



Three-Dimensional Analysis of Long-Term Midface Volume Change After Vertical Vector Deep-Plane Rhytidectomy

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Abstract

Background: Facial aging is a complicated process that includes volume loss and soft tissue descent. This study provides quantitative 3-dimensional (3D) data on the long-term effect of vertical vector deep-plane rhytidectomy on restoring volume to the midface.

Objective: To determine if primary vertical vector deep-plane rhytidectomy resulted in long-term volume change in the midface.

Methods: We performed a prospective study on patients undergoing primary vertical vector deep-plane rhytidectomy to quantitate 3D volume changes in the midface. Quantitative analysis of volume changes was made using the Vectra 3D imaging software (Canfield Scientific, Inc, Fairfield, New Jersey) at a minimum follow-up of 1 year.

Results: Forty-three patients (86 hemifaces) were analyzed. The average volume gained in each hemi-midface after vertical vector deep-plane rhytidectomy was 3.2 mL.

Conclusions: Vertical vector deep-plane rhytidectomy provides significant long-term augmentation of volume in the midface. These quantitative data demonstrate that some midface volume loss is related to gravitational descent of the cheek fat compartments and that vertical vector deep-plane rhytidectomy may obviate the need for other volumization procedures such as autologous fat grafting in selected cases.

Level of Evidence: 4



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Facial aging is a complex process that requires knowledge of the changes in bone, soft tissues, facial ligaments, and skin for a comprehensive understanding.^{1,2} The specific changes in the malar fat pad observed by aesthetic surgeons for years have been more clearly elucidated in cadaveric studies.^{3,4} More specifically, Rohrich and Pessa showed that there are distinct partitions of facial subcutaneous fat; changes to the individual compartments characterize the aging face. Their work clarifies that the cheek does not age as one “confluent mass”, or “malar fat pad.”⁴ The cheek fat compartments that make up the midface are 3 separate entities that lie between the orbital retaining ligaments superiorly and the jowl fat inferiorly. These 3 fat compartments consist of the nasolabial fat compartment and the medial and middle cheek fat compartments. The zygomatic ligament represents a zone of adherence and confluence where

the medial and middle cheek fat compartments meet, while the medial and inferior aspect of the zygomaticus major muscle is adherent to nasolabial fat compartment.^{4,5}

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The stigmata of facial aging in the midface occur due to both volume loss and soft tissue descent of these compartments.⁶ With descent of these fat pads, there is a decrease in volume and narrowing of the width of the upper midface in the zygomatic region and an increase in volume and width to the inferior midface periorally, lateral to the oral commissure. The 2 mainstay treatments for midface rejuvenation are the rhytidectomy and autologous fat grafting, which can be performed separately or together depending upon the relative degrees of deflation and ptosis. In the rhytidectomy, ptosis of these fat compartments cannot be elevated unless the zygomatic ligament and the dense fascial attachments of the zygomaticus musculature are adequately released. Without ligamentous release, poor postoperative midface results occur. Rather than ligamentous release and repositioning of the ptotic fat pads, the midface can be rejuvenated with autologous fat transfer directed to superior aspects of these fat compartments.⁷

The aim of this study is to provide quantitative 3-dimensional (3D) volume data on the long-term results of patients who underwent a vertical vector deep-plane rhytidectomy to restore volume to the midface. We accomplished this using a 3D camera and a digital image analysis method that has been validated for the midface.

METHODS

Study Design

Patients undergoing a primary deep-plane vertical vector rhytidectomy were prospectively enrolled over a 5-month period (September 2010 to February 2011). Informed consent for this study was obtained from all patients. Patients were excluded if they had a rhytidectomy with an extended superficial musculoaponeurotic system (SMAS) flap, SMASectomy, or SMAS plication approach, had concomitant autologous fat grafting with their rhytidectomy, or were undergoing a secondary or revision facelift.

Surgical Technique

The surgical technique utilized was a deep-plane rhytidectomy dissection as described by Hamra,⁸ with a vertical vector of the composite flap redraping as previously described.^{9,10} Briefly, after subcutaneous elevation of the facelift skin flap from the auricular incision to a line drawn from the lateral canthus to the angle of the mandible, the deep plane was entered sharply with a No. 10 blade followed by a blunt dissection. In the inferior cheek, the skin and SMAS were elevated as a composite unit in the sub-SMAS plane. In the superior cheek, the flap was dissected superficial to the orbicularis oculi and zygomaticus musculature, elevating the skin and the cheek fat compartments as a composite unit. This left the dense attachments of the

zygomatic ligament and the medial aspect of the zygomaticus major muscle. Blunt dissection was then performed from the superior pocket through the ligament in an inferior direction. This permitted release of the zygomatic ligament and the dense fibrous attachments from the zygomaticus major muscle to the skin while ensuring that the facial nerve was protected. The facial nerve branches enter the deep surfaces of the mimetic musculature; therefore, dissecting in this direction on the surface of the mimetic musculature protects the nerves from injury. This connected the superior and inferior pockets of dissection, releasing the cheek and its fat compartments (Figure 1). The deep plane cheek flap was suspended from the deep plane entry point to the zygomatic arch periosteum utilizing three 3-0 PDS sutures (Ethicon Endo-Surgery Inc, Cincinnati, Ohio) in an interrupted fashion that were spaced equidistant from the angle of the mandible to the lateral canthus (Figure 2). On average, the vector of suspension was approximately 60 degrees, which was more vertical than superolateral. This was not a purely vertical vector of suspension but rather an oblique vertical vector (Supplementary Video 1).

All patients had preoperative 3D imaging prior to deep-plane vertical vector rhytidectomy and then postoperative 3D imaging at follow-up at a minimum of 1 year. Additional facial cosmetic surgery procedures performed at the same time as the deep-plane facelift were recorded, including upper and lower blepharoplasty, submental liposuction, endoscopic browlift, lip augmentation, and rhinoplasty.

Protocol for 3D Imaging and Analysis

Three-dimensional imaging was obtained utilizing the Canfield Scientific Vectra camera and analysis software (Canfield Scientific Inc, Fairfield, New Jersey). Preoperative and postoperative imaging was obtained in standard nonexpressive relaxed facial tone in the same photographic studio. Volumetric analysis of the 3D imaging was performed using the Vectra software according to the validated methodology previously described by Glasgold et al.^{11,12}

Briefly, this system synchronizes the pre and postoperative images, utilizing anatomic landmarks for registration. The 3D Vectra photography system utilizes 5 camera pods to capture images. The system has been shown to be equivalent to caliper measurement of craniomaxillofacial anthropometric measurements and thus is a reproducible and reliable modality for facial volume analysis.¹³ The anatomic landmarks used for registering the 3D images include the medial canthus, lateral canthus, nasal sill, and bony nasal dorsum. This allows for precise calculations of volume changes within areas highlighted on the face, since these landmarks are not altered following the operation performed.

In this study, the midface region was the target location for evaluation of volume changes. As previously validated and published,^{11,14} the midface region was defined as the

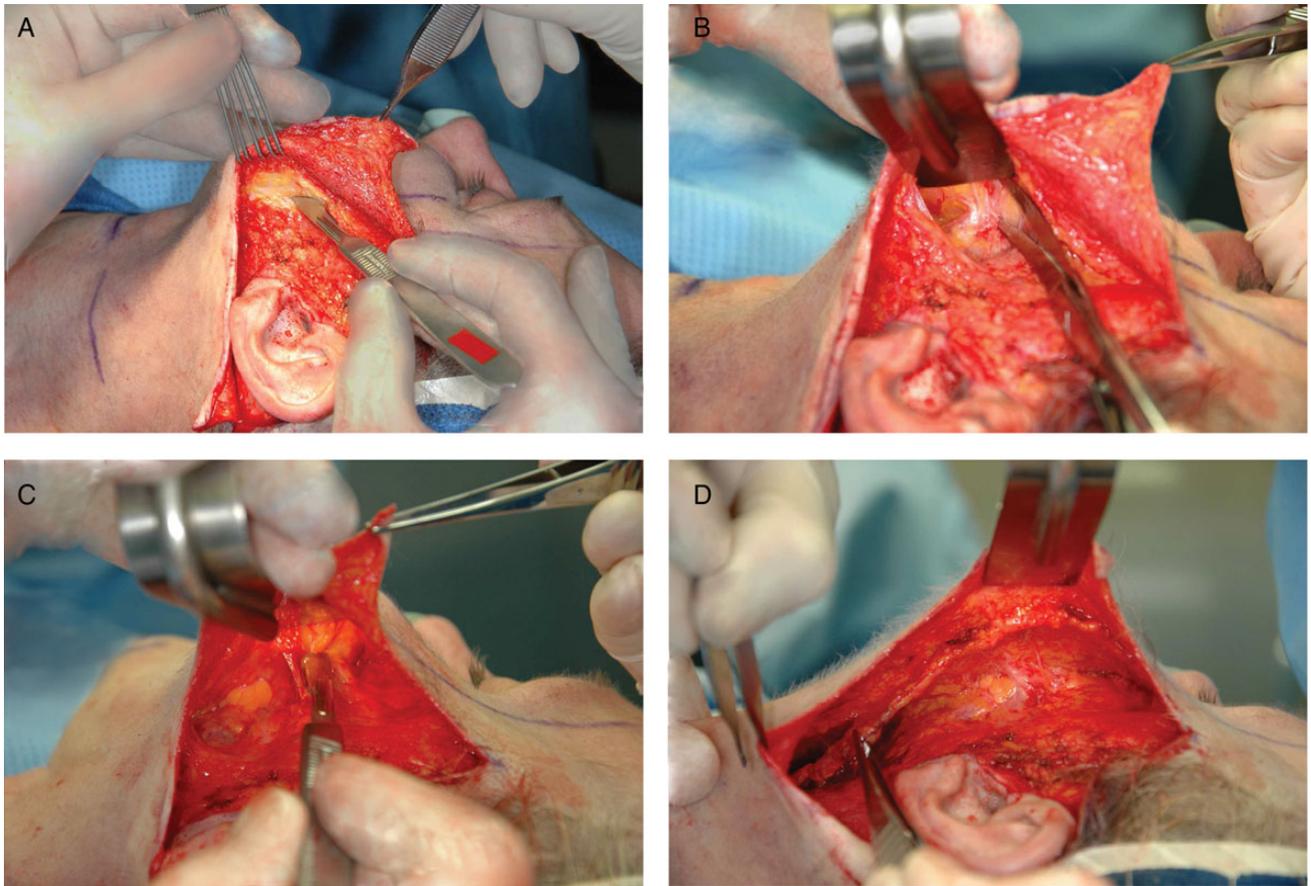


Figure 1. Deep plane dissection of the cheek during rhytidectomy in this 58-year-old woman. (A) Sharp entry into the deep plane along a line from the lateral canthus to the angle of the mandible. (B) Blunt vertical facelift spreading dissection raising the skin and superficial musculoaponeurotic system (SMAS) as 1 unit in the inferior cheek. (C) After dissection over the superior cheek superficial to the orbicularis and zygomatic musculature, the zygomatic ligament is released sharply. (D) Deep-plane cheek flap dissection completed.

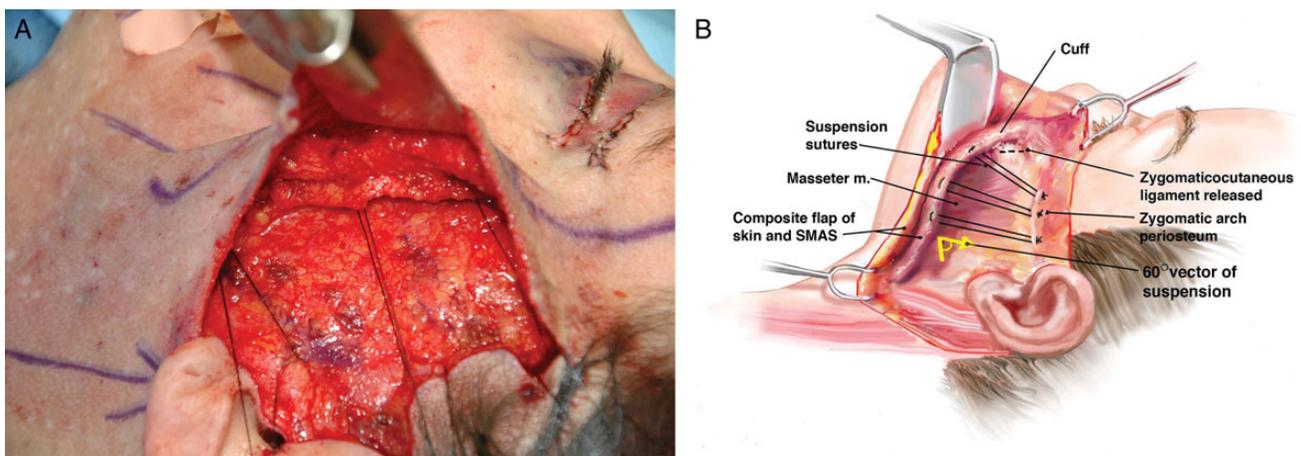


Figure 2. (A) Deep plane dissection in this 56-year-old female patient who underwent deep-plane rhytidectomy. The deep plane cheek flap is suspended with 3 PDS sutures from the deep plane entry point to the zygomatic arch periosteum in an interrupted fashion, spaced equidistant along a line from the angle of the mandible to the lateral canthus. (B) Medical illustration demonstrating suspension of composite deep plane flap of skin and SMAS after release of the zygomatic osseocutaneous ligaments at an angle of approximately 60 degrees. Note the suspension sutures are anchored in the posterior one-third of the zygomatic arch periosteum to avoid injury to the frontal branch of the facial nerve.

area inside the perimeter of the inferior orbital rim, the nasolabial fold, the anterior cheek, and the lateral cheek. The midface region as described above was selected for volume measurement (Figure 3A). Quantitative volume measurements were then made using the Vectra 3D imaging software that compared the volume difference of this selected midface region between the preoperative and postoperative images. These volume differences were a summation of the total volume change in the highlighted region, even though there may have been some areas of volume decrement and other areas of volume increase within the highlighted region.

Three-dimensional color schematic representation of volume changes between preoperative and postoperative photographs was obtained (Figure 3B). In these color schematic images, areas of postoperative volume decrease have been represented in green and areas of volume augmentation have been represented in blue. A topographic map is visible, with darker colors (eg, a darker blue) representing larger quantitative changes and lighter colors representing less change.

Statistical Analysis

The change in mean midfacial volume was analyzed using Microsoft Excel (Microsoft, Redmond, Washington). Pre and post rhytidectomy midface volumes were compared for

the hemifaces using a *t* test, assuming unequal variance. Statistical comparison was also made between the left and right hemifaces. Analysis of variance (ANOVA) was used to determine if there was any correlation between the amount of volume change achieved and the patient's age. ANOVA was also used to determine if the amount of volume change achieved correlated with any concurrent procedures. The only concurrent procedure that was considered to be relevant for this analysis was lower blepharoplasty because it abuts the defined zone analyzed for the midface. We performed an extended skin muscle flap blepharoplasty with fat preservation and transposition to the nasojugal groove.

RESULTS

Fifty-one patients were enrolled in the study and underwent a deep-plane vertical vector rhytidectomy. Of these, 43 patients were included in this study, allowing an analysis of 86 hemifaces (Table 1). Eight patients were excluded by the time of follow-up because they would not return for postoperative 3D imaging, having traveled from abroad. Forty patients were female and 3 were male. The patients' mean age was 61 years (range, 40-75 years). Mean follow-up time to postoperative imaging was 23 months (range, 12-36 months). One of 43 patients (2%) had a postoperative hematoma. There were no infections, skin slough, or facial nerve injuries. The amount of volume augmentation achieved postoperatively was recorded

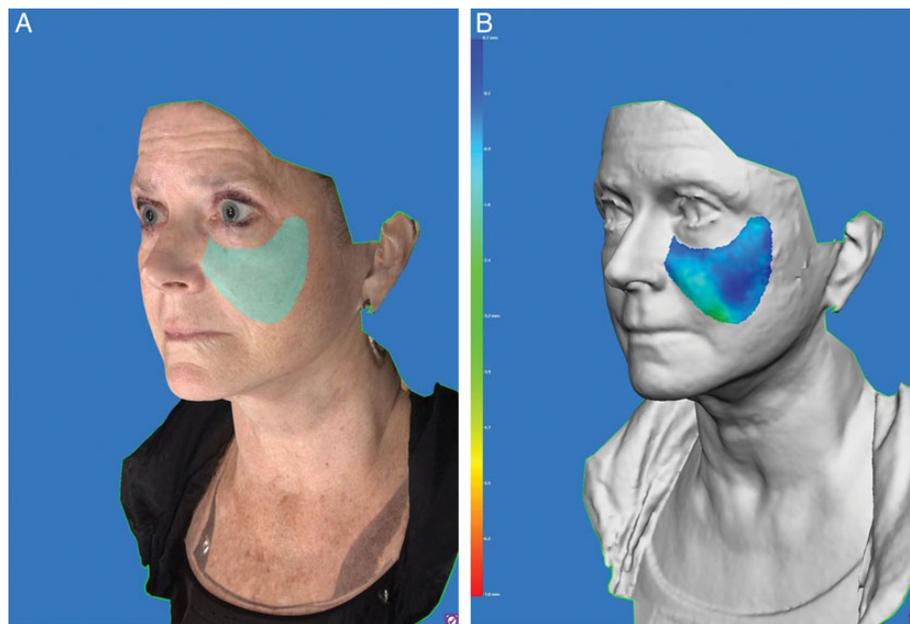


Figure 3. The midface region analyzed in this 64-year-old woman is the area inside the perimeter of the inferior orbital rim, the nasolabial fold, the anterior cheek, and the lateral cheek (A). Three-dimensional color schematic representation of volume change in the midface region between the pre and postoperative 3D photographs of this 64-year-old woman (B). Areas of blue in the upper midface represent areas of volume gain, and areas that are green represent areas of volume loss in the inferior midface and nasolabial fold region. The volume lost inferiorly is repositioned superiorly.

Table 1. Patient Data

Patient Number	Age at Operation, y	Sex	Follow-Up, mo	Volume Gain, mL	
				Right	Left
1	75	F	36	1.308	1.131
2	61	F	36	1.723	2.859
3	59	F	33	2.449	3.939
4	64	F	33	0.8526	0.5137
5	52	F	35	2.872	1.1509
6	63	F	32	3.421	5.617
7	51	F	34	5.82	6.646
8	60	F	31	2.4	1.252
9	54	F	30	3.157	6.664
10	51	F	30	8.357	7.021
11	74	F	28	7.86	2.174
12	60	M	28	1.76	1.926
13	66	M	28	4.53	3.086
14	63	F	28	3.369	2.813
15	68	F	27	1.863	4.21
16	40	F	27	0.5406	1.638
17	54	F	25	3.219	6.969
18	70	F	25	0.09148	0.708
19	61	F	22	1.5	4.03
20	57	F	26	1.964	0.9553
21	70	F	24	2.398	0.1589
22	74	F	24	9.579	5.863
23	63	F	22	9.62	4.95
24	69	F	21	2.675	4.732
25	55	F	21	3.663	3.101
26	60	F	21	1.802	4.201
27	67	F	20	1.271	1.503
28	61	F	18	5.93	2.82
29	65	F	20	2.304	3.438
30	61	F	17	4.122	0.874
31	69	F	17	1.057	1.061
32	54	F	15	5.272	6.187
33	59	F	14	3.663	2.669

(Continued)

Table 1. (Continued)

Patient Number	Age at Operation, y	Sex	Follow-Up, mo	Volume Gain, mL	
				Right	Left
34	52	F	16	2.704	3.8972
35	53	F	17	4.201	1.8305
36	56	F	15	1.243	3.816
37	73	F	15	1.262	2.621
38	65	F	15	3.414	1.555
39	59	F	12	4.653	1.045
40	54	M	12	1.5592	3.18
41	52	F	14	2.4264	3.651
42	53	F	12	3.192	1.655
43	57	F	19	6.754	2.93

in milliliters. The mean amount of volume gained in each hemi-midface after deep-plane rhytidectomy was 3.2 mL (standard deviation 2.1 mL) (Supplementary Figure 1).

The mean difference in volume gain between the left and right hemifaces in our patients was 0.2 mL (mean volume gain on right, 3.3 mL; mean volume gain on left, 3.1 mL), demonstrating reasonably symmetric results. There was no statistically significant difference in volume gain between the left and right hemiface.

The most common concurrent procedure was lower lid blepharoplasty ($n = 20$), followed by upper lid blepharoplasty ($n = 12$), rhinoplasty ($n = 5$), browlift ($n = 3$), lip augmentation ($n = 3$), and submental liposuction ($n = 1$). Concurrent lower lid blepharoplasty was analyzed for its effect on the amount of volume gained in the midface because the lower eyelid subunit is adjacent to the midface region analyzed. There was no statistically significant difference in midface volume augmentation after deep-plane vertical vector rhytidectomy in patients who underwent concurrent lower lid blepharoplasty vs patients that did not, and there was no trend noted between the 2 groups.

The difference in midface volume restoration achieved was also analyzed with respect to the patient's age. The mean volume gain in each hemi-midface in patients who underwent deep-plane rhytidectomy at ≤ 55 years of age was 3.9 mL. The mean volume gain in each hemi-midface in patients who underwent deep-plane rhytidectomy at > 55 years of age was 2.9 mL. Although this difference did not achieve statistical significance ($P = .07$), it may represent the trend that patients who undergo vertical vector deep-plane rhytidectomy at a younger age have a larger amount of volume restored to the midface than patients who undergo rhytidectomy at > 55 years of age.

DISCUSSION

Three-dimensional photography has been used when assessing facial volumization in the setting of dermal fillers¹² as well as autologous fat grafting.^{11,14} We present a novel application of 3D photography to assess volume augmentation of the midface after vertical vector deep-plane rhytidectomy. To the best of our knowledge, we present the first study quantifying the efficacy of vertical vector deep-plane rhytidectomy to restore volume to the midface. Midface volume augmentation in this study is the result of deep-plane rhytidectomy dissection, releasing the tethering effect of the zygomatic retaining ligaments and the zygomaticus musculature on the ptotic midfacial fat compartments. This allows the surgeon to vertically elevate them back to a more youthful position.¹⁵ Of note, no addition of adipose tissue by fat transfer or fat grafting was performed in these patients. In this cohort, an average of 3.2 mL of volume augmentation to the midface resulted at an average of 23 months follow-up. On close analysis of the 3D colorimetric images, which show volume augmentation throughout the midface and cheek, the average volume augmentation at any specific point in the cheek resulted in 0.5 mm of added malar height postoperatively. Although this measurement is a small increment, when considered at any one particular point, when distributed throughout the entire surface area of the malar region, this 0.5 mm of additional malar height provided a long-term volumetric effect of over 3 mL of volume gain—the equivalent of 3 vials of hyaluronic acid that might be injected to volumize 1 cheek. This finding adds to our understanding of the midface aging process, underscoring that ptosis of midfacial tissues significantly contributes to devolumization of the midface. Midface

devolumization is not simply due to atrophy and loss of midfacial tissues. Our findings also stress the importance of vertical vector face lifting in addressing the midface.

Our data conflict with a prior study by Ivy et al¹⁶ that showed no change in midface ptosis or nasolabial folds 1 year after deep-plane composite rhytidectomy. We believe this discrepancy can be theorized to be the result of traditional lateral-superolateral vectors of suspension utilized. This study preceded the advent of vertical vector face lifting as popularized by Tonnard.¹⁷ The deep plane release of the zygomatic ligaments and the fibrous attachments overlying the zygomatic musculature allows for greater mobilization of the SMAS and midfacial fat compartments,¹⁸ but more vertical suspension is required to redrape their volume back to the upper midface. Prior studies that have been performed show that while the vector for ideal repositioning of the midface varies in each individual case, the average angle of repositioning is 60 degrees from the Frankfort horizontal plane.^{4,10} This is a vector that is more vertical than simply equally superior and lateral (ie, 45 degrees). It minimizes midfacial flattening tendencies of more horizontal/lateral vectors and the midfacial and periorbital bunching tendencies of purely vertical vectors (ie, 90 degrees).

While we accomplish this with a vertical vector deep-plane rhytidectomy, there are other methods that can also elevate the malar fat pad, including high SMAS, extended SMAS and SMAS plication techniques. The degree to which our vertical vector deep-plane facelift can accomplish this vs other techniques is not the subject of this study and would require a separate prospective study using a similar method of volumetric analysis.

We acknowledge that there are inherent limits in utilizing the Vectra system's surface topography algorithm when measuring small volume changes, which was addressed in this paper. Ideally, magnetic resonance imaging (MRI) would allow for more accurate measurements; however, this is much more costly and logistically difficult for patients. Recently, Gerth et al¹⁴ utilized the same system to detect the same degree of volume change, approximately 3-4 mL, when comparing pre and post autologous fat grafting volume changes to the midface. In this paper, there were some cases with significant variability (eg, patients Nos. 23, 36, and 43 in Table 1) between the left and right sides of the face. In this small percentage of the total cohort, the accuracy may have been affected by registration of the pre and postoperative images, which can be difficult when the 3D image is not acquired at the proper angles. However, with these aberrations, the average difference in volume gain compared between the left and right sides of the face was 0.2 mL (3.3 vs 3.1 mL), suggesting sufficient consistency to make statistical conclusions included herein.

A limitation of our study is that we looked at volume augmentation at 1 long-term time point, on average 23 months postoperative, but did not evaluate how this effect

diminished over time. This would require further longitudinal study of each subject, taking more 3D images for analysis annually for the ensuing years after the procedure. We believe the effect is likely to diminish over a 10-year period, similar to the degradation of neck results in rhytidectomy, but this conclusion cannot be made without further study.

The midfacial fat compartments that make up the ptotic cheek include the nasolabial fat compartment and the medial and middle cheek fat compartments described by Rohrich et al.⁴ In addition to their atrophy, we believe these fat pads descend, resulting in a decreased volume and narrowing of the width of the upper midface in the zygomatic region and an increased volume and width to the inferior midface periorally. This phenomenon has been demonstrated when comparing MRIs of the medial cheek mass of younger patients in their 30 seconds with older patients in their 60 seconds.¹⁹ The persistent volume correction we have documented at on average 23 months supports our theory that midface ptosis contributes to midfacial devolumization. This ptosis helps describe why a youthful face has more of a heart-shaped appearance, while the aged face appears more square and bottom heavy. We believe that these cheek fat compartments behave differently than the fat pads of the periorbital region and lid-cheek junction (ie, suborbicularis oculi fat) that Lambros has shown photographically to undergo little vertical descent.²⁰ While it may be theorized that there are relative losses in the upper aspects of the cheek fat and gains of volume in the more inferior aspects of the cheek fat due to regional differences in fat metabolism, this seems unlikely. The fat compartments described by Rohrich et al⁴ traverse from superior to inferior and are unlikely to behave metabolically differently within the same anatomic structure. We believe it is much more plausible that gravity displaces more volume inferiorly within each compartment. In practice, however, the mechanism of volume loss of the upper midface and gain in the lower midface seems immaterial. The best approach is to elevate the relative hypertrophy of the lower midface up into the area of volume loss in the upper midface (Figure 4). We accomplish this with a vertical vector deep-plane rhytidectomy.

In this study, patients older than 55 years obtained on average only 2.9 mL of volume augmentation per hemiface, whereas those younger than 55 years had on average 3.9 mL of volume augmentation (Figure 5). While this difference did not achieve statistical significance ($P = .07$), it may suggest that statistical significance could have been achieved with a larger cohort. It seems plausible that younger patients have more facial fat in the midface region to reposition and hence may yield a greater volume augmentation. This data further support the idea that older patients have less midface volume and may benefit from concomitant fat grafting. When a lack of volume is determined in the preoperative evaluation, we combine fat grafting with our rhytidectomy.



Figure 4. (A, C) Three-dimensional photographs of this 54-year-old woman who underwent deep-plane rhytidectomy. (B, D) Seventeen months after vertical vector deep-plane rhytidectomy with no other concomitant procedures. (E, G, I) Two-dimensional photography was taken at the same time points before and (F, H, J) after. Note the reduction in volume in the inferior midface and the increased width of the upper midface on frontal view. (K) Three-dimensional color schematic of the upper midface. Blue represents areas of volume gain and green represents areas of volume loss in the inferior midface and nasolabial fold region.



Figure 4. Continued.

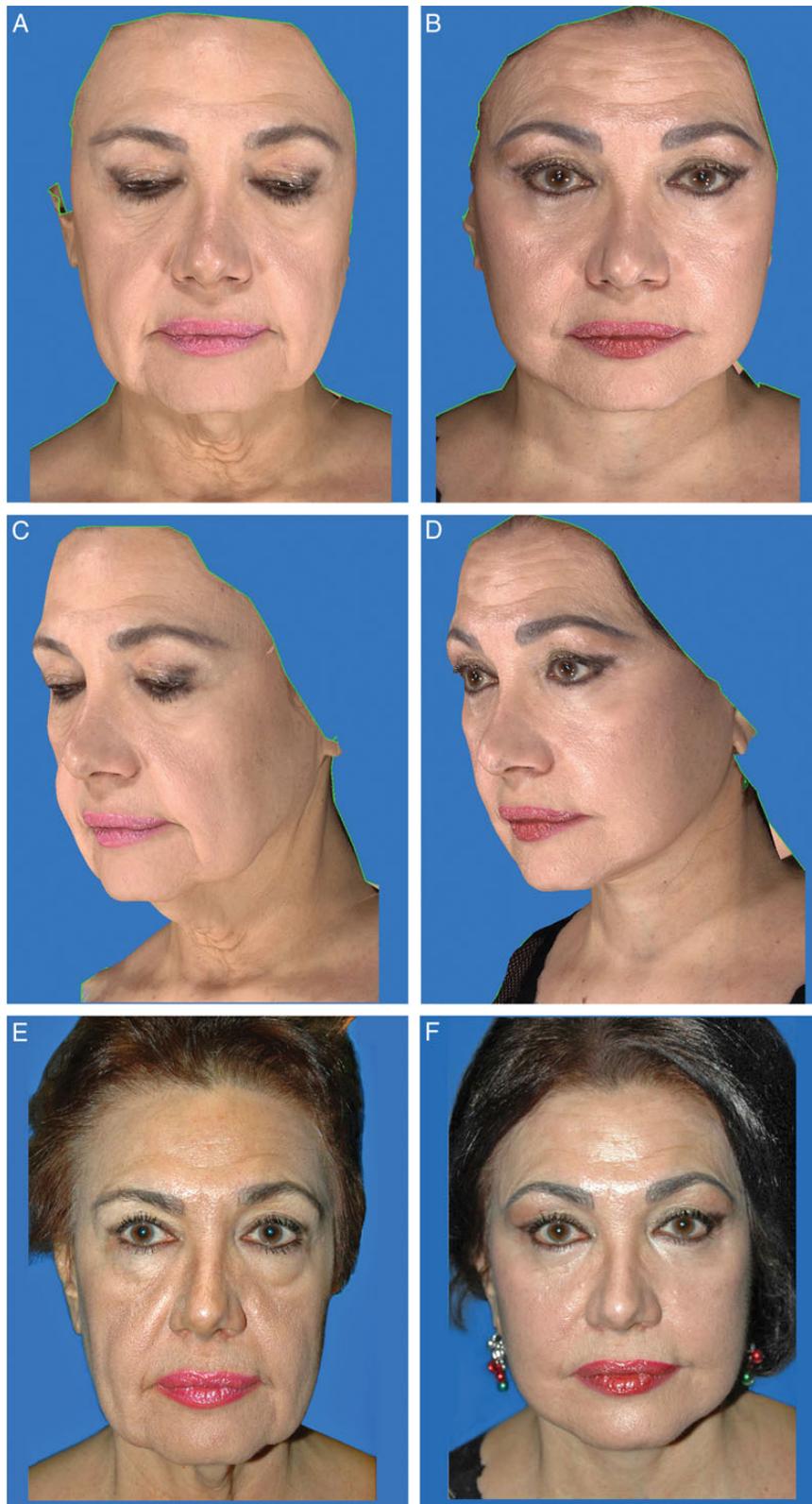


Figure 5. (A, C) Three-dimensional photographs of this 65-year-old woman who underwent deep-plane rhytidectomy. (B, D) Twenty months after vertical vector deep-plane rhytidectomy and lower blepharoplasty. (E, G, I) Two-dimensional photography was taken at the same time points before and (F, H, J) after. Note the volume augmentation of concave areas of the central cheek on frontal and three-quarter views. (K) Three-dimensional color schematic of the upper midface. Blue represents areas of volume gain and green represents areas of volume loss in the inferior midface and nasolabial fold region.



Figure 5. Continued.

We prefer injecting fat prior to the facelift dissection because fat grafting after facial flaps are elevated limits the ability to place the fat in the prior dissected planes, where it will migrate. The patients in this study only underwent a rhytidectomy with no fat grafting, so they all had adequate midface tissue volume for repositioning.

While autologous fat grafting is a powerful tool in surgical procedures for facial aging, we do believe it yields the best results when performed simultaneously with a rhytidectomy that elevates the malar fat pad. When autologous fat grafting is performed alone, the fullness of the inferior midface and the cheek lateral to the oral commissure is not lifted. The addition of fat above this widened area can result in an overly filled appearance. Fat grafting should be directed primarily to the upper midface and sparingly in the inferior midface to prevent a simian appearance.

A specific area in the midface that requires separate evaluation and treatment is the deep malar fat pad.⁴ As described by Rohrich and Pessa, the deep malar fat pad sits deep to the mimetic musculature and when deflated can create contour irregularities and a concavity of the anterior cheek. When noted preoperatively, directed injections of autologous fat to this region should be part of the comprehensive surgical procedure plan. When the contribution of the deep malar fat compartment to devolumize the midface is unclear, a vertical vector volumizing facelift can be performed primarily, and the anterior cheek can be re-evaluated for a staged fat transfer.

Despite the increase in fat grafting used in surgical procedures for facial aging, there remains an inconsistency of results and unreliable outcomes necessitating multiple revision procedures.^{7,21} The survival rates of grafted fat have been reported to be highly variable, ranging anywhere from 40% to 80%. The reasons for these disparate reports are unpredictable, and a recent comprehensive review of medical literature revealed a paucity of clinical data regarding the optimal technical steps to perform fat grafting.⁷ Due to the shortcomings of fat grafting, we prefer to use our rhytidectomy technique to improve midface volumization as a primary treatment, with fat grafting used as an adjunct.

CONCLUSION

In conclusion, vertical vector deep-plane rhytidectomy provides significant long-term volume augmentation of the midface. This procedure restores a youthful facial contour by correcting malar hollowing while sourcing that volume from the descended cheek fat compartments in the inferior midface. On average, 3.2 mL of volume augmentation is achieved in each hemi-midface after vertical vector deep-plane rhytidectomy, with no addition of grafted adipose tissue. This quantitative data demonstrates that some midface volume loss is related to gravitational descent of the cheek fat compartments and that vertical

vector deep-plane rhytidectomy may obviate the need for other volumization procedures such as autologous fat grafting in selected cases.

Supplementary Material

This article contains supplementary material located online at www.aestheticsurgeryjournal.com.

Disclosures

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