Original Article

Craniofacial Asymmetry in Development: An Anatomical Study

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Abstract: The purpose of this study was to evaluate the occurrence of craniofacial asymmetries in four areas of human skulls of various age groups to test the hypothesis that there is craniofacial symmetry before the chewing habit is established. The data were obtained from 95 skulls of fetuses, infants, children, and adults, from the collection of Federal University of São Paulo. The following measurements were taken on each skull with a digital caliper: from the infraorbital foramen to the anterior nasal spine (IOF); from the greater palatine foramen to the posterior nasal spine (GPF); from the spinous foramen to the basion (SF); and from the spinous foramen to the zygomatic arch (ZA). On different occasions, each measurement was taken three times on both sides of the skull in random order. The mean of the right-side measurements were subtracted from the mean of the left-side measurements, and the differences were transformed into percentages. Comparisons were made by analysis of variance. The presence of cranial asymmetry was statistically significant throughout the whole sample. The minimum value found was 2.8% and the maximum 6.5%. All age groups presented the same degree of asymmetry of distances IOF, GPF, and SF. The group of infants presented a higher degree of asymmetry on distance ZA, followed by the groups of fetuses, children, and adults. This study confirmed statistically significant craniofacial asymmetry in fetuses and infants (before dentition). Therefore, the hypothesis that craniofacial asymmetry only appears after establishment of the chewing habit was not supported. (*Angle Orthod* 2003;73:381–385.)

Key Words: Asymmetry; Aging; Skull; Craniofacial development

INTRODUCTION

Asymmetry is a usual finding in human craniofacial bones and is present in patients and nonpatients. The left- and right-side differences that occur in variable degrees in the population may cause interference with the normal dental function and esthetic appearance or may be so insignificant that it cannot be detected by mere observation.

Absolute symmetry could be considered as ideal,[1,2] as reflected in the assessment of patients as well as in surgical and orthodontic procedures. Notwithstanding, craniofacial asymmetry is generally observed throughout the population.[2–8] Harmonious faces, apparently symmetrical, also show skeletal asymmetry, suggesting that the soft tissues minimize the subjacent asymmetry.[2,5,9]

The organism does not favor identical growth of homologous bilateral structures.[10] 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.[1,11–13] 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.[7,14–16]

Craniofacial asymmetry has been investigated by various methods. Direct measurement on dry skulls[3] is the oldest method, but the most common method is cephalometric radiographic image analysis.[1,2,13,17] Posterior-anterior radiographic pictures,[4,18] anthropometrics,[5] and stereophotogrammetry[7,19] are also used, although by fewer researchers. The use of bilateral anatomical points related to an anatomical point located on the centerline is a good basis for quantification of skull asymmetries.[1]

Using the different evaluation methods of craniofacial symmetry mentioned, various conclusions were proposed by researchers. Some authors conclude that the right side of the face has dominance over the left side.[2,3,5] Others relate the predominance of the left side of the face[18] to the larger maxilla on that side[3,17] as well as the regions of the skull base.[17] The mandibular and dentoalveolar regions have shown a larger degree of asymmetry[1] because these regions would respond better to a functional adaptation.[2,17] The skull base, however, exhibits less asymmetry as a result

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of the interaction of various components of the craniofacial complex.

No statistical evidence has been found to demonstrate the relationship between malocclusion and asymmetry of the skull base and the jaw.[4] No significant influence of sex and age[1,5,7] was found to prevail in the asymmetries. Some authors show that age does not influence the asymmetry of the face except for the basal region of the nose.[7]

Craniofacial asymmetries are more evident when the functional dentition is established, at least in the literature, because the studies are scarce in early stages of development. Several factors related to dental arches were assumed as causes of craniofacial asymmetries, including asymmetric mastication, loss of deciduous and permanent teeth, and loss of contacts.[11] Therefore, facial asymmetry has been associated with functional activities of the masticatory musculoskeletal system.[14,15,19]

Several suggestions and conclusions are offered about the factors relative to craniofacial asymmetry. None of the conclusions were based on studies that included fetuses and infants. It is of interest to evaluate craniofacial asymmetry in these age groups because in these cases it is possible to test if the frequently mentioned masticating function is actually the main cause of asymmetries.

The aim of this study was to evaluate the presence of craniofacial asymmetry in four areas of human skulls of various age groups. The study also tests the hypothesis that there is craniofacial symmetry before the establishment of deciduous dentition.

MATERIALS AND METHODS

The skulls used were from the Museum of Anatomy Collection of the Federal University of Sao Paulo–Paulista School of Medicine. The skulls are cataloged and identified with their register number, age, sex, and *causa mortis*. The skulls were divided into groups of fetuses (four to nine months of intrauterine life), infants (one day to six months), children (six months to seven years), and adults (20 to 50 years). The study comprised 95 skulls without pathologies. There were 20 fetus skulls and 25 skulls from each of the other age groups. A digital caliper was used to measure the following distances:

- from the infraorbital foramen to the anterior nasal spine (IOF);
- from the greater palatine foramen to the posterior nasal spine (GPF);
- from the spinous foramen to the basion (SF);
- from the spinous foramen to the zygomatic arch, on the zygomatic-temporal suture (ZA).

The principal investigator undertook all measurements in a random manner. Three measurements of each distance in millimeters with two decimals were made at different times for the right and left sides of the skull in a random order of skulls. Means were obtained for each measurement. Left-side means were subtracted from right-side means. As the measurements are of skulls of different sizes, from fetus to adult, the differences obtained were converted into a percentage asymmetry index according to the following formula:

$$\text{asymmetry index} = \frac{\text{right side} - \text{left side}}{\text{right side}} \times 100$$

The right-side measurement was used as reference, negative values meaning that the left side was bigger than the right side. The minus symbol was not considered for the statistical analysis.

Analysis of variance (ANOVA) was used to detect differences between age groups.

TABLE 1. Asymmetry Indexes Means and Standard Deviations of the Variable IOF (Distance Between the Infraorbital Foramen and the Anterior Nasal Spine)

Group	Asymmetry Index Mean	SD	Number of Skulls
Fetuses	3.7526	1.9839	19
Infants	2.8067	2.3877	24
Children	3.1218	2.3387	25
Adults	3.7060	3.3501	25
Total	3.3264	2.5901	93

RESULTS

The results obtained are presented as the asymmetry index means and standard deviations in Tables 1 through 4. Graphic representations of asymmetry index means at 95% confidence interval are presented in Figures 1 through 4.

Table 1 presents the means of the values of the asymmetry indexes of the variable IOF of the four groups. The lowest mean of 2.8067 was found in the group of infants and the highest of 3.7526 corresponded to the group of fetuses. Standard deviations show that the homogeneity of each group is similar.

Figure 1 shows the confidence intervals for the means of each group. ANOVA established that the means are statistically equal ($P = .544$).

Table 2 presents the means of the values of the asymmetry indexes of the variable GPF of the four groups. The lowest mean of 4.1924 was found in the group of children and the highest of 6.4725 corresponded to the group of fetuses.

Figure 2 shows the confidence intervals for the means of each group. ANOVA established that the means are statistically equal ($P = .240$).

Table 3 presents the means of the values of the asymmetry indexes of the variable SF of the four groups. The lowest mean of 2.8465 was found in the group of fetuses and the highest of 3.3960 corresponded to the group of

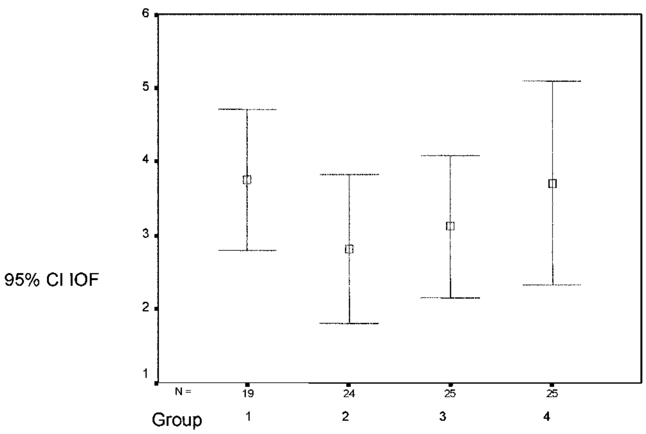

FIGURE 1. The 95% confidence interval for IOF asymmetry of each group. 1: Fetuses; 2: infants; 3: children; 4: adults.

TABLE 2. Asymmetry Indexes Means and Standard Deviations of the Variable GPF (Distance Between the Greater Palatine Foramen and the Posterior Nasal Spine)

Group	Asymmetry Index Mean	SD	Number of Skulls
Fetuses	6.4725	4.8742	20
Infants	6.0540	5.9240	25
Children	4.1924	2.4831	25
Adults	4.6472	3.6770	25
Total	5.2820	4.4352	95

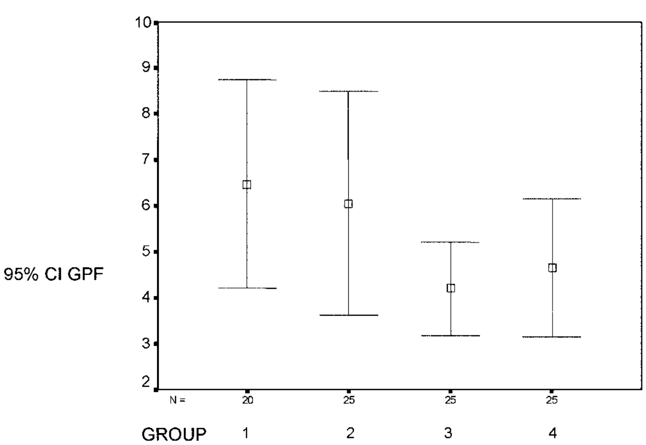

FIGURE 2. The 95% confidence interval for GPF asymmetry of each group. 1: Fetuses; 2: infants; 3: children; 4: adults.

TABLE 3. Asymmetry Indexes Means and Standard Deviations of the Variable SF (Distance Between the Spinous Foramen and the Basion)

Group	Asymmetry Index Mean	SD	Number of Skulls
Fetuses	2.8465	2.4283	20
Infants	3.3960	2.9517	25
Children	3.2116	2.5293	25
Adults	2.9892	2.2838	25
Total	3.1247	2.5346	95

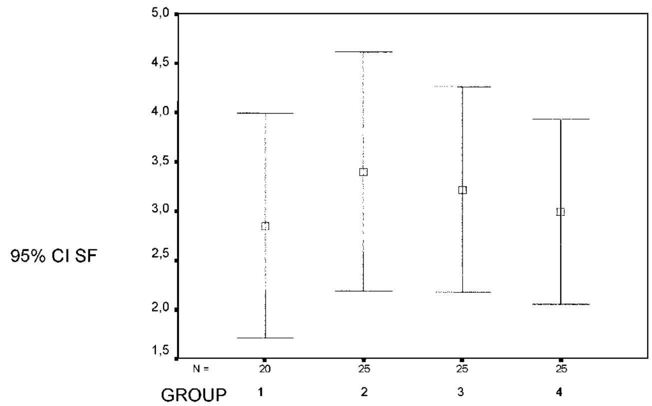

FIGURE 3. The 95% confidence interval for SF asymmetry of each group. 1: Fetuses; 2: infants; 3: children; 4: adults.

TABLE 4. Asymmetry Indexes Means and Standard Deviations of the Variable ZA (Distance Between the Spinous Foramen and the Zygomatic Arch, on the Zygomatic-Temporal Suture)

Group	Asymmetry Index Mean	SD	Number of Skulls
Fetuses	5.5370	4.2890	20
Infants	6.5256	4.8294	25
Children	3.7900	3.9726	25
Adults	2.9080	1.7549	25
Total	4.6456	4.0738	95

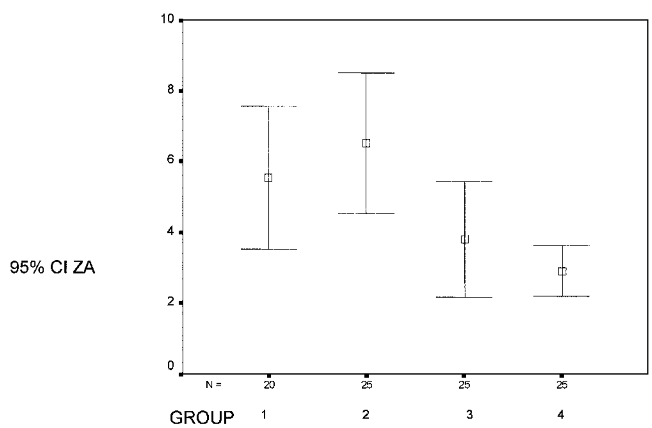

FIGURE 4. The 95% confidence interval for ZA asymmetry of each group. 1: Fetuses; 2: infants; 3: children; 4: adults.

infants. Standard deviations show that the homogeneity of each group is similar.

Figure 3 shows the confidence intervals for the means of each group. ANOVA established that the means are statistically equal ($P = .893$).

Table 4 presents the means of the values of the asymmetry indexes of the variable ZA of the four groups. The lowest mean of 2.9080 was found in the group of adults and the highest of 6.5256 corresponded to the group of infants.

Figure 4 shows the confidence intervals for the means of each group. ANOVA established that the means are statistically different ($P = .006$).

DISCUSSION

Craniofacial asymmetry is a common finding in nonpatients in studies performed on children and adults.[2–6,8] There is no record of studies of asymmetries in fetuses and newborn. In these age groups, the masticatory function, frequently mentioned in the literature as the main cause of the asymmetries, is not yet being exercised.

The difference between both sides was expressed in percentages. The lowest value found was 2.8% and the highest 6.5%, which may be considered significant. For the distance GPF, only one infant skull presented no difference between the right and left sides. No significant difference was found between the mean of the differences between the sides in any age group, that is, the degree of corrected asymmetry is similar in all age groups studied.

The study of craniofacial asymmetry presents methodological limitations. The majority of researchers used radiological techniques such as cephalometry. These are affected by image size distortion problems, and the quality and accuracy depends on many variables. Certain points, such as the root of the zygoma used in cephalometry, are not sharp[1,2,8,13,17] and cannot be pinpointed easily even in craniometry. Furthermore, cephalometry is bidimensional.

In all assessment methods, the use of bilateral anatomic points related to an anatomical point located on the centerline is a good standard for quantifying asymmetries in the skull.[1] The variable in this study that presented a difference in the degree of asymmetry between the groups, and which does not relate to the centerline, is ZA (spinous foramen to zygomatic arch distance). This measurement was made to test the above assertion, which was confirmed, thereby validating the others mensurations. The highest ZA asymmetry was found in infants and fetuses. This may be related to the manifest deformations caused by the preparation technique of these skulls because in these age groups the sutures are not consolidated as yet.

Among the bilateral anatomical points for the evaluation of skull growth, the literature mentions the use of the canal apertures through which nerves emerge.[20,21] A relationship between the growth of nervous tissue and the osseous growth in the craniofacial region was recognized previously.[22,23] In the present study, the measuring points used that represented the emergence of nerves in the skull were the infraorbital foramen and the major palatine foramen. Basion is also related to the nervous tissue because it represents the most forward craniometric point of the foramen magnum through which the spinal cord passes.

The absolute differences between the right and left sides are only comparable from one skull to the next through use of anatomical points if these skulls were of the same size, something that does not occur. Consequently, to affect the comparisons, it is of essence to convert absolute asymmetry values into relative values.[1] The present study uses percentages as the relative value.

Nevertheless, what are the limits that determine that a certain difference between homologous sides is to be considered an asymmetry? Why are certain distances predominant on one side and others predominant on the other side of the same skull?

Some authors considered that asymmetry existed when the means of the differences between the sides were statistically different from zero.[2,11] Others used the Student's *t*-test for paired samples to consider the differences between the right and left sides as asymmetries[4,13,17] or considered the measurements made on the face of the patient as asymmetries when the difference between the right and left sides was equal or larger than two mm.[5] This limit was chosen arbitrarily and turns out to be variable because it depends on the skull size. Many authors did not question as to what would be considered an asymmetry.[7,8,12] They used indexes of asymmetry and compared these values between groups.

Therefore, in the literature, there does not exist a defined criterion to determine what, in the presence of a set of measurements, could be considered an asymmetry. The present study considers as an asymmetry any difference between the homologous distances of the right and left sides. Evidently, the larger the asymmetry, the more the attention it has to be given because one may be nearer to a pathological condition. What determines whether a degree of asymmetry reaches pathological levels is not exactly measurable, and one must consider clinical parameters relative to esthetics and function.

Some distances predominant on one side and others predominant on the other side of the same skull may be related to the process of craniofacial growth that involves interrelationships between the various regions searching for a functional structural equilibrium. Therefore, an asymmetry at the base of the skull may be transferred to other regions of the same side or it can be compensated and can generate a contralateral asymmetry.[23]

Finally, the presence of asymmetries in fetuses and infants found in this study indicates that the hypothesis of asymmetry related to the appearance of dentition cannot be accepted. Other factors have to be considered.

CONCLUSIONS

As a consequence of the study of measurements of skulls of various age groups, the following conclusions may be reached:

- Craniofacial asymmetry was found throughout the whole sample;
- All age groups expressed the same degree of asymmetry of the distances IOF, GPF, and SF;
- For the distance ZA, the variances were statistically different among the groups. Infants presented the largest de-

gree of asymmetry, followed by fetuses, children, and adults.

Having verified the expression of craniofacial asymmetry in fetuses and infants, the hypothesis that symmetry occurs before the establishment of the masticatory function cannot be accepted.

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