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# Metrical characterization and bilateral asymmetry of human zygomatic bone (craniometrical study)

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*Abstract:* Zygomatic bone is situated in the upper and medial section of the facial part of the skull and is of great importance for its shape. Nevertheless, metrical data concerning dimensions, proportions and bilateral asymmetry of the zygomatic bone are not comprehensive enough. On the other hand, it is hard or completely impossible to compare data given from different authors. In this study a total of 125 adult male skulls were investigated to perform a detailed characterization of zygomatic bone as well as to evaluate the manifestation of bilateral asymmetry. Seven linear features were measured separately on both sides. Quantitative assessment of the bilateral asymmetry and converting the absolute asymmetry values into relative values was performed using the Index of Asymmetry (IA). According to our results, the left zygomatic bone is larger as a whole, while the right one is more projected with higher lateral surface and significantly wider frontal process.

*Keywords:* zygomatic bone, metrical characterization, bilateral asymmetry

## Introduction

Zygomatic bone is situated in the upper and medial section of the facial part of the skull and is of great importance for its shape. The zygomatic bone forms the prominences of the cheek and separates the orbit from the temporal fossa. It articulates with the maxilla, the greater wing of the sphenoid, and the zygomatic processes of the frontal and temporal bones. It is irregular in shape and has three surfaces, two processes and five borders [18]. The strongly prominent and situated more parallel to the frontal plane zygomatic bones contribute to enlargement of the face breadth.

Conversely, when the bones are less prominent and situated more sagittal the face looks narrower and gracile [27]. The size and curvature of the bone varies greatly in different population, being smaller and flatter in Caucasian skulls and larger and more curved in Mongoloid race [1, 23, 24].

Knowledge about human skull asymmetry in normal dry specimens is useful as a parameter for medical and dentistry practice. The caliper direct method for evaluation of the bilateral asymmetry is a reliable technique used in anatomical and anthropological studies [17]. Fazekas & Kósa [5] recorded the length and width of the bone during fetal life. Moss, Noback & Robertson [13] also recorded length and height of the bone from 8 to 20 weeks but landmarks are not defined. Nevertheless, metrical data concerning the dimensions, proportions and bilateral asymmetry of the zygomatic bone are not comprehensive enough. On the other hand it is hard or completely impossible to compare data given from different authors. This difficult comes from insufficient standard dimensions for this bone and the various measurements between different craniometrical points used by the researchers. In this context the aim of the study is to perform a detailed metrical characterization of zygomatic bone as well as to evaluate the manifestation of bilateral asymmetry.

## Material and Methods

A total of 125 male skulls from the ossuary at the National Museum of Military History, Sofia, were studied. The skulls belong to adult male individuals.

For quantification of craniofacial asymmetry are used measurements for the right and left sides separately. The differences between homologous measurements supply information about the dominant side. This method provides good information about side differences and local imbalance [7].

For the aim of this study were measured (in millimeters) bilaterally seven linear features between standard craniometrical points by Martin & Saller [11]:

1. Total height of zygomatic bone (*zm – fmt*). The linear distance between the landmarks *zygomaxillare* and *frontomalare temporale* (Fig. 1), sliding caliper.

2. Height of lateral (external) surface of zygomatic bone (*zm – ju*). The linear distance between the landmarks *zygomaxillare* and *jugale* (Fig. 1), sliding caliper.

3. Height of frontal process of zygomatic bone (*ju – fmt*). The linear distance between the landmarks *jugale* and *frontomalare temporale* (Fig. 1), sliding caliper.

4. Breadth of frontal process of zygomatic bone (*fmt – fmo*). The linear distance between the landmarks *frontomalare temporale* and *frontomalare orbitale* (Fig. 1), sliding caliper.

5. Arc of zygomatic bone, after Alekseev and Debetz [26]. The least distance on the zygomatic bone surface between the landmarks, in which the breadth of zygomatic bone is measured, tape.

6. Projection of zygomatic bone, after Alekseev and Debetz [26]. The greatest perpendicular, pulled down from the line of zygomatic bone breadth to the surface of the bone, coordinate caliper.

For more detailed metrical characterization and assessment of the bilateral asymmetry were included data for the breadth of zygomatic bone, obtained in our previous study on the same material [14]:

7. Breadth of zygomatic bone, chord – after Alekseev and Debetz [26]. The direct distance from the lowest point situated on temporozygomatic suture (at a transition from the lateral surface to the inferior surface of zygomatic arch) to the crossing point of zygomaticomaxillary suture with the lower rim of the orbit (Fig. 1), sliding caliper.

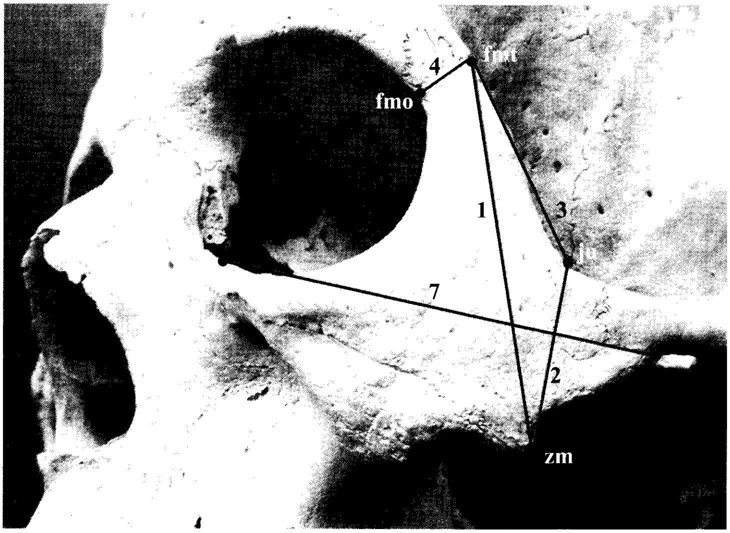


Fig. 1. Measurements of zygomatic bone: 1. total height of zygomatic bone (*zm – fmt*); 2. height of lateral surface of zygomatic bone (*zm – ju*); 3. height of frontal process of zygomatic bone (*ju – fmt*); 4. breadth of frontal process of zygomatic bone (*fmt – fmo*); 7. breadth of zygomatic bone, chord

In the present study any difference between the homologous distances of the right and left sides is considered as an asymmetry. Quantitative assessment of the bilateral asymmetry and converting the absolute asymmetry values into relative values were performed using Wolanski's index for intergroup comparison [21]. In this case, the index was used to evaluate the bilateral asymmetry and is referred to as Index of Asymmetry (IA): IA = $[2. (x_d - x_s).100]/(x_d + x_s)$, $x_d$ – value of the measurement on the right side; $x_s$ – value of the measurement on the left side.

The sign of the resulting IA value designates the direction of bilateral asymmetry; "-" signifies the left side priority and "+" signifies the right side priority. IA is calculated individually and the given data represent the mean from the individual values.

## Results

The biostatistical data are presented in Table 1.
The differences between both sides are expressed in index units (IU). The lowest value found is -0,68 IU and the highest is 4,31 IU, which may be considered as significant. Moreover, four of all investigated measurements show left side dominance. The left zygomatic bone is higher (-0,68 IU), it is also wider, with larger arc (-0,54 IU) and chord (-0,18 IU), and with insignificantly higher frontal process (-0,02 IU). The rest three measurements show priority for the right side. The right zygomatic bone is more projected (0,25 IU), with relatively higher lateral surface (0,77 IU) and with significantly wider frontal process (4,31 IU). Standard deviations show that the homogeneity of each measurement is similar with exception for the projection and the height of the frontal process of zygomatic bone, which are more dispersed. Nevertheless, Student's t-test shows that the breadth of frontal process is the only measurement, which displays statistically significant bilateral difference at $p< 0,05$ with priority for the right side.

ble 1. Biostatistical data about the investigated linear features of zygomatic bone

| lo | Measurements of zygomatic bone | Right | | | | | | Left | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | n | mean | SEM | SD | min | max | n | mean | SEM | SD | min | max |
| 1 | Total height (zm-fmt) | 125 | 46,96 | 0,27 | 3,04 | 38,50 | 54,50 | 125 | 47,28 | 0,28 | 3,11 | 39.00 | 55.00 |
| 2 | Height (zm-ju) | 124 | 27,54 | 0,25 | 2,78 | 18,00 | 37,00 | 125 | 27,32 | 0,25 | 2,74 | 19.00 | 37.50 |
| 3 | Height of frontal process (ju-fmt) | 124 | 25,40 | 0,20 | 2,27 | 20,00 | 32,00 | 125 | 25,38 | 0,20 | 2,27 | 20.00 | 30.00 |
| 4 | Breadth of frontal process (fmt-fmo) | 125 | 6,71 | 0,09 | 1,01 | 4,00 | 9,00 | 125 | 6,42 | 0,09 | 0,95 | 4.00 | 8.50 |
| 5 | Breadth - arc | 122 | 58,56 | 0,45 | 4,94 | 44,00 | 70,00 | 125 | 58,92 | 0,43 | 4,82 | 47.00 | 70.00 |
| 6 | Projection | 123 | 10,54 | 0,15 | 1,66 | 6,50 | 15,00 | 125 | 10,52 | 0,15 | 1,67 | 6.00 | 14.50 |
| 7 | Breadth - chord | 123 | 53,13 | 0,35 | 3,89 | 40,00 | 63,00 | 125 | 53,22 | 0,33 | 3,67 | 43.00 | 63.00 |

atistically significant difference at $p < 0,05$

## Discussion

Working on skulls, Woo [22] found that the left zygomatic bone was predominant. In their monograph, Kadanov and Mutafov [28] cited Ludwig (1932), that the left side was larger than the right side and the left zygomatic bone was more projected forward compared to the right one. In accordance with their own data from metrical investigation of contemporary cranial series, Kadanov and Mutafov [28] established that the middle section of the facial part of the skull (both zygomatic bone and maxilla) was more often symmetrical in vertical direction compared to horizontal direction. They also concluded that the asymmetry was more often manifested in the breadths than in the heights of that part of cranium. According to our results, the asymmetry was established in the breadths as well as in the heights of the zygomatic bone, but it was manifested to the greatest extend in the breadths (breadth of frontal process 4,31 IU). In other studies it was established that the manifestation and degree of craniofacial asymmetry were most pronounced in the mid-facial section, i.e. in the morphological structure maxilla-zygomatic bone [9, 10]. Kadanov, Yordanov and Aleksandrova [29] figured out the fact, that left half of the facial part was narrower and the entrance to the left orbit was situated more higher compared to the right one. According to our results, the left zygomatic bone was larger as a whole, while the right one was with more massive frontal process and lateral surface and more projected. The different results of the researchers probably could be explained with the different methods used to determine the craniofacial asymmetry.

In general facial asymmetry can be summarized and divided into three main categories, 1 – congenital, originating prenatally; 2 – developmental, arising during growth with inconspicuous etiology; and 3 – acquired, resulting from injury or disease. Based on the craniofacial structures involved, facial asymmetry can be classified into dental, skeletal, soft tissue and functional components. Skeletal asymmetry may involve one bone or it may affect a number of skeletal structures on one side of the face [4]. Normal asymmetry in the area of the craniofacial skeleton can be directional or fluctuating in nature. Directionality can in principle be found in three dimensions: anteroposterior, cranio-caudal, and asymmetries in the left-right dimension. Fluctuating asymmetry is another type of asymmetry normally found in the craniofacial structures, where the side of the larger and smaller paired structure is randomly determined [15].

Perfect bilateral symmetry in the body is basically a theoretical concept that rarely exists in live organisms [2]. The human skull is definitely asymmetrical, this is not a matter of skull bones that differ individually from a symmetrical model, but the skull is asymmetric as a whole. Some dimensions of the skull bones are prominent on the right side and some on the left [3, 22]. Knowledge of quantitative normal cranial asymmetry in a population without pathology or functional disturbance is necessary to avoid malpractice [17].

There is no consensus in the literature on the degree, side and spatial localization of facial asymmetry [7, 25]. A mild degree of asymmetry is common in the face of normal and healthy individuals. The point where the "normal" asymmetry becomes "abnormal" cannot be easily defined [2]. According to Rossi, Ribeiro & Smith [16] the larger the asymmetry, the more the attention it has to be given because one may be nearer to a pathological condition. Nevertheless, there are no clearly defined limits to determine certain difference between homologous measurements of both sides as an asymmetry. Some authors considered that asymmetry existed when the means of the differences between the sides were statistically different from zero. Others used the Student's t-test for paired samples to consider the differences between the right and left sides as asymmetries or considered as asymmetry when the differences between measurements of the right and left sides were 2 mm or larger. This limit was chosen arbitrarily and turns out to be variable because it depends on the skull size [16].

In general facial asymmetry affects the lower face more frequently than the upper face [4]. Severt & Proffit [19] reported frequencies of facial laterality of 5%, 36% and 74% in the upper, middle and lower thirds of the face. Furthermore, in the literature there is no agreement about the side of dominance. Using the different evaluation methods for assessment of craniofacial asymmetry, various conclusions were proposed by different researchers. However, it is difficult to compare these studies, since the methods, the measurements and the sample characteristics (sex, age, race) are very different [7]. Nevertheless, some authors conclude that the right side of the face has dominance over the left side [6, 8, 20, 22]. Others established that the left side of the face predominates over the right side [3]. According to Ferrario at al. [7] the two side of face showed significant differences in shape, but no differences in size. Moreover, the soft-tissue cover partly masks the underlying skeletal imbalances, and skeletal asymmetries less than 3% are not clinically discernible [6].

A number of explanations have been given for asymmetry causes, including genetic problems and environmental factors producing differences in the right and left sides [2]. According to Melnik [12], the organism does not favor identical growth of homologous bilateral structures. The difference in the degree of growth between the right and left sides may be caused by genetic factors, environmental factors, or a combination of the two factors. The expression of the craniofacial asymmetry can be related to heredity as well as to the functional activity of the skeletal muscular system, especially of the masticatory apparatus. Therefore, facial asymmetry has been associated with functional activities of the masticatory musculoskeletal system [16].

Because of the key role of zygomatic bone in the structure and aesthetical appearance of the face the evaluation of its bilateral asymmetry is of great importance to the morphologist, anthropologists, medics and in particular to the aesthetic surgeons. We believed that this study complements the knowledge of the zygomatic bone morphology and could be useful in further studies of the facial asymmetry manifestations.

## Conclusion

The metrical characterization shows that the breadth of frontal process is the only measurement, which displays statistically significant bilateral difference with priority for the right side. According to IA data, the left zygomatic bone is higher; it is also wider, with larger arc and chord, and with insignificantly higher frontal process. The right zygomatic bone is more projected, with relatively higher lateral surface and with significantly wider frontal process.

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