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GENDER DIMORPHISM OF ANTEROPOSTERIOR LATERAL DIMENSIONS AND PROFILE CONFIGURATION OF THE FACIAL DEPARTMENT OF THE SKULL IN ADULTS

Abstract. To date, the variability of the characteristics of the human skull profile by gender and craniotype remains insufficiently studied. The aim of our work was to determine the sexual dimorphism of the anteroposterior lateral dimensions and configurations of the facial skull profile in mature people. The study included 35 natural skull preparations and 80 CT images of the head of mature people (total 115 objects) without bone tissue pathology. Craniometric studies of computed tomography results were performed using measurement modules of computer programs used for tomogram analysis and three-dimensional reconstructions. Licensed versions of such programs are present on the tomograph and allow to obtain metric characteristics of the bone structure of the head with high accuracy. The following applications were used in this study: Ez3D Plus 3D, DICOM Vidar Dicom Viewer, and eFilmLite. Anatomage table was also used – a modern tool for studying and analyzing high-resolution 3D reconstructions, including those obtained using computed tomography. The properties of this device with the installed Launching Table 6.0 Application software allow to perform complex measurements with high accuracy or obtain detailed images of the smallest bone structures, which were used in this study. The study established statistical indicators of the anteroposterior lateral dimensions of the facial skull of adults. In men with a brachycephalic type of skull, the gl-n distance varied between 11 - 19 mm, and in women – 10 - 18 mm. The n-rhi distance was 18 - 28 mm in men and 16 - 26 mm in women. The following distances were also determined: rhi-ns (28 - 39 mm in men, 26 - 37 mm in women), ns-pr (10 - 20 mm and 9 - 18 mm, respectively), pr-id (20 - 26 mm and 18 - 25 mm), id-pg (12 - 26 mm and 11 - 24 mm). Representatives of the mesocephalic and dolichocephalic types of skull structure had smaller values of the studied parameters, with the exception of pr-id, which increased due to the larger sizes of the teeth of the upper and lower dentition.

Keywords: craniometry, craniotype, facial department of the skull, anteroposterior skull dimensions, sexual dimorphism, computed tomography.

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СТАТЕВИЙ ДИМОРФІЗМ ПЕРЕДНЬОЗАДНІХ БІЧНИХ РОЗМІРІВ ТА КОНФІГУРАЦІЇ ПРОФІЛЮ ЛИЦЕВОГО ВІДДІЛУ ЧЕРЕПА У ЛЮДЕЙ ЗРІЛОГО ВІКУ

Анотація. На сьогоднішній день варіабельність характеристик профілю черепа людини за статтю та краніотипом залишається недостатньо вивченою. Метою нашої роботи було визначення статевого диморфізму передньозадніх бічних розмірів та конфігурацій профілю лицевого черепа у людей зрілого віку. Дослідження включало 35 натуральних препарата черепа та 80 КТ-зображень голови людей зрілого віку (всього 115 об’єктів) без патології кісткової тканини. Краніометричні дослідження результатів комп’ютерної томографії проводили з використанням вимірювальних модулів комп’ютерних програм, що використовуються для аналізу томограм, та тривимірних реконструкцій. Ліцензійні версії таких програм присутні на томографі і дозволяють з високою точністю отримати метричні характеристики кісткової структури голови. У цьому дослідженні використовувалися такі програми: Ez3D Plus 3D, DICOM Vidar Dicom Viewer та eFilmLite. Також був застосований Anatomage table – сучасний інструмент для вивчення та аналізу 3D-реконструкцій високої роздільної здатності, в тому числі отриманих за допомогою комп’ютерної томографії. Властивості цього пристрою з встановленим програмним забезпеченням Launching Table 6.0 Application дозволяють проводити складні вимірювання з високою точністю або отримувати детальні зображення найдрібніших кісткових структур, які використовувалися в цьому дослідженні. У ході дослідження встановлено статистичні показники передньо-задніх бічних розмірів лицевого черепа дорослих людей. У чоловіків із брахіцефалічним типом черепа відстань gl-n коливалася в межах 11–19 мм, а у жінок – 10 – 18 мм. Відстань n-rhi становила 18 - 28 мм у чоловіків та 16 - 26 мм у жінок. Також було встановлено відстані: rhi-ns (28 - 39 мм у чоловіків, 26 - 37 мм у жінок), ns-pr (10 - 20 мм та 9 - 18 мм відповідно), pr-id (20 - 26 мм та 18 - 25 мм), id-pg (12 - 26 мм та 11 - 24 мм). Представники мезоцефалічного та доліхоцефалічного типів будови черепа мали менші значення досліджених параметрів, за винятком pr-id, який збільшувався через більші розміри зубів верхнього та нижнього зубного рядів.

Ключові слова: краніометрія, краніотип, лицевий відділ черепа, передньозадні розміри черепа, статевий диморфізм, комп’ютерна томографія.

Statement of the problem. To date, the range of individual anatomical variability in the profile characteristics of the human skull in adulthood, depending on sex and body type, has not been sufficiently established [1]. The bony structure of the skull exhibits an immense diversity of sections, bones, openings, and canals, the variability of which remains inadequately studied in relation to age, gender, and individual head shape [2]. Building on the classical works of renowned researchers, new morphological aspects, particularly regarding the improvement of profile craniometry, have gained importance [3].

Analysis of recent research and publications. The goal of craniometric research in this field is to determine the position of the jaws relative to the plane of the anterior part of the cranial base, to establish the facial type and detect deviations from average dimensions’ characteristic of a normal bite for that same facial type [4]. Notably, there has been a surge of interest among a large group of scientists in studying the living characteristics of skull sections, made possible by significant advancements in the latest systems for human instrumental research. Considering the importance for modern orthodontists of performing cephalometric analysis, where lateral projection is used, these methods are being enhanced with the most advanced technologies, including artificial intelligence [5].

Moreover, due to the rapid development of maxillofacial surgery, surgical and orthodontic dentistry, reconstructive surgery, and modern prosthetics techniques, there is a need for more detailed cranio- and morphometric data [6]. These studies will support the justification and development of rational treatment methods for individuals with maxillofacial pathologies [7, 8].

In summary, the study of the profile characteristics of the facial section of the skull during life, combining classical and modern craniometric methods, is highly relevant and timely in meeting the demands of morphological and dental sciences [9].

The aim of the article was to establish the gender dimorphism in the anteroposterior lateral dimensions and profile configuration of the facial section of the skull in adults.

Materials and Methods. The study material consisted of 115 adult human skulls of both genders. This included 35 dry bone specimens of intact or fragmented skulls from the museum collection of the Department of Human Anatomy, Clinical Anatomy, and Operative Surgery at Kharkiv National Medical University (KNMU), and 80 results of computed tomography (CT) scans of human heads, without existing bone tissue pathologies, collected from medical-diagnostic centers in collaboration with the department. The study selected adult males aged 22 to 60 years and adult females aged 21 to 55 years. Craniometric studies of the CT scan results were conducted using measurement modules from computer programs used for tomogram analysis and three-dimensional reconstructions. Licensed versions of such programs are always present on the tomograph and allow for obtaining metric characteristics of the bony structure of the head with high precision. In this study, the following programs were used: Ez3D Plus 3D, DICOM Vidar Dicom Viewer, and eFilmLite. At the Department of Human Anatomy, Clinical Anatomy, and Operative Surgery at KNMU, where this work was conducted, there is an Anatomage table system, a modern tool for studying and analyzing high-resolution 3D reconstructions, including those obtained from CT scans. The properties of this device, with the installed Launching Table 6.0 Application software, allow for conducting complex measurements with high precision or obtaining detailed representations of the smallest bony structures, which were used in this study.

The facial section of the skull [10] is divided into the orbital-frontal, nasal, and maxillary sections according to its development, functional significance, and structural features. Thus, polygons such as gl-po-n, n-po-rhi, and rhi-po-ns correspond to the orbital-frontal and nasal areas, while polygons ns-po-pr, pr-po-id, and id-po-pg are located in the maxillary section. Depending on the task, these figures can be combined to form other polygon varieties, such as quadrilaterals or pentagons.

Furthermore, a facial profilogram of the skull [11] was formed as a set of predetermined dimensions between facial profile points, presenting a continuous line passing through points gl-n-rhi-ns-pr-id-pg, reflecting the shape, dimensions, and position of the cranial profile of mature adults regardless of sex or cranial type.

Our research focuses on establishing the profile craniometric characteristics of the facial section of the skull. Additionally, the material used in our study had an almost equal gender distribution, with 59 male and 56 female skulls, enabling the identification of certain patterns and statistically significant differences in the studied parameters depending on their gender.

Presentation of the main material. Results of our study are present in the table 1.

Table 1

Range of individual variability of profile dimensions of the facial skull in mature women (mm)

Type of the cranium / Size	Brachicrany	Mesocrany	Dolichocrany
gl-n	10-18	10-17	9-16
n-rhi	16-26	15-25	14-24
rhi-ns	26-37	26-36	25-35
ns-pr	9-18	10-17	10-17
pr-id	18-25	19-26	20-28
id-pg	11-24	10-20	9-15

According to the obtained data, there is a certain craniometric relationship between the studied points of the facial skull, with maximum and minimum intervals of measurement variations. Their graphical relationships are shown in Figure 1.

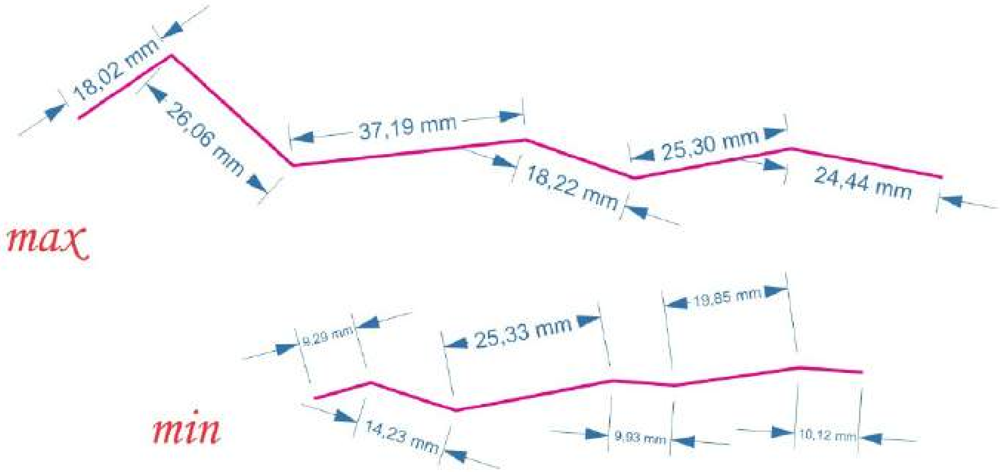

Fig. 1 The graphical relationships of the extreme forms of facial skull profilograms (rotated by 90° with proportions preserved).

Taking into account the existing craniotypes, an increase in profile parameters, on average by 1-3 mm, is observed in cases of established brachycephaly. This is primarily due, in our opinion, to the maximum values of the transverse dimensions of the bones and the increased prominence of the profile.

It was found that the distance between points gl-n in mature male brachycephalic individuals ranges from 11 mm to 19 mm, and in women from 10 mm to 18 mm. The distance between points n-rhi is 18 mm to 28 mm in men and 16 mm to 26 mm in women. For rhi-ns, the range is 28-39 mm in men and 26-37 mm in women; ns-pr ranges from 10 mm to 20 mm in men and from 9 mm to 18 mm in women; pr-id ranges from 20 mm to 26 mm in men and 18 mm to 25 mm in women; and id-pg ranges from 12 to 26 mm in men and from 11 to 24 mm in women.

In cases of mesocephaly and dolichocephaly, these parameters tend to average out and decrease, except for the pr-id dimension, where a slight increase is observed due to the enlargement of the teeth in both the upper and lower alveolar rows.

To confirm individual differences in the profile dimensions of the facial skull, a statistical analysis was conducted (Tables 2 - 4).

It has been established that the distance between the glabella-nasion (gl-n) points is characterized by the highest values in individuals with a brachycephalic skull shape, where the mean ($\bar{x}$) is 13.56 mm, with a standard deviation (σ) of 2.09 and a mean error ($m_{\bar{x}}$) of 0.62 in men, and a mean of 12.88 mm, $\sigma = 2.18$, and $m_{\bar{x}} = 0.81$ in women.

A gradual decrease in this parameter is observed in individuals with a mesocephalic skull shape, with $\bar{x} = 12.90$ mm, $\sigma = 1.82$, and $m_{\bar{x}} = 0.79$ in men, and $\bar{x} = 12.82$ mm, $\sigma = 1.68$, and $m_{\bar{x}} = 0.82$ in women.

In dolichocephalic skulls, a further reduction in the mean value of this size is noted, with $\bar{x}$ = 12.68 mm in men and $\bar{x}$ = 12.12 mm in women. This suggests that the initial gl-n parameter is somewhat larger in brachycephaly due to the thickening of the frontonasal suture and the nasal bridge area.

Table 2

Statistical Indicators of Profile Dimensions of the Facial Skull in Brachycephalic Individuals (mm)

Size \ Statistic indicator		$\bar{x}$	σ	$m_{\bar{x}}$
gl-n	male	13,56	2,09	0,62
	female	12,88	2,18	0,81
n-rhi	male	23,18	2,26	0,58
	female	22,16	1,89	0,76
rhi-ns	male	33,21	2,40	0,84
	female	32,78	2,01	0,77
ns-pr	male	15,06	1,78	0,68
	female	14,58	1,88	0,92
pr-id	male	22,82	2,19	1,02
	female	21,66	1,80	0,94
id-pg	male	19,86	1,42	1,06
	female	18,36	1,66	0,90

Table 3

Statistical Indicators of Profile Dimensions of the Facial Skull in Mesocephalic Individuals (in mm)

Size \ Statistical indicator		$\bar{x}$	σ	$m_{\bar{x}}$
gl-n	male	12,90	1,82	0,79
	female	12,82	1,68	0,82
n-rhi	male	21,75	1,56	0,72
	female	21,80	1,44	0,86
rhi-ns	male	31,28	1,32	0,68
	female	31,11	1,46	0,72
ns-pr	male	15,88	2,01	1,01
	female	15,42	1,78	0,98
pr-id	male	23,82	1,50	0,83
	female	23,30	1,18	0,62
id-pg	male	16,58	1,06	0,48
	female	15,44	1,21	0,71

Table 4

Statistical Indicators of Profile Dimensions of the Facial Skull in Dolichocephalic Individuals (in mm)

Size \ Statistical Indicator		$\bar{x}$	σ	$m_{\bar{x}}$
gl-n	male	12,68	1,28	0,59
	female	12,12	1,11	0,63
n-rhi	male	20,45	1,02	0,81
	female	20,10	1,08	0,77
rhi-ns	male	30,68	2,02	0,68
	female	29,72	1,89	0,91
ns-pr	male	16,66	1,70	0,60
	female	16,16	1,48	0,54
pr-id	male	26,80	1,33	0,48
	female	25,92	1,20	0,62
id-pg	male	14,48	1,24	0,78
	female	14,08	1,14	0,56

The distance between the nasion-rhinion (n-rhi) is also more pronounced in male brachycephalics, with a mean ($\bar{x}$) of 23.18 mm, a standard deviation (σ) of 2.26, and a mean error ($m_{\bar{x}}$) of 0.58, and in females, with $\bar{x}$ = 22.16 mm, σ = 1.89, and $m_{\bar{x}}$ = 0.76. In mesocephalics, a slight decrease in this parameter is noted, with $\bar{x}$ = 21.75 mm, σ = 1.56, and $m_{\bar{x}}$ = 0.72 for men, and $\bar{x}$ = 21.80 mm, σ = 1.44, and $m_{\bar{x}}$ = 0.86 for women. For dolichocephalics, the smallest statistical values are observed: $\bar{x}$ = 20.45 mm, σ = 1.02, and $m_{\bar{x}}$ = 0.81 for men, and $\bar{x}$ = 20.10 mm, σ = 1.08, and $m_{\bar{x}}$ = 0.77 for women. This difference is likely due to the formation of a more massive nasal bone, particularly in the nasal bridge, among brachycephalic individuals.

The distance between rhinion and nasion (rhi-ns) shows certain craniometric characteristics depending on facial skull structure and profile orientation. In brachycephalics, this parameter reaches maximum values: $\bar{x}$ = 33.21 mm, σ = 2.40, and $m_{\bar{x}}$ = 0.84 for men, and $\bar{x}$ = 32.78 mm, σ = 2.01, and $m_{\bar{x}}$ = 0.77 for women. Average values are noted for mesocephalics, with $\bar{x}$ = 31.28 mm, σ = 1.32, and $m_{\bar{x}}$ = 0.68 for men, and $\bar{x}$ = 31.11 mm, σ = 1.46, and $m_{\bar{x}}$ = 0.72 for women. In dolichocephalics, this parameter decreases further, not exceeding $\bar{x}$ = 30.68 mm, σ = 2.02, and $m_{\bar{x}}$ = 0.68 for men, and $\bar{x}$ = 29.72 mm, σ = 1.89, and $m_{\bar{x}}$ = 0.91 for women. This suggests that in brachycephalics, the nasal aperture has the largest dimensions due to the broader and more massive facial skull structure. However, the lower edges of the piriform aperture tend to narrow in meso- and dolichocephalics.

The distance between nasion and prosthion (ns-pr) is smallest in brachycephalics, where the mean does not exceed $\bar{x}$ = 15.06 mm, σ = 1.78, and $m_{\bar{x}}$ = 0.68 for men, and $\bar{x}$ = 14.58 mm, σ = 1.88, and $m_{\bar{x}}$ = 0.92 for women. In mesocephalics, the values are $\bar{x}$ = 15.88 mm, σ = 2.01, and $m_{\bar{x}}$ = 1.01 for men, and $\bar{x}$ = 15.42 mm, σ = 1.78, and $m_{\bar{x}}$ = 0.98 for women, with a slight increase in this parameter. In dolichocephalics, this measurement reaches its maximum: $\bar{x}$ = 16.66 mm, σ = 1.70, and $m_{\bar{x}}$ = 0.60 for men, and $\bar{x}$ = 16.16 mm, σ = 1.48, and $m_{\bar{x}}$ = 0.54 for women. This feature of the craniofacial profile is associated with a downward shift of the most protruding point, prosthion, and lengthening of the medial incisors in the maxilla of dolichocephalics.

The distance between prosthion and infradentale (pr-id) gradually increases from brachycephalics, with $\bar{x}$ = 22.82 mm, σ = 2.19, and $m_{\bar{x}}$ = 1.02 for men, and $\bar{x}$ = 21.66 mm, σ = 1.80, and $m_{\bar{x}}$ = 0.94 for women, to mesocephalics: $\bar{x}$ = 23.82 mm, σ = 1.50, and $m_{\bar{x}}$ = 0.83 for men, and $\bar{x}$ = 23.30 mm, σ = 1.18, and $m_{\bar{x}}$ = 0.62 for women. In dolichocephalics, the largest values are observed: $\bar{x}$ = 26.80 mm, σ = 1.33, and $m_{\bar{x}}$ = 0.48 for men, and $\bar{x}$ = 25.92 mm, σ = 1.20, and $m_{\bar{x}}$ = 0.62 for women. This feature is related to the elongation of the mandibular body in dolichocephalics, the increase in the curvature of the lower alveolar arch, and the positioning of the dental arch.

The final distance in the craniofacial profile is between infradentale and pogonion (id-pg), which also shows individual differences depending on skull shape. The largest values are observed in brachycephalics: $\bar{x}$ = 19.86 mm, σ = 1.42, and $m_{\bar{x}}$ = 1.06 for men, and $\bar{x}$ = 18.36 mm, σ = 1.66, and $m_{\bar{x}}$ = 0.90 for women. In mesocephalics, the arithmetic mean decreases to $\bar{x}$ = 16.58 mm, σ = 1.06, and $m_{\bar{x}}$ = 0.48 for men, and $\bar{x}$ = 15.44 mm, σ = 1.21, and $m_{\bar{x}}$ = 0.71 for women. Dolichocephalics exhibit the smallest values: $\bar{x}$ = 14.48 mm, σ = 1.24, and $m_{\bar{x}}$ = 0.78 for men, and $\bar{x}$ = 14.08 mm, σ = 1.14, and $m_{\bar{x}}$ = 0.56 for women. This can be explained by the increased massiveness of the mandibular body and the larger chin prominence in brachycephalics.

Discussion. By comparing the obtained craniofacial profiles, it has become possible to systematize the existing range of individual anatomical variability in the facial region of the skull, distinguishing brachycephalic, mesocephalic, and dolichocephalic cranial types (Fig. 2).

Profilograms illustrate the distinct anatomical variations in the structure and proportions of the facial region across different individuals. These profilograms provide a visual representation of the diversity in cranial dimensions and profiles, emphasizing the unique characteristics of each person's facial skull shape, as identified by the corresponding CT scans.

Thus, the cranial topography of the facial region of the skull fully reflects the existing range of individual anatomical variability in the structure, shape, and size of the head and skull as a whole.

Depending on the three somatotypes of human origin, the following cranial types are distinguished: brachycranial, mesocranial, and dolichocranial, which correspond to brachymorphic, mesomorphic, and dolichomorphic body types, respectively.

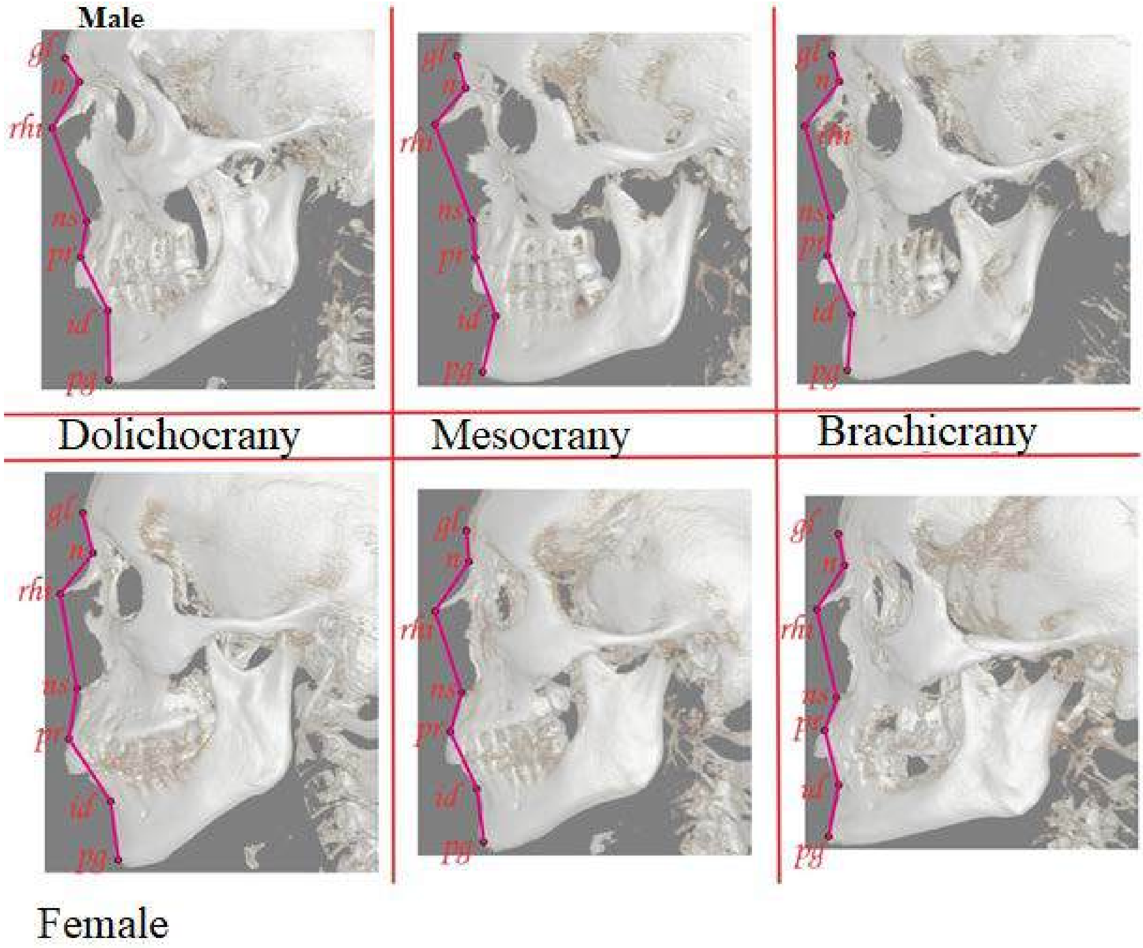

Fig. 2. The profilograms of individual differences in the facial skull.

Each of these cranial types is characterized by unique lateral (anteroposterior) and profile dimensions of the facial region of the skull, which ensures the distinctiveness of the human facial profile.

As is known, the visceral cranium is subdivided into the orbital-temporal, nasal, and maxillary regions based on its ontogenetic, functional, and structural characteristics. Based on the features of the conducted measurements and the spatial positioning of the constructed geometric figures, in our work, we propose combining the orbital-temporal and nasal regions into one, referred to as the orbital-nasal part. This includes three upper polygons: gl-po-n, n-po-rhi, and rhi-po-ns, along with the corresponding upper profile measurements, namely: gl-n, n-rhi, and rhi-ns. The obtained data allowed us to visually demonstrate the existing craniometric features of the orbital-nasal part of the facial section of the skull depending on gender (Fig. 3), and to compare the profile shape of this area in mature men and women (Fig. 4).

The primary task of any craniometric study is to establish the general linear dimensions of the skull, which include its length, width, and height. Considering the objective of our work, this also involves measuring the width and height of the facial section, which should be conducted on representatives of both sexes, in our case, within the boundaries of mature age (Fig. 5).

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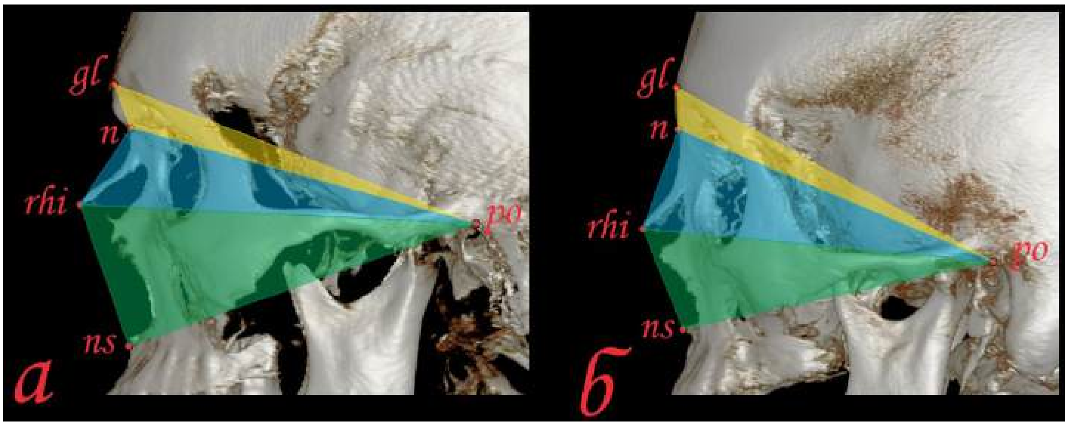

Fig. 3. Variations of craniometric polygons in the orbital-nasal part of the facial section of the skull in mature adults: a – male, b – female.

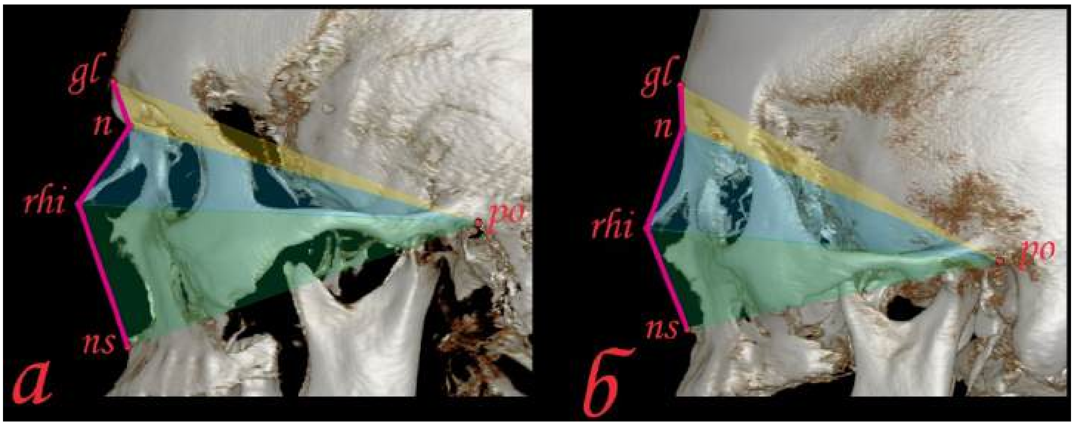

Fig. 4. Individual profile configuration of the orbital-nasal part of the facial section of the skull in mature adults: a – male, b – female.

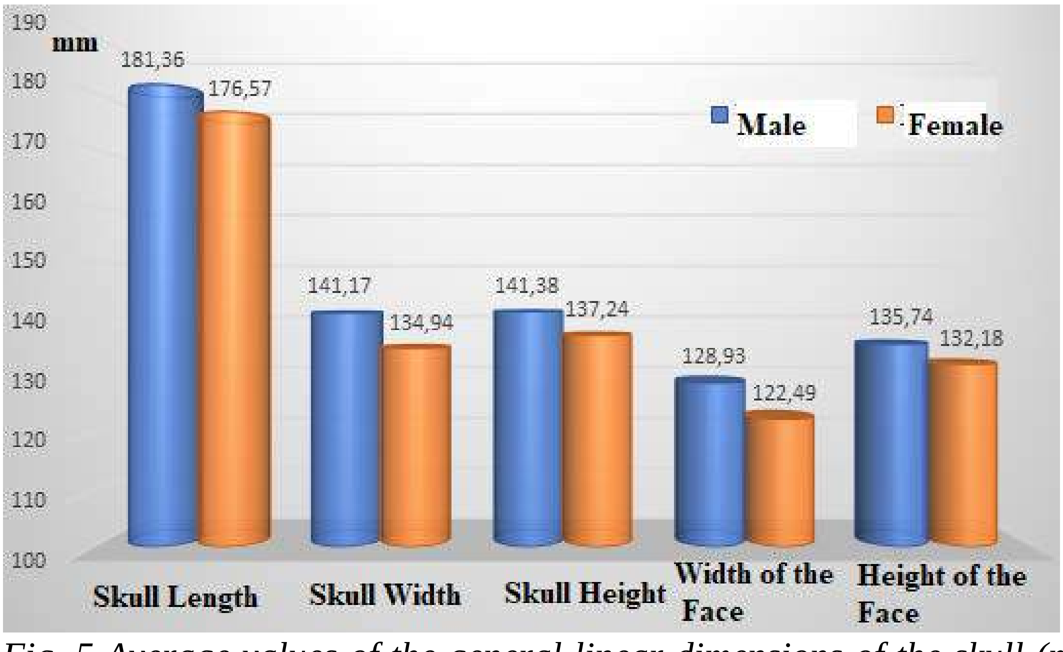

Fig. 5 Average values of the general linear dimensions of the skull (mm) in mature men and women.

Based on the obtained data, the length of the skull in men is, on average, 4.79 mm greater than in women, while the width of the skull is 6.23 mm greater, and the height is 4.14 mm greater. Additionally, the dimensions of the facial section of the skull in men were also larger, with facial width being 6.44 mm greater and facial height 3.56 mm greater. Thus, it can be stated that the overall linear dimensions of the skull and its facial section are generally larger in men than in women, a fact supported by the findings of many morphologists [12, 13].

It should be noted that despite the maximum values of all averages being obtained from male representatives, it is not possible to confirm a definitive characteristic, as all differences ranged from 0.33 mm (gl-n measurement) to 1.13 mm (id-pg measurement), which falls within the range of statistical error. However, when comparing profilograms, a more pronounced, sharper profile was observed in men, as opposed to the smoother and more proportionate profile seen in women.

The data from this study have profound implications for various medical disciplines, including ear, nose, and throat medicine, neurosurgery, ophthalmology, neurology, diagnostics, anatomy, dentistry, and pathological anatomy [15, 16]. They highlight early correlations between anatomical characteristics and the development of pathological processes [17, 18], particularly in complex disease mechanisms involving harmful factors, inflammation, and infections [19, 20]. While new medical technologies offer significant advancements in treatment and diagnosis, traditional anatomical methods remain indispensable. Future research could expand upon these findings, incorporate new investigative approaches, and enhance the educational and clinical practices of medical professionals [21, 22].

Conclusions. In the course of the study, statistical indicators of the anterior-posterior lateral dimensions of the facial skull in mature adults were determined. It was found that the distance between points gl-n in mature male brachycephalic individuals ranges from 11 mm to 19 mm, and in women from 10 mm to 18 mm. The distance between points n-rhi is 18 mm to 28 mm in men and 16 mm to 26 mm in women. For rhi-ns, the range is 28-39 mm in men and 26-37 mm in women; ns-pr ranges from 10 mm to 20 mm in men and from 9 mm to 18 mm in women; pr-id ranges from 20 mm to 26 mm in men and 18 mm to 25 mm in women; and id-pg ranges from 12 to 26 mm in men and from 11 to 24 mm in women.

In cases of mesocephaly and dolichocephaly, these parameters tend to average out and decrease, except for the pr-id dimension, where a slight increase is observed due to the enlargement of the teeth in both the upper and lower alveolar rows.

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