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The mobility of the superficial and deep midfacial fat compartments: An ultrasound-based investigation

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Abstract

Background: Understanding the mobility of the midface and the separate contributions of the superficial and deep fat compartments is essential for natural esthetic outcomes following soft tissue filler or fat grafting procedures. A study was designed that used ultrasound imaging to demonstrate in vivo visualization and quantification of distances and movements in the midface.

Methods: A total of 48 midfaces of 24 healthy Caucasian volunteers, all naïve of esthetic procedures, (22 females; 46.85 (9.8) years; 22.83 (3.1) kg/m^2) were scanned using 18 MHz ultrasound imaging. Distances between bony landmarks (inferior orbital rim, infraorbital foramen) were used as markers to measure the cranial movement of the superficial (superficial nasolabial and superficial medial cheek fat compartment) and the deep (deep pyriform space, deep medial check fat compartment, deep lateral cheek fat compartment) midfacial fat compartments between resting and smiling facial position.

Results: The superficial midfacial fat compartment moved, on average, 3.7 mm ($p < 0.001$) cranially, whereas the deep midfacial fat compartments moved, on average, 0.1 mm ($p > 0.05$) during smiling. No gender differences in mobility were identified ($p > 0.05$).

Conclusion: The results obtained are in line with previous cadaveric investigations and revealed, in a highly statistically significant fashion, that the superficial midfacial fat compartments move in cranial direction whereas the deep fat compartment did not display similar positional changes. These results help to guide facial injectable treatments and to understand why, in the midface, a deep supraperiosteal approach should be favored when augmenting the deep midfacial fat compartments.

KEYWORDS

facial anatomy, facial fat compartments, midface, mobility, ultrasound

1 | INTRODUCTION

Since the first introduction of the facial fat compartments,[1] a plethora of studies have increased our understanding of their precise location, their biomechanical behavior, and their surface effects following surgical and minimally invasive procedures. Schenck et al. demonstrated in a cadaveric computer tomographic (CT)-based investigation that the mobility of the superficial fat compartments is highly variable; some superficial compartments are stable, while others change their position when compared to bony landmarks.[2] The authors demonstrated this by injecting increasing amounts of soft tissue filler material into each superficial fat compartment and measuring its inferior displacement. This was performed while the cadaver was in an upright position to allow for the effects of gravity to take place.

On the contrary, Cotofana et al. showed, also by utilizing CT-imaging in a cadaveric model, that the deep midfacial fat compartments did not display similar positional changes when the measurements were adjusted to facial anthropometric landmarks.[3] These results were contradictory to previous cadaveric investigations which postulated that the deep midfacial fat compartments descend in their position.[4,5] However, the authors argued that, based on their anatomical dissections, the boundaries of the deep midfacial fat compartments were formed by muscles, ligaments, and septae attaching to bone; these structures do not change their relative position and therefore allow for a stable location of the deep fat compartments.

A major drawback of the studies mentioned above, however, is that they were performed in a cadaveric model analyzing non-living tissue with its respective limitations. Thus, it is questionable whether the results obtained are real and applicable to living individuals and can guide clinical procedures. Therefore, it would be welcomed to be able to replicate these results in a meaningful clinical scenario. Ultrasound imaging could allow for such verification; this imaging modality is non-invasive, can capture real-time movements, and allow for accurate measurement.[6-12]

Accordingly, it is the objective of this study to investigate the mobility of the superficial and deep midfacial fat compartments by ultrasound imaging and to compare the magnitude of movement between resting and smiling facial expressions. These clinical results may enable the verification of the results obtained from the cadaveric model and guide future clinical procedures.

2 | MATERIALS AND METHODS

2.1 | Study sample

The study included a total of 24 healthy, Caucasian volunteers, all naïve of previous esthetic procedures, (22 females, 2 males) with a mean age of 46.85 (9.8) years [range: 28 – 68] and a mean body mass index of 22.83 (3.1) kg/m^2 [range: 19.2–31.4]. The volunteers had the following distribution of Fitzpatrick skin type: Type I, n = 7 (29.2%); Type II, n = 9 (37.5%); and Type III, n = 8 (33.3%).

Volunteers were recruited from consecutive patients of the Department of Dermatology, Erasmus Medical Center, Rotterdam, Netherlands and from a private practice in Amsterdam, Netherlands. Volunteers were not included in this study if they had previous soft tissue filler treatments or surgical procedures of their midface that could have disrupted the integrity of their facial anatomy.

This study was performed in adherence with the Declaration of Helsinki (1996) and in accordance with regional laws and Good Clinical Practice for studies in human subjects.[13] Written informed consent was obtained for all participants for use of their related images and data for research purposes prior to inclusion in the study.

The study did not require ethics committee approval as ultrasound imaging is considered standard of care before routine soft

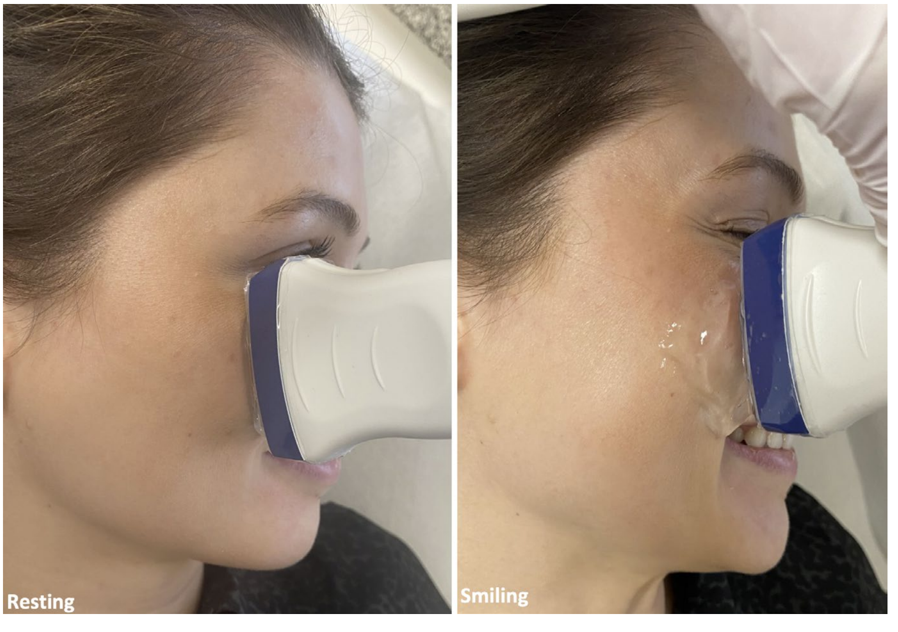

FIGURE 1 Ultrasound imaging of a female volunteer during resting and smiling facial expression. Note that the ultrasound transducer does not touch the skin to allow for normal soft tissue movements

tissue filler injections by the respective approval board according to The Medical Research Involving Human Subjects Act.10.[14]

2.2 | Ultrasound imaging

Patients were positioned in a 45 degrees upright position for all conducted measurements. Ultrasound measures were performed by the same investigator (L.S.) using an Affiniti 70 device with an 18 MHz broadband compact linear array transducer (Philips N.V.). The transducer was positioned only into the contact gel, (Aquasonic® Clear Ultrasound Gel, Parker Laboratories Inc.) without skin contact, to not compress the underlying fascial anatomy (Figure 1). The mobility of the superficial and the deep midfacial fat compartments was evaluated during a resting facial expression and during a smiling facial expression; the latter was standardized by asking the patients to smile with inclusion of the orbicularis oculi muscle (Duchenne type smiling[15]).

The mobility of the superficial and deep midfacial fat compartments was evaluated bilaterally and included vertical distance measurements. Mobility of each investigated fat compartment was defined as the magnitude in positional change between a resting and smiling facial expression (Figures 2 and 3). The following measurements were made:

1. The movement of the inferior boundary of the superficial nasolabial and the superficial medial cheek fat compartments, the distance between the inferior orbital rim (bony landmark), and the nasolabial sulcus was quantified at rest and during smiling at the level of the medial canthus, in the midpupillary line, and at the level of the lateral canthus.
2. The movement of the floor of the superficial nasolabial and the superficial medial cheek fat compartments, the distance between the inferior orbital rim (bony landmark), and the most caudal visible end of the orbicularis oculi muscle (OOM) was quantified at rest and during smiling at the level of the medial canthus, in the midpupillary line, and at the level of the lateral canthus.
3. The movement of the fat within the deep pyriform space, the distance between the horizontal level of the infraorbital foramen (IOF) (bony landmark), and the most cranial boundary of this fat compartment (formed by the levator labii superioris alaeque nasi muscle (LLSAN)) was quantified at rest and during smiling; this measurement was performed at the level of the medial canthus.
4. The movement of the deep medial cheek fat compartment, the distance between the horizontal level of the IOF (bony landmark), and the most cranial boundary of this fat compartment (formed by the LLSAN) was quantified at rest and during smiling; this measurement was performed at the level of the lateral limbus.
5. The movement of the deep lateral cheek fat compartment, the distance between the horizontal level of the IOF (bony landmark), and the most cranial boundary of this fat compartment (formed by the zygomaticus minor muscle (ZMi)) was quantified at rest and during smiling; this measurement was performed at the level of the lateral canthus.

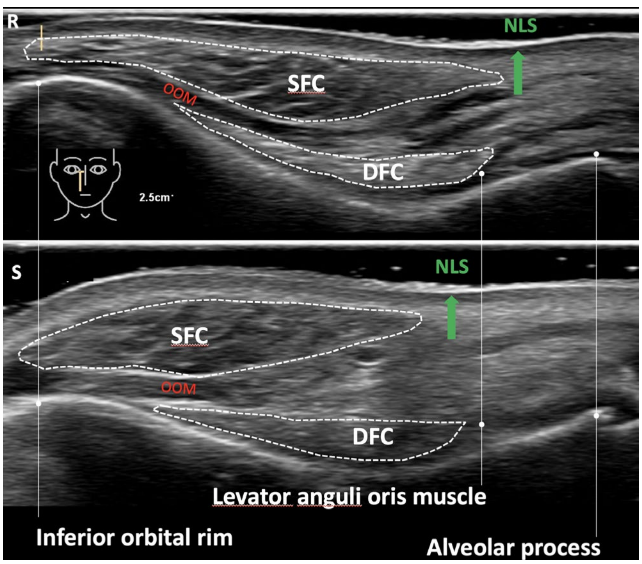

FIGURE 2 Ultrasound images obtained in the medial canthal (vertical) line showing the facial soft tissues at rest (R= rest; upper image) and during smiling (S= smiling; lower image). The superficial (= SFC) and the deep (= DFC) fat compartments are outlined for a better visualization. The orbicularis oculi muscle has been indicated (= OOM) as was the nasolabial sulcus by the green arrow (= NLS). Bony landmarks are indicated for reference purposes

2.3 | Statistical analysis

Paired statistical testing (distances during resting vs. smiling) was performed using SPSS Statistics 23 (IBM, Armonk, NY, USA) and presented as mean value with the respective standard deviation. Generalized linear models were calculated to identify the multifactorial influence of age and body mass index on the measurements. Results were considered statistically significant at a probability level of ≤0.05 to guide conclusions.

3 | RESULTS

3.1 | General results

No gender differences were observed between values obtained from every measurement performed, all with $p > 0.05$.

3.2 | Superficial Midfacial Fat Compartments

The inferior boundary (represented by the nasolabial sulcus) of the superficial midfacial fat compartments changed during smiling toward a more cranial position, in a statistically significant manner, at all three measured locations, all with $p < 0.001$. The positional change at the level of medial canthus was 5.1 (0.4) mm with $p < 0.001$; in the midpupillary line was 5.1 (0.4) mm with $p < 0.001$; and at the level of the lateral canthus was 4.2 (0.4) mm with $p < 0.001$.

During smiling, the position of the floor of the superficial midfacial fat compartments (represented by the most caudal end of the OOM) changed toward a more cranial location, in a statistically significant manner, for all conducted measurements, all with $p < 0.001$. The cranial shift during smiling at the level of the medial canthus was 2.4 (1.9) mm with $p < 0.001$, in the midpupillary line was 2.7 (1.2) mm with $p < 0.001$, and at the level of the lateral orbital rim was 2.8 (1.2) mm with $p < 0.001$ (Figures 4, 5, and 6).

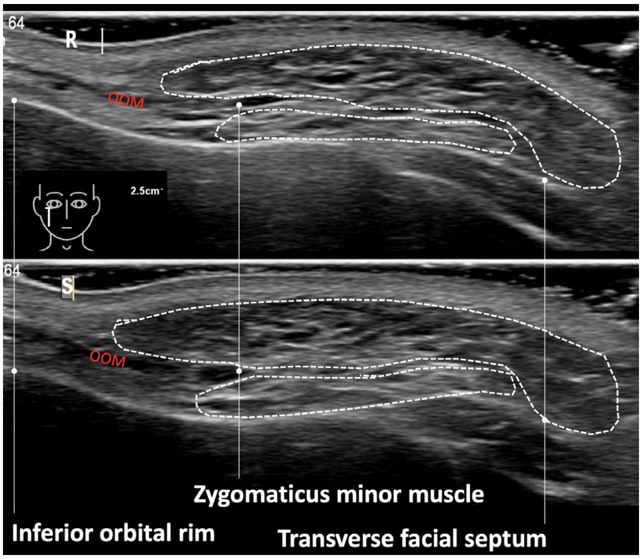

FIGURE 3 Ultrasound images obtained in the lateral canthal (vertical) line showing the facial soft tissues at rest (R= rest; upper image) and during smiling (S= smiling; lower image). The superficial (= SFC) and the deep (= DFC) fat compartments are outlined for a better visualization. The orbicularis oculi muscle has been indicated (= OOM). Bony landmarks and the zygomaticus minor muscle are indicated for reference purposes

3.3 | Deep midfacial fat compartments

The position of the deep pyriform space, the deep medial cheek fat compartment, and the deep lateral cheek fat compartment did not differ in their position between the resting and the smiling facial positions, in a statistically significant manner, all with $p > 0.05$. In detail, the difference between facial expressions was 0.1 (0.4) mm for the deep pyriform space with $p = 0.365$, was 0.0 (0.2) mm for the deep medial cheek fat compartment with $p = 0.888$, and was 0.0 (0.2) for the deep lateral cheek fat compartment with $p = 0.527$ (Figures 4, 5, and 6).

3.4 | Influences of age or body mass index

No statistically meaningful influences of age or body mass index were identified when computing generalized linear models with adjustment for both factors.

4 | DISCUSSION

The aim of the present study was to verify in a clinical scenario previously presented results on the mobility of the superficial

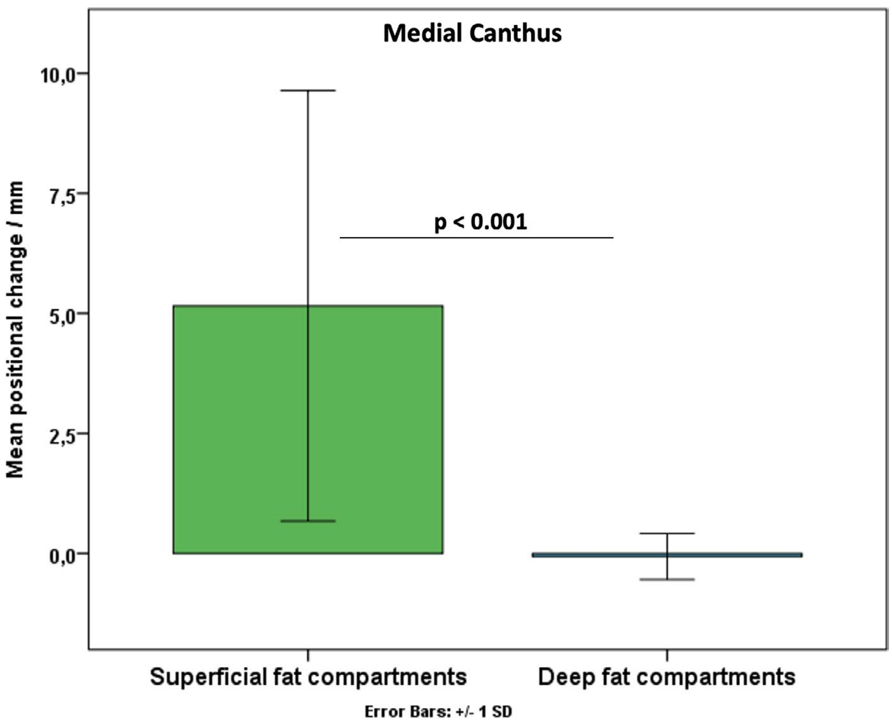

FIGURE 4 Bar graph indicating the positional change in mm of the superficial and of the deep facial fat compartments in the medial canthal (vertical) line. Error bars indicate ±standard deviation (= SD), and the statistical difference is presented with the probability value (=*p*-value)

and the deep midfacial fat compartments obtained from cadaveric research models. The mobility of the superficial and the deep midfacial fat compartments was postulated to be different when measured in relation to bony landmarks: the superficial fat compartments displayed high mobility in the midface, whereas the deep midfacial fat compartments were reported to display no positional changes.[3] The superficial fat compartments located in the midface are the superficial nasolabial fat compartment and the superficial medial cheek fat compartment—also termed the malar fat pad.[2,16,17] They are bounded inferiorly by the nasolabial sulcus[2] and cranially either by the nasojugal groove or by the orbicularis retaining ligament (ORL).[2,17,18] The deep fat compartments in the midface are the deep pyriform space,[19] the deep medial cheek fat compartment,[1,5] and the deep lateral cheek fat compartment. The boundary of the deep midfacial fat compartments is formed by the bony attachments of the muscles (LLSAN, ZMi), ligaments

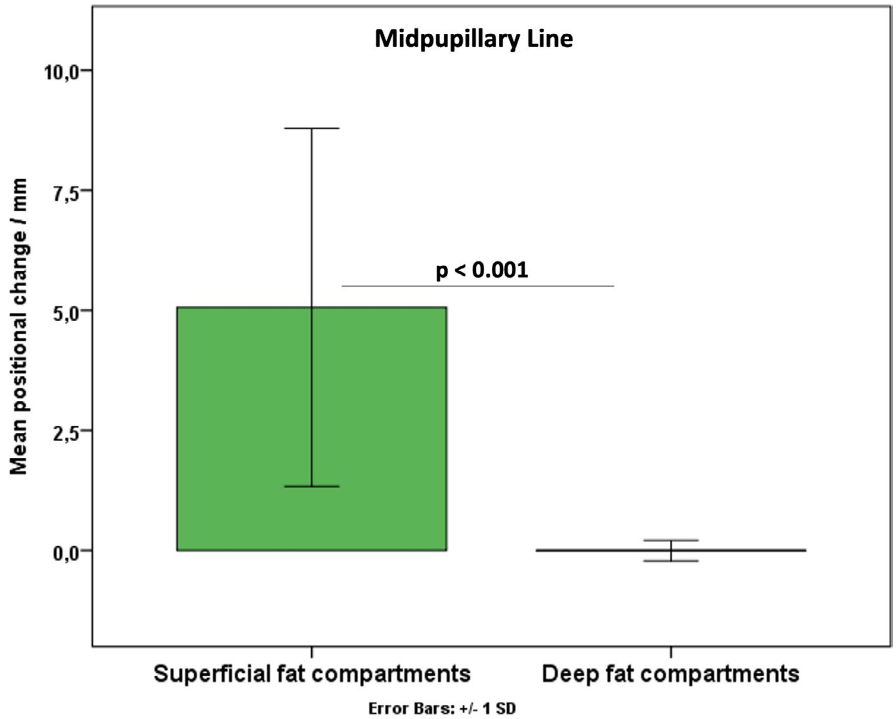

FIGURE 5 Bar graph indicating the positional change in mm of the superficial and of the deep facial fat compartments in the midpupillary line. Error bars indicate ±standard deviation (= SD), and the statistical difference is presented with the probability value (=*p*-value)

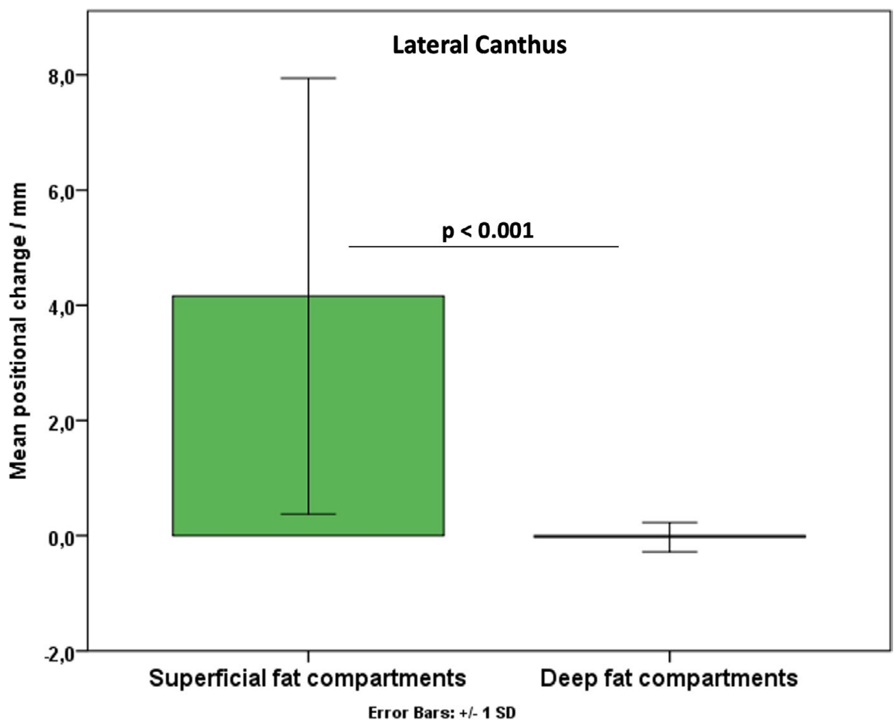

FIGURE 6 Bar graph indicating the positional change in mm of the superficial and of the deep facial fat compartments in the lateral canthal (vertical) line. Error bars indicate ±standard deviation (= SD), and the statistical difference is presented with the probability value (=*p*-value)

(zygomatico-cutaneous ligament), septae (facial vein canal, transverse facial septum), or neurovascular structures (infraorbital nerve and artery).[20]

The present study utilized ultrasound imaging to conduct distance measurements during repose and during a standardized smiling facial expression (Duchenne type smiling). The measurements are based on the identification of visible landmarks in ultrasound that can be used as markers for compartment boundaries. The ultrasound imaging marker for the inferior boundary of the superficial fat compartments was the nasolabial sulcus; here, the skin forms a visible surface depression and at the dermal underside, the strong attachment between some of the muscles of facial expression (LLSAN, ZMi) can be identified. This zone of adhesion has been previously identified using histologic analyses[21,22] and is currently the accepted explanatory model for the formation of the nasolabial fold deformity at increasing age.[23] The analysis of the measurements revealed a statistically significant cranial shift in the position of the nasolabial sulcus (the boundary of the superficial midfacial fat compartment) in relation to the bony inferior orbital rim during smiling. This was observed to be, on average, 4.8 mm ($p < 0.001$) and indicates that the cranially located superficial fat compartments alter their position to be closer to the inferior orbital rim.

These results are in line with the measurements performed for the positional change of the floor of the superficial midfacial fat compartments. The OOM is continuous with the midfacial superficial musculo-aponeurotic system (SMAS)[24,25] which also fuses with the dermal undersurface at the nasolabial sulcus. The transition between OOM and SMAS can be identified via ultrasound imaging and can be used as a marker for the movement of the overlying superficial midfacial fat compartments. Our study revealed that the most caudal end of the OOM changed, on average, 2.6mm ($p < 0.001$) toward a more cranial position during smiling; this is in line with the muscular contraction pattern of the OOM and was a defining factor during data acquisition (Duchenne type smiling). With a cranial shift of the floor of the superficial midfacial fat compartments closer to the bony inferior orbital rim, it can be most likely assumed that the overlying compartments move simultaneously; this is in line with the measurements obtained from the movement of the nasolabial sulcus. These results are also in line with previous cadaveric work by Schenck at al.[2] and, therefore, can confirm that the superficial midfacial fat compartments display a high mobility during facial expressions. This is also important for age-related changes of the midface: The increased mobility most likely results in increased soft tissue descent. This was postulated previously from the cadaveric model and was recently confirmed in clinical CT-imaging study focusing on the midface.[26] The results presented herein are in line with those previous observations and provide an explanation for why soft tissue filler or fat injections into the superficial nasolabial fat compartment increase the severity of the nasolabial deformity. The increased volume causes more gravitational pressure on the sulcus in repose, more compartmental descent during facial expression, and more mobility during facial aging—all of which results in an increase of the depression.

The deep midfacial fat compartments, on the contrary, did not display positional changes during smiling. The movement of each of the investigated compartments was less than 0.1 mm ($p > 0.05$), on average, when related to the IOF. The IOF was chosen as a stable and reliable visual imaging marker (comparable to the inferior orbital rim) and was used to measure the potential cranial positional change of each of the deep midfacial fat compartments. The decision to measure a cranial boundary for the deep compartments (as opposed to an inferior boundary of the superficial compartments) was the reliable and reproducible visibility of the respective boundaries; the boundary was limited inferiorly for the deep midfacial fat compartments and was limited superiorly for the superficial fat compartments. The results obtained are in line with the previous work by Cotofana et al.[3] which postulated in a cadaveric model that the relative position of the deep midfacial fat compartments does not undergo positional changes. The clinical results obtained in this study confirm those previous findings and validate the results obtained from their cadaveric model.

This is clinically important, especially relative to minimally invasive soft tissue filler injections and fat grafting. Midfacial volumization procedures inject filler into the deep planes with most of the product implantation occurring with the needle in constant contact with the bone. This allows for the product to be positioned inside the deep midfacial fat compartments and allows for a more natural volume restoration. The volume loss of the facial fat compartments can be restored by re-creating a more youthful foundation without increasing the volume or influencing the mobility of the overlying superficial midfacial fat compartments. The latter have been shown by this study to be of great importance during facial expression as they are an integral part of facial mobility. Injecting soft tissue fillers into the superficial midfacial fat compartments would reduce their mobility during facial expressions and would increase their inferior descent with increasing age. This could result either from the increased weight of the material itself or could be caused from the increased stiffness of the fatty tissue due to fibrosis. These effects can be observed clinically as a deep nasolabial sulcus and prominent and visible palpaebromalar grooves. Administering material into the superficial midfacial fat compartments could also influence negatively the natural mobility of the fat compartments; such mobility is mandatory for a natural appearance during smiling and other facial expressions. Trying to restore the volume of the midface with superficial injections instead of deep injections could also result in the facial overfilled syndrome[20]; this is especially visible during smiling. The present study explains this phenomenon by providing evidence that the majority of midfacial mobility results from the movement of the superficial fat compartments. Increasing the volume of this mobile soft tissue mass might not be visible at rest but might become abnormally prominent during smiling. This sudden unnatural increase in volume is a sign of unnatural midfacial filling; the results presented herein provide an explanation for this clinical phenomenon.

5 | CONCLUSION

This study was designed to investigate the mobility of the superficial and deep midfacial fat compartments using ultrasound imaging to provide clinically meaningful insights into facial biomechanics. The results obtained are in line with previous cadaveric investigations and revealed, at high statistical significance, that the superficial midfacial fat compartments move in a cranial direction, whereas the deep midfacial fat compartments did not display similar positional changes. These results help to understand why a deep supraperiosteal approach should be favored in the midface and provide clinical guidelines for facial injectable treatments in this area.

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CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and publication of this article.

AUTHOR CONTRIBUTIONS

L.S., P.J.V., N.L., R.J.R, A.S., R.H.G., N.M., K.F., M.D., and S.C. have made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data. L.S., P.J.V., N.L., R.J.R, A.S., R.H.G., N.M., K.F., M.D., and S.C. have been involved in drafting the manuscript or revising it critically for important intellectual content and given final approval of the version to be published. Each author has participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

ETHICAL APPROVAL

The study did not require ethics committee approval as ultrasound imaging is considered standard of care before routine soft tissue filler injections by the respective approval board according to The Medical Research Involving Human Subjects Act.10.[14]

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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