CRANIAL BASE SYMMETRIC AND NORMAL LOWER JAW ROTATION

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ABSTRACT

Understanding the complexities of cranial base development, function, and architecture is important for testing hypotheses about many aspects of craniofacial variation and evolution. Architecturally, the cranial base provides the platform upon which the brain grows and around which the face grows. In addition, the cranial base connects the cranium with the rest of the body: it articulates with the vertebral column and the mandible, provides conduits for all the vital neural and circulatory connections between the brain, the face and the neck, houses and connects the sense organs in the skull, and forms the roof of the nasopharynx.

The shape of the cranial base is therefore a multifactorial product of numerous phylogenetic, developmental, and functional interactions.

Aim. The aim of this research is to perform a morphometric analysis of the skull base to investigate the symmetry between the two hemibases of the cranial fossa with each other in adult patients with normal type of lower jaw rotation using cone beam copmuted tomography CBCT in transversal plane.

Materials and methods. In result of radiographic study, 35 Caucasian adult patients with no prior orthodontics treatment were selected (16 males, 19 females) from 16 to 27 years (mean age of 20.02 years: females average age was 20.15 years; males average age was 21.84 years) of age with normal type of lower jaw rotation according to the sum of Björk. Pearson's Correlation Coefficient was calculated to investigate the symmetry between the two hemibases of the cranial fossa with each other.

Results. A difference was found amongst the two genders of the sample subjects in the strength of the correlation between the CBCT angular measurements evaluating the two hemibases of the cranial base symmetry.

Conclusion. A difference was found amongst the two genders. This study found no exact symmetry between the samples, but it was in high level for adult females.

Keywords: cranial base, symmetry, CBCT, normal lower jaw rotation

INTRODUCTION

The cranial base plays a major role in the skull integration and function, which it can be considered as the oldest part of the vertebrate skull according to its phylogenetic history (de Beer, 1937) (1).

Also it effects facial orientation proportionally to neurocranium, on the other hand there isn't enough information about the probable effect of the cranial base on other aspects of facial shape such as height, length, and width. To what extent is overall facial shape independent of the cranial base? It is supposed that the main facial growth is independent of cranial base growth, basically because the majority of the face grows in a skeletal growth development path after the neural growth phase ends.

In humans, for example, the human face reaches 95% adult size by 16-18 years, which is after the cranial base reaches adult size by 10 years at least (Stamrud, 1959; Moore and Lavelle, 1974) (2,3).

In addition it seems that the most facial and basicranial dimensions are genetically not related in adults (Cheverud, 1996) (4).

However, there is some evidence proposes that changes in the ratios of the cranial base can effect facial shape. This kind of interaction is predicted to be particularly important, and exclusive to humans, in which the upper face lies almost completely under the anterior cranial fossa (Weidenreich, 1941; Howells, 1973; Enlow and Bhatt, 1984; Enlow, 1990; Lieberman et al., 2000) (5-9).

The importance of the cranial base is matched by several challenges that make it difficult to study.

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Because of the difficulties in surgical accessing to the cranial base, there have been few experimental studies of cranial base growth and function. Also, a large part of the cranial base considered complex anatomically, and not easy to measure and/or see externally. In addition, the cranial base in many fossils is missing, damaged, or unable to observe without using special technology. However, new developmental researches, and new imaging techniques, cause a modest renaissance of research on cranial base morphology (reviewed in Spoor et al., 2000) (10).

In addition, new analysises and techniques, which quantitatively compare three-dimensional differences in form, gave us more possibilities for studying growth and variation in complex regions such as the cranial base (Cheverud and Richtsmeier, 1986; Bookstein, 1991; Lele, 1993; O'Higgins, 2000). Finally, more information about the relationships between cranial base morphology and development of other parts of skull may help us to understand and resolve a number of important phylogenetic and behavioral issues throughout primate evolution (11-14).

Björk and Skieller were the first who described upper and lower jaws rotations during human growth and development. They described the rotation in terms of either a forward or a backward direction. Forward rotation occurs when there is more vertical facial growth posteriorly than anteriorly. For backward rotation this pattern is reversed, relatively greater vertical growth occurring anteriorly compared to posteriorly. This vertical rotation of the maxillary complex is generally less than that seen in the mandible due to the contribution of middle cranial fossa growth. This study used sum of Björk to determine the type of lower jaw rotation, which consist of three angles as following:

1. Saddle angle: Angle formed by joining N (Nasion) – s (Sella) – Ar (articular), is an assessment of the relationship between anterior and posterior lateral cranial base.
2. Articular angle: The constructed angle that lies between upper and lower parts of the posterior contours of the facial skeleton. It indicates the position of the mandible.
3. Gonial angle: Angle formed by tangents to the body of the mandible and posterior border of the ramus. This angle expresses the form of the mandible and its growth direction (15-17).

STUDY OBJECTIVES

The aim of this research is to perform a morphometric analysis of the skull base to investigate the symmetry between the two hemibases of cranial fossa with each other in adult patients with normal type of lower jaw rotation using cone beam copmuted tomography CBCT in transversal plane.

MATERIALS AND METHODS

Subjects

Sample's subjects were selected from adult patients who, any way, had to have a CBCT scan for non-neurological disorders purpose, but not especially for this study.

Criteria for selecting the subjects:

1. No supernumerary tooth/supplementary tooth/missing tooth/impacted tooth.
2. No history of trauma to the dento-facial structures.
3. Subjects must have fully erupted permanent dentition up to second molar tooth.
4. Exclusion criteria also were subjects with open bite, deep bite, closed bite.
5. Exclusion criteria also were subjects with congenital anomalies/ evident signs of neurological impairment and/or syndromes and/or craniofacial malformation.

Ninety Caucasian adult subjects (30 males, 40 females) with no prior orthodontics treatment (16 to 27 years of age) (mean age of 20.02 years: females average age was 20.15 years; males average age was 21.84 years), and they were submitted to select normal type of lower jaw rotation (according to Björk) adult subjects; gender of subjects was randomly selected.

Sample estimation

To determine the minimum sample size to be statistically significant, a pilot study was realized on 40 subjects (who were selected with normal type of face growth according to Björk). It has been found that descriptive statistics results follow the normal distribution; therefore, determining the minimum sample size to be statistically significant was according to the following formula:

$$n = \frac{Z^2 . \sigma^2}{(e)^2}$$

(N): the sample size;

(z): is the value corresponding to a confidence level, estimated at 95% (Z = 2.58) at Confidence level of 99 % (i.e. significance level is 0.019);

(σ): highest Standard Deviation value within the all the variables (σ 6.25);

(e): margin of error (maximum acceptable error in mean estimate) (e=5).

Thus:

$$n = \frac{(2.58)^2(6.25)^2}{5^2} \approx 10.4$$

According to this pilot study, our study determined that to get an exact estimate about the mean of patients' results, and the error in estimating doesn't exceed 5 of the mean, with a significance level of 99%, this requires a sample size (n) of 11 patients as minimum, whereas the size of the sample in this study was n = 35.

Only 35 Caucasian adult patients (16 males, 19 females) from 16 to 27 years of age (mean age of 20.02 years: females average age was 20.15 years; males average age was 21.84 years), with sum of Björk ranging from (390 to 401 degree) (mean sum was 395.29 degree for all sample; females average angle was 395.90 degree; males average angle was 394.32 degree) were selected to be as subjects for this current study, all 35 subjects have normal type of lower jaw rotation according to sum of Björk (cephalometric measurements were obtained from CBCT Images according to Lee F.C., Noar J.H., Evans R.D., van Vlijmen O.J., Bergé S.J., Swennen G.R., Bronkhorst E.M., Varghese S., Kailasam V., Padmanabhan S., Vikraman B., Chithranjan A., Ludlow J.B., Gubler M., Cevidanes L., Mol A.) (18-22).

Descriptive statistics for the sum of Björk of the male, female, and all subjects (both gender) of the sample are presented in Table 1.

***TABLE 1.** Descriptive statistics for the sum of Björk of the male, female, and all subjects (both gender) of the sample*

	Count	Min	Max	Mean	Standard Deviation	Sample Variance
♂ sum Björk	16.00	390.51	398.96	394.32	3.35	11.23
♀ sum Björk	19.00	390.54	401.44	395.90	3.77	14.18
♂&♀ sum Björk	35.00	390.51	401.44	395.29	3.56	12.65

CBCT study

CBCT scans were obtained in centric occlusion (maximum dental intercuspation); data were obtained using a 3D cone-beam volume scanner (SCANORA® 3D FOVs). Used settings were as following: Standard scan mode with an imaging volume of 40 cmx13 cm, Scan speed of 9 s, Slice thickness 0.3 mm, 120 kV, 47mA.

CBCT Cranial base measurements

CBCT points for evaluating the symmetry between hemibase of skull:

(C) crista gall (23,24).

(S) sella turcica (23,24).

(X) xiphoid of the lesser wing of the sphenoid (23,24).

(M) the internal acoustic meatus (23,24).

(O) opisthion (23,24).

Evaluating the symmetry between the two hemibases of the skull, angular measurements were performed on the CBCT as following:

– **Anterior cranial fossa** (left side): anterior cranial base fossa(left side) was evaluated by using the angle between crista galli (C), sella turcica (S) and xiphoid of the lesser wing of the sphenoid (X) angle (CSXL). Angle was read in degrees (23,24).

– **Anterior cranial fossa** (right side): anterior cranial base fossa(right side) was evaluated by using the angle between crista galli (C), sella turcica (S) and xiphoid of the lesser wing of the sphenoid (X) angle (CSXR). Angle was read in degrees (23,24).

– **middle cranial fossa** (left side): middle cranial fossa(Left side) was evaluated by using angle between the xiphoid of the lesser wing of the sphenoid (X), sella Turcica (S) and internal acoustic meatus (M) angle (XSML). Angle was read in degrees (23,24).

– **middle cranial fossa** (right side): middle cranial fossa (right side) was evaluated by using angle between the xiphoid of the lesser wing of the sphenoid (X), sella Turcica (S) and internal acoustic meatus (M) angle (XSMR). Angle was read in degrees (23,24).

– **posterior cranial fossa** (left side): posterior cranial fossa (left side) was evaluated by using the

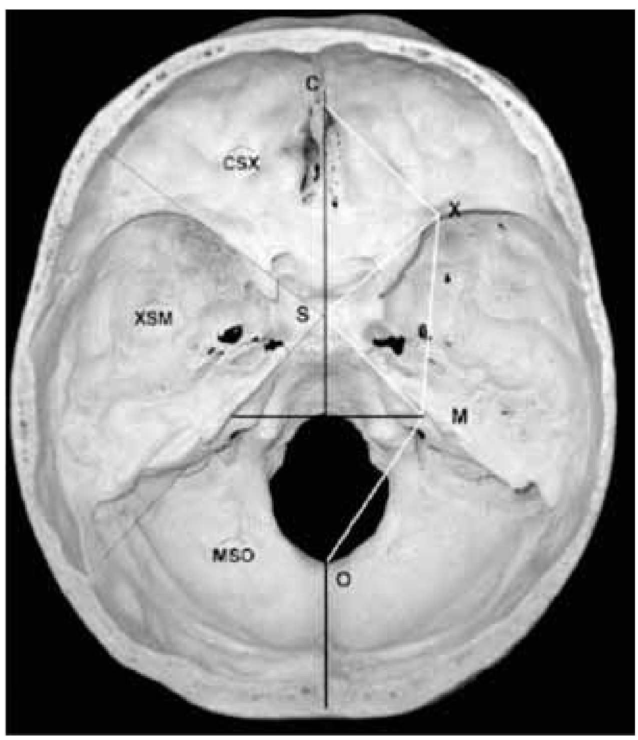

***FIGURE 1.** CBCT cranial base measurements*

angle between the internal acoustic meatus (M), sella Turcica (S) and opisthion (O) angle (MSOL). Angle was read in degrees (23,24).

– **posterior cranial fossa** (right side): posterior cranial fossa (right side) was evaluated by using the angle between the internal acoustic meatus (M), sella Turcica (S) and opisthion (O) angle (MSOR). Angle was read in degrees (23,24).

Error of method

All the CBCT measurements in this study were only angular measurements, all of it were repeated twice with a minimum interval of one month by the same investigator. The initial measurements and the repeated measurements were compared by using a paired t-test to check any systematic error. Random errors were also checked using the Dahlberg formula. The t-test at the 0.5 level did not show any significance. The random error for the measurements varied between 0.33 and 0.42.

Statistical method

Using Microsoft Excel of Microsoft office 2013, Pearson's Correlation Coefficient was calculated to investigate:

1. The strength of a linear association (dependence) of **CSXL angle** (indicating the left anterior cranial base angle) with **CSXR angle** (indicating the right anterior cranial base angle), to test the null hypothesis (there is no relationship between the left anterior cranial base angle and the right anterior cranial base angle).

2. The strength of a linear association (dependence) of **XCML angle** (indicating the left middle cranial base angle) with **XCMR angle** (indicating the right middle cranial base angle), to test the null hypothesis (there is no relationship between the left middle cranial base angle and the right middle cranial base angle).

3. The strength of a linear association (dependence) of **OSML angle** (indicating the left posterior cranial base angle) with **OSMR angle** (indicating the right posterior cranial base angle), to test the null hypothesis (there is no relationship between the left posterior cranial base angle and the right posterior cranial base angle).

RESULTS

Descriptive statistics for CSXL angle, XSML angle, MSOL angle, CSXR angle, XSMR angle and MSOR angle of all samples (both gender) are presented in Table 2.

Descriptive statistics amongst male samples (only) for CSXL angle, XSML angle, MSOL angle, CSXR angle, XSMR angle and MSOR angle are presented in Table 3.

***TABLE** 3. Descriptive statistics for CSXL, XSML, MSOL, CSXR, XSMR, and MSOR angles amongst male samples only*

	CSXL	XSML	MSOL	CSXR	XSMR	MSOR
Mean	62.16	77.07	40.77	61.95	80.22	37.83
Standard Error	2.05	2.32	1.48	2.00	2.33	1.31
Median	60.04	77.54	41.68	62.54	80.81	36.76
Standard Deviation	4.59	5.19	3.31	4.48	5.20	2.93
Sample Variance	21.04	26.89	10.98	20.06	27.07	8.60
Range	10.31	13.68	8.17	10.60	14.45	6.95
Minimum	58.34	69.85	36.73	55.99	72.79	34.59
Maximum	68.65	83.52	44.90	66.60	87.25	41.54
Count	16.00	16.00	16.00	16.00	16.00	16.00
Confidence Level (95.0%)	5.70	6.44	4.11	5.56	6.46	3.64

Descriptive statistics amongst female samples (only) for CSXL angle, XSML angle, MSOL angle, CSXR angle, XSMR angle and MSOR angle are presented in Table 4.

To test the relationship between the right anterior cranial base side and the left anterior cranial base side each one to other, Pearson's Correlation

***TABLE 2.** Descriptive statistics for CSXL, XSML, MSOL, CSXR, XSMR,MSOR angles amongst all samples (both gender)*

	CSXL	XSML	MSOL	CSXR	XSMR	MSOR
Mean	63.04	77.40	39.56	63.55	78.82	37.63
Standard Error	1.23	1.55	0.86	1.12	1.73	1.02
Median	61.69	77.71	39.13	64.78	78.28	37.00
Standard Deviation	4.44	5.60	3.09	4.03	6.25	3.67
Sample Variance	19.69	31.40	9.57	16.23	39.10	13.46
Range	13.29	20.53	10.37	12.33	19.54	11.36
Minimum	57.67	65.82	34.53	55.99	68.53	31.78
Maximum	70.96	86.35	44.90	68.32	88.08	43.15
Count	35.00	35.00	35.00	35.00	35.00	35.00
Confidence Level (95.0%)	2.68	3.39	1.87	2.43	3.78	2.22

***TABLE 4.** Descriptive statistics for CSXL, XSML, MSOL, CSXR, XSMR, MSOR angles amongst female samples only*

	CSXL	XSML	MSOL	CSXR	XSMR	MSOR
Mean	63.59	77.60	38.81	64.54	77.95	37.50
Standard Error	1.61	2.19	1.03	1.29	2.48	1.50
Median	63.24	78.43	38.87	65.98	77.63	37.03
Standard Deviation	4.57	6.19	2.90	3.66	7.02	4.26
Sample Variance	20.84	38.33	8.44	13.42	49.30	18.12
Range	13.29	20.53	8.69	8.96	19.54	11.36
Minimum	57.67	65.82	34.53	59.37	68.53	31.78
Maximum	70.96	86.35	43.22	68.32	88.08	43.15
Count	19.00	19.00	19.00	19.00	19.00	19.00
Confidence Level (95.0%)	3.82	5.18	2.43	3.06	5.87	3.56

test was performed between **CSXL angle** and **CSXR angle** amongst: **male** subjects and **female** subjects. Results in Table 5.

***TABLE 5.** Pearson's Correlation test relationship of the CSXL angle with the CSXR angle*

	CSXL angle	
♂ **CSXR angle**	R = 0.27 ▲	Positive **weak** correlation.
♀ **CSXR angle**	R = 0.89 ▲▲▲	Positive **strong** correlation.

Where:
▲: Positive **weak** strength of correlation,
▲▲: Positive **Moderate** strength of correlation.
▲▲▲: Positive **Strong** strength of correlation.

Within female samples, Pearson's Correlation test showed strong positive strength of correlation between CBCT measurements of the interior cranial base which determining the symmetry between the two hemibases of the interior cranial base in samples with normal type of lower jaw rotation. Whereas it showed a weak positive correlation in male subjects.

To test the relationship between the right middle cranial base side and the left middle cranial base side, Pearson's Correlation test was performed between **XSML angle** and **XSMR angle** amongst: **male** subjects and **female** subjects. Results in Table 6.

***TABLE 6.** Pearson's Correlation test relationship of the XSML angle with XSMR angle*

	XSML angle	
♂ **XSMR angle**	R = 0.50 ▲▲	Positive **medium** correlation
♀ **XSMR angle**	R = 0.87▲▲▲	positive **strong** correlation

Where:
▲: Positive **weak** strength of correlation,
▲▲: Positive **Moderate** strength of correlation.
▲▲▲: Positive **Strong** strength of correlation.

Within female samples, Pearson's Correlation test showed positive strong strength of correlation between CBCT measurements of the middle cranial base which determining the symmetry between the two hemibases of the middle cranial base in samples with normal type of lower jaw rotation. While it showed a moderate positive correlation in male subjects.

To test the relationship between the right posterior cranial base side and left posterior cranial base side, Pearson's Correlation test was performed between **MSOR angle** and **MSOL angle** amongst: **male** subjects and **female** subjects. Results in Table 7.

***TABLE 7.** Pearson's Correlation test relationship of the MSOR angle with MSOL angle*

	MSOL angle	
♂ **MSOR angle**	R= 0.30 ▲	Positive **weak** correlation
♀ **MSOR angle**	R=0.80▲▲▲	positive **strong** correlation

Where:
▲: Positive **weak** strength of correlation,
▲▲: Positive **Moderate** strength of correlation.
▲▲▲: Positive **Strong** strength of correlation.

Within female samples, Pearson's Correlation test showed positive strong strength of correlation between CBCT measurements of the posterior cranial base which determining the symmetry between the two hemibases of the posterior cranial base in samples with normal type of lower jaw rotation. While it was a weak positive correlation showed in sample male subjects.

DISCUSSION

Analyzing the samples showed that the ratio of female samples larger than males. It was obvious that all subjects are young, this maybe due to the fact that the Syrian society is considered youthful, with higher females ratio compared with males. Also it's noticeable that young people especially females more demanding for orthodontic treatment than males.

A difference was found amongst the two genders of the samples in the strength of the correlation between the CBCT angular measurements evaluating the two hemibases of the cranial base symmetry. In detail, there was a significant relationship between the CBCT angular measurements evaluating the two hemibases of the anterior cranial fossa (CSXL, CSXR), it was positive strong correlation for adult female subjects, while it was positive weak correlation in the adult male subjects (Table 5). This means that the two hemibases of the anterior cranial base in adult female subjects are more symmetric comparing with adult males, there was no researches in agree with this conclusion, possibly because of the reason that the most of research didn't distinguish between the two genders in there samples. Furthermore, there was no angular correlation between the two hemibases of cranial base in adult male subjects, this was in a good agreement with Mari who found that the apparently symmetrical normal skulls demonstrated some differences between the right and left hemibases of cranial base with dominance for the right side in most distances evaluated but with no clinical significance (25). And also it was similar to Rossi who found a statically significant cranial asymmetry in adults, this could be because Rossi discuss the symmetry of the cranial base as whole, and didn't distinguish between the two genders. (26(And this was also in good agreement with Vk Taneja, who studied asymmetry of the cranial base in south Indian population and found that the total facial structures in the south Indian population were larger on the left side (statistically insignificant) and the cranial base area exhibited a greater degree of asymmetry than any other component area of the face.)27(

According to the Pearson's Correlation test, there was positive strong strength relationship between the CBCT angular measurements evaluating the two hemibases of the middle hemibases of the cranial base (XSML,XSMR) in the female subjects, while there was a positive moderate strength relationship in sample female subjects (Table 6).

This means; there was symmetric between the two hemibases of the middle cranial base in famle subjects only but there was no researches in agree with our study, maybe because most of researches didn't distinguish between two gender in there samples. While there was no angular relation between the two hemibases of the middle cranial base in male subjects of the sample, this was in a good agreement with Mari who found that the apparently symmetrical normal skulls demonstrated some differences between the right and left hemibases of cranial base, with dominance for the right side in most distances evaluated but with no clinical significance(25). And also it was similar to Rossi who found a statically significant cranial asymmetry in adults, this could be because Rossi discussed the symmetry of the cranial base as whole, and didn't distinguish between the two genders. (26) And this was also in a good agreement with Vk Taneja, who studied asymmetry of the cranial base in south Indian population and found that the total facial structures in the south Indian population were larger on the left side (statistically insignificant), and the cranial base area exhibited a greater degree of asymmetry than any other component area of the face.) 27

According to the Pearson's Correlation test, there was positive strong strength relationship between the CBCT angular measurements evaluating the two hemibases of the posterior hemibases of the cranial base (MSOL,MSOR) in the female subjects, while there was a positive weak strength relationship in the male subjects. This means; there was symmetric between the two hemibases of the posterior cranial base in female subjects only but there is no researches in agree with our study, maybe because most of research didn't distinguish between two gender in there samples, while there was no angular relation between the two hemibases of the posterior cranial base in male subjects of the sample and this was in a good agreement with Mari who found that the apparently symmetrical normal skulls demonstrated some differences between the right and left hemibases of cranial base with dominance for the right side in most distances evaluated but with no clinical significance (25). And also it was similar to Rossi who found a statically significant cranial asymmetry in adults, this could be because Rossi discussed the symmetry of the cranial base as whole, and didn't distinguish between the two genders. (26) And this was also in good agreement with Vk Taneja, who studied asymmetry of the cranial base in South Indian population and found that the total facial structures in the South Indian population were larger on the left side (statistically insignificant), and the cranial base area exhibited a greater degree of asymmetry than any other component area of the face. (27)

CONCLUSION

1. A difference was found amongst the two genders of the sample subjects in the strength of the correlation between the CBCT angular measurements evaluating the two hemibases of the cranial base symmetry.
2. There was no significant correlation of symmetry in skull (anterior, middle, posterior) in adult males.
3. Our study didn't find exact symmetry in our subjects but it was in high level for adult females.
4. There was a significant correlation of symmetry in skull (anterior, middle, posterior) in adult females.

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