Aesth Plast Surg (2018) 42:1261–1270
https://doi.org/10.1007/s00266-017-0936-6

REVIEW FACE AND NECK SURGERY

Fat Injection: A Systematic Review of Injection Volumes by Facial Subunit

Shirley Shue[1] · David E. Kurlander[1] · Bahman Guyuron[1]

Received: 24 February 2017 / Accepted: 24 June 2017 / Published online: 8 August 2017

Abstract

Background Fat grafting to the aging face has become an integral component of esthetic surgery. However, the amount of fat to inject to each area of the face is not standardized and has been based mainly on the surgeon's experience. The purpose of this study was to perform a systematic review of injected fat volume to different facial zones.

Methods A systematic review of the literature was performed through a MEDLINE search using keywords "facial," "fat grafting," "lipofilling," "Coleman technique," "autologous fat transfer," and "structural fat grafting." Articles were then sorted by facial subunit and analyzed for: author(s), year of publication, study design, sample size, donor site, fat preparation technique, average and range of volume injected, time to follow-up, percentage of volume retention, and complications. Descriptive statistics were performed.

Results Nineteen articles involving a total of 510 patients were included. Rhytidectomy was the most common procedure performed concurrently with fat injection. The mean volume of fat injected to the forehead is 6.5 mL (range 4.0–10.0 mL); to the glabellar region 1.4 mL (range 1.0–4.0 mL); to the temple 5.9 mL per side (range 2.0–10.0 mL); to the eyebrow 5.5 mL per side; to the upper eyelid 1.7 mL per side (range 1.5–2.5 mL); to the tear trough 0.65 mL per side (range 0.3–1.0 mL); to the infraorbital area (infraorbital rim to lower lid/cheek junction) 1.4 mL per side (range 0.9–3.0 mL); to the midface 1.4 mL per side (range 1.0–4.0 mL); to the nasolabial fold 2.8 mL per side (range 1.0–7.5 mL); to the mandibular area 11.5 mL per side (range 4.0–27.0 mL); and to the chin 6.7 mL (range 1.0–20.0 mL).

Conclusions Data on exactly how much fat to inject to each area of the face in facial fat grafting are currently limited and vary widely based on different methods and anatomical terms used. This review offers the ranges and the averages for the injected volume in each zone.

Level of Evidence III This journal requires that authors assign a level of evidence to each article. For a full description of these Evidence-Based Medicine ratings please refer to the Table of Contents or the online Instructions to Authors www.springer.com/00266.

Keywords Facial fat grafting · Lipofilling · Micro-fat filling

Introduction

The importance of volume changes in an aging face is well recognized, and autologous facial fat grafting is being used with increasing popularity. While facial rhytidectomy techniques may improve soft tissue descent and deep creases on the face, these procedures do not address the underlying volume loss that occurs due to senile fat atrophy thoroughly. Since the introduction of Coleman's fat grafting technique [1], volumetric restoration using autologous fat has become an integral part of rejuvenation. The technique is simple and largely safe.

However, autologous fat grafting can produce variable results, and objective, credible evaluation of volume replacement therapy is still lacking. The amount of fat to be injected to each facial compartment is typically based on surgeon's experience rather than based on scientific data.

✉ Bahman Guyuron
bahman.guyuron@gmail.com

[1] Case Western Reserve University School of Medicine, 29017 Cedar Road, Cleveland, OH 44125, USA

Success of intervention has traditionally relied on patient satisfaction rather than quantitative analysis of volume change. Scant data exist on the retention of fat volume in a clinical setting [2].

The volume of fat to inject in each facial compartment during autologous fat grafting remains poorly standardized, leading to unsatisfactory results in some patients and a slow learning course. Here we systematically review the literature to elucidate volumes of fat injected in each facial subunit.

Materials and Methods

Study Design

We conducted a systematic literature review to assess the volume injected to each area of the face for volumetric rejuvenation. We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) protocol and performed a MEDLINE database search via PubMed in November–December 2016 using the keywords "facial," "fat grafting," "lipofilling," "Coleman technique," "autologous fat transfer," and "structural fat grafting." We also reviewed the references of retrieved articles to search for other potentially relevant research articles.

Inclusion Criteria

All relevant articles in which study participants received facial fat grafting for aging were reviewed. We included prospective and retrospective observational studies, case series, and case reports. We excluded review articles, animal studies, articles written in languages other than English, and articles that studied fat grafting for purposes other than aging (e.g., trauma, scars, congenital disorders). We also excluded articles not reporting volumes of fat injected (in mL) and not reporting the facial subunits injected.

Data Collection

Two independent reviewers read the titles and abstracts of retrieved articles. The full text was retrieved. The following data points were recorded: author(s), year of publication, study design, sample size, donor site, fat injection technique, average and range of volume injected, duration of follow-up, percentage of volume retention, and complications.

Results

A total of 2145 articles were initially identified by our MEDLINE search, and 19 articles with 510 patients were included in this systematic review (Fig. 1). The types of articles included case reports [3], case series [1, 4, 5], prospective studies [2, 6–13], retrospective studies [14–18], and observational studies [19]. The sample size ranged from 1 to 83 patients per article (Table 1). The range and average amount of fat injected to each area of the face is depicted in Fig. 2. Rhytidectomy was the most common concurrent procedure performed along with facial fat grafting (7 articles). Fat was harvested from the abdomen, hips, thighs, buttocks, flank, lower abdomen, periumbilical area, trochanteric area, knee, submental area, and neck. Percent of fat retention at follow-up was objectively measured using 3D photography or 2D photography in three articles [2, 7, 12] and subjectively measured by the surgeon in two articles [11, 16].

Forehead and Glabella (Table 2)

Three studies with 11 subjects measured fat injection to the forehead [4, 5, 9]. The average volume injected was 6.5 mL with range of 4.0–10.0 mL. Four studies with 30 subjects measured fat injection to the glabellar region [5, 6, 14, 16]. The average volume injected was 1.4 mL with range of 1.0–4.0 mL. No objective information on retention rate was given.

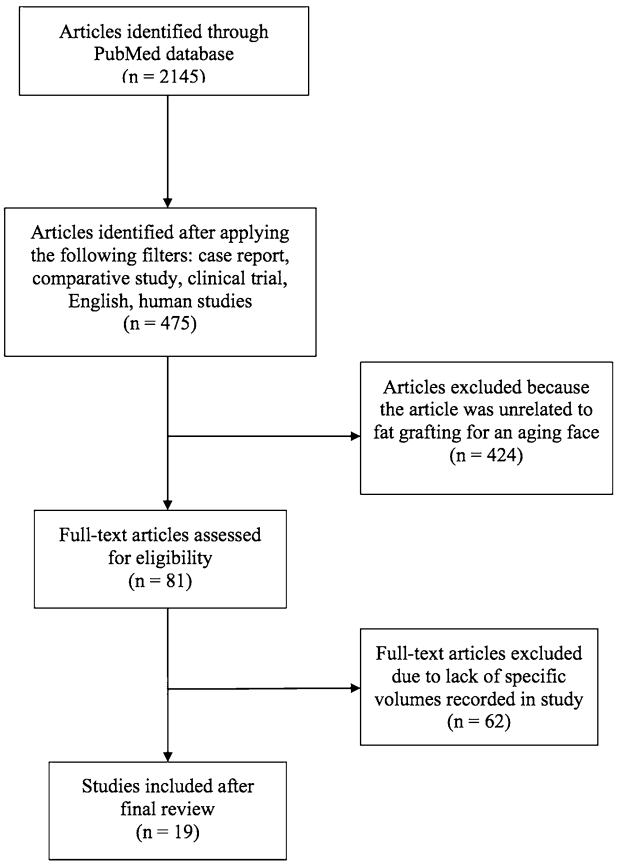

Fig. 1 Flowchart of article research

Table 1 All articles included in systematic review

Article	Type of article	Sample size	Donor site	Fat preparation technique	Concurrent procedure	Mean time to follow-up (months)	Complications
Boneti et al. [6]	Prospective study	22	Abdomen	Harvested fat was filtered and emulsified	Rhytidectomy and laser-assisted lipolysis	24	Temporary bruising and edema; raised spot on cheek; temporary hematoma
Coleman and Katzel [5]	Case series	3	Knees, thighs, suprapubic area, hips	Structural fat grafting	NR	28	NR
Coleman [1]	Case series	2	Submental region, abdomen	Structural fat grafting	NR	77.5	Temporary bruising and edema
Coleman [4]	Case series	4	NR	Structural fat grafting	NR	25	NR
Coleman [3]	Case report	1	Thighs, flanks	Structural fat grafting	NR	96	NR
Gamboa and Ross [14]	Retrospective review	8	Abdomen, neck, thighs, buttocks	Harvesting syringe placed upright until fat was separated to distinct layer	NR	25	Minor asymmetry in nasojugal area (1 patient); prolonged malar swelling (1 patient)
Gerth et al. [7]	Prospective study	26	Abdomen, thigh	Closed-membrane filtration system	Rhytidectomy (7 patients)	17	Donor-site hematoma (1 patient)
Hendy [8]	Prospective study	20	Abdomen, trochanteric area	Structural fat grafting	NR	9	Asymmetries (8 patients)
Isik and Sahin [9]	Prospective study	9	Abdomen, thigh	Structural fat grafting	Rhinoplasty	28.1	Undercorrection (1 patient)
Lawrence [10]	Prospective study	46	Abdomen, hips, femoral–gluteal region	Harvested fat micrograft stood on rack and sedimented for 1 h	NR	12	Temporary edema
Le et al. [15]	Retrospective review	70	Knees, thighs	Steel mesh strainer and saline wash	Rhytidectomy (24 patients)	117	Postinjection subcutaneous induration (5 patients)
Mailey et al. [16]	Retrospective review	9	NR	Celution device to obtain stromal vascular fraction cells (some patients)	Rhytidectomy (9 patients), brow lift (2 patients)	6.4	NR
Meier et al. [2]	Prospective study	33	Abdomen, thigh	Structural fat grafting	Rhytidectomy (10 patients), blepharoplasty (25 patients)	16	Undercorrection (8 patients)
Niechajev and Sevcuk [11]	Prospective study	9	Trochanteric area, thigh, periumbilical area	Mechanical aspiration and saline wash	NR	42	NR
Pallua and Wolter [19]	Observational study	12	Submental region	Structural fat grafting	Rhytidectomy	12	Temporary edema and bruising, wound-healing disorder (2 patients)
Pezeshk et al. [17]	Retrospective review	65	Abdomen, thigh	Structural fat grafting	Rhytidectomy	12	NR

Table 1 continued

Article	Type of article	Sample size	Donor site	Fat preparation technique	Concurrent procedure	Mean time to follow-up (months)	Complications
Roh et al. [18]	Retrospective review	10	Abdomen, buttocks	Filtration using autoclaved filter paper	NR	14.2	Temporary bruising and edema
Wang et al. [12]	Prospective study	78	Abdomen, thigh	Structural fat grafting	NR	12	NR
Xie et al. [13]	Prospective study	83	Abdomen, thigh	Saline wash and centrifugation	NR	50.8	Temporary bruising and edema

NR none reported, *Coleman* [3] structural fat grafting: more than a permanent filler, *Coleman* [4] facial augmentation with structural fat grafting

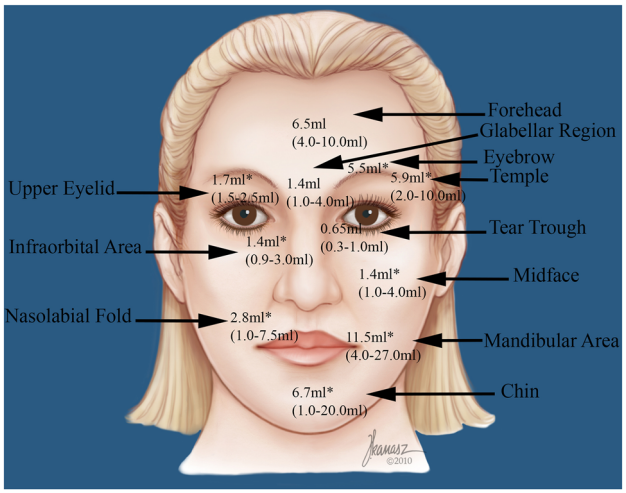

Fig. 2 Average and range of fat injected to each area of the face. *asterisk* amount injected per side

Temple (Table 3)

Five studies with 47 subjects measured fat injection to the temple [4, 5, 13, 16, 19]. The average volume injected was 5.9 mL with range of 2.0–10.0 mL per side. No objective information on retention rate was given.

Periorbital (Table 4)

One study with seven subjects measured fat injection to the eyebrow [6]. The average volume injected was 5.5 mL per side. Two studies with three subjects reported fat injection to the upper eyelid [4, 5]. The average volume injected was 1.7 mL with range of 1.5–2.5 mL per side. One study with eight subjects included fat injection to the tear trough [14]. The average volume injected was 0.65 mL with range of 0.3–1.0 mL per side. Four studies with 19 subjects measured fat injection to the infraorbital area (infraorbital rim

Table 2 Volume injected to forehead and glabellar region

	Author	Sample size	Average volume injected (mL)	Range of volume injected (mL)
Forehead	Isik and Sahin [9]	9	6.88	4–10
	Coleman and Katzel [5]	1	6	6
	Coleman [4]	1	4	4.0
Frontal area	Xie et al. [13]	11	8.5	6–12
Glabella	Mailey et al. [16]	9	NR	1–3
	Gamboa and Ross [14]	8	1	1
	Boneti et al. [6]	11	1	1
	Coleman and Katzel [5]	2	2.75	1.5–4
Glabella, nasion, nasal dorsum	Coleman [3]	1	2.25	2.25
Forehead, glabella, temples	Lawrence [10]	46	32	32

NR none reported, *Coleman* [3] structural fat grafting: more than a permanent filler, *Coleman* [4] facial augmentation with structural fat grafting

Table 3 Volume injected to temple

	Author	Sample size	Average volume injected per side (mL)	Range of volume injected per side (mL)
Temple	Mailey et al. [16]	9	NR	2–5
	Xie et al. [13]	22	8	5–10
	Pallua and Wolter [19]	12	4	3–5
	Coleman and Katzel [5]	3	5.1	3.1–6
	Coleman [4]	1	4.5	4.0–5.0
Temple, brow, and upper eyelids	Coleman [3]	1	26.5	26.5

NR none reported, *Coleman* [3] structural fat grafting: more than a permanent filler, *Coleman* [4] facial augmentation with structural fat grafting

Table 4 Volume injected to periorbital area

	Author	Sample size	Average volume injected per side (mL)	Range of volume injected per side (mL)
Periocular area	Xie et al. [13]	2	1.2	0.8–2
Lower eyelid tear trough and malar region	Le et al. [15]	70	6	2–10
Infraorbital area	Roh et al. [18]	10	1.5	1–2
	Boneti et al. [6]	7	1	1
	Coleman [4]	1	2.75	2.5–3.0
	Coleman and Katzel [5]	1	1.1	0.9–1.2
Tear trough	Gamboa and Ross [14]	8	0.65	0.3–1
Upper eyelid	Coleman and Katzel [5]	2	1.9	1.5–2.5
	Coleman [4]	1	1.5	1.5
Lateral eyelid	Coleman and Katzel [5]	3	0.94	0.8–1.0
	Coleman [4]	1	0.8	0.8
Medial eyelid	Coleman and Katzel [5]	2	0.4	0.3–0.5
Eyebrow	Boneti et al. [6]	7	5.5	NR

NR none reported, *Coleman* [4] facial augmentation with structural fat grafting

to lower lid/cheek junction) [4–6, 18]. The average volume injected was 1.4 mL with range of 0.9–3.0 mL per side. No objective information on retention rate was given.

Cheek and Midface (Table 5)

Four studies with 91 subjects measured fat injection to the midface [2, 7, 8, 19]. The average volume injected was 8.7 mL with range of 1.0–22.5 mL per side. The midface was further subdivided into cheek, buccal region, posterior buccal cheek, lateral malar, anterior malar fold, anterior malar region, zygomatic area, or "cheeks, lower eyelids, zygomatic region." Four studies with 118 subjects measured fat injection to the cheek [5, 11–13]. The average volume injected was 25.7 mL with range of 4.0–47.0 mL per side. Two studies with 24 subjects measured fat injection to the zygomatic area [6, 13]. The average volume injected was 4.7 mL with range of 3.0–10.0 mL per side. Gerth et al. noted 41.2% volume retention in the midface after 17 months [7]. Meier et al. noted 31.8% volume retention in the midface after 16 months [2]. Wang et al. noted 27.1% volume retention in the cheek after 12 months [12]. Gerth et al. and Meier et al. used 3D photography to measure volume retention, while Wang et al. used 2D photography to measure volume retention.

Nasolabial Fold (Table 6)

Seven studies with 38 subjects measured fat injection to the nasolabial folds [1, 3–6, 16, 19]. The average volume injected was 2.8 mL with range of 1.0–7.5 mL per side. No objective information on retention rate was given.

Perioral (Table 7)

Six studies with 25 subjects measured fat injection to the upper lip [1, 3–5, 14, 19]. The average volume injected was 3.0 mL with range of 1.0–5.0 mL. Five articles with 24

Table 5 Volume injected to cheek and midface

	Author	Sample size	Average volume injected per side (mL)	Range of volume injected per side (mL)
Midface	Gerth et al. [7]	26	8.88	2.3–18.0
	Meier et al. [2]	33	10.1	3.0–22.5
	Hendy et al. [8]	20	10	10
	Pallua and Wolter [19]	12	2.5	1–4
Cheek area	Wang et al. [12]	78	29.3	15–47
	Niechajev and Sevcuk [11]	9	18	7–27
	Xie et al. [13]	29	20	12–26
	Coleman and Katzel [5]	2	5.3	4.0–6.0
Buccal region	Mailey et al. [16]	9	NR	3–7
Posterior buccal cheek	Coleman and Katzel [5]	1	3.5	3.0–4.0
Lateral malar	Coleman and Katzel [5]	1	7.5	7.0–8.0
Anterior malar fold	Coleman and Katzel [5]	3	1.5	1.3–2.0
	Coleman [4]	1	1.75	1.5–2.0
Anterior malar region	Coleman and Katzel [5]	2	3.1	2.5–4.0
	Coleman [4]	1	1.5	1.5
Zygomatic area	Xie et al. [13]	9	7.5	5–10
	Boneti et al. [6]	15	3	3
Cheeks, lower eyelids, zygomatic region	Lawrence [10]	46	42	42

NR none reported, *Coleman* [4] facial augmentation with structural fat grafting

subjects measured fat injection to the lower lip [3–5, 14, 19]. The average volume injected was 3.7 mL with range of 2.5–6.0 mL. Four studies with 33 subjects measured fat injection to the marionette lines [4–6, 19]. The average and range of fat injected was 1.3 mL with range of 1.0–3.5 mL per side. No objective information on retention rate was given.

Mandibular Area (Table 8)

Three studies with 18 subjects measured fat injection to the mandibular area [3, 5, 13]. The average volume injected was 11.5 mL with range of 4.0–27.0 mL per side. No objective information on retention rate was given.

Chin (Table 9)

Three studies with six subjects measured fat injection to the chin [3, 5, 13]. The average volume injected was 6.7 mL with range of 1.0–20.0 mL. No objective information on retention rate was given.

Discussion

Fat grafting has evolved and improved since Neuber first introduced the idea in 1893 [20]. Coleman popularized this technique that has become an essential part of facial rejuvenation and harmonization [1]. The goal of autologous fat grafting for an aging face is to create a natural, rejuvenated appearance. This requires knowledge of the aging process and an understanding that facial subcutaneous fat is not a "confluent mass" but rather a highly compartmentalized arrangement [21]. The changes that occur as the face ages are well described [21–25]. Briefly, volume loss in soft tissue and bony structures is an inherent part of the aging process. In a young face, fat is homogeneously distributed, creating a full face without demarcation of subcutaneous regions. The young face is made up of a prominent jawline, convex temples, lateral projection of cheeks, and multiple smaller arcs of the lips [24]. As the face ages, the anatomical compartments become more well defined, leading to abrupt contour changes and disharmony. Unlike the young face, which stores fat evenly, the subcutaneous fat in an older person gets redistributed, leading to atrophy in some areas and hypertrophy in others [24]. Atrophy typically occurs in the forehead, temporal, periorbital, buccal, and perioral areas. Hypertrophy typically occurs submentally, in the jowl, lateral nasolabial fold, lateral labiomental crease, and lateral malar areas [24]. Additionally, the maxilla and mandible become thinner, lips become straight or angular, and the forehead loses its anterior projection [24]. However, fat injection's unpredictable resorption is still a major limitation.

Multiple interventions are currently available to achieve volumetric rejuvenation. Lifting procedures, though

Table 6 Volume injected to nasolabial fold

Author	Sample size	Average volume injected per side (mL)	Range of volume injected per side (mL)
Mailey et al. [16]	9	NR	1–3
Pallua and Wolter [19]	12	1.5	1–2
Boneti et al. [6]	10	4	4
Coleman and Katzel [5]	2	5.3	4.5–7.0
Coleman [1]	2	2.25	2.0–2.5
Coleman [4]	2	3.5	3.0–4.0
Coleman [3]	1	6.75	6.0–7.5

NR none reported, *Coleman* [3] structural fat grafting: more than a permanent filler, *Coleman* [4] facial augmentation with structural fat grafting

Table 7 Volume injected to perioral region

	Author	Sample size	Average volume injected (mL)	Range of volume injected (mL)
Perioral region	Mailey et al. [16]	9	NR	2–10
Lips	Boneti et al. [6]	21	6	6
Upper lip	Coleman and Katzel [5]	1	1.5	1.5
	Coleman [1]	1	1	1
	Coleman [4]	2	2.75	2.0–3.5
	Coleman [3]	1	4.5	4.5
	Pallua and Wolter [19]	12	2.5	2–3
	Gamboa and Ross [14]	8	4	3–5
Lower lip	Coleman and Katzel [5]	1	2.5	2.5
	Coleman [4]	2	5.75	5.5–6.0
	Coleman [3]	1	6	6
	Pallua and Wolter [19]	12	3	2–4
	Gamboa and Ross [14]	8	4	3–5
Rim of lower lip	Coleman [4]	1	1	1.0
Marionette lines	Pallua and Wolter [19]	12	1.5	1–2
	Boneti et al. [6]	19	1	1
	Coleman and Katzel [5]	1	3.1	2.6–3.5
	Coleman [4]	1	1.8	1.8
Upper lip wrinkle	Coleman and Katzel [5]	1	0.9	0.9
White roll	Coleman and Katzel [5]	1	1	1.0
	Coleman [4]	1	1	1.0
Deep vermillion along white roll	Coleman [4]	1	1	1.0
Philtrum	Coleman and Katzel [5]	1	1	1.0
	Coleman [4]	1	0.75	0.75

NR none reported, *Coleman* [3] structural fat grafting: more than a permanent filler, *Coleman* [4] facial augmentation with structural fat grafting

commonly performed to achieve a more youthful appearance, do not address the issue of volume loss that occurs due to craniofacial remodeling and fat atrophy. Bone-mobilization techniques are invasive and are associated with higher morbidity [26]. Injectable fillers, such as hyaluronic acid, collagen, and poly-L-lactic acid, have been used to restore facial volume. Their shortfalls include the results being temporary, cost, and potential adverse allergenic reactions [27]. Autologous fat transfer, on the other hand, is cost efficient, biocompatible, and abundant for most patients.

We, like others, have anecdotally found fat injection safe with long-lasting results. There is growing consensus among surgeons to use fat injection to further augment

Table 8 Volume injected to mandibular area

	Author	Sample size	Average volume injected per side (mL)	Range of volume injected per side (mL)
Mandibular area	Xie et al. [13]	15	11	8–14
	Coleman and Katzel [5]	2	10.25	4–17
	Coleman [3]	1	22.25	17.5–27.0
Anterior border of mandible	Coleman [4]	1	8	8.0

NR none reported, *Coleman* [3] structural fat grafting: more than a permanent filler, *Coleman* [4] facial augmentation with structural fat grafting

Table 9 Volume injected to chin

	Author	Sample size	Average volume injected (mL)	Range of volume injected (mL)
Supramental crease	Mailey et al. [16]	9	NR	1–3 (per side)
Chin crease	Boneti et al. [6]	12	1	1
Chin	Xie et al. [13]	4	2	1–4
	Coleman and Katzel [5]	1	12	12
	Coleman [3]	1	20	20
Posterior border of chin	Coleman [4]	1	18.5 (per side)	18–19 (per side)
Lower body of chin	Coleman [4]	1	16	16
Mental groove	Coleman and Katzel [5]	1	0.5	0.5
Submental region	Coleman and Katzel [5]	1	6	6.0

NR none reported, *Coleman* [3] structural fat grafting: more than a permanent filler, *Coleman* [4] facial augmentation with structural fat grafting

facelift results [28]. There is no scientific evidence suggesting that a specific site demonstrates increased viability of injected fat. However, it is uniformly believed that fat injection is more successful in more static anatomic areas. Best results are usually obtained when less than 0.1 mL aliquots are injected to promote revascularization of the grafts.

Volume retention is multifactorial and depends on how the fat is harvested, processed, transplanted, and managed [29]. These factors have been studied in various laboratories, but no consensus exists in the literature thus far [30]. Using a larger bore cannula to harvest the fat generally helps maintain the cellular architecture and maximize the number of cells within fat particles [30]. The grafted fat should be placed within 0.2 cm from arterial blood supply to avoid central necrosis [31] and prevent complications such as hematoma, oil cysts, and calcifications [30]. As the total volume of transplanted fat increases, there is increased likelihood of central necrosis and lower volume retention [32]. Recent advances to improve graft retention have introduced the use of adipose-derived stem cells (ASCs) and platelet-rich plasma (PRP) [33]. A randomized clinical trial in 2015 found that adding plasma rich in growth factors to the grafted fat did not make a significant difference in volume retention [34]. Further research will be required to elucidate clinical efficacy.

Clinical data on volume retention overtime are limited. In our systematic review, only three articles included objective assessment of volume retention during follow-up, and two of the studies provided a subjective estimate when documenting this value. Instead, most articles in our study measure fat grafting success using surgeon and patient's satisfaction. This lack of objective data has led many patients to receive multiple touch-up surgeries before they are satisfied with their results.

To our knowledge, this is the first review that specifically tries to quantify the volume of fat typically injected during fat grafting for facial aging. Many limitations exist in this systematic review. Few studies assessed volume retention at long-term follow-up. More recent development of 3D imaging may be utilized to provide an objective assessment of volume retention, though to date 3D photography has only been studied in the midface [2, 7]. Comparing before-and-after photographs can be misleading due to variability in film color, position, flash intensity, and facial expression [1]. Radiographic imaging may also

be utilized to objectively evaluate volume loss. Fontdevila et al. have utilized computed tomography to quantify volume retention after facial fat grafting in HIV patients with facial lipoatrophy in two studies [34, 35]. Magnetic resonance imaging has also been used in studies to measure facial fat atrophy overtime [36–39]. Use of magnetic resonance imaging to measure volume retention after fat grafting to the breast has helped to standardize injection techniques [40].

The anatomic specificity reported by each author varies greatly and limits comparison between studies. For example, when describing the midface, studies we incorporated into our review use "midface," "cheek area," "buccal region," "posterior buccal cheek," "lateral malar," "anterior malar fold," "anterior malar region," "zygomatic area," and "cheeks, lower eyelids, zygomatic region."

The biggest limitation to this study is the lack of reporting in the literature to draw from. Despite the ubiquity of fat grafting [35] and extensive laboratory research, little has been done to define its efficacy in patients. We included all relevant studies in our systematic review, including case reports and case series. Surgeons must rely on understanding of anatomy and individualized patient need based on bony and soft tissue changes to determine injection volume. Additionally, it is critical to understand each patient's goals, as some patients wish to address facial aging and others to enhance a certain feature. Therefore, the findings in this systematic review are not intended to be general guidelines. Nonetheless, this paper can serve as a starting point for the less experienced surgeon, a base for research, and a clinical estimate that must be adjusted based on each patient's unique needs.

Conclusion

Here we undertake a systematic review of the literature to better understand volumes of fat injected to different facial subunits. To determine volumetric needs and retention rates, we encourage standardization of terminology and further reporting of injection volumes and outcomes.

Acknowledgment BG owns stock and receives royalties from Elsevier and serves as board member/CEO of Innovative Medical Equipment (IME). The other authors have no conflicts of interest to declare.

References

1. Coleman SR (1995) Long-term survival of fat transplants: controlled demonstrations. Aesthetic Plast Surg 19:421–425
2. Meier JD, Glasgold RA, Glasgold MJ (2009) Autologous fat grafting: long-term evidence of its efficacy in midfacial rejuvenation. Arch Facial Plast Surg 11:24–28
3. Coleman SR (2006) Structural fat grafting: more than a permanent filler. Plast Reconstr Surg 118:108S–120S
4. Coleman SR (2006) Facial augmentation with structural fat grafting. Clin Plastic Surg 36:567–577
5. Coleman SR, Katzel EB (2015) Fat grafting for facial filling and regeneration. Clin Plastic Surg 42:289–300
6. Boneti C, Anakwenze CP, Torre J, Weaver TL, Collawn SS (2016) Two-year follow-up of autologous fat grafting with laser-assisted facelifts. Ann Plast Surg 76:S260–S263
7. Gerth DJ, King B, Rabach L, Glasgold RA, Glasgold MJ (2014) Long-term volumetric retention of autologous fat grafting processed with closed-membrane filtration. Aesth Surg 34:985–994
8. Hendy A (2010) Facial re-contouring using autologous fat transfer. J Plast Reconstr Surg 34:65–69
9. Isik S, Sahin I (2012) Contour restoration of the forehead by lipofilling: our experience. Aesth Plast Surg 36:761–766
10. Lawrence CY (2000) Rejuvenative facial lipomorphoblasty. Aesth Plast Surg 24:22–27
11. Niechajev I, Sevcuk O (1994) Long-term results of fat transplantation: clinical and histologic studies. Plast Reconstr Surg 94:496–506
12. Wang W, Xie Y, Huang RL, Zhou J, Tanja H, Zhao P, Cheng C, Zhou S, Pu LLQ, Li Q (2017) Facial contouring by targeted restoration of facial fat compartment volume: the mid-face. Plast Reconstr Surg 139:563–572
13. Xie Y, Zheng DN, Li QF, Gu B, Liu K, Shen GX, Pu LLQ (2010) An integrated fat grafting technique for cosmetic facial contouring. J Plast Reconstr Aesth Surg 63:270–276
14. Gamboa GM, Ross WA (2013) Autologous fat transfer in aesthetic facial recontouring. Ann Plast Surg 70:513–516
15. Le TP, Peckinpaugh J, Naficy S, Amadi AJ (2014) Effect of autologous fat injection on lower eyelid position. Ophthal Plast Reconstr Surg 30:504–507
16. Mailey B, Baker JL, Hosseini A, Collins J, Suliman A, Wallace AM, Cohen SR (2016) Evaluation of facial volume changes after rejuvenation surgery using a 3-dimensional camera. Aesth Surg 36:379–387
17. Pezeshk RA, Stark RY, Small KH, Unger JG, Rohrich RJ (2015) Role of autologous fat transfer to the superficial fat compartments for perioral rejuvenation. Plast Reconstr Surg 136:301e–309e
18. Roh MR, Kim TK, Chung KY (2009) Treatment of infraorbital dark circles by autologous fat transplantation: a pilot study. Br J Dermatol 160:1022–1025
19. Pallua N, Wolter T (2013) The lipo-facelift: merging the face-lift and liposculpture: eight years experience and a preliminary observational study. Aesth Plast Surg 37:1107–1113
20. Billings E Jr, May JW Jr (1989) Historical review and present status of free fat graft autotransplantation in plastic and reconstructive surgery. Plast Reconstr Surg 83:368–381
21. Rohrich RJ, Pessa JE (2007) The fat compartments of the face: anatomy and clinical implications for cosmetic surgery. Plast Reconstr Surg 119:2219–2227
22. Buckingham ED, Bader B, Smith SP (2010) Autologous fat and fillers in periocular rejuvenation. Facial Plast Surg Clin N Am 18:385–398
23. Glasgold M (2015) Introduction to volumetric facial rejuvenation. Facial Plast Surg 31:10–14
24. Donofrio LM (2005) Panfacial volume restoration with fat. Dermatol Surg 31:1496–1505
25. Sadick NS, Manhas-Bhutani S, Kreuger N (2013) A novel approach to structural facial volume replacement. Aesth Plast Surg 37:266–276
26. Reuther M, Watson D (2016) Tissue engineering and the future of facial volumization. Facial Plast Surg 32:565–568
27. Kim IA, Keller GK, Groth MJ, Nabili V (2016) The downside of fat: avoiding and treating complications. Facial Plast Surg 32:556–559

28. Sinno S, Mehta K, Reavey PL, Simmons C, Stuzin JM (2015) Current trends in facial rejuvenation: an assessment of ASPS members' use of fat grafting during face lifting. Plast Reconstr Surg 136:20e–30e
29. Del Vecchio D, Rohrich RJ (2012) A classification of clinical fat grafting: different problems, different solutions. Plast Reconstr Surg 130:511–522
30. Gause TM II, Kling RE, Sivak WN, Marra KG, Rubin PJ, Kokai LE (2014) Particle size in fat graft retention: a review on the impact of harvesting technique in lipofilling surgical outcomes. Adipocyte 3:273–279
31. Khouri RK, Rigotti G, Cardoso E, Khouri RK Jr, Biggs TM (2014) Megavolume autologous fat transfer: part I. Theory and principles. Plast Reconstr Surg 133:550–557
32. Bourne DA, James IB, Wang SS, Marra KG, Rubin PJ (2016) The architecture of fat grafting: what lies beneath the surface. Plast Reconstr Surg 137:1072–1079
33. James IB, Coleman SR, Rubin PJ (2016) Fat, stem cells, and platelet-rich plasma. Clin Plastic Surg 43:473–488
34. Fontdevila J, Guisantes E, Martinez E, Prades E, Berenguer J (2014) Double-blind clinical trial to compare autologous fat grafts versus autologous fat grafts with PDGF: no effect of PDGF. Plast Reconstr Surg 134:219e–230e
35. Fontdevila J, Serra-Renom JM, Raigosa M, Berenguer J, Guisantes E, Prades E, Benito-Ruiz J, Martinez E (2008) Assessing the long-term viability of facial fat grafts: an objective measure using computed tomography. Aesthet Surg J 28:380–386
36. Horl HW, Feller AM, Biemer E (1991) Technique for liposuction fat reimplantation and long-term volume evaluation by magnetic resonance imaging. Ann Plast Surg 26:248–258
37. Gosain AK, Klein MH, Sudhakar PV, Prost RW (2005) A volumetric analysis of soft-tissue changes in the aging midface using high-resolution MRI: implications for facial rejuvenation. Plast Reconstr Surg 115:1143–1155
38. Darcy SJ, Miller TA, Goldberg RA, Villablanca JP, Demer JL, Rudkin GH (2008) Magnetic resonance imaging characterization of orbital changes with age and associated contributions to lower eyelid prominence. Plast Reconstr Surg 122:921–931
39. Wysong A, Joseph T, Kim D, Tang JY, Gladstone HB (2013) Quantifying soft tissue loss in facial aging: a study in women using magnetic resonance imaging. Dermatol Surg 39:1895–1902
40. Del Vecchio DA, Bucky LP (2011) Breast augmentation using preexpansion and autologous fat transplantation: a clinical radiographic study. Plast Reconstr Surg 127:2441–2450