Journal of Plastic, Reconstructive & Aesthetic Surgery 102 (2025) 231–237

Volume and patient satisfaction, 5 years of follow up after facial fat grafting

J.A.M. Schipper [a,*], A.J. Tuin [a], T.G.J. Loonen [b], P.U. Dijkstra [c,d], F.K.L. Spijkervet [a], R.H. Schepers [a,e], J. Jansma [a,e]

[a] *University Medical Center Groningen, Department of Oral and Maxillofacial Surgery, University of Groningen, Groningen, the Netherlands*
[b] *Radboudumc 3D-Lab, Department of Oral and Maxillofacial Surgery, Radboud University Medical Centre, Nijmegen, the Netherlands*
[c] *University of Groningen, University Medical Center Groningen, Department of Rehabilitation Medicine, Groningen, the Netherlands*
[d] *Sirindhorn School of Prosthetics and Orthotics, Faculty of Medicine, Siriraj Hospital, Mahidol University, 14 Arunamarin Road, Bangkoknoi, Bangkok 10700, Thailand*
[e] *Martini Hospital, Department of Oral and Maxillofacial Surgery, Groningen, the Netherlands*

Received 13 September 2024; Accepted 24 January 2025

KEYWORDS
Fat grafting;
Facial volume;
Long term;
Volume retention;
3D surface imaging

Summary *Background:* Autologous facial fat grafting is used to restore volume loss in the facial region. The volume retention after grafting is not stable over time.
Objectives: The aim of this study was to assess long-term visible volume retention measured with 3-dimensional surface imaging and long-term patient-reported satisfaction 5 years after facial fat grafting.
Methods: Twelve patients were included for 3-dimensional analysis and satisfaction measurements with 5 years of follow-up. Volume was measured with a validated automatic algorithm using three-dimensional surface imaging and patient satisfaction was recorded with the FACE-Q questionnaire.
Results: After 5 years, the face volume increase was associated with the weight gain of the person and not with the injected volume. Weight gain beta (95% confidence interval) = 1.40 (0.37; 2.42), p = 0.013. Injected volume beta (95% confidence interval) = 0.30 (−0.28; 0.88), p = 0.268. Satisfaction returned to pre-operative levels (facial appearance score pre-operative) median 45.0 (IQR 25.5; 47.3); after 5 years median 39.0 (IQR 28.0; 57.0).
Conclusion: After 5 years of facial fat grafting, volume retention was related to weight gain. Patient satisfaction returned to pre-operative levels. An increase in volume due to weight gain does not lead to increased patient satisfaction. Repeated fat grafting is necessary which will

* Correspondence to: Hanzeplein 1, 9713GZ Groningen, the Netherlands.
E-mail address: j.a.m.schipper@umcg.nl (J.A.M. Schipper).

https://doi.org/10.1016/j.bjps.2025.01.052

potentially increase satisfaction in the long term. Weight change as a confounder complicates long-term studies of volume retention.

Autologous facial fat grafting is a procedure used to restore volume loss in the facial region due to aging, congenital defects, or trauma.[1] It is a simple and safe method using adipose tissue obtained from liposuction of donor sites such as lower abdomen, hips, and thighs.[2] The volume retention after grafting decreases over time.[3–7] Follow-up of patients is often for the maximum duration of 1 year and graft volume is considered stable after this time point.[3] However, no objective evidence exists to support this.

After transplantation, fat graft survival depends on the diffusion of nutrients until the reconnection with donor vasculature occurs.[8] In this dynamic ischemia-reperfusion process, part of the graft does not survive and part of the graft regenerates from adipose-derived stromal cells to adipocytes.[7] Data about retained volume after grafting range considerably between 20% and 90% because variety exists in processing methods, donor variation, injection site, recipient tissue type, injected particle size, and measurement methods.[3] Differences in measurement methods can also explain variability in the results reported.[3]

Currently, the preferred imaging modality to measure visible volume retention objectively is 3-dimensional (3D) surface imaging, because subjective surgeon and patient-assessed volumes with grading scales are prone to information bias (observer bias and social desirability bias).[9] Computed tomography (CT) scanning involves ionizing radiation and magnetic resonance imaging (MRI) is time-consuming, which makes them less practical for follow-up, although these modalities have the advantage that subcutaneous tissue can be distinguished. Measurement methods to assess visible volume with 3D surface imaging should be objective, reproducible, and validated. In this study we used an objective and validated method to measure visible volume with an algorithm that matches an aesthetic template to the 3D scans of the patients, which delineates the face in certain areas.[10] Patient satisfaction is often measured by non-validated outcome measurement tools.[11] The FACE-Q questionnaire is a validated, patient-reported outcome measurement that assesses the overall appearance and specific sites of the face.[12–15]

This study aimed to assess long-term visible volume retention measured with 3D surface imaging and long-term patient-reported satisfaction 5 years after facial fat grafting.

Material and methods

This study was conducted in accordance with the principles of the Declaration of Helsinki and approved by the medical ethical review board of the University Medical Center Groningen (protocol no. NL51511.042.14). We performed an additional measurement of visible volume retention and patient satisfaction 5 years after inclusion in the study of the original study.[4]

Clinical trial design

A prospective cohort study was performed at the Department of Oral and Maxillofacial Surgery, University Medical Center Groningen, Groningen, the Netherlands between March 2015 and January 2019.[4] All female patients, older than 18 years, scheduled for a facial fat grafting procedure without any additional surgical procedure were asked to participate. Patients underwent the procedure either for aesthetic reasons or to restore a volume deficiency resulting from oncological ablative surgery or facial trauma. Exclusion criteria were pregnancy at the moment of the procedure, American Society of Anesthesiologists classification 3 or higher, use of anticoagulants that could not be stopped, other facial surgical procedures during the study, and a medical history of body dysmorphic disorder. At baseline, after 6 weeks, 6 months, 1 year and 5 years 3-dimensional photograph series were captured using the 3dMDtrio system (3dMD Inc., Atlanta, GA, USA) following a standardized clinical three-dimensional photograph protocol and the patient's height and body weight were measured.

Patient selection

Five years after inclusion in the study, patients were asked to participate in this follow-up study. Patients were included when they did not have had facial surgery, such as a facelift or osteotomy, cosmetic procedures, such as hyaluronic acid fillers, or additional fat grafting procedures in the last 5 years that could influence volume measurements in the regions of interest. During follow-up, patients were asked about their medical history and smoking habits in the past years. They were excluded from this study when they developed systemic diseases during follow-up.

Fat grafting procedure

Fat grafting was performed as described in the paper describing results after 1 year follow-up [4]. The fat grafting was performed under local or general anesthesia depending on the patient's preference. The donor site (abdomen, flank, thigh, or inner knee) was infiltrated with a tumescent solution (5 ml xylocaine 2% in 45 ml Ringers lactate). The adipose tissue was manually harvested under a negative pressure of 2 cc using a Sorensen cannula (Tulip Medical, San Diego, CA, USA). The harvested tissue was processed with

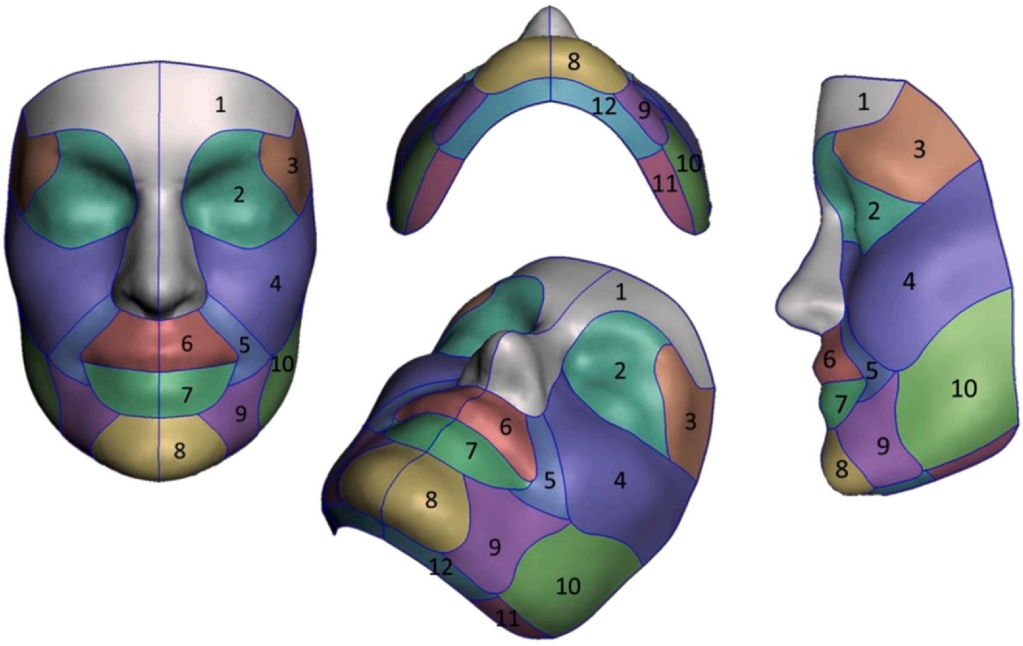

Figure 1 Automatic algorithm with predefined areas for volume calculation.

the PureGraft 50 closed wash system (Cytori, San Diego, CA, USA) according to the manufacturer's protocol. Processed adipose tissue was injected with a 0.9 mm blunt cannula (Tulip Medical, San Diego, CA, USA) in different subcutaneous layers (both deep and superficial). Data on the procedure, such as total harvested volume and injected volumes per aesthetic area, were collected.

Three-dimensional visible volume measurements

The most similar images compared with their initial three-dimensional photographs were selected for analysis. Scans were first registered by one observer using a T-shape on the forehead and nose (areas of the face that were not treated) using the iterative closest point algorithm in 3DMedX® software (v1.3.0.0, 3D Lab Radboudumc, Nijmegen, The Netherlands). Visible volume was then calculated by matching a template over the face according to a previously published protocol (Figure 1).[10] These measurements were valid and reproducible (root mean square errors < 1 mm [7]). To assess the inter-observer reliability of the registration process, one extra observer registered 3D data from 3 patients and volume measurements were repeated for these registrations. In the method we are using, only relative volumes or volume changes can be measured. No absolute volume is known of the pre-operative scan. It is technically impossible to calculate a volume from a single 3D surface scan since it is a surface. Volume changes are calculated by matching the surfaces of the post-operative time points to the pre-operative surface. Post-operative volume was measured directly post-operative, after 6 weeks, after 6 months, after 1 year and after 5 years.

Patient satisfaction

Patient satisfaction was measured using the FACE-Q questionnaire.[12-15] Patients were informed that these questionnaires were analyzed anonymously. The FACE-Q was sent through email and was filled in at home without the surgeon or researcher present. Rasch scores were then calculated from the FACE-Q scores according to the protocol of the FACE-Q editorial board.[15]

Statistical analysis

SPSS (IBM SPSS Statistics, IBM corporation 2023, 29.0.2.0) was used for statistical analyses. Descriptive statistics were calculated for baseline characteristics, visible volume and RASCH FACE-Q scores. Univariate linear regression was performed with weight change and injection volume as independent variables and visible volume at 5 years follow-up as dependent variable. Residuals were checked for a normal distribution. We used non-parametric tests after inspection of histograms of visible volume and FACE-Q scores. Differences between measured visible volume over time were tested with the non-parametric Friedman's 2-way ANOVA by ranks, multiple comparisons stepwise step-down. FACE-Q scores were tested with non-parametric testing using the Wilcoxon signed-rank test to compare the pre-operative score with the post-operative scores. Benjamini-Hochberg procedure was used to correct for multiple comparisons.

Results

Inclusion

Seventeen patients from the 29 patients of the original study were considered eligible for inclusion in this study on the 5-year follow-up, 14 were not suitable for inclusion (secondary fat grafting, n=7; facelift, n=2; pregnant, n=1; mandibular resection, n=1; hyaluronic acid fillers, n=1; multiple missing data, n=1; and 1 person died). 12 patients were included in the final analysis (Table 1).

Table 1 Baseline characteristics of participants (n=12) and details of fat grafting.

Characteristic	Descriptive statistics
Median age at baseline[a], yr	35.6 (27.3; 60.6)
Median length[a], cm	165.3 (167.5; 173.3)
Median weight at baseline[a], kg	62.0 (58.0; 69.3)
Median weight change after 5 years[a], kg	2.7 (1.3; 8.0)
Medication use, yes (n)	7
Psychological treatment (n)	
No	71
Yes, current treatment	1
Yes, in the past	4
Smoking, yes (n)	4
Menopause, yes (n)	6
Population (n)	
Aesthetic	5
Congenital disorders	1
Tumors and neoplasm	5
Trauma	1
Anesthesia	
Local	9
General	3
Harvest location[b]	
Abdomen	9
Knee	3
Flank	3
Hip	0
Thigh	1
Median total injected volume[a], cm^3 (n=12)	14.9 (11.7; 20.7)
Median injected volume in injected zygoma areas[a] (n=9)	11.0 (9.6; 15.3)
Injected volume in injected lips (n=1)	3.5

[a] Interquartile range are reported.
[b] In some patients, multiple harvest locations were used; After inspection of histograms, a skewed data distribution data was noted hence Med = Median.

Visible volume effect

The inter-observer reliability showed a mean difference of 1.5 ml between 2 observers with a standard deviation of 5.5 ml.

The overall visible volume (all sites n=12) and the visible volume in the zygoma region (n=9) decreased during the first year but then increased 5 years after inclusion (Table 2). The longitudinal development of visual volume is illustrated in Figure 2.

Simple linear regression analysis showed that body weight change was significantly associated with the volume of the face measured at 5-year follow-up (Table 3; Supplemental Figures 3, 4).

There was no significant difference in measured visible volume between the time points 5 years, 1 year and 6 months when compared to the measured visible volume after 6 weeks (Table 2). Since it is not possible to compare the absolute volume pre-operatively with the absolute volume of the follow-up points, we used the relative volume change at 6 weeks as a comparison for the follow-up points.

All patients experienced weight loss or weight gain more or less. One kg was the smallest weight gain. In this patient, there was 21 ml injected in the face and after 5 years was measured to be 1.3 ml increase in volume. In another patient with a 1.2 kg reduction of weight, 10 ml was injected in total and a volume loss of 3.7 ml was measured. When we look at the data, it seems that in the patients with the least amount of weight change, there was generally (almost) no volume difference compared to the pre-operative values.

Patient satisfaction

Social function was significantly better in the year after surgery compared with before. At 5 years follow-up the difference was not significant. Facial appearance, psychological well-being and satisfaction regarding the zygomatic region did not show differences (Table 4).

Discussion

In this prospective observational study, overall and zygomatic visible volume was measured with a follow-up of 5 years. Visible volume decreased during the first year after fat grafting but then increased after 5 years. This increase was associated with the increase in weight of the persons. Patient satisfaction was back at pre-operative levels after

Table 2 3D visible volume measurements.

	Full face, med ml (IQR) (n=13)	Zygoma, med ml (IQR) (n=9)	Lip (ml) (n=1)
Injected volume	14.0 (11.5; 17.7)	11.0 (9.55; 15.3)	3.5
Measured volume			
Post-op	11.9 (4.6; 15.2)	6.0 (1.6; 10.7)	1.1
6 weeks	−0.5 (−2.8; 6.3)	0.4 (−2.2; 4.5)	0.3
6 months	2.5 (−0.8; 7.2) p = 0.646	0.4 (−2.9; 5.4)	0.4
1 year	−0.4 (−4.2; 4.1) p = 0.209	0.3 (−3.3; 3.2)	−1.1
5 years	6.4 (0.22; 15.5) p = 0.117	6.7 (−0.9; 12.4)	−0.9

Tests were performed with the related samples Wilcoxon signed-rank test. The measured volume after 6 weeks was compared with the volume after 6 months, 1 year and after 5 years. med = median, IQR = interquartile range, ml = millilitres.

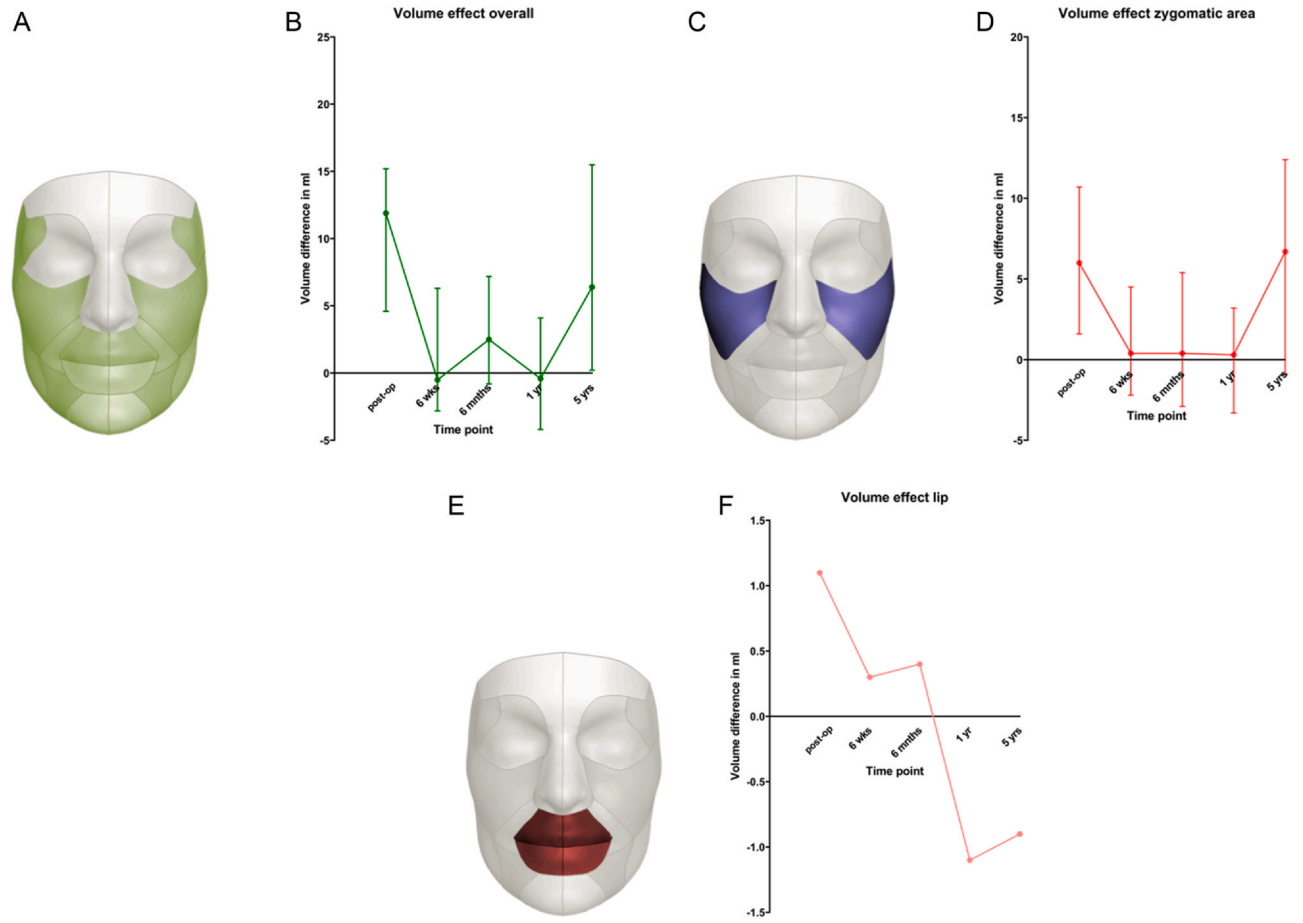

Figure 2 Volumetric changes over time. The figure shows the median of the measured visible volume with the interquartile range. The volume effect of the lip was only for one patient. Our data suggests that on average there was no volume increase after 6 weeks and 1 year for the overall effect.

Table 3 Regression analysis of measured visible volume with coefficients of injected volume and weight change.

Measured volume after 5 years	Coefficient (95% CI)	*p*
Full face		
Constant	−1.3 (−10.9; 8.4)	0.771
Injected volume	0.3 (−0.28; 0.88)	0.268
Weight change	1.4[a] (0.37; 2.42)	0.013

[a] Considered significant $p < 0.05$.

5 years. Repeated fat grafting procedures could therefore be necessary that will potentially increase patient satisfaction in the long term.

To the best of our knowledge, there is no literature published on long-term volume retention after facial fat grafting. In a meta-analysis of 27 studies, the maximum follow-up duration was 24 months and the retention rate varied from 26% to 83% measured with 3D surface imaging or CT scanning.[3] Volume is known to decrease during the first year after grafting.[16,17] Part of the graft dies, part regenerates and part survives.[7] However, compared with the temporary effects of hyaluronic acid fillers, facial fat grafting is often marketed as being permanent after 1 year.[18] In this study, measured visible volume increased after 5 years although not associated with injection volume and patient satisfaction was back at pre-operative levels. For the overall measured visible volume, this could be explained by an increase in body weight. However, visible increased volume due to weight change did not lead to increased patient satisfaction.

Body weight increase is a significant confounder to measuring objectively visible volume increase in the face. In our cohort, many patients increased in body weight considerably. Subtle weight changes are known to influence facial volume.[19] Our results were therefore influenced by these weight changes. Although weight increase over 5 years was similar in other studies of the general population, it influenced our results considerably.[20] In a study of obstructive sleep apnea, weight decreased by approximately 8 kg. The associated volume decrease measured with CT in the mid-and lower face was 8 cm^3 (or ml).[21] Those outcomes correspond to our results of the regression analysis: for every kg body weight change a change of 1.4 ml of facial visible volume was found. Also, in our validation study of the aesthetic template that we used, we already discovered that facial visible volume increased in volunteers with a weight change of 2 kg.[10] However, other factors can also influence facial volume during follow-up such as subcutaneous changes due to aging, facial expressions or skin disturbances.[22,23]

Table 4 3D visible volume measurements and FACE-Q score.

	Pre median (IQR)	6 wks median (IQR)	6 mnths median (IQR)	1 yr median (IQR)	5 yrs median (IQR)
Facial appearance	45.0 (25.5; 47.3) n=12	62.5 (46.0; 73.0) n=12	54.5 (46.0; 67.0) n=12	50.0 (37.0; 65.5) n=10	39.0 (28.0; 57.0) n=10
Psychological well-being	52.5 (45.0; 61.0) n=12	61.5 (49.0; 78.5) n=12	71.0 (41.8; 84.5) n=11	61.0 (47.5; 69.5) n=10	53.5 (52.0; 60.3) n=11
Social function	49.0 (37.8; 61.0) n=12	62.0 (43.0; 65.0)[a] n=11	62.0 (46.8; 90.5)[b] n=11	62.0 (48.3; 65.0)[c] n=10	49.0 (25.3; 60.3) n=11
Subgroups					
Zygomatic area	39.5 (22.5; 66.3) n=9	56.5 (35.0; 73.5) n=9	56.5 (36.3; 94.3) n=9	37.5 (35.0; 68.3) n=7	45.0 (18.5; 61.0) n=8
Lip area	53.0 n=1	64.0 n=1	47.0 n=1	50.0 n=1	42.0 n=1

After testing with the related samples Wilcoxon signed-rank test, critical p-values were calculated according to the Benjamini-Hochberg method. Values marked with a symbol were considered significantly different compared to the pre-operative FACE-Q value, other values were above the critical p-value.

[a] p = 0.035; crit-p = 0.0375.

[b] p = 0.017; crit-p = 0.025.

[c] p = 0.017; crit-p = 0.025.

Volume retention in current literature is often expressed as a percentage of the measured surface volumetric effect divided by the total injected volume. This definition suggests that the part of the graft that is not retained was resorbed or that part died. However, the injection volume is not equal to the surface visible volume *i.e.* surface projection effects but depends on localization and the quantity of the injection volume. The degree to which the injected volume leads to surface projection is also called the surface-volume coefficient (visible measured volume = surface projection divided by injection volume). A recent study showed that the surface-volume coefficient for the deep fat compartment of the medial cheek was 0.29 and for the suborbicularis oculi fat compartment was 0.95.[24] These numbers indicate that for the deep fat compartment of the medial cheek only 29% and for the suborbicularis oculi fat compartment approximately 95% of the injected volume can be measured as the surface-volume effect. We therefore chose to report the visible volume in ml compared with baseline and not in percentages. However, because injection volume is not equal to visible surface volume, we suggest that when percentages are used in literature, they should not be defined relative to the injection volume but to the measured volume after 6 weeks since this would better approximate the graft loss.

The measurement method is also a contributor to the variability of volume retention reported in the literature.[3] Often, non-validated and non-reproducible areas have been applied. We have used a registration method based on a T-shape on the forehead using the iterative closest point algorithm and then used a validated algorithm-based aesthetic template to calculate the volume in the areas of the face.[10] This procedure eliminates the possibility of manual selection of areas of interest that can vary per observer or patient. However, 3D surface imaging does not measure the volume of subcutaneous tissue but measures a surface and the difference between 2 surfaces then renders a visible volume difference. This difference completely depends on the correct registration of the images for a correct volume measurement, which influences volume measurements considerably.[25] Slight changes in muscle tension in the forehead (the area used for registration) could potentially influence registration quality.

Limitations

Our study has some limitations. We included patients for several indications such as congenital disorders, trauma, aesthetic, and oncological reasons. These different indications might have introduced variations in our results. However, in our previous study, indication did not affect measured visible volume.[4] Multiple injection sites and volumes were used in these patients, due to the variety of indications to undergo fat grafting which introduced heterogeneity in our data but despite this heterogeneity effects of weight change were found in this small sample size follow-up.

Conclusion

We have shown that long-term follow-up after fat grafting showed a visible volume increase related to body weight increase and patient satisfaction returned to baseline levels. The increase in volume did not lead to increased patient satisfaction. Future observational cohort studies should focus on improving sample size in homogeneous patient populations with fixed injection volumes.

The FACE-Q subgroups of zygomatic area and lip area are the components of the FACE-Q with specific questions on the perceived satisfaction with these anatomical areas. Only patients who were injected in that area were included in these subgroups.

Ethical approval statement

This study was conducted in accordance with the principles of the Declaration of Helsinki and approved by the medical

ethical review board of the University Medical Center Groningen (protocol no. NL51511.042.14).

Funding

None.

Conflict of interest

No conflicts of interest are declared by all authors.

Acknowledgements

None.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.bjps.2025.01.052.

References

1. Van Dongen JA, Van Boxtel J, Harmsen MC, Stevens HP. The development of facial lipofilling from a historical point of view. *Facial Plast Surg* 2019;**35**(4):358–67.
2. Gornitsky J, Viezel-Mathieu A, Alnaif N, Azzi AJ, Gilardino MS. A systematic review of the effectiveness and complications of fat grafting in the facial region. *JPRAS Open* 2019 Mar;**19**:87–97.
3. Lv Q, Li X, Qi Y, Gu Y, Liu Z, Ma GE. Volume retention after facial fat grafting and relevant factors: a systematic review and meta-analysis. *Aesthetic Plast Surg* 2021 Apr;**45**(2):506–20.
4. Tuin AJ, Schepers RH, Spijkervet FKL, Vissink A, Jansma J. Volumetric effect and patient satisfaction after facial fat grafting. *Plast Reconstr Surg* 2022;**150**(2):307e–18e.
5. Gerth DJ, King B, Rabach L, Glasgold RA, Glasgold MJ. Long-term volumetric retention of autologous fat grafting processed with closed-membrane filtration. *Aesthet Surg J* 2014;**34**(7):985–94.
6. PEER LA. Loss of weight and volume in human fat grafts: with postulation of a "cell survival theory. *Plast Reconstr Surg* 1950;**5**:217–30. Available from: ⟨https://journals.lww.com/plasreconsurg/fulltext/1950/03000/loss_of_weight_and_volume_in_human_fat_grafts_.2.aspx⟩.
7. Eto H, Kato H, Suga H, et al. The fate of adipocytes after non-vascularized fat grafting: evidence of early death and replacement of adipocytes. *Plast Reconstr Surg* 2012;**129**(5):1081–92.
8. Koh YJ, Koh BI, Kim H, et al. Stromal vascular fraction from adipose tissue forms profound vascular network through the dynamic reassembly of blood endothelial cells. *Arterioscler Thromb Vasc Biol* 2011;**31**(5):1141–50.
9. Herold C, Ueberreiter K, Busche MN, Vogt PM. Autologous fat transplantation: volumetric tools for estimation of volume survival. A systematic review. *Aesthet Plast Surg* 2013;**37**(2):380–7.
10. Tuin AJ, Meulstee JW, Loonen TGJ, et al. Three-dimensional facial volume analysis using algorithm-based personalized aesthetic templates. *Int J Oral Maxillofac Surg* 2020 Feb;**49**(10):1379–84.
11. Schipper JAM, Vriend L, Tuin AJ, et al. Supplementation of facial fat grafting to increase volume retention: a systematic review. *Aesthet Surg J* 2022 Dec;**42**(12):NP711–27.
12. Tuin AJ, van Dongen JA, van der Lei B, et al. Effect of age on satisfaction with facial appearance in women based on the FACE-Q questionnaire in a Dutch Normative Population. *Plast Reconstr Surg* 2021 Oct;**148**(4):679e–681ee.
13. Klassen AF, Cano SJ, Schwitzer JA, et al. Development and psychometric validation of the FACE-Q skin, lips, and facial rhytids appearance scales and adverse effects checklists for cosmetic procedures. *JAMA Dermatol* 2016 Apr;**152**(4):443–51.
14. Klassen AF, Cano SJ, Schwitzer JA, Scott AM, Pusic AL. FACE-Q scales for health-related quality of life, early life impact, satisfaction with outcomes, and decision to have treatment: development and validation. *Plast Reconstr Surg* 2015 Feb;**135**(2):375–86.
15. Pusic AL, Klassen AF, Scott AM, Cano SJ. Development and psychometric evaluation of the FACE-Q satisfaction with appearance scale: a new patient-reported outcome instrument for facial aesthetics patients. *Clin Plast Surg* 2013 Apr;**40**(2):249–60.
16. Shih L, Davis MJ, Winocour SJ. The science of fat grafting. *Semin Plast Surg* 2020 Feb;**34**(1):5–10.
17. Zielins ER, Brett EA, Longaker MT, Wan DC. Autologous fat grafting: the science behind the surgery. *Aesthet Surg J* 2016 Apr 1;**36**(4):488–96.
18. Tezel A, Fredrickson GH. The science of hyaluronic acid dermal fillers. *J Cosmet Laser Ther* 2008 Jan 1;**10**(1):35–42.
19. Re DE, Holzleitner IJ, Coetzee V, Tiddeman BP, Xiao DK, Perrett DI. Wie viel Gewicht liegt im Gesicht?: Wahrnehmungsschwellen für körpergewichtsassoziierte Veränderungen der dreidimensionalen Gesichtsform. *J Asthet Chir* 2013;**6**(3):141–6.
20. Colditz GA, Willett WC, Stampfer MJ, London SJ, Segal MR, Speizer FE. Patterns of weight change and their relation to diet in a cohort of healthy women. *Am J Clin Nutr* 1990;**51**(6):1100–5.
21. Sutherland K, Lee RWW, Phillips CL, Dungan G, Yee BJ, Magnussen JS, et al. Effect of weight loss on upper airway size and facial fat in men with obstructive sleep apnoea. *Thorax* 2011;**66**(9):797–803.
22. Boehm LM, Morgan A, Hettinger P, Matloub HS. Facial aging: a quantitative analysis of midface volume changes over 11 years. *Plast Reconstr Surg* 2021;**147**(2):319–27.
23. Rawlani R, Qureshi H, Rawlani V, Turin SY, Mustoe TA. Volumetric changes of the mid and lower face with animation and the standardization of three-dimensional facial imaging. *Plast Reconstr Surg* 2019;**143**(1):76–85.
24. Cotofana S, Koban KC, Konstantin F, Green JB, Etzel L, Giunta RE, et al. The surface-volume coefficient of the superficial and deep facial fat compartments: a cadaveric three-dimensional volumetric analysis. *Plast Reconstr Surg* 2019;**143**(6):1605–13.
25. Wang CL, Luan SS, Panayi AC, Xin MQ, Luan J. Methods used for evaluation of volume retention rate in autologous fat grafting for breast augmentation: a systematic review. *Chin Med J (Engl)* 2019;**132**(18):2223–8.