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Sexual Dimorphism of Calvarial Thickness Parameter in Different Skeletal Patterns

Dr.Mustafa M. Al-Khatieeb B,D,S ; M.Sc.

Abstract

The purpose of the current study was to evaluate the calvarial thickness parameter in both genders, and in different skeletal patterns. The sample included 120 pretreatment digital lateral cephalometric radiographs of Iraqi subjects (60 males and 60 females) aged between 17 to 30 years, attending Orthodontic Clinic in the College of Dentistry; Baghdad University, and private clinics in Baghdad city. The 120 radiographs were divided into 3 groups (40 radiographs for each group) according to the ANB angles: ANB angle smaller than one degree (Class III), between two and four degrees (Class I), and larger than four degrees (Class II)**,** each group was further subdivided into two subgroups according to gender (20 radiographs for each gender). Four linear measurements were used exclusively in the assessment of calvarial thickness parameter in both genders.

The mean calvarial thickness values changed from highest to lowest in sphenoid, parietal, occipital, and frontal bones respectively. In the skeletal class II malocclusion the frontal and occipital bones' thickness showed highly significant gender differences ($P<0.01$) using Student's t- test, with females had thicker frontal bone than males, and males had thicker occipital bone than females, in addition the skeletal glass II group showed no significant gender difference ($P>0.05$) regarding sphenoid and parietal bones' thickness**.** The most vital outcomes of the present study were the frontal and occipital bones can be used as important key bones for understanding the calvarial phenotypic description and sexual dimorphism in different skeletal patterns**,** while the sphenoid and parietal bones can be used as reference bones for standardization of cephalometric analysis.

Keywords: Sexual dimorphism; Calvarial thickness parameter; Skeletal patterns.

Introduction

Skull can be divided into two main parts, the first is the calvaria (brain box), which encloses the brain, the second is the facial skeleton, which is the rest of the skull including the mandible [(1)]. The first report on calvarial thickness was by Anderson [(2)] in 1882, which was followed by Todd [(3)] in 1924. Then further studies were estimated and analyzed for long period and becoming a critical issue for medical, forensic medicine, and anthropological studies, and different relationships between calvarial thickness, gender, age, general body build mass, and race have been studied [(4-10)]. Furthermore, the calvaria is an important site of bone graft harvest in reconstructive maxillofacial and plastic surgery [(11-14)]. The reasons behind the pattern of cranial vault thickness in normal and pathological development have been discussed over years [15-19]. The relationship between calvarial thickness and skeletal malocclusion has not been published until very recently [20,21].

Jacobsen et al [20] measured the thickness of the skull in patients with vertical malocclusion, and they found that the patients with deep bite have a general thickening of the skull. While Arntsen et al [21] found that there was an association between deviation in the theca cranii and skeletal class II malocclusion.

The knowledge of calvarial thickness in both genders in different skeletal patterns is mandatory for forensic dentistry and physical anthropology, in addition giving us an aid in understanding the etiology of skeletal pattern and subsequently helping the orthodontist, maxillofacial, and plastic surgeons in correct diagnosis and treatment plane, which will reflect a successful treatment end result. Therefore, the aim of the current study was to evaluate the calvarial thickness parameter in both genders, and in different skeletal patterns.

Subjects and Methods

The sample of the present study included 120 pretreatment digital lateral cephalometric radiographs of Iraqi subjects (60 males and 60 females) were selected from 259 subjects attending Orthodontic Clinic in the College of Dentistry; Baghdad University, and private clinics in Baghdad city. All the 120 subjects fulfilled the criteria of the sample selection which were:

1. Adult subjects aged between 17 to 30 years.
2. No history of orthodontic, orthopedic or facial and surgical treatments.
3. At least 28 permanent teeth present.
4. No craniofacial anomalies or systemic, bone, muscle, or joint disorders.

The 120 radiographs were divided into 3 groups (40 radiographs for each group) according to the ANB angles: ANB angle smaller than one degree (Class III), between two and four degrees (Class I), and larger than four degrees (Class II) [22-25], each group was further subdivided into two subgroups according to gender (20 radiographs for each gender).

Digitization: Every lateral cephalometric radiograph was analyzed by AutoCAD software computer program 2011 (Figure 1) to define and mark the locations of the cephalometric reference points, planes, and four linear measurements were used exclusively in the assessment of calvarial thickness parameter in both genders at each straight side of a rhombus like pattern in the digitization of cephalometric radiographs (figures 1 and 2). All the measurements were put in excel sheet for whole sample. Linear measurements were divided by scale to overcome the magnification factor.

A. Cephalometric Points (Figure 2)**:** Which were used include:

1. Point S (Sella): Midpoint of the shadow of the sella turcica [26,27].
2. Point N (Nasion): The most anterior point in the fronto-nasal suture [28,29].
3. Point Ba (Basion): The most posterior inferior point on the clavius, which is located on the anterior margin of the foramen magnum in the median plane [27,28,29]
4. Point J (Sphenoid): The point where the perpendicular dropped from the point S intersected the Ba-N line [30].

5. Point Br (Bregma): The intersection between the sagittal and coronal sutures on the surface of the cranial vault [21,29] .
6. Point L (Lambda): The intersection between the lambdoid and sagittal sutures on the surface of cranial vault [21,29].
7. Point F (Frontale): The point on the surface of the frontal bone determined by a perpendicular to the nasion- bregma line and passing through its midpoint [21,29].
8. Point P (Parietal): The point on the surface of the Parietal bone determined by a perpendicular to the bregma-lambda line and passing through its midpoint [21,29].
9. Point O (Occipital): The point on the surface of the occipital bone determined by a perpendicular to the lambda-basion line and passing through its midpoint [21,29].

B. Cephalometric planes (Figure 2)**:** Include

1. N-Br plane: It is the line between point N and point Br [20,21] .
2. Br-L plane: It is the line between point Br and point L [20,21].
3. L-Ba plane: It is the line between point L and point Ba [20,21] .
4. Ba-N plane: It is the line between point Ba and point N [28,30] .

C. Linear Measurements (Figure 2)**:** Include

1. S-J (Sphenoid) thickness: It is the linear distance from point S to point J [30]**.**
2. F (Frontal) thickness: It is the linear distance between inner and outer contours of the frontal bone, where the perpendicular bisector extended from the mid of the N-Br plane to the point F [20,21,31].
3. P (Parietal) thickness: It is the linear distance between inner and outer contours of the parietal bone, where the perpendicular bisector extended from the mid of the Br-L plane to the point P [20,21,31].
4. O (Occipital) thickness: It is the linear distance between inner and outer contours of the occipital bone, where the perpendicular bisector extended from the mid of the L-Br plane to the point O [20,21,31].

Statistical analysis:

All the data of the sample were subjected to computerized statistical analysis using SPSS version 17 computer program. In which the descriptive statistics include mean and standard deviation, and the inferential statistics include Student's t-test, and it was conducted to detect calvarial gender differences, and F test analysis of variance and Post-hoc least significant difference were carried on to determine the skeletal pattern differences, the probability values were considered significant at $p < 0.05$, and highly significant at $p < 0.01$.

Results and discussion

The orthodontists and orthognathic surgeons often have profile radiographs at their disposal for skeletal analysis, linear measurement of the calvaria can be simple and informative procedure useful for treatment planning, as the calvarial thickness can be an indicator for the bone thickness in general [7, 20], and subsequently this information could also contribute to estimate the treatment time, so in order to evaluate the calvarial thickness, it is important to have normative cephalometric data, there is probably no way to rigorously standardize cranial thickness measurements. However, lateral cephalometic x-ray is convenient to analysis, as the bone structures are visualized adequately, easily, and inexpensively in relation to other studies [32,33] using CT or MRI. In the current study, the ANB angle was used as a method of grouping of the subjects according to their skeletal patterns, four linear measurements were used exclusively in the assessment of calvarial thickness parameter in both genders at each straight side of a rhombus like pattern in the digitization of cephalometric radiographs (Figures 1 and 2), thus the four linear measurements made the current research differed dramatically from other similar studies [20,21].

The descriptive statistics including mean and standard deviation of the calvarial thickness parameter for the three skeletal groups in both genders demonstrated in table 1. The mean calvarial thickness values changed from highest to lowest in sphenoid, parietal, occipital, and frontal bones respectively, as seen in tables 1 and 2. Student's t-test showed no significant gender differences (P>0.05) were found regarding calvarial thickness parameter of sphenoid, frontal, parietal, and occipital bones in skeletal class I and class III groups, while in skeletal class II group, the frontal and occipital bones' thickness showed highly significant gender differences (P<0.01), with females had thicker frontal bone than males, and males had thicker occipital bone than females, in addition the skeletal class II group showed no significant gender difference (P>0.05) regarding sphenoid and parietal bones' thickness, as illustrated in table 1, so it can be concluded that a deviation in the theca cranii are interrelated with skeletal class II malocclusion, this can be explained by sexual dimorphism of frontal and occipital bones' thickness between males and females in skeletal class II malocclusion, also it has been observed that there were no significant gender differences in skeletal class I, and class III groups in calvaial thickness parameter of sphenoid, frontal, parietal, and occipital bones, this is in agreement with several studies [14, 21, 32], and disagreement with others [17,18] regarding frontal, parietal, and occipital bones, so no clear trends have emerged, and the findings have been somewhat conflicting, and this confliction might be attributed to the variety of the sampling method (sampling points, race, and age), and insufficient medical data about these researches, and this might result upon inclusion of subjects and exclusion of others in the current study with contrary studies [21,31-33].

The results of F-test analysis of variance for total skeletal groups in males showed highly significant differences in the thickness of occipital bones, while the females and total genders showed highly significant differences in the thickness of frontal and occipital bones, as shown in table 2, this may be due to the higher mean values of frontal bones' thickness in females than males, and higher mean values of occipital bones' thickness in males than females, as previously demonstrated in tables 1 and 2, this finding is not easy to explain, but it may be due to the gender difference in the level of circulating hormones (sex, growth, and thyroid hormones) during the growth spurt, which subsequently can affect on the growth rhythm of frontal and occipital bones in females and males, and this explanation is in accordance with other studies [34,35], so it can be concluded that the calvarial thickness parameter could be used as a gender indicator specially for the frontal and occipital bones. On the other hand, the sphenoid and parietal bones showed no significant differences between total skeletal groups in males, females, and total genders, as seen in tables 1 and 2, this finding represents the most unique important outcome of the current study than other studies on calvaria [20,21,31-33], since the parietal bone located in the upper mid boundary of the calvaria, while the sphenoid bone located in the lower mid boundary of the calvaria, so these two bones' thickness can be used as new references in the standardization of cephalometric radiographies about the calvaria and/or craniofacial region, since these two bones no significantly changed in males, females, total genders, and total skeletal groups as previously illustrated in tables 1 and 2, this finding is hard to be explained, but it may be attributed to a different growth rhythm of the sphenoid and parietal bones, which it was not dramatically affected by the circulating hormones, as same as that occurred in frontal and occipital bones during the growth spurt, and this explanation needs further studies to be confirmed.

The Post-hoc least significant difference test was used to assess between which skeletal group the variables differ, as shown in table 3. In regard to total males, there were highly significant differences (P<0.01) in the occipital bones' thickness between skeletal class III versus class I and class II skeletal groups, this may be due to the highest mean value of occipital bone thickness in skeletal class III males subjects as previously demonstrated in table 1, this finding may be attributed to a local factor, which is the attachment of the neck of the musculature at the occipital sequama, subsequently it could influence on its thickness, due to altered function of the neck muscles and changes in the cervical spine due to altered head posture in skeletal class III malocclusion[36,37] . On the other hand, the total females and total genders reflect the same skeletal differences regarding frontal and occipital bones' thickness, where there were highly significant differences between all skeletal groups (class II versus class I and class III), except the females' frontal bones showed no significant differences in skeletal class I versus class III groups, as seen in table 3, this may be due to the highest mean values of females' frontal bones than males in skeletal class II malocclusion, and in total skeletal groups, as shown in tables 1 and 2, this result agreed with a study [21] and disagreed with another [4] , so it can be concluded that the thickness of the females' frontal bones in skeletal class II malocclusion plays an important role in their highly significance difference of the skeletal class II versus class I and class III groups for total genders as demonstrated in table 3, this local thickening of the females' frontal bones in skeletal class II malocclusion is not easy to explain, but it may be due to excessive bone deposition in this region during and after adolescence, and this might be interrelated with the finding of thick frontal and short nasal bones in skeletal class II malocclusion [38] , and both areas (frontal and nasal bones) belong to the frontonasal developmental field.

Conclusion

The most vital outcomes of the present study were:

1. The frontal and occipital bones are important key bones for understanding the calvarial phenotypic description, and sexual dimorphism in different skeletal patterns, because subjects with skeletal class II malocclusion showed that females had thicker frontal bone than males, and males had thicker occipital bone than females.
2. The sphenoid and parietal bones can be used as reference bones for standardization of cephalometric analysis, because these two bones not significantly changed in both genders, and in different skeletal patterns.

Clinical importance

This study gives us a fascinating morphological insight into the phenotypic characteristics and sexual dimorphism of the calvaria in different skeletal patterns, which is necessary for understanding the etiology of malocclusion, diagnosis, treatment planning, and treatment duration, it is further beneficial in forensic dentistry and physical anthropology, especially in dealing with human remains and in interpersonal violence, thus it makes an easy and inexpensive identification of the victims in our country the Iraq.

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Table 1: Descriptive statistics, and gender difference in each of the three skeletal groups using Student's t-test.

Variables		Males(N=20)		Females(N=20)				
		Mean (mm)	**SD**	**Mean (mm)**	**SD**	**Mean Difference**	**T-Test Df=38**	**P-Value**
Class I	**S-j**	21.10	2.43	20.87	2.44	0.23	0.36	0.719
	F^{th}	7.47	0.45	7.33	0.38	0.14	1.03	0.307
	P^{th}	8.24	0.66	8.21	0.55	0.03	0.15	0.883
	O^{th}	8.05	0.47	7.95	0.41	0.10	0.67	0.506
Class II	**S-j**	20.91	2.61	20.83	2.61	0.08	1.00	0.921
	F^{th}	7.31	0.43	7.93	0.39	0.62	1.40	0.000**
	P^{th}	8.14	0.47	8.11	0.61	0.03	0.95	0.349
	O^{th}	8.01	0.46	6.99	0.44	1.02	0.69	0.000**
Class III	**S-j**	20.97	2.41	20.86	2.41	0.11	0.15	0.884
	F^{th}	7.34	0.42	7.30	0.41	0.04	0. 20	0.843
	P^{th}	8.18	0.61	8.09	0.55	0.09	0.45	0.653
	O^{th}	8.77	0.55	8.74	0.54	0.03	0.17	0.863

S-j= Sphenoid thickness; F^{th}=Frontal thickness; P^{th}=Parietal thickness; O^{th}=Occipital thickness.
**=Highly significant @p<0.01 Df=Degree of freedom. N=Number of sample.

Table 2: Descriptive and comparative statistics for males, females, and total genders between total skeletal groups using F-test analysis of variance.

Variables		Mean(mm)	SD	F-Test		P-Value
Males (N=60)	S-j	20.99	2.44	Df=59	0.04	0.950
	F^{th}	7.40	0.43		0.44	0.640
	P^{th}	8.18	0.59		1.38	0.259
	O^{th}	8.28	0.60		14.51	0.000**
Females (N=60)	S-j	20.85	2.45	Df=59	0.001	0.990
	F^{th}	7.52	0.47		14.23	0.000**
	P^{th}	8.14	0.57		0.230	0.791
	O^{th}	7.89	0.85		69.33	0.000**
Total (N=120)	S-j	20.92	2.44	Df=119	0.04	0.990
	F^{th}	7.46	0.45		6.03	0.000**
	P^{th}	8.13	0.58		0.66	0.651
	O^{th}	8.08	0.76		35.69	0.000**

S-j= Sphenoid thickness; F^{th}=Frontal thickness; P^{th}=Parietal thickness; O^{th}=Occipital thickness.
**=Highly significant @p<0.01 Df=Degree of freedom. N=Number of sample.

Table 3: Least significant difference test (LSD) for the measurements in males, females, and total genders between different skeletal patterns

Variables		Class (I and II) P-Value	Class (I and III) P-Value	Class (II and III) P-Value
Males	F^{th}	0.597	0.354	0.689
	O^{th}	0.827	0.000**	0.000**
Females	F^{th}	0.000**	0.782	0.000**
	O^{th}	0.000**	0.000**	0.000**
Total	F^{th}	0.009**	0.636	0.002**
	O^{th}	0.000**	0.000**	0.000**

F^{th}=Frontal thickness.; O^{th}=Occipital thickness. **=Highly significant @p<0.01

Figure 1: Digitization of lateral cephalometric radiograph by AutoCAD software computer program 2011.

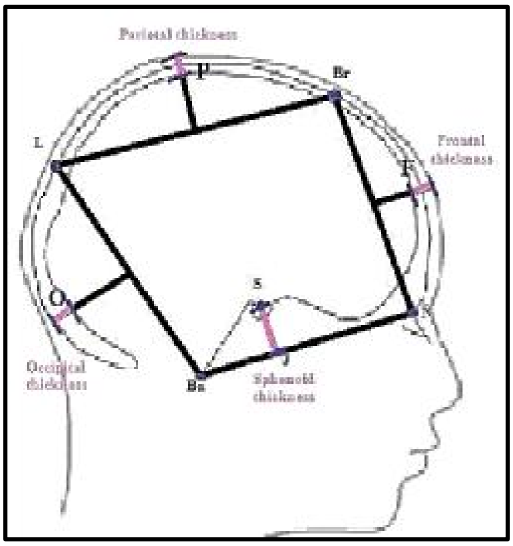

Figure 2: Cephalometric Points, Planes, and the four linear measurements of the calvarial thickness parameter.