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Asymmetry of Human Skull Base During Growth

Asimetría de la Base de Cráneo Durante el Crecimiento

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SUMMARY: Knowledge about human skull asymmetry in normal dry specimens is useful as a parameter for medical and dentistry practice. Skull base was investigated with the objective to validate the method of indirect measurement with digital pictures and to evaluate the degree of asymmetry from human skull base in different ages. We analyzed 176 normal identified human skulls, divided by age in the following groups: Fetuses, newborn, children and adults. Measures were taken from a central point: pharyngeal tubercle and 4 lateral points: foramen ovale, foramen spinosum, carotid canal and stylomastoid foramen using digital biometry after a comparative validation with directed method performed with caliper. Results were presented as asymmetry indexes and data were expressed as percentage. The digital method presented validity in relation to the direct method with caliper. The skulls in all age groups presented asymmetry. The smallest asymmetry index was 2.6% and the largest 6.6%. In the literature, there are no patterns for defined values of asymmetry in normal skulls. The asymmetry of the foramina related to midline was verified in the whole sample and was considered as normal corresponding to an average asymmetry index of 4%. In this study we also observed that in most of the measures there was prevalence of the right side over the left side.

KEY WORDS: Anatomy; Asymmetry; Growth; Skull.

INTRODUCTION

The degree of asymmetry in anatomy may indicate a genetic, congenital or acquired pathological condition, but there is any absolute standard to establish the boundary between "normal asymmetry" and "pathologic asymmetry". Knowledge of this difference is important for diagnosis and procedures. Some small asymmetries are not detected in clinical practice and it is necessary to establish a range of "normal asymmetry", the greater the asymmetry, the more likely is a pathological condition (Shah & Joshi, 1978; Rossi *et al*., 2003; Moreira *et al.*, 2006).

Although the human skull is apparently symmetrical, there are differences when we consider the right and left sides. This asymmetry is a common finding, especially in the skull base (Shah & Joshi), where development is associated with neural structures such as the brain and the senses (Brodie, 1955). The skull presents significant changes during growth, mainly related to size, until the end of adult life. The skull growth occurs through bone deposition and resorption. The remodeling promotes the movement of bone as a whole keeping the same shape. In fact, some areas may grow faster than others (Enlow & Hans, 1996).

Serjsen *et al*. (1997) used cranial foramina to assess skull growth and found more intense growth in the base in children aged 4-5 years old, continuing to decrease until growth stops. They also noted an area in skull base bounded by the foramen spinosum, foramen stylomastoid and foramen magnum which did not present anatomical variation. This stability in the central region of the skull base was already been reported in a study of skull base postnatal growth (Moss & Greenberg, 1967).

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 (Woo, 1931). Some dimensions of the skull bones are prominent on the right side and some on the left and the predominance of volume of right over the left frontal and parietal bones (Woo; Chebib & Chamma, 1981). A study with cephalometric radiographs also highlights further development of the right side over the left side suggesting that this difference is related to brain development since the right side is larger than the left (Shah & Joshi).

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Some hypothesis was made about factors that promote asymmetry during craniofacial growth, one possible factor is chewing (Shah & Joshi) and another is imbalance of muscle activity, especially in the stomatognathic system (Chebib & Chamma). Those hypotheses were not supported by a study with skulls aged from fetal to adult (Rossi *et al.*). The authors compared indexes of asymmetry obtained from various measures and concluded that the craniofacial asymmetry was found in whole sample and in all age groups, even before birth (Rossi *et al.*).

Studies of asymmetry and growth were conducted with some methods, among them directed measurements on the bone structure, cephalometric radiographs, digital photography and analysis on computer programs. Traditional method with caliper directly applied on the anatomical structure is simple, objective and well defined. However, the use of technology to capture digital images opens new horizons such as high resolution images, easily archived in digital media and new possibilities of rapid data transmission (Moreira *et al.)*. The objective of this study is to evaluate the degree of the skull base asymmetry in human growth and analyze the measurement methods by comparing direct (digital caliper) with indirect measurements (digital photography and software Image J).

MATERIAL AND METHOD

The study was carried out with 176 human identified dry skulls from the Museum of Anatomy Collection of the Universidade Federal de São Paulo. The sample was divided into five age groups: A - fetuses (7 months up to term, n=15, 10 male, 5 female); B - newborn up to one year old (n=32, 22 male, 10 female), C - 13 months up to 9 years old (n=19, 12 male, 7 female); D - 18 years up to 44 years old (D1 male, n=30; D2 female, n=30) and E - 45 up to 100 years old (E1 male, n=25; E2 Female, n=25). The investigation protocol was approved by the Bioethics Committee for Scientific Research of the Universidade Federal de São Paulo, Brazil.

The inclusion criterion was the existence of complete record of identification: age, sex, cause of death and the good condition of the skull and exclusion criterion was an inability to determine the precise points of reference or any condition that affects growth and development identifiable in records or specimens.

For this study, we used four bilateral reference points in relation to a central point of skull base to determine the measurements. The central point was the pharyngeal tubercle (PT) and the 4 lateral points at the sides were: foramen ovale: the most anterior outline (FO), foramen spinosum: medial outline (FS), carotid canal: the most medial outline (CC) and stylomastoid foramen: medial outline (FSM) (Fig. 1).

With the objective of validating an indirect method of digital biometry, comparing with a direct method of measurement with caliper, a pilot study in 10 skulls randomly selected among the groups was realized. Measures were obtained by the two methods, in a blind study, repeating the measurements 3 times on different days.

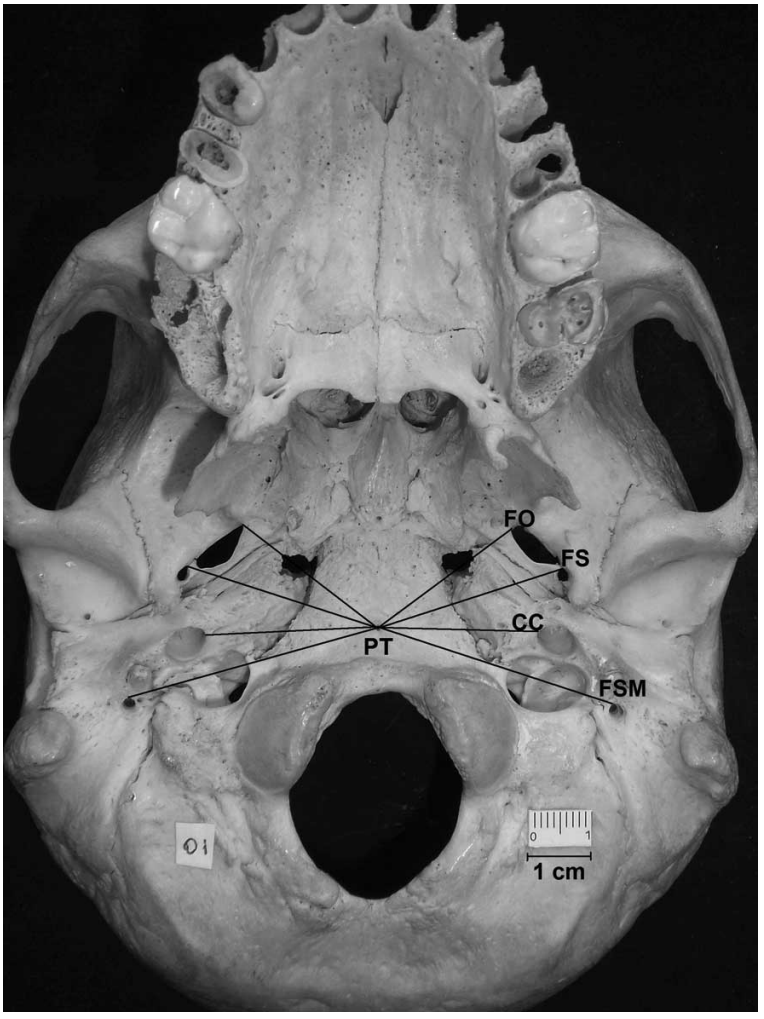

Fig. 1. Skull base photograph with the points of reference: pharyngeal tubercle (PT), foramen ovale (FO), foramen spinosum (FS), carotid canal (CC) and stylomastoid foramen (FSM). The lines indicate the distances measured.

Initially the observer was submitted to a training or calibration for better effectiveness and homogeneity of the data obtained. The distances among the points selected in relation to the pharyngeal tubercle were measured with a digital caliper (Mitutoyo, Japan) with precision of 0.01 mm. The methodology of digital biometry was used, based on obtaining digital pictures and processing in software (Moreira *et al.*).

Each skull was placed in a support always in the same position leveled in agreement with a horizontal plan. A scale of 10 mm was put over the specimen allowing to gage the software. The digital pictures were taken with a Casio Exilim EX-Z60, with 6.0 mega pixels camera. The digital images were analyzed with software Image J, using the described point of reference.

As the measurements were made in skulls of different sizes, from fetuses to adults, it was necessary to transform the differences in percentage, adapting the evaluation of the proportionality regarding the different sizes found in the groups and analyzed skulls. The percentage was obtained as an asymmetry index according to the following formula (Rossi *et al.*):

$$\text{Asymmetry index} = \frac{\text{Right side} - \text{Left side}}{\text{Right side}} \times 100$$

The result of the comparison among the direct and indirect method was analyzed by the General Linear Model test with repeated measures being considered significant with values of $p<0.05$. For the analysis of the asymmetry Wilcoxon test was used for the paired measures, Mann Whitney for comparison between genre and variance analysis (ANOVA) with correction of Tuckey for comparisons among age groups. The tests were accomplished with SSPS 15 program.

RESULTS

No statistically significant differences ($p<0.05$) were found among the two methods. The standard deviation of the two methods indicated that the indirect method for digital biometry is low and it can be applied to obtaining symmetry data. The obtained results are presented in a synthetic way in Table I, the percentages represent the asymmetry index.

All skulls expressed asymmetry. The smallest index (2.6%) and the largest index (6.6%) were found in fetuses group (stylomastoid foramen and carotid canal respectively). The graphic representation is shown in Fig. 2.

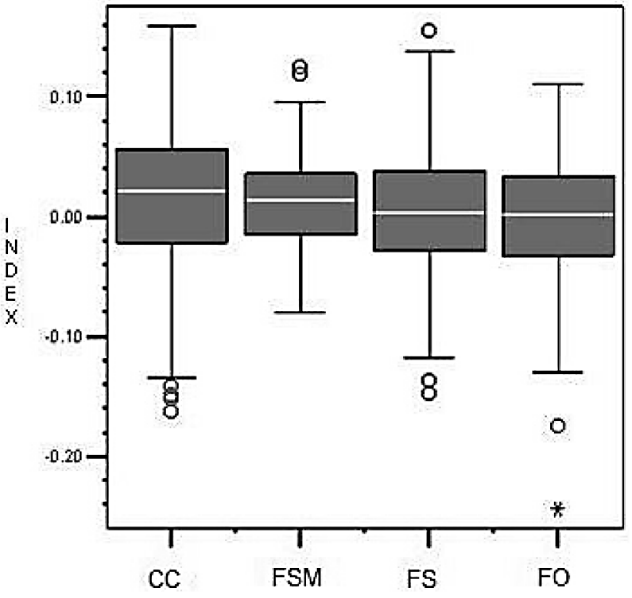

Fig. 2. Box plot graphic of the asymmetry indexes. The measurements CC, FSM, FS and FO in all groups are indicated in the horizontal table, below. Asymmetry indexes in percentages are indicated in the vertical at left. The circles represent the outlines. The median are represented by the white lines inside boxes sample and minimum and maximum values at the end of straight vertical lines.

Table I. Mean of the asymmetry indexes of groups in each point of reference.

Groups	n	FO	FS	CC	FSM	Mean/group
A - Fetuses	**15**	**5.5%**	**4.8%**	**6.6%**	**2.6%**	**4.9%**
B - newly born - one year old	**32**	**5.2%**	**3.8%**	**5.7%**	**2.8%**	**4.4%**
C - 13 months - 9 years old	**19**	**3.0%**	**4.6%**	**4.2%**	**3.8%**	**3.9%**
D1 - 18 years - 44 years old, Female	**30**	**3.5%**	**3.6%**	**4.4%**	**2.9%**	**3.6%**
D2 - 18 years - 44 years old, male	**30**	**4.1%**	**4.6%**	**5.8%**	**3.0%**	**4.4%**
E1 - 45 up to 100 years old Female	**25**	**3.1%**	**2.9%**	**3.9%**	**2.9%**	**3.2%**
E2 - 45 up to 100 years old male	**25**	**4.6%**	**5.2%**	**5.6%**	**4.8%**	**5.1%**
Mean/reference point	**176**	**4.2%**	**4.2%**	**5.2%**	**3.3%**	

The comparison of the asymmetry index among the age groups revealed that the difference is not significant for all of the points (ANOVA, Tuckey correction, $p<0.05$).

DISCUSSION

Perfect bilateral symmetry in the body is basically a theoretical concept that rarely exists in live organisms (Bishara *et al.*, 1994). Knowledge of quantitative normal cranial asymmetry in a population without pathology or functional disturbance is necessary to avoid malpractice. Professionals that perform craniofacial surgery, orthodontic treatment and clinical diagnosis of deformities must consider and interpret cranial asymmetries.

The use of bilateral points in relation to a central anatomical point is a method for evaluating asymmetry and the use of channels where nerves and blood vessels emerge made possible an evaluation in the skull sample in several ages.

In this study, asymmetry of the skull base was evaluated by method of digital biometry for its advantages in relation to other methods, as the caliper direct method or image methods are costly (Moreira *et al.*).

The direct method is a reliable technique used in anatomical and anthropological studies, but there are some disadvantages in its execution, since some points of reference are reached with difficulty by the caliper stems, in addition to fragile sample manipulation and the excessive time spent in obtaining data.

The advantages of the digital method were pointed out elsewhere (Moreira *et al*.), among them: precision and reproducibility to assess the points to be measured, possibility to accomplish measurements with good accuracy, smaller manipulation of the specimens reducing the risk of damages, practical storage in digital media of the pictures and protocol of each sample and the possibility to measure surfaces with a very irregular perimeter.

The validation was confirmed by statistical analysis since there were not significant differences among the direct method, considered as the gold pattern, and the indirect method.

The results of this study showed that all the skulls of the considered sample present some asymmetry degree. In agreement with the inclusion criteria, this sample was considered as belonging to a normal population that could be settled as a normal pattern for asymmetry. The use of an asymmetry index was necessary because there were skulls of several ages with different dimensions.

The asymmetry index found in skulls of all age groups showed no significant differences. When the measures in millimeters are compared, no significant differences were detected between fetuses (A) and newborn (B) and also between adult groups (D and E) meaning that close age groups have similar metric measures. Otherwise the measures in millimeter were significantly different when fetuses were compared with children and adult skulls. Thus the use of an index that supplies the data of asymmetry as percentage meaning quantitative difference among the sides is necessary.

The asymmetry of position of vessel and nerves foramina (carotid canal, foramina spinosum, ovale and stylomastoid) verified in the whole sample and considered as normal corresponds to a medium index of 4%, being the smallest 2.6% and the largest 6.6%.

The point where the "normal" asymmetry becomes "abnormal" cannot be easily defined. A number of explanations have been given for asymmetry causes, including genetic problems and environmental factors producing differences in the right and left sides (Bishara *et al*.).

According to some authors, the asymmetry presence would be considered when the averages of the differences among the sides go statistically different from zero (Shah & Joshi; Lundström, 1991) or when the statistical analysis accomplished by Student's t test for paired sample reveal differences among the right and left sides (Letzer & Kronman, 1967; Vig & Hewitt, 1975; Melnik, 1992). The position and shape of 27 paired foramina in the skull was considered asymmetric, when the difference is larger than 0.5 mm (Berge & Bergman, 2001). In the literature there are neither patterns nor defined values of asymmetry for normal skull. Rossi *et al.* considered asymmetry as any difference among the sides and highlighted that the greater the asymmetry, the greater is likelihood of a pathological condition.

It was shown that asymmetry of facial bones exists in fetuses and newborn with the same index as adults (Rossi *et al*.). This fact demonstrated that the asymmetry considered normal is not linked with the action of chewing muscles. However, the central area of skull base is subject to mechanical conditions related to head control as the column and cervical muscles. The central area of skull base is essentially stable with less variability, while the lateral areas suffer larger changes (Moss & Greenberg; Vinkka & Koski, 1975). This assumption was confirmed in a study that pointed out an invariable area in the skull base limited by foramen spinosum, stylomastoid foramen and foramen magnum (Serjsen *et al*.).

In conclusion the asymmetry degree of the skull base considered as normal in the studied sample was around 4%. This information may be used by professionals to orientate diagnosis and avoid unnecessary procedures.

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RESUMEN: El conocimiento sobre asimetrías craneales a partir de especímenes secos es de gran utilidad en la determinación de parámetros relevantes para las prácticas médica y odontológica. Se estudió la base del cráneo con el objetivo de validar el método de mediciones indirectas con fotografías digitales y evaluar el grado de asimetría en diferentes edades. Se analizaron 176 cráneos humanos identificados, agrupándolos por edad en fetos, recién nacidos, niños y adultos. Las mediciones fueron realizadas a partir de un punto central: el tubérculo faríngeo y de cuatro puntos laterales: foramen oval, foramen espinoso, canal carotideo y foramen estilomastoideo, usando biometría digital, luego de una validación por criterio concurrente respecto de mediciones directas con caliper. Los resultados son presentados como índices de asimetría y los datos son expresados en porcentajes. El método digital evidencia validez concurrente en relación al método directo con caliper. Los cráneos en todos los grupos étareos presentaron asimetrías. El índice de asimetría menor correspondió a 2,6%, mientras que el mayor a 6,6%. En la literatura no se reportan parámetros para definir valores de asimetrías en cráneos normales. La asimetría de la foramina respecto de la línea mediana se verificó en toda la muestra y fue considerada como normal, correspondiendo a un índice de asimetría promedio del 4%. En este estudio se observó también que en la mayoría de las medidas hubo predominancia del lado derecho sobre el lado izquierdo.

PALABRAS CLAVE: Anatomía; Asimetría; Crecimiento; Cráneo.

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