance (6.7 ± 0.4 cm early vs. 6.3 ± 0.2 cm late, $p<0.01$), however, decreased significantly from the early to late measurements.

There was no change from the early to late postoperative measurements in the superomedial cohort in areola surface area (18.4 ± 0.8 cm^2 early vs. 18.4 ± 0.9 cm^2 late, $p=0.99$) and breast surface area (447 ± 11 cm^2 early vs. 446 ± 11 cm^2 late, $p=0.87$).

There was no significant change from early to late postoperative measurement in the superomedial cohort in total breast volume (801 ± 31 cc early vs. 772 ± 35 cc late, $p=0.72$). Proportion superior pole volume increased significantly from the early to late postoperative measurement (53.9 ± 1.2 % early vs. 58.8 ± 1.1 % late, $p<0.01$). Proportion medial pole volume decreased significantly from the early to late postoperative measurement (42.4 ± 2.1 % early vs. 38.1 ± 2.0 % late, $p<0.01$).

Change Over Time for the Inferior Cohort (Table 3)

Analyzing the change over time from the early to late postoperative period within the inferior pedicle cohort, the sternal notch to nipple distance (24.1 ± 0.3 cm early vs. 24.6 ± 0.4 cm late, $p<0.01$) and nipple to inframammary fold distance (11.0 ± 0.3 cm early vs. 11.4 ± 0.4 cm late, $p=0.01$) increased significantly from the early to the late measurements. The inter-nipple distance (22.3 ± 0.8 cm early vs. 22.0 ± 0.6 cm late, $p=0.20$), nipple projection distance (7.1 ± 0.3 cm early vs. 6.7 ± 0.2 cm late, $p=0.15$), and maximum projection distance (6.8 ± 0.2 cm early vs. 6.7 ± 0.2 cm late, $p=0.59$), however, had no significant change from the early to the late measurements.

Areola surface area increased in the inferior pedicle cohort from the early to late postoperative period (18.9 ± 0.6 cm^2 early vs. 21.7 ± 0.9 cm^2 late, $p<0.01$). There was no change in breast surface area from the early to late postoperative period (444 ± 15 cm^2 early vs. 443 ± 16 cm^2 late, $p=0.74$).

There was no significant change from early to late postoperative measurement in the inferior cohort in total breast volume (779 ± 31 cc early vs. 765 ± 46 cc late, $p=0.43$). Proportion superior pole volume did not change from the early to late postoperative measurement (57.3 ± 1.1 % early vs. 59.6 ± 1.3 % late, $p=0.12$). Similarly, proportion medial pole volume did not change from the early to late postoperative measurement (44.4 ± 1.7 % early vs. 45.8 ± 1.4 % late, $p=0.53$).

Comparing Superomedial Cohort with Inferior Cohort in the Early Postoperative Period (Table 4)

In the early postoperative period, the following linear measurements were significantly different between the two cohorts: the sternal notch to nipple distance (21.6 $\pm$ 0.4 cm SMP vs. 24.1 $\pm$ 0.3 cm IP, $p<0.01$) and the nipple to inframammary fold distance (12.6 $\pm$ 0.3 cm SMP vs. 11.0 $\pm$ 0.3 cm IP, $p<0.01$). This is a reflection of a higher nipple position on SMP compared to IP breasts. There was no significant difference between inter-nipple distance (21.9 $\pm$ 0.8 cm SMP vs. 22.3 $\pm$ 0.7 cm IP, p=0.75), nipple projection (6.6 $\pm$ 0.3 cm SMP vs. 7.1 $\pm$ 0.2 cm IP, p=0.12), or maximum projection (6.7 $\pm$ 0.2 cm SMP vs. 6.8 $\pm$ 0.2 cm IP, p=0.62).

There was no difference in areola surface area between the two cohorts (18.4 $\pm$ 0.8 cm^2 SMP vs. 18.9 $\pm$ 0.6 cm^2 IP, p=0.65). Total breast surface area (447 $\pm$ 11 cm^2 SMP vs. 444 $\pm$ 15 cm^2 IP, p=0.87) was not significantly different between the cohorts.

Total volume was not significantly different between the two cohorts (801 $\pm$ 31 cc vs 779 $\pm$ 42 cc IP, p=0.68). Proportion superior pole volume was greater in the IP cohort compared to the SMP cohort (53.9 $\pm$ 1.1 % SMP vs. 57.3 $\pm$ 1.2 % IP, p=0.04). Proportion medial pole volume was not different between the two cohorts (42.4 $\pm$ 2.1 % SMP vs. 44.4 $\pm$ 1.7 % IP, p=0.46).

Comparing Superomedial Cohort with Inferior Cohort in the Late Postoperative Period (Table 5)

In the late postoperative period, the same linear measurements were significantly different between the two cohorts as in the early postoperative period. These included the sternal notch to nipple distance (21.6 ± 0.4 cm SMP vs. 24.6 ± 0.4 cm IP, $p<0.01$) and the nipple to inframmamary fold distance (12.3 ± 0.3 cm SMP vs. 11.4 ± 0.4 cm IP, $p=0.05$). As in the early postoperative period, there was no significant difference between inter-nipple distance (22.4 ± 0.8 cm SMP vs. 22.0 ± 0.6 cm IP, $p=0.66$), nipple projection (6.3 ± 0.3 cm SMP vs. 6.9 ± 0.2 cm IP, $p=0.09$), or maximum projection (6.2 ± 0.2 cm SMP vs. 6.7 ± 0.2 cm IP, $p=0.10$).

Areola surface area was larger in the IP cohort as compared to the SMP cohort (18.4 ± 0.9 cm^2 SMP vs. 21.7 ± 0.9 cm^2 IP, $p=0.01$). Total breast surface area (446 ± 11 cm^2 SMP vs. 443 ± 16 cm^2 IP, $p<0.88$) was not significantly different between the two cohorts.

Total volume was not significantly different between the two cohorts (772 ± 35 cc vs 765 ± 46 cc IP, $p=0.91$). Proportion superior pole volume equilibrated and was no longer different between the two cohorts (58.5 ± 1.1 % SMP vs. 59.6 ± 1.3 % IP, $p=0.55$); however, the difference in the proportion medial pole volume magnified and reached significance with a larger medial pole percentage in the inferior pedicle cohort (38.1 ± 2.0 % SMP vs. 45.7 ± 1.4 % IP, $p<0.01$).

<u>Comparing Changes Over Time Between Superomedial vs. Inferior Pedicle Cohorts (Table 6)</u>

There were significant differences in the change from early to late postoperative periods between the two cohorts in sternal notch to nipple distance (0.01 ± 0.16 cm SMP vs. 0.51 ± 0.13 cm IP, $p=0.02$) and in nipple to inframammary fold distance (-0.28 ± 0.18 cm SMP vs. 0.34 ± 0.12 cm IP, $p<0.01$). Nipple to nipple distance increased in the SMP cohort by 0.52 ± 0.34 cm but decreased in the IP cohort by -0.27 ± 0.20 cm (p=0.05). The change in nipple projection (-0.31 ± 0.11 cm SMP vs. -0.24 ± 0.16 cm IP, p=0.73) and point of maximum projection (-0.42 ± 0.13 cm SMP vs. -0.10 ± 0.17 cm IP, p=0.13) decreased in both cohorts over time with no significant difference between the two cohorts. (Figure 1)

Areola surface area increased by 0.01 ± 0.57 cm2 in the SMP cohort but increased by 2.87 ± 0.77 cm2 in the IP cohort (p<0.01). The decrease in breast surface area was not significantly different between the two cohorts (-0.90 ± 5.41 cm2 SMP vs. -1.08 ± 3.17 cm2 IP, p=0.98). (Figure 2)

The decrease in total breast volume was not significantly different between the two cohorts (-28.5 ± 15.2 cc SMP vs. -13.6 ± 17.1 cc IP, p=0.52). Proportion superior pole volume increased for the SMP cohort over time by 4.65 ± 1.22 % and increased in the IP cohort by 2.24 ± 1.41 % (p=0.20). The change in proportion medial pole volume decreased in the SMP cohort by 4.24 ± 1.28 % but increased in the IP cohort by 1.37 ± 1.26 % (p<0.01). (Figure 2, 3)

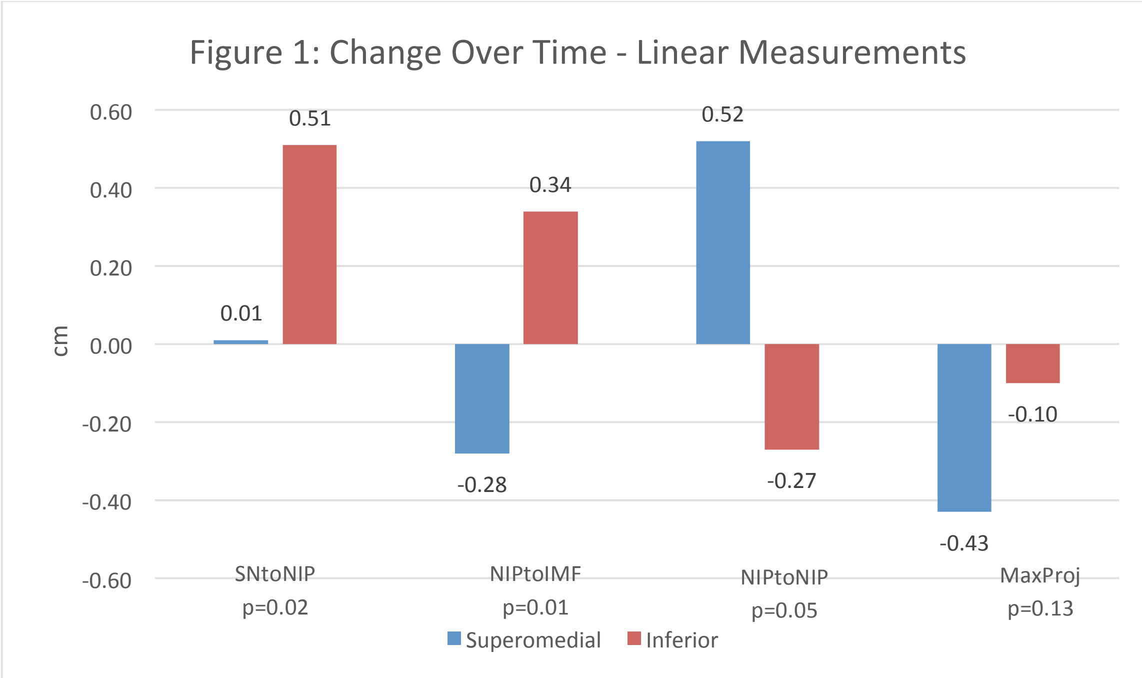
Figure 1: Change Over Time - Linear Measurements
cm
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
0.51
0.34
0.52
0.01
-0.28
-0.27
-0.10
-0.43
SNtoNIP
p=0.02
NIPtoIMF
p=0.01
NIPtoNIP
p=0.05
MaxProj
p=0.13
Superomedial
Inferior

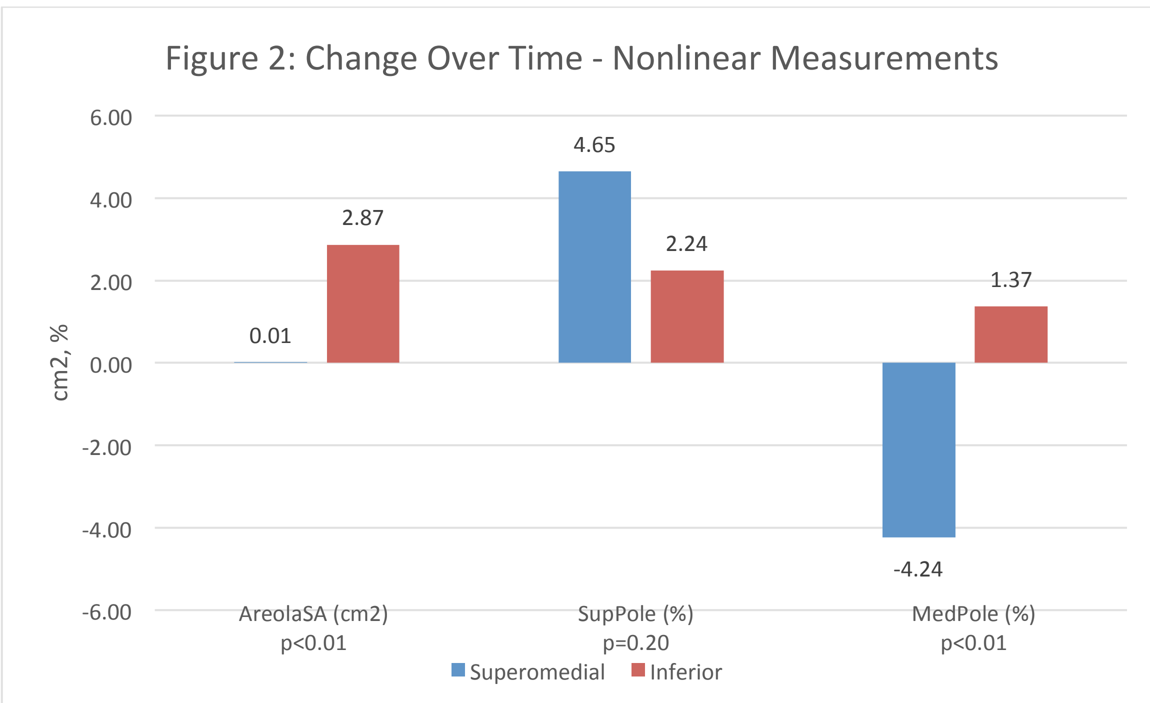
Figure 2: Change Over Time - Nonlinear Measurements
cm2, %
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
4.65
2.87
2.24
1.37
0.01
-4.24
AreolaSA (cm2)
p<0.01
SupPole (%)
p=0.20
MedPole (%)
p<0.01
Superomedial
Inferior

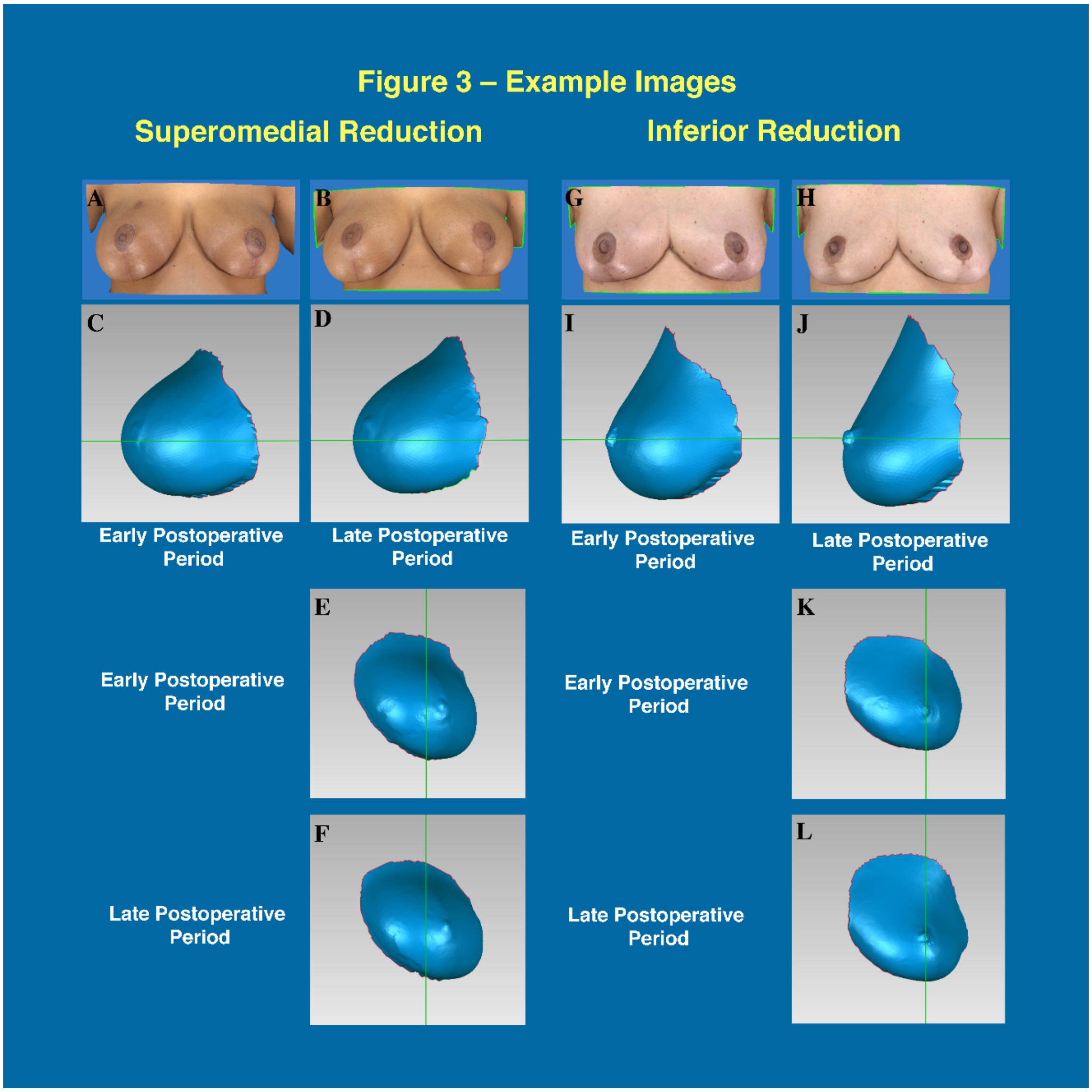
Figure 3 – Example Images
Superomedial Reduction
Inferior Reduction
A
B
G
H
C
D
I
J
Early Postoperative Period
Late Postoperative Period
Early Postoperative Period
Late Postoperative Period
E
K
Early Postoperative Period
Early Postoperative Period
F
L
Late Postoperative Period
Late Postoperative Period

DISCUSSION

This study is the first of its kind to provide objective volumetric analysis comparing superomedial pedicle (SMP) and inferior pedicle (IP) reduction mammoplasty with a Wise pattern skin incision. In this study, the resolution of surgical edema is reflected in the reduction of total volume from the early to late postoperative period. There was no significant difference in the change of total volume between the two cohorts, suggesting that edema was not significantly different between the two reduction techniques.

The significant difference between the two cohorts in sternal notch to nipple distance and nipple to inframammary fold distance can be explained by the fact that the inframammary fold tends to rise after superomedial reductions and drop after inferior reductions. This difference was maintained throughout the study period from the early to late postoperative period. However, when looking at change over time, the IP breasts demonstrated increased lengthening of the sternal notch to nipple distance and the nipple to inframammary fold distance when compared to the SMP cohort. Although the changes over time in sternal notch to nipple distance (0.01 $\pm$ 0.16 cm SMP vs. 0.51 $\pm$ 0.13 cm IP) and nipple to inframammary fold distance (-0.28 $\pm$ 0.18 cm SMP vs. 0.34 $\pm$ 0.12 cm IP) were numerically small, it is possible that this difference represents increased ptosis and pseudoptosis in the IP cohort as compared to the SMP cohort.

There was no difference between the two cohorts in inter-nipple distance, nipple projection, or maximum projection at either the early or late postoperative time point. However, when looking at change over time, the inter-nipple distance increased in the SMP cohort by 0.52 $\pm$ 0.34 cm whereas decreased 0.27 $\pm$ 0.20 cm in the IP cohort.

Although these distances are numerically small, this difference may represent increased lateral rotation of the breast in the SMP cohort due to settling of the superomedial pedicle into other areas of the breast.

Areola surface area increased by 2.87 $\pm$ 0.77 cm^2 in the IP cohort over time whereas the SMP cohort had minimal change. Despite the resolution of post-operative edema and volume reduction in both cohorts, the IP areola surface area increased in the late time period. This may reflect increased pressure from the inferior pedicle behind the areola that may not be present in the SMP technique. For IP reductions, surgeons may consider this change when planning the areola diameter preoperatively.

Differences in volumetric distribution suggest that in the early postoperative period, superior pole fullness is greater in the IP cohort; however, by the late postoperative period there is no longer a difference in superior pole fullness between the two cohorts. This may be explained by the maintenance of superior pole fullness in the SMP breast compared to the IP breast, once edema is resolved.

Interestingly, in the late postoperative period, there is more medial pole fullness in the inferior pedicle group than the superomedial pedicle group. This was unexpected given the preservation of medial breast tissue in the SMP technique. In the SMP technique the medial pole volume diminished by 4.65 $\pm$ 0.12 % over time whereas remained relatively stable in the IP technique. This may be explained by slight lateral deviation of the SMP breast on the chest wall over time due to settling of the superomedial pedicle across the breast.

This is also the first study that quantitatively measures, using 3D spectrophotogrammetry, how inferior pedicle breast reductions change over time postoperatively. This data is obtained by isolating the data from the IP cohort. Significant findings include a lengthening of sternal notch to nipple distance and nipple to inframammary fold distance over the course of the study. Additionally, areola surface area increased significantly from the early to late postoperative period. While these results were already touched upon earlier in the discussion, it is important to remunerate them as these results may facilitate inferior pedicle breast surgeons in preoperative planning.

Data isolated from the SMP cohort can be compared to the results of the Small et al. (2010) study that also used 3D stereophotogrammetry to evaluate postoperative changes in superomedial/medial pedicle reductions. It is important, however, to keep in mind that Small et al. (2010) used a vertical skin resection pattern (instead of a Wise skin resection pattern). Additionally, their early postoperative period was at 2-4 months (instead of 1-3 months) and late postoperative period was at 13-16 months (instead of 6-12 months). The majority of the measurements of this study were in agreement with the Small et al. (2010) study, indicating consistency in 3D stereophotogrammetric methods. Inter-nipple distance did not have significant changes between early and late postoperative measurements. This finding was in agreement with the Small et al. (2010) inter-nipple distance measurements, which also found no significant changes (21.8 ± 4.4 cm early vs. 21.7 ± 4.0 cm late, $p=0.80$). The significant decreases in both nipple projection and maximum projection distances were also in agreement with Small et al. (2010) nipple projection decreases (5.8 ± 1.4 cm early vs. 5.2 ± 1.4 cm late, $p<0.01$).[61] Nipple to inframammary fold distance, breast surface area, areola surface area, and proportion in the medial pole were not measured in the Small et al. (2010) study and as such no comparison can be made.

There were some discrepancies between this research and the Small et al. (2010) study. There was no significant change in the sternal notch to nipple distance or total breast volume from the early to late postoperative period in the superomedial pedicle cohort. The Small et al. (2010) study, on the other hand, found a significant decrease in sternal notch to nipple distance (21.8 $\pm$ 1.6 cm early vs. 20.7 $\pm$ 1.7 cm late, $p<0.01$). Additionally, the decrease in total breast volume in the Small et al. (2010) was significant (557 $\pm$ 144 cc early vs. 481 $\pm$ 184 cc late, $p<0.01$).[61] These discrepancies may be explained by the differences in protocols, which include skin resection pattern and timing of postoperative photographs.

Arguably, the most important measurement in this study and the Small et al. (2010) study is the proportion superior pole volume. Unfortunately, a direct comparison was not possible due to differences in the methodology for calculating proportion superior pole volume. Previous studies in mammometrics, including the Small et al. (2010) study, have used the medial most and lateral most points of the inframammary fold for the creation of an axial plane separating the superior and inferior portions of the breast.[48] In our patient population, the majority of our patients had excess lateral chest tissue, making the lateral inframammary fold difficult to define. Therefore, we chose the point of maximal projection as the point to create an axial plane parallel to the ground to separate the superior and inferior poles. During visual inspection of our 3D images, we felt that the eye naturally identifies the point of maximal projection as a division between the superior and inferior poles. We also chose this point to create the sagittal plane separating the breast into medial and lateral poles.

Previous studies, including the Small et al. (2010) study, also maintained the same plane through different time points by superimposing images. We found this difficult to accomplish due to minor positional changes of the patient when the picture was acquired. These positional changes included the angle of arm placement, small angles of rotation of the body, and changes in the chest wall during different phases of respiration, all of which influenced our ability to superimpose early and late images. Therefore, we decided to recreate both the axial and sagittal planes at each time point.

To compare our results with previous studies on mammometrics, we performed a fixed plane analysis where the plane separating superior/inferior poles and medial/lateral poles were kept at the same location (based on a fixed distance from the sternal notch). Fixed plane analysis found reductions in percent superior pole volume in both cohorts, with a larger reduction in the inferior pedicle cohort (-3.73 $\pm$ 1.52 % SMP vs. -8.14 $\pm$ 1.53 % IP, p=0.05). These results indicate that according to the fixed plane method, the inferior pedicle cohort undergoes greater tissue shifting into the inferior pole as compared to the superomedial pedicle cohort. The decrease over time in the proportion superior pole volume in the superomedial cohort (p=0.02) is also consistent with the Small et al. (2010) study, which similarly found a decrease (-6.5%, p<0.01).[61]

Measurements were conducted to see if the point of maximum projection shifted between the early and late time points. The point of maximum projection in the Y axis shifted inferiorly by 0.76 $\pm$ 0.21 cm in the SMP cohort and 1.11 $\pm$ 0.27 cm in the IP cohort; however, this difference was not significant (p=0.32). The point of maximum projection in the X axis shifted towards the midline in the SMP cohort by 0.39 $\pm$ 0.16 cm whereas shifted away from the midline in the IP cohort by 0.05 $\pm$ 0.17 cm; however, this was not significant (p=0.07). This difference may have contributed to the increased medial pole fullness in the IP cohort at the late postoperative time point.

In this study, we standardized the final breast volume for our three dimensional analysis. We recognized a significant difference in the volume of tissue resected between the two cohorts, therefore we also performed a separate analysis where the cohorts were matched based on the volume of tissue resected (495 $\pm$ 26 cc SMP vs. 555 $\pm$ 20 cc IP, p=0.08). This analysis contained 9 patients in each cohort, and revealed similar results including increased medial pole fullness in the IP cohort at the late postoperative period (36.3 $\pm$ 1.5 % SMP vs. 47.0 $\pm$ 2.0 % IP, $p<0.01$) and no difference in superior pole fullness (59.6 $\pm$ 0.9 % SMP vs. 58.6 $\pm$ 1.8 % IP, p=0.61) or maximum projection (6.24 $\pm$ 0.2 cm SMP vs. 6.01 $\pm$ 0.2 cm IP, p=0.47) at the late postoperative period. Since the final outcomes were comparable when standardizing final breast volume and resected breast tissue weight, we feel the cohorts were consistent.

Complications were minimal in this study and comparable between the two study cohorts. This is consistent with previous studies that have noted similar complication rates between the two techniques.[32,33,35,46,63] One study, did note that there was a higher rate of complications in LeJour vertical reductions in patients with BMI > 30 and tissue resected > 500g.[37]

Preoperative photos of all patients were taken as part of the standard preoperative protocol at our institution. Mammometric analysis of these preoperative photos may yield insights into the different results that were found between the two cohorts; however, we chose not to include analysis of the preoperative photos because any differences in preoperative measurements would be compensated for during the surgical reduction, rendering preoperative measurements invalid for comparison with postoperative measurements.

Swanson (2012) has argued for the use of 2D mammometrics due to the impractibility of 3D measurements for most plastic surgeons who do not have access to 3D cameras and analysis software.[64] 2D analysis was not conducted in this study due to availability of 3D analysis techniques and equipment. It is unclear whether 2D analysis would yield similar outcomes as the 3D results presented in this study.

There are many limitations to this study, including the one-year follow-up period. It is possible that further changes will occur past this time point and would thus not be captured by this study. Future studies may address this limitation. Previous research, has shown that no statistically significant changes occur between one year and three years postoperatively with superomedial pedicle reductions[62]; however, no such long term data exists for inferior pedicle reductions and it would be interesting to see how changes may occur past the one year mark.

Furthermore, this report represents the outcomes of individual surgeons at one institution, and may not be generalizable to other surgeons, as there are many technical variations within each pedicle type. Although some surgeons may believe that the pedicle type affects outcomes, it is possible that the variation in surgical technique, rather than the chosen pedicle type, has a greater impact on volumetric distribution. This limitation could be investigated through further study of other surgeons who perform these techniques to determine reproducibility of our results. It is also possible that the skin incision pattern plays a more significant role in determining final morphologic outcomes than pedicle design. Future studies could also evaluate different skin incision patterns using the same pedicle.

Our objective measurements, demonstrating small differences between the SMP and IP reduction mammoplasty, is in agreement with a study that asked medical personnel (plastic surgeons, physicians, and medical students) to judge aesthetic outcomes (aesthetic appearance, symmetry, scaring, and nipple appearance) based on postoperative pictures. When the participants were asked to compare Lejour superior pedicle and inferior pedicle breast reductions, there was no difference in aesthetic scores.[37] Another study that compared patient satisfaction between the two techniques also found no difference.[35]

In summary, this study indicates that the SMP and IP reduction mammoplasty techniques yield similar 3D outcomes except for medial pole fullness and areola surface area. Therefore surgeons can choose the technique with which they are most comfortable and expect comparable results. This report represents the outcomes of individual surgeons at one institution, and may not be generalizable to other surgeons, as there are many technical variations within each pedicle type. It is also possible that the skin incision pattern plays a more significant role in determining final morphologic outcomes than pedicle design. Future studies are warranted to address the impact of skin incision pattern on postoperative breast morphology.

CONCLUSIONS

Using three-dimensional objective analysis, our results indicate that there is little difference in superior pole volume and projection between the superomedial pedicle and inferior pedicle breast reductions over time. In this study, the inferior pedicle reduction mammoplasty demonstrated increased medial pole volume and areolar surface area compared to the superomedial pedicle reductions over time. As such, surgeons can perform either breast reduction technique and expect comparable outcomes.

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TABLE/FIGURE REFERENCES AND LEGENDS

Table Legend

Table 1: Demographic Statistics

Table 2: Change Over Time for Superomedial Cohort

Table 3: Change Over Time for Inferior Pedicle Cohort

Table 4: SMP vs. IP Cohorts in the Early Postoperative Period

Table 5: SMP vs. IP Cohorts in the Late Postoperative Period

Table 6: SMP vs. IP Cohort Change Over Time

Figure Legend

Figure 1: Change Over Time – Linear Measurements. Change from early postoperative period to late postoperative period of selected linear measurements. Y-axis displays units in cm. SMP cohort is represented by blue bars and IP cohort is represented by red bars. Sternal notch to nipple (SNtoNIP) distance increased significantly more in the IP cohort than the SMP cohort. Nipple to inframammary fold distance decreased in SMP breasts whereas increased in the IP breasts. Inter-nipple (NIPtoNIP) distance increased in the SMP cohort and decreased in the IP cohort. Maximum projection (MaxProj) decreased more in the SMP cohort than in the IP cohort, although this did not reach statistical significance.

Figure 2: Change Over Time – Nonlinear Measurements. Change from early postoperative period to late postoperative period of selected nonlinear measurements. Y-axis units are in centimeters squared for areola surface area (AreolaSA) and percent for superior pole volume (SupPole) and medial pole volume (MedPole). SMP cohort is

represented by blue bars and IP cohort is represented by red bars. AreolaSA increased significantly in the IP cohort but stayed about the same in the SMP cohort. SupPole increased more in the SMP cohort than the IP cohort; however, this did not reach statistical significance. MedPole decreased in the SMP cohort and increased in the IP cohort.

Figure 3A-L: Example Images. Patient photographs and 3D reconstruction images showing volumetric analysis. Images A-F are from the same SMP patient and images G-L are from the same IP patient. A) AP photograph of SMP breasts at early postoperative time period. B) AP photograph of SMP breasts at late postoperative time period. Note minimal change in areola size. C) 3D reconstruction lateral view of left breast of SMP patient at early postoperative period showing 56.9% superior pole volume. D) 3D reconstruction lateral view of left breast of SMP patient at late postoperative period showing large increase in superior pole volume to 64.5%. E) 3D reconstruction frontal view of left breast of SMP patient at early postoperative period showing 58.4% medial pole volume. F) 3D reconstruction frontal view of left breast of SMP patient at late postoperative period showing decrease in medial pole volume to 35.9%. G) AP photograph of IP breasts at early postoperative time period. H) AP photograph of IP breasts at late postoperative time period. Note increase in areola size from preoperative time period. I) 3D reconstruction lateral view of left breast of IP patient at early postoperative period showing 60.5% superior pole volume. J) 3D reconstruction lateral view of left breast of IP patient at late postoperative period with superior pole volume of 63.1%. K) 3D reconstruction frontal view of left breast of IP patient at early postoperative period showing 40.4% medial pole volume. L) 3D reconstruction frontal view of left breast of IP patient at late postoperative period showing increase in medial pole volume to 44.1%.

TABLES

Table 1: Demographic Statistics

	Superomedial (Range)	Inferior (Range)	P-Value
Age (yrs)	36.7 ± 3.0 (16-58)	37.5 ± 3.0 (21-53)	0.84
BMI	30.9 ± 1.3 (25.4-40.6)	32.5 ± 1.4 (26.4-41.9)	0.39
Total Breast Vol (cc)	801 ± 31 (540-1129)	779 ± 42 (554-1253)	0.68
Tissue Resected (cc)	417 ± 3.0 (154-672)	846 ± 3.0 (449-1838)	0.00

Table 2: Change Over Time for Superomedial Cohort

	Early Postop (Range)		Late Postop (Range)		P-Value
SNtoNIP (cm)	21.6 ± 0.4	(17.0-26.5)	21.6 ± 0.4	(17.0-26.7)	0.93
NIPtoIMF (cm)	12.6 ± 0.3	(9.2-16.8)	12.3 ± 0.3	(9.8-15.8)	0.13
NIPtoNIP (cm)	21.9 ± 0.8	(15.0-25.4)	22.4 ± 0.8	(16.3-25.8)	0.15
NipProj (cm)	6.6 ± 0.3	(3.6-9.2)	6.3 ± 0.3	(3.7-8.5)	0.01
MaxProj (cm)	6.7 ± 0.2	(4.6-9.2)	6.3 ± 0.2	(4.5-8.3)	0.00
AreolaSA (cm2)	18.4 ± 0.8	(12.8-30.5)	18.4 ± 0.9	(11.9-25.8)	0.99
BreastSA (cm2)	447 ± 11	(361-517)	446 ± 11	(333-542)	0.87
TotVol (cc)	801 ± 31	(540-1129)	772 ± 35	(415-1141)	0.72
SupPole %	53.9 ± 1.2	(41.0-63.7)	58.5 ± 1.1	(49.5-66.8)	0.00
MedPole%	42.4 ± 2.1	(27.3-64.7)	38.1 ± 2.0	(24.1-67.2)	0.00

Table 3: Change Over Time for Inferior Pedicle Cohort

	Early Postop (Range)		Late Postop (Range)		P-Value
SNtoNIP (cm)	24.1 ± 0.3	(20.9-25.7)	24.6 ± 0.4	(21.6-29.8)	0.00
NIPtoIMF (cm)	11 ± 0.3	(8.4-14.4)	11.4 ± 0.4	(8.3-15.3)	0.01
NIPtoNIP (cm)	22.3 ± 0.7	(17.0-26.9)	22.0 ± 0.6	(17.3-26.4)	0.20
NipProj (cm)	7.1 ± 0.2	(4.7-9.3)	6.9 ± 0.2	(4.7-8.5)	0.15
MaxProj (cm)	6.8 ± 0.2	(4.7-9.3)	6.7 ± 0.2	(4.5-8.9)	0.59
AreolaSA (cm2)	18.9 ± 0.6	(13.2-24.0)	21.7 ± 0.9	(12.9-33.7)	0.00
BreastSA (cm2)	444 ± 15	(355-608)	443 ± 16	(344-622)	0.74
TotVol (cc)	779 ± 42	(555-1253)	765 ± 46	(489-1176)	0.43
SupPole %	57.3 ± 1.1	(44.2-66.6)	59.6 ± 1.3	(42.3-69.9)	0.12
MedPole%	44.4 ± 1.7	(31.2-63.1)	45.8 ± 1.4	(30.1-63.0)	0.53

Table 4: SMP vs. IP Cohorts in the Early Postoperative Period

	Superomedial	(Range)	Inferior	(Range)	P-Value
SNtoNIP (cm)	21.6 + 0.4	(17.0-26.5)	24.1 + 0.3	(20.9-25.7)	0.00
NIPtoIMF (cm)	12.6 + 0.3	(9.2-16.8)	11 + 0.3	(8.4-14.4)	0.00
NIPtoNIP (cm)	21.9 + 0.8	(15.0-25.4)	22.3 + 0.7	(17.0-26.9)	0.75
NipProj (cm)	6.6 + 0.3	(3.56-9.15)	7.1 + 0.2	(4.67-9.26)	0.12
MaxProj (cm)	6.7 + 0.2	(4.57-9.15)	6.8 + 0.2	(4.67-9.26)	0.62
AreolaSA (cm2)	18.4 + 0.8	(12.8-30.5)	18.9 + 0.6	(13.2-24.0)	0.65
BreastSA (cm2)	447 + 11	(361-517)	444 + 15	(355-608)	0.87
TotVol (cc)	801 + 31	(540-1129)	779 + 42	(555-1253)	0.68
SupPole %	53.9 + 1.2	(41.0-63.7)	57.3 + 1.1	(44.2-66.6)	0.04
MedPole%	42.4 + 2.1	(27.3-64.7)	44.4 + 1.7	(31.2-63.1)	0.46

Table 5: SMP vs. IP Cohorts in the Late Postoperative Period

	Superomedial (Range)		Inferior (Range)		P-Value
SNtoNIP (cm)	21.6 ± 0.4	(17.0-26.7)	24.6 ± 0.4	(21.6-29.8)	0.00
NIPtoIMF (cm)	12.3 ± 0.3	(9.8-15.8)	11.4 ± 0.4	(8.3-15.3)	0.05
NIPtoNIP (cm)	22.4 ± 0.8	(16.3-25.8)	22.0 ± 0.6	(17.3-26.4)	0.66
NipProj (cm)	6.3 ± 0.3	(3.7-8.5)	6.9 ± 0.2	(4.7-8.5)	0.09
MaxProj (cm)	6.3 ± 0.2	(4.5-8.3)	6.7 ± 0.2	(4.5-8.9)	0.10
AreolaSA (cm2)	18.4 ± 0.9	(11.9-25.8)	21.7 ± 0.9	(12.9-33.7)	0.01
BreastSA (cm2)	446 ± 11	(333-542)	443 ± 16	(344-622)	0.88
TotVol (cc)	772 ± 35	(415-1141)	765 ± 46	(489-1176)	0.91
SupPole %	58.5 ± 1.1	(49.5-66.8)	59.6 ± 1.3	(42.3-69.9)	0.55
MedPole%	38.1 ± 2.0	(24.1-67.2)	45.8 ± 1.4	(30.1-63.0)	0.00

Table 6: SMP vs. IP Cohort Change Over Time

	Superomedial (Range)		Inferior (Range)		P-Value
SNtoNIP (cm)	0.01 ± 0.16	(-1.64,1.10)	0.51 ± 0.13	(-0.53,2.10)	0.02
NIPtoIMF (cm)	-0.28 ± 0.18	(-2.28,1.33)	0.34 ± 0.12	(-0.76,1.82)	0.01
NIPtoNIP (cm)	0.52 ± 0.34	(-2.51,2.43)	-0.27 ± 0.20	(-1.66,.87)	0.05
NipProj (cm)	-0.31 ± 0.11	(-1.45,0.73)	-0.24 ± 0.16	(-2.15,1.42)	0.73
MaxProj (cm)	-0.43 ± 0.13	(-2.47,0.72)	-0.10 ± 0.17	(-2.24,2.01)	0.13
AreolaSA (cm2)	0.01 ± 0.57	(-5.83,5.58)	2.87 ± 0.77	(-3.86,10.14)	0.00
BreastSA (cm2)	-0.90 ± 5.41	(-52.1,63.0)	-1.08 ± 3.17	(-29.50,36.55)	0.98
TotVol (cc)	-28.5 ± 15.2	(-158.1,133.9)	-13.6 ± 17.1	(-168.1,216.5)	0.52
SupPole %	4.65 ± 1.23	(-4.01,24.6)	2.24 ± 1.28	(-11.16,22.05)	0.20
MedPole%	-4.24 ± 1.41	(-21.10,4.50)	1.37 ± 1.26	(-17.94,17.96)	0.00