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Bioanthropological analysis of human occipital condyles using geometric morphometric method

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ABSTRACT

Sex differences are present in all parts of the body, including the skeletal system. Several methods are used to analyze the sex differences of skeleton, while more recently, a new method called geometric morphometry has been used. The aim of this study was to examine the sexual dimorphism of occipital condyles on human skulls originating from the population of Bosnia and Herzegovina using the geometric morphometric method.

Material and methods: The study was conducted on 214 human skulls of known gender from Bosnian population. For analysis of sexual dimorphism of occipital condyles, we used geometric morphometry, where all the skulls were scanned to obtain three-dimensional skull models. On the obtained models, we marked anthropometric points on occipital condyles in a Landmark Editor program from which we exported data in the form NTSYS file and analyzed it in MorphoJ program.

Results: First principal component PC1 describes 26.917% of total variability, the second principal component PC2 describes 20.992% of total variability, while the first eight principal components together describe 100% of total variability. The greatest variability between the male skulls and female skulls was present in the anterior-posterior diameter (length of occipital condyles). Discriminant functional analysis of the shape and size of the occipital condyles was possible with 69.50% accuracy for male skulls and with 60.27% accuracy for female skulls. The size of the occipital condyles showed a statistically significant effect on sexual determination. Discriminant functional analysis of the shape of the occipital condyles without affecting size enabled the determination of gender with with 65.96% accuracy for male skulls and with 63.01% accuracy for female skulls.

Conclusion: Analysis of sexual dimorphism of occipital condyles using geometric morphometry showed statistically significant differences in the shape and size of occipital condyles between the sexes. The accuracy of sex determination based on occipital condyles was higher for male gender.

1. Introduction

Gender differences are expressed on all body structures and are also present on the occipital condyles and as such can be used for gender determination (Gapert et al, 2009).

Occipital condyles are part of the occipital bone located laterally from the foramen magnum, which articulated with atlas (first vertebra) and formed atlantoaccipital joint. Through foramen magnum intracranial part of the central nervous system continues on spinal cord. Occipital condyles are different on size and shape between different sexes which is of particular importance for the mobility of the atlantooccipital joint, and knowledge of the shape and size of the occipital condyles is important for orthopedists, for neurosurgeons and vascular surgeons (Naderi et al, 2005).

Zirahei and the authors in their study examined the sexual dimorphism of the occipital condyles on CT scans of 110 patients (60 men and 50 women) between 18 and 65 years. They measured the right and left anterior-posterior diameter and the transverse diameter of the occipital condyles. The results of the study showed

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that the mean values of all measured linear diameters were significantly higher in male skulls than in female skulls (Zirahei J.V. et al, 2018).

El-Barrany and authors in 2016. analyzed sexual dimorphism of occipital condyles and foramen magnum on CT scans of 400 patients (200 men and 200 women). They measured nine linear diameters. All nine linear diameters are statistically significantly larger in men than in women (El- Barrany et al., 2016).

In a study on CT images of 240 individuals from Nigeria, Bello et al measured three diameters on the occipital condyles and one between the occipital condyles, analyzing sex differences between them. The results of the study show that all measured diameters are larger in male individuals (Bello et al, 2013).

Kumar and authors analyzed the sexual dimorphism of the occipital condyles by measuring the length, width, and height of the occipital condyles, and the anterior and posterior intercondylar diameters. The results of this study show that the mean values of length, width and height are higher on the left side in the examined sample, and that the occipital condyles are statistically significantly higher in male skulls than in female skulls (Kumar and Nagar, 2014).

In 2019, George and authors analyzed the diameters and shape of 30 human occipital condyles. They measured eight linear diameters, determined their shape, calculated the occipital condylar index and measured the length and diameter of the hypoglossal canal. The researchers was conducted that collect data may be useful for neurosurgeons and orthopedists. (George et al., 2019).

In their research, Kavitha and authors analyzed shape and size of the occipital condyles on 145 examined human skulls. They analyzed the presence of four forms of occipital condyles, where oval and crescent-shaped forms were mostly present in the examined sample. They measured the length and width of the occipital condyles and concluded that the mean length values were 21.97 mm on the right and 22.34 mm on the left side. The mean widths of the occipital condyles were 13.05 mm on the right and 13.30 mm on the left side. The authors of this study believe that knowledge of the shape and size of occipital condyles can significantly contribute to the work of neurosurgeons and orthopedists (Kavitha et al., 2013).

Aragao and authors analyzed the morphological characteristics of occipital condyles on 107 skulls. They analyzed 10 types of occipital condyles where three types (type 8, type S and ring type) were present in 50% of the examined occipital condyles. In male skulls, type 8 dominated on the left occipital condyles and type S on the right occipital condyles, while on female skulls these two types (type 8 and type S) were equally represented on both side (Aragao et al, 2017).

The analysis of occipital condyles on skulls from the Rajasthan population was conducted in 2019 by a group of authors which are measured the anterior-posterior and transverse diameters on occipital condyles, and anterior and posterior intercondylar diameters between occipital condyles. The authors believe that knowledge of the mean values of these diameters can significantly contribute to surgical procedures in this region (Kumar et al., 2019).

Lyrtzis and authors conducted research on 141 skulls of known sex and known age, where they analysed sex and age differences on the foramen magnum, occipital condyles, and hypoglossal canal. The authors measured the length, width, anterior and posterior intercondylar distances on condyles, where all these diameters were statistically significantly larger in male skulls than in female skulls (Lyrtzis et al., 2016).

Zirahei and researchers analysed gender differences of distances between the occipital condyles. The research was conducted on CT images of 110 patients from Nigeria of known sex and known age. The results of the study showed that the mean values of both linear diameters, anterior and posterior intercondylar distance, were higher in men than in women. The authors also calculated the ratio between the mean values of these diameters in men and women and they concluded that these values are different between different populations (Zirahei et al, 2019).

A group of authors analyzed the existence of differences in occipital condyles between the four examined groups of skulls from Europe using discriminant functional analysis. The study included 146 skulls originating from England (London), 68 skulls originating from France (Paris), 74 skulls originating from Germany and 282 skulls originating from Romania. They measured three linear diameters on the occipital condyles and the length and width of the foramen magnum. The results of discriminant analysis showed that the results of gender differences in one group are not the same if applied in another group of the skulls (Inskip et al., 2016).

Pelin and the authors conduct research on 100 occipital bones of unknown sex and age of individuals from the Turkish population. They measured four diameters on the foramen magnum and eight diameters on and between the occipital condyles. They calculated the mean values of the measured linear diameters and analyzed the shape of the foramen magnum (Pelin et al., 2017).

Sahoo and researchers conducted a study on 150 human skulls of the known sex from the Indian population, performing measurements on the foramen magnum and occipital condyles. They measured the length and width of the foramen magnum, calculated the foramen magnum index, and measured six diameters on and between the occipital condyles bilaterally (Sahoo et al., 2015).

Das and the authors present analysis of specific caracteristics of occipital condyles. Specificity is reflected in the serrated edges (on right and left side), in shape of joint surface, the existence of longitudinal and transverse grooves on occipital condyles, which ultimately has a very important impact on the function and mechanics of the atlantooccital joint (Das et al., 2006).

In 2020, Gundemir and authors in their research used geometric morphometry to analyze sex differences on turkey skulls by analyzing the four sides of the skull (basal, cranial and lateral, right and left). (Gundemir et al, 2020).

2. Material and method

The research was conducted on 214 human skulls of known sex and known age (141 male skulls and 73 female skulls) from Osteological Collection of the Department of Human Anatomy, Medical Faculty of Sarajevo originating from the population of Bosnia and Herzegovina dating from the first half of the twentieth century. In this study we used geometric morphometric method. All examined skulls were scanned with a laser scanner named DAVID Structured Light Scanner SLS-2 to obtain three - dimensional models. On each three-dimensional model we marked four paired anthropometric points, landmarks (Table 1) on the occipital condyles in the Landmark editor program Wiley et al. (2005). We entered the obtained data into the MorphoJ program, which uses this data for the analysis of the shape of the occipital condyles, but also for the analysis of gender differences on the occipital condyles.

Table 1
Anthropometric points on occipital condyles of human skull and their position on the skull

Anthropometric points	Position
Occipitocondylion anterior	Point on anterior end of occipital condyle
Occipitocondylion posterior	Point on posterior end of occipital condyle
Occipitocondylion mediale	Point on medial end of occipital condyle
Occipitocondylion laterale	Point on lateral end of occipital condyle

2.1. Statistical analysis

Analysis of sexual dimorphism of occipital condyles was performed using geometric morphometric method contained in the MorphoJ program (Klingenberg 2011). (19) The total variability of occipital condyles throughout the examined sample was examined by PCA analysis. The size of the examined condyles in the MorphoJ program was expressed as centroid size (CS). The influence of the size of the occipital condyles on the sexual dimorphism of their shape was examined by regression analysis. A discriminant analysis was performed to compare the differences between male and female skulls and a validation test was used to compare the two groups. The results of the study are presented using graphs and tables.

3. Results

Sexual dimorphism of occipital condyles within geometric morphometry is presented by principal components analysis. Fig. 1 presents landmarks used for the analysis of sexual dimorphism of occipital condyles, while Fig. 2 presents the position of the examined skulls in the morphological space based on the main components.

The first two principal components describe the highest percentage of occipital condyle variability between the sexes, and the percentage of eigenvalues of principal components are presented on Fig. 3. The first principal component PC1 describes 26.917% of total variability, the second component PC2 describes 20.992% of total variability, while the first eight principal components together describe 100% of the total variability.

The existence of gender differences in the size and shape of occipital condyles was determined using discriminant functional analysis contained in the MorphoJ program ($p < 0.0001$ with 1000 repetitions). The obtained results are presented in Table 2.

Using discriminant functional analysis, 98 skulls of 141 skulls was correctly classified as male skulls which is 69.50% accuracy for male gender, while of 73 female skulls 44 skulls was correctly classified as female skulls which is 60.27%. accuracy for female gender.

The results of the discriminant functional analysis of the influence of the shape and size of the occipital condyles on the sexual dimorphism of the skull of the examined sample are presented in Fig. 4.

After discriminant functional analysis, regression analysis was performed within the MorphoJ program where we examined the influence of occipital condyle size on sexual dimorphism of the shape of the occipital condyles where size in geometric morphometry is expressed as centroid size (CS). Occipital condyle size has a statistically significant effect on sexual differentiation as shown by the regression analysis test ($p < 0.0022$ after 10.000 replicates), which is shown in Fig. 5. The effect of size on sexual dimorphism of occipital condyle shape is 1.769%.

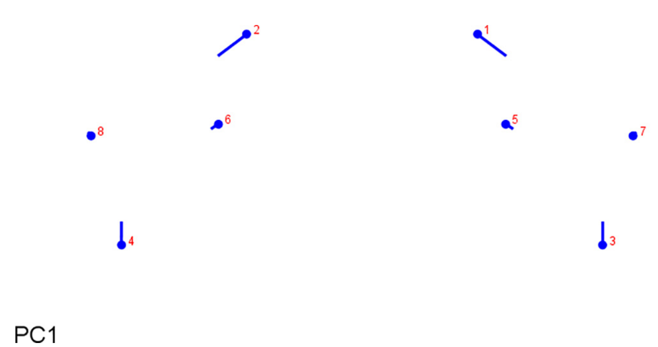

Fig. 1. Patterns of change in the shape of the occipital condyles described by the PC1 component.

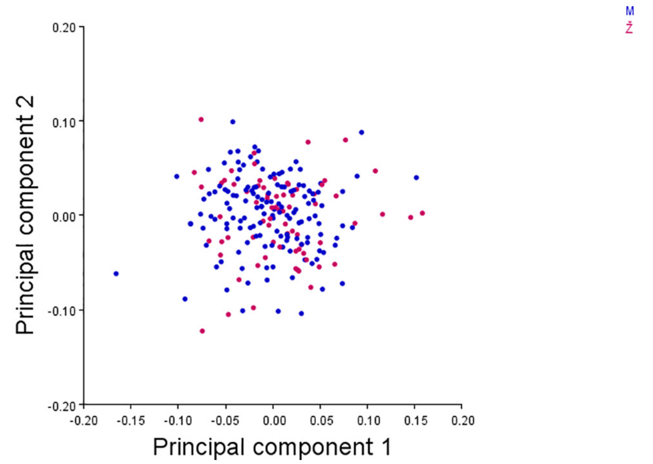

Fig. 2. Position of the skulls based on differences in shape and size of the occipital condyles in the morphological space defined by the first two principal components (PC1 and PC2).

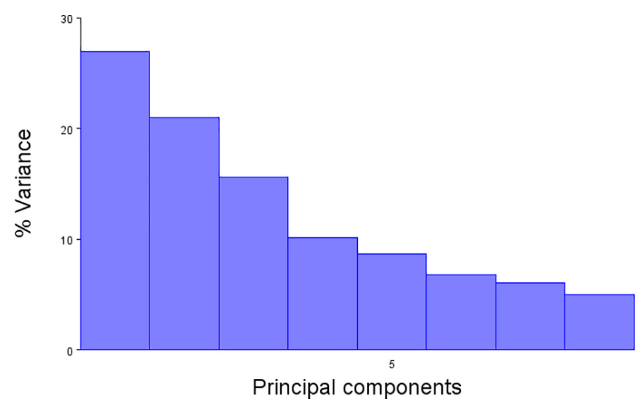

Fig. 3. Eigenvalues and percentage variability of shape and size of occipital condyles.

Table 2
Gender predictability based on shape and size of occipital condyles

		Predictability of gender		Total
Gender	Male	**98**	43	141
	Female	29	**44**	73
Total		*127*	*87*	*214*

After excluding the effect of size on the shape of the occipital condyles, we performed Generalized Procrustes analysis in MorphoJ program. After that, we examined the sexual dimorphism of the shape of occipital condyle shape using discriminant functional analysis where statistical significance was determined ($p < 0.002$ with 1000 replicates). The results are shown in Table 3.

Using discriminant functional analysis, 93 skulls of 141 skulls was correctly classified as male skulls which is 65.96% accuracy for male gender, while of 73 female skulls 46 skulls was correctly classified as female skulls which is 63.01% accuracy for female gender.

The results of the discriminant functional analysis of the influence of the shape of the occipital condyles on the sexual

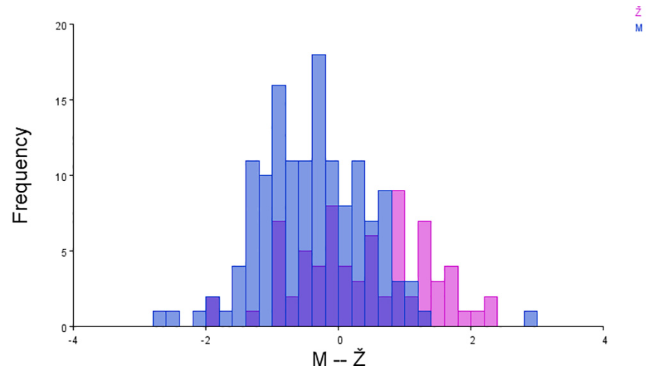

Fig. 4. Discriminant functional analysis of the sexual dimorphism of shape and size of occipital condyles.

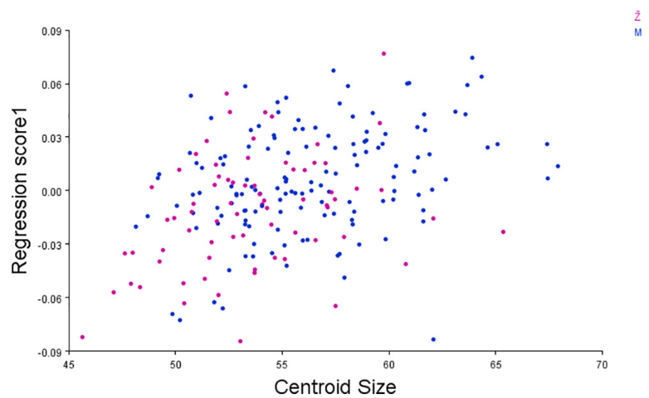

Fig. 5. Influence of the size of occipital condyles on their sexual dimorphism of the shape.

Table 3
Predictability of gender based on the shape of occipital condyles

		Predictability of gender		Total
Gender	Male	**93**	48	141
	Female	27	**46**	73
Total		*120*	*94*	*214*

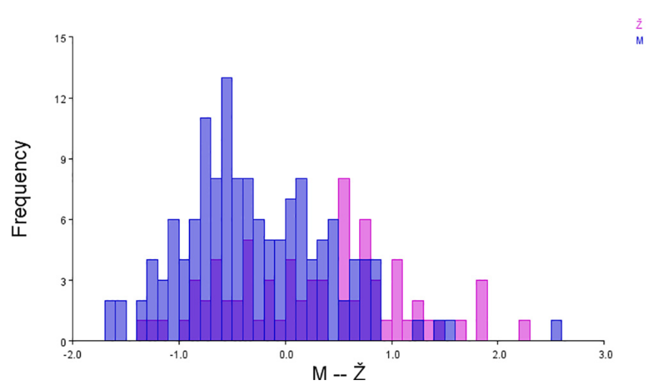

Fig. 6. Discriminant functional analysis of the sexual dimorphism of shape on occipital condyles.

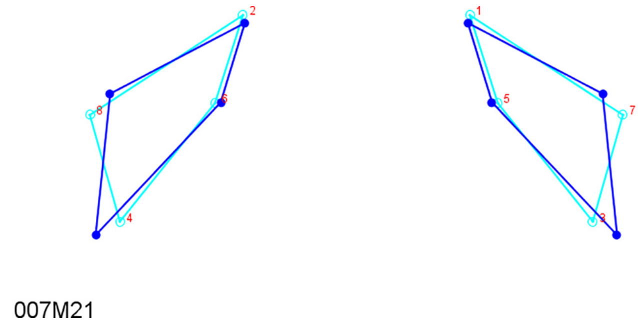

Fig. 7. Interval of changes of shape of occipital condyles on examined skulls.

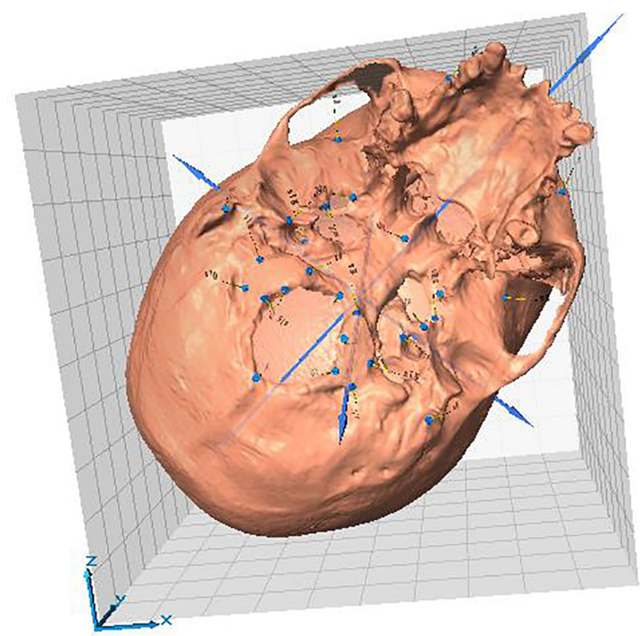

Fig. 8. Small and short occipital condyles on analysed female human skull.

dimorphism of the skull of the examined sample are presented in Fig. 6 while interval of changes of shape of occipital condyles are presented in Fig. 7. On Figs. 8 And 9 was presented two skulls with different shape of occipital condyles. On Fig. 8 was presented female skull with small and short occipital condyles, while on Fig. 9 was presented male skull with big and long occipital condyles.

On Figu. 10 was presented one three-dimensional skull model.

4. Discussion

In this study, we analyzed the sexual dimorphism of occipital condyles on the occipital bone using geometric morphometric method.

The study included 214 human skulls of known sex and known age (141 male skulls and 73 female skulls).

The greatest variability between the sexes was present at the position of landmark occipitocondylion anterior and then at landmark occipitocondylion posterior indicating that the greatest variability was present in the anterior-posterior diameter.

In the MorphoJ program, a discriminant functional analysis of sexual dimorphism of the size and shape of occipital condyles

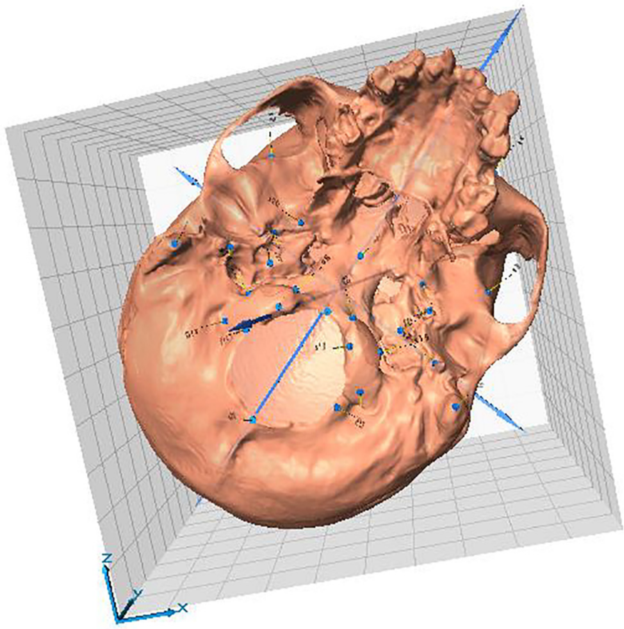

Fig. 9. Big and long occipital condyles on analysed male human skull.

was performed, where the accuracy of sex determination was 69.50% for male gender and 60.27% for female gender.

After examining the sexual dimorphism of the form (size and shape) of the occipital condyles, we examined the influence of the size of the occipital condyles on the sexual dimorphism of the shape expressed in geometric morphometry as centroid size (CS). The influence of size on the sexual dimorphism of the shape of the occipital condyles was 1.769%.

After excluding the effect of size on the shape of the occipital condyles, we examined the sexual dimorphism of the shape of the occipital condyles using discriminant functional analysis. Based on the shape of the occipital condyles, sex determination was possible with 65.96% accuracy for male gender and with 63.01% accuracy for female gender in our examined sample.

Zirahei and authors in their study of the sexual dimorphism of the occipital condyles calculated the Baudoin condylar index which enabled sex determination with 52.92% accuracy for male and 46.67% for female gender (Zirahei J.V. et al., 2018).

El-Barrany and authors in their study measured nine linear diameters on the foramen magnum and on the occipital condyles and analysed sex differences of the occipital condyles and the foramen magnum. All nine linear diameters were statistically significantly larger in men than in women, while multivariate analysis showed that three diameters, right condylar length, minimum intercondylar diameter, and foramen magnum width, allow sex determination with 83% accuracy (El- Barrany et al. (2016)).

In their study of the sexual dimorphism of occipital condyles, Oliveira and coauthors used the length and width of occipital condyles for calculation Baudoin condylar index on the basis of which it is possible to determine the male sex with 44.83% accuracy and the female sex with 51.93% accuracy (Oliveira et al, 2013).

Rai and the authors conducted research on CT images of 200 patients of known sex and known age, analyzing the sexual dimorphism of the foramen magnum and occipital condyles. They measured foramen magnum length and width, length, width, anterior and posterior intercondylar distance, and bicondylar width, concluding that all measured diameters were statistically significantly larger in men than in women. They also performed a discriminant functional analysis that showed 91% accuracy for male gender and 97% accuracy for female gender in sexual determination (Rai et al., 2017).

On 100 human skulls of the known sex from the Indian population, a group of authors in 2017 analyzed the sexual dimorphism of the occipital condyles. They measured the length and width of the occipital condyles on both side and based on them they calculated the condylar index. They also analyzed the shape of the occipital condyles. The results of this study show that the oval shape of the occipital condyles is the most common on both side. All measured diameters and condylar index were higher in male skulls. The statistically significant effect on sexual determination was shown by the length of the occipital condyles and the condylar index bilaterally, while the width of the occipital condyles (transverse diameter) did not show a stratistically significant effect on sexual proliferation (Sholapurkar et al., 2017).

Saluja and the authors analyzed the size of occipital condyles on human skulls originating from India and compared them with the results of studies conducted on occipital condyles of skulls originating from other populations. The study was conducted on 228 occipital condyles (114 human skulls) and measured the length and width of the occipital condyles using a caliper, while using Image J software they calculated two angles, sagittal condylar and sagittal intercondylar angle. The authors concluded that the mean values of the width of the occipital condyles are higher on the skulls of the examined sample compared to the skulls from other populations. Anterior and posterior intercondylar distance as well as diameters occipital condyles-opistion and occipital

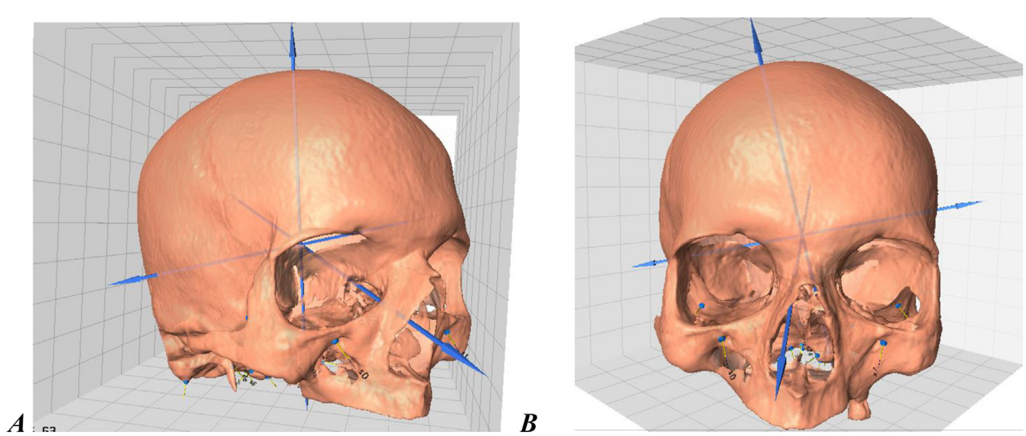

Fig. 10. Three-dimensional model of human skull obtained scanning skull with a laser scanner (DAVID Structured Light Scanner SLS-2) (A and B).

condyles-basion shorter on the examined skulls originating from the Indian population compared to the same measures of skulls originating from other populations (Saluja S. et al 2016).

5. Conclusions

- PCA analysis showed that the first eight PCA components describe 100% of the total variability. The first principal component PC1 describes 26.917% of the total variability of the analyzed sample, the second principal component PC2 describes 20.992% of the total variability.
- The greatest variability between the sexes was present in the position of landmark occipitocondylion anterior and then in position of landmark occipitocondylion posterior indicating that the greatest variability was present in the anterior-posterior diameter (length) of occipital condyles.
- Discriminant functional analysis of form enabled sex determination with 69.50% accuracy for male gender and 60.27% accuracy for female gender.
- The size of the occipital condyles showed a statistically significant effect for sex determination ($p < 0.0022$, the percentage of size influence is 1.769%).
- Discriminant functional analysis of the shape of the occipital condyles without the influence of size enabled the determination of sex with 65.96% accuracy for male and 63.01% accuracy for female gender in our study.

Declaration of Coompeting Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Gapert, R., Black, S., Last, J., 2009. Sex determination from the occipital condyle: discriminant function analysis in an eighteenth and nineteenth century British sample. Am. J. Phys. Anthropol. 138, 384–394.

Naderi, S., Korman, E., Citak, G., Guvencer, M., Arman, C., Senoglu, M., Tetik, S., Arda, M.N., 2005. Morphometric analysis of human occipital condyle. Clin. Neurol. Neurosurg. 107 (3), 191–199.

Zirahei, J.V., Amaza, D.S., Otashu, K.F., Nkimanya, F., Gadzama, N.M., Mailabari, H.Y., 2018. Sex differences in occipital condyles in Maiduguri, Northeastern Nigeria using computed tomographic scan images. Kanem. J. of Med. Sci. 12 (2), 73–77.

El- Barrany, U.M., Ghaleb, S.S., Ibrahim, S.F., Nouri, M., Ali, Hassan M., 2016. Sex prediction using foramen magnum and occipital condyles computed tomography measurements in Sudanese population. Arab. J. Foren. Sci. and Foren. Med. 1 (3), 414–423.

Bello, S.S. et al., 2013. Measurements of occipital condyles using computerised tomography from sokoto State, Nigeria. I. J. Health. Med. Inf. 2 (3), 10–17.

Kumar, A., Nagar, M., 2014. Human adult occipital condyles: a morphometric analysis. Res.R. J. M. H. S. 3 (4), 112–116.

George, J.R., Francis, T., Francis, J., Samuel, J.E., 2019. Morphometric study of dry human occipital bone and its clinical relevance. Int. J. Anat. Res. 7(1.2):6230–33.

Kavitha, S., Chandrasekaran, S., Anand, A., Shanthi, K.C., 2013. Morphometric study of occipital condyles in adult human skulls. Int. J. Cur. Res. Rev. 5 (15), 31–34.

Aragao, J.A., De Santana, M.G., Da Cruz De Mores, Z.R., Aragao, I.C.S.A., Aragao, F.M.S. A., Reis, F.P., 2017. Morphological analysis on the occipital condyles and review of the literature. Int. J. Morphol. 35 (3), 1129–1132.

Kumar, D.S., Merha, S., Kumar, A.S.B., 2019. Morphometric study of occipital condyles in adult dry human skulls of Rajasthan population. Int. J. Sci. Res. 8 (12), 15–18.

Lyrtzis, Ch., Piagkou, M., Gkioka, A., Anastasopoulos, N., Apostolidis, S., Natsis, K., 2016. Foramen magnum, occipital condyles and hypoglossal canals morphometry: anatomical study with clinical implications. Folia Morpholog. 76 (3), 446–457.

Zirahei, J.V., Amaza, D.S., Mailabari, H.Y., Buba, H., Mado, A.A., 2019. Morphometric evaluations of intercondylar distances using computed tomographic scan images in Maiduguri, Northeastern Nigeria. Anatom. J. Africa. 8 (2), 1519–1522.

Inskip, S., Constantinescu, M., Brinkman, A., Hoogland, M., Sofaer, J., 2016. The effect of population variation on the accuracy of sex estimates derived from basal occipital discriminant functions. Archeol. Anthropol. Sci. https://doi.org/10.1007/s12520-016-0380-6.

Pelin, I., Kayhar, B., Erturk, M., Sengul, G., 2017. Morphological analysis of occipital condyles and foramen magnum as a guide for lateral surgical approaches. MOJ. Anat. Physiol. 3 (6), 188–194.

Sahoo, S., Giri, S.K., Panda, S.K., Panda, P., Sahu, M.Ch., Mohapatra, Ch., 2015. Morphometric analysis of the foramen magnum and the occipital condyles. Int. J. Pharm. Sci. Rev. Res. 33 (2), 198–204.

Das, S., Suri, R., Kapur, V., 2006. Unusual occipital condyles of the skull: an osteological study with clinical implications. Sao Paulo Med. J. 124 (5), 278–279.

Gundemir, O., Ozkan, E., Dayan, M.O., Aydogdu, S., 2020. Sexual analysis in turkey (Meleagris gallopavo) neurocranium using geometric morphometric methods. Turk. J. Vet. Anim. Sci. 44, 681–687.

Wiley, D.F., Amenta, N., Alcantara, D.A., Ghosh, D., Kil, Y.J., Delson, E., et al. Evolutionary morphing In: IEEE Visualization, 2005. VIS 05. Minneapolis, MN, USA: IEEE; 2005. p. 431–438.

Klingenberg, C.P., 2011. MorphoJ: an integrated software package for geometric morphometrics. Mol. Ecol. Res. 11, 353–357.

Oliveira, O.F., Tinoco, R.L.R., Daruge, Junior E., Araujo, L.G., Silva, R.H.A., Paranthos, L. R., 2013. Sex determination from occipital condylar measurements by baudoin index in forensic porpoises. Int. J. Morphol. 31 (4), 1297–1300.

Rai, H., Keluskar, V., Patil, S., Bagewadi, A., 2017. Accuracy of measurements of foramen magnum and occipital condyle as an indicator for sex determination using computed tomography. Ind. J. Health. Sci. Biomed. Research. KLEU. 1 (19), 80–83.

Sholapurkar, V.T., Virupaxi, R.D., Desai, S.P., 2017. Morphometric analysis of human occipital condyles for sex determination in dry adult skulls. Int. J. Anat. Res. 5 (1), 3318–3323.

Saluja, S., Das, S.S., Vasudeva, N., 2016. Morphometric analysis of the occipital condyle and its surgical importance. J. Clinic. and Diag. Res. 10 (11), AC01-AC04.