Facial aesthetic fat graft retention rates after filtration, centrifugation, or sedimentation processing techniques measured using three-dimensional surface imaging devices

Guan-Hui-Er Wang[1], Jian-Fang Zhao[2], Hong-Yu Xue[1], Dong Li[1]

[1]Department of Plastic and Reconstructive Surgery, Peking University Third Hospital, Peking University, Beijing 100191, China;
[2]Beijing University Health Science Center, Peking University, Beijing 100191, China.

Abstract

Objective: How to increase the long-term retention rate of autologous fat grafting has been widely discussed. This study aimed to evaluate long-term fat graft retention rates for the most widely used fat processing methods in the area of facial esthetic surgery, including centrifugation, filtration, and sedimentation, using three-dimensional (3D) imaging.

Data Sources: PubMed, Embase, Wiley/Cochrane Library, and Web of Science databases were comprehensively searched from inception to July 2018 according to the guidelines of the American Society of Plastic Surgeons Fat Graft Task Force Assessment Methodology.

Study Selection: Articles were screened using predetermined inclusion and exclusion criteria. Data collected included patient characteristics, follow-up devices, fat grafting techniques, and clinical outcomes. Patient cohorts were pooled, and fat graft retention rates were calculated. Complications were summarized according to different clinical characteristics.

Results: Of 77 articles, 10 clinical studies met the inclusion criteria and reported quantified measurement outcomes with 3D imaging which provide precise volumetric data with approximately 2% standard deviation compared to real volumes. Data of 515 patients were included. Fat grafting retention varied from 21% to 82%. We found filtration and centrifugation techniques could result in better retention outcomes. However, retention varied within each processing technique, with no significant difference among the 3 techniques. Twenty-two complications were reported among 515 patients, including donor-site hematoma (1 case), mild post-operative erythema (2 cases), mild volumetric asymmetries (2 cases), chronic edema (2 cases), overcorrection (2 cases), skin irregularity (6 cases), and headache or dysesthesia (7 cases).

Conclusions: Filtration and centrifugation techniques may result in better fat grafting retention outcomes than gravity sedimentation; however, more accurate statistical evidence is needed. Controversies continue to exist with respect to the performance of the different fat-processing techniques in fat graft retention.

Keywords: Autologous fat grafting; fat retention rate; filtration; centrifugation; sedimentation

Introduction

Autologous fat transfer was first attempted by Neuber in the 1890s followed by Lexer in the 1900s, both of whom used adipose tissue to treat facial deformities.[1,2] In the 1950s, Peer first calculated the resorption rate of transplanted autologous fat 1 year after surgery.[3] Since then, the retention rate of autologous fat grafts has always been closely monitored. In 1983, Illouz successfully injected aspirated fat that was harvested by a suction technique.[4] Over the subsequent 3 decades, surgeons continued to optimize techniques to improve the viability and longevity of fat grafting. Currently, fat grafting is used for facial contouring, breast augmentation, breast reconstruction, repair of radiation damage, and treatment of post-traumatic deformities, congenital anomalies, and burn injuries.[5–11]

Although the techniques of harvesting, processing, and injecting autologous fat have been developed and modified, the long-term retention of grafted material has been highly variable in different reports. Factors that may have led to this variability remain uncertain; however, surgeons believe that this variability may have resulted in a lack of

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Guan-Hui-Er Wang and Jian-Fang Zhao contributed equally to this work.

Correspondence to: Prof. Dong Li, Department of Plastic and Reconstructive Surgery, Peking University Third Hospital, Peking University, Beijing 100191, China
E-Mail: lidong9@sina.com

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procedural standardization, specifically with respect to the fat processing methods after fat harvesting.[9,12] The main methods for fat processing are simple decantation, cotton gauze rolling, filtration, and centrifugation.[9,13,14] The detailed procedures for each of these processing methods have been different among different surgeons and reports.

Three-dimensional (3D) surface analysis systems can provide precise and exact volume analyses with rapid data acquisition while patients are in the standing position.[15] The ability to perform this test repeatedly and with relative ease makes it more practical to use than computed tomography (CT) and magnetic resonance imaging (MRI) for patients that require frequent clinical follow-up.[16] Hence, the 3D surface analysis method has been commonly used in volumetric studies in recent years. Of the many authors who have used 3D surface analysis systems to follow surgical-site volumetric changes, some have collected abundant data on volume and fat graft retention changes in long-term follow-up. Many clinical trials have been designed and published comparing the outcomes of different surgical techniques in the collection, processing, and injection of fat, as measured by 3D surface analysis systems.

According to our retrieval, no systematic review has been published that report the use of a unified measuring device to explore whether 1 fat processing technique is superior at contributing to better fat graft survival outcomes.

In this review, we sought to evaluate the long-term fat graft retention rates of the most widely used fat processing methods, including centrifugation, filtration, and sedimentation in the area of facial esthetic surgery. By selecting and reviewing the related articles and clinical trials that used 3D surface analysis systems for volumetric measurement, we hope to clarify the optimal methods for processing autologous fat grafts.

Methods

Study design

This was a systematic review of the literature to report on the post-harvest fat graft processing methods in facial esthetic surgery and the efficiency of these procedures as represented by fat graft retention rates. This study was conducted according to the PRISMA guidelines. The PubMed, Embase.com, Wiley/Cochrane Library, and Web of Science databases were searched from inception (by Wang GHE and Zhao JF) to the final screening on July 2018. The following terms were used (including synonyms and closely related words) as index terms or free-text words: “fat” or “adipocyte” or “lipo” and “grafting” or “filling” or “transplant” and “three dimensional” or “3D” and “face.” Articles were restricted to those written in English and Chinese. The 2 reviewers mentioned above independently screened the titles, keywords, and abstracts of the retrieved records. Articles were included if they reported on volumetric measurements of autologous fat grafting (AFG; including detailed fat graft retention data) in facial esthetic surgery using 3D surface analysis systems.

Inclusion and exclusion criteria

The inclusion criteria were: (1) articles reporting on adult patients that received facial fat grafting for esthetic purposes; (2) articles in which the researchers used 3D surface analysis systems to evaluate the volumetric measurements and fat graft retention rate during follow-up; (3) articles that reported follow-up periods of at least 3 months; (4) explicit data including injection volumes and fat graft retention rates were reported; (5) prospective and retrospective clinical trials, observational studies, and case series with sample sizes larger than 10; and (6) trials or case series including normal-sized fat grafts without cell-assisted lipo-transfer (CAL).

The exclusion criteria were: (1) review articles and animal studies; (2) articles that studied fat graft retention for purposes other than esthetics (eg, trauma, scars, congenital disorders); (3) articles that used ultrasound, CT, or MRI for volumetric measurements; and (4) articles that reported follow-up periods of <3 months.

Results

Using the search terms described above, 77 publications were identified in total. After applying the inclusion and exclusion criteria, 10 studies[17–26] on 515 patients that reported volumetric outcomes and fat graft retention rates met the standard for this review [Figure 1]. The sample sizes ranged from 13 to 96 patients per article. The data extracted from clinical articles included patient characteristics (average age and sample size), fat grafting techniques (donor site, harvesting technique, fat-processing technique, fat injection technique, recipient site, and fat injection volume), and clinical outcomes (follow-up time, measurement technique, fat volume change, fat retention rate, and complications). Articles were reviewed manually for patient characteristics, follow-up devices, fat grafting techniques, and clinical outcomes. The data of patient characteristics and fat grafting techniques in each article are shown in Table 1. The most commonly used donor sites were the abdomen and thigh. The most commonly used fat grafting technique was Coleman technique, with multiple holes and blunt cannulae used for harvesting, and blunt cannulae used for injection. Most surgeons chose to inject into multiple planes or into multiple fat compartments.

Fat grafting retention in the 3 fat-processing techniques

According to the 10 clinical studies in this article, the average injected volume varied from 1.7 to 35.0 mL. For patients who received a partial augmentation of the chin,[24] nasal dorsum,[20] or cheek,[19,21] the injected volumes were relatively small, commonly <10 mL. For patients who received augmentation of multiple facial subunits,[22,23] the injected volumes were relatively large, commonly from 20 to 35 mL.

In all, the fat grafting retention rates varied from 21.0% to 82.3% with 3- to 36-month follow-up periods. Among these articles, some studies[17,20–25] were designed to collect follow-up data at unified time points, commonly 3, 6, and/or 12 months. For these studies, we tried to list

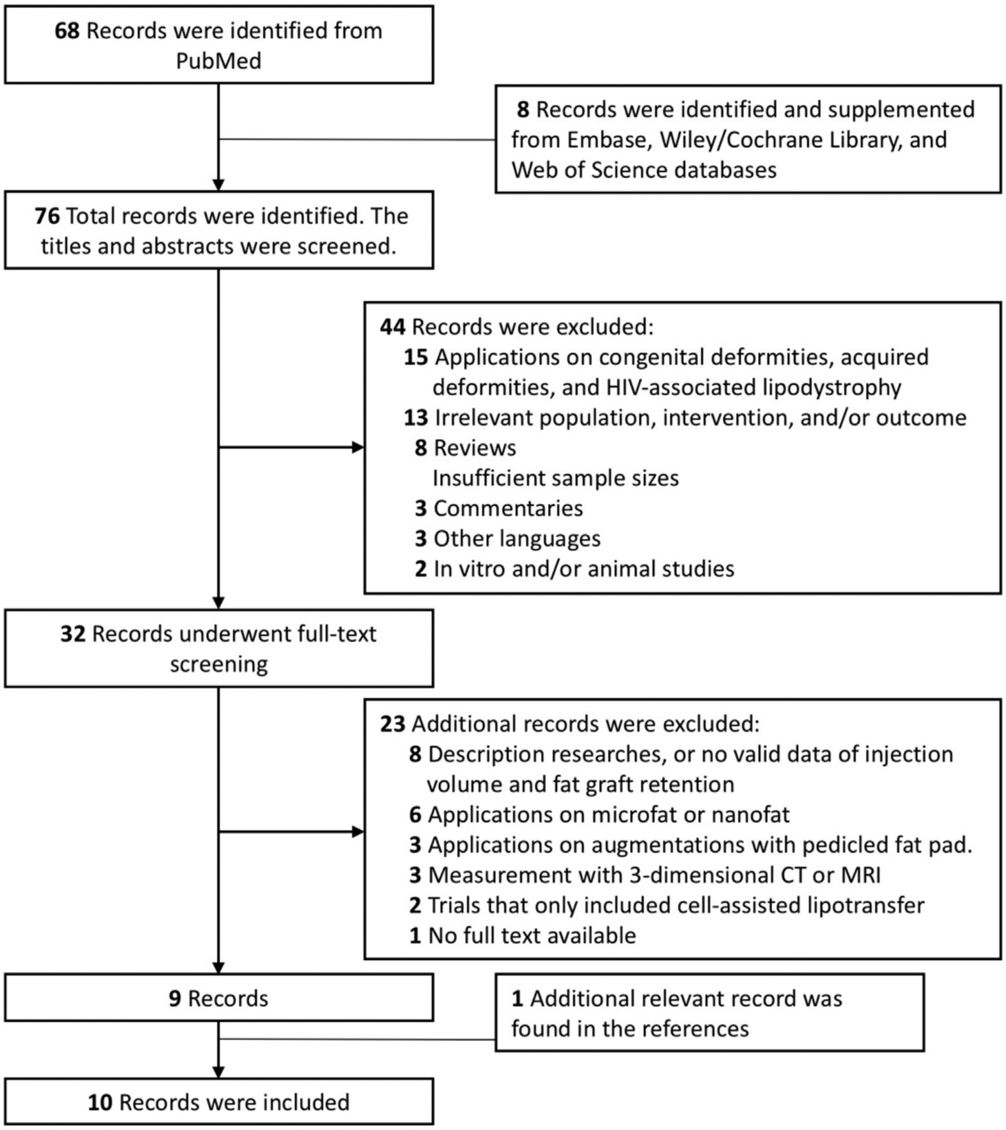

Figure 1: Flow chart of the study. CT: computed tomography; HIV: human immunodeficiency virus; MRI: magnetic resonance imaging.

the measurement data of the unified points of time to better analyze the fat grafting retention rates among the different fat-processing techniques. Other studies[18,19,26] were designed to collect follow-up data at the latest follow-up time point (which did not occur at the same time), and we recorded the related fat grafting retention rates in these cases as well. Detailed information on the volumetric measurement outcomes is shown in Table 2. Two randomized controlled trials gave convincing evidence as to the priority of fat-processing techniques. Wu *et al*[22] reported the volumetric outcomes of facial AFG using the centrifugation processing technique with cotton pad filtration and sedimentation. Their data showed that fat grafts processed by cotton pad filtration had significantly higher retention rates compared to the centrifugation and sedimentation methods at 3, 6, and 12 months follow-up. An[23] reported the volumetric outcomes of facial AFG using the filtration and sedimentation processing techniques. Their data showed that fat grafts processed by filtration had a better retention rate than those processed by sedimentation, but the result was not statistically significant. Huang *et al*[25] reported an average fat grafting retention rate of 65.7% using the centrifugation processing technique in temporal augmentation. In their research, an average of 1.5 procedures was performed per temple, and the retention of the last procedure was calculated, which might explain why the retention rate in this study was higher than the rate that is commonly reported. Basile *et al*[24] compared the total volume of the chin pre- and post-operatively to estimate the "remaining volume." This calculation method could result in a larger retention rate compared to the result obtained based on our commonly used calculation. Apart from the studies of Huang *et al* and Basile *et al*, the retention rates varied from 20% to 50% among the 3 processing techniques reported in the other 8 studies. Our average retention rates at the 3-, 6-, and(or) 12-month follow-up points, and the average retention rates at the latest follow-up points in other studies with

Table 1: Detailed data of patient characteristics and fat grafting techniques in each article

Year	Author	Country/region	Sample size, *n*	Age (years), mean ± SD	Measurement device	Donor site	Harvesting technique	Fat-processing technique	Assisted factors or cells	Fat injection technique	Recipient site
2009	Meier *et al*[18]	USA	33	54 (39–70)	Vectra 3D	Abdomen, thigh	3-mm bullet-tip blunt cannulas	Centrifugation (3000 rpm, 3 min)	None	Tulip blunt cannulas, injected in multiple planes	Multiple subunits of the face
2014	Gerth *et al*[19]	USA	26	55 ± 11	Vectra 3D	Abdomen, thigh	3-mm keel type	Filtration: Puregraft processing bag	None	Tulip blunt cannula, injected in subcutaneous plane (cheek) or suborbicularis plane	Cheek and periorbital area
2015	Sasaki *et al*[21]	USA	92	60.5 (58–63)	Artec 3D	Hip, abdomen	3–4 mm blunt tip Mercedes cannula	Centrifugation (3000 rpm, 3 min)	None	Blunt 1.3 mm cannula, injected in deep medial cheek fat, medial suborbicularis fat, lateral suborbicularis fat, superficial nasolabial fat, and superficial medial fat	Cheek
2016	Zhu *et al*[17]	China	22	39.50 ± 8.67	3D-Konica Minolta Vivid 910	Lower body	2.5-mm 2 holes cannula, with low-pressure aspiration	Centrifugation (1000 rpm, 2 min)	None	Blunt cannula, injected in multiple planes	Multiple subunits of the face
2017	Basile *et al*[24]	Brazil	42	28 (19–50)	Fiji package of ImageJ	Abdomen	2-mm blunt cannula	Sedimentation	None	Blunt 2 mm cannula, injected in supraperiosteal (subcutaneous) plane	Chin
2017	Lin *et al*[20]	Taiwan, China	13	34.03 ± 7.28	3dMD System	abdomen	2.5-3 mm blunt one whole cannula	Centrifugation (3000 rpm, 3 min)	None	Blunt 18-G cannula, with MAFT-GUN, injected in multiple planes	Nasal dorsum

(*continued*)

Table 1
(continued).

Year	Author	Country/region	Sample size, *n*	Age (years), mean ± SD	Measurement device	Donor site	Harvesting technique	Fat-processing technique	Assisted factors or cells	Fat injection technique	Recipient site
2017	Wang *et al*[26]	China, Germany	78	35.1 ± 11.2	Konica Minolta Vivid 910	Abdomen, thigh	16-G cannula	Centrifugation (3000 rpm, 3 min)	None	18-G cannula, injected in multiple planes	Cheek
2017	An *et al*[23]	China	24	33.6 ± 10.0	Vectra 3D	Abdomen, thigh	2–3 mm 1-hole blunt tip cannula	Filtration	None	Not mentioned	Multiple subunits of the face
			26	30.8 ± 9.0				sedimentation			
2018	Huang *et al*[25]	China	96	34.4 ± 7.4	Konica Minolta Vivid 910	Abdomen, thigh	2-holed blunt-tip cannula	Centrifugation (500 rpm, 3 min)	None	Single-holed blunt tip cannula, injected in the upper temporal compartment, the lower temporal compartment, the lateral temporal-cheek fat compartment, and the lateral orbital fat compartment.	Temporal region
2018	Wu *et al*[22]	China	21	22.0 ± 8.0	Artec 3D	Lower abdomen	2.5 mm blunt cannula	centrifugation, (1000 rpm, 3 min)	None	Not mentioned	Multiple subunits of the face
			21	22.0 ± 8.1				cotton pad filtering			
			21	22.0 ± 8.2				Sedimentation			

3D: three-dimensional; SD: standard deviation.

Table 2: Detailed data of volumetric outcomes in each article

Year	Author	Country/region	Sample size, *n*	Fat process-ing technique	Follow-up point of time	Follow-up time (months)	Injected volume (mL), mean ± SD	Maintained volume in the latest follow-up (mL), mean ± SD	Fat grafting retention at 3 months (%), mean ± SD	Fat grafting retention at 6 months (%), mean ± SD	Fat grafting retention at 12 months (%), mean ± SD	Fat grafting retention in the latest follow-up period (%), mean ± SD
2018	Wu *et al*[22]	China	21	Centrifugation	Unified	12	25.29 ± 7.57	–	38 ± 4	36 ± 4	34 ± 3	–
2016	Zhu *et al*[17]	China	22	Centrifugation	Unified	12	18.00 ± 12.68	7.97 ± 4.57	61.08 ± 9.85	49.06 ± 7.27	44.53 ± 6.32	–
2015	Sasaki *et al*[21]	USA	92	Centrifugation	Unified	12	8.5 ± 1.0	–	51.9 ± 10.0	46.3 ± 8.5	38.3 ± 12.9	–
2018	Huang *et al*[25]	China	96	Centrifugation	Unified	12	17.8 ± 7.5	11.7 ± 3.0	–	–	65.7 ± 12.6	–
2017	Lin *et al*[20]	Taiwan, China	13	Centrifugation	Unified	3	1.67 ± 0.95	0.74 ± 0.42	44.54 ± 15.13	–	–	–
2009	Meier *et al*[18]	USA	33	Centrifugation	Latest	12–21	10.18 ± 4.31	–	–	–	–	31.79 ± 20.28
2017	Wang *et al*[26]	China, Germany	78	Centrifugation	Latest	12–27	29.3 ± 9.7	–	–	–	–	27.1 ± 3.6
2018	Wu *et al*[22]	China	21	Filtration: cotton pad	Unified	12	22.40 ± 15.67	–	45 ± 3	43 ± 3	41 ± 3	–
2017	An *et al*[23]	China	24	Filtration: cotton pad	Unified	12	20.3 ± 16.0	–	36.9 ± 13.2	30.8 ± 10.6	26.1 ± 9.1	–
2014	Gerth *et al*[19]	USA	26	Filtration: Puregraft processing bag	Latest	10–36	8.88 ± 3.78	3.71 ± 2.64	–	–	–	41.2 ± 24.4
2018	Wu *et al*[22]	China	21	Sedimentation	Unified	12	34.38 ± 10.80	–	34 ± 4	31 ± 3	31 ± 3	–
2017	An *et al*[23]	China	26	Sedimentation	Unified	12	35.0 ± 28.3	–	34.1 ± 13.3	26.7 ± 9.6	21.0 ± 2.8	–
2017	Basile *et al*[24]	Brazil	42	Sedimentation	Unified	6	7.5 ± 1.3	–	–	82.3 ± 11.60	–	–

–: not applicable; SD: standard deviation.

respect to each of the 3 fat-processing techniques, are shown in Figure 2. We found a trend showing that the filtration and centrifugation techniques may result in better retention outcomes. However, the retention outcomes varied remarkably within the same processing techniques and we could not find a significant difference among these techniques.

Complications of facial autologous fat grafting

Four studies reported multiple complications, while 3 reports showed no complications and 3 reports did not mention complications at all. These complications reported in the 4 studies included donor-site hematoma (in 1 patient),[19] mild post-operative erythema (in 2 patients),[24] mild volumetric asymmetries (in 2 patients),[21] chronic edema (in 2 patients),[25] overcorrection (in 2 patients),[25] skin irregularity (in 6 patients),[24,25] and headache or dysesthesia (in 7 patients).[25]

Discussion

Three-dimensional surface imaging devices

Three-dimensional surface imaging devices can create a virtual 3D model of the face, breasts, and body contour in a standing patient and can simulate the post-augmentation appearance and calculate desired augmentation volumes.[27] Studies have shown that the standard deviation of volume measurements in 3D imaging is approximately 2% compared to the real volumes.[27–29] This finding revealed good accuracy and reproducibility in volume measurements. There are several commonly used 3D surface imaging systems in the marketplace: the Axis3 (AX3 Technologies LLC, Miami, FL), the 3dMD (3dMD LLC, Atlanta, GA), and the Vectra (Canfield, Parsippany, NJ). These systems require an operator capable of clinical judgment. A not yet commercially available system called Precision Light presented by Creasman *et al* is able to automatically recognize anatomical landmarks. It can measure linear, contour, and volume parameters in the breasts. The reproducibility of its measurements is very high, with a reliability of 99.6%.[30] This mechanism of combining 3D systems with automation is considered 4-dimensional technology, which can reduce operator/evaluator subjectivity and function at higher speed, thus improving the experience of clinical users.[31]

Although the 3D imaging systems are relatively costly,[29] the analysis of their output is free, non-invasive, and harmless to the human body. These systems can build simulations of post-operative imaging outcomes and assist the surgeons and patients in reaching an agreement as to the desired augmentation volumes.[27] Precise reports of fat grafting retention rates could be used to evaluate the efficiency of certain fat grafting techniques and develop accurate designs of post-operative outcomes. Currently, surgeons attempt to inject larger volumes of fat in grafts, considering the long-term survival issues. Through more accurate and reasonable data on fat graft retention, predicting excessive injection volumes could achieve more precise and personal results. One systematic review concluded that the volume of injected fat into each facial

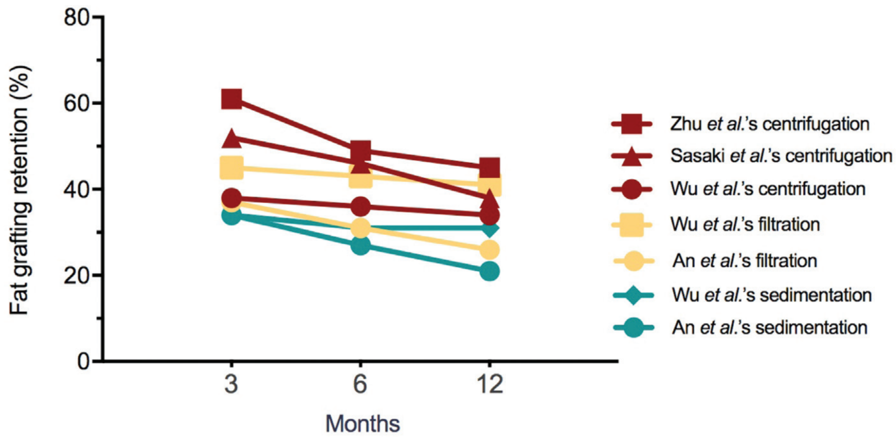

Figure 2: The average retention rate for the different follow-up periods for each of the 3 fat-processing techniques in studies with unified follow-up periods. The average retention rates for centrifugation, filtration, and sedimentation methods in studies with unified follow-up periods are shown in red, yellow, and green, respectively. The average retention is recorded for "3, 6, and (or) 12 months". Three studies used the last follow-up point >12 months. The average retention is 41.2% in Gerth *et al*'s filtration, 31.8% in Meier *et al*'s centrifugation, and 27.1% in Wang *et al*'s centrifugation, respectively. Lin *et al*'s centrifugation used the last follow-up point at 3 months, and the average retention is 44.5% in this study.

subunit is currently limited but widely variable based on the different methods and anatomical terms used.[32] The retention rates in the different facial subunits could be quite different. However, relative data are insufficient, and thus we look forward to further studies.

Controversial factors relevant to autologous fat survival

Many factors have been considered relevant to the long-term retention of autologous fat. Studies have evaluated the impact of harvesting methods on fat graft retention rates, including hand-held syringe aspiration,[33–35] suction-assisted lipectomy,[33–36] and ultrasound-assisted lipectomy.[36,37] These studies demonstrated differences in cell survival and adipocyte functionality among *in vivo* animal experiments and human studies. However, no significant differences in the volume or weight of the fat grafts isolated by the different methods were observed in a study of immunocompromised mice.[12] Surgeons now seem to agree that the actual harvesting methods are less important, as fat survival has been comparable among the different harvesting methods.[38]

In recent years, adipocyte-derived stem cells, platelet-rich plasma (PRP), and stromal vascular fraction (SVF) have been widely used for both therapeutic and esthetic indications because of their capacity for angiogenesis and wound healing.[39] Many studies have investigated the effects of cell-assisted fat grafting on increasing fat survival. Sasaki *et al*[21] reported a prospective study of 236 patients in 4 groups using conventional fat grafting, PRP-assisted fat grafting, SVF-assisted fat grafting, and PRP/SVF-assisted fat grafting. This study showed that PRP, SVF, and PRP/SVF cell assistance of processed fat resulted in a statistically significant mean graft retention rate (68.5%, 72.9%, and 69.7%, respectively) over their baseline control at 12 months compared to conventional fat grafting methods (38.3%).

In the last 2 years (2016–2018), 3 systematic reviews and meta-analyses have yielded statistical evidence of the effect of increasing fat grafting retention rates in cell-assisted fat grafting techniques. In Zhou *et al*'s review,[40] the pooled fat survival rate was significantly higher ($P = 0.0096$) in the CAL group (60%) than in the non-cell-assisted lipotransfer (non-CAL) group (45%). In Laloze *et al*'s review,[41] the fat survival rate was significantly higher ($P < 0.0001$) in the CAL group (64%) than in the non-CAL group (44%), independent of injection site (breast or face). In Wang and Wu's review,[42] the fat survival rate was significantly higher in the CAL group than in the non-CAL group, with a weighted mean difference of 25.85%, ($P = 0.013$). All of these studies revealed that CAL can result in superior fat survival rates compared to conventional lipoinjection.

Studies have also investigated the impact of fat-processing techniques. According to an American national consensus survey, 34% of plastic surgeons used centrifugation as a processing technique for fat grafting, 45% used gravity sedimentation, 34% used filtration, and 11% used gauze rolling.[43–46] In the latest animal studies, no significant difference was found in the structure or weight of the fat graft when comparing centrifugation, filtration, and sedimentation methods.[12,47–49] Another study showed better outcomes in terms of fullness and smoothness with centrifugation than with gravity sedimentation.[44] Recently, in a randomized controlled trial of cotton pad filtration, centrifugation, and gravity sedimentation, the authors showed that cotton pad filtration demonstrated the highest fat graft retention rate, and this result was statistically significant.[22] Another randomized controlled trial of filtration and gravity sedimentation showed that there was no statistically significant difference between these 2 techniques. However, there was a trend showing better performance of filtration in fat survival.[23]

Our study has 2 primary limitations. In this updated systematic review, we concentrated on fat survival only in facial esthetic AFG measured with the 3D surface imaging technique. This was done to try to restrict bias and come to a convincing conclusion. Additionally, until now, the number of relative clinical trials and cases has not been adequate to make a strong comparison through a meta-analysis. To explore more convincing database evidence on this topic would require additional randomized controlled trials and multiple center trials with large samples to be conducted.

In this review, we observed a trend showing that filtration and centrifugation techniques might result in better fat grafting retention outcomes than gravity sedimentation, but more accurate statistical evidence is still needed. Controversies continue to exist regarding the performance of the different fat-processing techniques in fat graft retention. With the development of 3D measurement techniques, additional clinical trials with sufficient sample sizes and accurate volumetric measurements are necessary to identify the optimal technique for fat graft processing.

Conclusion

This article presents a systematic review of 10 studies on 3 different fat-processing techniques, wherein the fat graft retention rates were measured using 3D imaging devices. We found that there was a trend toward filtration and centrifugation techniques resulting in better retention outcomes. However, there was a wide variation with respect to the retention outcomes within each single processing technique, and we could not find a significant difference among these 3 techniques.

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Conflict of interest

The authors report no conflict of interest.

Author contributions

Wang GHE: conception and design, collection and assembly of data, data analysis and interpretation, manuscript writing, manuscript revising. Zhao JF: conception, collection and assembly of data, manuscript writing, manuscript revising. Xue HY: manuscript revising, interpretation. Li D: conception and design, interpretation, provision of study.

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