Assessment of Craniometric and Skeletotopic Characteristics of the Facial Skeleton and Palate in a Population of North-West Croatia

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Summary

The entire osseous system of transmission of mastication forces may be divided into five smaller units: the lower jaw, the anterior and posterior system of facial mid-portion, the frontal bone with the base of the cerebral cranial segment and the cerebral part of the skull. The development of these regions is simultaneously influenced by genetic determinants and numerous external (environment, climate) and general factors (statics, gravity, upright walking).

The objective was to study basic craniometric and skeletotopic characteristics of the facial skeleton and hard palate in osteologic samples kept at the "Drago Perović" Department of Anatomy. A total of 64 skulls pertaining to both sexes were included in the study. Following determination of craniometric points, measurements of twelve selected indicators were made by electron gliding meter with 0.01 error probability and by goniometer with 1 percent error probability. The obtained results were compared with the data of similar studies and, together with other harmonic distances, they were mathematically inserted into a harmonic circle with the diameter of 2R. The height of the skull is taken to be 2R, which is one sixth of an adult person's height.

The obtained measurements have ensured the basis for further mathematical and structural analyses of the cranial structure.

Key words: *facial skeleton, palate, harmonic analysis.*

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Introduction

The size, form and position of the skull and its parts are influenced by various factors. A number of authors are of the opinion that the development of basicranial flexure (at the base of the cerebral part of the skull) is the result of adjustment to upright position and walking. However, this assumption has often been disputed. The size of the brain and development of cerebral masses seem to have greater importance, so that in modern man the frontal bone shifts forward, the occipital bone is pushed backward, while the cerebral part of the skull roofs over the visceral one. Furthermore, the mastication system and even the size of the body seem to have great impact, although these factors have not yet been fully investigated.

Anthropometric studies in dentistry enable better analysis and definition of morphological particularities of the orofacial system. Comparison of the obtained results with those reported in reference literature enables definition of anthropometric and skeletotopic characteristics of people from different geographic areas. Furthermore, additional comparative analyses of these measurements and dentition sizes enable definition of the degree and location of possible aberrations and incompatibilities of facial and jaw parameters with the teeth, which facilitates diagnosis and contributes to correct planning of treatment (1,2).

Theoretical considerations and functional studies of the skull, especially the mastication forces, undoubtedly lead to a number of possible conclusions.

The upper jaw and the palatal bone that form the hard palate serve as central support in the transmission of forces occurring in dental processes in the course of mastication. The two bones together with the zygoma and wing process of the sphenoid bone make a unique dynamic osseous transmission system by which the mastication forces reach the supporting points of the osseous system in the cerebral part of the cranium. In the posterior part of the system the osseous trajectories of mastication forces are joined in the median plane by vomer.

Therefore, for the purpose of more detailed research, the entire osseous system of mastication forces transmission may be resolved into five smaller entities, or units, related to each other through their interactions as follows: osseous entity of the lower jaw, anterior and posterior transmission systems in the facial skeleton, frontal bones with the base of the cerebral cranial portion, and finally, the cerebral segment of the skull (3-5).

The region of the posterior transmission system is located between several different functional elements, substantiating the assumption regarding the action of multiple insurance or supplementation process. The development, growth, structure and relations between osseous entities in the posterior transmission system primarily result from the activities of oro-naso-pharingeal and cerebral capsules (6-7).

Upon the development of dental processes and germination of teeth the action of mechanical forces occurring during mastication begins and so does the influence of the development of functional spaces, muscles and other soft tissues. It is an established fact that developmental and growth irregularities cause the majority of orthodontal abnormalities most commonly occurring in decidual and mixed dentition (11). Also, numerous internal and external factors participate in the formation of the posterior transmission system.

Hence to determine the characteristics and growth pattern of craniofacial systems is among the essential tasks of the study. Consequently our scientists were also involved in the measurement of distances and analyses of anthropometric and cephalometric parameters as part of the study on the characteristics of craniofacial growth (8-12).

Sample and methods

The study sample comprised 64 skulls. There were 32 male skulls, of men aged 18 to 75 years, and 32 female skulls, of women aged 22 to 83 years.

The specimens were prepared by standard maceration and bleaching procedures followed by polishing for reasons of better preservation of bone matter.

For the purpose of obtaining an appropriate mathematical model that would be as accurate as possible in functional analysis, standard osteometric measurements were used as described by Martin and Saller (13). The procedure included determination of craniometric points, distances, angles and indexes of the face and palate. It is important to point out that the index, i.e. the arithmetic relations between distances, more accurately describes the shape of the organ in numerical terms than the individual distances themselves. The following craniometric points, or landmarks, were used for the purpose of measurement: basion (ba), bregma (b), frontotemporale (ft), glabella (gl), gnathion (gn), nasion (n), opisthocranion (op), orale (or), orbitale (o), porion (p), prosthion (pt), staphylion (st) and zygion (zy).

On the basis of these points 12 distances were measured and a total of 768 variables were obtained. The following were determined by craniometry: height, width and indexes of the skull and face.

The height of the skull (H) was determined on the basis of the distance between the coronal and sagittal suture intersection - bregma (b) and the intersection between the median plane and anterior edge of the foramen magnum - basion (ba).

The width of the skull (B) was measured on the basis of the distance between both euryons (eu).

The length of the skull (L) was measured as the distance between glabella (gl) and opisthocranion (op).

Based on the obtained results the length-width-height index of the head was estimated showing interesting relations between the basic dimension of the skull, particularly important in determination of racial characteristics. In the calculation of index the following formula was used:

$$LWHI = \frac{\text{height (ba - b) x 100}}{\text{lenght (gl - op) + width (eu - eu)}} / 2 \quad (1)$$

The height of the face (Hf) was taken as the distance between the intersection of the median plane, i.e. internasal and nasofrontal suture (n), and the lowest point of the mental process (gnathion).

The width of the face (Wf) was determined on the basis of the interzygomatic space, i.e. linear distance between the most protuberant points of the left and right zygomatic arch (zygion).

The width of the forehead (Wfo) was defined as the distance between the frontotemporal points (ft).

The profile angle (Pa) was determined on the basis of the decline of the conjunction of nasion and the intersection between the median plane and anterior edge of the upper jaw alveolar process (prosthion) in relation to the Frankfurt plane.

The facial index was estimated using the above variables and the following formula:

$$FI = \frac{\text{height of face (n - gn) x 100}}{\text{span between two zygions (zy - zy)}} \quad (2)$$

The following palatal landmarks were measured:

Length of the bony palate (Lp) - the distance between anthropometric points of orale and staphylion, i.e. the transverse palatal suture.

Width of the bony palate (Wp) - the distance between central fissures of the right and left uper first molar.

Height of the bony palate (Hp) - the deepest point of the perpendicular upon the palate in the span between the fissures of first upper molars.

Length of the palatal process (Lpn) - the space between orale and transverse palatal suture (staphylion - st).

Length of the palatal bone process (Lpbp) - the distance between transverse palatal suture (st) and its posterior edge (spina nasalis posterior ossis palatini).

Based on these measurements the anthropo-metric index of the bony palate is presented as follows:

$$AIP = \frac{\text{palatal width x 100}}{\text{palatal lenght}} \quad (3)$$

According to the equation:

$$IHN = \frac{\text{palatal height x 100}}{\text{palatal width}} \quad (4)$$

the palatal height index was calculated.

Measurements were made by electron gliding meter and goniometer with the possibility of error of 0.01 mm, i.e. 1 degree. In statistical analysis of craniologic and skeletotopic data the standard calculations of quantitative characteristics of single measurements were used. The measurements served as the basis for further procedures of harmonic analysis used to indicate the proportions and harmony between single parts of the orofacial system by appropriate mathematical expressions (models).

Results

Our study measurements were used for calculating harmonic relations between the bones of the skull and face in a population of northern Croatia. The values obtained for the distances in the skull and face are shown in Table 1.

The average length of the skulls was 173.27 mm ± 7.355 mm; all the male skulls had higher values than the female skulls and their ratio was 175.59:170.94 mm.

The average width of the skulls in our specimens was 131.46 mm ± 7.891 mm; the ratio between male and female skulls was 132.28 : 130.56 mm.

The average height of the skulls was 219.17 mm; the relation between male and female skulls was 227 : 224 mm respectively.

Based on the obtained values the length-width-height index of the head (LWHI) was estimated and it was 71.92.

Facial dimensions are also shown in Table 1 as follows:

The average height of the facial skeleton in our study sample was 111.09 mm ± 9.386 mm, whereas the ratio between male and female dimensions was 114.63 : 106.94 mm respectively ($p < 0.05$).

The average width of facial skeleton in our study specimens was on the average 131.44 mm ± 7.535 mm; the ratio between male and female values for this parameter was 133.72 : 128.69 mm respectively.

Based on these dimensions the index for face (FI) was calculated, which was 84.49.

The dimensions of the bony palate with palatal processes are shown in Figure 1.

The average length of the hard palate was 45.59 mm ± 4.345 mm; the ratio between male and female dimensions was 47.38 : 43.81 mm respectively.

The average width of the hard palate was 48.65 mm ± 5.543 mm; the ratio between male and female dimensions was 46.85 : 45.72 mm respectively.

The height of the hard palate was 12.86 mm ± 4.621 mm; the ratio between male and female dimensions was 13.91 : 11.84 mm respectively.

The average length of the palatal process was 35.25 mm ± 3.901 mm.

The average length of the palatal process of the palatal bone was 13.72 mm ± 3.209 mm; the ratio between the average lengths of the palatal processes of the upper jaw and the palatal bone was 35.25 : 13.72 mm, i.e. 2.56:1 respectively.

The anthropologic index of the bony palate (palato-alveolar index) was 81.58, whereas the index of the palatal height (IPH) was 34.7.

It is commonly known that many geometric relations may be determined on the basis of the harmonic analysis of the skull. Thus, for instance, the radius of the harmonic circle, the short leg and the hypotenuse of the pertaining triangle are obtained from simple geometric relations:

$$a : b : R = 1 : 2/2 : 5/2 \quad (5)$$

at which :

a = 1 - hypotenuse of a harmonic triangle
b = 2/2 - short leg of a harmonic angle
R = 5/2 - radius of a harmonic angle;

i.e., when calculated then:

$a = 1$
$b = 0.707$
$R = 1.118$
$r = 0.207$
$d = 0.618$
$b + r = 0.914$

When the obtained dimensions are compared with the values obtained in harmonic analysis and with regard to the obtained height of the skull, it follows that :

$$R = H/2 = 219.17/2 = 109.59 \text{ mm} \quad (6),$$

according to which the width of the skull (B) is:

$$B = b/2 = 268.93/2 = 134.46 \text{ mm} \quad (7),$$

and the length of the skull is:

$$L = 2a = 2 \times 97.50 = 195 \text{ mm} \quad (8).$$

Discussion and conclusions

The entirely different individual formation and development of functions of the skull together with many other factors are reasons for numerous individual differences in both single segments and the entire skull. Anthropologic study procedures are aimed at contributing to knowledge of functional inter-relations between the bones of the face and head, which is highly significant to the studies of interior osseous structure.

Craniometric procedure included the determination and marking of craniometric points, variables, angles and indexes. The obtained values were further used in harmonic analysis of the skull (14-18).

When comparing our measurements with those performed by Volkov (19) it may be concluded that the data in both studies are overlapping on a wide basis. For instance, the relation between skull lengths obtained in our study and those reported by Volkov et al has the ratio of 17.32:18.80 mm respectively. The ratios for skull widths are 13.14:14.80 mm, and 21.91:21.80 mm for skull heights.

The values of the average head index (LWHI) of 72.76 indicate that, according to Saller (71.0-76.9) and Broca (x-77.0), the samples belong to the group of dolichocephalic skulls (13).

The average face index values (FI) of 84.49 classify our specimens as europrosopic skulls, according to Kollmann (80.0-84.9), or hypereuroprosopic skulls, (x - 84.9) according to Sawalisch.

Ferrari (20) reported significant differences in measured variables between men and women, although in our studies the differences have been statistically insignificant and for this reason they are not presented in the tables.

The distances and indexes of the upper palate are characteristic features of functional entity that transmits mastication forces from posterior parts of the dental arch to the base of the cerebral segment of the skull.

Different data exist about the dimensions of the hard palate, which is probably due to different approaches and measurements, but also to marked variability in single structures like the torus palatinus and similar. The length of the hard palate in our sample when compared with the data reported by Jo et al (10) was in the ratio 45.59 : 48.50 mm, the height of palate was in the ratio 12.86:18.60 mm, and the width of palate was in the ratio 48.65:46.32 mm.

The palato-alveolar index (APN=81.58) shows that our specimens belong to the group of medium wide palates (mesostaphyline, 80.0-84.99) (13).

Index of the height of the palate (IHP) shows that according to Bauer (13) our specimens belong to the group of medium wide palates (orthostaphyline, 34.7).

On the basis of the obtained measurement values and appropriate mathematical expressions radius R of the harmonic circle of the skull was determined. Thus, out of simple geometric relations there follows the expression of harmonic relations that insert the obtained values into the harmonic skull system.

The growth of the facial skeleton is definitely controlled by the growth surfaces and not by active central growth points, as previously assumed. On the other hand, these activities cause changes in the size and shape of bones in three dimensions, especially in the jaw bones and their alveolar ridges (17-20).

In recent years knowledge of craniofacial growth has been broadened by many findings, especially the discovery of functions of morphogenetic proteins as factors of growth and regeneration, reaching deeper into the roots of events contributing to human development, the consequences of which are yet to be defined by craniometric and cephalometric analyses (21).