

The Clinical Importance of the Fat Compartments in Midfacial Aging

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Summary: The recent identification of the facial fat compartments has greatly affected our understanding of midfacial aging. This article chronicles the discovery of these fat compartments including the shift of attention from a purely gravitational to a volumetric approach to facial aging and the series of methodologies attempted to ultimately define the anatomy of these compartments. The revived interest in volumetric facial rejuvenation including compartment-guided augmentation techniques is discussed. Lastly, the article discusses interesting distributional patterns noted in these fat compartments likely related to the different mechanical and biologic environments of the deep and superficial facial fat pads. (*Plast Reconstr Surg Glob Open* 2013;1:e92; doi: 10.1097/GOX.0000000000000035; Published online 30 December 2013)

Facial aging is a multifactorial process that has been extensively studied. Changes in the skin, facial skeleton, and soft tissue all play contributory roles.¹⁻³ Epidermal thinning, collagen loss, and dermal elastosis over time contribute to the fine rhytids of the aging face. Remodeling of the facial skeleton also adds to the gross morphological changes of aging. Computed tomographic (CT) studies have shown that posterior retrusion of the bony maxilla with age leads to a blunted midface and loss of support for the periorbital tissues above.^{4,5} The soft tissue is the third major component of facial aging and is also the focus of this article. Facial fat is compartmentalized in a multidimensional fashion on the midface. Distributional changes in these fat compartments contribute to the distinct morphology of the aging face.

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A SHIFT IN THEORIES

Two main schools of thought characterize the soft-tissue changes observed in midfacial aging. The gravitational theory is centered on changes in the ligamentous system of the cheek, whereas the volumetric theory is based on the fat compartments of the face. These 2 theories are by no means mutually exclusive, and facial aging likely reflects a complex morphologic change that involves both elements of gravitational ptosis and volume deflation. The gravitational theory is a more traditional concept that originated earlier on in facial aging research, with the volumetric theory following thereafter. Over the last 2 decades in facial aging literature, we observed a shift from almost exclusive descriptions of gravitational descent to more recent discussions of volumetric facial aging.^{3,6-10}

The gravitational theory of midfacial aging proposes that vertical descent of facial soft tissue secondary to ligamentous attenuation contributes to the deep creases of the aging face.³ In 1989, Furnas¹¹ first described ligaments within the cheek which anchor the dermis to the underlying fibro-osseous structures. In 1992, Stuzin et al¹² suggested that age-related elastosis and attenuation of these ligaments contribute to descent of the midfacial soft tissue, leading to the sagging appearance of the aging face. Repeated animation of facial mimetic muscles,

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such as in smiling, was also thought to contribute to this ligamentous attenuation.¹²⁻¹⁴ Later in a magnetic resonance imaging (MRI) study, Gosain et al¹³ showed a relative descent in position of the cheek fat pad in older faces (>60 y) compared to their younger counterparts (16-30 y). These collective observations led to the adoption of the gravitational theory by many early on.

Almost a decade passed before the volumetric theory became salient in facial aging literature. In 2000, Donofrio⁶ stated that “we have been conditioned for so long to accept ‘sagging secondary to gravity’ as a dictum that we have forgotten that it is only a supposition.” Donofrio brought to attention the “compartmentalized” appearance of the clinically aging face, created by juxtaposing hypertrophic “hills” and atrophic “valleys.” She suggested that rather than gravitational descent, it is the relative volume loss and gain in neighboring regions of the face that create the deep creases of age.

In 2007, Lambros⁹ popularized the volumetric theory among plastic surgeons. In his analysis of 130 subjects, each photographed at 2 separate points in time ranging 10-56 years apart, Lambros⁹ noted that the lid-cheek junction remained stable within subjects. Furthermore, skin landmarks such as moles and wrinkles in the periorbital and upper midface areas did not descend with time. Lambros⁹ suggested that the fibrous network of the face is actually relatively immobile. He reiterated Donofrio’s proposition that the changing morphology of the midface may not be completely due to gravitational soft tissue descent, but also due to the relative deflation of certain fat pads. Concurrently, Rohrich and coworkers released a series of anatomic studies^{10,15-18} attesting to the facial fat compartments as conceptualized by Donofrio⁶ and Lambros⁹, gaining even more momentum for the volumetric theory of facial aging.

FINDING THE FAT COMPARTMENTS

Traditionally, facial fat is broadly divided into superficial and deep layers relative to the superficial musculoaponeurotic system or mimetic muscles (Fig. 1). This broad layout comes about naturally as the superficial musculoaponeurotic system and mimetic muscles are easily visualized structures that explicitly separate the deep and superficial soft tissues. However, further partitioning of these 2 layers into distinct compartments is not as intuitive. Arbitrarily defined landmarks were often used as boundaries for these compartments until a truly anatomical method to delineate the facial fat compartments was finally implemented in 2007.¹⁵

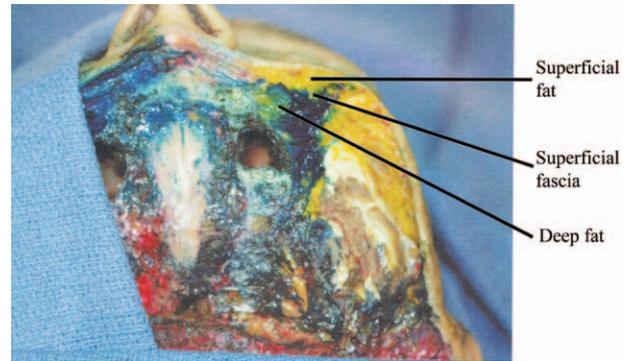


Fig. 1. Midfacial fat is broadly divided into superficial and deep layers relative to the superficial fascia or superficial musculoaponeurotic system (SMAS). Reprinted with permission from Pessa JE, Rohrich RJ. *Facial Topography: Clinical Anatomy of the Face*. St. Louis: Quality Medical Publishing, 2012.

In 1996 and 2005, Gosain et al^{13,19} divided the superficial cheek fat into medial and lateral masses based on their relationship with the underlying mimetic muscles on MRI. They called the soft tissue above the levator labii superioris and the zygomaticus major muscles the “medial” and the “lateral” cheek mass, respectively. In Macchi et al’s^{20,21} cadaveric studies of facial anatomy, the “cheek” mass was vaguely defined as the soft tissue medial to the parotid and lateral to the nasolabial crease. Raskin and Latrenta²² used arbitrary markings based on the aesthetic subunit principle of Gonzales-Ulloa et al²³ to divide the midfacial fat into the “anterior upper cheek,” “middle cheek,” and “posterolateral cheek” compartments. Each of the above studies is limited by the use of arbitrary and widely variable landmarks to define the boundaries of the midfacial fat compartments.

It was not until 2007 when Rohrich and Pessa^{10,15,17,18} published the seminal studies that provided an anatomical and reproducible method to qualify the facial fat compartments. This group injected methylene blue dye into hemifacial cadaveric specimens and allowed it to diffuse through the fat compartments as dictated by their natural septal boundaries (Fig. 2). These septal boundaries, which act as a retaining system, were henceforth used as the anatomic basis of the fat compartments.^{16,24} This methodology has since been replicated by additional groups^{25,26} to identify additional facial fat compartments in cadaveric dissections.

In 2012, Gierloff et al⁷ published the next landmark anatomic study that used CT images to both qualify and quantify the fat compartments of the face. Analogous to Rohrich et al’s studies that used methylene blue dye diffusion to dictate compartmental boundaries, Gierloff et al injected iodinated



Fig. 2. Rohrich and Pessa¹⁵ injected methylene blue dye into cadaveric specimens, allowing dye diffusion to dictate the natural septal boundaries of the facial fat compartments. The nasolabial fat (blue) and lateral temporal cheek fat (arrow) are partitioned in this manner. Reprinted with permission from *Plast Reconstr Surg.* 2007;119:2219–2227.

contrast medium in hemifacial cadaveric specimens. This contrast medium demonstrated similar homogeneous distribution within the fat compartments without penetrating their ligamentous boundaries. The individual fat compartments were isolated in this manner and visualized on 3D CT images (Fig. 3). This method offered the additional advantage of multiplanar qualification and volumetric quantification of the fat compartments.

THE NOMENCLATURE

The nomenclature for these fat compartments was subsequently established based on Rohrich et al's and Gierloff et al's anatomic studies.^{7,10,15,16,18} The compartments can be broadly categorized as superficial or deep (Fig. 4).

The superficial compartments were the first to be anatomically portrayed in 2007.¹⁵ From medial to lateral, these consist of the nasolabial fat (NLF), superficial medial cheek (SMC), middle cheek, and lateral temporal cheek fat. The infraorbital fat (IOF) lies immediately cephalad to the SMC. The NLF, SMC, and IOF are often collectively referred to as the “malar fat” and are considered the superficial fat of the midface.²⁷

Identification of the deep fat compartments followed closely thereafter.^{10,17} The deep medial cheek fat is located deep to the upper lip elevators and is divided into a medial (DMC) and lateral part (DLC).⁷ The DMC lies deep and medial to the NLF and is

bordered posteriorly by Ristow's space, a potential space directly overlying the maxilla.^{7,10} The DLC lies deep to the SMC. The buccal extension of the buccal fat pad is located just lateral to the DLC. The suborbicularis oculi fat (SOOF) lies deep to the orbicularis oculi muscle of the lower lid, densely adherent to the underlying periosteum, and consists of a medial and lateral part.¹⁷

REGIONAL MORPHOLOGIC DIFFERENCES

Although earlier studies propose that the aging face experiences a global atrophy of subcutaneous fat,² our current understanding of facial fat as highly compartmentalized rather than a confluent mass suggests that things may not be as cut and dry. Selective hypertrophy and atrophy of various fat pads have been suggested a number of times based on clinical observations.^{9,17} Donofrio⁶ proposed that the periorbital, buccal, and perioral fat tend to atrophy while the submental, jowl, nasolabial, and lateral malar regions tend to hypertrophy. Rohrich et al¹⁷ noted that older patients may demonstrate excess fat in superficial compartments such as the IOF, lateral temporal cheek fat, and submental fat, with a concomitant deflation of deep cheek fat.

The differential behaviors of deep versus superficial fat pads have also been shown in imaging and

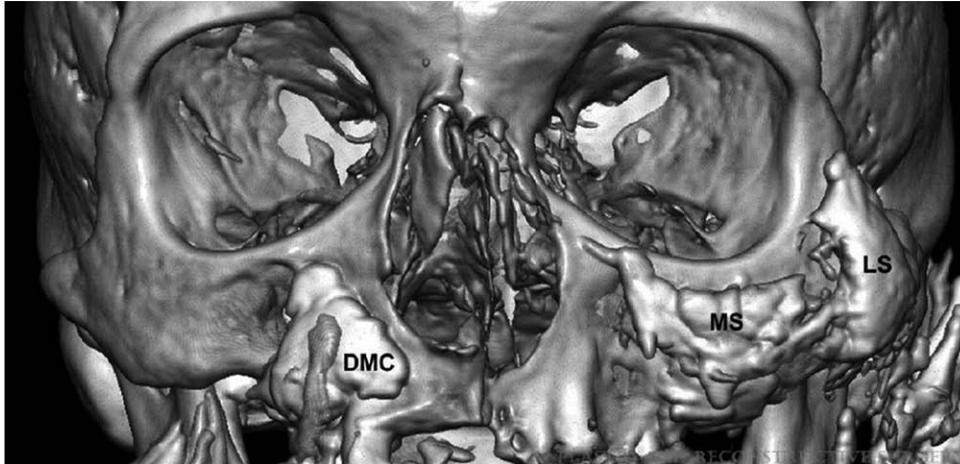


Fig. 3. Gierloff’s⁷ group injected iodinated contrast medium into cadaveric specimens followed by CT scanning. The homogenous distribution of the medium within the facial fat compartments allowed these compartments to be isolated and volumetrically measured on 3D CT images. The medial part of the deep medial cheek fat (DMC) and the medial (MS) and lateral (LS) sub-orbicularis oculi fat pads are portrayed in this CT image. Reprinted with permission from *Plast Reconstr Surg.* 2012;129:263–273.

histologic studies. Gosain’s MRI study of 20 healthy female subjects showed a relative hypertrophy of superficial cheek fat mass in the older group (60–70 y) compared to the younger group (16–30 y).¹⁹ On the other hand, Gierloff et al’s⁷ CT study of 12 cadaveric heads demonstrated a relative deflation of deep cheek fat in older specimens (75–104 y) compared to younger specimens (54–75 y). Recently, a histologic study demonstrated smaller average adipocyte size in the deep cheek compartment compared to

the superficial cheek compartment in 63 older cadaveric specimens with the mean age of 71 years.²⁸

It is unclear what drives the morphologic differences between the superficial and deep midfacial fat. Speculations range from intrinsic metabolic differences⁹ to different mechanical forces and architectural network^{16,22,29,30} surrounding the fat layers. Although causation remains unclear, the observations thus far have pointed toward a recurrent trend suggesting that the deep fat compartments tend

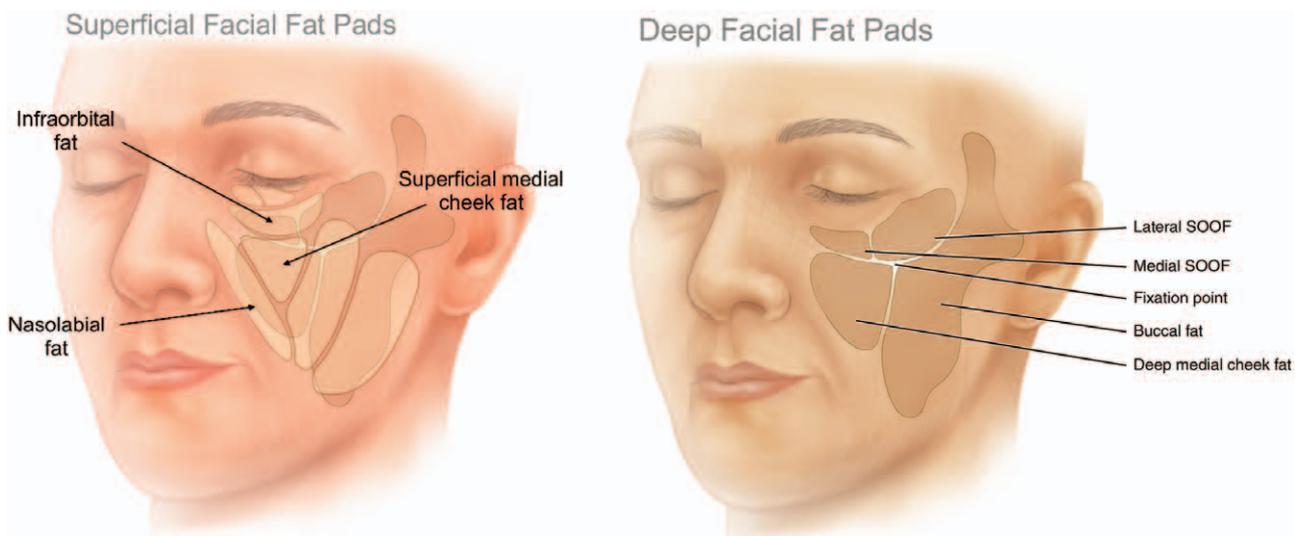


Fig. 4. Schematic depiction of the superficial (light beige) and deep (dark tan) facial fat compartments. A, The superficial midfacial fat compartments include the infraorbital fat, superficial medial cheek fat, and nasolabial fat. B, The deep midfacial fat compartments include the medial and lateral SOOF, deep medial cheek fat which can be further divided into medial and lateral parts, and the medial portion of the buccal fat pad. Reprinted with permission from Pessa JE, Rohrich RJ. *Facial Topography: Clinical Anatomy of the Face.* St. Louis: Quality Medical Publishing, 2012.

to atrophy with age, while the superficial compartments may be more prone to hypertrophy.

A VOLUMETRIC APPROACH TO FACIAL REJUVENATION

In 2008, Rohrich et al¹⁰ documented that volume augmentation of deep cheek fat successfully restored anterior cheek projection and diminished the nasolabial crease. Based on this finding, the group proposed a volumetric model of facial aging which they coined “pseudoptosis.” The theory suggests that selective deflation of the deep fat pads with age leads to loss of support and descent of the overlying superficial fat, thereby contributing to the ptotic appearance of the aging face. Gierloff et al⁷ used this same theory to explain the findings of their 2012 CT study. They proposed that deflation of the deep fat pads, DMC and buccal fat pad, contributed to the inferior volume shift or ptosis seen in the overlying superficial fat pads, NLF and SMC.

These observations prefaced the primary clinical relevance of the facial fat compartments. Specifically, the compartments can serve as a map of facial aging and henceforth a global positioning system for volume augmentation, allowing us to precisely and directly augment select deep fat compartments. This has revolutionized not only how we look at aging but also how natural a patient can look after volume augmentation procedures. Rather than masking the creases of facial aging with superficial multilayering of fat in nonspecific malar regions,³¹ we propose that the direct augmentation of specific deep cheek compartments creates a more natural look.

In the aging face, deflation of the deep periorbital fat forms a relative concavity between the thin medial eyelid skin and thicker cheek skin, creating a nasojugal groove or tear-trough deformity.³² The smooth blend between the medial SOOF and the superior edge of the malar fat pad is lost, leading to a harsh transition between the lid-cheek junction.¹⁴ Understanding this mechanism, deep augmentation of the medial SOOF or DMC just superficial to the underlying periosteum has been shown to improve the tear-trough deformity.^{17,32,33} The concomitant deflation of the deep medial cheek fat leads to ptosis of the overlying superficial malar fat including the NLF and SMC, further elongating the tear-trough deformity. The inferior orbital rim becomes visible, and a centromedial cheek hollow below the tear-trough termed the “V” deformity results.³ As such, fat injection in the DLC and medial SOOF has been performed to improve this “V” deformity.^{10,17,30} Augmentation of the DLC has also been used to improve anterior cheek projection and to smooth the

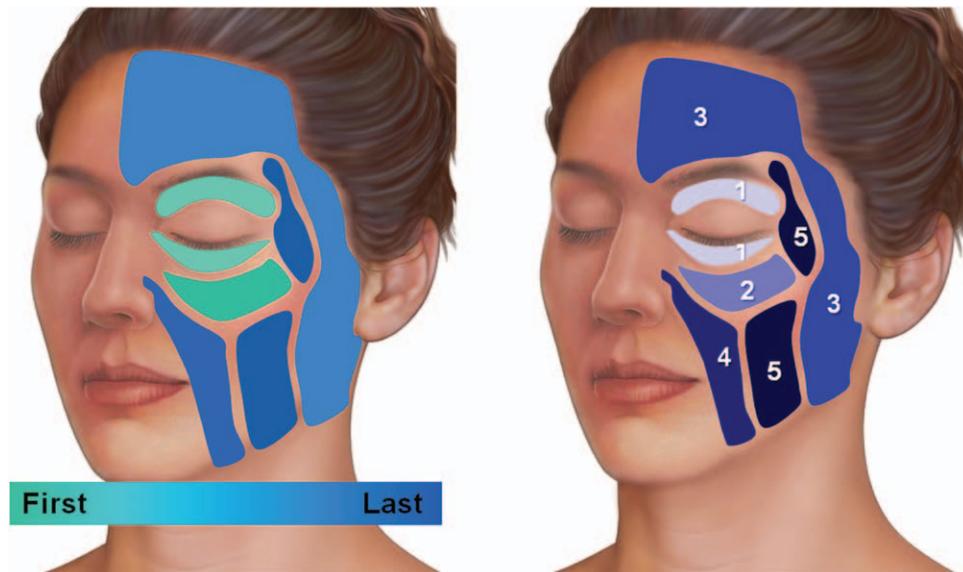
transition between the anterior and lateral cheek.^{7,30} Lastly, the nasolabial fold is harshened as the deep medial cheek compartments deflate with age. This crease is shown to soften with volume augmentation of the DMC and Ristow’s space.^{10,33}

Although the above outlines a very basic guide for deep fat injections, the effects of compartmental volume augmentation on overall facial morphology are in fact much more complex and multifactorial. A single-compartment injection may affect adjacent soft tissues in multiple dimensions, ultimately resulting in a single, dominant direction of volume change (ie, anterior projection versus cephalad movement). Being able to systematically predict the dominant effect of a single-compartment injection is an area that requires further clinical experience. Furthermore, a firm understanding of the sequence of regional fat deflation observed with aging is integral to volumetric rejuvenation. With earlier mention of the regional morphologic differences between fat compartments, it is not surprising that some compartments tend to deflate earlier in middle age, while others deflate later in life. Clinical trends show that the periorbital and malar fat pads tend to be affected first in life, followed by the lateral cheek, deep cheek, and lateral temporal areas (Fig. 5).^{3,34}

Despite the promising results of volume augmentation, surgical resuspension has remained the mainstay procedure in facial rejuvenation. Many plastic surgeons today still perform surgical resuspension alone without volume reshaping. Yet, as the facial fat compartments become more clinically relevant, we propose a change in thinking about facial rejuvenation from a predominantly “lift” to one of a “lift and fill” procedure in which both components are essential to achieve a truly natural rejuvenated look.

FUTURE DIRECTIONS

Clinical observations suggest that fat compartments tend to atrophy with age, specifically in the deep compartments.^{6,10} Yet, the scientific support for this remains scant. Although Gierloff’s CT study showed a relative volume decrease in the deep cheek compartments of “older” cadaveric specimens (75–104 y), their study included only 12 specimens, and the “younger” group (54–75 y) which they used for comparison is still considered relatively old.⁷ A more recent histologic study of 63 “older” cadaveric specimens (47–101 y, mean 71 y) demonstrated smaller adipocyte size in the deep DMC compared to the superficial NLF; however, there was no “younger” group to compare these findings to.²⁸ For a truly controlled study of how fat pads change with age, we must have younger counterparts to compare our



Facial Aging Occurrence

Facial Aging Occurrence

Fig. 5. Sequence of fat compartment deflation commonly observed in facial aging. Reprinted with permission from Dr. Rohrich's lecture from *Plastic Surgery—The Meeting* at San Diego on October 12, 2013. (CO205) The “lift and fill” face/necklift—Obtaining natural results in facelifts using facial fat augmentation.

elderly subjects to. Cadaveric studies are limited in the availability of young specimens. Ideally, this trend would be best studied with a longitudinal study of younger, live subjects with serial adipocyte samples collected over a certain age span.

Given the rising prevalence of weight gain with age, baseline body habitus and weight changes should also be accounted for when studying these fat compartments. Weight gain may or may not influence the fat compartments differentially. The clinical observation of submental fat hypertrophy concomitant with deep cheek fat atrophy in overweight patients suggests that weight gain may preferentially target the superficial compartments.¹⁷ On the other hand, our recent cadaveric study showed similar increases in adipocyte size in both the superficial and deep cheek compartments with increasing body mass index, suggesting that weight gain affects the fat compartments equally.²⁸ Dedicated studies in this regard will aid our clinical understanding of facial morphologic changes when encountered with weight gain or loss.

Another intriguing yet nebulous topic revolves around the morphologic differences between fat compartments. This idea has been tossed around since the fat compartments were first conceptualized, yet remains poorly defined.^{6,9} The trends observed so far suggest that the primary dimorphism exists between the deep and the superficial fat.^{7,28–30}

Whether this dimorphism is due to intrinsic metabolic differences between the adipose tissues or the different mechanical environments between the superficial and deep layers or a combination of both remains to be determined.

Lambros' theory⁹ that regional differences in fat metabolism exist in the face is mostly conjectural and poorly substantiated. Yet, distinct regional adipocyte morphological patterns correlative with biological factors such as weight and sex suggest that intrinsic metabolic variances may in fact exist between the fat pads. A recent histologic study of 63 cadavers showed overall larger adipocyte size in female midfacial fat pads compared to their male counterparts.²⁸ Interestingly, after further distinguishing between the deep and superficial fat pads, this sexual dimorphism became apparent only in the deep adipocytes of overweight subjects and in the superficial adipocytes of normal-weight subjects. Although the reasons behind these variations remain unclear, these findings suggest that the deep and superficial facial adipocytes respond differently to biologic influences such as sex and body weight. Future biochemical studies to elucidate adipocyte metabolism in setting of different biological influences will provide invaluable information in this regard.

The different mechanical environments of the 2 adipose layers of the midface also likely contribute to their morphological variance. The superficial

fat pads are located adjacent to the facial mimetic muscles, while the deep fat lies directly on the facial skeleton. The continuous compression of the deep fat pads against bone and their relatively inert role as space-filling interfaces over which the somatic muscles slide during mastication may explain their tendency to selectively atrophy over time.^{21,29} On the other hand, the superficial fat pads' proximity to the dynamic muscles of facial expression may render it more metabolically active, thus requiring a more extensive and vascularized fascial network compared to the deep fat compartments as shown in histologic studies.^{16,22,24,28–30} Dedicated histologic studies are needed to further characterize the architectural networks of the deep and superficial fat layers.

CONCLUSIONS

The recent identification of the facial fat compartments elicited a surge of interest in the volumetric patterns of midfacial aging. Clinically, it introduced the idea of compartment-specific volume augmentation that has promising results in facial rejuvenation. Yet, there are many intricacies regarding how these fat compartments behave with age that remain to be explored. Further metabolic and histologic characterization of these fat compartments is necessary. The regional trends likely to be discovered among these fat compartments will contribute greatly to our understanding of volumetric midfacial aging and can be translated clinically to various facial rejuvenation techniques.

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