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Validity of Metric Assessment of Mastoid Triangle in Sex Determination: An Anatomical Study

Cinsiyet Belirlemede Mastoid Üçgenin Metrik Değerlendirmesinin Geçerliliği: Anatomik Bir Çalışma

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Abstract

Objective: This study aimed to evaluate the validity of the mastoid triangle anthropometric measurements and area between the three craniometric points, namely porion (po), asterion (ast), and mastoidale (ms) as a sex determinant.

Materials and Methods: A total of 60 dry skulls (30 males and 30 females) were assessed for 10 morphometric measurements with a compass, and a total of 120 mastoid triangles were evaluated.

Results: Statistically significant differences were found in all the mastoid triangle measurements between males and females ($p \leq 0.01$). Discriminant function analyses revealed that the left po-ms length and the total area of the mastoid triangle were two variables with the highest sensitivity at an accuracy rate of 90%. The models with three mastoid triangle variables including the total po-ms, total ms-ast, and total po-ast measurements, in combination, provided high discriminant potentials of 96.7% and 93.3% in females and males, respectively. When the total po-ms, total ms-ast, and total po-ast were used together, a greater sexual dimorphism was observed, correctly classifying the sex with a 95% accuracy rate. The mean value of the total area which is preferred due to the asymmetry between the sides of the skull was 1455.2 mm^2 in males and 1341.2 mm^2 in females.

Conclusion: In the light of the obtained results, the discriminant function analyses of the mastoid triangle measurements are concluded to be reliable in sex determination and preferable in forensic medicine and anthropology.

Öz

Amaç: Bu çalışmanın amacı, porion (po), asterion (ast) ve mastoidale (ms) olmak üzere üç kraniyometrik nokta arasındaki mastoid üçgen antropometrik ölçümlerinin ve alanının cinsiyet belirleyicisi olarak geçerliliğini değerlendirmektir.

Gereç ve Yöntemler: Toplam 60 kuru kafatası (30 erkek ve 30 kadın) kullanılarak kaliper ile on adet ölçüm gerçekleştirildi, 120 mastoid üçgen değerlendirildi.

Bulgular: Erkekler ve kadınlar arasında tüm mastoid üçgen ölçümlerinde istatistiksel olarak anlamlı farklılık bulundu ($p \leq 0,01$). Diskriminant fonksiyon analizinde sol po-ms uzunluğu ve mastoid üçgenin toplam alanının %90 doğruluk oranıyla en yüksek duyarlılığa sahip iki değişken olduğu bulundu. Toplam po-ms, toplam ms-ast ve toplam po-ast ölçümlerini bir arada içeren üç mastoid üçgen değişkenli modeller,

kadınlarda ve erkeklerde sırasıyla %96,7 ve %93,3'lük yüksek diskriminant potansiyeli sağladı. Total po-ms, total ms-ast ve total po-ast birlikte kullanıldığında, cinsiyeti %95 oranında doğru sınıflandıran daha fazla cinsel dimorfizme sahiptiler. Kafatası kenarları arasındaki asimetri nedeniyle tercih edilen toplam alanın ortalama değeri erkeklerde 1455,2 mm², kadınlarda 1341,2 mm² olarak bulundu.

Sonuç: Elde edilen sonuçlar ışığında mastoid üçgen ölçümlerinin diskriminant fonksiyon analizlerinin cinsiyet belirlemede güvenilir, adli tıp ve antropolojide tercih edilebilir olabileceği sonucuna varılabilir.

Introduction

Clinically, knowledge of the morphometric assessment of the cranium may be important for neurosurgeons so that they may avoid inadvertent procedures during various surgical approaches (1,2). More importantly, skeletal features of the cranium are considered important in terms of sex determination in legal medicine and forensic anthropology. Thus, it is of great importance for paleoanthropologists to identify sex confidentially by using skeletons, which constitutes the basis for later evaluations. In particular, discriminant function analysis of the human skull has become important in legal medicine and forensic anthropology (3-5). Classically, two methods have been used for sex determination based on bone characteristics, that is, morphological (non-metrical) and metrical (5,6).

The results of morphometric measurements on the bones in sex determination are of great importance at all times. Therefore, we aimed to perform a morphometric method easily applicable with high accuracy and very little observer error in this study. Processus mastoideus and the surrounding space can be used for sex determination. Since recent studies focused on whether the landmark of asterion (ast) was reliable, we investigated its role in sex determination (3,7,8). Many authors have drawn attention to preservation of the petrous portion of the temporal bone and its use in identity and sex determination. Compact structure and protected position of the petrous bone at the base of the skull have made it preferable in sex determination (1,3,9). As a result of these craniometric features, the mastoid triangle is an important anatomic area in terms of sex determination.

In this study, the method was based on measurements of the distances between three craniometric points, easily identified as porion (po), ast and mastoidale (ms). The measurements of the triangle drawn between these three points and the measurement of the triangular area were used to identify sex (3,7,8).

Materials and Methods

We performed morphometric measurements of 60 adult craniums which belonged to 30 females and 30 males in the Laboratory of the Department of Anatomy, Aydın Adnan Menderes University Faculty of Medicine, Aydın, Turkey. The skulls with intact craniometric points and with no evidence of trauma or deformations in the mastoid space were selected for this study.

Metric Assessment of Mastoid Triangle

In this study, a total of 10 randomly selected craniums were assessed independently by two examiners with regard to parameters. A week later, the same measurements were repeated and inter- and intraobserver reliability were assessed. Thus, a total of 120 mastoid triangles were assessed by a single observer to minimize observer error on the right and left side. The mastoid triangle was defined by between three points; po the superior surface of the meatus acusticus externus, as the craniometric point at the junction of the sutura lambdoidea, sutura occipitomastoidea, sutura parietomastoidea, and ms the lowest craniometric point at the mastoid process (Figure 1). The po, ast and ms both on the right and left sides were identified in each skull and the mastoid triangle was obtained when three lines were drawn between these three points. Dimensions of the triangle were measured with a compass sensitive at 0.01 mm, similar to those of (8,10). Measurement results were expressed in mm and mm².

Linear measurements of the triangle were as follows: Po-ms, distance between po and ast; ms-ast, distance between ms and ast; po-ast, distance between po and ast. Firstly, the circumferences (C) of the triangles both on the right and the left were measured and each triangular area was estimated based on the Heron's formula, as described below (8).

Heron's formula: A= √ [s(s–a) (s–b) (s–c)]

A= triangular area, a: po-ms distance, b: ms-ast distance, c: po-ast distance, s; semi-circumference of the triangle calculated with s=(a+b+c)/2

Then, similar measurements obtained from the right and left sides of the same cranium were summed and total po-ms distance, ms-asc distance, po-ast distance, mastoid triangle circumference and area were calculated according to the method described by de Paiva and Segre (11). The calculated measurements were as follows: total po-ms, sum of right and left po-ms distances; total ms-ast, sum of right and left ms-ast distances; total po-ast, sum of right and left po-ast distances; mastoid triangle circumference, three dimensions of the triangle on one side (po-ms + ms-ast + po-ast); total circumference, the sum of the C of the right and left mastoid triangles; mastoid triangle area based on Heron's formula using semi-circumference; and total area, sum of right and left mastoid triangles area on the same cranium.

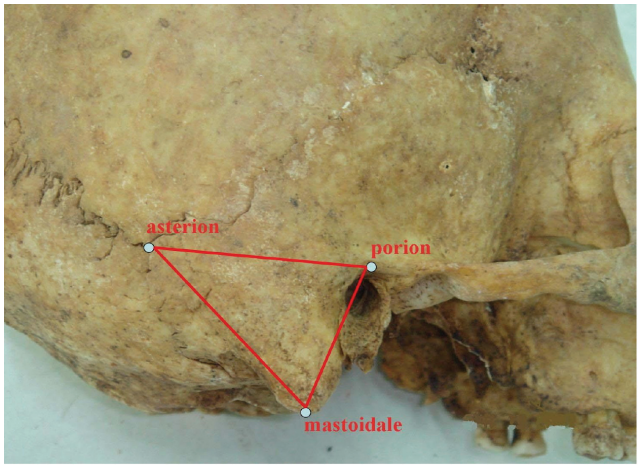

Figure 1. Mastoid triangle drawn between three points; asterion, porion and mastoidale, lateral view of the skull

Statistical Analysis

Statistical Package for Social Sciences (Version 18.0, SPSS Inc., Chicago, IL, USA) software was used for analysis of the data obtained in this study. The normality of the data was evaluated with the Shapiro-Wilk test and expressed as the mean ± standard deviation (SD) since all of them showed normal distribution. Statistical difference was evaluated with Student's t-test between genders and paired t-test between right and left sides. Discriminant function analysis was performed to determine the effectiveness of parametric variables in separating genders from each other.

Results

In this study, all measured and calculated parameters of which are mean, SD, minimum and maximum values are given in Table 1, were found to be statistically significant higher in males than females with a 95% confidence interval ($p \leq 0.01$). In Table 2, gender specific Student's t-test values of the measurements are shown. The results of paired t-test used to detect differences according to right and left sides are presented in Table 3. As shown in the Table 3, there was not a significant difference between any of the individual mastoid triangle measurements in both males and females ($p>0.05$). Regardless of gender

Table 1. Summary statistics of parametric measurements by gender, right and left sides

Measurements	Male (n=30) Mean ± SD (min-max)			Female (n=30) Mean ± SD (min-max)		
	Right	Left	Total	Right	Left	Total
Po-ms	32.2±3.2 (26.6-40.7)	32.2±3 (28.9-41)	64.7±6.0 (55.6-81.7)	26.1±3 (20.0-30.6)	26.8±2.1 (20.8-29.8)	52.9±4.7 (40.8-59.8)
Ms-ast	49.8±5.7 (36-61)	48.7±4.8 (41-62.7)	98.5±10.1 (79.5-123.7)	46.3±4.5 (35-56.8)	45.4±4.5 (35.5-55.8)	91.7±8.5 (70.5-112.6)
Po-ast	46.6±3.2 (41-55)	47.3±2.6 (42-53.6)	93.9±5.0 (85-105.5)	42.9±2.7 (36.0-48.5)	42.8±3.3 (35.4-48)	85.7±5.2 (71.4-94.3)
C	128.6±10.2 (107.8-151.7)	128.6±9.1 (112-150.2)	257.2±18.2 (224.6-294.8)	115.3±8.1 (92.4-131)	115±8.6 (93.7-128.4)	230.3±15.5 (186.1-259.4)
A	723.9±111.5 (516.4-1050.4)	731.3±103.4 (563.5-963.7)	1455.2±201.2 (1107.3-1990.9)	545.6±77.9 (361.8-678.9)	556.8±73.5 (382.7-662.3)	1102.3±137.4 (744.4-1341.2)

SD: Standard deviation, min: Minimum, max: Maximum, po-ms: Porion, ms-ast: Mastoidale asterion, po-ast: Porion, C: Mastoid triangle circumference, A: Mastoid triangle area

Table 2. The distribution of gender specific differences by measurements				
Measurements	**Side**	**t**	**df**	**p (sig. two tailed)**
Po-ms	Left	8.514	58	p<0.01
	Right	7.719	58	p<0.01
Ms-ast	Left	2.723	58	p<0.01
	Right	2.627	58	p<0.01
Po-ast	Left	5.957	58	p<0.01
	Right	4.769	58	p<0.01
Circumference	Left	5.951	58	p<0.01
	Right	5.612	58	p<0.01
Area	Left	7.537	58	p<0.01
	Right	7.181	58	p<0.01
Total po-ms	Both	8.524	58	p<0.01
Total ms-ast		2.804	58	p<0.01
Total po-ast		6.226	58	p<0.01
Total circumference		6.152	58	p<0.01
Total area		7.934	58	p<0.01
Po: Porion, ms: Mastoidale, ast: Asterion, t: The test statistics, df: The degrees of freedom for the test, Sig.: Significance. The p-value corresponding to the given test statistic t with degrees of freedom df				

Table 3. Distribution of the side differences by gender				
Measurements	**Gender**	**t**	**df**	**p (Sig. two tailed)**
po-ms	Males	0.923	29	0.364
	Females	1.978	29	0.058
Ms-ast	Males	1.877	29	0.071
	Females	1.619	29	0.116
po-ast	Males	1.347	29	0.188
	Females	0.321	29	0.751
Circumference	Males	0.032	29	0.975
	Females	0.277	29	0.784
Area	Males	0.536	29	0.596
	Females	0.961	29	0.344
Po: Porion, ms: Mastoidale, ast: Asterion, t: The test statistics, df: The degrees of freedom for the test, Sig.: Significance. The p-value corresponding to the given test statistic t with degrees of freedom df				

(n=60), there were no significant side differences except for two lengths of the triangles. As seen in Table 4, only po-ms and ms-ast were statistically different between the left and right sides.

The results of the discriminant function analysis performed to determine the importance of the measurements in terms of sex determination are given in Table 5. Discriminat analysis showed that left po-ms and total area values were the most reliable variables at an accuracy rate of 90%. The second and third most reliable variables were total po-ms at an accuracy rate of 88.3% and right and left triangular area at an accuracy rate of 83.3% respectively. Besides, the least reliable measurement in sex determination was found to be right ms-asth distance at an accuracy rate of 63.3%. The second and the third least reliable measurements were left ms-ast at an accuracy rate of 66.7% and total ms-ast at an accuracy rate of 68.3% respectively. Overall, the discriminant function of the individual measures from the female skulls yielded a

Table 4. The distribution of side differences regardless of gender			
Measurements	**t**	**df**	**p value (Sig. two tailed)**
Po-ms	2.105	59	0.040
Ms-ast	2.497	59	0.015
Po-ast	0.725	59	0.472
Circumference	1.039	59	0.828
Area	0.219	59	0.303
Po: Porion, ms: Mastoidale, ast: Asterion, t: The test statistics, df: The degrees of freedom for the test, Sig.: Significance. The p-value corresponding to the given test statistic t with degrees of freedom df			

Table 5. Discriminant function analyses of measures: Accuracy by gender			
	Accuracy rates of discriminate function (%)		
Measurements	**Female**	**Male**	**Total**
Left po-ms	96.7	83.3	90.0
Left ms-ast	70.0	63.3	66.7
Left po-ast	70.0	80.0	75.0
Left circumference	73.3	73.3	73.3
Left area	86.7	80.0	83.3
Right po-ms	83.3	80.0	81.7
Right ms-ast	66.7	60.0	63.3
Right po-ast	73.3	73.3	73.3
Right circumference	76.7	76.7	76.7
Right area	83.3	83.3	83.3
Total po-ms	90.0	86.7	88.3
Total ms-ast	73.3	63.3	68.3
Total po-ast	80.0	70.0	75.0
Total circumference	80.0	83.3	81.7
Total area	96.7	83.3	90.0
Total po-ms, ms-ast, po-ast	96.7	93.3	95.0
Left and right po-ms	96.7	83.3	90.0
po: Porion, ms: Mastoidale, ast: Asterion			

higher accuracy rate of sex determination and so did the discriminant function of multiple variables.

Accuracy rates increased when more than one measure of the mastoid triangle especially total values of all three dimensions of both the left and the right triangles, i.e. total po-ms, ms-ast and po-ast was used. It was striking that the measure of the right and left po-ms had a high accuracy rate without ast. The discriminant function of total po-ms, total ms-ast and total po-ast provided accuracy rates of 96.7% and 93.3% for sex determination in females and males respectively. An overall assessment showed that the individual measurements had a higher discriminant function in the females and the multiple variables yielded similarly higher rates of accuracy in the females.

Discussion

When one has to determine sex of a skeleton dating back to old times and broken into pieces, both morphological and metric features of the skeleton can be utilized (5,6). In this study, measurements of the mastoid triangle in skulls were evaluated for sex determination.

Many authors have proposed that an analysis of characteristics of the mastoid process is an indicator

of sexual dimorphism (9). There have been studies on the presence of sexual dimorphism in the mastoid triangle with conflicting results (8,10). Some authors described morphologic indicators from South African indigenous skulls different from the classic indicators described by Krogman (12). Kemkes and Gobel (8) did not obtain accuracy rates sufficient to discriminate sex from the mastoid triangle; they reported a better sensitivity of the method in females. On the other hand, Suazo et al. (10) drew the conclusion that the mastoid triangle was underestimated in sex determination inwomen, hence being of less utility in practice, which is not compatible with the results of the present study. Our results differ from them but similar to de Paiva and Segre (11). Consistent with the results of a study by de Pavia and Segre (11), we found that mastoid triangle dimensions had a high rate of discriminant function for sex determination. In fact, we found significant differences not only in the total triangle area but also all dimensions and the circumference of the triangle between male and female skulls ($p<0.01$). We think that the real indicator should have an application in sex determination and a good sensitivity in both sexes.

In the current study, we used the same compass as the one described by Kemkes and Göbel (8) and Suazo at al. (10). However, de Paiva and Segre (11) used a xerographic copy of a structure of certain convexity and all of them are lineal dimensions. de Paiva and Segre (11) reported that the mean total area, which is the preferred measurement because of the asymmetry between the sides of the skull, was 1505.32 mm² for male skulls, which was greater than the maximum value obtained in the female skulls. In this study the mean total area for female skulls was 1221.24 mm², which was lower than the minimum total area for the male skulls, which is consistent with the results of the study of de Paiva and Segre (11). In fact, we found that the mean total cranial area was 1455.2±201.2 mm² in the males, which was larger than the maximum total cranial area in the females and that the mean total cranial area was 1102.3±137.4 mm² in the females, which was smaller than the minimum total cranial area in the males (1107.3 mm²). de Pavia and Segre (11) noted that values of ≥1447.40 mm² for the total triangle are typical of male crania, while values of ≤1260.36 mm² are indicative of female skulls at a confidence interval of 95%.

Discriminant analysis, made to determine which parameter better differentiates gender, showed that using more than one measure of the mastoid triangle, i.e., summation of three dimensions of the triangles on the left and the right yielded an accuracy rate of 95% for sex determination. Toneva et al. (13) measured mastoid triangle edge and area values in 148 computed tomography scans in Bulgarians, and performed discriminant function analysis to investigate the usability of these measurements in sex determination. They found that the po-mastoidal distance was statistically higher on the right side in males unlike our study. Besides, they found that mastoid triangle edge and area measurements were significantly different in both genders, similar to our study. The mastoid triangle dimensions showed sufficient discriminating power for sex estimation among Bulgarians (up to 89%), and the total mastoid triangle area is found to be the best single-sex discriminating trait (13). Another study (14) using a total of 102 lateral cephalograms in Nigerians, reported that the only mean values of the ast-ms distance and mastoid triangle area were found to be higher in males than females. Sinhorini et al. (2) reported that the use of mastoid triangle parameters had an accuracy of 80.8% for sex estimation in a hundred Brazilian skulls.

In our study, the mean total cranial area in both females and males overlapped and therefore, it is not a cranial feature than can be used for sex determination. To the best of our knowledge, however, this is the first study reporting the metric assessment of the mastoid trianglein Turkish population for sex determination in forensic medicine and anthropology.

The ast has got various positions. Its reliability has been put into question due to its population-specific variability in position (15). Kemkes and Gobel (8) emphasized that variability of the location of the ast lessened the value of the mastoid triangle as a marker of sex determination. Therefore, we performed a discriminant analysis of po-ms only without the ast and found that it had a high discriminant capability at a rate of 90%. Discriminant function of the measures including the ast was the least reliable for sex determination. In fact, the least reliable mastoid triangle dimension was the right ms-ast at a rate of 63.3%, followed by left ms-ast at a rate of 66.7% and total ms-ast at a rate of 68.3%.

Conclusion

The results of the present study underline the role of the mastoid triangle in sex determination. It can be concluded that several metric values of the cranium can be reliable and yield a high rate of accuracy in paleoanthropological studies when morphological features of the bones such as the cranium cannot be used or when these bones have suspicious features.

Ethics

Ethics Committee Approval: Ethics committee approval is not required to carry out this study.

Informed Consent: Informed consent approval is not required to carry out this study.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept: H.K.B., N.G.Ç., M.T., Design: H.K.B., N.G.Ç., M.T., Supervision: H.K.B., N.G.Ç., M.T., E.D.İ., Fundings: H.K.B., N.G.Ç., M.T., Materials: H.K.B., N.G.Ç., M.T., E.D.İ., Data Collection or Processing: E.D.İ., G.S., Analysis or Interpretation: H.K.B., N.G.Ç., M.T., E.D.İ., G.S., Literature Search: H.K.B., N.G.Ç., M.T., E.D.İ., G.S., Writing: H.K.B., N.G.Ç., M.T., E.D.İ., G.S., Critical Review: H.K.B., N.G.Ç., M.T., E.D.İ., G.S.

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