ORIGINAL ARTICLE   **FACE AND NECK SURGERY**

Objective Evaluation of Eyebrow Position After Autologous Fat Grafting to the Temple and Forehead

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Abstract

Background Fat grafting can be used to correct age-related volume loss in the face. However, the degree of rejuvenation is difficult to be evaluated.

Objectives The author sought to objectively verify the change in patients' eyebrow position after fat grafting to the upper face.

Methods The charts of 175 consecutive patients who underwent autologous fat grafting to the forehead and temple were reviewed. Perioperative changes in the heights of medial, middle, and lateral segments of the eyebrow and the eyebrow slant were recorded and compared. Key prevention strategies to avoid potential complications were discussed.

Results The eyebrow slant was increased by 2.4° after the operation which was statistically significant ($p < 0.05$). On the other hand, the medial eyebrow height was decreased, while the middle and lateral eyebrow heights were increased after the surgery which were of no significance. No major complications such as vision loss or vascular compromise were noted.

Conclusions Simultaneous autologous fat grafting to the temple and forehead significantly increased the slant of the eyebrows and corrected the loss of upper facial fullness as well. Collectively, these changes made the patient look younger and aesthetically more pleasant.

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Introduction

Traditionally, aging has been viewed as the result of tissue descent and skin laxity, and therefore, associated rejuvenation treatments focused on these conditions. However, the idea has been changing and the concept of revolumization for age-related volume loss has been gaining popularity over the past decade [1]. The loss of fullness in the face, like in other parts of the body, is the major cause of aging. The process of aging in the upper third of the face is due to more deflation than ptosis [2].

Endoscopic brow lifting and botulinum neurotoxin injection have been used to rejuvenate the upper third of the face widely. Unfortunately, undesirable results such as over-elevation and separation of the brows can be created. Botulinum neurotoxin injection may even produce an expression of surprise in terms of the brow shape [3].

A brand new paradigm of rejuvenation has been invoked by treatment targeting replacement of volume loss in the face. Aging in the face is no longer corrected by simply excising the skin and lifting the tissue, but instead restoring the volume to rebuild the facial contours. Improved outcomes have been reported by surgeons when facial volume is dealt with during facial rejuvenation [4–11].

Autologous fat grafting in cosmetic and reconstructive surgery has gained more and more popularity as it is easy to obtain, rich in source, economical in use, and capable of improving tissue defects in many portions of the body.

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However, unpredictable outcomes and variable survival rates remain drawbacks of fat grafting [12–15]. Furthermore, the lack of objective evaluation contributes to this problem as most literature in this field is based on subjective analysis of photographs [12, 16].

Volume retention of grafted fat can be assessed with three-dimensional photography [17]. However, the degree of rejuvenation is not easily evaluated. In a cohort study, Matros et al. [18] demonstrated objective measurements of the changes in eyebrow shape occurring with aging. Based on their study, brows, particularly the medial and mid-brow segments, elevate with age. This finding explains why current brow-lift surgeries which tend to preferentially elevate the medial brows create an unnatural appearance [3, 19–21].

In this article, we described our technique of autologous fat grafting to the forehead and temple and discussed the results from a series of 175 consecutive patients treated with this approach. We also implemented objective measurements of patients' eyebrows to verify the change after fat grafting to the upper face. To our knowledge, this is the first study conducted to objectively evaluate the degree of change in patients' eyebrows undergoing fat grafting to the upper third of the face.

Materials and Methods

This study was conducted according to the principles of the Declaration of Helsinki and was approved by the institutional review board. Informed consent for autologous fat grafting to the temple and forehead was obtained from each patient before treatment. This was a retrospective study which included patients with retruded foreheads and hollow temples asking for help to correct their problems. Patients with a history of coagulation disorders, previous botulinum toxin injections, forehead surgeries, or filler injections were not included in this study. After exclusion of the patients with inadequate follow-up time (<12 months), and those lost to follow-up, 175 patients were enrolled in this study.

The charts of these patients who underwent autologous fat grafting to the forehead and temple from June 2010 to July 2015 were reviewed. All the procedures were performed by the author. Patient demographics, complications, and clinical results (based on pre- and postoperative photography) were recorded.

Harvesting of Adipose Tissue

The operation was performed under intravenous sedation for all patients, and local anesthesia was given to the donor sites. The selection of donor sites depended on whether breast augmentation with fat grafting was performed or not. The abdomen was preferred and other areas such as inner thighs, lateral thighs, anterior thighs, or the knees were also used if the patient underwent concurrent fat grafting to the breasts.

After the donor areas were made sterile and draped, a typical tumescent solution (1000 mL of lactated Ringer's solution, 40 mL of 2% lidocaine, and 1 mL of 1:1000 epinephrine) was infiltrated [22]. A 3-mm stab incision was made along the skin tension line with a No. 11 blade, and liposuction was then performed with a 3-mm-diameter Mercedes cannula which was attached to a low-pressure suction machine set to under −500 mm Hg.

The liposuctioned aspirate was then centrifuged at 2100 rpm (approximately $800 \times g$) for 4 min in a cone tube. After centrifugation, the supernatant oil and inferior blood component were decanted. The fat was then transferred into 1-mL Luer-lock syringes connected to 18-gauge, 9-cm-length, blunt-tip, cannulae (Tulip Medical, San Diego, California) ready for injection.

Injection of the Graft

The cannulae were introduced via a puncture hole made at the lateral end of the eyebrow with an 18-gauge needle. To minimize the risk of vascular compromise, the areas to be augmented were marked preoperatively into three zones with the patient in a standing or sitting position (Fig. 1). Zone A comprised the upper portion of the forehead with the lower border located 20 mm above the supraorbital rim and lateral borders located along bilateral temporal suture lines. Zone B comprised the area of temporalis muscle with the lower border just above the ear. Zone C comprised the lower part of the forehead between the supraorbital rim and the lower border of Zone A with the height of around 20 mm. The injection of fat on Zones A and B was mostly performed in the deep plane, whereas in Zone C it was as superficial as possible.

Prior to the injection, the pre-processed platelet-rich plasma (1 mL from 10 mL withdrawn blood) was evenly added to the graft [23]. The injection was performed according to the principle of the "Coleman Method" [12, 15]. In addition, special care was taken to avoid potential crowding of grafted fat by using the "Solid Injection Technique" described in the author's previously published article [23, 24].

The amount of fat injected varied depending upon the loss of volume in the upper face and the desired amount of fullness. On average, total amount of fat injected into the temple and forehead varied from 12 to 68 mL.

Postoperative Care

Cold compression with wet gauze to the recipient sites was applied after the injection was completed. Due to the small
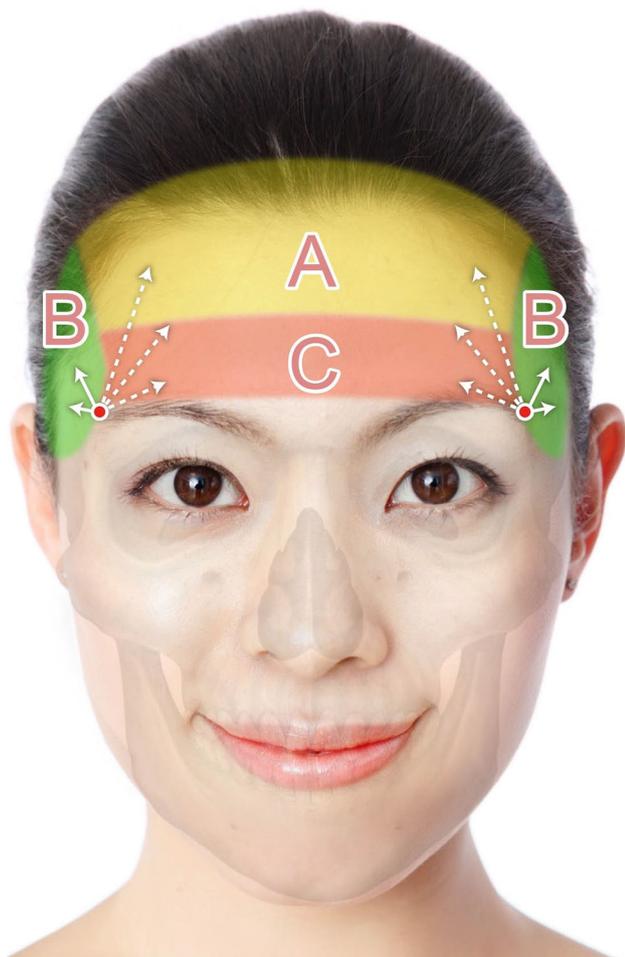
Fig. 1 To minimize the risk of potential vascular complications, the areas to be augmented were marked preoperatively into three zones. Zone A comprised the *upper* portion of the forehead with the *lower* border located 20 mm above supraorbital rim. Its lateral borders were located along bilateral temporal suture lines. Zone B comprised the area of temporalis muscle with the *lower* border just above the ear. Zone C comprised *lower* part of the forehead between the supraorbital rim and the lower border of zone A with the height of around 20 mm. The injection of fat on Zone A and B was mostly performed at deep (supraperiosteal) plane, while on Zone C as superficial (subdermal) as possible. *Red* spots indicated the entries of injection. The *solid arrows* indicated the injection directions using direct cannula. The *broken arrows* indicated the directions of injection using curved cannula

size of the entry, no suture was placed, instead a bean-sized duoderm was applied to seal the entry after the injection. Routine postoperative medications such as oral antibiotics and non-steroidal anti-inflammatory drugs were administered for 3 days or as needed. The sutures placed at the donor site were removed at 7–10 days postoperatively. All patients underwent routine follow-up at 3, 6, and 12 months postoperatively. Digital photographs were taken at each visit, and any potential complications were recorded.

Aesthetic Evaluation

All of the patients were photographed for the purpose of this study with the head in the upright position and the neck in neutral position. Digital photographs were obtained with the forehead and eyebrows in a maximally relaxed position.

For objective evaluations, a metric ruler was taped to the mid-forehead anterior to the hairline of the patients. Patients were asked not to shape their eyebrows at least 1 week before every visit. Also, before the photographs were taken, any makeup was removed. The eyebrow heights were determined by measuring from a reference horizontal plane drawn between the medial canthus to vertical points on the upper brow margin at the medial canthus, pupil, and lateral canthus. These heights were defined as medial, middle, and lateral eyebrow heights (Fig. 2). By using Adobe imaging software (San Jose, Calif.), the metric ruler was manipulated on screen to exactly measure these distances [18]. The slant of the eyebrows was also calculated and recorded for each patient both pre- and post-treatment. Eyebrow slant was defined as the angle between the perpendicular line to the ground and the line joining upper margins of medial and middle eyebrow heights. An example of the methodology, including sample measurements, is shown in Fig. 2.

For the assessment of patient and investigator satisfaction, a five-point Likert scale (1, worse; 2, no change; 3, improved; 4, much improved; and 5, very much improved) was used to indicate their subjective satisfaction with regard to the result of the operation. The investigator was not involved in the operation and was blinded regarding the photographs that were before or after treatments.
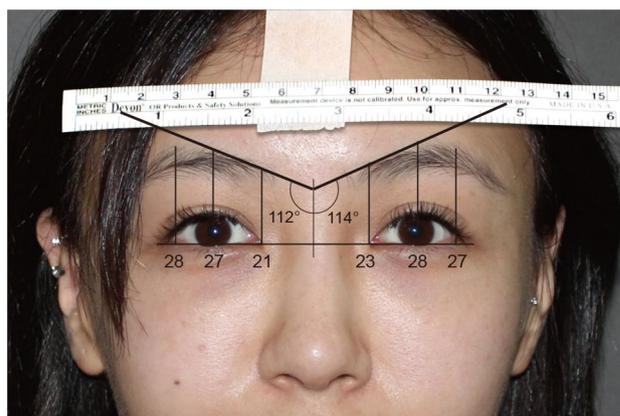
Fig. 2 All images included a metric ruler taped to the mid-forehead *above* the brows. Each eyebrow position was determined by measuring from a reference *horizontal* plane drawn between the medial canthi to *vertical* points on the *upper* brow margin at the medial canthus, pupil, and lateral canthus. These heights were defined as medial, middle, and lateral eyebrow heights

Statistical Analysis

Demographics and results (including complication rates) were analyzed with SPSS software, version 17.0 (SPSS, Inc, an IBM Company, Chicago, Illinois). Statistical significance by t test was defined as $p < 0.05$.

Results

The mean patient age was 42 years (range 21–76), and mean BMI was 20 (range 15–32). The mean transplanted volume of graft was 42 mL (range 12–68), and the follow-up period was 26 months (range 12–74) (Table 1).

The medial eyebrow heights in some patients were decreased, while in others were increased. On average, this height was slightly decreased and the change was very subtle which was not statistically significant. On the other hand, the middle and lateral eyebrow heights were increased after the surgery. All these changes were not significant. However, the eyebrow slant was increased by 2.4° after the operation which was statistically significant ($p < 0.05$) (Table 2).

There were no major complications after the procedure. All the adverse events were minor in nature and subsided spontaneously several weeks after the treatment. Most patients undergoing fat graft injection to the upper third of the face developed injection site edema which could be seen in almost all other facial surgeries and was self-limited. Under-correction was overcome by further session of treatment (Table 3). Postoperative hyperpigmentation developed on the inner thighs in 36% of our patients as most of them underwent simultaneous fat grafting to the breasts in which the inner thighs were used as a part of the donor sites. However, in almost all cases the hyperpigmentation disappeared within a year after the surgery.

Patient satisfaction was 90% (with 14% very much improved, 60% much improved, and 16% improved), and investigator satisfaction was 91% (with 16% very much improved, 58% much improved, and 17% improved), which is demonstrated in Fig. 3. An illustration of perioperative changes in eyebrow position and eyebrow slant is demonstrated in Fig. 4. Typical results of patients are shown in Figs. 5 and 6.

Discussion

Aging has been regarded as a process of tissue descent and skin texture change and the associated treatment focused on these issues from the past to the present. However, loss in facial volume as a portion of facial aging has become accepted recently, and revolumization for age-related

volume loss has gained more popularity [1]. The age-related changes in the upper face, similar to other regions of the face, should be considered in three-dimensional form with deflation rather than ptosis being the major factor in the aging process [2].

The concept about age-related facial volume loss is not new although the popularity is a recent phenomenon. Nearly 50 years ago, Gonzalez et al. [14] described senile facial change after measuring thickness of adipose tissue in various areas of the faces of newborn, young adult, and old cadavers. They found that the progressive loss of volume in the face is associated with age.

It remained unclear why their findings did not get appropriate attention. Either surgeons at that time did not accept the validity of the study or the inadequacy in the techniques and materials to address this issue might be the cause [7, 25–31].

Autologous fat grafting can be used to address the volume loss in the face. It is easy to obtain, rich in source, economic in use, and capable of improving tissue defects in many portions of the body. However, unpredictable outcomes and variable survival rates remain disadvantages of fat grafting [12–15]. Furthermore, the lack of objective evaluation contributes to this problem as most literature in this field is based on subjective analysis of photographs [12, 16].

In a cohort study, Matros E. et al. [18] demonstrated objective measurements of the changes in eyebrow shape that happened with aging. In the 20–30-year-old cohort, the lateral brow was positioned significantly higher than the mid-brow. In contrast, the 50–60-year-old patients have lateral and mid-brow segments at similar heights, creating a flat appearance or in some cases an apex medial configuration. These measurements were described as youth's aesthetically ideal eyebrow appearance, which, in turn, could serve as the target for forehead rejuvenation [32]. Theoretically, correction of volume loss with fat grafting rebuilds the volume and shape in the upper face. The droopy eyebrow, the lateral portion in particular, due to a saggy temple can be corrected after volume replacement to this area. The effect in this procedure resembles inflating a flaccid balloon and accordingly elevating the droopy eyebrow. This explains why fat grafting to the temple and forehead has influences on eyebrow height.

In the current study, we used fat grafting to address the aging in the upper third of the face. The average age of our patients was 42 and the average BMI was 20 (Table 1). After this procedure, the medial eyebrow heights in some patients were decreased, while in others they were increased. On average, this height was slightly decreased by 0.15 mm which was very subtle and not statistically significant. The middle and lateral segments of the brows were elevated by 0.22 and 0.29 mm, respectively. These

Fig. 3 Patient and investigator satisfaction

Fig. 4 An illustration to demonstrate perioperative changes in a patient's eyebrow height and slant. Note the increase in eyebrow slant in postoperative view (**b**) as compared with preoperative view (**a**)
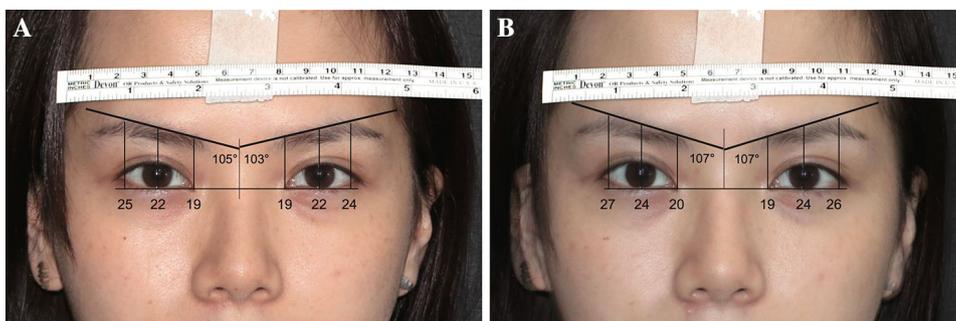
changes were not statistically significant either. However, the eyebrow slant was significantly increased ($p < 0.05$) by 2.4° on average (Table 2). A youthful and aesthetically pleasing appearance in the upper third of the face could be restored after this procedure.

The influence of upper eyelid blepharoplasty on eyebrow position remains controversial. Some authors in their articles concluded that the position of the eyebrow is not lowered after an upper eyelid blepharoplasty [33–35]. However, for some patients, in particular those who are male and senile and those presenting for the correction of redundant tissue in the brow, there is a tendency of the eyebrow to move down after upper eyelid blepharoplasty [36–38]. Six patients (3%) in our study underwent subsequent upper eyelid blepharoplasty several months after the procedure. They were female and young. No concurrent brow surgery was performed. According to the published literature, the impact of upper eyelid blepharoplasty on eyebrow heights in these patients was neglectable and the inclusion of these patients in our study did not decrease the power of evidence.

Based on our study, the aging appearance in the upper face could be effectively corrected by fat grafting to the

temple and forehead. The effect could last as long as 3 years after one session of treatment. Almost all of our patients were satisfied with the result (with 14% very much improved and 60% much improved).

Aesthetic Discrepancy in Asian Women

Upper face volumization is widely accepted among Asian women. Most females hope to have a full temple and forehead due to physiognomic considerations as they believe hollow temples could potentially lead to a bad relationship between couples [39, 40]. Therefore, apart from youthful skin, an oval shape of the face and clearly defined facial contours, the goals of anti-aging treatment in the upper face for Asian women are restoring the volume in the temples and correcting the retrusion in the forehead.

Data from the present study also objectively demonstrated that there was an ethnic difference in the ideal brow shape. Asian women are more interested in the correction of hollow temples and a retruded forehead than the height of their eyebrows. People with a well-projected forehead and full temples were usually regarded as young and

Fig. 5 Patient 1: Pre-treatment views (**a, c, e**) and post-treatment views at 56 months (**b, d, f**). This 40-year-old woman with a body mass index of 25.9 (height, 170 cm; weight, 75 kg) presented for the correction of retruded forehead and hollow temple. She also asked for cosmetic augmentation of the nose and chin. Autologous fat grafting of 27 mL in the forehead and temple per side, 5 mL in the nose, 3 mL in nasolabial folds per side, 8 mL in the chin, 3 mL to tear trough and upper cheeks per side. Three months later, laser lipolysis of her face and submental area, upper blepharoplasty, and hyaluronic acid injection in the lips were performed. The desired volume in the upper third of the face was restored, and she was happy with the result

Fig. 6 Patient 2: Pre-treatment views (**a, c, e**) and post-treatment views at 12 months (**b, d, f**). This 31-year-old woman with a body mass index of 17.8 (height, 163 cm; weight, 47.3 kg) presented for a more aesthetically pleasing face. Autologous fat grafting of 6 mL in the forehead per side, 3 mL in tear trough per side and 3 mL in lower cheek per side. She was very happy with the result

aesthetically pleasing. This explained why the satisfaction rate of fat grafting to those areas was high as a result although the change in eyebrow slant was subtle.

Avoidance of Potential Complications

There were no major complications, such as vision loss, infection, or uneven surface over the recipient sites developed in our patients. Most patients experienced transient swelling and minor bruising at the injection sites several days after the procedure which were also noted in almost all other surgeries performed in the face as well. The swelling and bruising subsided spontaneously without treatment within 1–2 weeks.

In a review article, Beleznay et al. described the most serious complication of vision loss resulting from filler injection in the face. The regions with highest risk indicated by them were the glabella, nasal region, nasolabial fold, and forehead. The filler type most likely to create blindness was autologous fat graft [41]. Due to the lack of successful treatment for blindness and the low chance of recovery in most cases of vision loss, they strongly recommended surgeons have a thorough understanding of the vascular anatomy and to keep the key prevention strategies in mind.

For injection in the glabellar and forehead regions, the operator must understand the anatomy of the supratrochlear and supraorbital arteries which are most likely to cause complications if a filler injection is to be performed. Both these arteries are branches of the ophthalmic artery. Therefore, if with enough pressure a filler would be placed

Box 1 Key prevention methods to avoid substantial vascular compromise in autologous fat grafting for facial rejuvenation

Key prevention methods	Possible mechanism and reasons
Inject slowly and with minimal pressure.	Inject in smaller increments in order that any filler inadvertently injected into the artery can be flushed distally. Bolus injection of the filler can lead to retrograde traveling and subsequent arterial occlusion. No more than 0.3 mL of filler should be injected with each increment
Use 1-mL syringe	Smaller syringes are preferred to larger ones as a large syringe may make it more difficult to control the volume and increase the probability of injecting a larger bolus
Use cannula with the diameter no less than 18 gauge.	Larger caliber cannulae are less likely to pierce a blood vessel
Follow the principle of injection on A, B, C zones.	Reasons have been highlighted in the text
Stop the injection and skip to work on another zone if bleeding is encountered.	Compress the bleeders and redo the injection after bleeding stops. Since the injection pressure is low, the risk of intravenous injection is low as well

intravascularly into either of these arteries, it can retrogradely move into the ophthalmic artery and result in ocular complications [42].

The supratrochlear artery travels along the medial canthal vertical line in a relatively constant manner usually within 5 mm from this vertical line. After starting its course deep at the superior medial orbit, this artery then goes superiorly and becomes subcutaneous from 15 to 25 mm above the supraorbital rim. The supraorbital artery also starts its course deep and becomes subcutaneous approximately 15–20 mm above the supraorbital rim. It travels along a vertical line corresponding to the medial limbus of the cornea and becomes subcutaneous as it goes superiorly [43].

As such, injections at the glabella or inferior forehead (Zone C) at the level of the supraorbital rim or within 20 mm of that location should be superficial. However, injection more superiorly on the forehead (Zone A) should be deep in a supraperiosteal plane to avoid intravascular injection [43].

For injection in the temple area (Zone B), it is also very important to realize that the lateral face, scalp, and forehead are primarily supplied by the superficial temporal artery and its branches. This artery starts in the superficial lobe of the parotid gland as the terminal branch of the external carotid artery. At the superior border of the zygomatic arch, the superficial temporal artery continues higher and branches into the frontal branch and parietal branch. As the frontal branch of the superficial temporal artery moves medially, it becomes more superficial up to a subdermal plane [44].

However, ocular complications when injecting in the temple may result from injection into the middle temporal vein (MTV). It has been hypothesized that it may be easier for a filler to be unintentionally injected into the MTV due to its larger caliber and tortuous courses distributed along the superficial plane in the temple. It is suggested that the safest area to inject a filler in the temple is one finger

breadth above the zygomatic arch as the MTV was not found in that area. In addition, it is recommended that the filler be placed in a supraperiosteal plane rather than subcutaneously as the MTV is located more superficially when the graft injection is performed on zone B [45].

After successfully treating 175 patients for the correction of aged upper face by autologous fat grafting without any major complications, we recommended the use of 1-mL syringes and blunt-tip cannulae with diameters equal to or larger than 18 gauge. The volume placed during each pass should be less than 0.3 mL. We also recommended the use of curved cannula to circumvent the convexity of the forehead scalp. Fat injection through the entry made at the lateral end of the eyebrow could be easily performed at all layers beneath the skin of the scalp especially on zone A and B by using a curved cannula and following the rules of proper layering technique. Key prevention methods are collectively highlighted in Box 1.

Limitations

Our study has some limitations. First, our sample only included female patients because Asian males were concerned about the aging of the middle and lower face rather than the upper face, and accordingly, the number of male patients was very small. Second, we did not use three-dimensional photography to assess the volume change of the grafted fat. The survival rate of the grafting was not

Table 1 Patient demographics

Characteristic	Value (range)
Age (years)	42 (21–76)
BMI	20 (15–32)
Volume transplanted (mL)	42 (12–68)
Follow-up period (mo)	26 (12–74)

Table 2 Objective changes in eyebrow position

	Before treatment (SD)	After treatment (SD)	p value (by t test)
Eyebrow height			
Medial (mm)	22.99 (3.15)	22.84 (3.15)	0.481
Middle (mm)	26.14 (2.96)	26.36 (2.92)	0.339
Lateral (mm)	26.81 (2.82)	27.10 (2.88)	0.204
Eyebrow slant, degree	101.93 (4.25)	104.33 (5.10)	0.000

Table 3 Postoperative events $n = 175$

Items	No. (%)
Complications at recipient sites	
Bruising	61 (35)
Postoperative edema	168 (98)
Under correction	21 (12)
Oily skin	4 (2)
Complications at donor sites	
Uneven surface of donor sites	5 (3)
Hyperpigmentation	63 (36)
Reoperation	
Second session	11 (6)
Third session	2 (1)
Subsequent upper eyelid blepharoplasty	6 (3)

known. Future studies should take this volumetric technique into consideration.

Conclusions

Fat grafting can be used to correct the aging appearance of the upper face. In Asian women, this procedure significantly increases the slant of the eyebrows and corrects the loss of facial fullness as well. More than 90% of the patients were satisfied after one session of fat grafting to their upper face.

However, published literature reveals that inadvertent intravascular injection can result in severe complication such as blindness. This complication can be prevented if a surgeon has good knowledge of the facial anatomy and follows proper injection technique focusing on the use of 1-mL syringes and 18-gauge cannulae. Most importantly, vary the injection layer depending on different zones in the upper third of the face and take advantage of a curved cannula to perform fat grafting on patient's forehead to circumvent the convexity of the skull.

Compliance with ethical standards

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