CHAPTER 4

INTRA-POPULATION COMPARISONS OF CRANIOFACIAL MORPHOLOGY IN MALAYSIAN MALAYS BASED ON 3D COMPUTED TOMOGRAPHY

4.1 Introduction

In Chapter 3, references for a number of craniofacial variables were established for Malaysian Malays, for both sexes at different age intervals. In this Chapter, differences between males and females at selected age intervals, and differences between the left and right sides of selected craniofacial structures, are considered. Therefore, this chapter is divided into two sections; Section A will discuss sexual dimorphism and Section B will present the results of an analysis of asymmetry of selected craniofacial structures.

Section A

4.2.1 Sexual Dimorphism of Craniofacial Structures

Differences in craniofacial structures between males and females have often been related to the overall body size of males who tend to be larger than females (Enlow, 1990). Males then need to have correspondingly bigger lungs to support their relatively more massive muscles and body organs. Because of this, males need a larger airway, beginning with the nose and nasopharynx. Sexual dimorphism in the size of the nose in turn leads to accompanying differences in other structures of the face.

Three-dimensional quantitative analysis of growth and development of the nose (Ferrario *et al.*, 1997) revealed that nasal structures manifested sexual dimorphism. The male

nose in general tends to be more protrusive, longer, and wider and have larger and more flaring nostrils. The interorbital part of the nasal bridge in the male also tends to be much higher. In contrast, the female nose tends to be relatively thinner and less protrusive. Because of the larger and more protuberant male nose, the part of forehead continuous to it is also more protrusive. The male forehead, including the supraorbital and glabellar parts, tends to be more sloping in contrast to the more bulbous, upright female forehead (Enlow, 1990).

The greater protrusiveness of the male forehead and nose results in eyes that appear more deep-set, whereas female eyes appear more proptotic. Because of this, the female cheek bones look much more prominent because the nose and forehead are less prominent. This malar protuberance is not actual but rather relative (Enlow, 1990). Sexual dimorphism in the facial region has been studied in three-dimensions and significant differences between males and females have been noted (Ferrario *et al.*, 1994a). In males, the protuberant supraorbital part of the more sloping forehead is produced by a greater extent of separation between the inner and outer tables of the frontal bone. The growth of inner table stops when enlargement of the frontal lobes of the brain ceases around 5 to 6 years of age. The outer table continues to remodel forward until nasal growth ceases at later ages. The inner and outer tables separate and the cancellous bone between them is filled with the frontal sinus. The nasal part of the male face continues to grow several years longer than that of females, leading to larger frontal sinuses in males than in females (Enlow, 1990). The smaller frontal sinus in females gives rise to a less full appearance of the temporal regions of the lateral forehead. The female face also appears flatter than the more coarse, irregular and deep male face.

Some other differences between males and females that have been reported include differences in the occipital region, mastoid process, muscle insertions, mandible, palate size and also teeth. Males tend to have larger mastoid processes, squarer chins, stronger muscle markings such as temporal lines, nuchal crest and gonial eversion. They also tend to have thicker zygomatic arches, longer palates and larger sinuses. In a study of Australian

Aborigines, sexual dimorphism in tooth size, particularly the mesiodistal and buccolingual crown diameters of the canine teeth, was reported (Townsend and Brown, 1979). All distance variables for lips and nose, lip vermillion areas and lip volumes were found to be significantly larger in young adult males than females in a three-dimensional study of the nose and lips (Ferrario *et al.*, 2000).

Cranial capacity has been reported to be different between males and females but a large range of variations occurs between the two sexes. The average cranial capacity in European males is about 1450cc and females have about 10% lower volumes than males. Abbott *et al.* (2000) have reported that the increase of the male and female intracranial volume is similar over time, but the female mean value is 1.3 standard deviations below the male mean value at 20 years.

Numerous studies that have investigated craniofacial morphology and growth quantitatively have also looked into differences between the sexes. The majority of these studies utilised cephalometric radiography with records collected usually on yearly intervals over the growth period of children. Several studies have found that various linear and angular measurements differ between males and females and change with age. Several normative cephalometric standards published from different parts of the world have revealed that differences take place in the measurements of the face and cranial base for males and females at different age group (Riolo *et al.*, 1974; Bhatia and Leighton, 1993; el-Batouti *et al.*, 1994). A study in Icelandic children showed that boys have consistently larger values for most of linear craniofacial variables, but no differences were found for angular variables (Johannsdottir *et al.*, 1999). Their findings are in agreement with another Scandinavian study conducted on children of the same age range (Odegaard, 1970).

The neurocranium was found to be larger in size in males than in females (Axelsson *et al.*, 2003). Differences were also observed in the shape of some craniofacial regions. For

instance, females displayed more prominent frontal bones and frontal bones with a greater curvature than males.

Due to perceived differences between the sexes, Bishara (1981) constructed a number of normative cephalometric standards separately for males and females at different age intervals. These included skeletal and dental linear and angular measurements based on longitudinal cephalometric data for a Caucasian population.

Based on established reports from previous studies of other racial and ethnic groups, the author was interested to find out whether any differences between the two sexes were also present in the collected samples of Malaysian Malays. It is anticipated that differences may occur between the sexes but the behaviour and extent of these differences may be different in the Malay sample. Moreover, the observations are based on 3D-CT records that enable the study of sex differences in craniofacial regions that are difficult to visualise using conventional methods. Therefore the aims of this section are:

- To compare linear and angular variables of different craniofacial regions between male and female Malays in selected age groups;
- To study the pattern of differences between males and females for different craniofacial regions and across different age categories.

4.2.2 Materials and Methods

The methods of data collection have already been outlined in Chapter 2.

4.2.2.1 Data Collection

The sources of patients selected for this study, and the breakdown by age categories and sex are detailed in Section 2.5.

4.2.2.2 CT Protocol

Axial scans were obtained with a GE Lightspeed Plus CT Scanner System at the Department of Radiology, Hospital Universiti Sains Malaysia. The protocol used is detailed in Section 2.6.3

4.2.2.3 Craniofacial Variables

Craniofacial variables were grouped according to different regions of the face, cranial base and cranial vault. The face was further categorised into separate major structures, i.e. orbit, maxilla, zygoma and mandible. All regions were represented by width or distance, height and length measurements. There were also a few variables that described inter-regional dimensions. Additionally, a few angular variables and indices were identified.

The linear variables, angles and indices are represented diagrammatically in Figures 2.7 to 2.21 and defined in the legends for the figures in Section 2.6.9. Analysis in this section was performed for 110 linear 13 angular variables, and 3 indices.

Values for males and females were compared at three different age groups. They were compared during infancy (0 to 1 year), during childhood (5 to 10 years age group) and during adulthood (18 and above years).

4.2.2.4 Statistical Analysis

A linear modelling analysis was used to make comparisons between the sexes. Linear modelling is a flexible statistical model that incorporates normally distributed dependent variables and categorical and continuous independent variables. In this study, the males and females were matched for age as closely as possible in their corresponding age categories but achieving an exact match was not possible. Therefore, a t-test was not utilised for

comparisons because the ages of males and females were not exactly matched in all groups. Instead, the use of a covariate model that accounted for possible age effects was preferred.

Linear modelling enables comparisons to be made between adjusted mean values at adjusted mid-ages for males and females. This test will also give R^2 and adjusted R^2 values. The computer software R version 2.2.0 was used to perform linear modelling analysis on the data. For differences between the sexes, a linear model incorporating the fixed effects of 'sex' using 'age' as covariates was fitted to all measurements.

The model was as follows:

Variable = Age (0-1 or 5-10 or 18 and above years)

Sex (male, female)

This analysis was performed separately for the age categories selected to compare differences between males and females during infancy, childhood and adulthood. The model generated an adjusted mean at adjusted mid-age in each age category for each measurement. The model applied sums of squares calculation to generate the adjusted mean.

The adjusted mean values were then utilized to calculate percentage values of sexual dimorphism that were employed to quantify the magnitudes and patterns of differences between the sexes at each age category. Following Garn *et al.* (1967), the percentage of sexual dimorphism was calculated using the following formula:

$$\% \text{ dimorphism} = \frac{\text{Male value} - \text{Female value}}{\text{Female value}} \times 100$$

The purposes of generating this percentage value were to detect any patterns of differences that may be exhibited by the data and to determine how much male or female values exceeded that of each other so that comparisons between the craniofacial regions and across different ages could be performed.

4.2.2.5 Errors of the Method and Data Cleaning

The methods for determining errors in landmark determination and anthropometric variables derived from these landmarks, based on repeated determinations, are outlined in Section 2.8.4. Systematic errors in landmark location were tested using Hotelling's T^2 statistic. For anthropometric variables, Student's paired t-tests were used to detect systematic errors (i.e. to ascertain whether the mean difference between repeated measures deviated significantly from zero) and Dahlberg's (1940) method of double determination was used to quantify the magnitude of random errors.

Data cleaning was performed and has already been explained in detail in Section 3.6.7.

4.2.3 Results

Graphical presentations of values for males and females at selected age categories are presented in Figures 4.2.1 to 4.2.5. The purpose of these figures is to provide some visual confirmation of qualitative and also quantitative differences in skeletal appearance between the males and females.

The results for quantitative comparisons between males and females are presented in Tables 4.2.1 to 4.2.27. The tables are presented for different craniofacial regions at different age intervals. Tables contain adjusted mean values and standard errors of the mean (SE) for males and females for each variable for the mid-age of the age intervals under investigation. Tables also present probability for age and sex differences and R^2 and adjusted R^2 values. Statistically significant differences between the two sexes at $p<0.05$ are marked with (*) as and those at $p<0.0$ with (#). In the infancy period (0 to 1 years), a few variables are marked with N/A which means readings for these variables were not available. This is due to inability to determine landmark *'es'* which had not fully developed during this stage.

Another set of tables that contain information on percentage dimorphism values of the measurements are presented in Tables 4.2.28 to 4.2.36 for each craniofacial region at different age categories.

From the 3D-CT graphical presentations of the male and female skeletal features in Figures 4.2.1 to 4.2.3, the skeletal features look very similar during infancy. During childhood, male skeletal features are beginning to appear more angular and robust whereas females are more rounded. The female face seems wider than it is in height and the male face appears longer than females. Nasal apertures are wider and longer in males than females. During adulthood, both males and females are in their early 20s, marked differences are evident. The male face looks very robust with very prominent supraorbital ridges and the frontal area continuous with the nose. In fact, for this male subject, the whole orbital area is very prominent. Nasal apertures are wider and longer, the chin is squarer and the gonial angle shows marked eversion and strong muscle markings. Temporal lines look obvious for this subject. The zygomatic arches are thicker and the teeth in this male subject are bigger than those of the female. The female face looks softer with the zygomatic area quite prominent, giving the appearance of high cheek bones. The forehead is more rounded in females with less prominent supraorbital ridges.

The male and female differences described so far concern structures on the outer craniofacial surface. The use of 3D-CT in this study has given the author the opportunity to view the cranial base region more closely. 3D-CT reconstructions of the cranial base for males and females during childhood and adulthood are presented in Figures 4.2.4 to 4.2.5. Because we are generally not very familiar with the appearance of the cranial base, it is difficult to express qualitatively differences between the sexes. The cranial base is in fact a very complex region. The spheno-occipital synchondrosis was not yet closed in either sex during childhood although it was closed in adults. Apart from this difference, explanations of other possible differences between the sexes are not attempted.

During infancy (0 to 1 year), only 3 out of 110 (2.7%) linear variables were found to be significantly different between males and females (Tables 4.2.1 to 4.2.9). The variables that were found to be significantly different were inferior orbital width, right orbital height and external cranial base width. However, for the majority of these variables (88.9%) males exhibited larger values than females. This suggests that, although size differences are not significantly different in a statistical sense at this stage, there is a tendency for males to be slightly larger than females. No statistically significant differences in angular variables or indices were detected. However, females had slightly larger angular values for about 50% of the variables. Males and females had similar values for indices.

During this infancy stage, age was found to be a statistically significant factor for the majority of variables in all regions. It was observed to be significant at $p<0.01$ level for 71.4% of cranial vault variables, 53.6% of cranial base variables, 70.6% of orbital variables, 27.3% of nasal variables, 13.3% of maxillary variables, 25% of zygomatic variables, 16.7% of inter-regional variables and for one angular measurement. Moreover, age was noted to be a significant factor at $p<0.05$ for 28.6% of cranial vault variables, 17.9% of cranial base variables, 94% of orbital variables, 54.5% of nasal variables, 33.3% of maxillary variables, 50% of zygomatic variables, 54.5% of mandibular variables, 66.7% of inter-regional variables and for two angular and one index variables.

At later ages of 5 to 10 years, 8 out of 110 (7.3%) linear variables were found to show statistically significant differences between the sexes but none of the angular variables or indices differed. The variables that showed significant differences were in orbital, cranial base and cranial vault regions. However, the males displayed larger values than females for the majority of the linear variables (70.8%), suggesting that size differences continued to occur at this stage. Moreover, the number of differences that were statistically significant increased slightly in this age period compared to infancy. For angular variables, males had larger values

for 43.7% of the variables. Again, similar values were observed for indices in both males and females.

Age was also found to be a statistically significant factor for the majority of variables in all regions during childhood stage. It was observed to be significant at $p<0.01$ level for 25% of cranial base variables, 17.6% of orbital variables, 36.4% of nasal variables, 46.7% of maxillary variables, 87.5% of zygomatic variables, 36.4% of mandibular variables and 33.3% of inter-regional variables. Furthermore, age was noted to be a significant factor at $p<0.05$ for 7% of cranial vault variables, 14.3% of cranial base variables, 27.3% of nasal variables, 33.3% of maxillary variables, 45.5% of mandibular variables and for one angular variable.

It was during adulthood that sex differences in the size of craniofacial structures became most obvious. At this stage, 50 out of 110 (45.5%) linear variables showed statistically significant differences. 33 variables showed marked differences at $p<0.01$. These differences were distributed across all of craniofacial regions, including the cranial vault, cranial base, orbital, maxillary, zygomatic, mandibular and inter-regional variables. The number of variables that displayed bigger values for males was also increased compared with the younger age groups. 92.5% of the linear variables showed larger values for males compared to females. However, even at this stage only one index showed a statistically significant difference. Males had larger values for 37.5% of the angular variables. For indices, females had significantly larger values for right orbital index.

During adulthood, age was observed to be a statistically significant factor for only a few variables in each craniofacial region. It was observed to be significant at $p<0.01$ level for 18.2% of nasal variables. It was also significant at $p<0.05$ for 3.6% of cranial base variables, 6% of orbital variables, 18.2% of nasal variables, 13.3% of maxillary variables, 25% of zygomatic variables and 9% of mandibular variables. None of the cranial vault, angular and index variables showed a significant age effect at this age category.

The percentage of sexual dimorphism for cranial vault variables was found to be the highest during infancy with males having bigger values than females for almost all variables. The percentage values were in the range of 2.2 to 15.5% with two measurements exhibiting percentage differences of over 10%. The magnitude of sexual dimorphism decreased during childhood, with female measurements being larger for almost half of the variables. The magnitude of sexual differences increased slightly during adulthood for the majority of cranial vault variables, with this magnitude in the range of 0.1 to 4.2%.

Percentage sexual dimorphism values for cranial vault measurements were in the range of 1.5 to 14.6%, with the males showing larger measurements for 75% of the variables during infancy. Five of these variables had dimorphism percentages over 10%. This magnitude of dimorphism decreased during childhood for 46.4% of the variables. All variables that had bigger female values during infancy showed a reversed pattern during childhood, males being larger. There were also some variables associated with larger values in males during infancy that were found to have higher female values during childhood stage. 14.3% of the cranial vault variables displayed this pattern. During adulthood, males displayed larger dimensions than females for the majority of variables (85.7%).

Varying patterns of changes in the magnitude of sexual dimorphism were observed for cranial base variables from infancy to adulthood. The majority (64.3%) of cranial base variables were found to show increases in the magnitude of sexual dimorphism from childhood to adulthood. 28.6% of the variables showed a pattern whereby the highest magnitude of dimorphism occurred during infancy followed by a decrease in magnitude during childhood and then an increase again during in adulthood. However, the magnitude of sexual dimorphism in adulthood was not as high as during infancy. There were also variables (14.3%) that showed a similar pattern except that the magnitude of dimorphism was higher during adulthood. For one variable (*petsa.l-petsa.r*), the magnitude of dimorphism increased from infancy to adulthood whereas for another one (*spa.l-spa.r*) the magnitude decreased with

age. For another variable (*pts.r-petsa.r*), the magnitude of sexual dimorphism increased from infancy to childhood and then decreased during adulthood.

The range of percentages of sexual dimorphism for orbital variables during infancy was between 1.3 to 10.7%, with one variable (*sor.r-or.r*) showing a magnitude over 10%. For the majority of variables (94.1%), males had larger values than females. These magnitudes of dimorphism were found to decrease during childhood for the majority of orbital variables. The measurements for males still exhibited larger values, albeit with a reduced magnitude of dimorphism, during this time. During adulthood, for 94.1% of the variables, males displayed larger values of sexual dimorphism - between 1 to 9.3%.

Various patterns of changes of the magnitude of dimorphism could be observed for orbital variables from infancy to adulthood. For 29.4% of the variables, there was a pattern of high sexual dimorphism during infancy followed by a decrease during childhood and then an increase again during adulthood. However, the magnitude of dimorphism during adulthood was lower than during infancy. Other variables (23.5%) displayed a similar pattern except that the magnitudes of differences between the sexes during adulthood were higher than during infancy. Another pattern that was noted for some variables was one in which the magnitude of sexual dimorphism increased from infancy to adulthood. This pattern was exhibited by 17.6% of the orbital variables. One variable demonstrated a pattern of decreasing sexual dimorphism from infancy to adulthood.

The percentage of sexual dimorphism for nasal variables was in the range of 1 to 10%, with males having larger values for 90.9% of the variables. In males, the magnitude of dimorphism decreased during childhood for the majority of nasal variables. During the childhood stage, females were larger for 36.4% of the variables. For 90.9% of the variables males were larger, percentage values ranging from 0.4 to 7.3% during adulthood.

Several different patterns of change in the magnitude of sexual dimorphism were also revealed for nasal variables from infancy to adulthood. There was a pattern of high magnitude

of sexual dimorphism during infancy, followed by a decrease in the magnitude during childhood, and then an increase again during adulthood. However, the magnitude of sexual dimorphism during adulthood was lower than during infancy. This pattern was noted for 27.3% of the nasal variables. Another 27.3% of nasal variables displayed a similar pattern except that the magnitudes of the differences between the sexes during adulthood were higher than those during infancy. One variable (*pns-h*) showed a pattern in which the magnitude of sexual dimorphism decreased from infancy to adulthood. Another pattern, displayed by one of the nasal variables (*ans-al.r*), was that the magnitude of sex differences increased from infancy to childhood stage, followed by a decrease from childhood to adulthood.

Maxillary variables displayed sexual dimorphism percentages in the range of 1 to 12.5% during infancy, with almost all measurements being larger in males. For 20% of these variables, the magnitude of differences was over 10% during this time. During childhood, females had larger measurements for about half of the maxillary variables. Males displayed bigger sizes for all maxillary variables during adulthood, with the magnitude of sexual differences ranging from 3.4 to 15%.

Maxillary variables also showed several patterns of change in the magnitude of sexual dimorphism from infancy to adulthood. There was a pattern of high magnitude of sexual dimorphism during infancy followed by a decrease during childhood and then an increase again during adulthood. However, the magnitude during adulthood was lower than during infancy. This pattern was evident for 20% of the maxillary variables. Another 26.7% of maxillary variables displayed a similar pattern except that the magnitude of differences between the sexes during adulthood was higher than during infancy. One variable (*ms.l-ms.r*) showed a pattern of an increased in the magnitude of sexual dimorphism from infancy to adulthood. Another pattern noted was for variables that showed larger measurements in males during infancy but a reversed pattern during childhood. The pattern changed again in

adulthood, with measurements for males exceeding those for females. This latter pattern was observed for about half of the maxillary variables.

The zygomatic region also showed high sexual dimorphism during infancy with all variables exhibiting larger male values (over 5%) and half of being associated with magnitudes of over 10%. This percentage decreased during childhood but the males were still larger. During adulthood, the magnitudes of dimorphism values were in the range of 2.5 to 12.8%. All zygomatic measurements for males were larger than those for females across all ages.

Most zygomatic variables (62.5%) showed a pattern of high sexual dimorphism during infancy followed by a decrease during childhood and then an increase again during adulthood, with the magnitude during adulthood being lower than during infancy. Another 25% of zygomatic variables displayed a similar pattern except that the magnitude of differences between the sexes during adulthood was greater than during infancy. One variable (*slor.r-zmi.r*) showed a pattern of a decrease in the magnitude of sexual dimorphism from infancy to adulthood.

At 20.6%, the mandibular measurement of anterior alveolar height (gn-id) showed the highest magnitude of sexual dimorphism in this study and this occurred during infancy stage. Dimorphism percentage values were also quite high for anterior alveolar height and left and right ramus heights, ranging from 11.8 to 15% during adulthood. During infancy and adulthood, all mandibular variables were larger in males than females to varying degrees. Sexual dimorphism values during infancy and adulthood ranged from 1.6 to 20.6% and 1.5 to 15% respectively, with the majority of variables being associated with values of over 5%. During childhood, females displayed larger values for about half of the mandibular variables. The percentage of sexual dimorphism for variables where male values exceeded that of female values during this time was in the range of 1.4 to 4.7%. The magnitude of dimorphism for variables where female values were larger was in the range of 2.4 to 4.8%.

18.2% of mandibular variables showed a pattern of high sexual dimorphism values during infancy followed by a decrease in the values during childhood and then an increase during adulthood, with the magnitude during adulthood being lower than during infancy. Another 36.4% of mandibular variables displayed a similar pattern except that the magnitude of differences between the sexes during adulthood was greater than during infancy. About half of the mandibular variables showed a pattern in which males had larger measurements during infancy but the pattern was reversed during childhood with females being larger in size. The pattern changed again during adulthood with measurements for males being larger.

Inter-regional variables displayed sexual dimorphism values in the range of 3.5 to 8% during infancy. These values decreased during childhood. Two patterns of changes in the magnitude of dimorphism from infancy to adulthood were noted. Half of the inter-regional variables showed a pattern of high dimorphism values during infancy followed by a decrease during childhood and then an increased during adulthood, but the magnitude during adulthood was lower than during infancy. Another half of the variables displayed a similar pattern but the differences between the sexes during adulthood were greater than during infancy.

The magnitude of sexual dimorphism was found to be in the range of -6.5 to 6.4% for angular variables during infancy, between -12.2 to 4.2% during childhood, and in the range of -5.9 to 5.5% during adulthood. Indices were associated with dimorphism values in the range of 2.5 to 6% during infancy, 0.1 to 3.9% during childhood, and -7.8 to 0.5% during adulthood.

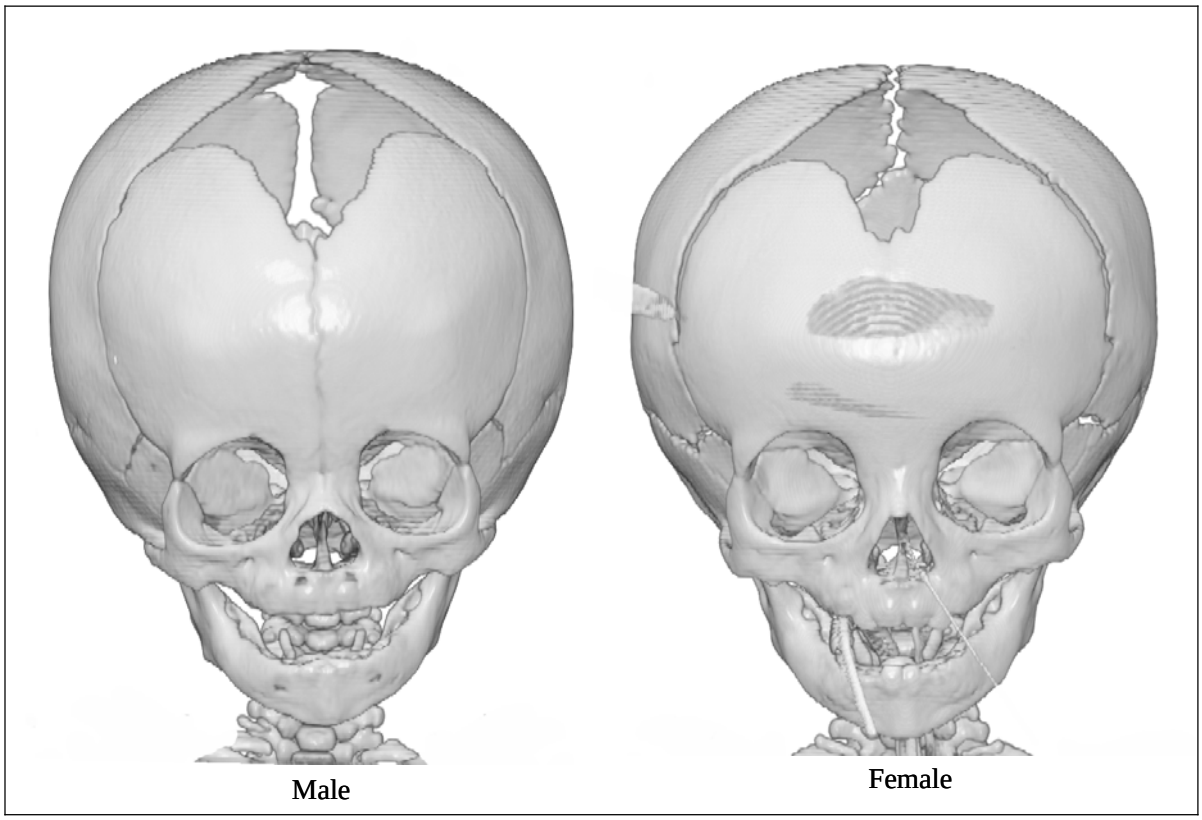

Figure 4.2.1 3D-CT reconstruction of the craniofacial complex showing skeletal appearance of a male and a female in 0 to 1 year age category.

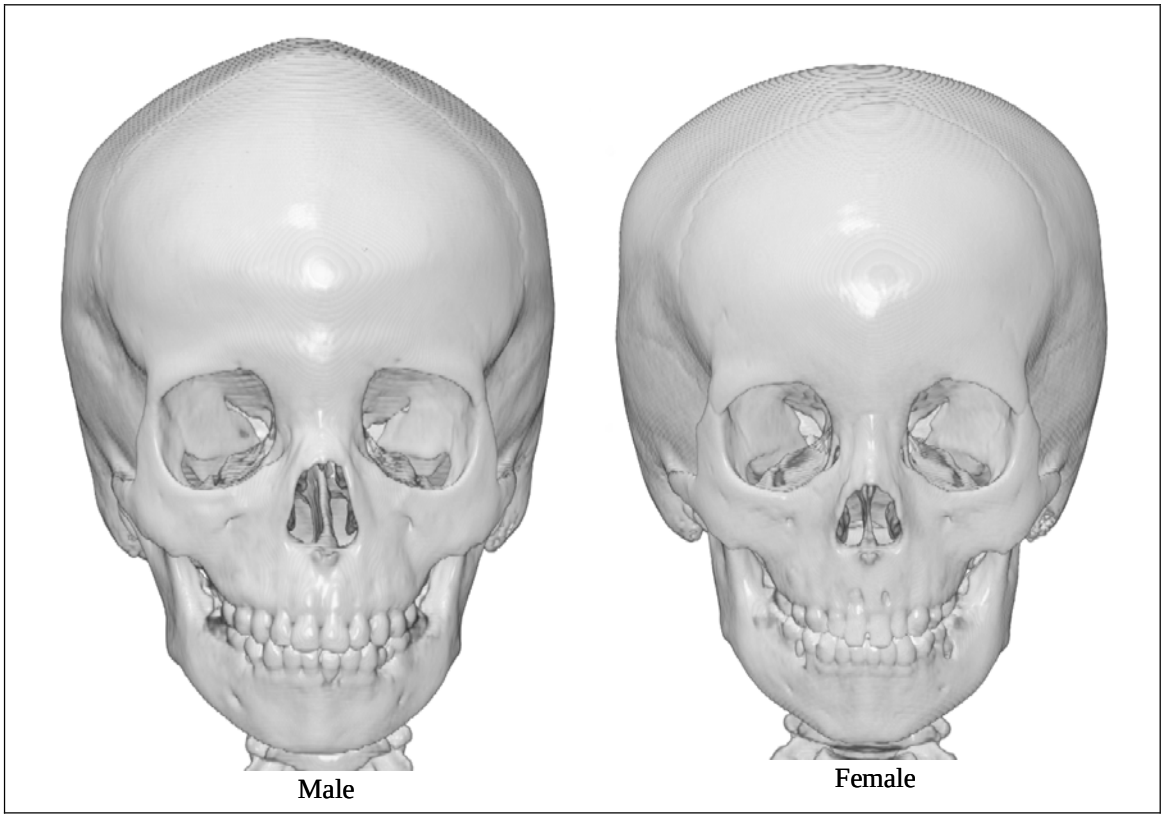

Figure 4.2.2 3D-CT reconstruction of the craniofacial complex showing skeletal appearance of a male and a female in 5 to 10 years age category.

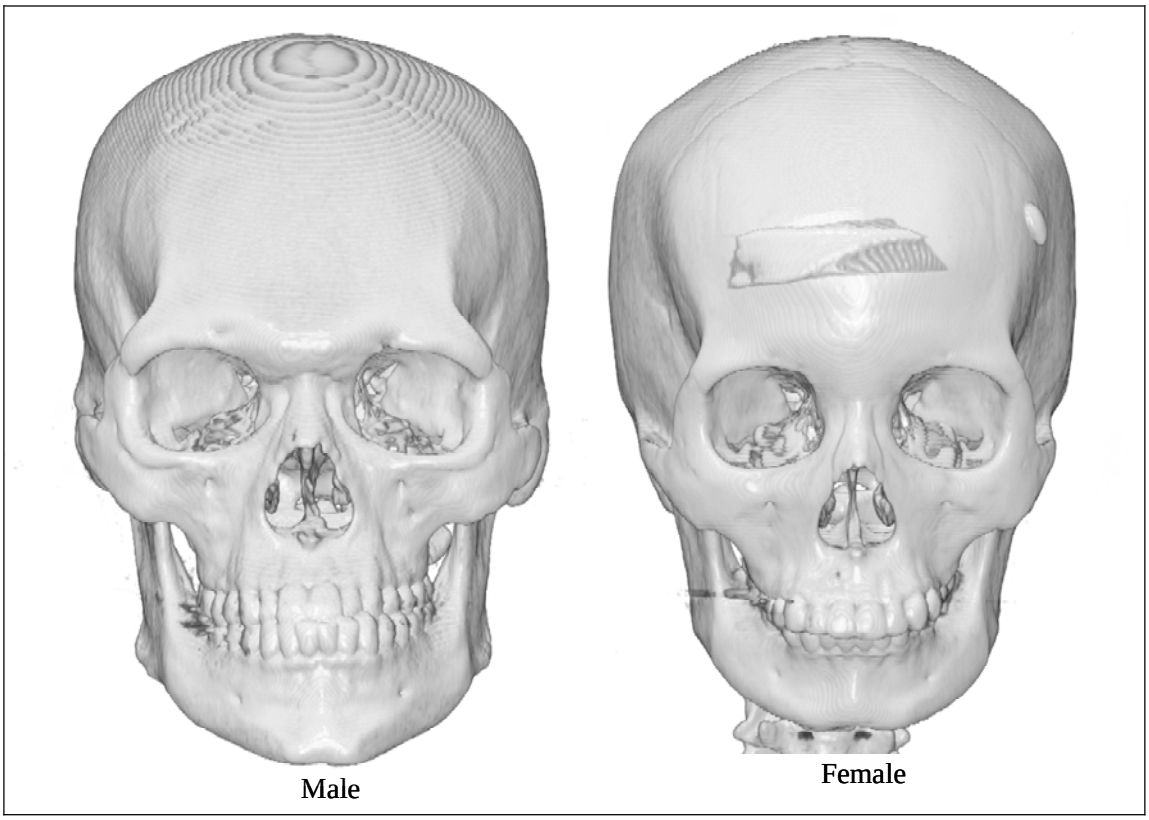

Figure 4.2.3 3D-CT reconstruction of the craniofacial complex showing skeletal appearance of a male and a female in 18 years and above age category.

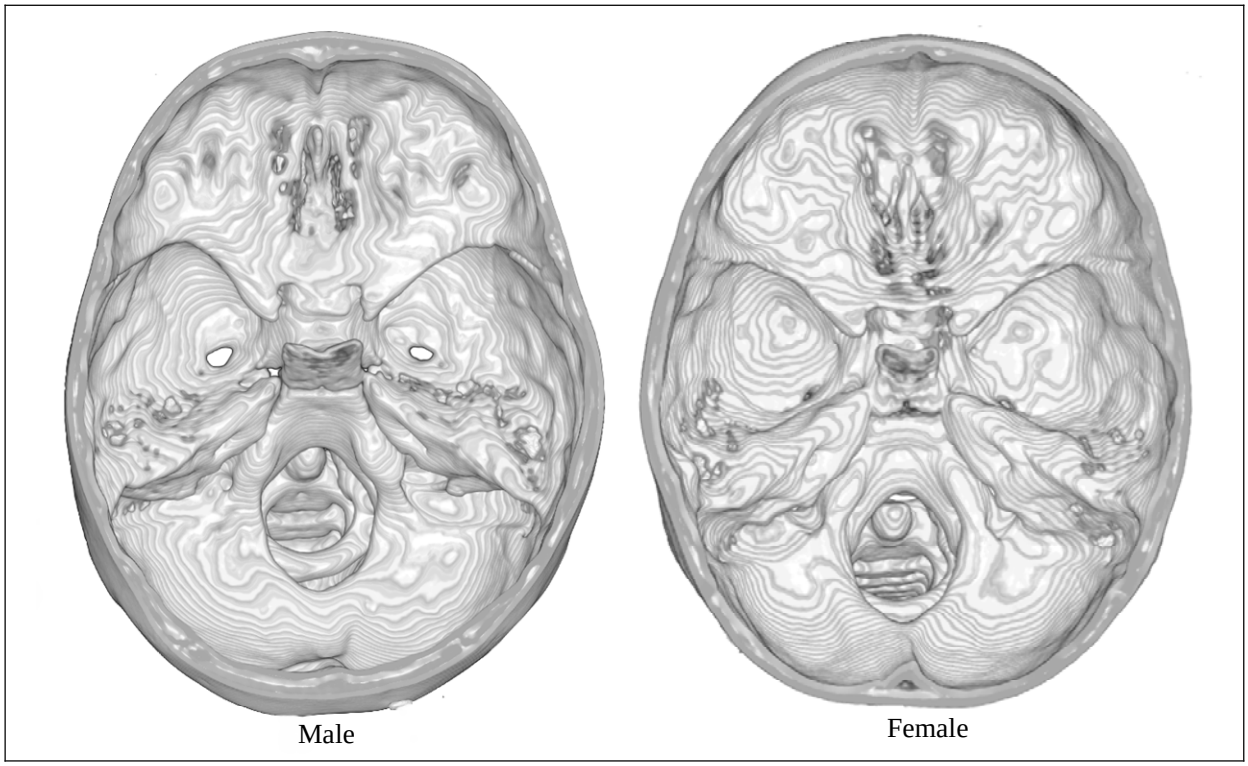

Figure 4.2.4 3D-CT reconstruction of the cranial base of a male and a female in 5 to 10 years age category.

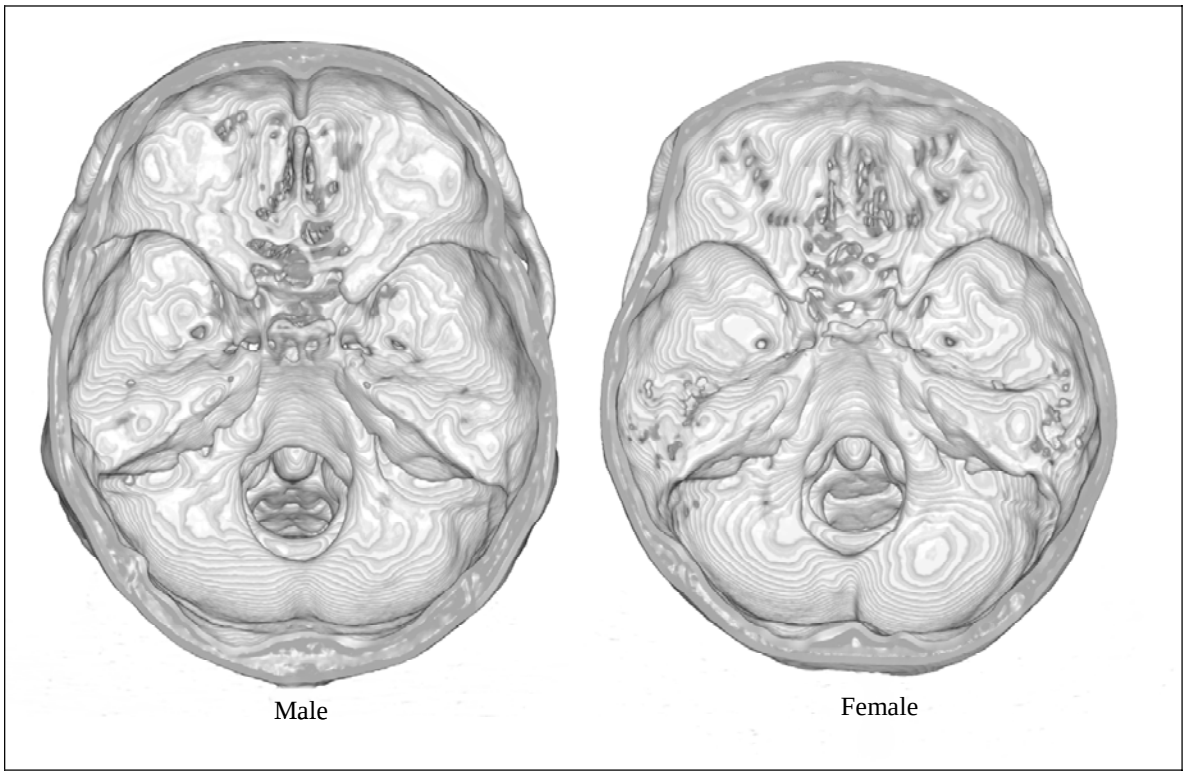

Figure 4.2.5 3D-CT reconstruction of the cranial base of a male and a female in 18 years and above age category.

Table 4.2.1 Adjusted mean and adjusted SE for cranial vault variables for males and females at age interval 0 to 1 year. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
cindx.l-cindx.r	0.5	116.0	3.75	110.8	4.90	<0.01#	0.40	0.53	0.48
as.l-as.r	0.5	81.4	3.36	78.3	4.08	<0.01#	0.56	0.49	0.41
po.l-po.r	0.5	74.3	2.80	64.4	4.37	<0.01#	0.08	0.60	0.53
ba-br	0.5	104.4	3.34	97.2	3.95	0.02*	0.20	0.53	0.42
br-po.l	0.5	104.6	3.42	96.2	4.04	0.01*	0.14	0.58	0.49
br-po.r	0.5	104.5	3.17	93.0	4.21	0.01*	0.06	0.65	0.57
n-br	0.5	83.7	2.36	77.0	3.47	<0.01#	0.14	0.62	0.56
l-o	0.5	78.3	2.76	77.0	3.87	<0.01#	0.79	0.53	0.45
l-br	0.5	89.4	1.76	86.4	2.10	<0.01#	0.29	0.58	0.52
cindxa-cindxp	0.5	131.2	2.85	128.4	3.73	<0.01#	0.55	0.59	0.54
spc.l-as.l	0.5	66.7	2.23	63.1	2.96	<0.01#	0.35	0.60	0.52
spc.r-as.r	0.5	67.5	2.22	63.6	2.95	<0.01#	0.32	0.59	0.52
l-as.l	0.5	70.5	2.73	71.1	3.13	0.02*	0.88	0.41	0.31
l-as.r	0.5	71.5	2.67	70.8	3.06	<0.01#	0.86	0.48	0.39

*significant at $p<0.05$ #significant at $p<0.01$

Table 4.2.2 Adjusted mean and adjusted SE for cranial base variables for males and females at age interval 0 to 1 year. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		p age	p sex	R2	Adjusted R2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
spa.l-spa.r	0.5	46.0	1.35	43.3	1.77	<0.01#	0.24	0.61	0.57
spa.l-es	0.5	N/A							
spa.r-es	0.5	N/A							
ac.l-spa.l	0.5	21.0	0.79	18.6	1.06	<0.01#	0.08	0.50	0.45
ac.r-spar	0.5	21.2	0.77	18.9	1.01	<0.01#	0.08	0.49	0.44
ac.l-ac.r	0.5	15.9	0.38	16.6	0.51	<0.01#	0.25	0.55	0.50
petsa.l-petsa.r	0.5	18.5	0.54	18.2	0.72	<0.01#	0.70	0.46	0.41
pts.l-pts.r	0.5	15.0	0.64	15.1	0.80	0.01*	0.94	0.37	0.28
petp.l-petp.r	0.5	83.8	2.24	81.9	2.76	<0.01#	0.60	0.58	0.53
ss.l-ss.r	0.5	46.6	1.00	40.9	1.81	<0.01#	0.02*	0.69	0.62
fmlhg.l-fmlhg.r	0.5	22.1	0.90	20.9	1.19	0.07	0.45	0.24	0.13
sor.l-spa.l	0.5	26.4	0.73	26.7	0.95	<0.01#	0.77	0.43	0.37
sor.r-spa.r	0.5	26.9	0.79	27.3	1.01	<0.01#	0.78	0.46	0.40
spa.l-petp.l	0.5	51.9	1.08	50.1	1.33	<0.01#	0.30	0.54	0.49
spa.r-petp.r	0.5	52.6	1.15	49.4	1.38	<0.01#	0.09	0.50	0.44
petsa.l-petp.l	0.5	41.1	0.88	40.1	1.09	<0.01#	0.45	0.56	0.51
petsa.r-petp.r	0.5	41.4	0.88	40.4	1.09	<0.01#	0.46	0.55	0.50
pts.l-petsa.l	0.5	10.1	0.57	10.6	0.72	0.17	0.60	0.14	0.02
pts.r-petsa.r	0.5	10.1	0.58	10.0	0.72	0.16	0.95	0.13	0.01
hn.l-pts.l	0.5	19.6	0.90	17.4	1.30	0.02*	0.19	0.45	0.35
hn.r-pts.r	0.5	20.3	0.87	17.7	1.26	0.01*	0.12	0.47	0.38
ba-n	0.5	65.8	1.75	64.0	2.73	<0.01#	0.60	0.55	0.47
ba-s	0.5	26.7	0.81	24.6	1.16	0.01*	0.17	0.43	0.34
s-n	0.5	44.1	0.95	43.4	1.38	<0.01#	0.67	0.61	0.56
n-es		N/A							
ba-h	0.5	24.5	0.71	24.1	1.02	0.04*	0.78	0.30	0.19
ba-o	0.5	29.4	1.06	29.5	1.47	0.12	0.98	0.19	0.05

*significant at p<0.05 #significant at p<0.01

Table 4.2.3 Adjusted mean and adjusted SE for orbital variables for males and females at age interval 0 to 1 year. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
sor.l-sor.r	0.5	70.2	1.74	68.8	2.74	<0.01#	0.67	0.46	0.39
or.l-or.r	0.5	38.7	0.72	36.2	0.92	<0.01#	0.04*	0.72	0.67
morfl.l-morfl.r	0.5	16.5	0.63	15.2	0.78	0.08	0.22	0.26	0.16
lor.l-lor.r	0.5	69.8	2.34	66.3	2.68	0.01*	0.32	0.43	0.34
ofa.l-ofa.r	0.5	17.4	0.58	18.2	0.69	<0.01#	0.41	0.61	0.56
lor.l-morfl.l	0.5	27.9	0.82	27.0	0.94	<0.01#	0.47	0.54	0.46
lor.r-morfl.r	0.5	28.0	0.80	26.9	0.91	<0.01#	0.35	0.54	0.47
sor.l-or.l	0.5	27.4	0.68	25.4	0.77	<0.01#	0.06	0.78	0.74
sor.r-or.r	0.5	27.6	0.71	24.9	0.90	<0.01#	0.03*	0.76	0.72
ofa.l-sor.l	0.5	36.7	1.01	35.4	1.19	<0.01#	0.39	0.58	0.53
ofa.r-sor.r	0.5	36.9	0.94	35.6	1.11	<0.01#	0.39	0.55	0.49
ofa.l-or.l	0.5	30.7	0.90	30.3	1.03	0.02*	0.78	0.40	0.30
ofa.r-or.r	0.5	30.8	0.93	29.6	1.18	0.03*	0.41	0.37	0.25
ofa.l-morfl.l	0.5	28.6	0.70	28.6	0.83	<0.01#	0.99	0.70	0.65
ofa.r-morfl.r	0.5	28.6	0.68	28.1	0.80	<0.01#	0.65	0.64	0.59
ofa.l-slor.l	0.5	34.4	1.14	33.0	1.47	<0.01#	0.46	0.48	0.39
ofa.r-slor.r	0.5	34.5	1.25	33.2	1.77	0.02*	0.55	0.38	0.27

*significant at p<0.05 #significant at p<0.01

Table 4.2.4 Adjusted mean and adjusted SE for nasal variables for males and females at age interval 0 to 1 year. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
snm.l-snm.r	0.5	10.7	0.54	10.1	0.66	0.01*	0.54	0.37	0.29
inm.l-inm.r	0.5	10.7	0.53	10.7	0.60	0.52	0.94	0.04	-0.12
al.l-al.r	0.5	16.9	0.67	15.3	0.91	0.04*	0.20	0.39	0.27
inm.l-snm.l	0.5	12.8	0.84	12.6	0.97	0.24	0.89	0.12	-0.03
inm.r-snm.r	0.5	12.7	0.79	12.5	0.90	0.24	0.91	0.11	-0.03
n-al.l	0.5	25.6	0.86	24.2	1.35	<0.01#	0.41	0.58	0.49
n-al.r	0.5	25.6	0.91	24.4	1.42	0.01*	0.49	0.53	0.42
na-ans	0.5	15.3	0.52	14.9	0.71	<0.01#	0.63	0.57	0.48
pns-h	0.5	11.1	0.56	10.4	0.81	<0.01#	0.49	0.48	0.39
na-n	0.5	12.2	0.43	11.9	0.60	0.17	0.76	0.15	0.01
h-ans	0.5	39.0	1.16	37.6	1.68	0.02*	0.49	0.39	0.27

*significant at p<0.05 #significant at p<0.01

Table 4.2.5 Adjusted mean and adjusted SE for maxillary variables for males and females at age interval 0 to 1 year. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
zmi.l-zmi.r	0.5	62.5	2.26	56.7	3.26	0.04*	0.16	0.38	0.27
ms.l-ms.r	0.5	24.4	0.83	23.9	1.17	0.13	0.71	0.19	0.06
mxt.l-mxt.r	0.5	27.7	1.08	26.7	1.56	0.03*	0.58	0.35	0.24
gpf.l-gpf.r	0.5	21.4	0.88	20.6	1.27	0.05*	0.62	0.31	0.18
n-ans	0.5	27.2	0.95	26.2	1.48	0.02*	0.62	0.49	0.37
ans-pr	0.5	8.0	0.46	7.8	0.66	0.30	0.83	0.10	-0.07
mxt.l-ms.l	0.5	16.5	0.80	15.4	1.10	0.05*	0.45	0.34	0.21
mxt.r-ms.r	0.5	16.5	0.85	15.4	1.16	0.06	0.46	0.32	0.18
or.l-zmi.l	0.5	19.7	1.04	17.5	1.42	0.17	0.24	0.24	0.09
or.r-zmi.r	0.5	19.4	1.15	17.5	1.58	0.13	0.33	0.25	0.10
ms.l-inm.l	0.5	28.7	0.89	28.4	1.13	<0.01#	0.84	0.49	0.39
ms.r-inm.r	0.5	29.1	0.86	28.2	1.09	<0.01#	0.56	0.56	0.48
mxt.l-pr	0.5	28.9	0.81	29.0	1.17	0.07	0.94	0.28	0.15
mxt.r-pr	0.5	28.9	0.88	28.4	1.28	0.07	0.73	0.27	0.14
pns-ans	0.5	30.3	0.92	29.6	1.33	0.06	0.66	0.29	0.17

*significant at p<0.05 #significant at p<0.01

Table 4.2.6 Adjusted mean and adjusted SE for zygomatic variables for males and females at age interval 0 to 1 year. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
zt.l-zt.r	0.5	76.8	2.87	70.9	3.47	0.02*	0.20	0.39	0.30
zti.l-zti.r	0.5	77.7	2.73	71.8	3.30	0.01*	0.18	0.42	0.33
slor.l-zmi.l	0.5	26.2	1.16	23.0	1.79	0.03*	0.18	0.48	0.35
slor.r-zmi.r	0.5	26.2	1.21	23.7	1.86	0.03*	0.30	0.48	0.35
zti.l-or.l	0.5	30.6	1.36	27.6	1.56	0.08	0.17	0.29	0.18
zti.r-or.r	0.5	31.1	1.33	27.6	1.68	0.09	0.12	0.35	0.23
zt.l-au.l	0.5	19.8	0.48	18.8	0.58	<0.01#	0.20	0.72	0.68
zt.r-au.r	0.5	20.0	0.56	18.8	0.62	<0.01#	0.14	0.65	0.60

*significant at p<0.05 #significant at p<0.01

Table 4.2.7 Adjusted mean and adjusted SE for mandibular variables for males and females at age interval 0 to 1 year. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
go.l-go.r	0.5	54.9	2.05	50.5	2.96	0.04	0.25	0.36	0.24
cd.l-cd.r	0.5	73.2	2.64	69.6	3.82	0.05	0.44	0.31	0.18
cd.l-ct.l	0.5	15.1	0.63	14.5	0.91	0.09	0.60	0.24	0.10
cd.r-ct.r	0.5	15.8	0.67	14.5	0.98	0.11	0.30	0.25	0.11
cd.l-go.l	0.5	20.4	1.07	20.0	1.55	0.14	0.86	0.19	0.04
cd.r-go.r	0.5	20.7	1.06	20.0	1.54	0.09	0.69	0.24	0.11
gn-id	0.5	15.7	0.87	13.0	1.16	0.02*	0.09	0.52	0.41
go.l-gn	0.5	46.5	2.18	41.9	2.94	0.02*	0.23	0.51	0.40
go.r-gn	0.5	45.7	2.06	41.5	2.77	0.01*	0.26	0.55	0.44
gn-cd.l	0.5	60.7	2.45	57.2	3.30	0.02*	0.41	0.47	0.36
gn-cd.r	0.5	61.1	2.25	56.9	3.03	0.01*	0.29	0.54	0.44

*significant at $p<0.05$ #significant at $p<0.01$

Table 4.2.8 Adjusted mean and adjusted SE for inter-regional variables for males and females at age interval 0 to 1 year. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
au.l-ans	0.5	60.9	1.93	57.3	2.78	0.02*	0.30	0.42	0.32
au.r-ans	0.5	61.2	1.73	56.4	2.45	<0.01#	0.14	0.54	0.45
s-pns	0.5	23.6	0.95	21.9	1.37	0.04*	0.31	0.34	0.22
s-ans	0.5	48.3	1.39	46.7	2.00	0.05	0.51	0.31	0.18
ba-pns	0.5	30.6	1.02	28.8	1.47	0.03*	0.31	0.37	0.26
ba-ans	0.5	60.9	1.76	58.1	2.55	0.02*	0.40	0.39	0.28

*significant at $p<0.05$ #significant at $p<0.01$

Table 4.2.9 Adjusted mean and adjusted SE for angular and index variables for males and females at age interval 0 to 1 year. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
ba-s-n	0.5	139.5	2.21	140.0	3.45	0.36	0.90	0.09	-0.08
s-n-na	0.5	95.7	2.37	97.3	3.26	0.02*	0.69	0.38	0.28
morfl.l-n-morfl.r	0.5	100.1	2.82	94.1	3.75	0.48	0.22	0.14	0.02
petsa.l-au.l-zt.l	0.5	98.6	2.56	103.3	3.10	0.34	0.24	0.15	0.01
petsa.r-au.r-zt.r	0.5	97.7	2.16	104.2	2.40	0.32	0.06	0.29	0.18
cd.l-go.l-gn	0.5	126.1	2.82	132.2	3.80	0.21	0.23	0.26	0.09
cd.r-go.r-gn	0.5	129.8	2.74	133.1	3.69	0.13	0.49	0.26	0.09
go.l-gn-go.r	0.5	72.0	2.71	77.0	3.64	0.09	0.29	0.33	0.19
petp.l-es-petp.r	0.5	N/A							
s-n/ac.l-spa.l	0.5	131.2	1.41	131.3	2.04	0.40	0.97	0.04	-0.07
s-n/ac.r-spa.r	0.5	128.9	1.01	129.9	1.46	0.04*	0.59	0.25	0.15
s-n/ans-pns	0.5	11.5	1.31	11.0	2.05	0.75	0.85	0.01	-0.21
n-ans/ans-pns	0.5	87.2	1.38	82.6	2.15	<0.01#	0.11	0.58	0.49
cindx.l-cindx.r:cindxa-cindxp	0.5	0.9	0.02	0.9	0.03	0.19	0.60	0.12	0.01
sor.l-or.l:lor.l-morfl.l	0.5	1.0	0.02	0.9	0.02	0.01*	0.09	0.47	0.38
sor.r-or.r:lor.r-morfl.r	0.5	1.0	0.02	0.9	0.03	0.06	0.14	0.37	0.25

*significant at p<0.05 #significant at p<0.01

Table 4.2.10 Adjusted mean and adjusted SE for cranial vault variables for males and females at age interval 5 to 10 years. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
cindx.l-cindx.r	7.5	140.1	1.53	139.8	1.49	0.61	0.88	0.01	-0.06
as.l-as.r	7.5	104.7	0.93	107.5	0.85	0.74	0.04*	0.15	0.08
po.l-po.r	7.5	106.3	1.22	104.6	1.12	0.01*	0.32	0.22	0.17
br-po.l	7.5	127.8	1.39	124.8	1.46	0.14	0.14	0.18	0.09
br-po.r	7.5	128.1	1.29	124.7	1.42	0.09	0.08	0.21	0.13
ba-br	7.5	130.1	1.68	130.0	2.10	1.00	0.98	0.00	-0.15
n-br	7.5	107.3	1.47	109.5	1.53	0.22	0.32	0.11	0.00
l-o	7.5	99.5	1.67	100.4	1.84	0.68	0.71	0.01	-0.10
l-br	7.5	105.1	1.75	105.0	1.71	0.86	0.98	0.00	-0.08
cindxa-cindxp	7.5	166.6	1.85	165.7	1.81	0.98	0.72	0.01	-0.07
spc.l-as.l	7.5	91.2	0.94	91.4	0.93	0.69	0.88	0.01	-0.08
spc.r-as.r	7.5	92.1	0.86	89.4	0.83	0.76	0.03*	0.22	0.15
l-as.l	7.5	83.5	1.65	85.7	1.68	0.37	0.38	0.05	-0.03
l-as.r	7.5	85.0	1.44	85.2	1.44	0.70	0.90	0.01	-0.07

*significant at p<0.05

Table 4.2.11 Adjusted mean and adjusted SE for cranial base variables for males and females at age interval 5 to 10 years. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
spa.l-spa.r	7.5	72.4	1.25	68.7	1.12	<0.01#	0.04*	0.44	0.41
spa.l-es	7.5	38.1	0.89	35.8	0.75	<0.01#	0.06	0.28	0.23
spa.r-es	7.5	39.4	0.92	36.5	0.76	<0.01#	0.02*	0.30	0.25
ac.l-spa.l	7.5	31.9	0.58	30.5	0.52	<0.01#	0.08	0.39	0.35
ac.r-spa.r	7.5	32.1	0.74	30.5	0.65	<0.01#	0.13	0.21	0.17
ac.l-ac.r	7.5	23.6	0.36	22.4	0.33	0.14	0.02*	0.17	0.12
petsa.l-petsa.r	7.5	22.9	0.43	22.4	0.38	0.06	0.37	0.10	0.06
pts.l-pts.r	7.5	22.3	0.44	22.0	0.43	0.03*	0.58	0.18	0.12
petp.l-petp.r	7.5	108.1	0.86	106.3	0.78	0.16	0.15	0.09	0.04
ss.l-ss.r	7.5	62.1	0.54	60.5	0.55	<0.01#	0.04*	0.37	0.31
fmlhg.l-fmlhg.r	7.5	28.5	0.49	27.7	0.51	0.54	0.30	0.05	-0.03
sor.l-spa.l	7.5	38.0	0.78	36.7	0.72	0.06	0.22	0.15	0.09
sor.r-spa.r	7.5	38.3	0.75	36.7	0.67	0.05	0.12	0.16	0.11
spa.l-petp.l	7.5	66.0	0.81	66.0	0.75	0.92	1.00	0.00	-0.06
spa.r-petp.r	7.5	66.1	0.84	66.6	0.74	0.55	0.65	0.02	-0.04
petsa.l-petp.l	7.5	53.3	0.57	52.2	0.52	0.54	0.19	0.05	0.00
petsa.r-petp.r	7.5	53.7	0.59	53.0	0.52	0.67	0.38	0.02	-0.03
pts.l-petsa.l	7.5	15.9	0.52	15.7	0.48	0.20	0.77	0.07	-0.01
pts.r-petsa.r	7.5	16.0	0.52	15.6	0.49	0.03*	0.61	0.18	0.11
hn.l-pts.l	7.5	30.8	0.47	29.6	0.50	0.01*	0.12	0.31	0.24
hn.r-pts.r	7.5	30.9	0.55	30.0	0.59	0.09	0.32	0.15	0.07
ba-n	7.5	88.5	0.92	88.0	0.93	<0.01#	0.73	0.35	0.29
ba-s	7.5	37.1	0.83	38.1	0.84	0.01*	0.43	0.30	0.23
s-n	7.5	59.8	0.71	59.2	0.63	0.15	0.50	0.08	0.02
n-es	7.5	32.7	0.66	33.6	0.56	0.26	0.31	0.08	0.01
ba-h	7.5	27.2	0.49	28.3	0.49	0.36	0.14	0.13	0.06
ba-o	7.5	35.0	0.62	33.2	0.61	0.76	0.05*	0.15	0.09

*significant at $p<0.05$ #significant at $p<0.01$

Table 4.2.12 Adjusted mean and adjusted SE for orbital variables for males and females at age interval 5 to 10 years. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
or.l-or.r	7.5	46.8	0.71	46.3	0.77	<0.01#	0.67	0.37	0.32
morfl.l-morfl.r	7.5	18.8	0.46	18.6	0.43	0.58	0.69	0.02	-0.06
lor.l-lor.r	7.5	86.5	1.22	85.0	1.30	0.13	0.39	0.15	0.06
ofa.l-ofa.r	7.5	25.6	0.43	24.1	0.40	<0.01#	0.02*	0.47	0.44
lor.l-morfl.l	7.5	35.8	0.53	35.1	0.56	0.35	0.37	0.09	-0.02
lor.r-morfl.r	7.5	36.3	0.54	34.9	0.56	0.17	0.10	0.19	0.11
sor.l-or.l	7.5	31.2	0.48	30.6	0.51	0.97	0.43	0.03	-0.07
sor.r-or.r	7.5	30.7	0.50	30.7	0.52	0.14	0.96	0.11	0.02
ofa.l-sor.l	7.5	46.4	0.44	46.0	0.40	0.48	0.57	0.02	-0.04
ofa.r-sor.r	7.5	46.8	0.48	46.4	0.44	0.69	0.56	0.02	-0.05
ofa.l-or.l	7.5	42.5	0.59	41.3	0.62	0.24	0.16	0.16	0.07
ofa.r-or.r	7.5	42.9	0.62	42.0	0.65	0.46	0.33	0.07	-0.03
ofa.l-morfl.l	7.5	40.1	0.62	39.4	0.54	0.48	0.43	0.04	-0.03
ofa.r-morfl.r	7.5	39.9	0.63	39.2	0.55	0.63	0.39	0.04	-0.04
ofa.l-slor.l	7.5	43.5	0.32	43.6	0.31	0.13	0.75	0.08	0.02
ofa.r-slor.r	7.5	44.2	0.44	43.9	0.42	0.51	0.58	0.02	-0.04

*significant at p<0.05 #significant at p<0.01

Table 4.2.13 Adjusted mean and adjusted SE for nasal variables for males and females at age interval 5 to 10 years. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
snm.l-snm.r	7.5	10.4	0.52	10.1	0.48	0.27	0.67	0.06	-0.01
inm.l-inm.r	7.5	14.1	0.39	14.2	0.43	0.54	0.76	0.02	-0.07
al.l-al.r	7.5	20.3	0.44	19.9	0.44	0.09	0.61	0.13	0.05
inm.l-snm.l	7.5	21.2	0.50	21.7	0.56	0.01*	0.48	0.32	0.25
inm.r-snm.r	7.5	20.7	0.43	21.6	0.48	<0.01#	0.19	0.44	0.38
n-al.l	7.5	40.3	0.67	39.8	0.72	<0.01#	0.59	0.43	0.37
n-al.r	7.5	40.0	0.73	39.7	0.79	<0.01#	0.74	0.44	0.37
na-ans	7.5	22.6	0.66	22.7	0.61	0.12	0.89	0.14	0.04
ans-al.l	7.5	11.6	0.26	11.5	0.23	0.03*	0.63	0.21	0.13
ans-al.r	7.5	12.1	0.38	11.6	0.34	0.07	0.29	0.17	0.09
pns-h	7.5	19.6	0.51	18.6	0.57	0.20	0.19	0.12	0.04
na-n	7.5	20.5	0.73	20.3	0.80	<0.01#	0.91	0.32	0.25
h-ans	7.5	58.8	0.94	57.5	0.93	0.01*	0.33	0.30	0.22

*significant at p<0.05 #significant at p<0.01

Table 4.2.14 Adjusted mean and adjusted SE for maxillary variables for males and females at age interval 5 to 10 years. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
zmi.l-zmi.r	7.5	83.9	0.83	83.9	0.82	<0.01#	0.96	0.57	0.53
ms.l-ms.r	7.5	35.7	0.70	33.9	0.66	<0.01#	0.06	0.44	0.39
mxt.l-mxt.r	7.5	40.6	0.82	40.0	0.84	0.02*	0.62	0.22	0.15
gpf.l-gpf.r	7.5	28.3	0.46	27.7	0.47	<0.01#	0.40	0.33	0.27
n-ans	7.5	41.7	0.75	41.1	0.73	<0.01#	0.61	0.46	0.40
ans-pr	7.5	14.3	0.69	14.4	0.58	0.99	0.93	0.00	-0.14
mxt.l-ms.l	7.5	33.7	0.66	34.1	0.71	0.02*	0.68	0.31	0.23
mxt.r-ms.r	7.5	33.8	0.67	34.0	0.73	<0.01#	0.85	0.36	0.28
or.l-zmi.l	7.5	28.7	0.47	28.5	0.50	0.03*	0.82	0.21	0.13
or.r-zmi.r	7.5	28.4	0.40	28.0	0.42	0.23	0.57	0.07	-0.02
ms.l-inm.l	7.5	45.5	0.57	45.6	0.61	0.01*	0.84	0.33	0.25
ms.r-inm.r	7.5	45.8	0.56	45.4	0.61	<0.01#	0.64	0.40	0.33
mxt.l-pr	7.5	44.9	1.00	45.9	0.84	<0.01#	0.45	0.44	0.36
mxt.r-pr	7.5	45.6	0.98	45.7	0.83	0.01*	0.93	0.39	0.30
pns-ans	7.5	42.9	0.82	43.0	0.74	0.03*	0.95	0.22	0.14

*significant at p<0.05 #significant at p<0.01

Table 4.2.15 Adjusted mean and adjusted SE for zygomatic variables for males and females at age interval 5 to 10 years. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
zt.l-zt.r	7.5	99.8	1.16	98.3	1.23	<0.01#	0.38	0.26	0.20
zti.l-zti.r	7.5	104.9	1.14	102.8	1.19	<0.01#	0.22	0.40	0.34
slor.l-zmi.l	7.5	36.7	0.55	36.1	0.56	<0.01#	0.42	0.34	0.26
slor.r-zmi.r	7.5	37.0	0.52	35.8	0.53	<0.01#	0.12	0.46	0.40
zti.l-or.l	7.5	45.2	0.69	43.2	0.77	0.15	0.07	0.22	0.13
zti.r-or.r	7.5	44.5	0.60	43.1	0.63	<0.01#	0.11	0.34	0.28
zt.l-au.l	7.5	31.7	0.81	31.5	0.77	<0.01#	0.88	0.30	0.24
zt.r-au.r	7.5	31.9	0.76	31.2	0.81	<0.01#	0.53	0.35	0.29

*significant at p<0.05 #significant at p<0.01

Table 4.2.16 Adjusted mean and adjusted SE for mandibular variables for males and females at age interval 5 to 10 years. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
go.l-go.r	7.5	76.9	1.48	76.3	1.41	<0.01#	0.76	0.32	0.25
cd.l-cd.r	7.5	106.0	1.41	102.4	1.42	0.01*	0.09	0.29	0.23
cd.l-ct.l	7.5	24.8	0.48	24.4	0.52	<0.01#	0.65	0.37	0.32
cd.r-ct.r	7.5	25.0	0.44	24.5	0.47	<0.01#	0.43	0.30	0.24
cd.l-go.l	7.5	40.2	0.78	38.5	0.75	<0.01#	0.12	0.40	0.34
cd.r-go.r	7.5	40.6	0.72	39.0	0.70	0.04*	0.11	0.28	0.20
gn-id	7.5	24.5	0.69	25.2	0.90	0.94	0.56	0.05	-0.16
go.l-gn	7.5	70.0	0.92	73.5	1.19	0.13	0.05	0.60	0.51
go.r-gn	7.5	70.5	0.92	73.5	1.20	0.02*	0.08	0.68	0.61
gn-cd.l	7.5	99.1	1.18	101.4	1.54	0.04*	0.26	0.56	0.46
gn-cd.r	7.5	100.2	1.16	102.6	1.50	0.02*	0.24	0.64	0.57

*significant at p<0.05 #significant at p<0.01

Table 4.2.17 Adjusted mean and adjusted SE for inter-regional variables for males and females at age interval 5 to 10 years. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
au.l-ans	7.5	89.9	1.06	87.5	0.94	<0.01#	0.11	0.52	0.45
au.r-ans	7.5	90.0	1.29	87.2	1.19	<0.01#	0.12	0.52	0.45
s-pns	7.5	39.0	0.77	38.1	0.82	0.10	0.45	0.16	0.07
s-ans	7.5	70.6	1.15	69.5	1.04	0.12	0.49	0.18	0.07
ba-pns	7.5	39.4	0.77	38.0	0.84	0.20	0.24	0.11	0.02
ba-ans	7.5	82.1	1.28	81.1	1.22	0.07	0.59	0.17	0.08

*significant at p<0.05 #significant at p<0.01

Table 4.2.18 Adjusted mean and adjusted SE for angular and index variables for males and females at age interval 5 to 10 years. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
ba-s-n	7.5	130.5	1.96	131.0	1.93	0.69	0.88	0.01	-0.09
s-n-na	7.5	102.3	1.64	98.1	1.58	0.64	0.08	0.17	0.09
morfl.l-n-morfl.r	7.5	89.3	1.83	88.6	2.01	0.60	0.79	0.01	-0.06
petsa.l-au.l-zt.l	7.5	89.4	1.24	87.5	1.31	0.99	0.28	0.06	-0.03
petsa.r-au.r-zt.r	7.5	89.9	1.41	87.0	1.37	0.27	0.16	0.13	0.04
cd.l-go.l-gn	7.5	124.3	2.55	125.1	1.96	0.89	0.81	0.01	-0.20
cd.r-go.r-gn	7.5	125.6	2.48	125.7	1.90	0.98	0.97	0.00	-0.22
go.l-gn-go.r	7.5	65.3	1.87	66.0	1.44	0.32	0.78	0.11	-0.08
petp.l-es-petp.r	7.5	77.0	0.97	75.6	1.17	0.10	0.38	0.10	0.04
s-n/ac.l-spa.l	7.5	126.3	1.35	125.3	1.55	0.16	0.62	0.08	0.01
s-n/ac.r-spa.r	7.5	125.7	1.16	123.4	1.37	0.02*	0.21	0.21	0.15
s-n/ans-pns	7.5	7.4	1.18	8.4	1.31	0.65	0.55	0.04	-0.09
n-ans/ans-pns	7.5	85.8	1.12	86.8	1.15	0.34	0.54	0.09	-0.03
cindx.l-cindx.r: cindxa-cindxp	7.5	0.8	0.01	0.8	0.01	0.62	0.96	0.01	-0.06
sor.l-or.l:lor.l-morfl.l	7.5	0.9	0.02	0.9	0.01	0.38	0.95	0.04	-0.06
sor.r-or.r:lor.r-morfl.r	7.5	0.9	0.01	0.8	0.01	0.97	0.09	0.15	0.06

*significant at p<0.05 #significant at p<0.01

Table 4.2.19 Adjusted mean and adjusted SE for cranial vault variables for males and females at age interval 18 years and above. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
cindx.l-cindx.r	22.3	146.8	1.52	143.0	1.93	0.37	0.08	0.21	0.11
as.l-as.r	22.3	110.9	1.91	111.1	2.19	0.19	0.93	0.09	-0.01
po.l-po.r	22.3	118.8	1.33	114.0	1.48	0.49	<0.01#	0.33	0.27
br-po.l	22.3	133.1	1.32	130.1	1.72	0.30	0.12	0.23	0.12
br-po.r	22.3	133.0	1.19	130.6	1.53	0.45	0.15	0.16	0.05
ba-br	22.3	139.1	2.03	135.4	2.61	0.32	0.20	0.16	0.05
n-br	22.3	114.7	1.39	112.7	1.74	0.86	0.29	0.08	-0.05
l-o	22.3	102.9	2.00	101.1	2.57	0.50	0.51	0.06	-0.07
l-br	22.3	108.8	2.62	106.1	3.37	0.55	0.46	0.06	-0.06
cindxa-cindxp	22.3	174.9	2.77	171.2	3.54	0.40	0.33	0.10	-0.02
spc.l-as.l	22.3	99.0	2.81	95.1	4.00	0.97	0.14	0.20	0.07
spc.r-as.r	22.3	103.0	3.24	98.5	4.45	0.27	0.12	0.33	0.22
l-as.l	22.3	87.0	1.18	86.8	1.52	0.11	0.90	0.16	0.05
l-as.r	22.3	87.5	1.46	87.4	1.87	0.28	0.96	0.08	-0.05

*significant at p<0.05 #significant at p<0.01

Table 4.2.20 Adjusted mean and adjusted SE for cranial base variables for males and females at age interval 18 years and above. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
spa.l-spa.r	22.3	80.8	1.63	79.3	1.88	0.27	0.45	0.09	0.00
spa.l-es	22.3	43.1	0.99	43.2	1.14	0.17	0.91	0.10	0.00
spa.r-es	22.3	43.6	1.23	43.7	1.42	0.46	0.93	0.03	-0.07
ac.l-spa.l	22.3	34.9	1.03	35.0	1.16	0.22	0.96	0.08	-0.02
ac.r-spa.r	22.3	34.3	1.02	34.7	1.15	0.47	0.74	0.03	-0.07
ac.l-ac.r	22.3	25.4	0.57	23.7	0.62	0.65	0.02*	0.25	0.17
petsa.l-petsa.r	22.3	26.9	0.60	26.1	0.67	0.17	0.28	0.12	0.05
pts.l-pts.r	22.3	28.0	0.80	27.4	0.88	0.12	0.53	0.12	0.04
petp.l-petp.r	22.3	110.6	1.29	108.5	1.48	0.81	0.20	0.09	-0.01
ss.l-ss.r	22.3	66.4	1.00	64.5	1.10	1.00	0.10	0.11	0.04
fmlhg.l-fmlhg.r	22.3	29.8	0.73	28.8	0.80	0.33	0.23	0.10	0.02
sor.l-spa.l	22.3	44.5	1.51	43.8	1.75	0.15	0.72	0.12	0.02
sor.r-spa.r	22.3	42.9	1.58	42.3	1.78	0.88	0.76	0.01	-0.10
spa.l-petp.l	22.3	71.2	1.11	69.1	1.32	0.21	0.14	0.19	0.10
spa.r-petp.r	22.3	72.1	1.17	67.8	1.35	0.32	<0.01#	0.35	0.28
petsa.l-petp.l	22.3	55.1	0.86	53.5	0.97	0.62	0.12	0.12	0.04
petsa.r-petp.r	22.3	55.4	0.82	53.8	0.92	0.91	0.13	0.11	0.02
pts.l-petsa.l	22.3	19.2	0.64	18.6	0.72	0.90	0.45	0.03	-0.06
pts.r-petsa.r	22.3	19.0	0.73	18.7	0.82	0.90	0.77	0.00	-0.08
hn.l-pts.l	22.3	34.0	0.64	31.4	0.73	0.68	<0.01#	0.37	0.31
hn.r-pts.r	22.3	34.5	0.58	31.8	0.66	0.58	<0.01#	0.43	0.38
ba-n	22.3	103.1	0.77	96.8	0.86	0.01*	<0.01#	0.75	0.72
ba-s	22.3	45.8	0.88	42.4	0.99	0.87	<0.01#	0.34	0.28
s-n	22.3	68.7	0.94	65.0	1.05	0.08	<0.01#	0.44	0.38
n-es	22.3	37.6	1.02	33.5	1.12	0.86	<0.01#	0.40	0.33
ba-h	22.3	32.2	0.85	29.6	0.92	0.47	0.01*	0.26	0.20
ba-o	22.3	32.9	0.66	32.5	0.75	0.09	0.64	0.13	0.06

*significant at p<0.05 #significant at p<0.01

Table 4.2.21 Adjusted mean and adjusted SE for orbital variables for males and females at age interval 18 years and above. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
slor.l-slor.r	22.3	100.2	1.20	94.5	1.35	0.10	<0.01#	0.53	0.47
or.l-or.r	22.3	56.8	0.94	52.6	1.07	0.08	<0.01#	0.49	0.44
morfl.l-morfl.r	22.3	21.4	0.63	21.0	0.71	0.02*	0.66	0.28	0.20
lor.l-lor.r	22.3	100.1	1.37	94.3	1.54	0.09	<0.01#	0.52	0.45
ofa.l-ofa.r	22.3	31.3	0.98	28.7	1.05	0.38	0.03*	0.24	0.17
lor.l-morfl.l	22.3	40.9	0.62	38.1	0.70	0.71	<0.01#	0.47	0.40
lor.r-morfl.r	22.3	41.5	0.68	37.9	0.74	0.95	<0.01#	0.53	0.48
sor.l-or.l	22.3	33.3	0.59	32.8	0.69	0.77	0.53	0.03	-0.09
sor.r-or.r	22.3	32.8	0.73	32.9	0.80	0.60	0.88	0.02	-0.09
ofa.l-sor.l	22.3	49.7	0.68	48.2	0.76	0.28	0.07	0.22	0.13
ofa.r-sor.r	22.3	49.3	0.79	48.1	0.85	0.51	0.17	0.12	0.03
ofa.l-or.l	22.3	47.6	0.91	45.1	1.03	0.70	0.04*	0.24	0.15
ofa.r-or.r	22.3	47.5	0.81	45.5	0.87	0.97	0.04*	0.20	0.12
ofa.l-morfl.l	22.3	42.3	0.82	41.3	0.90	0.79	0.35	0.05	-0.06
ofa.r-morfl.r	22.3	42.6	0.74	41.5	0.81	0.41	0.23	0.12	0.01
ofa.l-slor.l	22.3	48.1	0.80	47.6	0.91	0.27	0.65	0.09	-0.02
ofa.r-slor.r	22.3	48.5	0.74	47.4	0.80	0.34	0.20	0.13	0.04

*significant at p<0.05 #significant at p<0.01

Table 4.2.22 Adjusted mean and adjusted SE for nasal variables for males and females at age interval 18 years and above. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
snm.l-snm.r	22.3	11.7	0.68	11.0	0.75	0.03*	0.44	0.22	0.14
inm.l-inm.r	22.3	16.4	0.56	16.3	0.63	<0.01#	0.92	0.30	0.24
al.l-al.r	22.3	22.1	0.54	22.7	0.61	<0.01#	0.38	0.46	0.40
inm.l-snm.l	22.3	26.6	0.71	25.1	0.81	0.43	0.10	0.16	0.08
inm.r-snm.r	22.3	26.3	0.83	24.7	0.93	0.65	0.10	0.14	0.05
n-al.l	22.3	48.8	0.91	47.8	1.09	0.22	0.37	0.13	0.03
n-al.r	22.3	48.8	0.96	47.5	1.14	0.28	0.29	0.13	0.03
na-ans	22.3	29.8	0.83	27.7	0.98	0.94	0.07	0.17	0.08
ans-al.l	22.3	14.5	0.41	14.3	0.47	0.14	0.60	0.11	0.02
ans-al.r	22.3	14.4	0.40	13.7	0.45	0.03*	0.19	0.28	0.20
pns-h	22.3	23.0	0.71	22.1	0.82	0.44	0.29	0.09	0.00
na-n	22.3	24.6	1.04	23.8	1.19	0.79	0.54	0.02	-0.08
h-ans	22.3	70.1	1.19	66.5	1.37	0.16	0.02*	0.28	0.21

*significant at p<0.05 #significant at p<0.01

Table 4.2.23 Adjusted mean and adjusted SE for maxillary variables for males and females at age interval 18 years and above. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
zmi.l-zmi.r	22.3	102.4	1.47	96.0	1.68	0.24	<0.01#	0.43	0.37
ms.l-ms.r	22.3	44.2	0.96	41.5	1.06	0.02*	0.03*	0.44	0.37
mxt.l-mxt.r	22.3	48.4	1.14	45.9	1.32	0.17	0.10	0.22	0.13
gpf.l-gpf.r	22.3	34.7	1.00	32.9	1.20	0.09	0.12	0.22	0.13
n-ans	22.3	51.4	0.96	48.9	1.14	0.87	0.06	0.21	0.11
ans-pr	22.3	18.8	0.83	18.0	1.05	0.62	0.50	0.04	-0.09
mxt.l-ms.l	22.3	46.1	0.99	40.1	1.21	0.02*	<0.01#	0.64	0.59
mxt.r-ms.r	22.3	46.4	1.14	41.8	1.36	0.43	<0.01#	0.41	0.33
or.l-zmi.l	22.3	34.7	1.13	32.9	1.37	0.51	0.22	0.11	0.01
or.r-zmi.r	22.3	35.8	0.95	33.3	1.10	0.68	0.04*	0.21	0.13
ms.l-inm.l	22.3	53.8	0.88	49.3	0.99	0.50	0.01#	0.52	0.46
ms.r-inm.r	22.3	54.2	0.97	50.1	1.10	0.72	<0.01#	0.41	0.35
mxt.l-pr	22.3	60.6	1.08	58.6	1.37	0.07	0.21	0.26	0.16
mxt.r-pr	22.3	60.8	1.06	57.9	1.34	0.09	0.07	0.33	0.23
pns-ans	22.3	52.1	1.11	48.4	1.28	0.91	0.02*	0.29	0.21

*significant at p<0.05 #significant at p<0.01

Table 4.2.24 Adjusted mean and adjusted SE for zygomatic variables for males and females at age interval 18 years and above. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
zt.l-zt.r	22.3	119.5	1.48	111.9	1.73	0.17	<0.01#	0.52	0.47
zti.l-zti.r	22.3	127.1	1.39	119.5	1.62	0.17	<0.01#	0.55	0.51
slor.l-zmi.l	22.3	44.5	0.75	43.1	0.91	0.77	0.19	0.12	0.00
slor.r-zmi.r	22.3	44.2	0.75	43.1	0.85	0.68	0.25	0.09	-0.02
zti.l-or.l	22.3	53.9	0.80	51.4	0.93	0.43	0.02*	0.29	0.22
zti.r-or.r	22.3	54.3	0.77	50.6	0.86	0.79	<0.01#	0.47	0.42
zt.l-au.l	22.3	43.0	0.88	39.2	1.02	0.02*	<0.01#	0.50	0.45
zt.r-au.r	22.3	43.4	1.04	38.5	1.18	0.04*	<0.01#	0.50	0.46

*significant at p<0.05 #significant at p<0.01

Table 4.2.25 Adjusted mean and adjusted SE for mandibular variables for males and females at age interval 18 years and above. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
go.l-go.r	22.3	95.4	2.52	87.8	2.95	0.15	0.02*	0.29	0.22
cd.l-cd.r	22.3	125.0	1.62	119.3	1.78	0.05*	<0.01#	0.40	0.35
cd.l-ct.l	22.3	32.0	0.88	30.2	0.97	0.18	0.07	0.21	0.13
cd.r-ct.r	22.3	31.9	0.80	31.4	0.87	0.22	0.59	0.07	-0.01
cd.l-go.l	22.3	55.0	1.88	47.9	2.19	0.85	<0.01#	0.34	0.27
cd.r-go.r	22.3	54.8	1.68	49.1	1.95	0.70	<0.01#	0.28	0.21
gn-id	22.3	34.1	1.40	29.7	1.70	0.17	0.04*	0.34	0.25
go.l-gn	22.3	87.7	1.96	84.6	2.37	0.26	0.25	0.16	0.04
go.r-gn	22.3	89.5	1.95	85.6	2.36	0.07	0.16	0.29	0.19
gn-cd.l	22.3	124.1	2.04	114.5	2.46	0.14	<0.01#	0.50	0.43
gn-cd.r	22.3	125.0	2.24	117.2	2.71	0.16	0.02*	0.38	0.30

*significant at p<0.05 #significant at p<0.01

Table 4.2.26 Adjusted mean and adjusted SE for inter-regional variables for males and females at age interval 18 years and above. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
au.l-ans	22.3	108.2	1.43	101.1	1.73	0.08	<0.01#	0.49	0.43
au.r-ans	22.3	108.8	1.35	101.6	1.64	0.29	<0.01#	0.50	0.45
s-pns	22.3	47.5	1.12	44.7	1.35	0.97	0.06	0.19	0.10
s-ans	22.3	85.2	1.27	79.8	1.53	0.52	<0.01#	0.38	0.31
ba-pns	22.3	45.4	0.93	43.6	1.08	0.24	0.13	0.18	0.09
ba-ans	22.3	97.4	1.38	91.8	1.60	0.39	<0.01#	0.36	0.30

*significant at p<0.05 #significant at p<0.01

Table 4.2.27 Adjusted mean and adjusted SE for angular and index variables for males and females at age interval 18 years and above. Probability of age (*p* age) and sex (*p* sex) differences and R^2 and adjusted R^2 are also presented.

Measurement	Mid Age	Male		Female		*p* age	*p* sex	R^2	Adjusted R^2
		Adjusted Mean	Adjusted SE	Adjusted Mean	Adjusted SE				
ba-s-n	22.3	128.1	1.89	126.9	2.12	0.93	0.60	0.01	-0.08
s-n-na	22.3	110.0	1.98	107.5	2.25	0.89	0.30	0.06	-0.04
morfl.l-n-morfl.r	22.3	88.1	3.62	86.0	4.05	0.69	0.63	0.02	-0.08
petsa.l-au.l-zt.l	22.3	87.8	1.62	90.4	1.87	0.48	0.20	0.10	0.01
petsa.r-au.r-zt.r	22.3	87.1	1.74	88.8	1.98	0.91	0.41	0.03	-0.06
cd.l-go.l-gn	22.3	118.8	2.74	120.2	3.32	0.86	0.72	0.01	-0.13
cd.r-go.r-gn	22.3	117.9	2.86	121.7	3.46	0.67	0.34	0.07	-0.06
go.l-gn-go.r	22.3	66.0	1.80	62.5	2.17	0.91	0.18	0.13	0.00
petp.l-es-petp.r	22.3	70.8	1.39	70.4	1.60	0.22	0.82	0.08	-0.01
s-n/ac.l-spa.l	22.3	119.6	1.50	118.7	1.70	0.14	0.63	0.13	0.03
s-n/ac.r-spa.r	22.3	120.9	1.62	120.8	1.83	0.48	0.97	0.03	-0.08
s-n/ans-pns	22.3	7.7	1.05	8.2	1.25	0.64	0.72	0.02	-0.11
n-ans/ans-pns	22.3	83.2	1.11	83.7	1.32	0.21	0.75	0.11	-0.01
cindx.l-cindx.r: cindxa-cindxp	22.3	0.8	0.02	0.8	0.02	0.81	0.84	0.01	-0.12
sor.l-or.l:lor.l-morfl.l	22.3	0.8	0.02	0.9	0.03	0.64	0.11	0.17	0.06
sor.r-or.r:lor.r-morfl.r	22.3	0.8	0.02	0.9	0.02	0.76	0.02*	0.29	0.20

*significant at $p<0.05$

Table 4.2.28 The magnitudes of differences between males and females for cranial vault variables at different age categories are presented as percentage of dimorphism.

Measurement	Mid age 0.5 year					Mid age 7.5 year					Mid age 22.3 year				
	Male		Female		% dimorphism	Male		Female		% dimorphism	Male		Female		% dimorphism
	N	Adjusted mean	N	Adjusted mean		N	Adjusted mean	N	Adjusted mean		N	Adjusted mean	N	Adjusted mean	
cindx.l-cindx.r	12	116.0	7	110.8	4.73	13	140.1	15	139.8	0.23	11	146.8	6	143.0	2.67
as.l-as.r	9	81.4	6	78.3	4.08	12	104.7	16	107.5	-2.53	11	110.9	8	111.1	-0.17
po.l-po.r	10	74.3	4	64.4	15.45	13	106.3	17	104.6	1.58	13	118.8	11	114.0	4.21
br-po.l	7	104.6	5	96.2	8.78	10	127.8	11	124.8	2.41	11	133.1	6	130.1	2.29
br-po.r	7	104.5	4	93.0	12.36	11	128.1	11	124.7	2.76	11	133.0	6	130.6	1.85
ba-br	7	104.4	5	97.2	7.37	9	130.1	7	130.0	0.05	11	139.1	6	135.4	2.75
n-br	11	83.7	5	77.0	8.59	9	107.3	10	109.5	-2.03	10	114.7	6	112.7	1.83
l-o	10	78.3	5	77.0	1.70	10	99.5	11	100.4	-0.95	11	102.9	6	101.1	1.82
l-br	10	89.4	7	86.4	3.44	13	105.1	14	105.0	0.07	11	108.8	6	106.1	2.54
cindxa-cindxp	12	131.2	7	128.4	2.24	13	166.6	15	165.7	0.57	11	174.9	6	171.2	2.18
spc.l-as.l	9	66.7	5	63.1	5.74	11	91.2	13	91.4	-0.23	9	99.0	5	95.1	4.08
spc.r-as.r	9	67.5	5	63.6	6.11	11	92.1	14	89.4	3.11	10	103.0	5	98.5	4.56
l-as.l	10	70.5	6	71.1	-0.89	13	83.5	14	85.7	-2.52	11	87.0	6	86.8	0.25
l-as.r	10	71.5	6	70.8	1.06	12	85.0	14	85.2	-0.29	11	87.5	6	87.4	0.12

Table 4.2.29 The magnitudes of differences between males and females for cranial base variables at different age categories are presented as percentage of dimorphism.

Measurement	Mid age 0.5 year					Mid age 7.5 year					Mid age 22.3 year				
	Male		Female		% dimorphism	Male		Female		% dimorphism	Male		Female		% dimorphism
	N	Adjusted mean	N	Adjusted mean		N	Adjusted mean	N	Adjusted mean		N	Adjusted mean	N	Adjusted mean	
spa.l-spa.r	14	46.0	8	43.3	6.17	15	72.4	20	68.7	5.36	10	80.8	9	79.3	1.89
spa.l-es	N/A	N/A	N/A	N/A	N/A	15	38.1	20	35.8	6.52	10	43.1	9	43.2	-0.30
spa.r-es	N/A	N/A	N/A	N/A	N/A	15	39.4	20	36.5	7.96	10	43.6	9	43.7	-0.30
ac.l-spa.l	15	21.0	8	18.6	12.71	16	31.9	21	30.5	4.60	9	34.9	10	35.0	-0.16
ac.r-spar	15	21.2	8	18.9	12.30	16	32.1	21	30.5	5.06	9	34.3	10	34.7	-1.13
ac.l-ac.r	15	15.9	8	16.6	-4.41	16	23.6	21	22.4	5.43	9	25.4	10	23.7	6.90
petsa.l-petsa.r	15	18.5	8	18.2	1.90	16	22.9	22	22.4	2.31	13	26.9	10	26.1	2.85
pts.l-pts.r	11	15.0	7	15.1	-0.47	13	22.3	15	22.0	1.60	13	28.0	11	27.4	2.07
petp.l-petp.r	12	83.8	8	81.9	2.32	15	108.1	21	106.3	1.61	11	110.6	8	108.5	1.90
ss.l-ss.r	10	46.6	3	40.9	13.91	13	62.1	13	60.5	2.76	13	66.4	11	64.5	2.95
fmlhg.l-fmlhg.r	11	22.1	6	20.9	5.51	13	28.5	13	27.7	2.74	13	29.8	11	28.8	3.45
sor.l-spa.l	14	26.4	8	26.7	-1.28	14	38.0	18	36.7	3.68	10	44.5	8	43.8	1.54
sor.r-spa.r	13	26.9	8	27.3	-1.30	14	38.3	19	36.7	4.43	10	42.9	9	42.3	1.36
spa.l-petp.l	12	51.9	8	50.1	3.61	15	66.0	20	66.0	0.00	10	71.2	8	69.1	3.02
spa.r-petp.r	11	52.6	8	49.4	6.61	15	66.1	21	66.6	-0.77	11	72.1	8	67.8	6.35
petsa.l-petp.l	12	41.1	8	40.1	2.64	15	53.3	21	52.2	1.98	12	55.1	9	53.5	3.02
petsa.r-petp.r	12	41.4	8	40.4	2.59	15	53.7	21	53.0	1.33	11	55.4	9	53.8	2.81
pts.l-petsa.l	11	10.1	7	10.6	-4.58	12	15.9	14	15.7	1.33	13	19.2	10	18.6	2.98
pts.r-petsa.r	11	10.1	7	10.0	0.55	12	16.0	14	15.6	2.33	13	19.0	10	18.7	1.28
hn.l-pts.l	10	19.6	4	17.4	12.67	11	30.8	11	29.6	3.83	13	34.0	9	31.4	8.31
hn.r-pts.r	10	20.3	4	17.7	14.58	11	30.9	11	30.0	2.76	13	34.5	9	31.8	8.39
ba-n	10	65.8	4	64.0	2.75	13	88.5	13	88.0	0.52	11	103.1	10	96.8	6.49
ba-s	11	26.7	5	24.6	8.36	12	37.1	12	38.1	-2.50	13	45.8	10	42.4	7.99
s-n	13	44.1	6	43.4	1.64	12	59.8	17	59.2	1.10	11	68.7	10	65.0	5.66
n-es	N/A	N/A	N/A	N/A	N/A	12	32.7	14	33.6	-2.68	11	37.6	10	33.5	12.30
ba-o	10	29.4	5	29.5	-0.19	13	35.0	15	33.2	5.42	13	32.9	10	32.5	1.09
ba-h	11	24.5	5	24.1	1.49	13	27.2	14	28.3	-3.76	13	32.2	11	29.6	8.76

Table 4.2.30 The magnitudes of differences between males and females for orbital variables at different age categories are presented as percentage of dimorphism.

Measurement	Mid age 0.5 year					Mid age 7.5 year					Mid age 22.3 year				
	Male		Female		% dimorphism	Male		Female		% dimorphism	Male		Female		% dimorphism
	N	Adjusted mean	N	Adjusted mean		N	Adjusted mean	N	Adjusted mean		N	Adjusted mean	N	Adjusted mean	
slor.l-slor.r	14	70.2	8	68.8	2.04	15	86.9	20	85.1	2.04	9	100.2	9	94.5	6.03
or.l-or.r	9	38.7	5	36.2	7.09	12	46.8	12	46.3	0.97	12	56.8	9	52.6	8.05
morfl.l-morfl.r	11	16.5	7	15.2	8.26	13	18.8	16	18.6	1.36	11	21.4	9	21.0	1.59
lor.l-lor.r	9	69.8	6	66.3	5.35	11	86.5	10	85.0	1.82	9	100.1	8	94.3	6.18
ofa.l-ofa.r	11	17.4	8	18.2	-4.11	16	25.6	20	24.1	6.09	9	31.3	10	28.7	8.89
lor.l-morfl.l	9	27.9	6	27.0	3.33	11	35.8	10	35.1	1.97	9	40.9	8	38.1	7.38
lor.r-morfl.r	9	28.0	6	26.9	4.25	11	36.3	11	34.9	3.82	9	41.5	9	37.9	9.34
sor.l-or.l	9	27.4	6	25.4	8.08	11	31.2	10	30.6	1.80	10	33.3	8	32.8	1.46
sor.r-or.r	9	27.6	5	24.9	10.70	11	30.7	11	30.7	-0.11	10	32.8	10	32.9	-0.39
ofa.l-sor.l	11	36.7	8	35.4	3.88	15	46.4	19	46.0	0.74	9	49.7	9	48.2	3.22
ofa.r-sor.r	11	36.9	8	35.6	3.52	15	46.8	19	46.4	0.83	9	49.3	10	48.1	2.65
ofa.l-or.l	9	30.7	6	30.3	1.26	11	42.5	10	41.3	2.97	10	47.6	9	45.1	5.43
ofa.r-or.r	9	30.8	5	29.6	4.13	11	42.9	11	42.0	2.07	10	47.5	10	45.5	4.40
ofa.l-morfl.l	10	28.6	7	28.6	-0.05	12	40.1	16	39.4	1.65	8	42.3	10	41.3	2.26
ofa.r-morfl.r	10	28.6	7	28.1	1.67	12	39.9	16	39.2	1.86	9	42.6	9	41.5	2.64
ofa.l-slor.l	10	34.4	6	33.0	4.34	15	43.5	18	43.6	-0.33	9	48.1	8	47.6	0.98
ofa.r-slor.r	10	34.5	5	33.2	4.02	15	44.2	18	43.9	0.78	9	48.5	10	47.4	2.36

Table 4.2.31 The magnitudes of differences between males and females for nasal variables at different age categories are presented as percentage of dimorphism.

Measurement	Mid age 0.5 year					Mid age 7.5 year					Mid age 22.3 year				
	Male		Female		% dimorphism	Male		Female		% dimorphism	Male		Female		% dimorphism
	N	Adjusted mean	N	Adjusted mean		N	Adjusted mean	N	Adjusted mean		N	Adjusted mean	N	Adjusted mean	
snm.l-snm.r	11	10.7	7	10.1	5.13	12	10.4	17	10.1	3.01	11	11.7	10	11.0	5.51
inm.l-inm.r	9	10.7	6	10.7	-0.57	12	14.1	12	14.2	-1.25	12	16.4	9	16.3	0.40
al.l-al.r	9	16.9	4	15.3	10.00	11	20.3	13	19.9	1.63	12	22.1	8	22.7	-2.62
inm.l-snm.l	9	12.8	6	12.6	1.43	12	21.2	11	21.7	-2.51	11	26.6	9	25.1	5.81
inm.r-snm.r	9	12.7	6	12.5	1.04	12	20.7	11	21.6	-4.05	11	26.3	9	24.7	6.73
n-al.l	9	25.6	3	24.2	5.83	11	40.3	10	39.8	1.32	11	48.8	7	47.8	2.23
n-al.r	9	25.6	3	24.4	5.12	11	40.0	10	39.7	0.92	11	48.8	7	47.5	2.77
na-ans	9	15.3	4	14.9	2.90	9	22.6	12	22.7	-0.54	12	29.8	7	27.7	7.28
ans-al.l	10	10.1	4	9.5	6.35	12	11.6	11	11.5	1.50	11	14.5	9	14.3	1.85
ans-al.r	10	9.9	4	9.6	3.58	12	12.1	11	11.6	4.81	11	14.4	9	13.7	4.79
pns-h	10	11.1	4	10.4	6.68	12	19.6	11	18.6	5.58	12	23.0	9	22.1	4.23
na-n	10	12.2	5	11.9	1.93	12	20.5	11	20.3	0.62	11	24.6	9	23.8	3.21
h-ans	10	39.0	4	37.6	3.79	9	58.8	11	57.5	2.30	13	70.1	8	66.5	5.38

Table 4.2.32 The magnitudes of differences between males and females for maxillary variables at different age categories are presented as percentage of dimorphism.

Measurement	Mid age 0.5 year					Mid age 7.5 year					Mid age 22.3 year				
	Male		Female		% dimorphism	Male		Female		% dimorphism	Male		Female		% dimorphism
	N	Adjusted mean	N	Adjusted mean		N	Adjusted mean	N	Adjusted mean		N	Adjusted mean	N	Adjusted mean	
zmi.l-zmi.r	10	62.5	4	56.7	10.38	11	83.9	13	83.9	0.07	12	102.4	8	96.0	6.63
ms.l-ms.r	10	24.4	5	23.9	2.20	11	35.7	15	33.9	5.54	9	44.2	9	41.5	6.58
mxt.l-mxt.r	10	27.7	4	26.7	4.04	12	40.6	13	40.0	1.47	12	48.4	8	45.9	5.34
gpf.l-gpf.r	10	21.4	4	20.6	3.77	12	28.3	13	27.7	2.05	12	34.7	7	32.9	5.58
n-ans	9	27.2	3	26.2	3.51	9	41.7	10	41.1	1.31	11	51.4	7	48.9	5.12
ans-pr	10	8.0	4	7.8	2.28	7	14.3	10	14.4	-0.53	11	18.8	5	18.0	4.49
mxt.l-ms.l	9	16.5	4	15.4	6.81	10	33.7	10	34.1	-1.18	10	46.1	7	40.1	14.93
mxt.r-ms.r	9	16.5	4	15.4	7.10	10	33.8	10	34.0	-0.56	10	46.4	7	41.8	11.07
or.l-zmi.l	9	19.7	4	17.5	12.51	11	28.7	11	28.5	0.57	13	34.7	7	32.9	5.60
or.r-zmi.r	9	19.4	4	17.5	11.24	11	28.4	12	28.0	1.21	12	35.8	8	33.3	7.47
ms.l-inm.l	9	28.7	5	28.4	0.96	10	45.5	10	45.6	-0.38	9	53.8	9	49.3	9.10
ms.r-inm.r	9	29.1	5	28.2	2.85	10	45.8	10	45.4	0.88	11	54.2	9	50.1	8.20
mxt.l-pr	10	28.9	4	29.0	-0.35	7	44.9	10	45.9	-2.19	11	60.6	5	58.6	3.43
mxt.r-pr	10	28.9	4	28.4	1.89	7	45.6	10	45.7	-0.24	10	60.8	5	57.9	5.08
pns-ans	10	30.3	4	29.6	2.46	9	42.9	13	43.0	-0.16	12	52.1	8	48.4	7.54

Table 4.2.33 The magnitudes of differences between males and females for zygomatic variables at different age categories are presented as percentage of dimorphism.

Measurement	Mid age 0.5 year					Mid age 7.5 year					Mid age 22.3 year				
	Male		Female		% dimorphism	Male		Female		% dimorphism	Male		Female		% dimorphism
	N	Adjusted mean	N	Adjusted mean		N	Adjusted mean	N	Adjusted mean		N	Adjusted mean	N	Adjusted mean	
zt.l-zt.r	10	76.8	6	70.9	8.28	12	99.8	13	98.3	1.57	12	119.5	9	111.9	6.76
zti.l-zti.r	10	77.7	6	71.8	8.20	11	104.9	12	102.8	2.06	12	127.1	9	119.5	6.38
slor.l-zmi.l	8	26.2	3	23.0	14.02	10	36.7	10	36.1	1.74	10	44.5	6	43.1	3.26
slor.r-zmi.r	8	26.2	3	23.7	10.58	10	37.0	10	35.8	3.36	10	44.2	8	43.1	2.51
zti.l-or.l	9	30.6	6	27.6	10.58	11	45.2	10	43.2	4.67	12	53.9	9	51.4	4.91
zti.r-or.r	9	31.1	5	27.6	12.49	11	44.5	12	43.1	3.38	12	54.3	10	50.6	7.35
zt.l-au.l	10	19.8	6	18.8	5.29	11	31.7	14	31.5	0.57	12	43.0	9	39.2	9.64
zt.r-au.r	9	20.0	7	18.8	6.66	11	31.9	12	31.2	2.33	13	43.4	10	38.5	12.80

Table 4.2.34 The magnitudes of differences between males and females for mandibular variables at different age categories are presented as percentage of dimorphism.

Measurement	Mid age 0.5 year					Mid age 7.5 year					Mid age 22.3 year				
	Male		Female		% dimorphism	Male		Female		% dimorphism	Male		Female		% dimorphism
	N	Adjusted mean	N	Adjusted mean		N	Adjusted mean	N	Adjusted mean		N	Adjusted mean	N	Adjusted mean	
go.l-go.r	10	54.9	4	50.5	8.62	9	76.9	12	76.3	0.84	13	95.4	8	87.8	8.67
cd.l-cd.r	10	73.2	4	69.6	5.30	12	106.0	13	102.4	3.50	12	125.0	11	119.3	4.77
cd.l-ct.l	10	15.1	4	14.5	4.02	12	24.8	13	24.4	1.36	12	32.0	11	30.2	6.22
cd.r-ct.r	10	15.8	4	14.5	8.67	12	25.0	12	24.5	2.12	13	31.9	11	31.4	1.52
cd.l-go.l	10	20.4	4	20.0	1.64	9	40.2	12	38.5	4.65	12	55.0	8	47.9	15.01
cd.r-go.r	10	20.7	4	20.0	3.81	9	40.6	11	39.0	4.28	13	54.8	8	49.1	11.78
gn-id	8	15.7	4	13.0	20.55	6	24.5	5	25.2	-2.80	10	34.1	6	29.7	14.70
go.l-gn	8	46.5	4	41.9	11.02	6	70.0	5	73.5	-4.76	10	87.7	6	84.6	3.70
go.r-gn	8	45.7	4	41.5	9.96	6	70.5	5	73.5	-4.17	10	89.5	6	85.6	4.49
gn-cd.l	8	60.7	4	57.2	6.13	6	99.1	5	101.4	-2.35	10	124.1	6	114.5	8.34
gn-cd.r	8	61.1	4	56.9	7.46	6	100.2	5	102.6	-2.38	10	125.0	6	117.2	6.68

Table 4.2.35 The magnitudes of differences between males and females for inter-regional variables at different age categories are presented as percentage of dimorphism.

Measurement	Mid age 0.5 year					Mid age 7.5 year					Mid age 22.3 year				
	Male		Female		% dimorphism	Male		Female		% dimorphism	Male		Female		% dimorphism
	N	Adjusted mean	N	Adjusted mean		N	Adjusted mean	N	Adjusted mean		N	Adjusted mean	N	Adjusted mean	
au.l-ans	10	60.9	4	57.3	6.28	7	89.9	11	87.5	2.72	13	108.2	7	101.1	7.07
au.r-ans	9	61.2	4	56.4	8.41	7	90.0	10	87.2	3.26	13	108.8	7	101.6	7.08
s-pns	10	23.6	4	21.9	7.98	11	39.0	10	38.1	2.23	12	47.5	8	44.7	6.38
s-ans	10	48.3	4	46.7	3.55	8	70.6	10	69.5	1.54	13	85.2	7	79.8	6.78
ba-pns	10	30.6	4	28.8	6.53	12	39.4	12	38.0	3.68	12	45.4	9	43.6	4.10
ba-ans	10	60.9	4	58.1	4.66	9	82.1	12	81.1	1.21	13	97.4	8	91.8	6.08

Table 4.2.36 The magnitudes of differences between males and females for angular and index variables at different age categories are presented as percentage of dimorphism.

Measurement	Mid age 0.5 year					Mid age 7.5 year					Mid age 22.3 year				
	Male		Female		% dimorphism	Male		Female		% dimorphism	Male		Female		% dimorphism
	N	Adjusted mean	N	Adjusted mean		N	Adjusted mean	N	Adjusted mean		N	Adjusted mean	N	Adjusted mean	
ba-s-n	10	139.5	4	140.0	-0.38	13	130.5	13	131.0	-0.32	11	128.1	10	126.9	0.92
s-n-na	13	95.7	6	97.3	-1.68	12	102.3	7	98.1	4.21	11	110.0	10	107.5	2.30
morfl.l-n-morfl.r	11	100.1	7	94.1	6.35	13	89.3	16	88.6	0.82	11	88.1	9	86.0	2.40
petsa.l-au.l-zt.l	10	98.6	6	103.3	-4.60	11	89.4	14	87.5	2.26	12	87.8	9	90.4	-2.83
petsa.r-au.r-zt.r	9	97.7	7	104.2	-6.24	11	89.9	12	87.0	3.28	13	87.1	10	88.8	-1.89
cd.l-go.l-gn	8	126.1	4	132.2	-4.59	6	124.3	5	125.1	-0.67	10	118.8	6	120.2	-1.14
cd.r-go.r-gn	8	129.8	4	133.1	-2.47	6	125.6	5	125.7	-0.09	10	117.9	6	121.7	-3.12
go.l-gn-go.r	8	72.0	4	77.0	-6.53	6	65.3	5	66.0	-1.04	10	66.0	6	62.5	5.47
petp.l-es-petp.r	N/A	N/A	N/A	N/A	N/A	15	77.0	20	75.6	1.79	10	70.8	8	70.4	0.55
s-n/ac.l-spa.l	13	131.2	6	131.3	-0.07	12	126.3	7	125.3	0.83	11	119.6	10	118.7	0.73
s-n/ac.r-spa.r	13	128.9	6	129.9	-0.74	12	125.7	7	123.4	1.87	11	120.9	10	120.8	0.07
s-n/ans-pns	10	11.5	4	11.0	4.50	9	7.4	13	8.4	-12.21	11	7.7	8	8.2	-5.97
n-ans/ans-pns	9	87.2	3	82.6	5.62	9	85.8	10	86.8	-1.15	11	83.2	7	83.7	-0.55
cindx.l-cindx.r:cindxa-cindxp	12	0.9	7	0.9	2.45	13	0.8	15	0.8	0.12	11	0.8	6	0.8	0.54
sor.l-or.l:lor.l-morfl.l	9	1.0	6	0.9	5.47	11	0.9	10	0.9	0.16	9	0.8	8	0.9	-5.53
sor.r-or.r:lor.r-morfl.r	9	1.0	5	0.9	6.02	11	0.9	11	0.8	3.87	9	0.8	9	0.9	-7.84

4.2.4 Discussion

During infancy only a few (2.7%) linear variables were found to differ significantly in size between the sexes. Furthermore, a lack of significant differences in angular variables and indices suggested that craniofacial shape was similar between boys and girls at this stage. Enlow (1990) has reported that during infancy boys and girls looks alike and often cannot be distinguished from their facial appearances alone. Nevertheless, for the majority of the linear variables (88.9%) in this study, males exhibited larger values (though not significantly larger in a statistical sense) than females. This indicates that there is the tendency for males to be slightly larger than females in infancy. In fact, the magnitudes of sex differences were quite high for some variables - male values exceeding female values by over 10%. Indeed, for several variables, the magnitudes of sexual dimorphism were higher during this time than during childhood or adulthood.

During this infancy stage, age was found to be a statistically significant factor for the majority of variables in all regions, even for a few angular measurements and indices. Many of these age effects were significant at $p<0.01$ level. This simply indicates that the subjects were still growing rapidly during this time and that minor differences in age could affect the size of dimensions.

At later ages of 5 to 10 years, more linear variables (7.3%) were found to differ between the sexes but none of the angular variables or indices showed any sex differences. Sexual dimorphism was not evident for most facial and cranial features at this stage but the number of variables showing significant differences was slightly greater compared to infants. In an established study of children of European origin, Riolo *et al.* (1974) demonstrated significant differences in craniofacial dimensions between the sexes for most variables as early as 6 years of age. In another study of 6- year-old Icelandic children (Johannsdottir *et al.*, 1999), it was shown that males consistently showed larger values for most linear craniofacial

variables. The angular variables were not found to differ between the sexes. These researchers also observed clear sex differences in the size of the cranial base and the absence of obvious sexual dimorphism in the cranial base angle.

The sex-related facial features begin to become more apparent during childhood. Male skeletal features are beginning to become more angular and robust whereas the female are more rounded. The female face seems wider than it is in height and the male face appears longer than females. Nasal apertures are wider and longer in males than females. Generally, the main features of a child's face, regardless of sex, include relatively short nose, low nasal bridge, bulbous and upright forehead, prominent cheekbones, flat face and rather widely set eyes (Enlow, 1990). Additionally, the lower face has been reported to undergo greater forward growth with age than the midface with a spurt of increased growth around the onset of puberty (Aydemir *et al.*, 1999). Females show significantly greater forward growth of the lower face with respect to the midface between the age of 12 and 14 years (Aydemir *et al.*, 1999).

During the childhood stage, for all craniofacial regions studied, the magnitudes of sexual dimorphism were lower than those during infancy or adulthood. For the majority of variables, measurements in males were greater than those in females but, for some variables, the females' measurements exceeded those in males. This suggests that growth of some female craniofacial structures was more advanced than in males during this time. This could correspond with periods of acceleration of growth in females. Many studies support the notion that females grow more than males during childhood and reach maturity earlier than males (Farkas *et al.*, 1992a, 1992b, 1992c; el-Batouti *et al.*, 1994; Bishara, 2000).

It was also found that age was a statistically significant factor for the majority of linear variables in all regions during this time, indicating that the subjects were still growing at this age.

It was during adulthood that sex differences in size of the craniofacial structures became more obvious. At this stage, 50 out of 110 (45.5%) linear variables showed size differences - 33 variables showed marked differences at $p<0.01$. These differences were distributed across all of craniofacial regions, including orbital, maxillary, zygomatic, mandibular, inter-regional, cranial base and cranial vault. Marked differences between adult males and females are evident as adult males tend to display prominent supraorbital ridges and frontal areas continuous with the nose. Nasal apertures tend to be wider and longer, the chin squarer and the gonial angle shows marked eversion and strong muscle markings in males. Furthermore, the zygomatic arches are thicker and the teeth are bigger in males than in females. The female face looks softer, with the zygomatic area being quite prominent giving the appearance of high cheek bone. The forehead is more rounded in female with lack of prominent supraorbital ridge.

Age was found to be a statistically significant factor for only a few variables during adulthood, suggesting that most had completed their growth.

Another important aspect of this study is that, through the use of 3D-CT, the author was able to view the cranial base region closely. This enabled an analysis of sex differences for selected cranial base structures. The cranial base region has been reported to be larger in males than in females (Axelsson *et al.*, 2003). The author initially attempted to describe qualitatively any differences between males and females in the cranial base but they were very difficult to describe. The cranial base is, in fact, a very complex region and because we are not very familiar with viewing it directly, we have not developed clear ways of expressing differences. Viewing the cranial base in both sexes during childhood confirmed that the spheno-occipital synchondrosis had not yet closed but, apart from this, no other obvious differences with the adult cranial base were evident.

The lack of significant size differences between the sexes in infancy and childhood was probably to the relatively small number of subjects available for comparison. This meant

that the power of the statistical tests comparing the sexes was low. Variables were presumably starting to show some size differences at these early stages that would become more obvious in adulthood. Indeed, a larger number of variables showed statistically significant differences in adulthood. Comparisons of sexual dimorphism at the three age groups are given in Figures 4.2.6 to 4.2.8 with those variables that showed significant sex differences overlaid on the 3D-CT reconstructions.

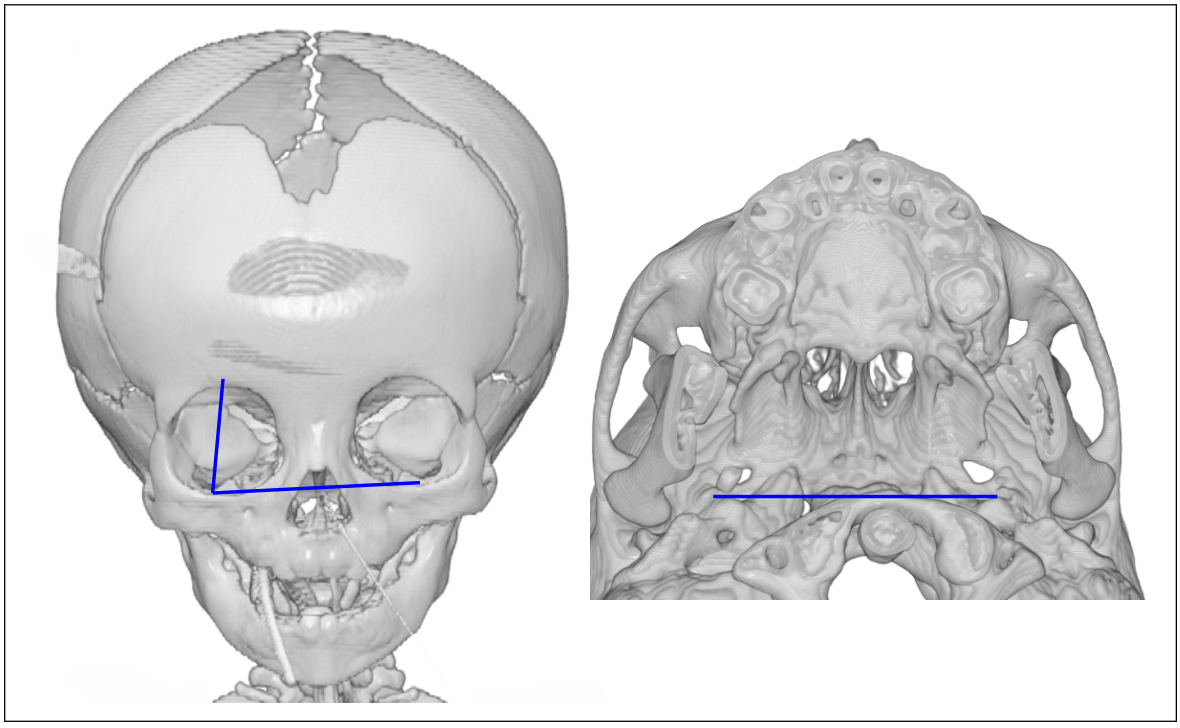

Figure 4.2.6 Variables that showed sexual differences during infancy are overlaid on the 3D-CT reconstructions.

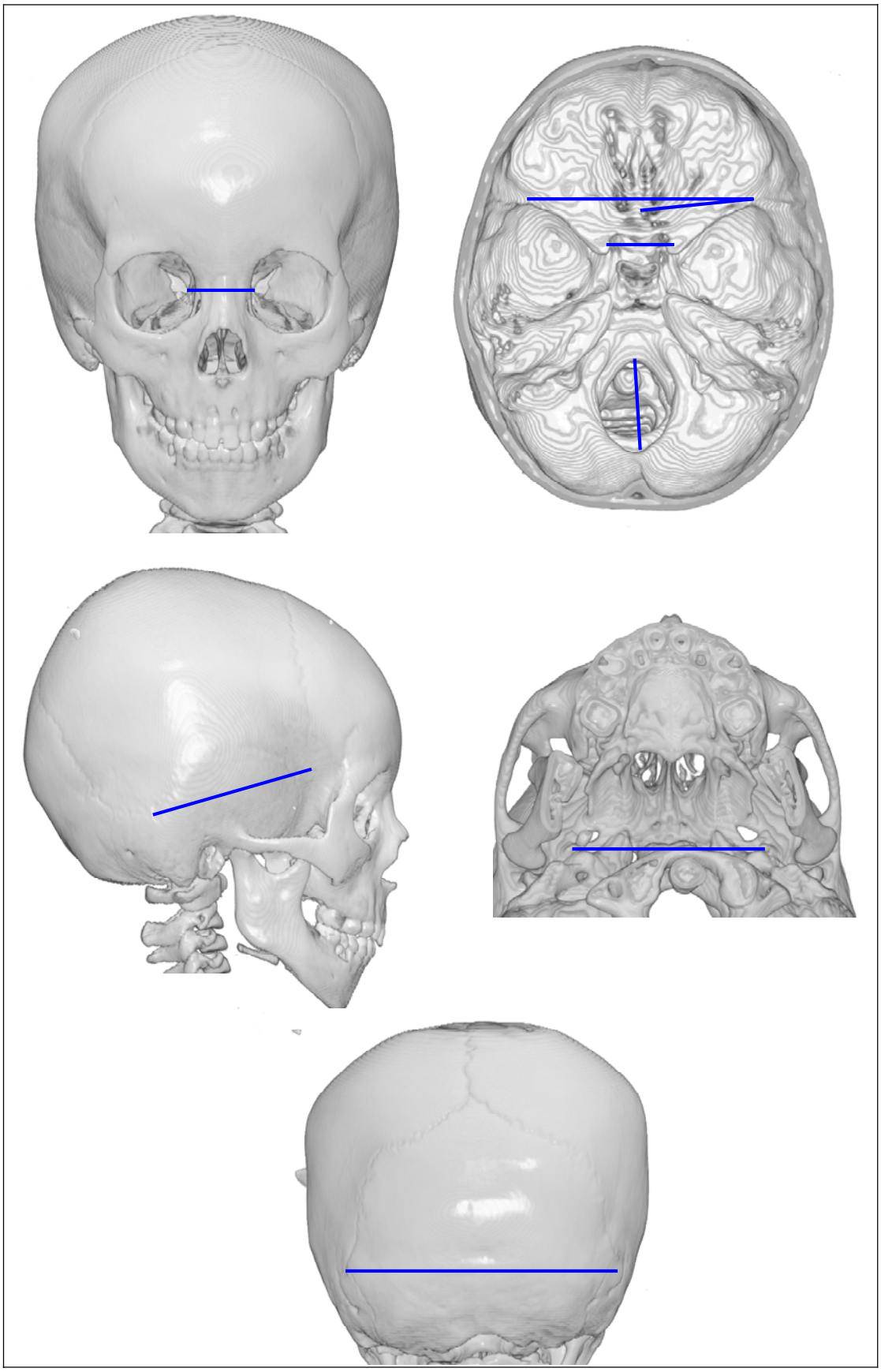

Figure 4.2.7 Variables that showed sexual differences during childhood are overlaid on the 3D-CT reconstructions.

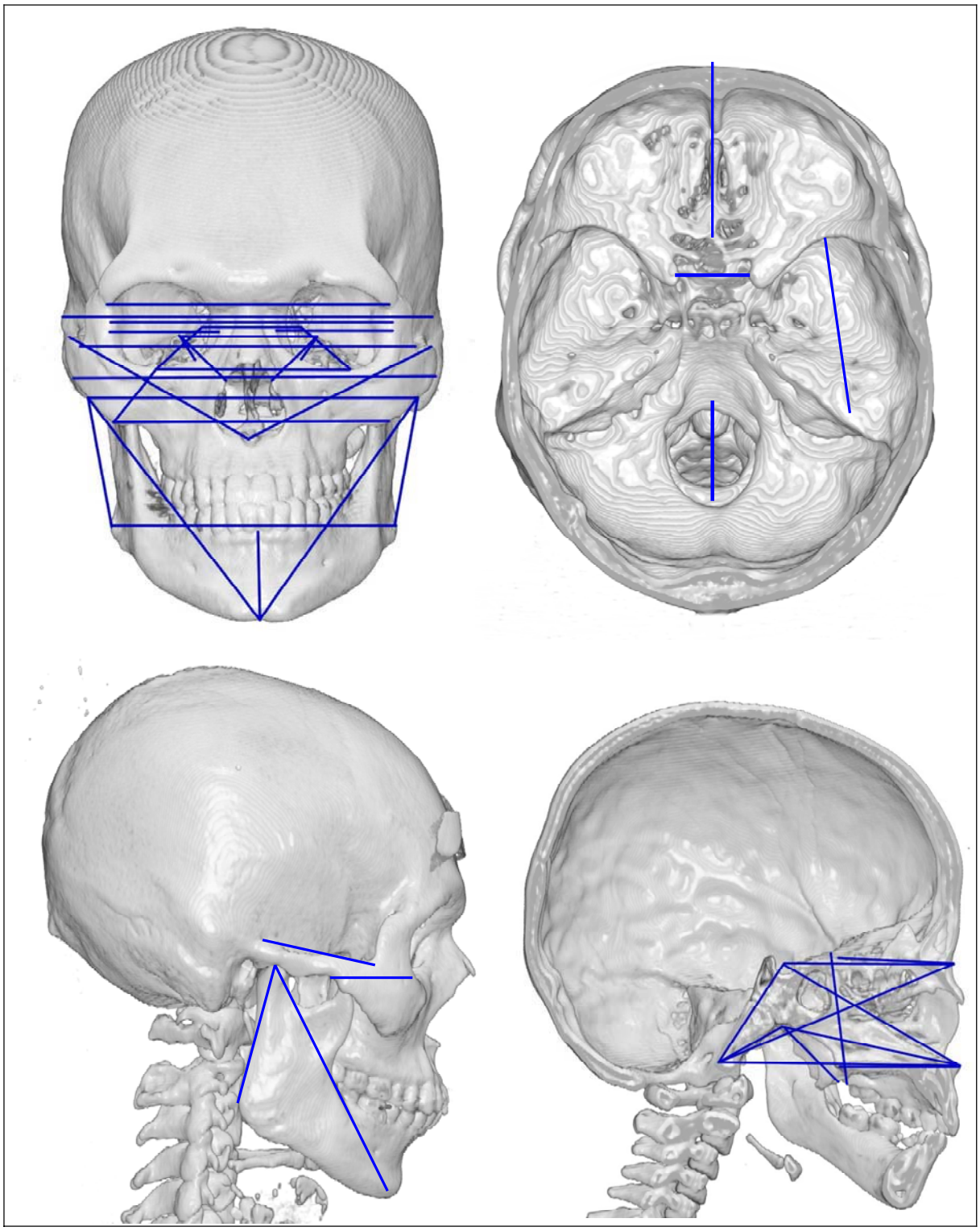

Figure 4.2.8 Variables that showed sexual differences during adulthood are overlaid on the 3D-CT reconstructions.

The findings in this study were in agreement with those of Snodell *et al.* (1993) who also found that only a small number of variables showed differences between males and females at 6 years of age. More variables showed differences at 12 years of age and, at age 18 years, only one variable in their study did not show sex differences. In other studies, more variables were observed to show statistically significant differences between the sexes at age 18 years than at age 10 years. These findings support the requirement for establishing different normative data for males and females when linear measurements are considered (Cortella *et al.*, 1997; Huertas and Ghafari, 2001).

In contrast to the above findings, a study of craniofacial morphology performed on a Nubian sample (Kowalski *et al.*, 1975a) showed no evidence of sexual dimorphism for angular and mandibular measurements at all age groups. A study of a Norwegian sample (el-Batouti *et al.*, 1994) established that pronounced differences between the sexes were observed after the age of 12 years with males consistently demonstrating significantly larger values. However, females displayed larger changes than males, particularly between the age of 12 and 15 years, which could be attributed to their earlier growth changes. Males also expressed larger increases in anterior and posterior face heights than females, with relatively greater vertical growth in the anterior than the posterior part of the face.

There was no clear pattern of differences between the sexes for angular variables. Indices showed no statistically significant differences in the first two stages and, at adulthood, only one orbital index showed a statistically significant difference between the sexes which could have been a sampling effect. Index or ratio measurements of the mouth (Ferrario *et al.*, 2000) and nasal width-to-height ratios have not shown evidence of sexual dimorphism (Ferrario *et al.*, 1997). However, the failure to discover more significant differences, particularly during adulthood, could once again be due to the relatively small number of subjects for comparison. More importantly, the failure to detect shape differences between the sexes may be due to the use of simple linear and angular dimensions alone that may not be

sufficient to detect subtle differences. For example, how might one best compare objectively the marked supraorbital ridges of males with females? The angular variables selected in this study were unable to detect these sorts of differences. Shape analyses need to be carried out using more sophisticated tools to be able to distinguish differences between males and females. Shape analyses should also be utilised to analyse the cranial base and to assess sexual dimorphism of the cranial base structures.

Another interesting finding in this study was the trend in sex differences over time. The statistical analyses may not have revealed many significant differences but there was a trend for linear dimensions in males to be consistently larger than in females during infancy. The magnitude of differences was also relatively high during this time. During childhood, the males still tended to be larger in craniofacial structures than females but the magnitude of the sexual dimorphism was lower than during infancy. Females were even larger than males for some variables. During the adult stage, males showed a consistent trend of having larger values than females for most variables.

The magnitudes of sexual dimorphism also varied across ages. The majority of variables showed high magnitudes of sexual dimorphism during infancy, followed by decreased magnitudes during childhood, and then increased magnitudes during adulthood. The magnitudes during adulthood tended to be lower than those during infancy. Another trend noted for some variables was for the magnitude of differences between the sexes in adulthood to be higher than during infancy. There was also a trend for some variables where males showed larger measurements during infancy but the pattern was reversed during childhood with females being bigger in size. This pattern changed again during adulthood with measurements for males being bigger than those for females.

At a value of 20.6%, the mandibular measurement of anterior alveolar height (gn-id) showed the greatest sexual dimorphism in this study and, interestingly, this occurred during infancy. The mandibular, nasal, maxillary and zygomatic regions and inter-regional variables

all showed high magnitudes of dimorphism during infancy and adulthood. The cranial vault, cranial base and orbital variables revealed moderate dimorphism during infancy and adulthood. Most variables in all regions showed relatively low magnitudes of dimorphism during childhood.

The findings from this investigation emphasise the need for clinicians to take sex differences in craniofacial structures into consideration when treatment needs are being considered as also suggested by Huertas and Ghafari (2001). Differences in timing of maturity in boys and girls and differences in the magnitudes of sexual dimorphism for different craniofacial regions, such as those highlighted by this study, need to be taken into account when planning orthodontic treatment or more invasive surgical interventions of abnormalities of the craniofacial structures.

4.2.5 Conclusion

Sexual dimorphism was observed in linear dimensions in all craniofacial regions. A few variables showed significant differences between the sexes during infancy and a few more variables displayed sexual dimorphism during childhood. The most marked sexual dimorphism was evident during adulthood. These findings support the requirement for different normative data to be established for males and females at different age groups when considering linear measurements. Angular measurements and indices did not show sex differences at any ages, suggesting the need for more sophisticated analyses to quantify the relatively subtle shape differences between the sexes. These shape analyses should also be used to quantify differences in the cranial base region because qualitative descriptions are too difficult and subjective. Patterns of differential magnitudes of sexual dimorphism for different craniofacial regions were observed in the Malay sample, and trends across ages were

also noted. The confirmation of sexual dimorphism in the craniofacial structures provided by this study reinforces the need for clinicians to take sex differences into account when planning treatment for their patients.

Section B

4.3.1 Nature and Extent of Craniofacial Asymmetry

A structure is considered to be symmetrical in respect to a line or plane when it can be divided into two mirror halves and has exact correspondence of form between the opposite sides. Biologic structures in vertebrates are built according to a midline plane, but during growth and development the two halves partially modify their basic design and different degrees of asymmetry can develop (Ferrario *et al.*, 1994b). Thus, morphological asymmetry can be defined as deviation from complete symmetry during development of the organism and its different parts in relation to the median plane of the body.

There are two main types of asymmetry: fluctuating and directional. In fluctuating asymmetry, the larger size of the right or left side in individuals occurs randomly and is not obvious in a series as whole. In other words, the mean difference between the two sides is not significant. Directional asymmetry is characterized by a significantly larger size of one side. But even this asymmetry has a fluctuating component which reflects the developmental instability of the organism. Directional asymmetry can also reflect the effect of function, for example where muscle development is greater on one side due to greater activity. The focus of investigation in this study is to quantify the nature and extent of directional asymmetry in the craniofacial structures.

The asymmetries developed can be the outcome of genetic, epigenetic and exogenous factors, and can be partially compensated for, or conversely magnified by, function. Genetic factors may cause differences in the degree of growth between left and right sides (Melnik, 1992). In these instances, conditions do not favour identical growth of homologous bilateral structures (Cassidy *et al.*, 1998). Therefore, asymmetry reflects developmental aspects of the organism and is often associated with the manifestation of congenital defects. Subjects with various congenital defects are often characterized by greater morphological and other

variability, including larger asymmetries (Livshits and Kobyliansky, 1991). Larger asymmetry provides one measure of developmental instability of the organism. It can be not only an indicator of developmental disorders but also of adverse influences of the external environment (stress), a poorer health status of the individual or of altered function.

For human craniofacial bones, asymmetry is a common finding and is present in patients as well as in people without medical problems (Rossi *et al.*, 2003). Differences between the left and right sides occur to varying degrees within human populations (Melnik, 1992). The extent of asymmetries can range from those that may lead to an interference with normal function and aesthetic appearance to those that are so insignificant that they cannot be detected by visual observation.

Previous studies have reported many contrasting results with respect to asymmetry in craniofacial regions. In a craniometric study of Egyptian skulls, Woo (1931) found that the right sides of the maxilla, frontal and parietal bones were larger more often than the left, and the malar bone was larger on the left more often than the right. Asymmetry was reported especially in the middle and lower parts of face, with a right side dominance being noted in another study (Ferrario *et al.*, 1994b). Other studies have noted that the right side of the maxilla tends to be larger (Vig and Hewitt, 1975; Shah and Joshi, 1978). Studies of the human dentition have revealed significant directional asymmetry in the size of some tooth crowns but without a clear pattern of side preference (Townsend *et al.*, 1999), as well as evidence of fluctuating asymmetry reflecting developmental instability (Kieser, 1990). Elsewhere in the body, dominance of right over left side has also been reported (Plato *et al.*, 1980; Schell *et al.*, 1985), with the bones of the hand and upper arm showing right side dominance that could not be explained fully by right-handed function.

Asymmetry in the craniofacial complex can change with age and be expressed to varying extents. It might be greater in childhood and adolescence due to relative growth imbalances between the right and left sides (Ferrario *et al.*, 1994b). However, it is common to

also find asymmetry in adulthood. In a study of facial soft tissues in Canadian children, Farkas and Cheung (1981) found larger measurements on the left in older age groups compared with younger age groups. In another study (Mulick, 1965), no age change in the amount of asymmetry was detected. The skeletal structures show greater degrees of asymmetry than their soft tissues which mask the underlying imbalances (Shah and Joshi, 1978).

Asymmetries in the cranial and craniofacial structures are influenced by asymmetry in brain structures. Bilateral variation in brain development occurs during growth, as the brain is normally asymmetric both anatomically and functionally. This in turn gives rise to asymmetric neurocranial structures and the cranial base follows changes in the neural tissues (Pirttiniemi, 1998). The asymmetric cranial base may then influence asymmetry of the craniofacial structures. Asymmetric brain function is also linked to handedness of individuals.

Systematic directional asymmetries have been observed for measurements of skull structures, including the cranial base foramina and the glenoid fossa (Pirttiniemi and Kantomaa, 1992). The glenoid fossa was found to be located more laterally on the right than on the left which correlates to other asymmetries found in cranial base structures. This finding further supports the observation that dental occlusion is commonly more posterior on the right (Pirttiniemi and Kantomaa, 1992).

Additionally, craniofacial asymmetries have been correlated to other skeletal asymmetries. One study reported that general asymmetric tendencies in the skeletal structures were found to correlate with differences in dental occlusions and mandibular ramal length asymmetries (Huggare and Houghton, 1995).

The expression of craniofacial asymmetry is also related to muscular functional activity, especially of the masticatory apparatus (Pirttiniemi, 1994). These functional activities include preference in chewing. Slight midline deviations in dentitions and size differences between bilateral craniomandibular structures have been observed in subjects with unilateral

chewing patterns (Pirttiniemi, 1994). Although the causes of this are not clear, side differences in muscular function are evidently the most important factors. Facial structures have been shown to be strongly dependent on muscular balance in both humans and animals (Raadsheer *et al.*, 1996). Experimentally induced change in one critical muscle can cause fundamental changes in facial structures during subsequent growth (Brennan and Antonyshyn, 1996). Another study reported that facial asymmetries are related to handedness and that right-handed persons have a larger facial area on the left side and vice versa (Keles *et al.*, 1997). This is thought to be related to the asymmetric function of the brain which is also linked to handedness.

For pathologic asymmetries, functional causes are found to be major aetiological factors. Disharmony due to malocclusion can be a major cause of facial and even craniofacial asymmetries that disturb normal development. The role of occlusion on the developmental balance of the facial structures is highly important during the early periods in life. This suggests that malocclusion should be corrected to avoid irreversible asymmetries in structures and possibly alterations in functions such as mastication.

Complete symmetry could be considered to be ideal but not necessarily attractive (Swaddle and Cuthill, 1995). During management of patients with craniofacial abnormality, important treatment goals include producing a balance of cranial and facial form and improving the quality of life of patients. Symmetry is taken into consideration in the assessment of patients undergoing surgical and orthodontic procedures as, normally, the goal is to achieve a symmetrical and harmonious face. However, a harmonious face may look symmetrical but the soft tissues may be masking an underlying osseous asymmetry.

Moreover, a certain degree of asymmetry in otherwise normal structures can be considered to fall within acceptable esthetic and functional limits. The extent of the range that can be considered to be normal is still unclear and many studies have attempted to describe this. Investigations of asymmetry are important not only from the point of view of general

developmental principles and developmental disorders but also for practical reasons such as defining the acceptable ranges of normal and abnormal asymmetry. The point at which normal asymmetry becomes abnormal cannot be easily defined and is often determined by the clinician's sense of balance.

There is no clearly defined criterion to determine what might be considered as evidence of asymmetry for a group of measurements. Some authors define asymmetry to be present when the mean of the differences between left and right sides is significantly different from zero (Shah and Joshi, 1978). Another study considered facial measurements were asymmetric when differences between the left and right sides were equal to or larger than two millimetres (Farkas and Cheung, 1981). Yet another study regarded differences of over four millimetres as indicated the presence of asymmetry (Kwon *et al.*, 2006). Ferrario *et al.* (1994) reported that skeletal asymmetry that is less than 3% is not clinically evident and appropriate measurements are needed for more precise quantification.

Various methods have been used to investigate craniofacial asymmetry. Some of these methods include direct measurements on dry skulls (Woo, 1931; Hershkovitz *et al.*, 1992), postero-anterior radiographs (Letzer and Kronman, 1967; Grummons and Kappeyne van de Coppello, 1987; Winning *et al.*, 1999), submento-vertex radiographs (Arnold *et al.*, 1994), soft tissues (Farkas and Cheung, 1981; Shaner *et al.*, 2000), dental casts (Townsend *et al.*, 1999), photographs (Swaddle and Cuthill, 1995), stereophotogrammetry (Burke and Healy, 1993) and laser surface scanning (Moss *et al.*, 1991; O'Grady and Antonyshyn, 1999). More recently, a few researchers have utilised 3D-CT to investigate craniofacial asymmetry (Katsumata *et al.*, 2005; Kwon *et al.*, 2006). The use of 3D-CT offers the ability to observe the craniofacial bones from several viewing angles with interactive and rapid repositioning of the 3D images. More importantly, the 3D-CT reconstructions allow the viewing of life-like cranial base structures, thus enabling the investigation of asymmetry to be carried out more extensively.

Investigations of asymmetry have often raised problems associated with measuring and analysing the asymmetry. This mainly concerns the choice of vertical reference lines that separate the craniofacial structures into left and right sides. The validity of these reference lines has been investigated (Trpkova *et al.*, 2003), and it has been reported that vertical lines constructed between two midline points with one point located on the lower part of the skull were not valid and did not give a true measurement of asymmetry. Excellent validity was observed for the best-fit line and all lines constructed as perpendiculars through midpoints between pairs of orbital landmarks. Moreover, the lines that connect crita galli-anterior nasal spine and nasion-anterior nasal spine had the lowest validity and should not be used in cephalometric analysis of asymmetries.

To avoid the difficulties of choosing reference lines, measurements of distances, areas, angles and ratios can be calculated on the left and right sides separately and differences between the homologous measurements will then supply information about the dominant side, without the need for reference lines. This approach provides a set of measurements that are sensitive to local imbalances and it was utilised in the present study.

Ranges of normal limits for craniofacial asymmetries have not been reported for Malaysian Malays. There has also been no information about whether asymmetry differs between the sexes and how it might change with increasing age. At the commencement of this study there were very few reports of craniofacial analysis utilising 3D-CT for any population. As far as the author is aware, there were only a few studies that utilised 3D-CT to perform asymmetry analyses for the craniofacial structures (Katsumata *et al.*, 2005; Kwon *et al.*, 2006). Therefore, the aims of this section of the thesis were to utilise 3D-CT:

- To quantify the nature and extent of directional craniofacial asymmetry in Malaysian Malays.
- To consider the development of facial asymmetry in relation to age and sex.

4.3.2 Materials and Methods

The methods of data collection have already been outlined in Chapter 2.

4.3.2.1 Data Collection

The sources of patients selected for this study, together with the breakdown by age categories and sexes, are detailed in Section 2.5.

4.3.2.2 CT Protocol

Axial scans were obtained with a GE Lightspeed Plus CT Scanner System at the Department of Radiology, Hospital Universiti Sains Malaysia. The protocol used is detailed in Section 2.6.3

4.3.2.3 Craniofacial Variables

Craniofacial variables were divided into regions of the face, cranial base and cranial vault. The face was further categorised into separate major structures i.e. the orbit, maxilla, zygoma and mandible. All regions have width or distance, height and length measurements.

The variables are represented diagrammatically in Figures 2.7 to 2.21 and defined in the legend for the figures in Section 2.6.9. Analysis in this section was performed for 37 pairs of linear measurements (74 variables).

The method chosen was to measure linear variables on the left and right sides separately and then to calculate the differences between the homologous measurements. This provided information about the dominant side without the need for midline reference lines.

4.3.2.4 Statistical Analysis

Firstly, paired t-tests were used to examine whether differences between the right and the left sides for each variable under investigation were significantly different from zero. Subject differences between the right and left sides were calculated and the mean differences and standard deviations of the differences were determined. Mean differences were compared to a value of zero, and statistical significance for the mean differences (asymmetries) was set at $p<0.05$ and $p<0.01$.

$$Right - Left = x \text{ value}$$

$$\text{Paired t-test} \rightarrow x = 0 \text{ or } x \neq 0$$

Statistically significant results suggested that there was evidence for directional asymmetry for the particular variable under investigation.

Secondly, the author utilised the following formula to obtain a percentage of asymmetry which is also referred to as the asymmetry index for all paired measurements:

$$\frac{Right - Left}{(Right + Left)/2} \; x\,100 = y \text{ value (asymmetry index)}$$

For each variable, asymmetry index values were calculated for each subject and the mean values and standard deviations were determined.

This calculation also gives some indication of the magnitude of asymmetry, so that interpretation of asymmetry can be performed unrelated to size. Therefore, it is possible to compare the magnitude of asymmetry between dimensions of differing size. Patterns and amount of asymmetry can then be described and compared between variables from different craniofacial regions.

Finally, linear modelling analysis was employed for asymmetry index values to test for sex and age effects. A description of the linear modelling procedure was provided in Section 4.2.2.4.

4.3.2.5 Errors of the Method and Data Cleaning

The methods for determining errors in landmark determination and anthropometric variables derived from these landmarks, based on repeated determinations, are outlined in Section 2.8.4. Systematic errors in landmark location were tested using Hotelling's T^2 statistic. For anthropometric variables, Student's paired t-tests were used to detect systematic errors (i.e. to ascertain whether the mean difference between repeated measures deviated significantly from zero) and Dahlberg's (1940) method of double determination was used to quantify the magnitude of random errors.

Data cleaning process was performed and has already been explained in detail in Section 3.6.7.

4.3.3 Results

The results for raw asymmetry or differences between the right and left measurements are displayed in Tables 4.3.1 to 4.3.6 and for the asymmetry index or percentages of asymmetry in Tables 4.3.7 to 4.3.12. The tables are presented separately for different craniofacial regions. Tables contain mean values, medians, standard deviations (SD), standard errors (SE), minimum and maximum values, and *p* values for asymmetry calculations. Statistically significant differences between the two sexes are marked with (*) for significance at $p<0.05$ and with (#) for significance at $p<0.01$. Negative values for raw asymmetry and indices indicated that the left side is bigger than the right.

For raw asymmetry, the cranial vault showed an equal number of statistically significant results for mean difference with right side greater than left, and left side greater than right. However, the number of variables that showed significant asymmetry was similar

to the number that did not reveal significant asymmetry. The range of normal asymmetry for cranial vault variables was between -6.1mm and 7.4mm.

The cranial base presented significant right side dominance for 5 out of 8 (62.5%) linear variables. Most of these were significant at $p<0.01$. One variable showed significant asymmetry with the left side being larger than the right side on average. The range of normal asymmetry for cranial base variables was between -3.6mm to 5.2mm.

Most orbital variables did not show significant asymmetry. There was one variable (inferior orbital length) that showed significant right side dominance and another one (orbital height) that showed significant left side dominance. The range of normal asymmetry for orbital was between -3.1mm to 2.8mm.

For maxillary and nasal regions, 2 out of 10 (20%) measurements showed significant directional asymmetry with the mean difference of the right measurements being larger than the left on average, and another two dimensions showed left side dominance. The remaining 60% of maxillary and nasal variables did not display significant directional asymmetry. The range of normal asymmetry for this region was between -3.1mm and 4.9mm.

Total face length showed significant asymmetry with the right face being bigger than the left at $p<0.01$ and none of the zygomatic variables revealed significant asymmetry. The range of asymmetry for this region was between -3.6mm and 4.7mm.

In mandibular region, almost all variables i.e. 4 out of 5 (80%) showed significant asymmetry with the right side being larger than the left. The range of normal asymmetry for mandibular variables was between -5.7mm and 6.9mm.

Generally, the average magnitudes of asymmetry displayed by all regions were low. Average asymmetry indices that showed the right side was larger then the left were in the range of 0.1 to 2% and the range of average asymmetry indices for left side dominance was -0.1 to -3.7%. The largest average percentage of -3.7% was displayed by palatal height. However, there were a few individual variables that displayed quite high asymmetry

magnitudes. These can be observed in the range of asymmetry percentage of more than 20% for anterior clinoid-petrous length in cranial base region and lower pyriform margin width, palatal height and palatal width in maxillary and nasal region. For asymmetry indices, negative value also means that the left side is larger than the right.

The cranial vault was associated with average asymmetry magnitudes between 0.2 and 0.6% for variables with right side dominance and average asymmetry magnitudes between -0.2 and -0.6% for variables with left side dominance. The range of asymmetry percentages for cranial vault region was between -6.9% and 9.6%.

Cranial base variables were associated with average percentages of asymmetry in the range of 0.2 to 2% with the right side exceeding the left. With an asymmetry index of -1.4%, spheno-occipital synchondrosis length displayed the left measurement larger than the right. This region showed moderate range of asymmetry indices for most variables but a few variables demonstrate quite high range of asymmetry indices.

For orbital variables, slightly more showed right side dominance with average asymmetry magnitudes in the range 0.1 to 0.5%. The range of asymmetry indices for orbital variables was between -8.5% and 6.6%.

For maxillary and nasal variables, dimensions with left side dominance had average asymmetry magnitudes in the range -0.2 to -3.7%, whereas other dimensions with right side dominance were associated with percentage values of 0.3 to 0.8%. The range of asymmetry indices for maxillary and nasal variables was generally low but a few variables displayed quite high asymmetry percentage.

Total face length was associated with an average asymmetry index of 0.5% with the right side being larger than the left. Zygomatic variables displayed moderate degree of asymmetry magnitude. The range of asymmetry indices for this region was between -9.8% and 10.6%.

The mandible was associated with average asymmetry indices between 0.2 to 2%, with right side measurements all being larger than the left. The range of asymmetry indices for mandibular variables was between -9.1% and 12.1%.

Table 4.3.1 Mean, median, standard deviation (SD), standard error (SE), minimum, maximum and *p* values for raw asymmetry for cranial vault variables.

Measurement		Mean (mm)	Median (mm)	SD (mm)	N	SE (mm)	Min (mm)	Max (mm)	*p*
br-po.r/br-po.l	Lateral cranial vault height	0.2	0	2.1	121	0.2	-4.1	5.3	0.30
br-spc.r/br-spc.l	Coronal suture length	-0.6#	-0.8	2.3	118	0.2	-6.1	5.2	0.01
l-as.r/l-as.l	Lambdoid suture length	0.5*	0.1	2.7	140	0.2	-6.1	7.4	0.03
spc.r-as.r/spc.l-as.l	Lateral cranial vault length	-0.2	-0.3	2.6	125	0.2	-6	5.3	0.40

*significant at p<0.05 #significant at p<0.01

Table 4.3.2 Mean, median, standard deviation (SD), standard error (SE), minimum, maximum and *p* values for raw asymmetry for cranial base variables.

Measurement		Mean (mm)	Median (mm)	SD (mm)	N	SE (mm)	Min (mm)	Max (mm)	*p*
spa.r-es/spa.l-es	Anterior lesser wing of sphenoid width	0.8#	0.5	1.6	137	0.1	-2.6	4.3	<0.01
ac.r-spa.r/ac.l-spa.l	Posterior lesser wing of sphenoid width	0	-0.1	1.6	178	0.1	-3.5	3.3	1.00
sor.r-spa.r/sor.l-spa.l	Anterior cranial fossa length	0	0.1	1.4	167	0.1	-3.3	2.9	1.00
spa.r-petp.r/spa.l-petp.l	Lateral middle cranial fossa length	0.4#	0.5	1.8	169	0.1	-3.6	4.3	<0.01
petsa.r-ac.r/petsa.l-ac.l	Anterior clinoid-petrous length	0.2*	0.2	1.3	187	0.1	-6	5.2	0.04
petsa.r-petp.r/petsa.l-petp.l	Petrous ridge length	0.6#	0.5	1.6	177	0.1	-3	4.1	<0.01
pts.r-petsa.r/pts.l-petsa.l	Spheno-occipital synchondrosis length	-0.2*	-0.2	1	160	0.1	-2.5	2.7	0.01
hn.r-pts.r/hn.l-pts.l	Pterygoid plate height	0.3#	0.4	1.1	144	0.1	-2.1	2.8	<0.01

*significant at p<0.05 #significant at p<0.01

Table 4.3.3 Mean, median, standard deviation (SD), standard error (SE), minimum, maximum and *p* values for raw asymmetry for orbital variables.

Measurement		Mean (mm)	Median (mm)	SD (mm)	N	SE (mm)	Min (mm)	Max (mm)	*p*
sor.r-or.r/sor.l-or.l	Orbital height	-0.2#	-0.2	0.8	134	0.1	-2.7	1.5	0.00
morfl.r-lor.r/morfl.l-lor.l	Orbital distance	0.1	0.2	0.7	137	0.1	-1.3	1.6	0.10
ofa.r-morfl.r/ofa.l-morfl.l	Medial orbital length	0	0	0.8	149	0.1	-1.8	1.9	1.00
ofa.r-slor.r/ofa.l-slor.l	Lateral orbital length	0.1	0.1	1.4	160	0.1	-3.1	2.8	0.37
ofa.r-sor.r/ofa.l-sor.l	Superior orbital length	0.1	0.2	1.1	169	0.1	-2.2	2.5	0.24
ofa.r-or.r/ofa.l-or.l	Inferior orbital length	0.2*	0.2	0.9	134	0.1	-1.6	2.3	0.01

*significant at p<0.05 #significant at p<0.01

Table 4.3.4 Mean, median, standard deviation (SD), standard error (SE), minimum, maximum and *p* values for raw asymmetry for maxillary and nasal variables.

Measurement		Mean (mm)	Median (mm)	SD (mm)	N	SE (mm)	Min (mm)	Max (mm)	*p*
ans-al.r/ans-al.l	Lower pyriform margin width	0.1	0.1	0.8	141	0.1	-2.7	3.6	0.14
n-al.r/n-al.l	Nasal height	-0.1	-0.1	0.8	130	0.1	-1.8	1.5	0.16
inm.r-snm.r/inm.l-snm.l	Naso-maxillary suture length	-0.2#	-0.2	0.8	146	0.1	-2	2.1	<0.01
mxt.r-ms.r/mxt.l-ms.l	Posterior maxillary height	0	-0.1	1.2	124	0.1	-3	2.9	1.00
or.r-zmi.r/or.l-zmi.l	Anterior zygo-maxillary suture length	0	0	1.4	139	0.1	-3.1	3.1	1.00
ms.r-inm.r/ms.l-inm.l	Superior maxillary length	0.3#	0.3	1.1	133	0.1	-2.1	3.1	<0.01
mxt.r-pr/mxt.l-pr	Inferior maxillary length	0.2	0.2	1.2	116	0.1	-2.5	2.7	0.08
pns-hn.r/pns-hn.l	Palatal width	-0.1	-0.1	1.1	147	0.1	-2.8	4.9	0.27
hn.r-gpf.r/hn.l-gpf.l	Palatal height	-0.3#	-0.3	0.9	146	0.1	-3	2.3	<0.01
zmi.r-pr/zmi.l-pr	Zygomaxillare-prosthion width	0.4*	0.4	1.7	114	0.2	-2.9	4.4	0.01

*significant at p<0.05 #significant at p<0.01

Table 4.3.5 Mean, median, standard deviation (SD), standard error (SE), minimum, maximum and *p* values for raw asymmetry for zygomatic and face variables.

Measurement		Mean (mm)	Median (mm)	SD (mm)	N	SE (mm)	Min (mm)	Max (mm)	*p*
au.r-ans/au.l-ans	Total face length	0.5#	0.7	2	125	0.2	-3.6	4.7	0.01
slor.r-zmi.r/slor.l-zmi.l	Zygomatic height	0	0.1	1.2	124	0.1	-3.5	2.7	1.00
zti.r-or.r/zti.l-or.l	Zygomatic length	0	0	1.5	142	0.1	-3.5	3.1	1.00
zt.r-au.r/zt.l-au.l	Zygomatic arch length	0	0	1.6	145	0.1	-3.4	3.3	1.00

*significant at p<0.05 #significant at p<0.0

Table 4.3.6 Mean, median, standard deviation (SD), standard error (SE), minimum, maximum and *p* values for raw asymmetry are displayed for mandibular variables.

Measurement		Mean (mm)	Median (mm)	SD (mm)	N	SE (mm)	Min (mm)	Max (mm)	*p*
gn-go.r/gn-go.l	Mandibular body length	0.3	0.1	1.8	99	0.2	-3.2	4.1	0.10
gn-cd.r/gn-cd.l	Total mandibular length	1.1#	0.9	1.9	99	0.2	-2.8	6.9	<0.01
gn-ct.r/gn-ct.l	Gnathion-coronoid length	0.7#	0.7	1.9	99	0.2	-5.7	6.6	<0.01
cd.r-go.r/cd.l-go.l	Posterior ramus height	0.4#	0.3	1.6	125	0.1	-3.3	3.8	<0.01
ct.r-cd.r/ct.l-cd.l	Superior ramus distance	0.5#	0.5	1.3	153	0.1	-2.1	3.3	<0.01

*significant at p<0.05 #significant at p<0.01

Table 4.3.7 Mean, median, standard deviation (SD), standard error (SE), minimum and maximum values for asymmetry index for cranial vault variables.

Measurement		Mean (%)	Median (%)	SD (%)	N	SE (%)	Min (%)	Max (%)
br-po.r/br-po.l	Lateral cranial vault height	0.2	0	1.7	121	0.2	-3.3	4.2
br-spc.r/br-spc.l	Coronal suture length	-0.6	-0.9	2.5	118	0.2	-6.2	5.5
l-as.r/l-as.l	Lambdoid suture length	0.6	0.1	3.2	140	0.3	-6.9	9.6
spc.r-as.r/spc.l-as.l	Lateral cranial vault length	-0.2	-0.3	2.9	125	0.3	-6.2	6.1

Table 4.3.8 Mean, median, standard deviation (SD), standard error (SE), minimum and maximum values for asymmetry index for cranial base variables.

Measurement		Mean (%)	Median (%)	SD (%)	N	SE (%)	Min (%)	Max (%)
spa.r-es/spa.l-es	Anterior lesser wing of sphenoid width	2.0	1.1	4	137	0.3	-7.3	10.9
ac.r-spa.r/ac.l-spa.l	Posterior lesser wing of sphenoid width	0	-0.2	5.1	178	0.4	-11.1	11.4
sor.r-spa.r/sor.l-spa.l	Anterior cranial fossa length	0.2	0.2	3.9	167	0.3	-7.7	9.2
spa.r-petp.r/spa.l-petp.l	Lateral middle cranial fossa length	0.5	0.6	2.8	169	0.2	-5.6	6.4
petsa.r-ac.r/petsa.l-ac.l	Anterior clinoid-petrous length	1.1	1.2	8.3	187	0.6	-29.3	29.3
petsa.r-petp.r/petsa.l-petp.l	Petrous ridge length	1.1	0.9	3	177	0.2	-5.7	7.7
pts.r-petsa.r/pts.l-petsa.l	Spheno-occipital synchondrosis length	-1.4	-1	6.9	160	0.5	-18.8	16.8
hn.r-pts.r/hn.l-pts.l	Pterygoid plate height	1	1	3.7	144	0.3	-6.4	8.8

Table 4.3.9 Mean, median, standard deviation (SD), standard error (SE), minimum and maximum values for asymmetry index for orbital variables.

Measurement		Mean (%)	Median (%)	SD (%)	N	SE (%)	Min (%)	Max (%)
sor.r-or.r/sor.l-or.l	Orbital height	-0.5	-0.7	2.7	134	0.2	-8.5	4.9
morfl.r-lor.r/morfl.l-lor.l	Orbital distance	0.4	0.5	1.9	137	0.2	-3.5	4.5
ofa.r-morfl.r/ofa.l-morfl.l	Medial orbital length	0	-0.1	2.2	149	0.2	-5	4.9
ofa.r-slor.r/ofa.l-slor.l	Lateral orbital length	0.1	0.2	3.3	160	0.3	-7.1	6.4
ofa.r-sor.r/ofa.l-sor.l	Superior orbital length	0.3	0.4	2.5	169	0.2	-5.1	6.6
ofa.r-or.r/ofa.l-or.l	Inferior orbital length	0.5	0.4	2.2	134	0.2	-3.7	5.3

Table 4.3.10 Mean, median, standard deviation (SD), standard error (SE), minimum and maximum values for asymmetry index for maxillary and nasal variables.

Measurement		Mean (%)	Median (%)	SD (%)	N	SE (%)	Min (%)	Max (%)
ans-al.r/ans-al.l	Lower pyriform margin width	1.0	0.7	6.8	141	0.6	-20.1	28.8
n-al.r/n-al.l	Nasal height	-0.2	-0.3	1.9	130	0.2	-4.5	3.4
inm.r-snm.r/inm.l-snm.l	Naso-maxillary suture length	-0.9	-0.9	3.6	146	0.3	-8.8	8.7
mxt.r-ms.r/mxt.l-ms.l	Posterior maxillary height	0.0	-0.1	3.4	124	0.3	-8	8.3
or.r-zmi.r/or.l-zmi.l	Anterior zygo-maxillary suture length	-0.2	0.1	4.7	139	0.4	-11.2	9.2
ms.r-inm.r/ms.l-inm.l	Superior maxillary length	0.5	0.7	2.4	133	0.2	-4.7	6.5
mxt.r-pr/mxt.l-pr	Inferior maxillary length	0.3	0.4	2.6	116	0.2	-4.9	5.8
pns-hn.r/pns-hn.l	Palatal width	-0.5	-0.8	5.5	147	0.5	-13.3	21.5
hn.r-gpf.r/hn.l-gpf.l	Palatal height	-3.7	-3.7	10.7	146	0.9	-28.7	26.8
zmi.r-pr/zmi.l-pr	Zygomaxillare-prosthion width	0.8	0.8	3.2	114	0.3	-6	7.4

Table 4.3.11 Mean, median, standard deviation (SD), standard error (SE), minimum and maximum values for asymmetry index for zygomatic and face variables.

Measurement		Mean (%)	Median (%)	SD (%)	N	SE (%)	Min (%)	Max (%)
au.r-ans/au.l-ans	Total face length	0.5	0.8	2.2	125	0.2	-5.7	4.5
slor.r-zmi.r/slor.l-zmi.l	Zygomatic height	0	0.4	3.1	124	0.3	-8	6.5
zti.r-or.r/zti.l-or.l	Zygomatic length	-0.1	-0.1	3.5	142	0.3	-8.5	8.2
zt.r-au.r/zt.l-au.l	Zygomatic arch length	0.1	0	4.8	145	0.4	-9.8	10.6

Table 4.3.12 Mean, median, standard deviation (SD), standard error (SE), minimum and maximum values for asymmetry index for mandibular variables.

Measurement		Mean (%)	Median (%)	SD (%)	N	SE (%)	Min (%)	Max (%)
gn-go.r/gn-go.l	Mandibular body length	0.2	0.1	2.4	99	0.2	-5.3	5.0
gn-cd.r/gn-cd.l	Total mandibular length	1.0	0.9	1.8	99	0.2	-2.4	5.9
gn-ct.r/gn-ct.l	Gnathion-coronoid length	0.8	0.9	2.2	99	0.2	-6.1	7.2
cd.r-go.r/cd.l-go.l	Posterior ramus height	1.1	1.0	3.8	125	0.3	-6.8	8.7
ct.r-cd.r/ct.l-cd.l	Superior ramus distance	2.0	2.3	4.9	153	0.4	-9.1	12.1

The asymmetry results are also presented graphically. Figure 4.3.1 provides a graphical presentation of measurements that showed significant asymmetry overlaid on 3D-CT reconstructions of craniofacial bones in anterior and posterior views of the face and skull and superior and inferior views of the cranial base.

As can be seen in the figures, there were more variables that showed right side dominance in all craniofacial regions in anterior, posterior and superior cranial base views.

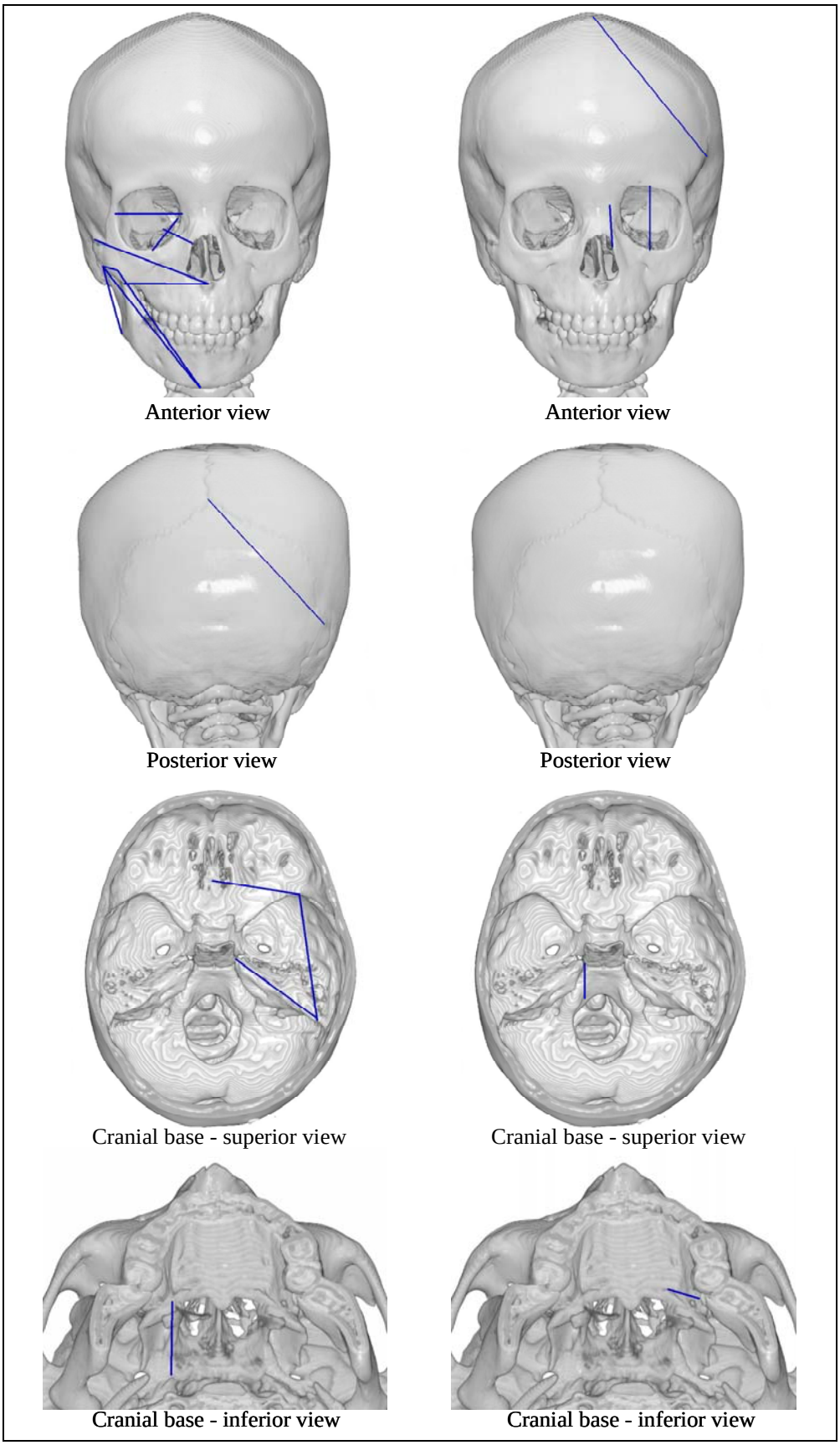

Figure 4.3.1 3D-CT reconstructions with those dimensions that showed significant directional asymmetry indicated. Those where the right side was larger than the left are indicated on the subject's right and those where the left side was larger than the right are indicated on the subject's left.

Linear modelling analysis revealed that the majority of craniofacial structures in this analysis did not display significant age and sex effects for asymmetry. Only those measurements associated with significant age or sex effects are presented here and the results can be observed in the form of scatter plots in Figures 4.3.2 to 4.3.5. Significant age affects were noted for anterior cranial fossa and mandibular body lengths and significant sex effects were observed for posterior lesser wing of sphenoid width and zygomatic height.

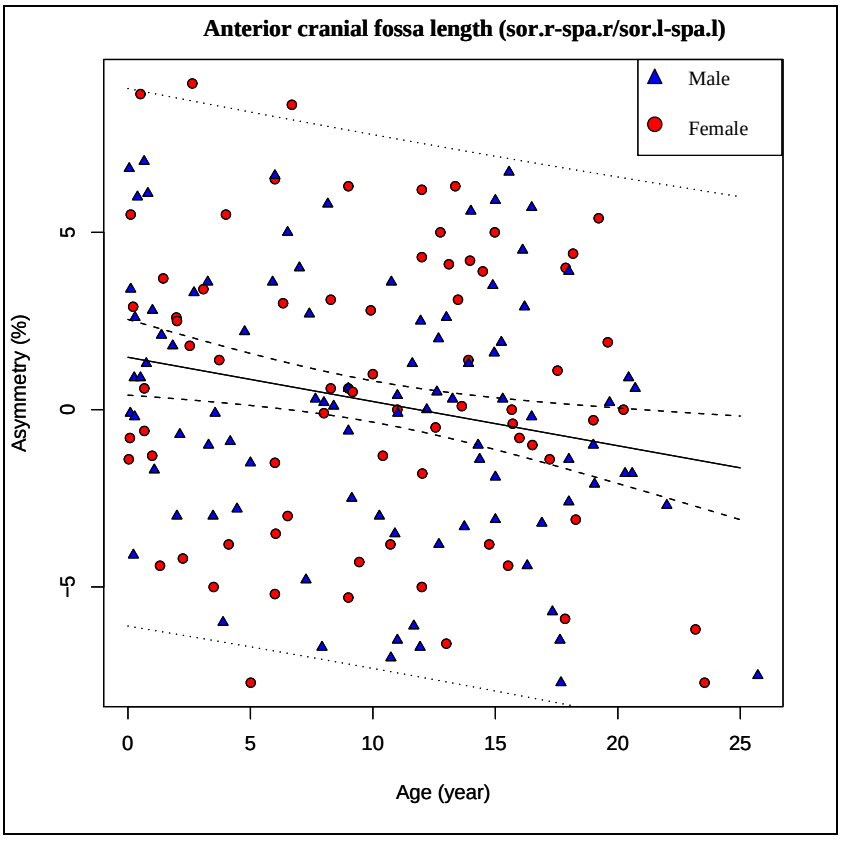

Figure 4.3.2 Scatter plot for asymmetry index values of anterior cranial fossa length versus age.

Figure 4.3.3 Scatter plot for asymmetry index values of mandibular body length versus age.

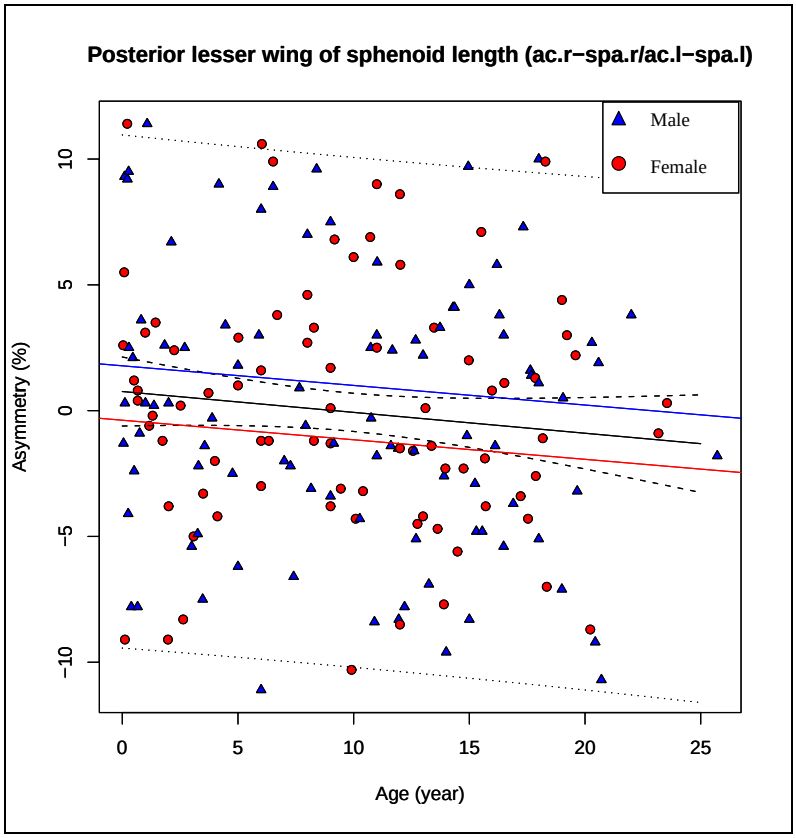

Figure 4.3.4 Scatter plot for asymmetry index values of posterior lesser wing of sphenoid length versus age.

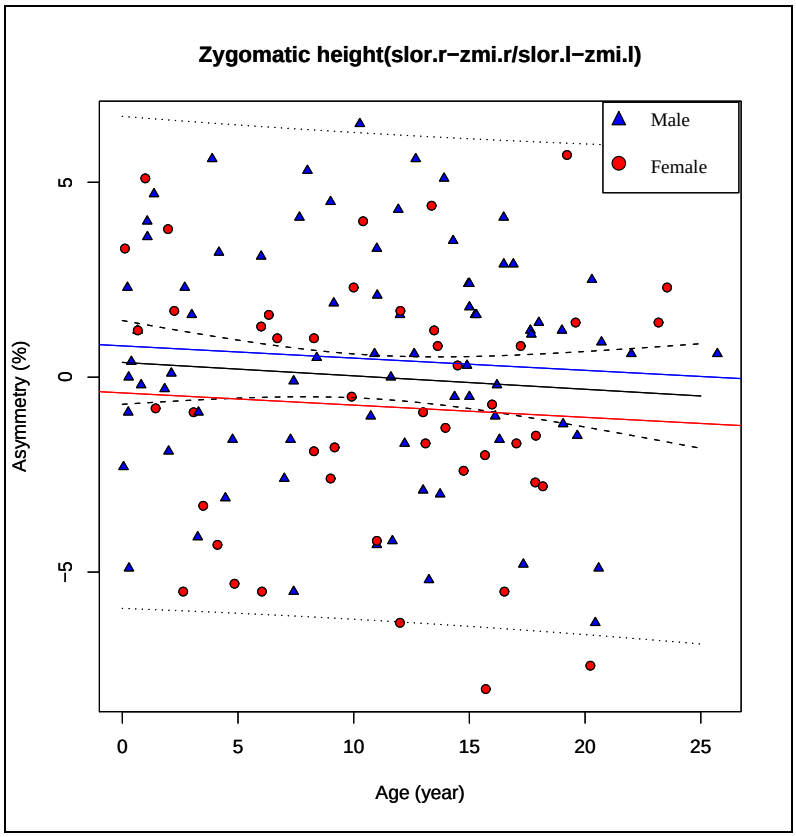

Figure 4.3.5 Scatter plot for asymmetry index values of zygomatic height versus age.

4.3.4 Discussion

The results show a small degree of asymmetry exists in the craniofacial structures of this sample of normal Malaysian Malays. Directional asymmetries were observed in all of the craniofacial regions investigated for more variables than would be expected purely due to chance. Structures that showed right side predominance were associated with average asymmetry indices ranging from 0.4 to 2% and those that revealed predominance on the left side were associated with average indices in the range -0.5 to -3.7%. Negative signs mean that the left measurement is larger than the right. Cranial base, total face length and mandibular measurements showed mainly right side predominance. The mandible showed the most dimensions with asymmetry, with 80% showing significant right side dominance. Cranial vault, orbital, maxillary and nasal measurements revealed evidence of asymmetry but with about the same number of dimensions showing right and left side dominance.

Directional asymmetry expressed as a percentage, or asymmetry indices, were calculated so that the magnitude of asymmetry unrelated to size could be demonstrated. The use of this index enables comparisons of asymmetry displayed by different craniofacial regions. This allows patterns or trends of asymmetry to be investigated so that regions showing the most asymmetry can be identified.

In this study, the average asymmetry indices were generally small with only one measurement associated with an average asymmetry index greater than 3%, i.e. for palatal height measurement. Values for asymmetry indices in this study ranged from low and moderate asymmetries with a few that demonstrated asymmetry index of more than 20%.

Cranial vault and orbital variables showed low range of asymmetry magnitudes with all variables displayed asymmetry index of less than 10%. Zygomatic and face and mandibular regions demonstrated low to moderate asymmetry percentages with some variables revealed asymmetry indices of more than 10% but less than 20%. Cranial base and maxillary and nasal regions contained a mixture of variables that displayed low and moderate

range of asymmetry magnitudes of less than 10% and 20% respectively. A few variables from these regions manifested quite high range of asymmetry indices of more than 20%. These high asymmetry magnitudes were observed for anterior clinoid-petrous length in cranial base region and lower pyriform margin width, palatal width and palatal height measurements from maxillary and nasal region.

The asymmetry indices for every measurement were subjected to linear modelling analysis to investigate age and sex effects. Only two measurements showed significant age effects, i.e. anterior cranial fossa length and mandibular body length. The asymmetry indices for anterior cranial fossa length showed that this structure tended to be larger on the right during infancy and childhood, but then larger on the left during adulthood. For mandibular body length, the opposite trend was noted, i.e. this dimension was larger on the left during infancy and childhood and then larger on the right during adulthood. These changes in asymmetry, particularly for the mandible, may be due to alterations in masticatory function. It is possible that the change of asymmetry from one side to the other may be associated with changing side preference during mastication or a change in the direction of the masticatory cycle.

Changes in the direction of the masticatory pattern occurred when children move from primary to permanent dentition (Gibbs *et al.*, 1982). These researchers reported that the masticatory pattern in the child with primary dentition is characterised by wide lateral movements on opening. As the child progresses into mixed dentition, the extent of lateral movement on opening decreases and the extent of lateral movement on closing increases. By the age of 12 to 14 years of age, the typical chewing pattern has changed almost completely and is characterised by medial opening and wide lateral closure. This pattern then continues throughout adulthood.

It has been noted that the expression of craniofacial asymmetry can be related to muscular functional activity, especially of the masticatory apparatus (Pirttiniemi, 1994).

Normal side differences were noted for size of the mandible in a sample of Indian subjects and it was suggested that unilateral chewing pattern which then developed differences in muscular function were important factors (Shah and Joshi, 1978).

For those structures that showed significant asymmetry but did not show age changes, genetic factors may be involved. Additionally, significant sex effects were revealed for only two measurements, one was a cranial base measurement and another one was a zygomatic measurement. These findings confirm a lack of sexual dimorphism in asymmetry for the majority of variables, with the ones that showing significant differences possibly occurring due to chance.

Previous studies are conflicting about the degree, side and location of craniofacial asymmetry. In agreement with this study, Shah and Joshi (1978) stated that overall facial structures were larger on the right side. Woo (1931), working on Egyptian skulls, found that the right maxilla, frontal and parietal bones were larger than the left. Woo (1931) also stated that the overall right side of the face was bigger due to greater development of the right side of the brain. In their three-dimensional evaluation of facial asymmetry, Ferrario *et al.* (1994b) observed that, on average, the right side of the face was larger than the left. They also found that there was no sex difference in the manifestation of asymmetry. A slight tendency toward larger right-sided structures was also noted in a study of subjects with aesthetically pleasing faces (Peck *et al.*, 1991).

In contrast to the current study, Vig and Hewitt (1975) observed that the cranial base and maxillary regions were significantly larger on the left side in their radiographic investigation. They also found that the mandibular and dento-alveolar regions exhibited a greater degree of asymmetry. These findings were in agreement with another asymmetry study (Chebib and Chamma, 1981).

In a study of a longitudinal series of postero-anterior radiographs of Australian Aboriginal children and young adults, Winning *et al.* (1999) observed a wide range of

asymmetry with considerable individual variation across different age groups. However, no significant age-related changes in asymmetry were noted for males and females. On the other hand, another study showed that the side of facial predominance was a function of age (Melnik, 1992), with early left-sided excess at 6 years of age which developed into right-sided excess with growth. Another study also revealed that asymmetries of craniofacial regions were present in foetuses and infants, indicating that asymmetry occurs before the establishment of masticatory function (Rossi *et al.*, 2003).

It is difficult to compare results of the present study with others because the methods, the measurements, and the sample characteristics (age, sex and race) are very different. Most differences may be methodological in nature, as investigators use different methods and measurements. Comparisons can only be made on a very general basis. Moreover, errors of measurements must be taken into consideration. This is especially crucial when lateral, postero-anterior and submento-vertex radiographs or photographic two-dimensional projections are used because errors of projection and errors of landmark identification can occur. The three- dimensional technique adopted in this study allowed direct identification of landmarks on the 3D-CTs, and enabled calculation of the asymmetry of undistorted measurements.

The measurement errors in this study were generally small, with a range of errors between 0.4mm to 0.5mm (Section 2.8.4.2). Measurement errors need to be considered to decide whether observed differences between the left and right sides represent true asymmetry or whether they are affected by measurement error. Since the measurements of facial asymmetry found in this study were quite small, the findings need to be assessed carefully to ensure that false conclusions are not drawn. However, calculations were made across all ages from birth to adulthood and the ranges of asymmetry values for every variable were noted to be larger than measurement error.

With the exception to the mandible, a few variables from each region studied showed statistically significant asymmetries. However, clinically some degree of asymmetry is anticipated and was confirmed with calculation of asymmetry index. Moreover, this study also offers the range of normal asymmetries for different variables in different regions. Treating patients within this range should achieve a more or less balanced face. Another issue to note is that asymmetry calculation for a particular variable in this study was generated from average of left and right differences from birth to adulthood. Segregation of subjects into smaller age groups will give readings of the asymmetry within those age groups and will provide more extensive study of age effects on asymmetry.

It is important to stress that the author only concentrated on the directional component of asymmetry in this study. The author was aware of the fluctuating component of asymmetry but did not attempt to quantify this component in this study. Differentiations of fluctuating asymmetry need different approaches and more statistical power and Livshits and Kobyliansky (1991) have given a comprehensive description of fluctuating asymmetry and its analysis. Results for directional asymmetry in this analysis may be compounded by inherent fluctuating asymmetry.

Another issue that the author would like to point out is that linear measurements on the left and right side were determined separately and the differences between the homologous measurements were calculated to generate asymmetry values. This method was chosen to avoid the ambiguity of selecting a reference vertical mid-line that separated the craniofacial structures into two halves. Numerous other studies have employed this approach to analyse asymmetry (Farkas and Cheung, 1981; Melnik, 1992; O'Grady and Antonyshyn, 1999; Rossi *et al.*, 2003). The validity of various reference vertical lines, as well as horizontal lines, for asymmetry analysis has been investigated (Trpkova *et al.*, 2003). In this 3D-CT analysis, reference lines were not used. Measurement of distances on the left and right side separately, followed by the calculation of the differences between homologous measurements was used

to supply information about side dominance. Unfortunately, this method provides a set of measurements that are sensitive only to local imbalances, and does not allow an all-encompassing analysis such as that used by Ferrario *et al.* (1994b).

The asymmetry of facial components observed in this study could be the result of an asymmetric cranial base. It was noted that the cranial base, total face and mandible were all associated with a right side dominance. This observation supports previous suggestions that asymmetry in craniofacial regions is influenced by cranial base asymmetry which in turn is influenced by asymmetrical brain structures (Pirttiniemi, 1998). Bilateral variation in brain development occurs during growth, as the brain is normally asymmetric both anatomical and functionally (Pirttiniemi, 1998). Moreover, the mandible connects directly to the cranial base through the condyles at the glenoid fossa of temporal bone. So, it is not surprising that the mandible followed the asymmetry pattern displayed by the cranial base which in this case was larger on the right for most variables. Moreover, the mandible being the farthest from the brain and also the movable part of the face, revealed greater asymmetry than other parts of the face. Together with an influence from the cranial base, functional effects of mastication may add to an already asymmetric mandible.

Additionally, the larger the asymmetry, the more attention needs to be given by the clinician because structures may approach a pathological condition. What determines whether a degree of asymmetry has reached a pathological level is not easy to decide, and clinical parameters relative to aesthetics and function must be taken into consideration. One of the objectives of the current study was to provide normative asymmetry reference values so that pathological conditions can be compared to them and the extent of deviation from normal determined.

As has been reported, some craniofacial measurements showed dominance on one side and others on the other side of the same skull. This condition may be related to the growth processes of craniofacial structures that involves interrelationships between the various

regions as they seek a functional equilibrium. Therefore, asymmetry at the cranial base may be transferred to other regions on the same side or it may be compensated for and generate a contralateral asymmetry.

4.3.5 Conclusion

A small degree of asymmetry was found in normal craniofacial features of Malaysian Malays. It was observed that the right side of the cranial base, face and mandible was significantly larger than the left. The majority of skeletal structures did not exhibit age changes or sex differences in directional asymmetry. Craniofacial structures may display a small degree of asymmetry but individuals can still have pleasing, normal faces. Asymmetry seems to be an intrinsic characteristic of the human face. Asymmetric brain development has been suggested to cause asymmetric cranial base development that can then influence the asymmetry of facial components. This study provides results that are consistent with this concept. Finally, functional activity, particularly mastication, may influence the asymmetry shown by craniofacial structures, especially the mandible.