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Breast Surgery

Objective Analysis of Breast Symmetry in Female Patients Undergoing Breast Reconstruction After Total Mastectomy

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Abstract

Background: Satisfaction with the breast aesthetic outcome is an expectation of breast reconstruction surgery, which is an integral part of cancer treatment for many patients. We evaluated postreconstruction breast symmetry in 82 female patients using distance and volume measurements.

Objectives: Clinical factors, such as reconstruction type (implant-based and autologous reconstruction), laterality, timing of reconstruction (immediate, delayed, and sequential), radiation therapy (RT), and demographic factors (age, BMI, race, and ethnicity), were evaluated as predictors of postoperative symmetry. Matched preoperative and postoperative measurements for a subset of 46 patients were used to assess correlation between preoperative and postoperative symmetry.

Methods: We used standardized differences between the left and right breasts for the sternal notch to lowest visible point distance and breast volume as metrics for breast, positional symmetry, and volume symmetry, respectively. We performed statistical tests to compare symmetry between subgroups of patients based on reconstruction type, laterality, timing, RT, and demographics.

Results: Overall, reconstruction type, reconstruction timing, and RT were observed to be factors significantly associated with postoperative symmetry, with implant reconstructions and immediate reconstruction procedures, and no RT showing better postoperative breast volume symmetry. Subgroup analyses, for both reconstruction type and laterality, showed superior volume symmetry for the bilateral implant reconstructions. No correlation was observed between preoperative and postoperative breast symmetry. Demographic factors were not significant predictors of postreconstruction symmetry.

Conclusions: This comprehensive analysis examines multiple clinical factors in a single study and will help both patients and surgeons make informed decisions about reconstruction options at their disposal.

Level of Evidence: 3

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Breast reconstruction is considered an integral part of breast cancer treatment. It helps mitigate body image concerns and improves overall quality of life for many mastectomy patients.[1-4] Satisfaction with breast appearance is a desired outcome of breast reconstruction for both patients and their surgeons, but a patient's satisfaction is largely dependent on their aesthetic perception, which varies across individuals and cultures.[5-7] Qualitative research tools include the BREAST-Q[8] patient-reported outcome measure, which is used to assess patient satisfaction with breast reconstruction, and the Kroll Scale,[9] which is used to rate the surgeon's perception of the aesthetic outcomes. Studies using quantitative research methods are scarcer (Table 1) and largely utilize measurements of breast volume, position, and shape to determine the degree of breast symmetry. Breast symmetry has been demonstrated to be a critical factor that influences breast aesthetics and, consequently, long-term patient satisfaction.[5-7,10] Symmetry is widely used as a surgical outcome using both subjective[11,12] and objective measures (Table 1).[13-19]

Breast symmetry is affected by several clinical factors, such as the reconstruction type, timing, and laterality of reconstruction and cancer therapeutics, such as the use of adjuvant chemotherapy and/or radiation therapy (RT). Studies that provide comparisons of these clinical factors are not only scarce but also predominantly report only subjective comparisions.[9,20-22] Of the few studies that utilize objective measures (Table 1), most studies compare a single factor, such as reconstruction procedure[9,13,20-22] or timing of reconstruction.[23,24] What is missing is a quantitative analysis of clinical factors as potential predictors of postreconstruction symmetry. In the current study, we evaluated postreconstruction breast symmetry using distance and volume measurements and assessed reconstruction type (implant vs autologous tissue), laterality (bilateral vs unilateral), timing of reconstruction (immediate vs delayed), RT, and demographic factors (BMI, age, race and ethnicity) as predictors of postoperative symmetry.

METHODS

Participants

The data used in this study were collected prospectively as part of a previous study (National Institutes of Health grant R01CA203984) approved by the IRB of MD Anderson Cancer Center (Protocol Number 2010-0321) and were obtained from the study database maintained at The University of Texas at Austin. The retrieved dataset included three-dimensional (3D) surface images of patients' frontal torso (3dMDtorso, 3dMD LLC, Atlanta, GA, USA), demographics information, and reconstruction details. Written consent was provided, by which the patients agreed to the use and analysis of their data.

Study inclusion criteria were as follows: patients who underwent bilateral reconstruction or unilateral reconstruction with contralateral symmetry procedures and had useable 3D surface images acquired at 18 months postoperatively. We identified 82 patients (Tables 2, 3) who met the study criteria. Legal sex as recorded in the medical record for all participants was female. A subset of 46 patients, for whom useable 3D surface images available at both preoperative and postoperative timepoints, were utilized to compare breast symmetry before and after reconstruction. Additionally, 8 of 33 autologous reconstructions, 6 of 29 implant reconstructions, and 5 of 15 mixed reconstruction patients received fat grafting procedures for contour corrections.

Symmetry Measurements

We annotated fiducial points[10,25] (Figure) on the patients' 3D images and computed breast volume[26] and the distance between the sternal notch (SN) and lowest visible point (LVP) for each breast. The distance from SN-to-LVP provides a measure of vertical positional symmetry. Prior studies using two-dimensional (2D) images[7] and 3D images[27] have shown vertical positional symmetry, and not horizontal positional symmetry, to be correlated with patient-reported breast cosmesis. Therefore, in this study, we utilized vertical positional symmetry, referred to as positional symmetry, henceforth. We utilized SN-to-LVP distance, instead of SN-to-nipple distance, to allow inclusion of patients who had not undergone nipple reconstruction or nipple tattooing. Deriving the metric from previous work on symmetry in natural breasts,[10] we calculated the standardized difference percentage (SD%, Eq. (1)) between the left and right breast using either SN-to-LVP distance (positional symmetry) or volume (volume symmetry). Lower SD% values indicate greater symmetry.

$$SD\% = 2 \times \frac{\left| Measurement_{LeftBreast} - Measurement_{RightBreast} \right|}{Measurement_{LeftBreast} + Measurement_{RightBreast}} \times 100\% \quad (1)$$

Statistical Analysis

We used descriptive statistics to summarize continuous variables, such as the SN-to-LVP distance and volume, and frequencies and percentages for categorical clinical factors. Normality of the distributions was evaluated using Q-Q plots and Shapiro–Wilk tests. We compared breast symmetry between cohorts of patients grouped based on clinical factors such as reconstruction type, laterality, timing, RT, and demographic factors such as age, BMI, race, and ethnicity. Comparisons across different cohorts were performed using the Mann–Whitney U test or Kruskal–Wallis test. The Bonferroni method was applied to adjust multiple comparisons. Categorical analysis[10] based on

Table 1. Breast Symmetry Studies Using Quantitative Measures

Study	No. of patients	Mean patient age	Mean patient BMI, kg/m^2	Symmetry		Modality	Major findings
				Comparisons	Objective measurements		
Edsander-Nord et al[13]	27 pedicled flaps, 26 TRAM free flaps	55 years	NP	Pedicled vs TRAM-free flap	Volume; breast firmness with applanation tonometry; C-IMF, M-L, M, SN-N distances	Direct measurement on patient's torso	TRAM-free flaps had greater volume and firmness symmetry than pedicled flaps.
Hartmann et al[14]	15 implants, 12 autologous (DIEP flap)	39 ± 10.5 years (implant), 57.5 ± 8 years (autologous)	21.2 ± 2.0 (implant), 25.5 ± 4.8 (autologous)	Implant vs autologous	Symmetry index (average of ratios of 7 distance measures obtained from 9 breast landmark points)	3D-SI	No difference in symmetry observed.
Gahm et al[15]	24 implants, 24 natural breast (control group)	47.2 years (implant), 41.3 years (control)	NP	Implant vs natural breast	L-R ratios of SN-N, M-N, SN-IMF; volume; breast firmness with applanation tonometry	Direct measurement on patient's torso	No difference in positional and volume symmetry between implant reconstruction and control group. Right breast was significantly firmer than the left in the patient group but not in the control group.
Nahabedian et al[16]	217 autologous, 117 implants	46.7 years	NP	Autologous vs implant; patients with 3D photographs vs patients without 3D photographs	Volume	3D-SI, volumes of autologous tissue and tissue expander (for patients without 3D images)	In women with 3D images, volume and contour symmetry (visual analysis) occurred more often with the use of autologous reconstruction. Women who did not have 3D images showed superior contour symmetry with autologous reconstruction. No significant difference observed in volume symmetry.
Cohen et al [17]	34 unilateral implants, 30 unilateral autologous (18 TRAM, 12 DIEP)	52.2 ± 10 years (implant) 50.7 ± 9.4 years (autologous)	23.9 ± 3.7 (implant) 25.4 ± 3.9 (autologous)	Autologous vs implant, TRAM vs DIEP	Volume, anterior-posterior projection, shape symmetry by 3D image analysis	3D-SI	Both implant and autologous reconstruction can achieve symmetrical surgical results with the same number of operations. No significant symmetry difference in TRAM vs DIEP reconstruction.
Henseler et al[18]	44 immediate unilateral LD flap	NP	NP	Reconstructed breast vs natural contralateral breast, age (≤50 vs >50), BMI (≤25 vs >25), parity (0 vs 1 vs 2 vs ≥3), chest wall size (≤36 vs >36), cup size (A-B vs > B)	Reflections of 4 landmark points, volume	3D-SI	1. Average volume of reconstructed breast was smaller than contralateral natural breast. 2. Shape and breast position were the main contributing factors to asymmetry. 3. Age, parity, chest wall size, cup size did not influence symmetry. 4. Patients with lower BMI had better symmetry.

Table 1. Continued

Study	No. of patients	Mean patient age	Mean patient BMI, kg/m^2	Symmetry		Modality	Major findings
				Comparisons	Objective measurements		
Teo et al[7]	Cross sectional sample of 199 patients in preoperative and various stages of reconstruction	49 ± 9 years	NP	Association between breast symmetry and patient-reported appearance investment while controlling for clinical factors	Distance ratios of L-M, SN-LVP	Clinical photographs	Greater BMI was significantly associated with lesser vertical and higher horizontal symmetry. Autologous reconstruction was associated with decrease in horizontal symmetry. Prior chemotherapy, prior radiation therapy, reconstruction timing, and stage of reconstruction were not significantly associated with symmetry.
Glener et al[19]	28 unilateral autologous	44.8 years	26.8	Autologous vs contralateral natural with or without revision	Volume ratio between reconstructed and contralateral breasts	MRI	Volume symmetry is achievable with unilateral autologous reconstruction but may require contralateral procedures. Initial symmetry is retained postoperatively, regardless of BMI.

3D-SI, 3-dimensional surface imaging; C, clavicle; DIEP, deep inferior epigastric perforator; IMF, inframammary fold; L-R, left to right; L, lateral; LD, latissimus dorsi; LVP, lowest visible point; M, midline; N, nipple; NP, not provided; SN, sternal notch; TRAM, transverse rectus abdominis muscle.

Table 2. Patient Demographics

Demographics	Average ± STD	Median (range)
Age, years	47.3 ± 10.0	47.0 (24.0-68.0)
BMI, kg/m^2	28.5 ± 5.3	27.9 (18.0-41.0)
Self-reported race	N (%)	Not applicable
Caucasian	62 (75.6)	
African American	6 (7.3)	
Asian	1 (1.2)	
Unknown	13 (15.8)	
Self-reported ethnicity		Not applicable
Hispanic	16 (19.5)	
Non-Hispanic	58 (70.7)	
Unknown	8 (9.7)	

STD, standard deviation.

Table 3. Reconstruction Details

Breast reconstruction laterality and type (N)	Immediate (63)	Delayed (12)	Sequential (7)
Bilateral (58)	45	6	7
Autologous (19)	15	1	3
Implant (20)	20	0	0
Mixed (autologous and implant) (19)	10	5	4
Unilateral with contralateral balancing procedure (24)	18	6	0
Autologous (14)	8	6	0
Implant (9)	9	0	0
Mixed (autologous and implant) (1)	1	0	0

classifying the extent of symmetry (high, moderate, low) was also performed. Correlation across the 46 patients with matched preoperative and postoperative measurements was evaluated using Pearson's and Spearman's correlation coefficients. Wilcoxon matched pairs signed rank test was used compare symmetry between preoperative and postoperative cohorts. All tests were two-sided, with $P < .05$ considered significant. Analyses were performed in SAS (SAS Institute Inc., Cary, NC), R (R Foundation, Vienna, Austria), and Python SciPy 1.8 library (Wilmington, DE).

RESULTS

Overall, the 82 patients studied had better postreconstruction positional symmetry (mean SD% ± STD = 3.8 ± 3.6%)

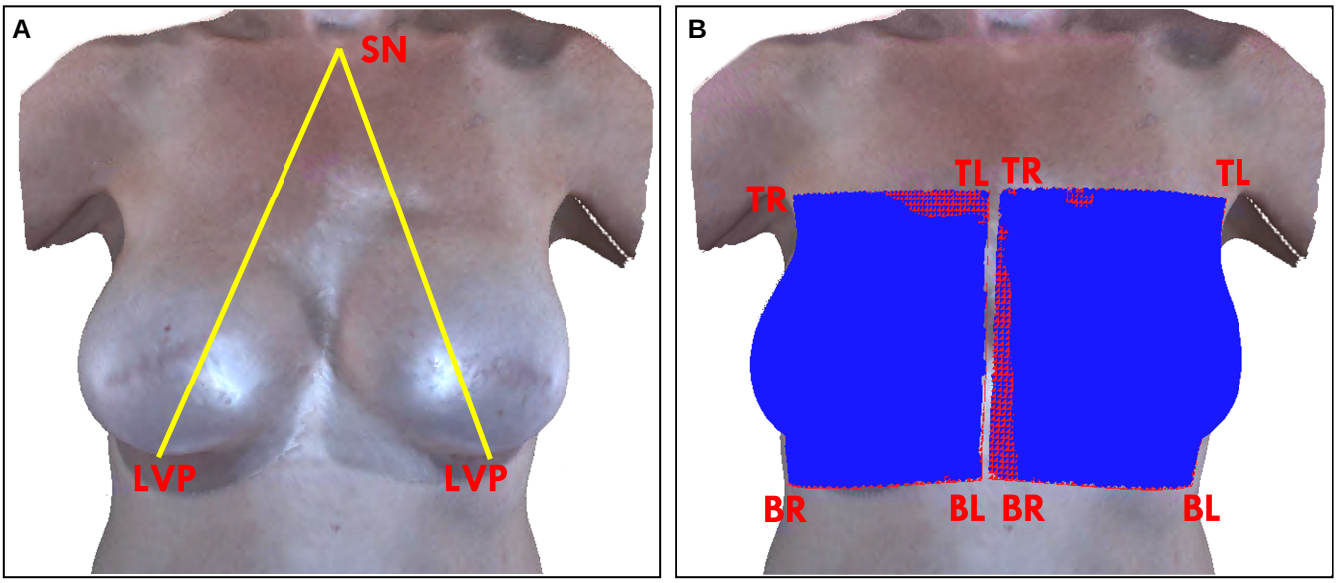

Figure. Illustration of fiducial point annotation on a 51-year-old female patient's image at 12 months postoperatively. The patient had tissue expander placement followed by bilateral implant-based reconstruction. (A) Annotated 3-dimensional surface images show the distance from the sternal notch (SN) to the lowest visible point (LVP) for each breast. (B) Boundary points delineating the breast extremities were marked. The volume enclosed within that boundary was computed for each breast.[26] BL, bottom left; BR, bottom right; TL, top left; TR, top right.

than volume symmetry (mean SD% ± STD = 9.9 ± 10.4%). Patient groups were compared to determine whether demographics (Supplemental Tables 1-4) or type of reconstruction, laterality, or timing (Tables 4-6, respectively) was associated with symmetry. We also determined whether these clinical factors affected categorical classification based on extent of symmetry, which did not reach statistical significance (Supplemental Tables 5, 6).

Demographics

We examined age (<50 and ≥50), BMI (underweight, healthy, overweight and obese), self-reported race (Caucasian and non-Caucasian), and ethnicity (Hispanic/Latino and non-Hispanic/non-Latino) as demographic variables. Overall, demographic factors were not significant predictors of postreconstruction breast volume or positional symmetry (Supplemental Tables 1-4).

Reconstruction Type

When comparing implant ($N = 29$), autologous ($N = 33$), and mixed ($N = 20$) reconstructions, implant-based reconstructions had the greatest volume symmetry (implant = 5.4 ± 5.0%, autologous = 12.4 ± 12.3%, mixed = 12.3 ± 10.8%; $P = .01$), with statistical significance also noted for pairwise comparisons of implant vs autologous ($P = .016$ after Bonferroni correction) and implant vs mixed ($P = .005$ after Bonferroni correction) reconstructions (Table 4). Subgroup analysis of laterality across the reconstruction types indicated greater volume symmetry for bilateral implant-based reconstructions (implant = 3.6 ± 3.7%, autologous = 13.8 ± 14.4%, mixed = 12.3 ± 11.1%; $P = .016$). Positional symmetry was similar across 3 types of reconstructions. When comparing the laterality subgroups, bilateral reconstructions also had similar positional symmetry, but among the unilateral reconstructions, the autologous subgroup had the greatest positional symmetry (implant = 6.6 ± 4.3%, autologous = 2.6 ± 2%, mixed = 14%; $P = .016$). Timing-based differences in symmetry were not significant across the different reconstruction types. Fat grafting procedures did not result in significant differences in volume and positional symmetry for all reconstruction types. (Supplemental Table 7).

Reconstruction Laterality

Overall, laterality (bilateral [N = 58] vs unilateral [$N = 24$]) did not significantly influence volume symmetry ($P = .17$) or positional symmetry ($P = .18$) (Table 5). However, subgroup analysis of patients with implants showed superior symmetry in bilateral relative to unilateral reconstructions in terms of both volume ($P = .007$) and SN-to-LVP distance ($P = .045$). Subgroup analyses of autologous patients and reconstruction timing did not show any significant differences.

Reconstruction Timing

Reconstruction timing (Table 6) was identified as a significant factor affecting volume symmetry ($P = .026$) but not

Table 4. Breast Symmetry Comparison Across Different Types of Reconstruction Procedures

Subgroups	Implant		Autologous		Mixed		*P*-value	Pairwise (*P*-value)
	N	Average SD%±STD, median (range)	N	Average SD%±STD, median (range)	N	Average SD%±STD, median (range)	N	
All patients								
Volume	29	5.4 ± 5.0, 3.9 (0-21)	33	12.4 ± 12.3, 7.6 (0-46.6)	20	12.3 ± 10.8, 9.8 (1.6-47.5)	**0.010**	Implant vs mixed (0.005[a]), autologous vs mixed (0.64)
SN-LVP	29	4.7 ± 3.7, 3.5 (0.2-16.3)	33	3.4 ± 3.4, 2.9 (0-14.6)	20	3.2 ± 3.6, 1.7 (0.1-14)	**0.07**	N/A
Unilateral								
Volume	9	9.4 ± 5.4, 9.6 (1.1-21)	14	10.4 ± 8.9, 8.1 (1.9-34.3)	1	10.6	**0.93**	N/A
SN-LVP	9	6.6 ± 4.3, 6.6 (2.6-16.3)	14	2.6 ± 2, 3 (0-6)	1	14	**0.016**	Implant vs autologous (0.013[a])
Bilateral								
Volume	20	3.6 ± 3.7, 2.7 (0-13.6)	19	13.8 ± 14.4, 7.6 (0-46.6)	19	12.3 ± 11.1, 9.5 (1.6-47.5)	**0.003**	N/A
SN-LVP	20	3.8 ± 3.1, 3 (0.2-12.6)	19	3.9 ± 4.1, 2.9 (0.1-14.6)	19	2.6 ± 2.6, 1.7 (0.1-10.1)	**0.29**	N/A
Immediate								
Volume	29	5.4 ± 5, 3.9 (0-21)	23	10.1 ± 11.2, 6 (0-41.8)	11	11.1 ± 7.8, 9.5 (2-25.1)	**0.06**	N/A
SN-LVP	29	4.7 ± 3.7, 3.5 (0.2-16.3)	23	3.6 ± 3.8, 3.1(0-14.6)	11	2.7 ± 3.8, 1.7 (0.5-14)	**0.06**	N/A
Delayed								
Volume	0	N/A	7	15.7 ± 10.1, 14.1 (4.4-34.3)	5	15.7 ± 18.8, 10.1 (1.6-47.5)	**0.62**	N/A
SN-LVP	0	N/A	7	2.9 ± 1.6, 2.9 (0.9-5)	5	3.1 ± 2.8, 3.9 (0.1-6.4)	**1**	N/A

Mixed reconstruction involves a combination of implant and autologous reconstructions. *P*-values were calculated using nonparametric tests. N/A, not applicable; SD, standardized difference; SN-LVP, sternal notch lowest visible point distance; STD, standard deviation. [a]Significant after Bonferroni correction.

positional symmetry ($P = .85$). Patients who underwent immediate reconstruction following mastectomy exhibited the greatest volume symmetry (8.1 ± 8.5%) compared with those who underwent delayed (15.7 ± 13.6%) or sequential (15.7 ± 15%) reconstructions. Immediate reconstruction also showed better volume symmetry ($P = .022$) in a pairwise comparison with delayed reconstruction, but the difference did not reach significance with Bonferroni correction. In the timing-based subgroup analyses, for both volume and positional symmetry, reconstruction type and laterality did not result in significant differences.

Radiation Therapy

Compared with patients who received either neoadjuvant or adjuvant extended-field RT, patients who did not receive RT had significantly better breast volume symmetry ($P = .004$) (Table 7). Likewise, breast volume symmetry was also better in patients who did not receive preoperative neoadjuvant RT compared with those who did ($P = .008$). Positional symmetry was slightly better in patients without preoperative RT, but the difference was not statistically significant. No significant difference was detected in the postoperative radiation group. The different dosages and fractions of RT for patients receiving RT were also investigated, but no obvious effect on postoperative symmetry was observed (Supplemental Table 8).

Comparing Preoperative and Postoperative Symmetry

Preoperative and postoperative measurements were available for SN-to-LVP distance in 46 patients and for breast volume in 41 patients. We measured change in symmetry as difference between postoperative and preoperative SD% (Table 8). Overall, postoperative positional symmetry

was slightly worse (0.9 ± 4.7%), whereas postoperative volume symmetry improved (−2.3 ± 10.6%), but the differences did not reach a statistically significant level. Preoperative and postoperative symmetry were not correlated, based on Pearson and Spearman's coefficients.

DISCUSSION

We performed quantitative analysis of breast symmetry in breast reconstruction patients after total mastectomy. This is the first comprehensive analysis that examined multiple clinical and demographic factors in a single study.

We observed no correlation between the preoperative and postoperative symmetry, indicating no effects of preoperative extent of symmetry with postoperative symmetry. Given that all patients underwent reconstruction after a total mastectomy, any influence of preoperative symmetry on postoperative symmetry is understandably eliminated. This is in contrast to breast conservation surgery, wherein the preoperative breast size and tumor size may influence postoperative symmetry.[28-30]

Choosing between an implant-based and an autologous-based breast reconstruction can be a perplexing decision to make. Implant reconstructions are the simplest and most common method of breast reconstruction,[31,32] whereas autologous reconstructions are complex but provide a more natural breast shape without the use of prosthetics.[33,34] Moreover, implant-based breast reconstruction is a less expensive index operation than autologous reconstruction, but it is associated with greater health care use, resulting in a similar total cost of care over 2 years.[35] In our analysis, implant-based reconstructions demonstrated greater volume symmetry overall when compared with autologous or mixed reconstructions. Previous work is conflicting, with some studies reporting improved volume symmetry for autologous reconstructions,[16,19,36] whereas others have shown similar volume symmetry[17] for implant vs autologous reconstructions. Within the bilateral subgroup, we also observed greater volume symmetry with bilateral implant-based reconstructions when comparing with bilateral autologous and bilateral mixed. Achieving initial volume symmetry with fewer revisions using implant-based reconstruction is plausible owing to the inherent ability to match implant volumes and shapes. We found positional symmetry to be similar across 3 types of reconstructions. A previous study with objective symmetry analysis[14] that utilized 7 distance measures from 9 breast landmark points to compute breast symmetry found no difference between implant and autologous reconstructions. Further, in our study, when comparing the laterality subgroups, bilateral reconstructions also had similar positional symmetry, but among the unilateral reconstructions, the autologous subgroup had the greatest positional symmetry.

Table 5. Breast Symmetry Comparison Between Unilateral and Bilateral Reconstruction

Subgroups	Unilateral		Bilateral		*P*-value
	N	Average SD% ± STD, median (range)	N	Average SD% ± STD, median (range)	
All patients					
Volume	24	10.1 ± 7.4, 9.3 (1.1-34.3)	58	9.8 ± 11.4, 4.9 (0-47.5)	**0.17**
SN-LVP	24	4.6 ± 4, 3.4 (0-16.3)	58	3.4 ± 3.3, 2.1 (0.1-14.6)	**0.18**
Implant					
Volume	9	9.4 ± 5.4, 9.6 (1.1-21)	20	3.6 ± 3.7, 2.7 (0-13.6)	**0.007**
SN-LVP	9	6.6 ± 4.3, 6.6 (2.6-16.3)	20	3.8 ± 3.1, 3 (0.2-12.6)	**0.045**
Autologous					
Volume	14	10.4 ± 8.9, 8.1 (1.9-34.3)	19	13.8 ± 14.4, 7.6 (0-46.6)	**0.92**
SN-LVP	14	2.6 ± 2, 3 (0-6)	19	3.9 ± 4.1, 2.9 (0.1-14.6)	**0.47**
Immediate					
Volume	18	8.1 ± 4.7, 8.4 (1.1-21)	45	8.1 ± 9.6, 4.2 (0-41.8)	**0.17**
SN-LVP	18	5.1 ± 4.5, 3.9 (0-16.3)	45	3.5 ± 3.4, 2.2 (0.1-14.6)	**0.14**
Delayed					
Volume	6	15.9 ± 11.1, 13.3 (4.4-34.3)	6	15.5 ± 16.9, 12.1 (1.6-47.5)	**0.68**
SN-LVP	6	3.1 ± 1.7, 3.1 (0.9-5)	6	2.8 ± 2.6, 2.7 (0.1-6.4)	**0.68**

N/A, not applicable; SD, standardized difference; SN-LVP, sternal notch lowest visible point distance; STD, standard deviation.

Overall, patient satisfaction studies[9,20-23,37,38] have shown that autologous reconstruction patients are more satisfied with their breast aesthetics than implant patients. Gahm et al[15] found that the results of objective assessments of volume and positional symmetry in patients who had undergone bilateral implants after prophylactic mastectomy were similar to those of a control group with natural breasts. However, in their subjective analysis, mean breast symmetry was assessed as "good" by plastic surgeons and only "acceptable" by the patients. In their subjective analysis, Craft et al[39] noted that bilateral reconstructions had similar general and aesthetic satisfaction scores across autologous, autologous with implant, and implant-based reconstructions. Choosing between implant and autologous reconstructions is a difficult decision that is likely to include factors beyond the aesthetic

Table 6. Breast Symmetry Comparison based on Reconstruction Timing

Subgroups	Immediate		Delayed		Sequential[a]		*P*-value	Pairwise (*P*-value)
	N	Average SD% ± STD, median (range)	N	Average SD% ± STD, median (range)	N	Average SD% ± STD, median (range)		
All patients								
Volume	63	8.1 ± 8.5, 5.5 (0-41.8)	12	15.7 ± 13.6, 13.2 (1.6-47.5)	7	15.7 ± 15, 11.7 (1.5-46.6)	**0.026**	Immediate vs delayed (0.022), Immediate vs both (0.09), delayed vs both (0.99)
SN-LVP	63	3.9 ± 3.8, 3 (0-16.3)	12	2.9 ± 2.1, 3.1 (0.1-6.4)	7	3.8 ± 3.7, 1.9 (0.4-10.1)	**0.85**	N/A
Autologous								
Volume	23	10.1 ± 11.2, 6 (0-41.8)	7	15.7 ± 10.1, 14.1 (4.4-34.3)	3	21.8 ± 22.9, 17.2 (1.5-46.6)	**0.18**	N/A
SN-LVP	23	3.6 ± 3.8, 3.1 (0-14.6)	7	2.9 ± 1.6, 2.9 (0.9-5)	3	3 ± 3, 1.9 (0.6-6.4)	**0.99**	N/A
Unilateral								
Volume	18	8.1 ± 4.7, 8.4 (1.1-21)	6	15.9 ± 11.1, 13.3 (4.4-34.3)	0	N/A	**0.057**	N/A
SN-LVP	18	5.1 ± 4.5, 3.9 (0-16.3)	6	3.1 ± 1.7, 3.1 (0.9-5)	0	N/A	**0.48**	N/A
Bilateral								
Volume	45	8.1 ± 9.6, 4.2 (0-41.8)	6	15.5 ± 16.9, 12.1 (1.6-47.5)	7	15.7 ± 15, 11.7 (1.5-46.6)	**0.11**	N/A
SN-LVP	45	3.5 ± 3.4, 2.2 (0.1-14.6)	6	2.8 ± 2.6, 2.7 (0.1-6.4)	7	3.8 ± 3.7, 1.9 (0.4-10.1)	**0.85**	N/A

N/A, not applicable; SD, standardized difference; SN-LVP, sternal notch lowest visible point distance; STD, standard deviation. [a]Patient has had a combination of immediate and delayed reconstruction.

outcomes of breast symmetry and appearance, such as personal preferences, medical history, costs, and time needed for completion of the reconstruction procedure.

Clinically, laterality is an option that many patients undergoing breast reconstruction encounter. Unilateral reconstructions warrant complex decision-making because they are limited by the size and shape of the existing contralateral breast. Surgeons must strive to match the contralateral shape as closely as possible considering the limitations of implant size, tissue harvested from the donor site, etc. Henseler et al[18] noted inferior volume symmetry in unilateral autologous reconstruction without contralateral corrections. Contralateral balancing procedures are commonly performed to achieve symmetry between the reconstructed and contralateral natural breast. Glener et al[19] demonstrated that volume symmetry is achievable in unilateral reconstructions with contralateral correction procedures. In our analysis, overall comparison of bilateral and unilateral groups, did not record significant difference in symmetry. However, the bilateral implant-based reconstruction subgroup exhibited superior volume and positional symmetry compared to unilateral implant-based reconstruction. With bilateral implant-based reconstructions, surgeons have the freedom to choose matching pairs of implants in terms of size, enabling volume symmetry. Sinno et al[40] noted greater patient satisfaction with breast symmetry in bilateral reconstruction compared to unilateral reconstruction for both autologous and implant reconstruction types.

Postmastectomy radiotherapy is a crucial factor in determining the timing of breast reconstruction. In our study, we analyzed these two parameters independently. Pairwise comparison of immediate vs delayed reconstruction vs both (irrespective of postoperative radiation) showed immediate reconstruction to have better volume symmetry. Menez et al[23] compared patient satisfaction between immediate autologous reconstruction and delayed reconstruction and did not record significant differences. O'Connell et al[24] noted that among women who had undergone radiotherapy, those who had an irradiated immediate reconstruction had significantly lower satisfaction with their breasts than those who underwent delayed flap reconstruction. O'Connell et al[24] highlighted the bias introduced in patient statisfaction because women who undergo immediate reconstruction are comparing the outcome against the natural

Table 7. Breast Symmetry Comparison based on Radiation Therapy

Subgroups	Radiation		No radiation		*P*-value
	N	Average SD% ± STD, median (range)	N	Average SD% ± STD, median (range)	
Any radiation					
Volume	34	14.2 ± 13.3, 9.8 (0-47.5)	45	6.5 ± 6.2, 4.2 (0-27.1)	**0.004**
SN-LVP	34	4.2 ± 3.9, 3.2 (0-14.6)	45	3.6 ± 3.3, 3 (0.1-16.3)	**0.59**
Preoperative radiation					
Volume	22	16 ± 14.5, 11.4 (1.3-47.5)	57	7.4 ± 7.3, 4.7 (0-34.4)	**0.008**
SN-LVP	22	4.3 ± 4.1, 3.2 (0-14.6)	57	3.7 ± 3.4, 3 (0.1-16.3)	**0.79**
Postoperative radiation					
Volume	14	10.4 ± 9.6, 5.8 (0-34.4)	68	9.8 ± 10.6, 7.3 (0-47.5)	**0.52**
SN-LVP	14	4.5 ± 4.4, 2.9 (0-14)	68	3.6 ± 3.4, 3 (0.1-16.3)	**0.60**

N/A, not applicable; SD, standardized difference; SN-LVP, sternal notch lowest visible point distance; STD, standard deviation.

Table 8. Difference Between Postoperative and Preoperative Symmetry (Postoperative SD%−Preoperative SD%)

Subgroup	N	Average SD% change ± STD, median (range)	*P*-value	Correlation (*P*-value)	
				Pearson's	Spearman's
Volume	41	−2.3 ± 10.6, −2.1 (−24.1 to 21.8)	0.08	0.07 (0.66)	0.15 (0.33)
SN-LVP	46	0.9 ± 4.7, 0.9 (−8.7 to 12.3)	0.32	−0.05 (0.69)	−0.20 (0.17)

SD, standardized difference; SN-LVP, sternal notch lowest visible point distance; STD, standard deviation.

breast, whereas in delayed reconstruction the outcome is compared with the flat chest that the women had been living with. Further, RT can result in complications requiring revisions that often affect breast aesthetics and symmetry. Our analysis showed that patients who did not receive RT had superior volume symmetry compared to patients who received any radiation or only preoperative radiation. Patients receiving postoperative RT during the course of their reconstruction did not show significant differences in symmetry when compared to those who did not.

Overall, reconstruction type, timing, and RT were observed to be factors significantly associated with postoperative volume symmetry. Our analysis shows that volume symmetry is achived more frequently than positional sysmmetry across all the clinical factors analyzed. Among the various factors analyzed, demographic parameters did not affect symmetry outcomes. The only comparison that showed significant differences for both positional and volume symmetry was observed when comparing bilateral and unilateral implant-based reconstructions.

CONCLUSIONS

Nipple position largely influences the perception of symmetry. Most patients in this dataset did not undergo nipple reconstruction, and thus, nipple position was not considered in the symmetry computation. We acknowledge that the manual annotation of fiducial points is susceptible to subjectivity.[41] However, we established strict guidelines to mark fiducial points and mitigate subjectivity (Figure). Alternatively, automated algorithms, such as the one proposed by Monton et al[42] which uses an optical flow algorithm or the automated identification of fiducial points by Kawale et al,[43] may be used for unbiased symmetry assessment. It should be noted that our dataset lacks diversity in the demographics, thus the analysis may not be generalizable to non-Caucasian populations. This study compares symmetry outcomes by reconstruction type, laterality, timing, and RT through quantitative measurements.

We do not advocate for any breast reconstruction procedure over another on the basis of this study of breast symmetry. Decisions about mastectomy and reconstruction are

multifaceted and depend on many factors about the patient (eg, financial resources, social support) and their healthcare situation (eg, access to care). We expect that this study will help plastic surgeons and patients take breast symmetry into consideration, among many other factors, when choosing a reconstruction option that is appropriate for their individual circumstances.

Supplemental Material

This article contains supplemental material located online at www.asjopenforum.com.

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