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Original Article

The Role of Density in Achieving Volume and Weight Symmetry in Breast Reconstruction

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Abstract

Background Knowledge of tissue and implant density is crucial in obtaining both volume and weight symmetry in unilateral breast reconstruction. Therefore, the aim of this study was to determine and compare the density of abdominal and breast tissue specimens as well as of 5th generation breast implants.

Methods Thirty-one breast tissue and 30 abdominal tissue specimens from 61 patients undergoing either mammaplasty or abdominoplasty as well as five different 5th generation breast implants were examined. Density (g/mL) was calculated by applying the water displacement method.

Results The mean specimen density was 0.94 ± 0.02 g/mL for breast tissue and 0.94 ± 0.02 g/mL for abdominal tissue, showing no significant difference ($p = 0.230$). Breast tissue density significantly ($p = 0.04$) decreased with age, while abdominal tissue did not. A regression equation to calculate the density of breast tissue corrected for age (breast density [g/mL] = 0.975–0.0007 * age) is provided. Breast tissue density was not related to body mass index, past pregnancy, or a history of breastfeeding. The breast implants had a density ranging from 0.76 to 1.03 g/mL which differed significantly from breast tissue density (–0.19 g/mL [–19.8%] to +0.09 g/mL [+9.58%]; $p \leq 0.001$).

Conclusion Our results support the suitability of abdominal-based perforator flaps in achieving both volume and weight symmetry in unilateral autologous breast reconstruction. Abdominal flap volume can be derived one-to-one from mastectomy weight. Further, given significant brand-dependent density differences, the potential to impose weight disbalances when performing unilateral implant-based reconstructions of large breasts should be considered.

Keywords
► breast reconstruction
► symmetry
► density

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The study protocol was approved by the institutional review committee (Technical University of Munich, registration number: 236/18s) and written informed consent was obtained from all patients.

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Since breast cancer death rates have been declining over the last decades, the long-term quality of life of breast cancer survivors has become increasingly important.[1] Despite the advances in screening modalities and treatment options, mastectomy still represents a cornerstone in surgical breast cancer therapy. About 35% of breast cancer patients in the United States receive a mastectomy, with increasing proportions of bilateral mastectomies.[2] The adverse effects of a mastectomy on psychosocial well-being, body image, sexuality, and body posture are well known.[3–5] Breast reconstruction has proven to be beneficial in the mental and physical recuperation after mastectomy and is therefore recognized as an integral part of breast cancer therapy.[6–9]

Overall, reconstruction rates have increased significantly over time. While autologous reconstructions were stable or even decreased, implant-based reconstructions increased and surpassed autologous methods as the leading reconstructive modality in the United States.[10,11] This trend is in contradiction to the evidence of significantly better patient satisfaction and long-term outcomes associated with autologous reconstructions.[12–16]

Applying the old, but still valid Gillie's plastic surgical principle of replacing lost tissue by similar tissue whenever possible,[17] abdominal skin and fat tissue constitute an ideal donor site to achieve the reconstructive goal of a breast with natural appearance and texture.[18] This is supported by a study of Calvo-Gallego et al[19] comparing the viscoelastic properties of breast and abdominal adipose tissue specimens. They found similar elastic constants for both tissue types and similar viscous constants between the deep breast tissue and abdominal fat. The only significant differences were found between the viscous constants in superficial breast tissue and medial and deep lateral abdominal tissue. Since the introduction of abdominal-based perforator flaps (i.e., deep inferior epigastric perforator flap and superficial inferior epigastric artery flap), which enable preservation of muscle and therefore reduce donor site morbidity, these flaps are considered as the gold standard for autologous reconstruction.[13,18]

Previous studies already investigated the density of breast tissue[20,21]; however, comparative information on the density of abdominal tissue is lacking. As density (ρ) is equal to mass (m) divided by volume (V), this information is clinically valuable to achieve both volume and weight symmetry in unilateral breast reconstruction. Therefore, the aim of this study was to determine and compare the density of abdominal and breast tissue specimens and five different 5th generation breast implants.

Methods

Study Sample

Between 2019 and 2021, tissue specimens from a total of 61 female patients were examined. Among them, 31 underwent mammaplasty, and breast tissue samples were collected, while 30 underwent abdominoplasty, with abdominal tissue samples collected. ►**Table 1** depicts the demographics and patient variables. The mean age was 46.6 ± 13.3 years for the abdominoplasty patients and 46.3 ± 15.4 years for the mammaplasty patients ($p = 0.829$). The mean body mass index was 29.8 ± 6.5 for the abdominoplasty patients and 30.0 ± 5.9 for the mammaplasty patients ($p = 0.907$). In addition, density measurements of the following silicone breast implants produced in 2020 were performed:

- *Implant I*: Polytech B-Lite/SL 410cc
- *Implant II*: Motiva Ergonomix demi 300cc
- *Implant II*: Motiva Round demi 300cc
- *Implant IV*: Mentor Siltex round BI moderate plus profile, cohesive I 125cc
- *Implant V*: Mentor Siltex round BI moderate plus profile, cohesive II 300cc

Density Measurement and Calculation

Measurements were performed directly after surgery in the operating room. The skin was separated from the resected tissue, leaving only the soft tissue as such. The specimen weight (g) was determined using a calibrated digital balance. The specimen volume (mL) was measured according to the Archimedes principle[22] of water displacement. Accordingly, the specimens were put into a measuring cylinder filled with a predefined volume of Ringer's lactate solution with care taken to completely submerge the tissue and avoid contact to the wall of the cylinder as much as possible. The amount of solution displaced equals the specimen volume and was indicated at the measuring cylinder. The specimen density (g/mL) was subsequently calculated from the measured specimen volume and specimen weight. The volume of the silicone breast implants was measured likewise based on the water displacement method and compared to the volume indicated by the manufacturer. Implant density (g/mL) was subsequently calculated based on the measured implant volume and implant weight.

Statistical Analysis

To test the difference between the means of a group and defined values, one-sample *t*-test was used. To compare the groups, the independent samples *t*-test was used for metric variables if they were normal distributed, otherwise the Mann–Whitney *U* test was performed. In the case of categorical variables, cross-tabulations utilizing the chi-square test were performed. If the conditions were not met, Fisher's exact test was used. In addition, Pearson's and Spearman's correlation coefficients were calculated to test for a relationship between tissue density and patient variables. To identify the influence of patient variables on tissue density, a multiple linear regression model with backward elimination was calculated. *F*-test was performed to prove significance of the regression model. R^2 value was calculated to determine the global fit of the statistical model. IBM SPSS Statistics (version 27, IBM Corporation, Armonk, NY) was used for all statistical analyses. A p-value of < 0.05 was considered statistically significant.

The study protocol was approved by the institutional ethical review committee and written informed consent was obtained from all patients.

Table 1 Patient demographics and characteristics

	All ($n = 61$)	Abdominoplasty group ($n = 30$)	Mammaplasty group ($n = 31$)	*p*-Value
Mean age ± SD	46.5 ± 14.3	46.6 ± 13.3	46.3 ± 15.4	0.926[a]
Age group: *n* (%)				0.336[b]
Premenopausal (18–49 y)	32 (52.5)	18 (60.0)	14 (45.2)	
Menopausal (50–64 y)	24 (39.3)	9 (30.0)	15 (48.4)	
Postmenopausal (≥ 65 y)	5 (8.2)	3 (10.0)	2 (6.5)	
Ethnicity: *n* (%)				0.533[b]
Asian	11 (18.0)	6 (20.0)	5 (16.1)	
Caucasian	49 (80.3)	23 (76.7)	26 (83.9)	
Black	1 (1.6)	1 (3.3)	0	
Mean weight ± SD in kg	79.9 ± 16.7	81.6 ± 15.8	78.2 ± 17.6	0.428[a]
Mean height ± SD in cm	164 ± 6.7	165 ± 7.1	162 ± 6.0	0.073[a]
Mean BMI ± SD in kg/m^2	30.0 ± 6.2	30.0 ± 5.9	29.8 ± 6.5	0.907[a]
BMI groups: *n* (%)				0.529[b]
Underweight (< 18.5 kg/m^2)	0	0	0	
Normal (18.5–24.9 kg/m^2)	15 (24.6)	7 (23.3)	8 (25.8)	
Obese (> 25 kg/m^2)	46 (75.4)	23 (76.7)	23 (74.2)	
Past pregnancy: *n* (%)				0.027[b]
No	27 (44.3)	9 (30.0)	18 (58.1)	
Yes	34 (55.7)	21 (70.0)	13 (41.9)	
History of breastfeeding: *n* (%)				0.003[b]
No	32 (52.5)	10 (33.3)	22 (71.0)	
Yes	29 (47.5)	20 (66.7)	9 (29.0)	
Smoking: *n* (%)				0.357[b]
No	44 (73.8)	21 (70.0)	24 (77.4)	
Yes	16 (26.2)	9 (30.0)	7 (22.6)	
Comorbidities: *n* (%)				0.467[b]
None	34 (55.7)	15 (50.0)	19 (61.3)	
Arterial hypertension	13 (21.3)	8 (26.7)	5 (16.1)	
Diabetes	7 (11.5)	4 (13.3)	3 (9.7)	
Asthma/COPD	2 (3.3)	0	2 (6.5)	
Thyroid dysfunction	3 (4.9)	1 (3.3)	2 (6.5)	
Cancer	1 (1.6)	1 (3.3)	0	
Others	1 (1.6)	1 (3.3)	0	

Abbreviations: BMI, body mass index; COPD, chronic obstructive pulmonary disease; SD, standard deviation.
[a] *t*-Test for independent samples.
[b] Chi-square test.

Results

Comparison between Breast Tissue and Abdominal Tissue Density

The mean density of breast tissue specimens was 0.94 ± 0.02 g/mL (range, 0.89–0.99 g/mL). Abdominal tissue specimens had a mean density of 0.94 ± 0.02 g/mL (range, 0.90–0.98 g/ml). Comparison between both specimen groups showed no statistically significant difference ($p = 0.230$) (►**Fig. 1**).

Factors Influencing Tissue Density

Age was statistically significant and negatively correlated with breast tissue density: rs = –500 ($p = 0.04$). No statistically significant correlations were found between breast tissue and the other patient variables surveyed. For multiple linear regression, all variables except for age were excluded from the model. The final model had medium goodness of fit ($R^2 = 0.240$). The variable age statistically significantly predicted breast tissue density ($p = 0.005$). The following

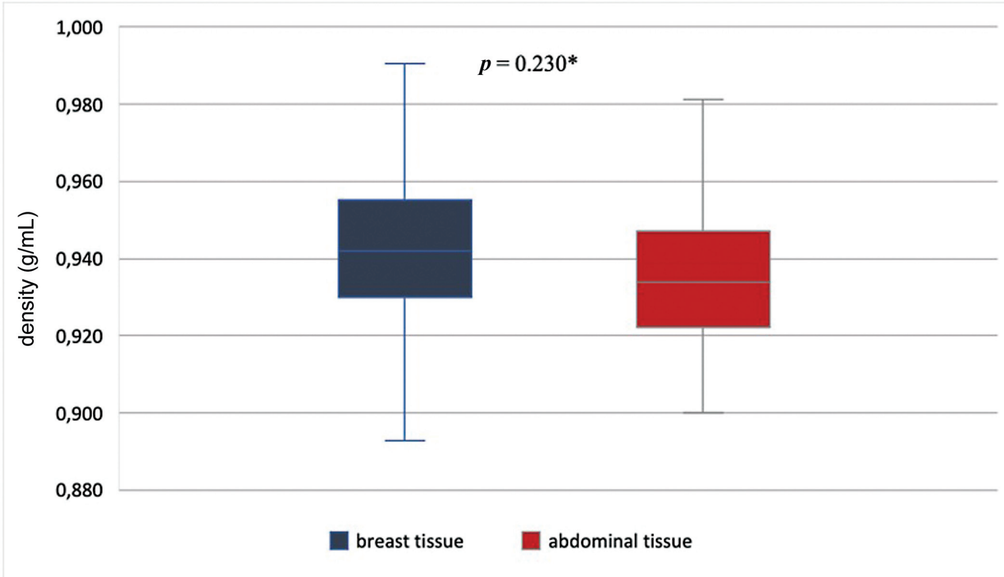

Fig. 1 Box plots showing the density values for breast tissue specimens (blue box) and abdominal tissue specimens (red box).

regression equation was obtained: age corrected breast tissue density (g/mL) = 0.975–0.0007 * age (years) (►**Fig. 2**). No statistically significant correlations were found between abdominal tissue and patient variables.

Silicone Implant Density

►**Table 2** demonstrates the breast implants' volume indicated by the manufacturer, measured volume, volume discrepancy, measured weight, density, and deviation from breast tissue density. For three implants, the volume indicated by the manufacturer differed from the calculated volumes. The density of the implants varied from 0.76 g/mL (*implant I*) to 1.03 g/mL (*implant V*). Related to breast tissue density, implant density differed from –0.19 g/mL (–19.8%) (*implant I*) to +0.09 g/mL (+9.58%) (*implant V*). The difference between breast tissue and implant density was statistically significant for all implants ($p < 0.001$).

Discussion

The present study investigated the density of breast tissue and abdominal tissue specimens in relation to age, ethnicity,

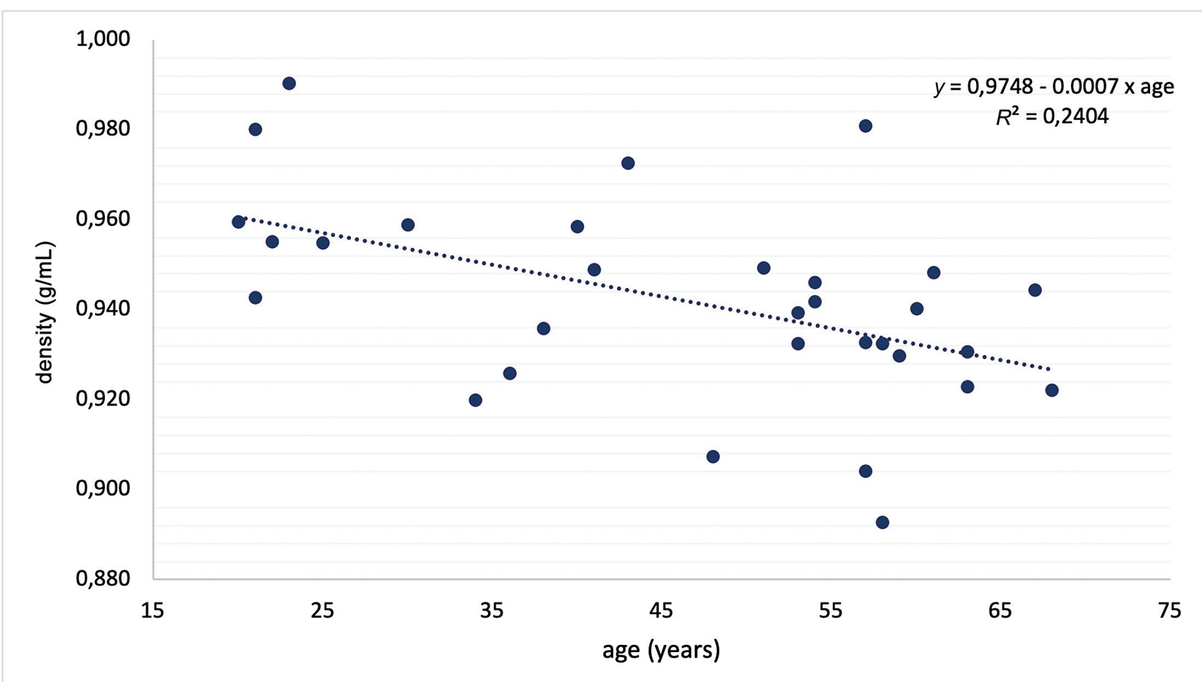

Fig. 2 Graph showing the linear regression of breast tissue density (in g/mL) (*y*-axis) in relation to age (in years) (*x*-axis).

Table 2 Implant characteristics and relation to breast tissue density

	Volume manufacturer (mL)	Volume measured (mL)	Volume discrepancy (mL/%)	Weight (g)	Density (g/mL)	Difference to breast tissue (g/mL/%)
Implant I	410	405	−5 /−1.22%	305.7	0.755	−0.186/−19.8%[a]
Implant II	300	300	–/0.00%	298.9	0.996	+0.055/+5.9%[a]
Implant III	300	300	–/0.00%	300.1	1.000	+0.059/+6.3%[a]
Implant IV	125	130	+5/+4.00%	132.9	1.022	+0.081/+8.6%[a]
Implant V	300	305	+5/+1.67%	314.5	1.031	+0.090/+9.6%[a]

Note: Implant I, Polytech B-Lite/SL 410cc; Implant II, Motiva Ergonomix demi 300cc; Implant III, Motiva Round demi 300cc; Implant IV, Mentor Siltex round BI moderate plus profile cohesive I 125cc; Implant V, Mentor Siltex round BI moderate plus profile cohesive II 300cc.
[a] $p < 0.001$.

body mass index, past pregnancy, history of breastfeeding, smoking, and comorbidities. Furthermore, the density of five different 5th generation breast implants was measured and compared to the density values of autologous breast tissue.

Despite the higher specific weight of glandular tissue compared to adipose tissue,[23] the results revealed that the density of breast tissue almost equals the density of abdominal tissue. While the density of breast tissue decreased significantly with increasing age, abdominal tissue density did not change with increasing age. However, while statistically significant, age-related changes of breast tissue density are likely not very relevant in the clinical setting of breast reconstruction (►**Fig. 3**).

Our findings emphasize the suitability of abdominal-based flaps to achieve the goal of replacing like with like in autologous breast reconstruction. For the clinical practice, this is particularly interesting as it allows a direct conversion of mastectomy weight to abdominal flap volume. Wilting et al[24] investigated the changes in breast volume after autologous breast reconstruction (deep inferior epigastric perforator, superficial inferior epigastric artery, and profunda artery perforator flaps) by using three-dimensional stereophotogrammetry. They found a statistically significant 11.1% decrease of breast volume at 6 months postoperatively compared to the baseline measurement at 2 weeks postoperatively, assuming fatty tissue atrophy as the underlying mechanism. Also concerning a potential additional negative effect of radiation therapy on flap volume after autologous breast reconstruction the existing literature is inconclusive.[25–28] Taking our results into account, the intraoperative flap weight should slightly exceed the mastectomy weight to address secondary reduction of flap volume and to achieve long-term symmetry. This is

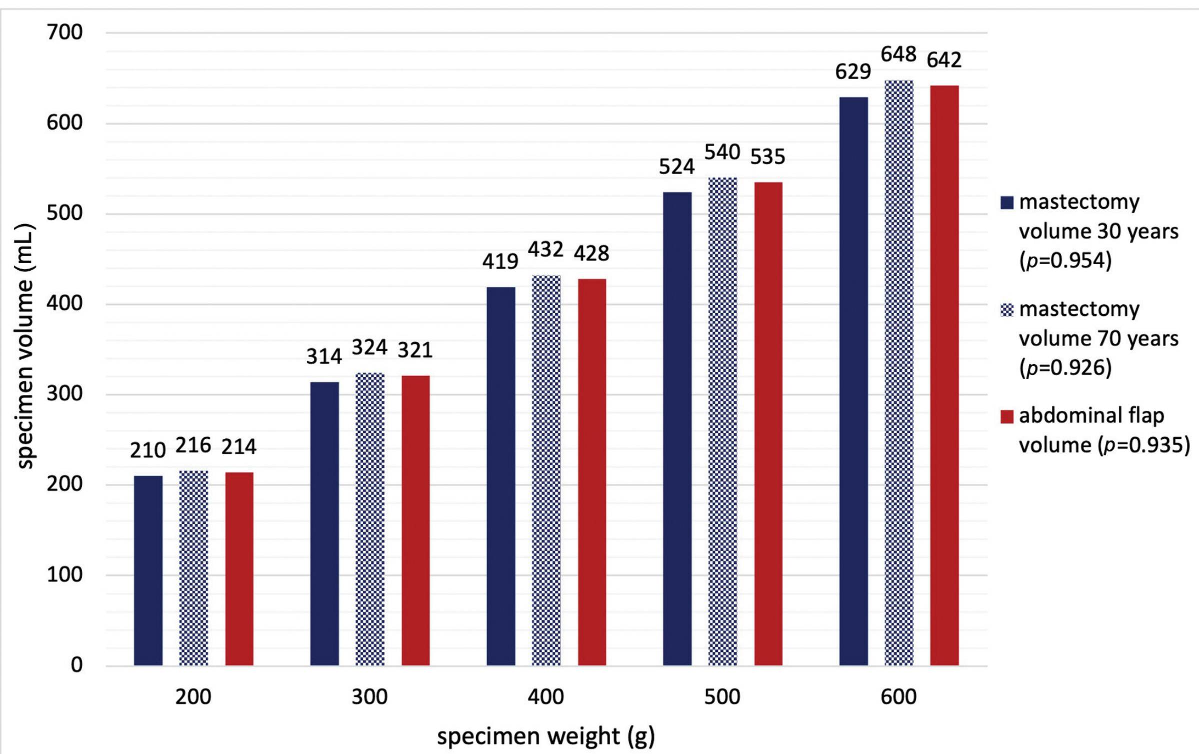

Fig. 3 Bar graph showing the age-corrected volume (mL) of mastectomy specimens in 30 years old patients (blue monochrome bars) and in 70 years old patients (blue patterned bars) compared to the volume (mL) of abdominal flap specimens (red bars) for various specimen weights. ρ = density.

also in accordance with the study of Di Pace et al[29] reporting less secondary balancing procedures when flap weight approximates or exceeds mastectomy weight.

The tissue composition of breasts and its relation to breast density was already assessed in previous studies. Lejour[30] found that the share of fat increases and glandular tissue relatively decreases with higher age, body mass index, and total breast volume, but also found major interindividual differences. Chan et al[20] calculated an average breast tissue density of 0.98 g/mL while Parmar et al[21] reported a mean density of 1.07 g/mL. In the present study, the breast tissue specimens were solely acquired during breast reduction or mastopexy, hence mainly from hyperplastic breasts. As the composition of fatty and glandular tissue might differ between normal and hyperplastic breasts, this could explain the lower density levels found in this study compared to previous studies. In addition, Parmar et al investigated the effect of the menstrual status on breast tissue density and found no significant differences between premenopausal and postmenopausal women. In contrast, Wazir et al[31] demonstrated significant lower relative breast weight in women aged 50 years and above compared to women under 50 years. This is consistent with our findings of breast density being significantly related to age. The present study further provides evidence that body mass index, past pregnancy, or history of breastfeeding seems to have no significant effect on breast tissue density. To our knowledge, the impact of these parameters on breast tissue density has not been studied before.

The second focus of the study was on breast implants granted they remain the most popular mean of reconstruction. Breast implants are typically categorized by volume and dimensions (such as height, base width, projection) and not weight. However, both volume and weight are recognized among the most critical operative determinants in implant-based breast surgery.[32] The weight of breast implants induces persistent mechanical stress potentially resulting in irreversible tissue atrophy and breast deformation.[32] Recognition of the weight-dependent forces has prompted the development of lightweight breast implants.[33] In our series of four standard 5th generation implants a density ranging from 1.00 to 1.03 g/mL was measured, which is slightly lower compared to the density levels ranging from 1.02 to 1.07 g/mL in a series of Mentor and McGhan breast implants reported by Hsieh et al in 2013.[34] The calculated density of the lightweight implant (*Polytech B-Lite/SL*) was 0.76 g/mL and thus 0.24 to 0.28 g/mL or 24.3 to 26.8% lighter compared to the "standard" implants. As implant brand choice is typically based on individual or institution preferences, it is advisable to consider the physical properties of the implants regularly used in one's own clinical practice and to adopt the personal surgical technique accordingly.

In unilateral implant-based breast reconstruction, implant dimension choice is determined by the preoperative breast volume, the contralateral breast volume, or the mastectomy specimen weight. Unlike in autologous breast reconstruction, implant volume cannot be directly derived one-to-one from mastectomy specimen weight or volume. Previously published formulas to estimate implant volume in breast reconstruction suggest that smaller mastectomy resection weights or breast volumes are preferably reconstructed with relatively bigger implant volumes while larger mastectomy weights are reconstructed with relatively smaller implant volumes.[35–37] The pivotal point of equilibrium between mastectomy weight and implant volume was found between 170 g and 300 cm^3, respectively.[36,37] Baek et al[38] reported the highest patient satisfaction at a ratio of implant volume to mastectomy specimen weight of 71.9% (range 54.5–96.7%). These recommendations follow the primary objective of maximum volumetric symmetry of the reconstructed and the healthy breast. However, with a mean mastectomy specimen weight of approximately 500 g,[39,40] a unilateral mastectomy not only affects appearance but also causes weight disbalance. Several studies demonstrated significant changes in body posture after unilateral mastectomy.[5,41,42] These changes are particularly relevant in patients with preexisting spine disorders. Gutkin et al[43] investigated 62 patients with scoliosis and found a significant increase of spine curvature after mastectomy. Immediate breast reconstruction significantly reduces the amount of change in spinal alignment after unilateral mastectomy.[3,44–46] In our study, implant density differed from –19.8% to +9.58% from breast tissue density. Replacing mastectomy volume with smaller implant volume thus might insufficiently address weight disbalances, especially in large breasts and when using lightweight implants. When striving to achieve perfect weight distribution between the native and the reconstructed side, we therefore recommend autologous reconstructions. The present study only evaluated the density of abdominal tissue representing the most commonly used donor site for autologous breast reconstructions. Future studies evaluating gluteal and thigh tissue to gain information about the specific weight of gluteal artery and profunda artery perforator flaps would be desirable.

Conclusion

Our results support the suitability of abdominal-based perforator flaps in achieving both volume and weight symmetry in unilateral autologous breast reconstruction. Abdominal flap volume can be derived one-to-one frommastectomy weight. Further, given significant brand-dependent density differences, the potential to impose weight disbalances when performing unilateral implant-based reconstructions of large breasts should be considered.

Conflict of Interest
None declared.

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