



Analysis of age-related changes in midfacial fat compartments in Asian women using computed tomography

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Summary Background: Volume restoration is no more a fresh theory for midfacial rejuvenation. However, lack of knowledge regarding the natural ageing process of fat compartments often leads to an insufficient or excessive clinical result. The aim of this study is to reveal the age-related changes in midfacial fat compartments and the correlation between midfacial grooves and the related fat compartments.

Methods: This study included 60 Asian females in defined age-based categories. The thickness of the infraorbital fat compartment, the nasolabial fat compartment, and the cheek fat compartments were measured using computed tomography (CT) images. Analysis of correlations between midfacial grooves and the related fat compartments was performed using the SPSS software.

Results: A tendency of thickening in the infraorbital fat and nasolabial fat compartments with age was observed. The superficial layer of cheek fat compartments was found to be thinner, and a similar tendency was observed in the medial part of deep medial cheek fat. However, it was thicker in the lateral part of deep medial cheek fat. There was a negative correlation between the fat thickness of deep medial cheek fat and both the severity of tear trough deformity

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and the nasolabial fold. A positive correlation between the lower third of the nasolabial fat compartment and the severity of the nasolabial fold was found as well.

Conclusion: Different midfacial fat compartments tended to undergo selective hypertrophy or atrophy with ageing. The findings of this study suggested that augmentation of the deflated fat compartment and liposuction of the hypertrophic fat compartment can provide a more natural effect in facial rejuvenation.

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Introduction

Facial ageing is a multifactorial process caused by changes in the structure of the skin, muscles, bones, and fat.¹⁻³ Gravity was used as the main cause for drooping facial soft tissue. However, a significant effort has proven that volume loss leads to the idea of “pseudoptosis,” illusion of ptosis.⁴⁻⁶ Several scholars have emphasized the importance of the facial fat to the complex process of facial ageing.^{7,8}

A study conducted by Rohrich et al.^{9,10} demonstrated that facial fat was highly compartmentalized by several independent anatomical units, which were separated from each other by vascularized boundaries instead of a homogeneous mass. These fat compartments could be distributed in two distinct planes, including the superficial plane and the other one located under the superficial musculoaponeurotic system. With the standardization of fat grafting techniques presented by Coleman et al., volume restoration has become relatively simple, reliable, and safe in facial rejuvenation.^{11,12} To date, regarding the lack of a sufficient understanding of age-related changes in midfacial fat compartments, it is indeed difficult to optimize facial rejuvenation and achieve a more natural appearance instead of a balloon face.

At present, a number of methods such as tissue puncture using needles,¹³ ultrasound,^{14,15} magnetic resonance imaging (MRI),¹⁶⁻¹⁸ and computed tomography (CT) are used for fat thickness measurement.^{19,20} Currently, describing the age-related changes in the facial fat compartments is challengeable because of the limitations of cadaveric studies. First, the morphological changes mainly occur during the preservation process. Second, the sample size is small. Third, there is a controversy regarding the age-related changes in the facial fat compartments.

The aim of our study was to demonstrate the age-related changes in midfacial fat compartments in Asian women using CT, with strict control of body mass index (BMI) and the underlying disease. We also assessed a relationship between related fat compartments and the nasolabial fold as well as tear trough deformity.

Patients and methods

Patients

Data were retrospectively collected from previously acquired head and neck CT scans using the picture archiving and communication system at Zhujiang Hospital of Southern Medical University (Guangzhou, China) from January 2015 to December 2017. The study included a total of 60 Asian females. Those who were diagnosed with facial deformity,

facial infections, cancer, chronic malnutrition, human immunodeficiency virus (HIV) infection, or a history of facial plastic surgery or of taking hormones were excluded. Moreover, the BMI of subjects was limited to a range of 18.0-23.9 kg/m². The patients were categorized into three age-based groups (20-39 years old, 40-59 years old, and 60-79 years old), and each group comprised 20 subjects. The current study obtained approval from the Ethics Committee of our institution.

Measurement of midfacial fat thickness

All sagittal images were standardized by the sella-nasion line as a reference line, of which the coronal images were perpendicular to the vertical line (Figure 1). The intersections of four vertical lines (medial 1/4 [S1], midline [S2], lateral 1/4 [S3], and lateral margin of the orbital rim [S4]) and four horizontal lines (infraorbital rim [C1], inferior margin of zygomatic arch [C2], hard palate [C3], and superior alveolar [C4]) were marked on the coronal plane, which could identify the whole orbital rim. Besides, 7 points were labelled as the medial part and the lateral part of the infraorbital fat (IO-Med and IO-Lat), the upper third, the middle third, and the lower third of the nasolabial fat compartment (N-Upp, N-Mid, and N-Low), as well as the medial part and the lateral part of the cheek fat compartment (C-Med and C-Lat) (Figure 2). In the infraorbital area, measurements were carried out at the superficial (superficial to the orbicularis oculi muscle) and the deep (orbicularis oculi muscle to the infraorbital rim) portions. For the cheek fat compartment, the superficial and the deep portions were measured based on the levator labii superioris muscle²¹ and the zygomaticus major muscle,²² respectively, and each portion was measured by three segments as well. Three repeated measurements were undertaken in a blind manner by three trained observers at each anatomic site on the sagittal images of the CT scan.

Grading evaluation of tear trough deformity and nasolabial fold

Three-dimensional (3D) reconstruction of the cranial skin and soft tissue was performed by adjusting the window width and window level at MxView workstation. When the 3D skull images were rotated at 45°, the grading evaluation could be made for the tear trough deformity based on Barton's grading standard²³ and for the nasolabial fold based on the Wrinkle Severity Rating Scale²⁴ (Figure 3).

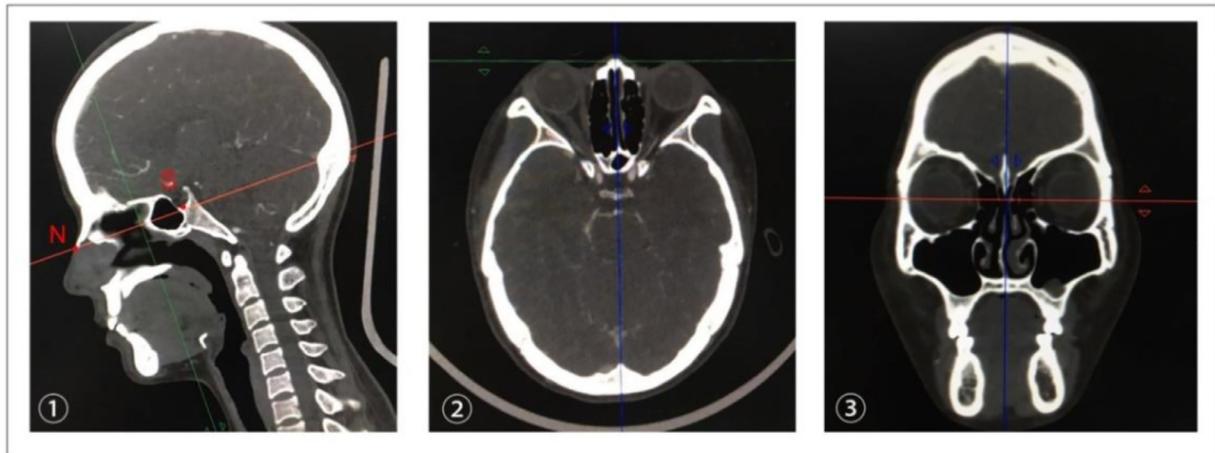


Figure 1 An illustration of the correction of three-dimensional images on computed tomography. The sagittal images were standardized by the reference line from the sella through the nasion, and the coronal images were perpendicular to sella (S) and nasion (N).

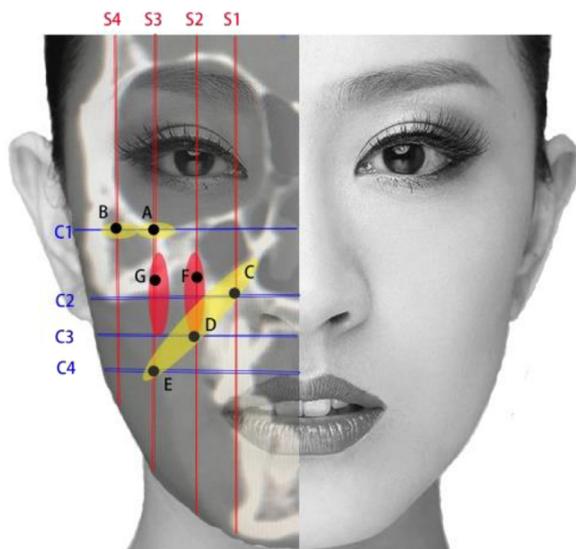


Figure 2 A location map of the seven measured points on the coronal plane. (A, B), Medial and lateral part of the infraorbital fat; (C, D, and E), upper third, middle third, and lower third of nasolabial fat compartment, respectively; (F, G), medial part and lateral part of the cheek fat compartment.

Statistical analysis

Statistical analysis was performed using the SPSS 20.0 software (IBM, Armonk, NY, USA), and a P -value ≤ 0.05 was considered statistically significant. The Kruskal-Wallis one-way analysis of variance or the least significant difference test was used for making a comparison between the groups, and a Dunn-Bonferroni test was used for making post hoc comparisons. The Spearman correlation coefficient was used to analyse the relationship between the thickness of related fat compartments and the severity of the tear trough deformity as well as the nasolabial fold.

Results

Patients' characteristics

A total of 120 midfacial fat compartments from 60 adult females were measured and analysed. The mean age was 32.25 ± 5.05 years for the young age group, 46.75 ± 6.16 years for the middle-aged age group, and 69.55 ± 5.87 years for the old age group. All three age groups had similar BMIs (Table 1).

Fat thickness in midfacial fat compartments

Regarding difference in fat thickness with age, it appeared to be thicker or thinner in different areas (Table 2).

The infraorbital fat compartment of the old age group was significantly thicker than that of the young age group in the medial site ($P=0.015$) and was significantly thicker than that of the middle-aged age group in the lateral site ($P=0.011$). For suborbicularis oculi fat, the fat compartments in both the middle-aged age group ($P=0.011$) and the old age group ($P=0.014$) were notably thicker than those in the young age group, and no significant differences were observed between the middle-aged age group and the old age group (Figure 4).

A similar difference in the nasolabial fat compartment was found in the lower third. The fat compartments in the old age group were remarkably thicker than those in the young age group ($P=0.000$) and the middle-aged age group ($P=0.004$). However, there were no significant differences found in the fat thickness of both the upper third and the middle third of the nasolabial fat compartment with age (Figure 5).

A high statistical significance of the fat thickness was observed in the medial part of superficial cheek fat compartment with age in both the middle third and the lower third, which showed that the fat compartments were thinner in the old age group compared with those in both the young age group (the middle third, $P=0.007$; the lower third, $P=0.006$) and the middle-aged age group (the mid-



Figure 3 Grading evaluation of tear trough deformity and nasolabial fold on the cranial skin and soft tissue reconstruction with three-dimensional image of the skull rotating 45°.

Table 1 Characteristics of study subjects.

	Young age, n = 40	Middle-aged, n = 40	Old age, n = 40
Age (range)	20-39	40-59	60-79
Age,* average ± SD	32.25 ± 5.05	46.75 ± 6.16	69.55 ± 5.87
BMI, average ± SD	21.53 ± 1.67	21.57 ± 1.22	21.39 ± 1.09

*P** = *P* < 0.05.

BMI, Body mass index; *SD*, standard deviation.

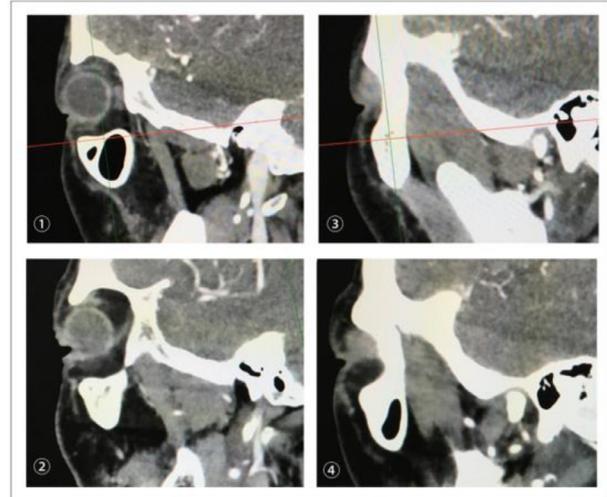
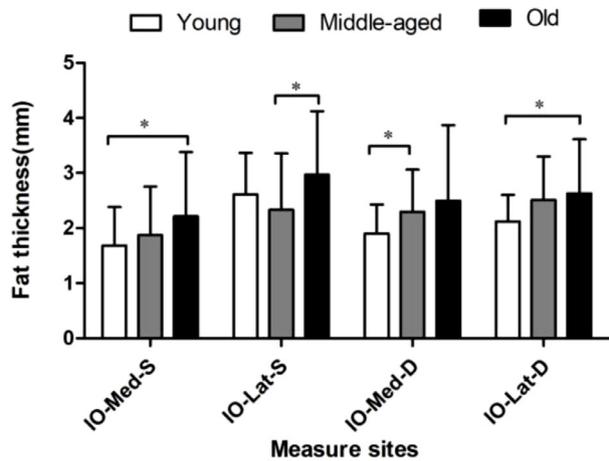


Figure 4 Multiple comparisons of thickness in young, middle-aged, and old age groups from the infraorbital fat compartment. *, *P* < 0.05. ①, ③, Medial and lateral part of the infraorbital fat compartment in the young age group. ②, ④, Medial and lateral part of the infraorbital fat compartment in the old age group. *S*, superficial; *D*, deep.

dle third, *P* = 0.014; the lower third, *P* = 0.010). A significant difference was noted in the lateral part of superficial cheek fat compartment in the middle third and lower third between the old age group and the middle-aged age group (the middle third, *P* = 0.015; the lower third, *P* = 0.015). Different changes were observed with age in both the medial part and the lateral part of the deep medial cheek fat. In the medial part, the fat compartments of the old

age group were thinner than those of both the young age group (*P* = 0.001) and the middle-aged age group (*P* = 0.014) in the upper third. In the middle third, the fat compartments were statistically thinner in both the old age group (*P* = 0.014) and the middle-aged age group (*P* = 0.000) compared with those in the young age group. A similar tendency was found in the lower third when comparing the fat thickness of the old age group (*P* = 0.013) and the young

Table 2 The fat thickness of midfacial fat compartments.

Sites	Young age	Middle-aged	Old age
Infraorbital fat compartment			
Medial	1.66 ± 0.72	1.90 ± 0.90	2.27 ± 1.18
Lateral	2.61 ± 0.76	2.33 ± 1.02	2.97 ± 1.16
Sub-orbicularis oculi fat			
Medial	1.90 ± 0.53	2.29 ± 0.77	2.50 ± 1.37
Lateral	2.12 ± 0.48	2.51 ± 0.79	2.63 ± 0.98
Nasolabial fat compartment			
Upper third	5.31 ± 1.30	5.01 ± 1.36	5.61 ± 1.21
Middle third	8.25 ± 1.44	8.12 ± 1.39	7.82 ± 1.04
Lower third	9.69 ± 1.32	10.58 ± 1.53	12.02 ± 2.23
Medial cheek fat compartment			
Upper third	6.67 ± 1.06	6.82 ± 0.73	7.06 ± 1.07
Middle third	7.63 ± 0.87	7.57 ± 0.82	7.08 ± 0.97
Lower third	6.60 ± 0.95	6.57 ± 0.91	6.05 ± 0.80
Middle cheek fat compartment			
Upper third	4.22 ± 1.04	3.86 ± 0.90	4.05 ± 0.99
Middle third	6.61 ± 1.36	6.38 ± 1.17	5.72 ± 1.03
Lower third	10.83 ± 1.19	10.94 ± 1.20	10.21 ± 1.49
Deep medial cheek fat (medial part)			
Upper third	3.70 ± 0.88	3.50 ± 0.75	3.00 ± 0.99
Middle third	5.07 ± 1.28	4.11 ± 0.89	4.43 ± 1.23
Lower third	6.19 ± 1.18	5.34 ± 1.16	6.00 ± 1.21
Deep medial cheek fat (lateral part)			
Upper third	3.86 ± 0.85	4.04 ± 0.92	3.79 ± 1.09
Middle third	4.46 ± 1.02	5.1 ± 1.11	5.45 ± 1.53
Lower third	4.73 ± 1.57	5.58 ± 1.19	5.70 ± 1.37

Length: mm.

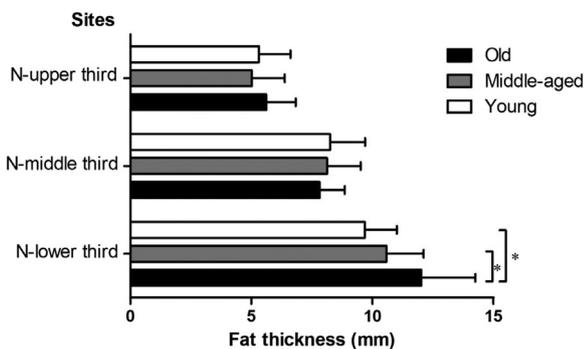


Figure 5 Multiple comparisons of fat thickness in young, middle-aged, and old age groups from the nasolabial fat compartment. *, $P < 0.05$.

age group ($P=0.002$) with that of the middle-aged age group. However, in the lateral part of the deep medial cheek fat, the compartments of the old age group were statistically thicker than those of the young age group in both the middle third ($P=0.005$) and the lower third ($P=0.002$) (Figure 6).

Correlations between midfacial grooves and fat thickness of the related fat compartments

The severity of tear trough deformity significantly decreased with the thicker deep medial cheek fat in the upper third ($P \leq 0.05$) (Table 3).

Table 3 Spearman’s correlation between tear trough deformity and the related fat compartments.

Facts	Rs	P
Infraorbital fat compartment (medial part)	0.263	0.06
Suborbicularis oculi fat (medial part)	0.619	0.09*
Nasolabial fat compartment	-0.432	0.04*
Medial cheek fat compartment	0.236	0.14
Deep medial cheek fat (medial part)	-0.514	0.00*

P^* : $P < 0.05$.

Table 4 Spearman’s correlations between nasolabial fold and the related fat compartments.

Facts	Rs	P
Nasolabial fat compartment		
Upper third	0.263	0.04*
Middle third	0.412	0.17
Lower third	0.636	0.00*
Medial cheek fat compartment		
Upper third	-0.242	0.06
Middle third	0.633	0.00*
Lower third	0.231	0.04*
Deep medial cheek fat		
Upper third	-0.379	0.00*
Middle third	-0.547	0.05*
Lower third	-0.725	0.02*

P^* : $P < 0.05$.

Additionally, the severity of the nasolabial fold decreased with the thicker deep medial cheek fat in the middle third and the lower third ($P \leq 0.05$) (Table 4). The severity of the nasolabial fold was closely and positively correlated with the thickness of the lower third of the nasolabial fat compartment ($P \leq 0.05$) (Table 4).

Discussion

Facial ageing is a complex process, involving changes in skin, muscle, fat, and bone structures.¹ Previous studies have demonstrated that facial fat is the most notable change with age.⁴ However, it is still hard to precisely describe the structural fat ageing changes based on cadaveric studies. A new stage for facial fat research came with the wide application of Radiology. Gierloff et al.^{19,20} described the morphology of facial compartments and the relationship of adjacent fat compartments through the 3D reconstruction CT images of cadaveric studies. However, such cadaveric studies had several limitations. The subjects of the study were old (ages 54-104 years old) and not alive, which was inevitable extrusion during specimen preservation, resulting in the fact that it could not precisely explain the morphological changes with age. In contrast, the subjects of our study included 60 adult females with the age range of 20-79 years old who were from Guangdong, Hunan, Hubei, Heilongjiang, Beijing, and other provinces across China. The study described the characteristics of facial fat compartments in Asian women with age representatively.

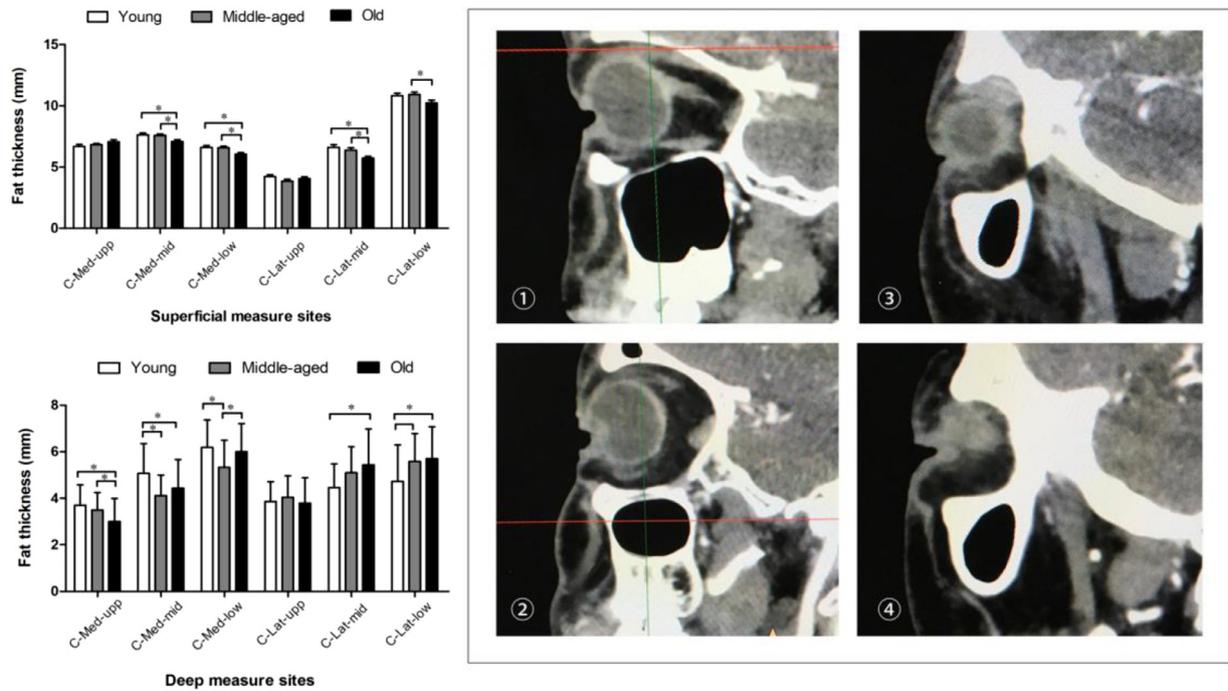


Figure 6 Multiple comparisons of fat thickness in young, middle-aged, and old age groups from the cheek fat compartment. *, $P < 0.05$. ①, ③, Medial and lateral part of the cheek fat compartment in the young age group. ②, ④, Medial and lateral part of the cheek fat compartment in the old age group.

In the present study, we demonstrated that Asian midfacial fat compartments continuously change throughout life and that they appear selectively thicker or thinner in different areas. It could be described by Lambros's theory²⁵ that the selective atrophy of deep compartments leads to the loss of support for the superficial compartment, causing a sagging appearance.

Our study revealed that the fat in the infraorbital area became thicker with ageing in both the superficial and deep layers, which was consistent with the findings of Jang et al.²⁶ The clinical phenomenon was in good agreement with our results that the fat thickness in the nasolabial area was thicker with age, mainly in the lower third. We confirmed that the thicker fat compartment was one of the reasons for the deep nasolabial fold and the sagging appearance. There are similarities in a study conducted by Gosain et al.^{18,27} They measured the nasolabial fat thickness using high-resolution MRI in both static and smiling states and found that the fat of the older age group was thicker than that of the young age group. In contrast to the infraorbital area and the nasolabial area, the fat of deep medial cheek became thinner with ageing, mainly in the medial part. This can also be described by the term *loss of midfacial projection*, causing a depressive and tired insight.

Further research regarding the correlation between facial grooves and the fat compartments was conducted in our study. It was revealed that there was a negative correlation between the severity of tear trough deformity and the thickness of deep medial cheek fat in the upper third. It was inferred that volume restoration in the upper third of the deep medial cheek fat could improve the tear trough deformity. We proposed that liposuction to the nasolabial

fat compartment could soften the nasolabial fold because the severity of the nasolabial fold was closely and positively correlated with the thickness of the lower third of the nasolabial fat compartment. Additionally, Wang and Huang²⁸ obtained a similar conclusion from their cadaver study and clinical surgery. The results of this study suggested that augmentation of deep medial cheek fat should be included in the correction of the nasolabial fold because of the statistical and negative correlation between the severity of the nasolabial fold and the fat thickness of deep medial cheek fat.

The treatment implications of these findings are significant. Rohrich insisted that knowing the anatomical location of the fat compartments serves as a global positioning system for volume correction injections.²⁹ They injected saline into the deep medial fat compartment, improving the anterior projection of the cheek and reducing the nasolabial fold.³⁰ However, the precise knowledge of modifications of the fat compartment is a prerequisite to correctly adjusting the quantities required for a natural-looking rejuvenation. We observed a tendency that selective thickening or thinning occurred in different fat compartments with ageing in our study. Following the age-related changes in facial fat compartments, we suggested that augmentation to the deflated fat compartment and liposuction to the hypertrophic fat compartment can provide a natural effect in facial rejuvenation. It is worth emphasizing that volumetric correction to deep medial cheek fat may improve the tear trough deformity and nasolabial fold.

The present study has several limitations. First, serial imaging of the same individual over time would be an ideal method to study the changes in the facial fat compartments. Because it is currently difficult to collect

data, the fat thickness at one time point among different individuals in defined age categories was compared in this study. It was revealed that there was no significant difference in BMI among subjects, which ruled out the effects of abnormal body weight and abnormal nutritional status on fat thickness. Second, CT images were acquired in a supine position, and therefore, they could not reflect the distribution of fat compartments by the alteration vector of gravity. The design with the upper body elevated 30° by Gosain et al.^{18,27} should be imitated in the further study. Third, this study only involved the change of fat thickness to represent the volume change in fat compartments. Thus, it did not precisely reflect the volume and morphological changes of each independent fat compartment with ageing. Therefore further study needs to be conducted. Finally, further research between women and men should be performed to reveal the correlation between the hormonal effect and ageing changes in the midfacial fat compartments.

Conclusions

The identification of fat compartments conducted by Rohrich et al.^{9,10,30} enabled the analysis of ageing in terms of the relative volumetric and positional modifications of the deep and superficial compartments. Based on the above-mentioned theory, this study described the age-related changes in midfacial fat compartments by measuring the fat thickness on CT images. It could be demonstrated that different fat compartments were undergoing selective hypertrophy or atrophy with ageing. It precisely illustrated the natural distribution of facial fat compartments and offered significant implication to volumetric rejuvenation.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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