Differences in Temporal Volume between Males and Females and the Influence of Age and BMI: A Cross-Sectional CT-Imaging Study

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Abstract

Background The temple has been identified as one of the most compelling facial regions in which to seek aesthetic improvement—both locally and in the entire face—when injecting soft tissue fillers.

Objective The objective of this study is to identify influences of age, gender, and body mass index (BMI) on temporal parameters to better understand clinical observations and to identify optimal treatment strategies for treating temporal hollowing.

Methods The sample consisted of 28 male and 30 female individuals with a median age of 53 (34) years and a median BMI of 27.00 (6.94) kg/m^2. The surface area of temporal skin, the surface area of temporal bones, and the temporal soft tissue volume were measured utilizing postprocessed computed tomography (CT) images via the Hausdorff minimal distance algorithm. Differences between the investigated participants related to age, BMI, and gender were calculated.

Results Median skin surface area was greater in males compared with females 5,100.5 (708) mm^2 versus 4,208.5 (893) mm^2 ($p < 0.001$) as was the median bone surface area 5,329 (690) mm^2 versus 4,477 (888) mm^2 ($p < 0.001$). Males had on average 11.04 mL greater temporal soft tissue volume compared with age and BMI-matched females with $p < 0.001$. Comparing the volume between premenopausal versus postmenopausal females, the median temporal soft tissue volume was 46.63 mL (11.94) versus 40.32 mL (5.69) ($p = 0.014$).

Conclusion The results of this cross-sectional CT imaging study confirmed previous clinical and anatomical observations and added numerical evidence to those observations for a better clinical integration of the data.

Keywords
- temporal fossa
- temple
- facial anatomy
- soft tissue filler
- volume augmentation

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Facial soft tissue volume augmentation procedures are increasingly popular due to their accessibility, cost effectiveness, and minimal downtime relative to invasive surgical procedures.[1,2] Augmenting facial soft tissues can increase the local volume as well as reposition more distant tissue layers, ultimately yielding a more youthful, attractive appearance.[3–8]

Of the different facial regions requiring aesthetic attention, the temple has become an area of increasing focus.[9–14] A recent study has described a total of six different injection techniques addressing temporal volume loss and facial lifting.[10] The study related the injection techniques to the temporal anatomy underscoring the importance of anatomic knowledge about fatty and fascial layers of the temple. However, anatomic descriptions rely on static cadaveric material with limited investigative range when it comes to age or body constitutional influences. Recent imaging studies have provided more clinically applicable information due to the inherent limitations of cadaveric studies.[15–20]

Based on clinical experience, it is known that temporal volume loss is predominantly visible in the anterior temple and that females require more frequent attention for temporal hollowing than males.[9] Age is thought to be an influencing factor but no study to date has investigated this relationship and provided numerical support for these confirmed clinical observations. The difficulty in assessing temporal parameters is the shape of the bony surface of the temporal fossa; it is uneven and curves medially toward the infratemporal fossa and leads to a gradual increase in temporal depth inferiorly.

Utilizing computed tomography (CT) imaging followed by postprocessing of analyzed images, a novel automated mathematical method, termed the Hausdorff method, could be applied to measure distances between two uneven surfaces and to compute the respective volumes.[21] This automated algorithm could exclude investigator bias and could be applied to surfaces which are difficult to measure—such as the irregular bony foundation of the temporal fossa. Additional measurements, such as skin surface area, bone surface area, and measures of maximal and minimal depth could be standardized, explored, and the influence of age, body mass index (BMI), and gender identified.

Therefore, the objective of this study is to investigate the various parameters of the temporal region and to relate them to clinically relevant observations.

Material and Methods

Study Sample

The study relied on retrospectively analyzed cranial CT images of 58 previously scanned consecutive patients. The indications for the cranial CT scans were cerebrovascular incidents or other clinical issues related to the neural tissue of the head and neck, that is, brain and cervical spinal cord. Patients were excluded from this study if their temporal skin surface or the anatomy of their temporal region was affected by trauma or tumors or any other clinical condition that could have disrupted the integrity of their temporal anatomy; this was verified by the screening process before transferring the data for further analyses. Their data sets were stored in the radiology database of the REDACTED, and sampled for the purposes of this study. The ethics committee of the REDACTED approved the study (retrospective analysis of CT scans; protocol number 5). Before the initial cranial CT scan, patients gave their informed consent for the use of their demographic and CT imaging data for research and educational purposes. The analyses of their cranial CT scans were performed between January and March 2020.

Image Analyses

CT scans were acquired via a Toshiba Aquilion 64 slice scanner (Toshiba Medical Systems Corporation, Ōtawara, Tochigi, Japan) with the following scanning parameters: voltage 120 kV, slice thickness 0.47 mm, field of view 220 mm, and tube current 140 mA. CT scans were imported from the radiologic database into the Mimics Innovation Suite software (Materialise NV, Leuven, Belgium) and the temporal region was bilaterally analyzed. The boundaries of the temporal fossa were as follows:

- Anterior – the posterior surface of the frontal process of the zygomatic bone.
- Posterior – a vertical line perpendicular to Frankfort plane passing through the anterior margin of the external acoustic meatus connecting to the temporal crest.
- Superior – the temporal crest.
- Inferior, for bone – the infratemporal crest.
- Inferior, for skin – the upper margin of zygomatic arch (►**Figs. 1–3**).

The surface of the skin and the surface of the bones forming the base or foundation of the temporal fossa were identified by

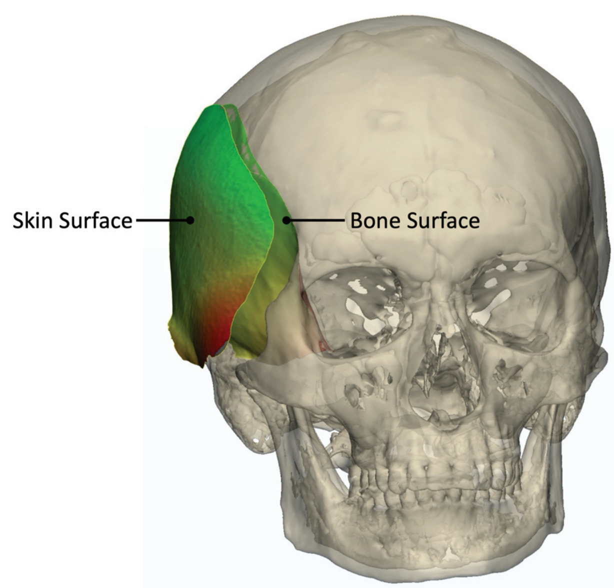

Fig. 1 Dimensional reconstruction of a cranial computed tomography (CT) image with the skin and the bone surface highlighted. The margins of the temporal bony surface is the posterior surface of the frontal process of the zygomatic bone (anterior), the temporal crest (superior), infratemporal crest (for bone, inferior), upper margin of zygomatic arch (for skin, inferior), and a vertical line passing through the anterior margin of the external acoustic meatus connecting to the temporal crest. The skin surface is adjusted to these boundaries.

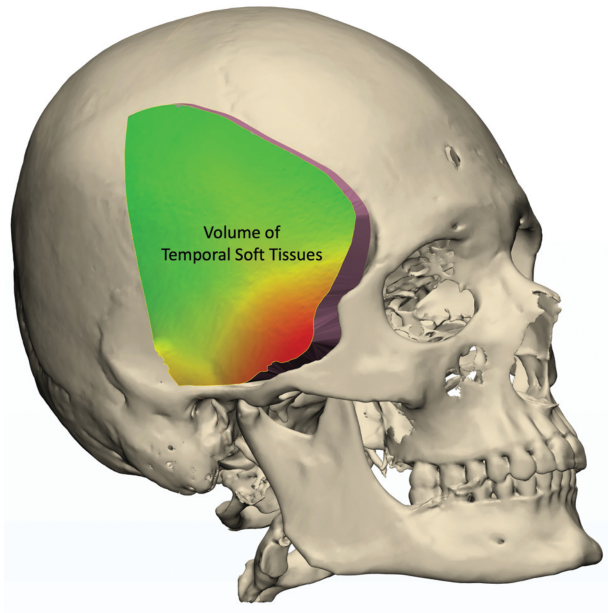

Fig. 2 Dimensional reconstruction of a cranial computed tomography (CT) image showing the volume of the temporal soft tissues located between the skin and bone surfaces. Please note that the depth of the temporal fossa is color coded with red areas indicating greatest depth.

the software algorithm, as per the differences in Hounsfield units on the CT scans (►**Fig. 1**). Distance measurements (minimum and maximum distance) between the two surfaces were automatically calculated and the volume between these two surfaces was computed; the latter was regarded as the soft tissue volume of the temporal fossa (►**Fig. 2**). All measurements were based on the Hausdorff minimal distance algorithm[21] (►**Fig. 3**).

Statistical Analyses

The Hausdorff algorithm determines the smallest distance between pixels of two marked surfaces: the skin and the bone surface and each surface had more than 1,000 pixels. This method allows measurement of precise distances between uneven and nonparallel surfaces and, furthermore, to determine the volume between them.[22] Comparable to previous applications,[21,23–25] the Hausdorff algorithm was applied to the temporal fossa—known to have varying surfaces both on bone and on the skin surface.

Testing for homogeneity and normal distribution revealed nonnormally distributed data. This resulted in the decision to conduct nonparametric statistical testing (Shapiro–Wilk test with $p < 0.05$) and to report values as median and the respective interquartile range.

No statistically significant differences between facial sides were identified in any of the tested parameters with all $p \geq 0.250$. This enabled the fusion of parameters of the left and right temple (each $n = 58$) and the subsequent calculations using a sample size of $n = 116$ temples.

According to a recent publication, the mean age for menopause in the western civilization was determined to be 50 to 51 years.[26] This cut-off value was used in the statistical analyses to determine premenopausal from postmenopausal females, that is, females below the age of 50 versus females above the age of 51 years.

Bivariate correlations computing Spearman's correlation coefficient (r_s) were run to identify linear relationships. Influence of age, gender, and BMI were identified using generalized linear models. Differences in results were considered statistically significant if $p \leq 0.05$. All tests were run using SPSS Statistics 23 (IBM, Armonk, NY).

Results

Demographic Data

The evaluated sample consisted of 28 male and 30 female Russian Caucasian individuals with a median age of 53 years and an interquartile range of 34 years (total data range: 22.0–80.0) and a median BMI of 27.00 kg/m^2 and an interquartile range of 6.94 kg/m^2 (total data range: 18.0–43.5). The median age of the female study participants was 51.5 (33) years whereas the median BMI was 25.94 (7.26) kg/m^2. The median age of the male study participants was 54.5 (36) years whereas the median BMI was 27.31 (5.90) kg/m^2. No statistically significant difference between genders for age ($p = 0.901$) or BMI ($p = 0.269$) was detected.

Depth of the Temporal Fossa

Overall, the location of the maximum depth of the temporal fossa was found to be inferior and anterior, whereas the minimum depth was found along and in proximity to the temporal crest (►**Figs. 1–3**).

The maximum depth (maximal distance between skin surface and bone surface) was 32.76 (5.76) mm in males whereas in females it was 29.90 (4.87) mm with $p = 0.004$. The minimum depth (minimum distance between skin surface and bone surface) was 3.78 (1.17) mm in males whereas in females it was 3.07 (1.05) mm with $p < 0.001$.

Adjusted generalized linear models (age, gender, and BMI) revealed that an increase in one unit of BMI resulted in an increase of 0.42 mm in the distance between skin surface and bone surface ($p < 0.001$). Age- and BMI-matched males had, on average, a greater maximal temporal depth by 1.58 mm compared with females ($p = 0.008$). Interestingly, there was no statistically significant influence of age on the maximal depth, with $p = 0.517$.

Temporal Skin Surface

The median skin surface area in males was 5,100.5 (708) mm^2 whereas in females it was 4,208.5 (893) mm^2 with $p < 0.001$. Adjusted generalized linear models (age, gender, and BMI) revealed that an increase in age by 1 year resulted in a decrease of temporal skin surface area of 10.3 mm^2 ($p = 0.001$) and that an increase in one unit of BMI resulted in an increase of 33.2 mm^2 ($p = 0.016$) in temporal skin surface area. Males had on average 750.0 mm^2 larger temporal skin surface area compared with age- and BMI-matched females with $p < 0.001$.

Temporal Bone Surface

The median bone surface area in males was 5,329 (690) mm^2 whereas in females it was 4,477 (888) mm^2 with $p < 0.001$.

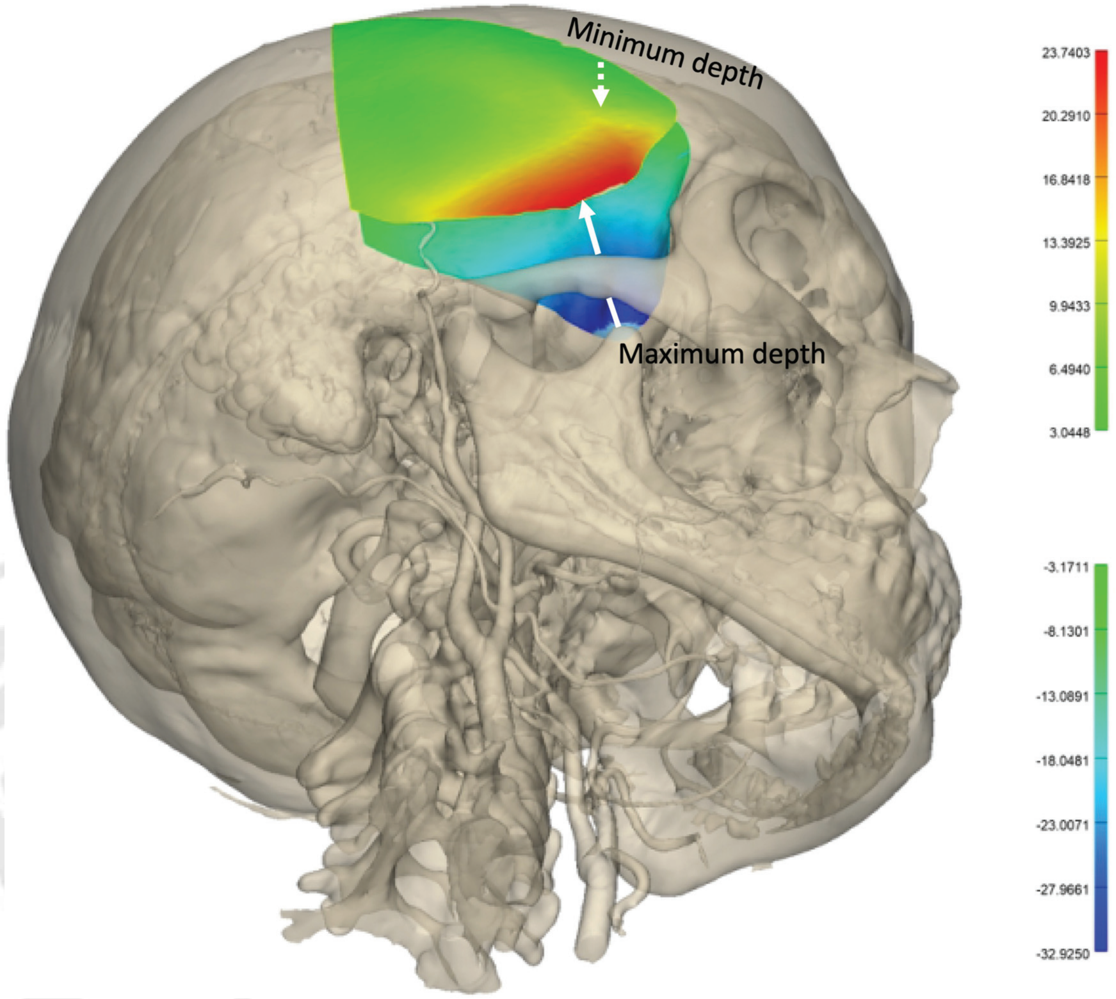

Fig. 3 Dimensional reconstruction of a cranial computed tomography (CT) image exemplifying the measuring methods according to the Hausdorff method. For each pixel in the skin surface and for each pixel in the bone surface, the smallest distance between them was computed. The smallest depth of the temporal fossa was measured as the distance from skin surface to bone surface (white arrow oriented superficial to deep), whereas the maximal depth of the temporal fossa was measured as the distance from bone surface to skin surface (white arrow oriented deep to superficial).

Adjusted generalized linear models (age, gender) revealed that an increase in age by 1 year resulted in a decrease of temporal bone surface area of 9.7 mm^2 ($p = 0.006$) and that males had, on average, 692.6 mm^2 larger temporal bone surface area compared with age-matched females.

Temporal Soft Tissue Volume

The median temporal soft tissue volume was 55.10 (17.89) mL in males whereas in females it was 41.27 (9.51) mL with $p < 0.001$. An increase in BMI correlated with a statistically significant increase in volume in both males ($r_s = 0.441$, $p = 0.001$) and females ($r_s = 0.414$, $p = 0.001$). However, an increase in age correlated with a statistically significant decrease in volume only in females ($r_s = -0.397$, $p = 0.002$), not in males ($r_s = 0.036$, $p = 0.791$). Adjusted generalized linear models (age, gender, and BMI) revealed that an increase in age by 1 year resulted in a decrease of temporal soft tissue volume of 0.17 mL ($p = 0.013$) and that an increase in one unit of BMI resulted in an increase of 1.12 mL ($p < 0.001$) volume. On average, males had 11.04 mL greater temporal soft tissue volume compared with age- and BMI-matched females with $p < 0.001$.

Comparing the volume between premenopausal (< 50 years) and postmenopausal females (> 51 years), the median temporal soft tissue volume was 46.63 mL (11.94) versus 40.32 mL (5.69) with $p = 0.014$; this trend was not observed in males using the same stratified statistic testing ($p = 0.831$) (►**Fig. 4**).

Discussion

The results of this cross-sectional CT imaging-based study are confirmatory to common clinical and anatomic observations: the temporal fossa is deepest close to the lateral orbital rim where it fuses with the zygomatic arch. The maximum depth in males was 32.76 mm whereas in females it was 29.90 mm; this represents a statistically significant difference of $p = 0.004$. The measurements performed were based on the Hausdorff method; this calculates the distance between two surfaces independent of their shape. These results indicate that

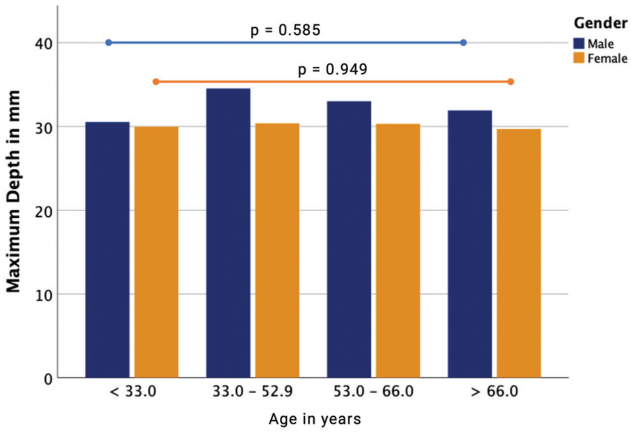

Fig. 4 Bar graph with the respective 95% confidence interval (CI) showing differences in the median temporal soft tissue volume between males and females of age below 51 years and age above 51 years.

if minimally invasive soft tissue filler volume augmentation of the temporal fossa is planned utilizing the deep, supraperiosteal injection technique,[27] the needle length should be selected appropriately. In males, a longer needle should be selected, compared with females, to establish bone contact and to allow for supraperiosteal product placement.

The results of this study also revealed that the area in proximity to the temporal crest had the smallest distance between skin surface and bone surface with 3.78 mm in males and 3.07 mm in females ($p < 0.001$). These findings imply that the depth of the temporal fossa becomes shallower in its cranial aspects with thinner soft tissues covering the bone closer to the temporal crest. It can be hypothesized that the administration of volumizers in more cranial locations of the temporal fossa might result in better surface projection due to the reduced soft tissue cover; this might effect a better restoration of temporal volume per unit volume of product administered.[28] This effect was recently investigated in a clinical interventional study; the authors reported that the deep, supraperiosteal (needle) injection technique in the anterior temple needed 69% more soft tissue filler to achieve a nondifferent aesthetic outcome when compared with a subdermal (cannula) injection technique positioned in the same location.[9] The results of that study can be explained by the reduced thickness of soft tissue covering the administered product. This supports more cranially located product administration wherein a smaller temporal soft tissue thickness is present. Furthermore, a previous study reported on the safety aspects of the supraperiosteal injection in the superior temple (as opposed to the inferior temple); this could favor a more superior dermal access point to perform minimally invasive temporal volumizing procedures in the future.[29]

The anterior and inferior location within the temple was identified to be the deepest location of the temple; this can be related to the underlying anatomy—unique and not observed in more cranial locations of the temple. The following layers can be identified here: skin, superficial fatty layer, superficial temporal fascia, deep fat (containing the frontal branches of the facial nerve), superficial lamina of the deep temporal fascia, superficial temporal fat pad (enclosing the middle temporal vein), deep lamina of the deep temporal fascia, temporal extension of the buccal fat pad, temporalis muscle, and periosteum.[10] The presence of this many layers in the inferior (anterior and posterior) temple predisposes for age, BMI, and gender-related differences in temporal soft tissue volume and this is confirmed clinically: the location where temporal hollowing is most frequently observed is the anterior and inferior temple. The loss in volume in this location additionally accentuates the visibility of adjacent bony prominences, that is, the temporal crest, the lateral orbital rim, and the upper margin of the zygomatic arch. This promotes an “aged,” skeletonized facial appearance. Volume loss of the inferior posterior temple is of less clinical relevance (despite having the same layered anatomy) due to the coverage with hair.

The results of the present study revealed that males had a larger temporal soft tissue volume compared with females—55.10 versus 41.27 mL, respectively—and this difference was statistically significant with $p < 0.001$. This could be due to the greater bone surface area and the greater skin surface area measured—the results of gender-related anthropometric differences confirmed in previous CT imaging studies.[15–17] Interestingly, an increase in one unit of BMI resulted in an increase of 1.12 mL ($p < 0.001$) of temporal soft tissue volume and this was reflected in similar correlation coefficients in both genders: males $r_s = 0.441$, $p = 0.001$, and females $r_s = 0.414$, $p = 0.001$. This indicates that an increase in BMI is reflected in an increase in temporal soft tissue volume independent of gender; this is plausible due to the presence of multiple fatty layers and fat pads of the temple. However, the influence of age on temporal soft tissue volume manifested differently in males and females. In males, no statistically significant correlation was found between age and volume ($r_s = 0.036$, $p = 0.791$) whereas in females, an inverse correlation was found ($r_s = -0.397$, $p = 0.002$). Based on the sample investigated in this study, at greater age, the temporal soft tissue volume was reduced in females but not in males. Further statistical analyses, with stratification for gender, revealed additional differences between premenopausal and postmenopausal women. Women under 50 years of age have a larger temporal soft tissue volume compared with those women over 51: 46.63 versus 40.32 mL, respectively, with $p = 0.014$. When conducting the same statistical testing in males, no such difference was found when using the same age cut-off values (below 50 years vs. above 51 years) with $p = 0.831$.

In our cross-sectional study, these results indicate that females at a greater age than the average age for menopause have a statistically significant reduction in temporal soft tissue volume. The demand for these procedures is based on the natural course of facial aging and on the process of sarcopenia—the loss of muscle mass. The latter is most likely related to the postmenopausal hormonal status of these women.[26,30–34] Sarcopenia is associated with loss in muscle mass (among other things) and would explain the effects observed in our sample of 60 female temples: a reduction in temporal soft tissue volume due to a reduction in temporalis muscle volume and temporal fat atrophy. In males, this effect was not observed despite equal statistical testing and similar sample size; this would support the hypothesis as males are not affected by this hormonal change when using the same statistical cut-off value for age.

A limitation of the study is that all of the individuals studied were Russian and all were Caucasian; results might differ if analyses were conducted on other ethnicities. Another limitation of the study is that analyses are based on a cross-sectional data set and any changes detected are found based on the evaluation of younger versus older individuals, not the same person studied over time. Cause and effect relationships and conclusions are thus to be considered with caution. A stronger study design would be the longitudinal follow-up of the same individuals at different time points; however, these types of studies are subject to larger dropout rates and biased if the assessment technology changes between baseline and follow-up—for instance, if another CT scanner was used to record the follow-up images due to technologic advancements.

Conclusion

The results of this cross-sectional CT imaging study confirmed previous clinical and anatomical observations and added numerical evidence to those observations for a better clinical integration of the data. The volume of the temporal fossa differs between genders with males having a greater temporal volume compared with females. Increases in BMI resulted in an increase in volume; this can be explained by the presence of the various fatty layers and fat pads of the temple. Advanced age, however, decreased the temporal soft tissue volume in females and this effect was more dominant in postmenopausal females. This age-related effect was interestingly not observed in males when conducting the same statistical approach.

Conflict of Interest
None declared.

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