RAP Conference Proceedings, vol. 9, pp. 13–17, 2024
ISSN 2737-9973 (online) | doi: 10.37392/RapProc.2024.04
RAP-PROCEEDINGS.ORG

GENDER PREDICTION BASED ON QUANTITATIVE ANALYSIS OF THE MASTOID PROCESS

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Abstract. *Osteoscopy and classic morphometric analysis of the skull can determine gender with an accuracy of 92%. The aim of our study was to determine the degree of accuracy in determining the gender of the skull based on the classic morphometric analysis of the mastoid process. The research was conducted on a sample of 100 macerated and degreased skulls of known gender and age from the second half of the 20th century, including the population of Bosnia and Herzegovina, which belong to the osteological collection of the Anatomy Department of the Faculty of Medicine, University of Sarajevo. It is a prospectively designed, osteometric study, where 3 diameters of the mastoid process were measured on each skull using a sliding compass (Schubler) on both sides: mastoid length, width and antero-posterior diameter. The size of the mastoid process was calculated according to the given formula. The antero-posterior diameter of the mastoid process was shown to be a significant predictor for the differentiation of skull gender p=0.0001. If the antero-posterior diameter of the mastoid process increases by 1 mm, the odds ratio (chance ratio) that it is a female skull decreases by 41% in our sample, while in the general population the chance ranges between 50-30%. The size of the mastoid process proved to be a significant predictor for the gender differentiation of the skull p=0.0001. If the size of the mastoid process increases by 1 mm3, the odds ratio (chance ratio) that it is a female skull decreases by 41% in our sample, while in the general population the chance ranges between 50-30%. Increasing values of length, width, antero-posterior diameter and size of the mastoid process increase the probability that the skull is classified as male. By multivariate binary logistic regression, the antero-posterior diameter of the mastoid process was singled out as statistically significant for the differentiation of skull gender.*

Keywords: *sexual determination, mastoid process, discriminatory functional analysis, morphometry*

1. Introduction

Osteoscopy and classic morphometric analysis of the skull can determine gender with an accuracy of 92%. The aim of our study was to determine the degree of accuracy in determining the gender of the skull based on the classic morphometric analysis of the mastoid process.

2. Materials and Methods

The research was conducted on a sample of 100 macerated and degreased skulls of known gender and age from the second half of the 20th century, including the population of Bosnia and Herzegovina, which belong to the osteological collection of the Anatomy Department of the Faculty of Medicine, University of Sarajevo. It is a prospectively designed, osteometric study, where 3 diameters of the mastoid process were measured on each skull using a sliding compass (Schubler) on both sides: mastoid length, width and antero-posterior diameter. The size of the mastoid process was calculated according to the given formula.

Length of the mastoid process: The length of the mastoid process was measured from the tip of the external acoustic meatus (Porion) vertically down to the tip of the mastoid process. The skull was laterally positioned so that one side was always facing the observer. The scale of the sliding caliper was laid behind the mastoid process, so that the fixed part of caliper was tangential with the upper edge of the external acoustic meatus. The movable part of the sliding caliper was moved to the top of the mastoid process and the measurement was read off from the scale of the slider.

Width of the mastoid process (medio-lateral diameter): The width was measured from the highest part of the medial side within the fossae digastricae to the highest laterally positioned point of the mastoid extension in the same plane.

Antero-posterior diameter of mastoid process: It was measured from the lowest point, where the tympanic part of the temporal bone contacts the anterior surface of the mastoid process to the posterior border of the mastoid process in the same plane.

Size of the mastoid process:

$$\frac{Length\ x\ Antero-posterior\ diameter\ x\ Width}{10} \tag{1}$$

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Figure 1. Mastoid length

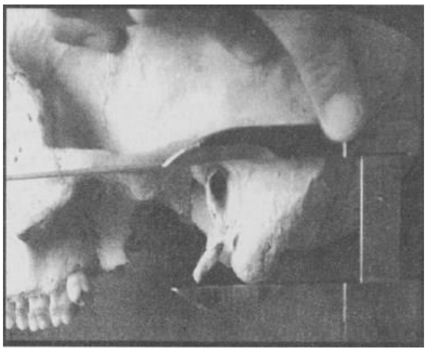

Figure 2. Mastoid width

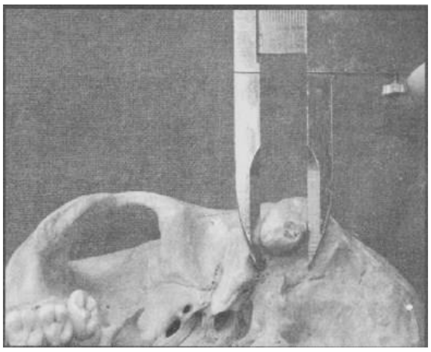

Figure 3. Antero – posterior diameter

3. Results

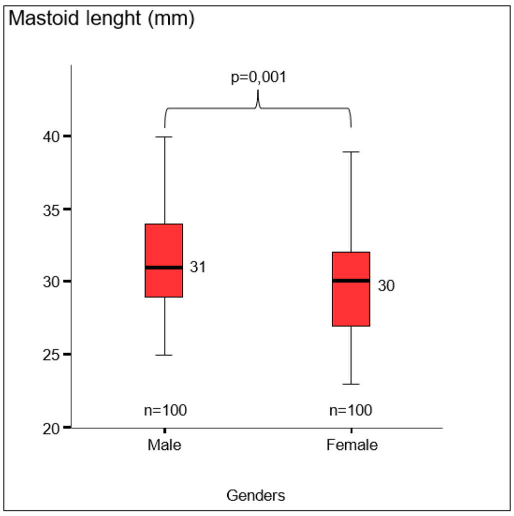

Figure 4. Mastoid length in relation to the gender of the skull

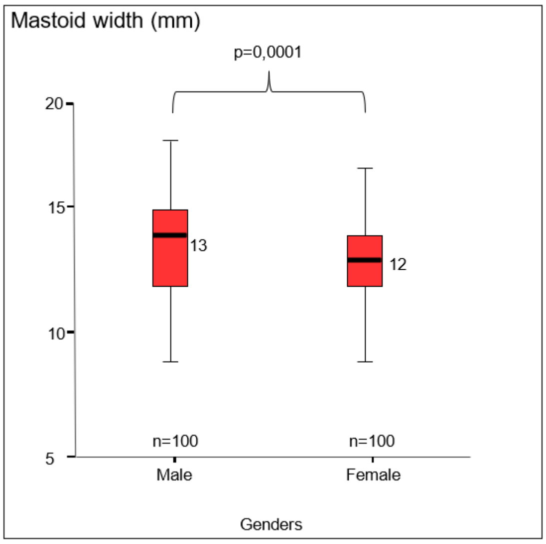

Figure 5. Mastoid width in relation to the gender of the skull

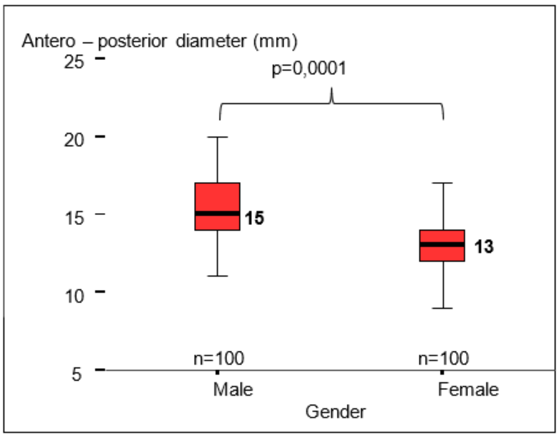

Figure 6. Anteroposterior mastoid diameter
in relation to the gender of the skull

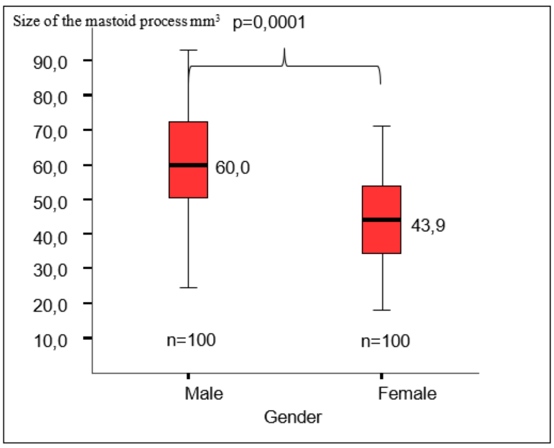

Figure 7. Size of the mastoid process
in relation to the gender of the skull

Male skulls have a longer (p=0.001), wider (p=0.0001) and larger anteroposterior diameter of the mastoid process (p=0.0001) on average. For all three sizes, the difference is statistically significant.

Male skulls have larger sizes of the mastoid process on average. The difference is statistically significant (p=0.0001).

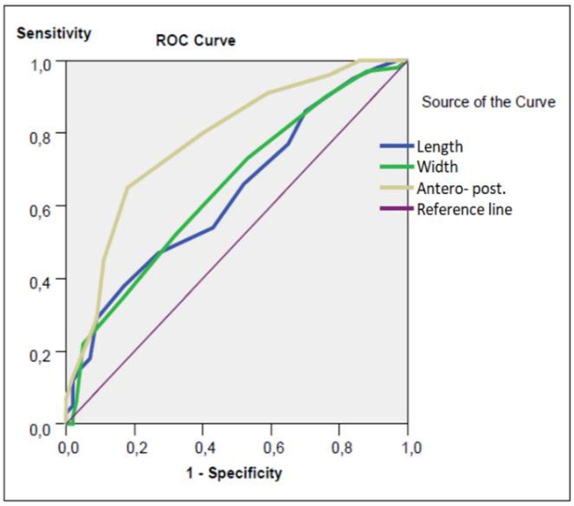

Figure 8. ROC curve of length, width and anteroposterior diameter of mastoid process, as a marker for distinguishing gender of the skull

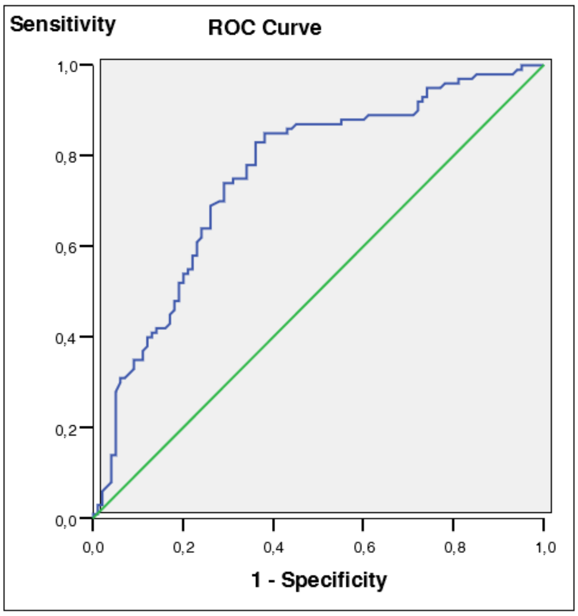

Figure 9. ROC curve of a size of the mastoid process as a marker for distinguishing gender of the skull

Table 1. Area under ROC curve for markers

Markers	AUC	St. error	p	95% Confidence Interval for AUC	
				Lower limit	Upper limit
Mastoid length (mm)	.635	.039	.001	.558	.711
Mastoid width (mm)	.651	.038	.0001	.576	.726
Anteroposterior mastoid diameter (mm)	.781	.033	.0001	.717	.845

Insight into Figure 8 and Table 1 mastoid length, width and anteroposterior diameter can distinguish male from female gender ($p<0.05$).

Insight into Figure 9 and Table 2 size of the mastoid process can distinguish male from female gender p=0.0001, AUC=0.758; 95%CI (0.69-0.82).

Table 2. Area under ROC curve for the size of the mastoid process

AUC	St. error	p	95% Confidence Interval for AUC	
			Lower limit	Upper limit
.758	.034	.0001	.690	.825

4. Discussion

Skeletal gender determination is the process of determining whether a skeleton or parts of a skeleton is male or female. For safe determination of gender and other indicators of identity, it is ideal if there is an intact, complete skeleton. However, due to various circumstances, both natural and artificial, often only parts of the skeleton are found. The accuracy of sex determination is highest when analyzing the pelvis, however, the pelvis itself is not always available for analysis. The skull is therefore considered the second-best option for sex determination. Scientists Broca and Hoshi have already suggested that when the skull is placed on a flat surface, the male skull rests on the mastoid processes, while the female skull rests on the occipital condyles or some other skull structure. Skeletal sex determinations are of the greatest importance in anatomical-anthropological approaches, forensic medicine, for understanding the process of evolution, gender differentiation, as well as for understanding the cause-and-effect relationship with other anatomical structures and physiological processes in the body.

In our study, univariate regression analysis was used to examine the influence of independent predictors - mastoid length, mastoid width, anteroposterior diameter of the mastoid process and the formula-derived size of the mastoid process on the differentiation of the gender of the skull: male or female. The anteroposterior diameter of the mastoid process proved to be a significant predictor for the differentiation of skull sex p=0.0001. If the anteroposterior diameter of the mastoid process increases by 1 mm, the odds ratio (chance ratio) that it is a female skull decreases by 41% in our sample, while in the general population the chance ranges between 50-30%.

Therefore, it was to be expected that the antero-posterior diameter of the mastoid process would stand out in the multivariate binary logistic regression as the most effective and thus be part of our "P" model for gender prediction based on the classic morphometric analysis of the mastoid process [1].

Of course, works that cover the population of Asia, North and South America in their prediction can also single out other parameters for gender profiling, so that the differences are expected and can be explained by population proliferation (geographical, racial, population differences).

Sumati et al. used the discriminant function and logistic regression to validate the discriminant function in his study. Univariate analyzes showed a high degree of differentiation. Sumati based his research on skulls from the area of northern India, while our specimens were from the Balkan area (Bosnian and Herzegovina population), and it can be said that there is a genetic and geographical factor in the different results. Johnson et al. concluded that the best discriminant predictors for race are not necessarily the best for gender. Sex for each race is best described by a unique discriminant function, which is in agreement with our results [2,3].

S. Galdames et al. during the analysis of the discriminant function found that the group of analyzed linear dimensions (Porion–Mastoidale, Porion–Asterion) represents a low discriminant capacity (Lambda of Wilks = 0.960, canonical correlation = 0.199); only Porion-Mastoidale was the variable that allowed the classification of male skulls from female with an overall accuracy of 64.2%, but with a high sensitivity for correctly classifying males (93%) and a very low sensitivity for females (17.7%). Results from S. Galdames et al. match our results for males (65%) but not with the results for females (85%) [4].

Abdelnasser Ibrahim concludes in his study that the best parameter, selected by gradual discriminant analysis, is the parameter of the mastoid triangle. Cross-validation accuracies for males, females, and the combination were 82.3%, 88.5%, and 84.4%, respectively. The prediction accuracy in the multivariate discriminant function is based on the asterion-mastoidal parameter and the mastoid width, which were considered the best parameters with 87% accuracy, which is in contrast to our study, but also to other studies on the Asian population, where the best parameter is often found to be the mastoid length [5].

Research by Amala Manivanan et al. statistically showed that the length and height of the mastoid extensions are smaller in women compared to men, and the mastoid width in women is greater than in men. This finding is not completely correlated with our findings, because in our study all three parameters are higher in men than in women. The findings of the width of the mastoid extensions for men are close to ours, although in this case the results we obtained are slightly higher. For the female skulls in our study, we obtained lower values than those of Amala Manivanan et al. [6].

S.B. Sukre et al. conducted a study where univariate analysis showed that the mean value of mastoid variables such as mastoid length (25.32 mm), mean lateral diameter (10.71 mm), antero-posterior diameter (21.60 mm) was greater in men than in women. All measurements of the mastoid process are significantly different in men and women, and the measurements are statistically significant ($p < 0.005$), which correlates with our study. He further states that the length of the mastoid process is the best discriminator, medio-lateral diameter is the second, and height the third best discriminator in determining sex from fragmented remains. This finding is in contrast to our finding where the antero-posterior diameter is the best discriminator in determining sex, followed by the width, and finally the height of the mastoid process [7].

5. Conclusion

1. Male skulls have on average a longer, wider, and larger anteroposterior diameter of the mastoid process than female skulls.
2. Male skulls have on average larger sizes of the mastoid process than female skulls.
3. With the increase in value of the mastoid length, width and anteroposterior diameter and size of the mastoid process the probability that the skull is classified as male increases.
4. We recommend combined qualitative and quantitative anatomical anthropological studies, with respecting population standards in order to better predict gender dimorphism.

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