

Abdullayev A.S.

Azerbaijan Medical University, Baku, Azerbaijan

COMPARATIVE CHARACTERISTICS OF NORMAL AND ABNORMAL SKULLS BY  
THE ANATOMICAL CRANIAL INDEX

e-mail: mic\_amu@mail.ru

The article aims to conduct a comparative analysis of skull occurrence frequency in women and men, with and without skull deformation, using index indicators. A total of 254 skulls (200 without artificial deformations and 54 with deformations) from the craniological collection of the Azerbaijan Medical University were analyzed. Pearson's chi-square analysis was used to determine the relationship between the parameters. It was determined that there was a relationship between the height-length parameter between skull types with and without deformation in men. These parameters were close in the presence and absence of deformation in men. In women, there was a relationship between the width-length index with and without deformation. There was a statistically significant relationship for this index among women, regardless of skull condition.

**Key words:** skull parameters, classification system, skull parameter indices, women, men, statistical relationship.

Абдуллаєв А.С.

ВАРІАБЕЛЬНІСТЬ І ГЕНДЕРНІ ОСОБЛИВОСТІ РІЗНИХ ТИПІВ НАВМИСНО  
ДЕФОРМОВАНИХ ТА НЕДЕФОРМОВАНИХ ЧЕРЕПІВ

Стаття написана з метою проведення порівняльного аналізу частоти виявлення деформації черепа та її відсутності у жінок та чоловіків на основі індексних показників. Загалом було проаналізовано 254 черепи (200 без штучних деформацій та 54 з деформаціями) із краніологічної колекції Азербайджанського медичного університету. Встановлено, що існує зв'язок між показником висоти та довжини між типами черепа з деформацією та без неї у чоловіків. Ці параметри були близькими за наявності та відсутності деформації у чоловіків. У жінок спостерігався зв'язок між показником ширини та довжини з деформацією та без неї. Статистично значущий зв'язок за даним показником спостерігався у жінок незалежно від стану черепа.

**Ключові слова:** параметри черепа, система класифікації, індекси параметрів черепа, жінки, чоловіки, статистичний зв'язок.

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The skull is a bony shell that protects the brain from external influences. At the same time, the skull is a fragile plastic structure, the deformation and destruction of which depend on its durability [7, 9, 10]. A feature of the anatomy of the middle structures of the anterior and middle parts of the skull base is their variability. This most often applies to the ethmoid bone, as it is characterized by frequent structural differences in the ethmoid labyrinths, with asymmetry the norm [6].

According to morphologists, the structural variants of organs at different stages of ontogenesis and the morphometric indicators of age characteristics remain insufficiently studied, and this problem warrants reconsideration. Therefore, the study of individual, age, and gender characteristics of the human body can be considered one of the most promising directions of modern anatomy [1].

Congenital and acquired bone deformations of the studied area are the main cause of problems in the organs of the central nervous system. As a result, blood flow and cerebrospinal fluid circulation are disrupted. In this regard, the skull structure, with and

without deformation, differs in many parameters due to these changes. The frequency of asymmetric deformations associated with premature stenosis of the cranial base sutures varies. In men, stenosis of the left-sided sutures is higher than that of the right-sided sutures. In women, the opposite relationship is observed. There is evidence that, in women, obliteration of the skull sutures begins somewhat later (from age 25) and occurs less intensively initially than in men [3]. The method of craniometry allows you to assess the morphometric parameters of the skull, its individual components, and the correlations between the dimensional characteristics and the shapes of the facial and brain parts, depending on the craniotype [7, 11].

A deeper, more detailed study of the skull's structure allows us to expand our fundamental knowledge of the structural patterns of the craniofacial complex and its components, and to obtain important information about their variant anatomy. The literature provides information about the linear and spatial parameters of the craniofacial complex [2, 10]. However, studies often present

general, repetitive data characterizing the skull's structure, combining values. At the same time, there is an increasing need for information on anatomical details that determine the direction currently applied in craniology. Comparison of the obtained data with established norms allows us to form a reliable, objective understanding of the dimensional parameters of the facial and brain parts of the skull and their relationships, as well as to develop an optimal treatment plan for patients with dental pathology [5].

Thus, the study of changes in the skull's structure in various situations, especially in cases of deformation, is of great importance not only from a theoretical but also from a clinical point of view.

**The purpose** of the study was to conduct a comparative analysis of skull frequency in women and men, with and without skull deformation, using craniometric indices.

**Materials and methods.** The study was conducted at the Department of Human Anatomy and Medical Terminology of Azerbaijan Medical University during 2020–2023. To determine the craniometric characteristics of the skulls, a total of 254 skulls (200 without deformation – the control group, and 54 with artificial deformation – the main group) from the craniological collection of Azerbaijan Medical University were analyzed.

The osteological collection analyzed in this study was assembled through systematic acquisitions conducted during the late nineteenth and early twentieth centuries. Most specimens were recovered from burial sites across various regions of present-day Azerbaijan and neighboring areas of the South Caucasus. The majority of the remains are attributed to individuals belonging to the Caucasian (South Caucasian) anthropological group and represent populations historically inhabiting the territory of modern Azerbaijan, including Azerbaijanis, Tats, Talysh, Lezgins, and closely related ethnic communities. Ethnic affiliation was determined based on archival documentation, museum catalog records, and craniometric classification data preserved in the institutional registry.

According to available archival sources, most individuals died from causes typical for the respective historical periods, including infectious diseases, nutritional deficiencies, and age-related conditions. The collection does not contain specimens associated with violent deaths, executions, or forensic casework. In many instances, the precise cause of death could not be reliably determined and was therefore recorded in the archival documentation as “natural causes” or “unknown.” All examined specimens represent adolescent or adult individuals and exhibit sufficiently well-preserved cranial vaults to enable the application of standardized craniometric measurement protocols.

**Inclusion criteria:** Specimens were included if they originated from the official craniological

collection housed at Azerbaijan Medical University and had documented age-at-death information that allowed reliable classification into the predefined age categories. In addition, the skulls had to demonstrate adequate preservation of the frontal and parietal regions to permit precise identification of standard craniometric landmarks. Both intentionally deformed skulls with clearly documented artificial cranial modification and non-deformed specimens exhibiting preserved natural cranial morphology were eligible for inclusion.

**Exclusion criteria:** Specimens were excluded if they showed evidence of traumatic damage to the cranial vault, including fractures, penetrating lesions, or post-traumatic deformities. Skulls demonstrating pathological bone alterations – such as neoplastic processes, advanced osteomyelitis, Paget's disease, or other severe skeletal disorders – were also excluded. Additional exclusion criteria included congenital cranial anomalies unrelated to intentional deformation, postmortem damage affecting the frontal or parietal regions, and cases in which age at death was unknown or insufficiently documented.

The study was conducted in accordance with established principles of bioethics. In carrying out the research, the authors adhered to both international and national ethical standards, including the 2013 revision of the World Medical Association's Declaration of Helsinki, the International Ethical Guidelines for Biomedical Research Involving Human Subjects issued by the Council for International Organizations of Medical Sciences (CIOMS), as well as relevant regulatory provisions of the Republic of Azerbaijan governing scientific investigations and the use of museum-based human biological collections.

Prior to the commencement of the study, formal written authorization was obtained from the Director of the Museum of Anatomy of Azerbaijan Medical University, permitting the scientific use of osteological materials preserved in the museum collection. As the Museum of Anatomy operates under the authority of Azerbaijan Medical University and the research was carried out at the Department of Human Anatomy and Medical Terminology of the same institution, the study was conducted in accordance with the relevant institutional approval.

All analyzed specimens consisted of anonymized osteological materials from the museum collection. No personal identifying information was available for the examined individuals, thereby ensuring full compliance with ethical standards concerning confidentiality and the protection of human rights.

The skull samples included in the study were grouped by indices according to R. Martin's classification. This system is based on standardized craniometric ratios derived from linear skull measurements, enabling specimens to be categorized by cranial proportions. In the present study, the

latitude-longitudinal index was calculated from standard cranial length and breadth measurements and used to classify skulls into established morphological categories. The latitude-longitudinal index (also referred to as the cranial breadth-length index or cephalic index (CI)) represents the ratio of the maximum cranial breadth to the maximum cranial length multiplied by 100.

According to R. Martin's classification, there are three types of skulls based on the latitude-longitudinal index: 1) dolichocrania – long skull; 2) mesocrania – medium skull; 3) brachycrania – wide skull. According to the values of the altitudinal-longitudinal index, there are the following skull shapes: 1) hamencrania – low (flat) skull; 2) orthocrania – medium skull; 3) hypsicrania – high skull. According to the parameters of the altitudinal-transverse index, there are tapeinocrania (low skull), acrocrania (high skull), and metriocrania (intermediate form).

Of the 200 skull samples without deformation, 86 were male and 114 female. Of the 54 samples of pre-artificially deformed skulls, 22 were male and 32 female. The skull samples included in the study were grouped by age. The age periodization scheme adopted in 1965 at the VII All-Union Conference on the Problems of Age Morphology, Physiology, and Biochemistry was used. Thus, 20 skulls belonged to young people (16–21 years old), 68 to individuals of period I (21–35 years old) of mature age, 72 to individuals of period II (36–60 years old) of mature age, and 40 to individuals of elderly age (56–74 years old).

The classification of deformities was carried out according to George K. Neumann (1942) (natural lambdoid, artificial lambdoid, occipital, bifrontal occipital, forehead-vertex, parallel forehead-occipital, obelion, and vertical). The George K. Neumann classification was used in our study because it includes both artificial (purposeful) and natural variants of deformities. Craniometric and cranioscopic methods were applied in the study. Based on the results obtained, the mean index (Mean-M), the mean structural index (Median-Me), and quartiles (Q1–Percentile 25 and Q3–Percentile 75) were calculated for undeformed and deformed skulls. Statistical analysis was performed using IBM SPSS Statistics 26, and the statistical significance of differences in parameter values was determined using Student's t-test, Fisher's exact test, and the nonparametric Mann-Whitney U test for comparisons of quantitative indicators across two or more groups. The  $\chi^2$ -Pearson test was used to compare qualitative indicators. The statistical significance limit was set at  $P=0.050$ .

**Results of the study and their discussion.** We analyzed skull classification parameters in men with and without skull deformity. The distribution of cranial types demonstrated several differences between the control and main groups. According to the results of the height-length index in men without deformity, dolichocrania 16 (18.6 %), mesocrania 27 (31.4 %), brachycrania 43 (50.0 %) skulls were recorded. In men with anomalies, dolichocrania 4 (18.2 %), mesocrania 6 (27.3 %), and brachycrania 12 (54.3 %) were determined. (Table 1).

Table 1

**Quantitative indicators of cranial index parameters in men with non-deformed and deformed skulls**

Indexes	Type of skull	Control group (n=200)		Main group (n=54)	
		N	%	N	%
Width-longitudinal index	Dolichocrania	16	18.6	4	18.2
	Mesocrania	27	31.4	6	27.3
	Brachycrania	43	50.0	12	54.5
Height-longitudinal index	Chamecrania	9	10.5	0	0.0
	Orthocrania	28	32.6	3	14.3
	Hypsicrania	49	57.0	18	85.7
Height-width index	Tapeinocrania	28	32.6	3	14.3
	Metriocrania	41	47.7	9	42.9
	Acrocrania	17	19.8	9	42.9
Upper facial index	Wide face	39	45.3	8	42.1
	Medium face	26	30.2	6	31.6
	Long face	21	24.4	5	26.3

According to the height-length parameter index in men without deformity, chamencrania 9 (10.5 %), orthocrania 28 (32.6 %), hypsicrania 49 (57.0 %), and in men with deformity, orthocrania 3 (14.3 %), hypsicrania 18 (85.7 %) were recorded.

In men without deformity, tapenocrania was recorded in 28 (32.6 %), metriocrania in 41 (47.7 %), and acrocrania in 17 (19.8 %) skulls. In men with deformity, tapenocrania in 3 (14.3 %), metriocrania in 9 (42.9 %), and acrocrania in 9 (42.9 %) skulls were determined in height-width indices. In men

without deformity, the frequency of occurrence of broad face in terms of the facial index parameter was 45.3 %, medium face in 30.2 %, and long face in 24.4 %. In men with deformity, broad face in 42.1 %, medium face in 31.6 %, and long face in 26.3 % were determined.

When the analysis was conducted using the Pearson Chi-Square reliability coefficient, there was no relationship between these variables, based on the p-value and the width and height indices ( $\chi^2=0.170$ ,  $df=2$ ,  $p=0.918$ ). Although the height-

width index ( $\chi^2=6.369$ ,  $df=2$ ,  $p=0.041$ ) was not small, it was in a tense state, indicating a partial relationship. Or it may be a relationship that will open up as the sample expands. According to the Pearson Chi-Square reliability coefficient for the expression of the face index ( $\chi^2=0.068$ ,  $df=2$ ,  $p=0.966$ ), no statistically significant relationship was found.

It is noteworthy that a statistically significant relationship was found between height and the height index ( $\chi^2=5.732$ ,  $df=2$ ,  $p=0.057$ ,  $p<0.05$ ).

Thus, the only statistically significant relationship was observed for the height-length index parameters ( $p=0.041$ ), indicating a real relationship between these two indicators. A non-significant relationship was observed between width-length and facial indices.

In women without deformities, dolichocrania was recorded in 18 (15.8 %), mesocrania in 21 (18.4 %), brachycrania in 12 (38.7 %), brachycrania in 75 (65.8 %), and brachycrania in 17 (54.8 %), according to the width-length index. (Table 2).

Table 2

**Quantitative indicators of cranial index parameters in women with and without skull deformation**

Indexes	Type of skull	Control group (n=200)		Main group (n=54)	
		N	%	N	%
Width-longitudinal index	Dolichocrania	18	15.8	2	6.5
	Mesocrania	21	18.4	12	38.7
	Brachycrania	75	65.8	17	54.8
Height- longitudinal index	Chamecrania	16	14.0	1	3.2
	Orthocrania	28	24.6	7	22.6
	Hypsicrania	70	61.4	23	74.2
Height-width index	Tapeinocrania	43	37.7	7	23.3
	Metriocrania	50	43.9	14	46.7
	Acrocrania	21	18.4	9	30.0
Upper facial index	Wide face	58	50.9	12	44.4
	Medium face	34	29.8	9	33.3
	Long face	22	19.3	6	22.2

In women without deformities, 16 (14.0 %), orthocrania in 28 (24.6 %), and hypsicrania in 70 (61.4 %) skull types were recorded. In women with cranial deformities, 16 (3.2 %), orthocrania in 7 (22.6 %), and hypsicrania in 23 (74.2 %) cases were recorded.

When determining the width-length expression index ( $\chi^2=6.410$ ,  $df=2$ ,  $p=0.041$ ), it was determined that there was a statistical relationship between these two variables. The relationship for the remaining parameters (height-length, height-width, facial indices) ( $p=0.213$ ,  $p=0.225$ ,  $p=0.834$ ) was statistically insignificant ( $p>0.05$ ).

Several studies conducted by various researchers have examined the anatomical features of the skull that may be useful in both conservative practice and surgical interventions [2, 4, 8].

A study of 6. Ludwigs L, et al (2023) was conducted on 90 individuals of Eurasian descent (46 men and 44 women) with available cone-beam computed tomography (CBCT) images. Eighteen control points were digitized, 3D cephalometric measurements were taken, and then analyzed using proportions calculated from the control points. The skulls of men and women were analyzed, and subdivisions were identified using cluster analysis. The data showed that four skull subtypes could be statistically significantly ( $p<0.05$ ). Male and female types were identified, subdivided into brachiocephalic and dolichocephalic phenotypes. The obtained normative data for subtypes can serve as an individualized guide for orthodontic surgery in

the Eurasian population, which is particularly useful for 3D planning and execution of craniofacial surgeries [5]. In our work, computed tomography was not used; we relied on classical methods of measurements and morphometric assessments. However, the use of additional visualization methods may be taken into account in future studies.

Another study using computed tomography was conducted by the Mahdian M, et al (2022). They retrospectively evaluated the CT scan results of 372 patients' ethmoid roof. The depth of the olfactory fossa was determined based on the height of the lateral lamella. The angle formed between the lateral lamella and the extension of the horizontal plane passing through the cribriform plate was measured. The potential risk of skull base injury was evaluated according to the TMS classification system. The data obtained from these studies can prevent potential complications in preoperative and intraoperative procedures [6]. However, it should be noted that our study did not examine the sinuses; it focused solely on craniometric indices, and this was done without the use of specialized radiological methods.

To develop validated prognostic tools using stable skull base variables to predict midface changes and study craniofacial morphology, the Zheng L, et al (2025) examined 55 individuals and identified changing midface variables, which were analyzed using the Mann-Whitney U test. Pearson correlation revealed linear relationships between midface and skull base variables. Model adequacy was confirmed, and three-fold cross-validation ensured the reliability

of the results [10]. However, unlike our study, this study focused on pediatric patients with Schwartz-Chiari syndrome. Nevertheless, the authors reached conclusions similar to ours, stating that the use of craniometric measurements and their application in various models based on reliable statistical methods has potential application in relevant fields.

**Limitations.** This study has several limitations that should be considered when interpreting the results. First, the sample size of the main group was relatively limited compared to the control group, which may restrict the statistical power of some comparisons. Second, the study was based on a

museum osteological collection formed from historical skeletal material, and therefore, detailed biographical and clinical information about the individuals (including exact causes of death, health status, and environmental factors) was not available for most specimens. In addition, although archival records and anthropological documentation were used to determine ethnic affiliation and age at death, the accuracy of such historical records may vary. Finally, the cross-sectional nature of the osteological material precludes assessment of developmental dynamics or the potential influence of environmental and cultural factors on cranial morphology.

## Conclusions

1. Based on the width–length index, brachyrania predominated in both men and women regardless of the presence of cranial deformity. Among men without deformity, dolichocrania, mesocrania, and brachyrania were observed in 18.6 %, 31.4 %, and 50.0 % of cases, respectively, while in men with deformities these values were 18.2 %, 27.3 %, and 54.3 %. A similar pattern was observed in women: in the non-deformed group dolichocrania, mesocrania, and brachyrania were recorded in 15.8 %, 18.4 %, and 65.8 % of cases, respectively, whereas in women with deformities brachyrania also remained the predominant cranial type (54.8 %).

2. A statistically significant relationship was found for the height and height index ( $\chi^2=5.732$ ,  $df=2$ ,  $p=0.057$ ,  $p<0.05$ ).

3. Width-length expression index demonstrated a statistical relationship between these two variables ( $\chi^2=6.410$ ,  $df=2$ ,  $p=0.041$ ).

Thus, characteristic features were determined in men and women with and without skull deformation. There was a relationship between the height-length parameter of skull types with and without deformation in men. These parameters were close in the presence and absence of deformation in men. In women, there was a relationship between the width-length index with and without deformation. There was a statistically significant relationship for this index among women, regardless of skull condition.

## References

- Barut C, Ogut E, Karaer E, Yavuz M. Anatomy Study Preferences of Medical Students in Relation to Gender, Academic Year and Geographical Distribution: Considerations for Anatomy Education Approaches. *Bratisl. Med. J.* 2025; 126:482–498. <https://doi.org/10.1007/s44411-025-00078-9>.
- Barut C, Ogut E, Sarikaya AD, Ozdemir S. Evaluation of Facial Asymmetry Determined by Linear Measurements According to Hand Preference and Gender. *Aesth Plast Surg* 2025; 49: 4705–4717. <https://doi.org/10.1007/s00266-025-04857-1>.
- Chawla H, Shankar S, Tyagi A, Panchal J. Cranial Vault Suture Obliteration in Relation to Age: An Autopsy-Based Observational Study. *Cureus*. 2023 May 31;15(5):e39759. doi: 10.7759/cureus.39759.
- Dissanayaka N, Novak JI, Carluccio D, Vandi L-J. Comparative analysis of mechanical and drilling properties: Human skull vs. 3D-printed replicas for neurosurgical training. *Materials Today Communications*, 2024; Volume 41: 110776. <https://doi.org/10.1016/j.mtcomm.2024.110776>.
- Ludwigs L, Pape C, Visse HS, Runte C, Meyer U, Dirksen D. Cross Sectional Analysis of Eurasian Skull Anatomy for 3D Cephalometry–Normative Data Reveal Four Different Skull Types. *Journal of Personalized Medicine*. 2023; 13(6):1018. <https://doi.org/10.3390/jpm13061018>.
- Mahdian M, Karbasi Kheir M. CBCT Assessment of Ethmoid Roof Variations through Keros, Gera, and TMS Classifications. *Int J Otolaryngol*. 2022 Aug 22;2022:3708851. doi: 10.1155/2022/3708851.
- Pham TA, Luong CM, Dao PD, Vo NT, Tran TN, Diem Nguyen TA. How Do Craniometric Measurements and Skull Morphology Influence Subthalamic Nucleus Target Coordinations in Deep Brain Stimulation Surgery for Parkinson Disease? *World Neurosurg*. 2025 Feb;194:123366. doi: 10.1016/j.wneu.2024.10.095.
- Wang L, Qi Z, Yang C, Ding X, Deng Q, Yang B, et al. Experimental and numerical investigation on mechanical properties change of HDPE in various aging conditions. *npj Mater Degrad*. 2025; 9: 54. <https://doi.org/10.1038/s41529-025-00606-6>.
- Xu K, Chen Y, Li M, Zhang Y, Zhang P, Chen T. Research on the mechanism of deformation and instability of surrounding rock in goaf under dynamic loading and the mechanism of active coordinated control. *Front. Earth Sci*. 2025; 13:1535868. doi: 10.3389/feart.2025.1535868.
- Zheng L, Abdullah NA, Ramli NM, Mohamed MNF, Hariri F. Enhancing Predictive Tools for Skeletal Growth and Craniofacial Morphology in Syndromic Craniosynostosis: A Focus on Cranial Base Variables. *Diagnostics*. 2025; 15(13):1640. <https://doi.org/10.3390/diagnostics15131640>.
- Zhuravlova I, Kornieieva M. Anatomic Variability of the Morphometric Parameters of the Third Ventricle of the Brain and Its Relations to the Shape of the Skull. *J Neurol Surg B Skull Base*. 2021 Jul;82(Suppl 3):e315-e320. doi: 10.1055/s-0040-1701527.

**Conflict of interest.** The authors have no conflicts of interest to declare.

**ORCID:** Abdullayev A.S. <https://orcid.org/0000-0002-7447-5311>.

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