Longitudinal Volume Assessment of Reconstructed Breast Using Three-Dimensional Measurement: How Do DIEP and LD Flap Change Immediately after Surgery?

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Abstract

Background The deep inferior epigastric perforator (DIEP) and latissimus dorsi (LD) flaps are two widely used autologous breast reconstructions. Despite studies on flap-volume changes, the time of the first measurement is not immediately after surgery. Therefore, this study aimed to investigate the change in volume over time from the immediate postoperative period using a three-dimensional (3D) scanner.

Methods Patients who underwent breast reconstruction with a DIEP or LD flap between October 2019 and December 2020 at Showa University Koto Toyosu Hospital were included. The Kinect 3D scanner was used to measure the reconstructed and healthy breast volumes immediately after surgery and at 1, 3, 6, and 12 months. The control group was the healthy side, and the volumes obtained at each time point and ratios (to the immediate postoperative period) were calculated and analyzed using a linear mixed model.

Results Of the 25 patients and 26 breasts examined, the postoperative increase in volume ratios was statistically significant in the DIEP flap group, except for the sixth month, but decreased significantly in the LD group. Compared with the control group, the volume ratio was significantly higher up to 3 months in the DIEP flap group and decreased significantly after 3 months in the LD flap group.

Conclusions The volume of the LD flap continued to decrease immediately after surgery, whereas the volume of the DIEP flap increased by 10% up to 1M. Therefore, this increase in volume should be taken into consideration in studies where the initial measurements were not taken immediately after surgery.

Keywords
- breast reconstruction
- latissimus dorsi
- perforator flap
- magnetic resonance imaging
- supine position

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Introduction

Breast reconstruction with autologous flap reconstruction, such as the deep inferior epigastric perforator (DIEP) flap and latissimus dorsi (LD) flap, is a common procedure. However, with autologous flap reconstruction, the flap volume may decrease after surgery, often requiring revision surgery. If we can predict future volume changes based on supporting data and adjust the volume during surgery, we can reconstruct a more symmetrical breast without the need for extensive revision surgery. To date, studies have reported flap-volume changes[1–12]; however, only a few have reported flaps used for breast reconstruction.[1,9–12] Furthermore, most studies[2–8,11] have conducted measurements using computed tomography (CT) or magnetic resonance imaging (MRI) in the supine position. Because the breast shape is determined in the upright position, measurement in the upright or sitting position is preferred. Wilting et al[9] measured the volume of DIEP, superficial inferior epigastric artery, and profunda artery perforator flaps using a three-dimensional (3D) scanner. Although their study provided useful findings, the first measurements were obtained 2 weeks postoperatively. Briefly, studies of volume changes in flaps used for breast reconstruction up to now have not been performed immediately after surgery. If several days have elapsed before the first measurement, volume changes may have occurred by then. In clinical practice, we believe that surgeons would be interested in how the breast changes over time immediately after reconstruction. In particular, elucidation of changes that may occur immediately after breast reconstruction surgery can potentially inform the decision-making process of surgeons when determining the volume of the reconstructed breast during the procedure. This study aimed to investigate how flap-volume changes from that moment immediately after the surgery is completed using a 3D scanner, a change that has been overlooked in previous studies.

Materials and Methods

All patients underwent breast reconstruction with a DIEP or LD flap between October 2019 and December 2020 at Showa University Koto Toyosu Hospital. Patients were excluded if breast volume data were unavailable for more than3 months postoperatively, if they were irradiated, if they had a weight change of more than5 kg, or if they had postoperative problems, such as flap necrosis and fat necrosis. In addition, no implants were used in DIEP and LD.

The study followed the principles of the Declaration of Helsinki, and written informed consent was obtained from all patients.

Breast Volume Measurements

The Kinect 3D scanner (Kinect V1; Microsoft Corporation, Redmond, Washington, United States), scanning and data processing software (Artec Studio PRO; Artec Group, Luxembourg City, Luxembourg), and 3D analysis software (Breast Rugle; Medic Engineering Corporation, Kyoto, Japan) were used in measuring breast volume. 3D scanning was performed twice, the analysis was conducted twice per imaging, and the average value was obtained from the four obtained volumes and used as one measurement.

Measurements were obtained immediately after surgery within 15 minutes after the completion of surgery and at 1, 3, 6, and 12 months after surgery. Measurements immediately after surgery were obtained in the operating room under general anesthesia. The patient remained in a sitting position, with both shoulder joints abducted at 90 degrees. Postoperative scans were obtained with the patient in the same sitting position. For logistical reasons, the timing of the appointments could deviate a week for the first month, a few weeks for 3- and 6-month follow-ups, and a few months for the 12-month follow-up.

Statistical Analysis

The control group was the healthy side, and the ratio of the volume obtained at each time point in the DIEP flap, LD flap, and control groups to the volume immediately after surgery was calculated. The repeated-measure breast volumes were analyzed using linear mixed models that included a group of flaps (control, LD, and DIEP), dummy variables for time (immediately after surgery and at 1, 3, 6, and 12 months), group-by-time interactions as covariates, and subjects as a random effect. In this model, common subject IDs were included in the random factors for the control group to correspond to the LD or DIEP group. Breast volume was used as the dependent variable by calculating its ratio to the immediate postoperative period. The covariance structure is a completely general covariance matrix. The results were reported as least squares means with 95% confidence intervals at each time point. A *p*-value of less than 0.05 was considered statistically significant, and all *p*-values were two-sided without multiplicity adjustment. All statistical analyses were performed using IBM SPSS for Windows version 24.0 (IBM Japan, Ltd., Tokyo, Japan).

Results

Of the 39 cases and 40 breasts reconstructed, 25 cases and 26 breasts (DIEP flap, 17 cases and 18 breasts; LD flap, eight cases and eight breasts) were analyzed in the study (►**Fig. 1**). The patient and breast characteristics are shown in ►**Table 1**. The mean ages were 50 (±6) and 50 (±9) years for the DIEP and LD flap groups, and the mean observation durations were 210 (±104) and 276 (±94) days for the DIEP and LD flap groups, respectively. The mean volumes in the DIEP flap group immediately after surgery and at 1, 3, 6, and 12 months were 245 (±114), 279 (±144), 274 (±137), 306 (±162), and 291 (±138) mL, and the mean volumes in the LD flap group immediately after surgery and at 1, 3, 6, and 12 months were 163 (±50), 150 (±58), 141 (±76), 135 (±76), and 134 (±89) mL, whereas the average volumes immediately after surgery and at 1, 3, 6, and 12 months in the control group were 173 (±91), 167 (±94), 173 (±102), 172 (±116), and 141 (±75) mL, respectively. ►**Table 2** and ►**Fig. 2** show the results of the comparison of the change in the breast volume between

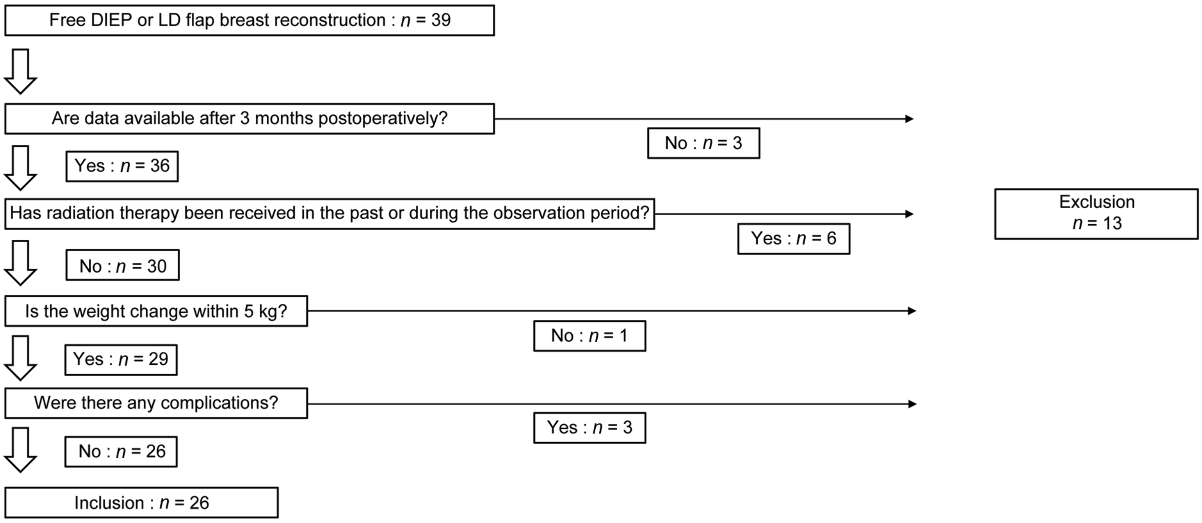

Fig. 1 Flowchart of case selection. DIEP, deep inferior epigastric perforators; LD, latissimus dorsi.

Table 1 Patient and breast characteristics

	DIEP	LD
Sample size: *n*	18	8
Age: years (range)	50 ± 6 (43–65)	50 ± 9 (35–70)
BMI: kg/m^2 (range)	22.7 ± 2.2 (18.3–28.4)	20.5 ± 2 (17.8–27.6)
Chemotherapy: *n* (%)	2 (11.1)	1 (12.5)
Hormonal therapy: *n* (%)	10 (55.6)	2 (25)
Axillary lymph node dissection; *n* (%)	1 (5.5)	0 (0)
Timing: *n* (%)		
Primary one-stage	0 (0)	0 (0)
Primary two-stage	15 (83.3)	6 (75)
Secondary one-stage	2 (11.1)	2 (25)
Secondary two-stage	1 (5.6)	0 (0)
Breast side: *n* (%)		
Right	8 (44)	4 (50)
Left	9 (50)	4 (50)
Bilateral	1 (6)	0 (0)
Follow-up time: days (range)	209 ± 104 (93–479)	276 ± 94 (184–376)

Abbreviations: BMI, body mass index; DIEP, deep inferior epigastric perforators; LD, latissimus dorsi.
Continuous data are presented as means ± standard deviations.

different flaps. The DIEP flap group showed a statistically significant increase in the volume ratio from the immediate postoperative period, except at 6 months ($p = 0.890$) and 12 months ($p = 0.070$). By contrast, the LD flap group showed a statistically significant decrease in the volume ratio immediately after surgery (12 months, $p = 0.034$). In the control group, no statistically significant change was noted throughout the 12 months ($p = 0.198$).

The volume ratio in the DIEP flap group was statistically significantly higher than that in the control group up to 3 months (difference in the volume ratio, 1 month, $p < 0.001$; 3 months, $p = 0.003$). The volume ratio was statistically significantly lower in the LD flap group after 3 months (difference in the volume ratio, 3 months, $p = 0.008$; 6 months, $p = 0.001$; 12 months, $p = 0.004$). In a direct comparison, the DIEP flap group always showed a statistically significantly higher volume ratio from 1 to 12 months than the LD flap group (difference in the volume ratio, 1 month, $p = 0.009$; 3 months, $p < 0.001$; 6 months, $p < 0.001$; 12 months, $p = 0.002$). ►**Fig. 3** shows a typical case of DIEP reconstruction in the immediate postoperative and postoperative periods.

Table 2 Examining intervention effects on volume ratio: a linear mixed model analysis

		Volume ratio at each point														
		Control ($n = 24$)					DIEP ($n = 18$)					LD ($n = 8$)				
		Mean	95% CI			*p*-Value (vs. IAS)	Mean	95% CI			*p*-Value (vs. IAS)	Mean	95% CI			*p*-Value (vs. IAS)
Volume ratio																
	IAS	1.00	Reference			–	1.00	Reference				1.00	Reference			
	1 month	0.97	0.91	,	1.03	0.504	1.13	1.06	,	1.19	0.003	0.97	0.87	,	1.07	0.689
	3 months	0.97	0.91	,	1.02	0.403	1.09	1.02	,	1.15	0.042	0.83	0.73	,	0.92	0.005
	6 months	0.97	0.91	,	1.03	0.493	1.01	0.92	,	1.09	0.890	0.78	0.69	,	0.88	0.001
	12 months	1.07	0.96	,	1.18	0.198	1.14	1.00	,	1.29	0.070	0.83	0.71	,	0.96	0.034

	Difference													
DIEP vs. control					LD vs. control					DIEP vs. LD				
Mean	95% CI			*p*-Value	Mean	95% CI			*p*-Value	Mean	95% CI			*p*-Value
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0.15	0.08	,	0.23	<0.001	0.00	−0.11	–	0.11	0.984	0.15	0.04	–	0.27	0.009
0.12	0.04	,	0.20	0.003	−0.14	−0.24	–	−0.04	0.008	0.26	0.15	–	0.37	<0.001
0.04	−0.06	,	0.13	0.438	−0.19	−0.29	–	−0.08	0.001	0.22	0.10	–	0.35	<0.001
0.07	−0.10	,	0.25	0.399	−0.24	−0.40	–	−0.08	0.004	0.31	0.12	–	0.50	0.002

Abbreviations: 95% CI, 95% confidence interval; DIEP, deep inferior epigastric perforators; IAS, immediately after surgery; LD, latissimus dorsi.

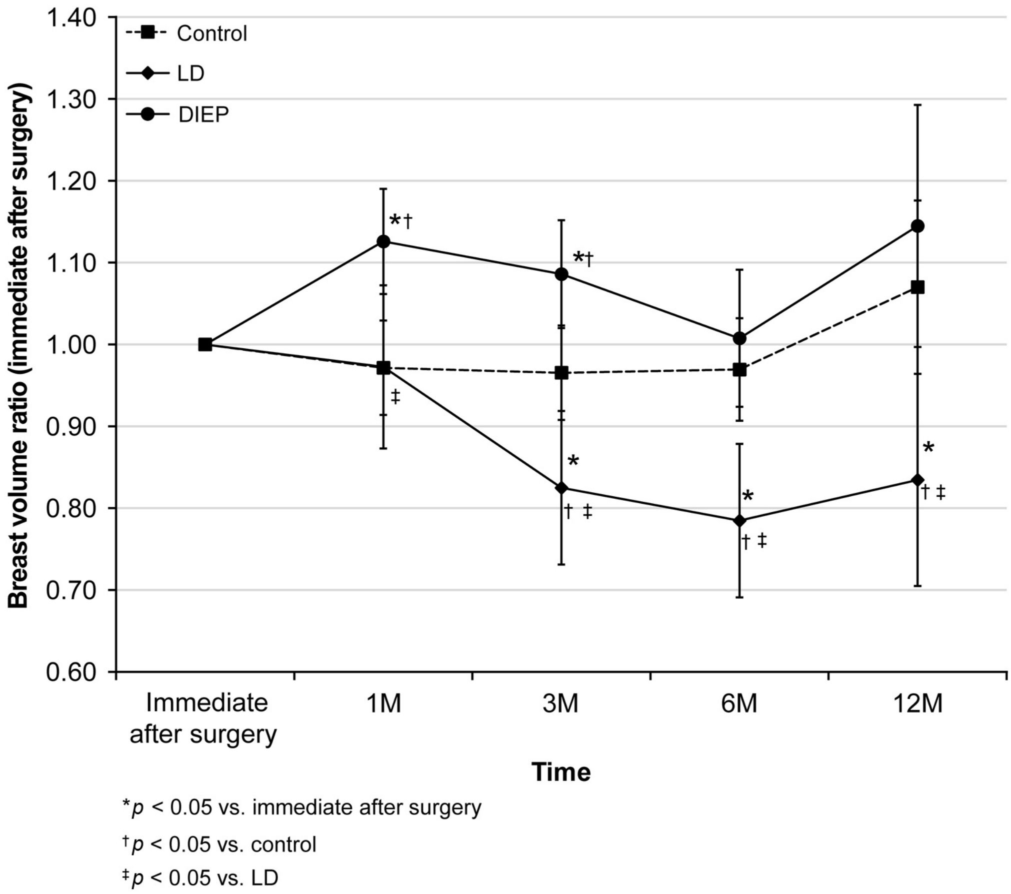

Fig. 2 Breast volume change over time for flap. DIEP, deep inferior epigastric perforators; LD, latissimus dorsi.

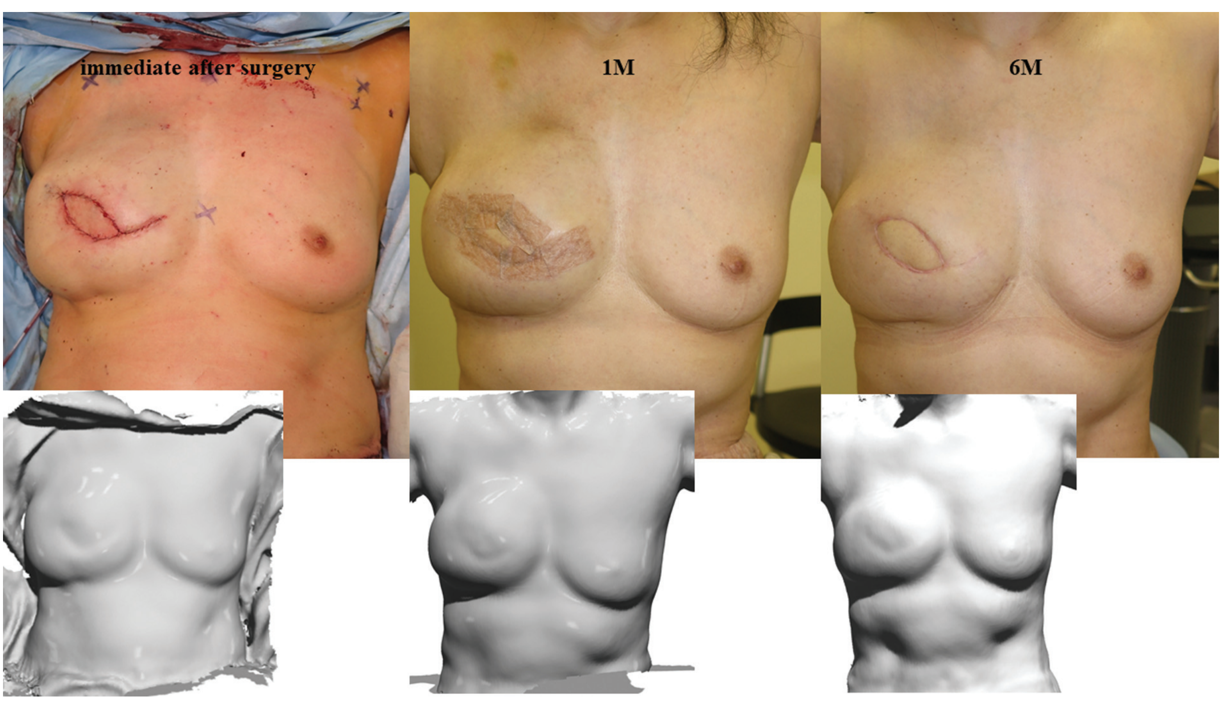

Fig. 3 Clinical photographs and three-dimensional images immediately after surgery and at 1 and 6 months. The volume ratio was 1.12 at 1 month and 0.84 at 6 months on the deep inferior epigastric perforator (DIEP) side (0.98 at 1 month and 1.03 at 6 months on the healthy side) when the immediate postoperative period was set as 1. Thus, most of the DIEP side tended to increase in volume after 1 month and further decrease.

Discussion

First, we describe the advantages and measurement errors of the 3D scanner that were used to measure breast volume. Other methods of volume measurement include thermoplastic molds, mammography, nuclear MRI, and anthropomorphic measurements.[13–16] The handheld 3D scanner has the advantages of easy transportation to the operating room, unrestricted body positions during measurements, and noninvasiveness, which made it the most suitable for this study. Previous studies have compared the accuracy of this method with that of other methods.[16–18]

For positions during measurement, Pöhlmann et al asked patients to assume various poses in a sitting position, and the breasts were measured in 3D.[19] The most reproducible pose was achieved when the patient sat upright with both arms above the head, and the most variability was found when the patient was asked to sit upright and hold hands behind the back. In our study, the patient was unconscious when measurements were taken immediately after surgery, and placing the patient's hands behind the head was not possible, so we used the sitting position with the patient's arms raised 90 degrees.

Chatterjee et al[1] and Wilting et al[9] reported that postoperative irradiation after DIEP flap reconstruction had no significant effect on the breast volume, although some studies have identified a correlation between flap-volume loss and irradiation in patients who underwent head and neck reconstruction.[4,7] This study aimed to investigate the effect of radiation; thus, we excluded it. Kimura et al[8] reported that weight change may affect the breast volume, so we excluded patients with large weight changes. Other complications that may have a significant effect on the volume change were also excluded.

The reconstructed breast was prepared slightly larger, compared with the healthy side, as shown in ►**Fig. 3**. This is because of inability to predict the decrease in the reconstructed breast volume at the time of surgery. The volume of the LD group was smaller than control group because the control group was the average of the healthy side of the DIEP and LD groups combined. However, the large or small volume of the reconstructed breast than control group would have little effect on the changes in the reconstructed breast over time and would not affect the results. This is due to using ratio calculated for each group (volume at each measurement point:volume immediately after surgery) in the analysis rather than values of volume. Additionally, comparisons between groups were also based on the ratios.

At present, for DIEP, as previously mentioned, Wilting et al[9] compared 136 breasts at 2 weeks and 6 months and found an 11.1% decrease. In this study, a slight change in DIEP was noted at 6 months compared with that immediately after surgery, which differs from the results obtained by Wilting et al. However, from 1 to 6 months postoperatively, the volume ratio in the DIEP flap group decreased from 1.13 to 1.02, which is not considerably different from the results of Wilting et al. This indicates that the volume increases for some reasons from immediately after surgery to 1 month and then begins to decrease. A possible main cause is edema. Greenhowe et al[20] reported changes in postoperative breast edema over time using the MoistureMeterD Compact (Delfin Technologies Ltd, Finland), a water-specific instrument for assessing water content in biological tissues. The flap types were DIEP, transverse rectus abdominus myocutaneous, and inferior gluteal artery perforator flaps. The results showed a significant increase in the mean water content (MWC) of free flap at the 5-day, 2-week, and 3-month measurement time points. The extent to which MWC actually affected the volume was not discussed by Greenhowe et al.[20] However, considering that the free flap in their study had a greater increase in postoperative MWC than the healthy side and that the DIEP flap group in our study also had a greater increase in volume immediately after surgery and during the first month compared with the control group, edema is a possible cause of the increased volume. However, in their study, edema was still present at 3 months, whereas in our study, the volume decreased from the volume at 1 month until 3 months. Thus, the volume decrease after 1 month may have been caused by factors other than edema reduction. Oashi et al[21] examined the volume reduction in vascularized fat flaps in rats and its causes and concluded that apoptosis influences volume reduction. In summary, volume increases largely due to edema immediately after surgery and up to 1 month postoperatively; however, volume decreases largely due to fat apoptosis and other factors later, in addition to edema reduction. Consequently, immediately after surgery, the volume does not change significantly at 6 months owing to the counterbalancing effect of increasing and decreasing factors.

A previous study measured postoperative muscle body volume via CT in a reconstruction case using the LD flap after partial mastectomy.[11] Consequently, the volume of the muscle portion of the LD flap decreased by approximately 24% by the second postoperative year, and from the third year, it decreased at a rate similar to that of normal muscle. In our study, the volume of the LD flap group significantly reduced after 3 months compared with that immediately after surgery or the volume in the control group. The volume at 6 months decreased by 21% from immediately after surgery, which we believe does not deviate significantly from the findings of Kang et al.[11]

In this study, the DIEP flap, LD flap, and control groups tended to increase between months 6 and 12. This may be attributable to the small amount of data at 12 months. However, some previous studies have also reported this phenomenon. Sakamoto et al[6] used MRI to measure changes in the volume of the muscle and fat components of the free rectus abdominal flap in patients undergoing head and neck reconstruction. They found that the mean fat volume increased slightly over the 6- to 12-month period. In a long-term study by Yamaguchi et al,[5] the fat volume of free flaps used in head and neck reconstruction tended to decrease over a short period; however, there was a period when the fat volume began to increase. The timing appeared to vary depending on the individual cases.

The temporary volume increase observed in the DIEP flap group from immediately after surgery to 1 month was not observed in the LD flap and control groups. We believe that the effect of edema is more pronounced in relatively large flaps that do not contain muscles.

The limitations of the study include insufficient number of cases, unequal numbers of patients, measurement errors, and lack of long-term follow-up after 12 months. Therefore, we would like to accumulate more cases and report the results of long-term follow-up in future.

Conclusion

The volume of the LD flap decreased by at least 20% in the period between surgery and 6 months postoperation, whereas the volume of the DIEP flap increased by 10% 1 month after surgery and then decreased. Therefore, the increase in volume in the period between surgery and the first measurement should be taken into consideration when using previously reported volume changes in DIEP flaps as an indicator.

Authors' Contributions

U.H. and K.K. conceived and designed the analysis. U.H., T. R., A.S., and K.T. helped in data collection.
U.H. and K.T. contributed to data/analysis tools.
U.H. performed the analysis and wrote the article.

Ethical Approval

Institutional Review Board approval was not obtained for this noninvasive, retrospective study based on patients conducted using their medical records. The study followed the principles of the Declaration of Helsinki, and written informed consent was obtained from all patients.

Conflict of Interest

None declared.

Acknowledgments

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References

1 Chatterjee JS, Lee A, Anderson W, et al. Effect of postoperative radiotherapy on autologous deep inferior epigastric perforator flap volume after immediate breast reconstruction. Br J Surg 2009;96(10):1135–1140
2 Cho KJ, Joo YH, Sun DI, Kim MS. Perioperative clinical factors affecting volume changes of reconstructed flaps in head and neck cancer patients: free versus regional flaps. Eur Arch Otorhinolaryngol 2011;268(07):1061–1065
3 Fujioka M, Masuda K, Imamura Y. Fatty tissue atrophy of free flap used for head and neck reconstruction. Microsurgery 2011;31(01):32–35
4 Joo YH, Hwang SH, Sun DI, Park JO, Cho KJ, Kim MS. Assessment of volume changes of radial forearm free flaps in head and neck cancer: long-term results. Oral Oncol 2011;47(01):72–75
5 Yamaguchi K, Kimata Y, Onoda S, Mizukawa N, Onoda T. Quantitative analysis of free flap volume changes in head and neck reconstruction. Head Neck 2012;34(10):1403–1407
6 Sakamoto Y, Takahara T, Ota Y, et al. MRI analysis of chronological changes in free-flap volume in head and neck reconstruction by volumetry. Tokai J Exp Clin Med 2014;39(01):44–50
7 Sakamoto Y, Yanamoto S, Ota Y, Furudoi S, Komori T, Umeda M. Magnitude of myocutaneous flaps and factors associated with loss of volume in oral cancer reconstructive surgery. J Oral Maxillofac Surg 2016;74(03):644–649
8 Kimura M, Takada K, Ishibashi K, et al. Quantitative analysis of chronological changes in the volume of flaps used for reconstruction of oral cavity defects. J Oral Sci 2017;59(04):499–503
9 Wilting FNH, Hameeteman M, Tielemans HJP, Ulrich DJO, Hummelink S. "Three-dimensional evaluation of breast volume changes following autologous free flap breast reconstruction over six months". Breast 2020;50:85–94
10 Eder M, v Waldenfels F,Sichtermann M, et al. Three-dimensional evaluation of breast contour and volume changes following subpectoral augmentation mammaplasty over 6 months. J Plast Reconstr Aesthet Surg 2011;64(09):1152–1160
11 Kang CM, Shim JS, Park SH, Jeong YJ, Seol KH, Kwak SG. Volume change of muscle and fat portions of latissimus dorsi myocutaneous flap after breast reconstruction. Plast Reconstr Surg Glob Open 2021;9(04):e3536
12 Myung Y, Son Y, Nam TH, et al. Objective assessment of flap volume changes and aesthetic results after adjuvant radiation therapy in patients undergoing immediate autologous breast reconstruction. PLoS One 2018;13(05):e0197615
13 Bulstrode N, Bellamy E, Shrotria S. Breast volume assessment: comparing five different techniques. Breast 2001;10(02):117–123
14 Galdino GM, Nahabedian M, Chiaramonte M, Geng JZ, Klatsky S, Manson P. Clinical applications of three-dimensional photography in breast surgery. Plast Reconstr Surg 2002;110(01):58–70
15 Kovacs L, Eder M, Hollweck R, et al. Comparison between breast volume measurement using 3D surface imaging and classical techniques. Breast 2007;16(02):137–145
16 Szychta P, Raine C, Butterworth M, et al. Preoperative implant selection for two stage breast reconstruction with 3D imaging. Comput Biol Med 2014;44:136–143
17 Kojima Y, Kuroki T, Sasaki Y, et al. Comparative study of breast measurements using a 3D scanner and manual breast measurements using a drawing instrument. Showa Gakushikai J 2021;81:297–305
18 Henseler H, Kuznetsova A, Vogt P, Rosenhahn B. Validation of the Kinect device as a new portable imaging system for three-dimensional breast assessment. J Plast Reconstr Aesthet Surg 2014;67(04):483–488
19 Pöhlmann STL, Harkness E, Taylor CJ, Gandhi A, Astley SM. Preoperative implant selection for unilateral breast reconstruction using 3D imaging with the Microsoft Kinect sensor. J Plast Reconstr Aesthet Surg 2017;70(08):1059–1067
20 Greenhowe J, Stephen C, McClymont L, Munnoch DA. Breast oedema following free flap breast reconstruction. Breast 2017;34:73–76
21 Oashi K, Furukawa H, Akita S, et al. Vascularised fat flaps lose 44% of their weight 24 weeks after transplantation. J Plast Reconstr Aesthet Surg 2012;65(10):1403–1409

