Examination of Facial Convexity and Concavity Values With Reference to the External Acoustic Pore: A Retrospective Study

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Abstract: The human skull serves as an essential material for facial reconstruction. In particular, the petrous part of the temporal bone is vital due to its compact structure, which can resist mechanical forces. The study aims to give descriptive values to estimate the face shape and produce regression formulas through the external acoustic pore as a reference point. The study was carried out on 3-dimensional computed tomography images, a total of 83 adult images (45 females and 38 males) in the Department of Radiology of Bursa Uludag University Medical Faculty. The distances between the imaginary vertical line passing through the porion and the anthropometric points revealing the facial features were measured for the soft and hard tissue. The vertical distances between the soft and hard tissue landmarks were also measured for both sexes. Measurements were performed with the Image *J* program, and for the statistical analysis, SPSS 25.0 was used ($P < 0.005$). Linear simple regression analysis was used to produce formulas to estimate the soft tissue thickness using hard tissue. Also, discriminant function analysis was performed to determine sex in the presence of an unknown skull. The descriptive values of the variables on the axial and vertical planes and the differences between sexes are given. Also, all formulas make accurate predictions of 90% or more. The authors tried to estimate the anatomical points that roughly reveal the facial features with the regression formulas developed using anthropometric measurements. The authors think that the shape of the face, which is more specific to the individual, can be reached more clearly using mathematical models, and the authors believe that this study will set an example for future studies.

Key Words: Computed tomography, face, facial reconstruction, porion, soft tissue, temporal bone

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The face is an external and unique representation of an individual's distinctive identity, allowing people to be recognized. Moreover, it changes quite a lot with many factors, including volumetric change, redistribution of subcutaneous fat, progressive bone resorption, and decreased tissue elasticity.[1] Facial reconstruction has become a crucial issue in recent years. With the impact of the improving technological techniques, especially in anthropology and forensic sciences, it is much more necessary. The remains of a human skull serve as an essential structure at our disposal to reshape the dead person's most likely facial appearance to allow for identification.[2]

Anthropometry refers to the systematic measurement of the physical properties of the human body, primarily the dimensional descriptions, including length and angle. It is used to create 3-dimensional (3D) visual images of people from skeletal remains, mummified bodies, or preserved bodies.[3] The basic knowledge of the relationship between the skeleton and soft tissue in the face is crucial to obtaining a reliable and proper depiction of the face in the forensic sciences.[4] There have been so many studies to determine the relationship between hard and soft tissues on the face.[5,6] Considering these studies, each individual has special facial features closely related to other facial structures found on that face.[7]

Regarding anatomical features, the frontal, zygomatic, temporal, occipital bones, and mandible mainly determine sex from the skull. In particular, the petrous part of the temporal bone is due to its compact structure, which can resist mechanical forces and other destructive factors such as temperature.[8] Thus, it maintains its integrity in most cases such as mass disasters, cremation, and burial, meaning it can be used as an anatomical point in forensic anthropology.[9] The external acoustic meatus arises from the anteriormost part of the concha, marks the beginning of the external auditory canal, opens to the outside as an opening, and is named the external acoustic pore (EAP).[10] Our observations of the dry skulls show that this opening almost completely preserves its structure and has no

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This study has been presented as a poster presentation at the 20th National Anatomy Congress on August 21–27, 2019. The study, which was presented at the congress as a pilot study, was repeated by increasing the number of individuals.

The authors declare that the study was performed in accordance with the ethical standards mentioned in the 1964 Declaration of Helsinki. The study was conducted with the decision of the Bursa Uludag University Faculty of Medicine Clinical Research Ethics Committee (Date: October 22, 2021-Decision No: 2021-15/15).

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deformity. The study aims to give descriptive values to estimate the face shape and produce regression formulas through the EAP as a reference point. We think the originality of these formulas will significantly contribute to the literature.

METHODS

The study was conducted with the decision of the Bursa Uludag University Faculty of Medicine Clinical Research Ethics Committee (Date: October 22, 2021-Decision No: 2021-15/15).

Image Protocol

The study was carried out on 3D cranial computed tomography images taken by Siemens Somatom Definition 128-slice multidetector computed tomography in the Department of Radiology of Bursa Uludag University Medical Faculty. Protocol numbers of the individuals were retrospectively evaluated using the Centricity RIS 4.2 Plus PACS system (General Electric). The reformed images were created with AW Suite 2.0 program by using thin-section axial images of 1.5 mm thickness. After the reform, the images were evaluated in the system's bone and soft tissue windows for optimal examination. Cranium has been rendered in 3D with the choice of volume rendering on the program. Three-dimensional cranium images were recorded in the PACS system through AW Suite 2.0.

Study Group

In the retrospective study, a total of 83 adult images (45 females and 38 males) who underwent cranial tomography at Bursa Uludag University between 2012 and 2022 were included. Individuals with fractures, deformities, or any pathological findings and a history of surgery were excluded from the study. The age range for females was 18 to 69, and the mean age was 36 ± 14.39 years. The age range for males was 19 to 85, and the mean age was 37.16 ± 13.95.

Measurements

The EAP's upper point, also named porion, was chosen as a reference. In the study, the distances between the imaginary vertical line passing through the porion point and the anthropometric points revealing the convexity and concavity of the facial features were measured for the soft and hard tissue. For the hard tissue, the linear distances on the axial plane from the imaginary line to the anthropometric points that glabella (G), nasion (N), rhinion (Rh), nasospinale (Ns), A point (A), prosthion (Pr), infrarenal (Id), B point (B), pogonion (Pg), menton (Me), and opisthocranion (Op) were measured. For the soft tissue, the linear distances from the imaginary line to the anthropometric points that glabella (G'), nasion (N'), rhinion (Rh'), pronase (Pn), subnasale (Sn), upper lip anterior (Christa philtrum), lower lip anterior (LLA, labiale inferius), B point (B'), pogonion (Pg'), menton (Me'), and opisthocranion (Op') were measured. In the study, the vertical distances between the anatomical points determined for soft and hard tissue were also measured for both sexes.[11,12] Measured anthropometric points and their explanations are shown in Figure 1. The parameters and measured distances for the axial plane are shown in Figure 2. The measured distances for the vertical plane for the hard and soft tissue are shown in Figure 3.

The first step of facial reconstruction is completing the missing or broken parts of the skull. This phase is done using the mirror method technique by accepting them as symmetrical concerning the existing side.[13] According to this rule, the study used the right side of the skull and face.

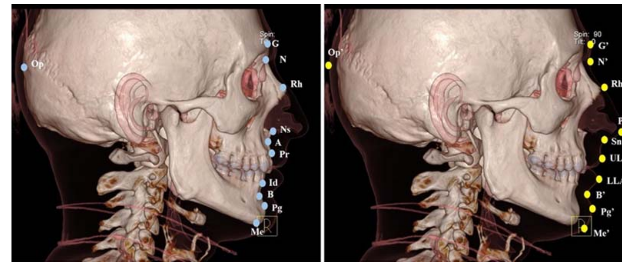

FIGURE 1. Anthropometric points, which are included in the study. A indicates point A; B, point B; B′, point B for the soft tissue; G, glabella; G′, glabella for the soft tissue; Id, infradentale; LLA, lower lip anterior; Me, menton; Me′, menton for the soft tissue; N, nasion; N′, nasion for the soft tissue; Ns, nasospinale; Op, opisthocranion; Op′, opisthocranion for the soft tissue; Pg, pogonion; Pg′, pogonion for the soft tissue; Pn, pronasale; Pr, prosthion; Rh, rhinion; Rh′, rhinion for the soft tissue; Sn, subnasale; ULA, upper lip anterior point.

Statistical Analyses

Measurements were performed with the Image *J* program, and SPSS 25.0 (IBM) was used for the statistical analyses. The descriptive values of the variables are given as mean ± standard deviation and the range of the variables for both sexes. To determine the sex differences, the Student *t* test and Mann-Whitney *U* test were used ($P < 0.005$).

Pearson correlation analysis was used to determine the correlation between the variables on the axial plane, and Spearman correlation analysis was used to determine the correlation between the variables ($P < 0.005$). In the continuation of the study, with variables having high correlation, linear simple regression analysis was used to produce formulas to estimate the soft tissue thickness using hard tissue. Also, discriminant function analysis was performed to determine sex in the presence of an unknown skull.

RESULTS

The descriptive values of the variables on the axial plane and the differences between sexes are shown in Supplemental Digital Content, Table 1, (http://links.lww.com/SCS/E769). For the variables on the vertical plane, descriptive values and sex differences are shown in Supplemental Digital Content, Table 2, (http://links.lww.com/SCS/E770). Although the distance be-

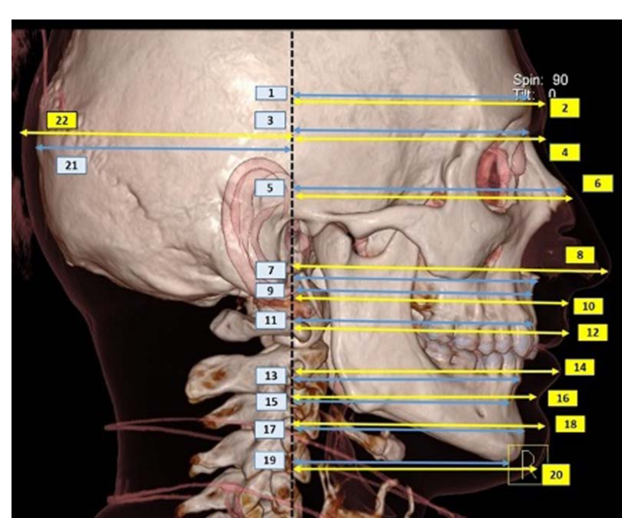

FIGURE 2. Hard and soft tissue parameters on the axial plane.

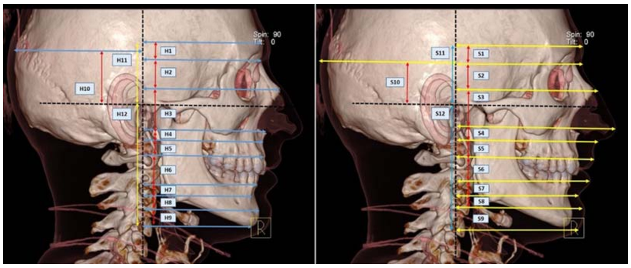

FIGURE 3. Hard and soft tissue parameters on the vertical plane.

tween the vertical line passing through the porion to the nasion for both soft and hard tissues (N and N') and the glabella just for hard tissue (G) did not show sex differences, from the line to the glabella for the soft tissue (G') and rest of the variables on the axial plane showed sex differences (Figs. 4,5). The variables on the vertical plane for the hard tissue, the vertical distance between Rh and Ns (H3), the vertical distance between Pr and Id (H6), the vertical distance between Pg and Me (H9), the vertical distance between Op and the axial plane passing through the porion (H10), and the vertical distance between G and the axial plane passing through the porion (H11) were found to differ between males and females. It is seen that these variables, which vary, have higher values in males. For the soft tissue, the vertical distance between G' and N' (S1), the vertical distance between LLA and B' (S7), the vertical distance between B' and Pg' (S8), the vertical distance between the Pg' and Me' (S9), the vertical distance between the Op' and the axial plane passing through the porion (S10), and the vertical distance between the glabella G' and the axial plane passing through the porion (S11) were found to differ between sexes. For the soft tissue landmarks, vertical distances, while the vertical distance between the G' and N' (S1) and the vertical distance between B' and Pg' (S8) have higher values for females, the rest of the soft tissue distances are higher in males. Also, soft tissue thicknesses were calculated by subtracting bone tissue distances from soft tissue distances (Supplemental Digital Content, Table 3, http://links.lww.com/SCS/E771)

When the results of the correlation analysis were evaluated, it was seen that the variables on the axial plane were in high correlation with each other, but no correlation finding was detected between any of the variables on the vertical plane. As a result of linear regression analyses carried out by considering high correlation coefficients, formulas with high reliability on the axial plane were obtained to estimate soft tissue thickness (Supplemental Digital Content, Table 4, http://links.lww.com/SCS/E772) As there is no correlation between the variables on the vertical plane, the formula could not be written by regression analysis except for the distance between the vertical distance between G' and the axial plane passing through the

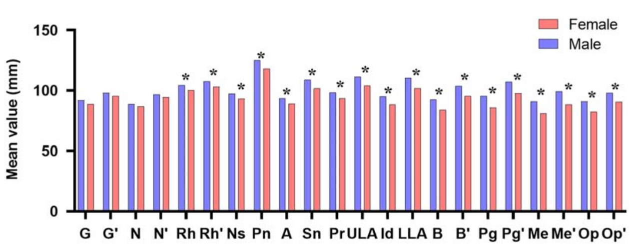

FIGURE 4. Descriptive values of the hard and soft tissue parameters on the axial plane and sex difference.

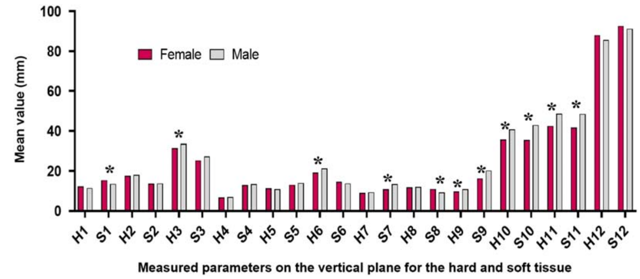

FIGURE 5. Descriptive values of the hard and soft tissue parameters on the vertical plane and sex difference.

porion (S11), the vertical distance between the axial plane passing through the porion and Me' (S12). The regression formulas are:

$$\text{For males; } S11 = -2.365 + (H11 \times 1.046)$$

$$\text{Adjusted } R^2 \text{ Value: } 0.927; \text{ S.E. : } 2.61$$

$$\text{For females; } S11 = 3.562 + (H11 \times 0.898)$$

$$\text{Adjusted } R^2 \text{ Value: } 0.836; \text{ S.E. : } 3.38$$

$$\text{For males; } S12 = 7.289 + (H12 \times 0.981)$$

$$\text{Adjusted } R^2 \text{ Value: } 0.944; \text{ S.E. : } 2.39$$

For females; unable to write a formula

In the presence of an unknown skull, discriminant function analysis was performed to determine sex. The formulas are:

$$\begin{aligned} \text{Males} = &- 384.997 + (3.579 \times P1) - (3.128 \times P3) \\ &+ (0.280 \times P5) + (0.939 \times P9) \\ &+ (0.069 \times P19) + (3.086 \times P21) \end{aligned}$$

$$\begin{aligned} \text{Females} = &- 337.149 + (2.343 \times P1) - (1.585 \times P3) \\ &+ (2.684 \times P5) + (., 258 \times P9) \\ &-(0.139 \times P19) + (2.855 \times P21) \end{aligned}$$

The canonical correlation value is 0.785 and Wilki λ value is 0.384 ($P < 0.001$).

DISCUSSION

We have presented the regression formulas to estimate facial soft tissue thicknesses of a sample of the Turkish population, taking as reference EAP. Facial contours are traditionally achieved by positioning the underlying hard tissue and then the soft tissue on top of it. Standard soft tissue thickness values and other anatomy-based rules are used for facial reconstruction.[14] Soft tissue thickness values are used to determine the amount of depth of tissues that coincides at specific predetermined landmarks in the skull. It helps to reconstruct the face by creating a boundary for work while developing the initial face shape in the early stages of the reconstruction procedure.[15]

Most of the time, the temporal bone preserved intact among the skeletal remains is one of the skull bones.[8] It is stated that the remains of thousands of cremated infants in the Phoenician

Carthage cemetery contain hundreds of well-preserved temporal bone petrous fragments.[16] Considering this information, it is aimed to estimate the facial soft tissue thickness by referring to the external acoustic porus, which is located on the petrous part of the temporal bone and maintains its integrity to a large extent as a result of our observations.

When the axial variables measured by creating the imaginary vertical line passing through the porion were examined, it was observed that all variables differed in male and female individuals, except for the distances to the glabella (only G), nasion (N), and soft tissue points (G', N'). When the vertical distance between glabella and nasion and the distance between nasion and rhinion were examined, no sex difference was determined in either parameter. In males, the supraorbital margin tends to have a rounded conformation, and its extension gives the glabella a more prominent appearance, whereas females are more precise.[17] For this reason, it is a striking finding that although a sex difference is expected for the glabellar region, which shows dimorphism, the opposite result is obtained. Although the sex difference was expected in this region, the opposite result was obtained, which made us think that the position of the porion point may differ in males and females. In another study, in which we made distances to the direct bone points by taking the porion as a reference to estimate the skull shape in case the skull is fractured or fragmented, it was seen the linear distance between the porion-glabella and the porion-nasion, the angle formed between the two points and all linear distances to the other points showed sex difference.[18] It is an interesting finding that although there is a difference in direct lengths, there is no difference in indirectly measured distances.

In the literature, soft tissue thicknesses are determined by measuring the distance between bone and soft tissue. In this study, soft tissue thickness was calculated by subtracting the bone tissue distances from the soft tissue distances calculated directly from the porion to the soft tissue. When the results were examined, no sex difference was observed in the glabella, nasion, and rhinion regions. When these results are compared with other studies in the literature, it is seen that some data are compatible. However, we state that these studies were performed by dividing them into age groups. While the sex difference was noted in the glabellar region, especially in the young group, the difference in tissue thickness decreased with age.[19,20] In addition, it should not be forgotten that soft tissue thicknesses are closely related to body mass index.[21]

It has been observed that the distance between the rhinion—nasospinale (Ns-Rh) and the distance between the prosthion—infradentale, which are the vertical parameters measured on the bone tissue, differ between males and females. Although the sex difference is expected in these bone points, which we can define as the piriform aperture and mouth height, it is interesting that this difference was not seen in soft tissue distances. However, when the data in terms of soft tissue thickness are examined, it is seen that there is a sex difference in these regions.

When the variables on the mandible, which is another bone showing dimorphism, were examined, the distances from the direct porion differed. While a difference was observed in the distances of bone tissue and soft tissue from the vertical parameters, it was observed that there was a difference in soft tissue thicknesses contrary to the nose and lip regions. Although there was a sex difference in the axial distances from the porion for the opisthocranion, which is the most posterior point of the skull, there was no difference in both bone and soft tissue distances from the vertical variables, but a sex difference was observed in the soft tissue thickness at this time. The soft tissue, bone tissue distances, and soft tissue thicknesses showing sex differences in the axial and vertical planes for the region are summarized in Supplemental Digital Content, Table 5, (http://links.lww.com/SCS/E773).

All bone and soft tissue distances on the axial plane were found to be higher in males. In the vertical plane variables, it is seen that the distance between the glabella and the nasion and the distance between the porion and the menton have a higher mean in females for both bone and soft tissue. Again, the distance between *A* point and prosthion (A—Pr) on the vertical plane soft tissue on the bone tissue, upper lip anterior—LLA on the soft tissue, and the distance between *B* point and pogonion (B'—Pg') on the soft tissue were found to be higher in females.

In a study, it is stated that postmortem shrinkage was observed in human fetal diaphyseal lengths when comparing the dry bones with the fresh bones.[22] According to this information, it seems that radiographic measurements of bones are troubled due to disruption of the integrity of the bones due to taphonomic reasons. Also, it is a fact that the appearance of the face of the individuals shows significant differences because of environmental and genetic reasons.[23] It can easily be seen that the relevance of the data with a dry skull obtained from living people or cadavers does not reflect the actual image. Because of the vast differences between individuals, it can be understood that facial reconstruction cannot give us an absolute result.

Forensic facial reconstruction is a method for predicting possible face shapes. Especially, estimation of the soft tissue thickness is the focal point of the studies. Although the face shape is specific to the individual, it is possible that using the average values of soft tissue thicknesses while performing the reconstruction cannot give accurate results. In this case, obtaining individual-specific values with mathematical models using an anatomical reference point will bring us closer to the final result. For this purpose, we developed regression formulas to predict soft tissue using bone tissue. It is possible to see that almost all of the formulas make accurate predictions of 90% or more. According to these results, it seems more likely to reach the correct result with higher rates. In addition, it should be reminded that these formulas are specific to Turkish individuals.

In conclusion, we performed measurements on both the vertical and the axial planes by referring to the EAP, as it largely preserves its integrity for facial reconstruction. We tried to estimate the anatomical points that roughly reveal the facial features with the regression formulas developed using these measurements. We think that the shape of the face, which is more specific to the individual, can be reached more clearly using mathematical models, and we believe that this study will set an example for future studies.

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REFERENCES

1. Zimbler MS, Kokoska MS, Thomas JR. Anatomy and pathophysiology of facial aging. *Facial Plast Surg Clin North Am* 2001;9:179–187
2. Gietzen T, Brylka R, Achenbach J, et al. A method for automatic forensic facial reconstruction based on dense statistics of sotf tissue thickness. *Plus One* 2019;14:e0210257
3. Kim SC, Kim HB, Jeong WS, et al. Comparison of facial proportions between beauty pageant contestants and ordinary young women of Korean ethnicity: a three-dimensional photogrammetric analysis. *Aesthetic Plast Surg* 2018;42:748–758
4. Babacan S, Isiklar S, Kafa IM, et al. Redesign of the missing mandible by determining age group and sex from morphometric

features of the skull for facial reconstruction (approximation). *Archaeol Anthropol Sci* 2021;13:75
5. Utsuno H, Kageyama T, Uchida K, et al. Pilot study to establish a nasal tip prediction method from unknown human skeletal remains for facial reconstruction and skull photo superimposition as applied to Japanese male populations. *J Forensic Leg Med* 2006;38:75–80
6. Codinha S. Facial soft tissue thicknesses for the Portuguese adult population. *Forensic Sci Int* 2009;30184:80.e1–7
7. Garlie TN, Saunders SR. Midline facial tissue thicknesses of subadults from a longitudinal radiographic study. *J Forensic Sci* 1999;44:61
8. Kozerska M, Skrtatz J, Sczepanek A. Application of the temporal bone for sex determination from the skeletal remains. *Folia Med Cracov* 2015;55:33–39
9. Pezo-Lanfranco LM, Heatinger RG. Tomographic-cephalometric evaluation of the pars petrosa of temporal bone assessing method. *Forensic Sci Int Report* 2021;3:100174
10. Fan H, Yu S, Wang M, et al. Analysis of the external acoustic meatus for ergonomic design: part II—anthropometric variations of the external acoustic meatus by sex, age and side in Chinese population. *Ergonomics* 2021;64:657–670
11. Cha KS. The soft-tissu thickness of South Korean adults with normal facial profiles. *Korean J Orthod* 2013;43:178–185
12. Bergman RT. Cephalometric soft tissue facial analysis. *Am J Orthod Dentofacial Orthop* 1999;116:373–389
13. Aka S, Şakul U. Anatomical facial reconstruction technique applied to an unrecognisable case for identification. *J Forensic Sci* 2007;6: 65–70
14. Ramesh G, Nagarajappa R, Sreedhar G. Facial soft tissue thickness in forensic facial reconstruction: is it enough if norms set? *Forensic Res* 2015;6:1–4
15. Cavanagh D, Steyn M. Facial reconstruction: soft tissue thickness values for South African black females. *Forensic Sci Int* 2011;206:215
16. Schwartz JH, Houghton F, Bondioli L, et al. Bones, teeth, and estimating age of perinates: Carthaginian infant sacrifice revisited. *Antiquity* 2012;86:738–745
17. Keaney TC, Alster TS. Botulinum toxin in men: review of relevant anatomy and clinical trial data. *Dermatol Surg* 2013;39:1434–1443
18. Tuncel Cini N, Arı I. Evaluation of the relationship between the anatomical formations on the temporal bone and the face shape. *PhD dissertation Bursa Uludag University Department of Anatomy* 2021.
19. Bulut O, Sipahioglu S, Hekimoglu B. Facial soft tissue thickness database for craniofacial reconstruction in the Turkish adult population. *Forensic Sci Int* 2014;242:44–61
20. Sipahioglu S, Ulubay H, Diren HB. Midline facial soft tissue thickness database of Turkish population: MRI study. *Forensic Sci Int* 2012;219:282.e1–8
21. Karaman A, Genc E. Evaluation of facial soft-tissue values and craniofacial morphology in obese adolescent patients with different skeletal classes. *APOS* 2021;11:270–278
22. Huxley AK. Analysis of shrinkage in human fetal diaphyseal lengths from fresh to dry bone using Petersohn and Kohler's data. *J Forensic Sci* 1998;43:423–426
23. Simpson E, Henneberg M. Variation in soft-tissue thicknesses on the human face and their relation to craniometric dimensions. *Am J Phys Anthropol* 2002;118:121–133

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