

What Patient-related Factors Most Strongly Influence Autologous Fat Grafting Volume Retention in Breast Augmentation?

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Background: Regarding autologous fat grafting for breast augmentation, the factors influencing volume retention are unclear. Few studies have assessed which factors, particularly patient-related variables, could affect volume retention and to what extent, without performing multivariate analysis. In this study, we performed three-dimensional breast volume measurements before and after autologous fat grafting, calculated the volume and volume retention, and investigated factors that may affect volume retention.

Methods: A total of 204 breasts that underwent autologous fat grafting by the same surgeon at our hospital between May 25 and December 25, 2021 were included. Volumetric measurements were taken preoperatively and at 1, 3, and 6 months postoperatively using a three-dimensional camera; volume retention was calculated. Linear mixed model analysis was performed to examine the effects of age, body mass index, number of total autologous fat grafting procedures, pregnancy and lactation history, smoking status, fat processing techniques (sedimentation versus centrifugation), preoperative volume, and weight change at the 3- and 6-month postoperative volume retention analyses.

Results: Using multivariate analysis, the preoperative volume was found to be a significant factor at 3 and 6 months. The preoperative volume affected fat volume retention rate by 0.004 ($P = 0.001$) and 0.008 ($P = 0.011$) per 10 mL at 3 and 6 months, respectively.

Conclusions: The preoperative volume likely affected fat volume retention. Specifically, a 100-mL increase in the preoperative breast volume might increase the volume retention by 4%–8%. Preoperative volume is an important confounding factor for future studies. (*Plast Reconstr Surg Glob Open* 2024; 12:e6194; doi: 10.1097/GOX.0000000000006194; Published online 19 September 2024.)

INTRODUCTION

Compared with breast augmentation using artificial materials such as silicone implants, autologous fat grafting for breast augmentation has the advantages of no complications such as deformation or leakage due to deterioration or capsular contracture, resistance to infection, and a more natural appearance. Furthermore, the procedure is currently performed at many facilities. However, because free tissue grafts are used, predicting the extent to which the graft will be retained is difficult; the actual reported

volume retention varies considerably. For example, a recent systematic review by Seth et al found that the volume retention of autologous fat grafting was 44%–83%.¹

The reason for this is that comparing volume retention under the same conditions is difficult because there are many factors that could affect volume retention, such as technique, fat processing method, and patient-related factors. To date, improved volume retention with the addition of stem cells and use of extracorporeal expanders has been reported.^{2–8} However, no multivariate studies on the factors that contribute to volume retention, particularly patient-related factors, have been conducted. Although the introduction of new medical technologies and devices is welcomed, comprehensively understanding them without solid evidence of the underlying patient-specific factors is difficult. Therefore, in this study, we aimed to assess the effect of patient-specific factors on autologous fat grafting volume retention in patients undergoing breast

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augmentation. We performed three-dimensional breast volume measurements before and after autologous fat grafting, determining the volume and volume retention rates, and identifying which factors influence the volume retention rate.

METHODS

The study followed the principles of the Declaration of Helsinki, and informed consent was obtained from all patients. Overall, 94 patients (204 breasts) who underwent fat augmentation by a single surgeon at our clinic between May 25 and December 25, 2021 were included. Those who had previously undergone breast augmentation at another hospital or by another surgeon, had a history of breast surgery, or were not followed up for more than 3 months were excluded. Patients who underwent the two procedures at our hospital were also included. The fat was processed by gravitational sedimentation or centrifugation. The injection volume was approximately 150–250 mL, and the volume was varied within this range to compensate for differences between the left and right sides. Volumetric measurements were determined using a three-dimensional (3D) camera (VECTRA H2; Canfield Scientific Inc., Parsippany, N.J.) and data processing and 3D analysis software (VECTRA Analysis Module; Canfield Scientific Inc., Parsippany, N.J.) preoperatively and at 1, 3, and 6 months postoperatively. The volume retention percentage was calculated by subtracting the preoperative breast volume from the postoperative breast volume, dividing by the injected fat volume, and multiplying by 100.

The following factors were also analyzed to determine the effect on volume retention: age, body mass index (BMI), number of total autologous fat grafting procedures, pregnancy and lactation history, smoking status, fat processing techniques (sedimentation versus centrifugation), preoperative volume, and weight change. The number of total autologous fat grafting procedures was defined as the number of fat grafting procedures the patient had undergone at the time of surgery. For example, if a patient had undergone the procedure once before this study, the number of total autologous fat grafting procedures would be two.

STATISTICAL ANALYSIS

Factors influencing breast volume retention at 3 and 6 months were examined. The 3- and 6-month analyses included cases wherein the breast volume retention at 3 and 6 months, respectively, could be calculated.

The data in this study included cases wherein information on two breasts from a single case were obtained. Therefore, the analysis was performed using a linear mixed model with the case as a variable. A linear mixed model analysis was performed with breast volume retention as the dependent variable and age, BMI, number of total autologous fat grafting procedures, pregnancy and lactation history, smoking status, fat processing technique (sedimentation versus centrifugation), preoperative volume, and weight change as fixed effects. Univariate

Takeaways

Question: What are the patient-related factors that most strongly influence autologous fat grafting volume retention in breast augmentation?

Findings: Using three-dimensional breast volume measurements and linear mixed model analysis, we identified preoperative volume as the most critical factor affecting fat volume retention following breast augmentation using fat grafting.

Meaning: Preoperative breast volume is a key confounding factor for fat grafting that should be considered in future studies and while developing new fat grafting technologies.

and forced entry multivariate analyses were performed. Regarding the multivariate analysis, a condition of no multicollinearity was used for the model construction. A linear mixed model was used to estimate the effect of each factor on breast volume retention. Continuous data are presented as means (standard deviations), and results of the linear mixed model analysis are presented as effect (95% confidence interval). Statistical significance was set at $P < 0.05$. All statistical analyses were performed using SPSS for Windows (version 24.0; IBM Corp., Armonk, N.Y.).

RESULTS

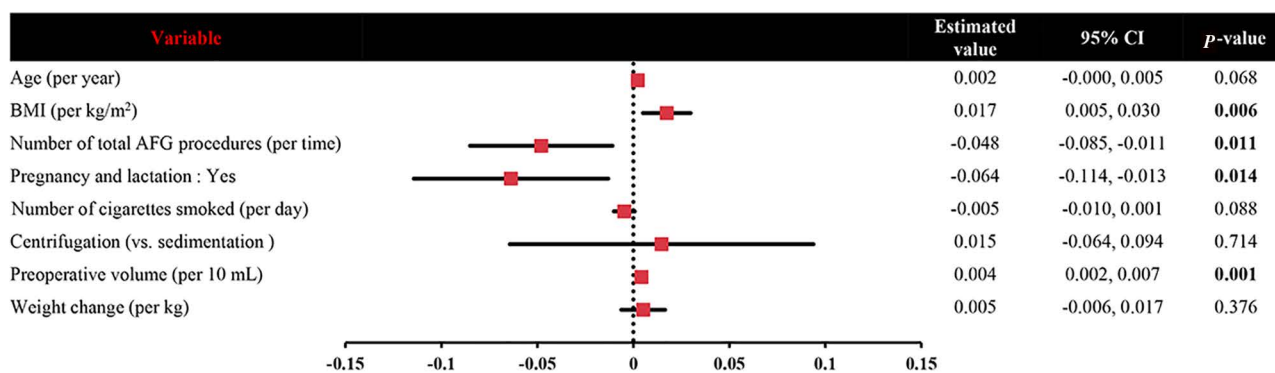
The data of 184 breasts of 87 patients were used to analyze breast volume retention at 1 month. Details are listed in [Table 1](#). The breast volume retention at 1 month was 39% (14). Data of 204 breasts of 92 patients were used to analyze breast volume retention at 3 months. The weight change data of eight breasts were missing. Therefore, the analysis was performed including data of 196 breasts for this factor. The volume retention was 32% (13). Details are presented in [Table 1](#). Univariate analysis showed that BMI, number of total autologous fat grafting procedures, pregnancy and lactation history, and preoperative volume were significantly associated with breast volume retention at 3 months (univariate analysis, estimate [95% confidence interval]; BMI [per kg/m²]: 0.027 [0.016–0.037], $P < 0.001$; number of total autologous fat grafting procedures [per time]: -0.040 [-0.075 to -0.004], $P = 0.028$; pregnancy and lactation history: -0.047 [-0.092 to -0.002], $P = 0.042$; preoperative volume [per 10 mL]: 0.005 [0.003–0.007], $P < 0.001$). [Figure 1](#) shows the results of the multivariate analysis. BMI, number of total autologous fat grafting procedures, pregnancy and lactation history, and preoperative volume were significantly associated with breast volume retention at 3 months (BMI, $P = 0.006$; number of total autologous fat grafting procedures, $P = 0.011$; pregnancy and breastfeeding, $P = 0.014$; preoperative volume, $P = 0.001$).

Data of 62 breasts in 31 patients were used to analyze breast volume retention at 6 months. No data were missing. The volume retention was 39% (20). Details are presented in [Table 1](#). BMI, pregnancy and lactation history, and preoperative volume were significantly associated with breast volume retention at 6 months using univariate analysis (BMI [per kg/m²]: 0.044

Table 1. Details of Study Factors

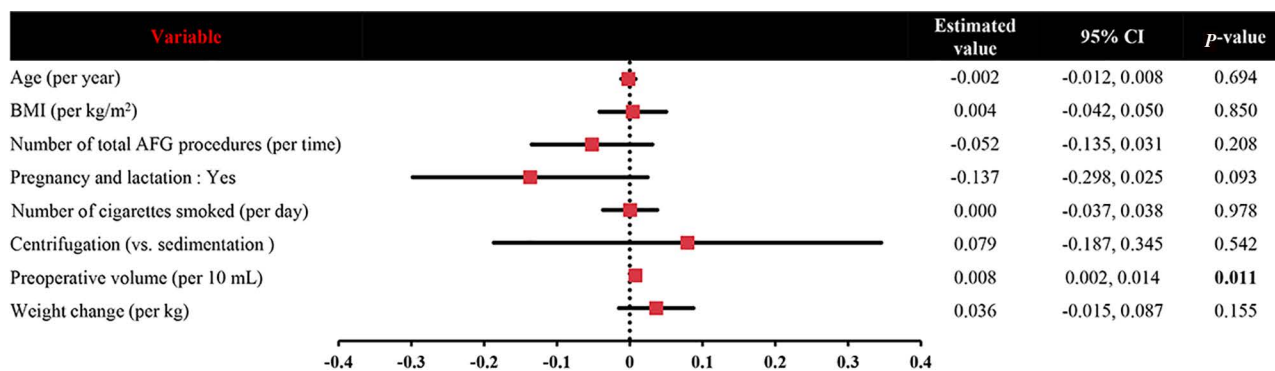
Parameters	1 Month	3 Months	6 Months
N	184	204	62
Age, y	32 (8.9)	32 (8.5)	30 (8.0)
BMI, kg/m ²	19 (1.5)	19 (1.6)	19 (1.6)
Pregnancy and lactation, yes:no	38:146	43:161	14:48
Number of cigarettes smoked, per day	1.0 (3.2)	1.0 (3.4)	0.6 (2.1)
Weight change, kg	0 (1.6)	-0.1 (1.5)	-0.1 (1.5)
Number of total autologous fat grafting procedures	1.4 (0.6)	1.3 (0.5)	1.3 (0.5)
Fat processing techniques; no. cases using sedimentation versus centrifugation	174:10	192:12	58:4
Preoperative volume, mL	109 (86)	112 (87)	126 (124)
Volume retention, %	39 (14)	32 (13)	39 (20)
Fat injection volume, mL	195 (20)	195 (20)	198 (18)

Continuous data are presented as mean (SD).



AFG, autologous fat grafting;

Fig. 1. Multivariate analysis of factors influencing volume retention at 3 months.



AFG, autologous fat grafting;

Fig. 2. Multivariate analysis of factors influencing volume retention at 6 months.

[0.003–0.084], $P = 0.036$; pregnancy and lactation history: $-0.227 [-0.377, -0.076]$, $P = 0.005$; preoperative volume [per 10 mL]: $0.008 [0.003, 0.012]$, $P = 0.001$. **Figure 2** shows the results of multivariate analysis. Preoperative volume was the only factor that significantly increased breast volume retention at 6 months ($P = 0.011$). **Figures 3** and **4** show pre- and postoperative images from the 3D camera.

DISCUSSION

Regarding the reliability of the 3D camera used in this study, a systematic review found that Vectra 3D imaging systems produced accurate and reproducible results.⁹ O’Connell et al¹⁰ validated measuring breast volume using the Vectra XT, one of the Vectra 3D imaging systems, and found that the Vectra XT had an accuracy of -2.2% of the true volume. Based on these reports, we suggest that the



Fig. 3. Preoperative photographs of a 35-year-old woman. The preoperative breast volume is 118 mL on the right and 137 mL on the left.



Fig. 4. Six months postoperative photographs of the same patient in [Figure 3](#). The volume injected is 230 mL on the right and 170 mL on the left; the breast volume at 6 months is 215 mL on the right and 230 mL on the left.

Vectra 3D imaging system is sufficiently reliable, although measurements may be slightly underestimated.

Regarding the fat processing methods, this study mainly used the gravitational sedimentation method. However, during gravitational sedimentation, the amount of fluid in the fat graft injection varied with the time between collection and injection. Therefore, although this study focused on patient-related factors, a comparison with centrifugation was included in the analysis. Because the results ([Figs. 1](#) and [2](#)) were not significantly different, we suggest that the gravitational sedimentation did not significantly affect the results of this study.

In addition to the aforementioned report by Seth et al¹ regarding autologous fat grafting volume retention, Voglimacci et al¹¹ and Groen et al¹² have provided systematic reviews and reported volume retention rates of 40%–84.64% and 44.7%–82.6%, respectively. Although the evaluation and fat processing methods differed and could not be directly compared, the volume retention ranged considerably among these reports. This is because several factors affect volume retention, particularly, the differences in the population composition. As summarized in [Table 1](#), the volume retention in our study also differed between months 1, 3, and 6. The decrease in volume retention between months 1 and 3 may be due to edema or because the fat was not yet stable. The increase in volume from 3 to 6 months may be due to population composition differences.

What were the factors in the population affecting volume retention?

In the present study, the significant difference at both the 3- and 6-month time points was the preoperative

breast volume. The larger the preoperative breast volume was, the higher the volume retention was.

Specifically, a 100-mL increase in preoperative breast volume may result in an increase in volume retention of 4%–8%. With this in mind, we considered the systematic review previously mentioned.^{1,11,12} In the study by Seth et al,¹ the average volume retention was 58.59%. However, the average preoperative volume of the seven cases was 359 mL, which was far larger than the preoperative volume in our study (112 mL at 3 months and 126 mL at 6 months). Similarly, the mean preoperative breast volumes in the articles by Voglimacci et al¹¹ and Groen et al¹² were 225 and 225 mL, respectively, which are larger than that of our cohort. Of these systematic reviews, Spear and Pittman⁴ reported the lowest preoperative volume of 75.3 mL and an average volume retention of 38.2%, which is consistent with our results.

The reason why the preoperative breast volume is related to the volume retention rate is that the larger the breast is, the less pressure is exerted on the skin when the same amount of fat is injected. In addition, the larger the volume, the more likely it is that the injected fat is surrounded by tissue with blood flow at the recipient site, making survival easier for the injected fat.

Del Vecchio et al¹³ reported in detail on the graft-to-capacity concept. According to their study, the average graft-to-capacity ratio in fat augmentation was 117%, and in cases where the average graft-to-capacity ratio exceeded one standard deviation, the capacity maintenance rate per 1% was lower. They concluded that the graft-to-capacity ratio was a relevant variable in percentage volume maintenance outcomes. Our multivariate analysis also supports the conclusions of Del Vecchio et al.

Fat volume retention reaches a steady state at 3–6 months.^{14–16} Therefore, we suggest that the results at 3 months are worth considering. Factors other than the preoperative volume that had an independent influence at 3 months included the BMI, number of total autologous fat grafting procedures, and pregnancy and lactation history, which were not significantly different at 6 months. However, the results may change if the sample size is increased to be as large as that at 3 months.

Chiu¹⁷ compared a BMI greater than and less than or equal to 18.5 kg per m² and found no significant difference in breast circumference change. Our results at 3 months showed that volume retention increased significantly with increasing BMI. The reason for this discrepancy could be that a BMI of 18.5 kg per m² was used for the analysis, which would have made differences less obvious. The volume retention increased with a larger BMI due to the abundance of donor fat, which makes harvesting good-quality fat easier, and the higher percentage of subcutaneous fat as a component of the breast, which provides more space for injections.

As for the decrease in volume retention with an increasing number of total autologous fat grafting procedures, the skin may become less stretchable, increasing the pressure as the number of total autologous fat grafting procedures increases.

The lower volume retention with a history of pregnancy and lactation could be due to a decrease in the quality of the recipient site or transplanted fat. Although volume retention is reportedly higher in women with prior breastfeeding experience,¹⁸ the BMI in the breastfeeding group was significantly higher than that in the nonbreastfeeding group, which may have biased the results because of differences in the BMI and preoperative breast volume. Regarding the effect of estrogen on fat, Bills et al¹⁹ compared fat grafts from ovariectomized and nonovariectomized mice and found vascular endothelial growth factor expression and a significant decrease in capillary density in the former group. Estrogen decreases rapidly after pregnancy and childbirth and remains low in women who breastfeed, during and after lactation, until menstruation returns.²⁰ Many women lose breast firmness after childbirth and lactation and opt for breast augmentation. The quality of transplanted fat grafts may be lower because breast augmentation during that period occurs after a low-estrogen state.

Injection volume may also be a factor for consideration. However, the injection volume was not included in the analysis for the following reasons. First, the volume retention percentage was adopted as the dependent variable and had already been divided by the injection volume. Therefore, further inclusion of the injection volume as an independent variable would have been an overadjustment. Second, univariate analysis of injection volume was performed as a reference. The results revealed little correlation between volume retention and injection volume, without showing significant differences. Therefore, we consider that an important outcome dependent on injection volume would be unlikely to occur.

The limitations of this study included measurement errors associated with the camera system, racial bias, and lack of long-term follow-up results beyond 6 months. In particular, dense tissue comprises a higher percentage of Asian breasts, which also have smaller breast volumes.²¹ The percentage of breast density could also have affected volume retention.

CONCLUSIONS

We found that preoperative breast volume impacted volume retention. Therefore, although volume retention can be used as a measure of success, if a new technique or procedure is reported, it cannot be assumed that the results (ie, volume retention) would be equal in populations with different body types. The same technique or procedure will likely result in a lower volume retention in patients with a lower preoperative breast volume when autologous fat grafting is performed. Preoperative breast volume is also a potentially important confounding factor that should be considered in future studies on autologous fat grafting.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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