A MORPHOMETRIC STUDY OF THE NORMAL HUMAN EAR IN HUSM USING COMPUTER BASED MEASUREMENT TECHNIQUE

Nor Azura Mohamed[1] and Zainul Ahmad Rajion[2]

[1]*Design Engineering Section,Sirim BERHAD, Lot 5285, Off Lebuhraya Sg. Besi-Puchong, 57000 Kuala Lumpur, Malaysia.*
[2]*School of Dental Science, University Science Malaysia, 16150 Kota Bharu, Kelantan*
(norazura@sirim.my)

RINGKASAN
Kajian mengenai telinga manusia adalah penting untuk memberi pengetahuan tentang nilai purata parameter standard untuk telinga. Prostodontik boleh menggunakan nilai ini semasa menghasilkan telinga palsu bagi mendapatkan pandangan estetik yang menyenangkan untuk pesakit yang mempunyai masalah kecacatan telinga. Hasil kajian ini telah berjaya menyediakan data beberapa parameter standard untuk telinga kiri dan kanan bagi penduduk di Kelantan. Kajian morphometric telah dijalankan ke atas 68 sampel telinga normal untuk kedua-dua kiri dan kanan dengan 15 parameter diukur. Data telah diambil dari imbasan CT dan ditukar kepada imej 3 dimensi (3D) menggunakan kaedah pembangunan '*soft tissue'*. Hasil kajian analisa morfometrik memberikan nilai purata dan sisihan piawai untuk panjang dan lebar telinga, panjang dan tinggi '*tragus'*, '*insertion length'* telinga, panjang dan lebar '*lobular'* dan '*conchal'*, '*protusion'* pada aras '*superaurale'* dan '*tragal'* dan juga nilai sudut kecenderungan dan simetri telinga.

ABSTRACT
A study of the human auricle is important to give prior knowledge of average value for standard parameters of the ear. Prosthodontist uses this value when reconstructing the prosthetic ear in order to achieve a pleasant aesthetic glance of the patient with a problem of ear deformity. This study has successfully provided morphometric data of standard ear parameters of both the left and right ear for the Kelantan population. Morphometric study was conducted on 68 samples of normal left and right ears. 15 parameters were measured. Data was retrieved from Computed Tomography (CT) scans and converted to 3-dimensional (3D) digital images using soft tissue development. Results from this morphometric analysis provided the mean and standard deviation values for auricular length and width, length and height of tragus, insertion length of auricle, length and width of lobular and conchal, protusion at superaurale and tragal level as well as the inclination and symmetrical angle.

KEYWORDS: Ear morphometric, CT scan, 3D image

INTRODUCTION

Knowledge of the normal ear morphology is important in the treatment and management of a variety of congenital deformities such as hemifacial microsomia, Tessier's facial cleft, microtia, etc. Also, its subtle structures show potential signs of age, gender and aesthetic appearance.

Several studies have been carried out to study the anthropometric data of auricle for several ethnic groups (Wang, 2011; Sforza, 2009; Kalcioglu, 2003) but none has been done in Malaysia. It is important to have prior knowledge of average values of each parameter and use these values to help in constructing prosthesis with the appropriate size and shape. Many of the existing anthropometry data on the auricle have been obtained from direct measurement techniques to assess the dimensions, locations, inclination and level of typical ear. Direct measurement technique means the measurement procedure requires the subject to be present and vernier caliper or other measuring devices are used to measure the required parameters (Purkait, 2012, Ekanam, 2010). The disadvantage of this conventional technique is that it limits the measurement of a number of landmark locations and that locating the landmark points themselves is a challenge.

In 2009, Sforza in his study, utilized a 3D computerized electromagnetic digitizer to capture a 3D image of the subject. However, recent studies (Marques, 2012 and Wang *et al.*, 2011) used CT image data to visualize the 3D image and performed the morphometric analysis as well.

With this 3D image, the quantitative assessment of the dimensions of human facial soft tissue structures such as eyes, nose, mouth and lips, chin and ears can easily be captured and used for multiple purposes for various studies.

MATERIAL AND METHODS

Population and Sample Study

The sample consisted of data of patients aged from 18 years and above who had undergone CT scan procedure from 2009 until 2014 at the Hospital Universiti Sains Malaysia (HUSM). The data were retrieved from the server of Picture Archiving and Communication System (PACS) at the Radiology Department, HUSM. They are in the form of CT images of patients with craniofacial tumours and fractures among others. Any CT data displaying auricular abnormalities or maxillofacial anomalies were excluded from this study. This study has obtained approval from the Human Research Ethics Committee USM (HREC), reference number USMKK/PPP/JEPeM [259.3.(2)] dated 15 January 2013 and their guidelines were followed.

Sample Size Determination for Morphometric Study

Descriptive statistic was used to determine the sample size using Equation 1 (Wang *et al.*, 2011).

$$n = \left(z\frac{\sigma}{\Delta}\right)^2 \quad \text{------------>} \quad (1)$$

where:-

n = no. of sample size
z = 1.96 (fix α = 0.05)
σ = determine from literature*
Δ = effect size (0.8)

The following criteria were also determined:

1. Power of the study = 0.8
2. Alpha, α = 0.05
3. Effect size = Large (0.8)
4. Drop out = 10%

From equation 1, the estimated sample size is 80. However, for this study, a sample size of 68 was used because only 68 samples met our criteria.

3D Image Processing

The following is the standard process for a data conversion of 2D dicom format to a 3D image in MIMICS. All samples obtained from the PACS server were in the form of a stack of slice images in a 2D dicom format (Figure. 1). This data was exported to MIMICS software for its conversion to a 3D image. Figure 2 gives an overview of the main section in MIMICS user interface after the data from CT scan dicom format was exported to the software.

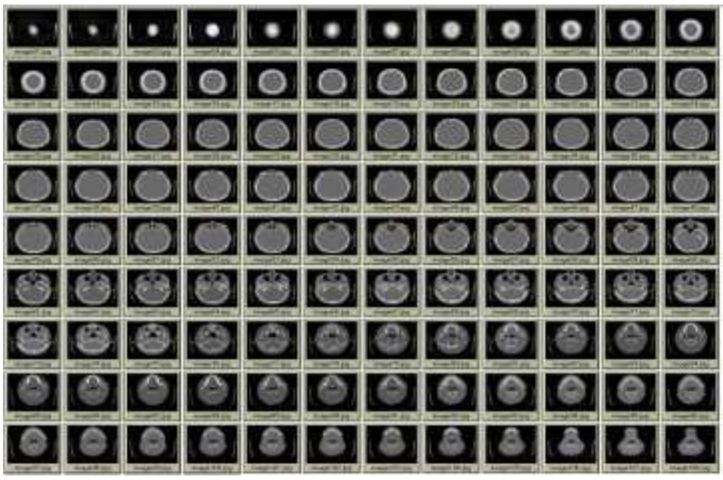


Figure 1: Stack of slice images from CT scan in 2D dicom format

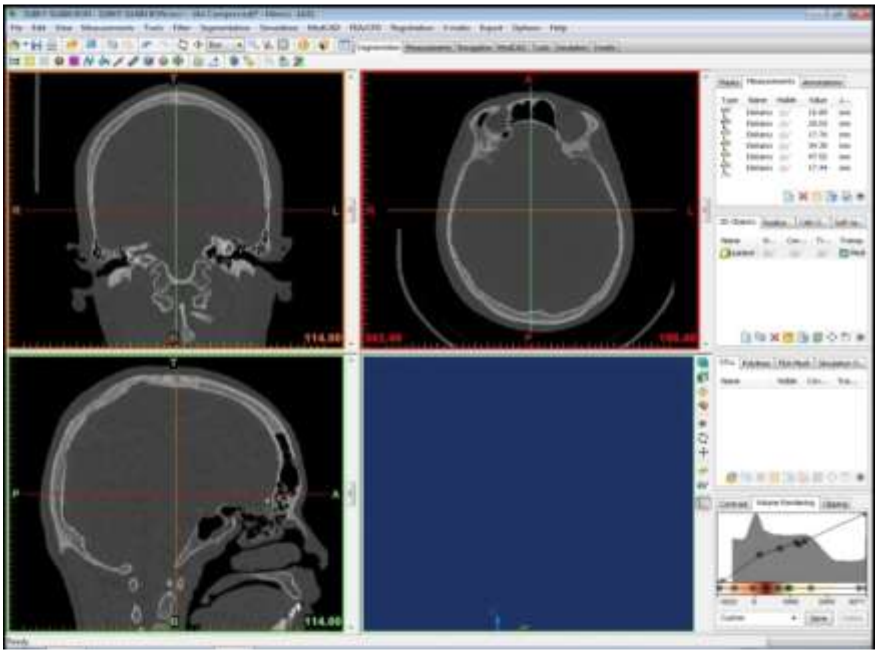


Figure 2: The MIMICS software user interface in 2D format at certain slice. Top left = Coronal view; top right = axial view; bottom left = sagittal view; bottom right = 3D reconstruction view

Once all the 2D images have been imported to the software, thresholding of the images was carried out to select the soft tissue of the sample. Region growing of the selected area removed any unnecessary pixel. Mask editing was used for any noise present in the sample. Finally, the 3D reconstruction of the images was selected to convert the data to a 3D image (Figure 3).

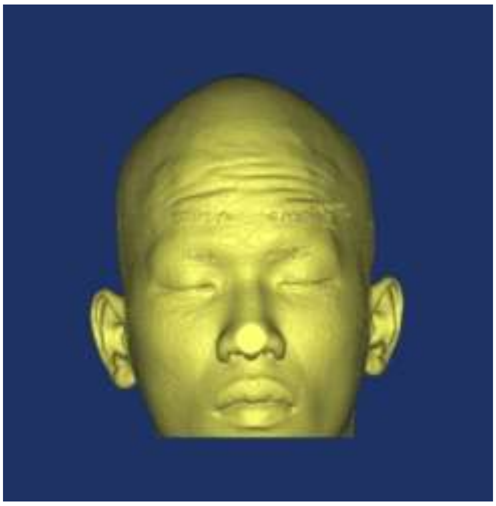


Figure 3: 3D image obtained from data conversion in MIMICS

Landmark Identification

Landmark points were identified (Figure 4) in order to measure the ear parameters. For the identification of the landmark points, the study carried out by Coward *et al*. (2000) was used as a reference.

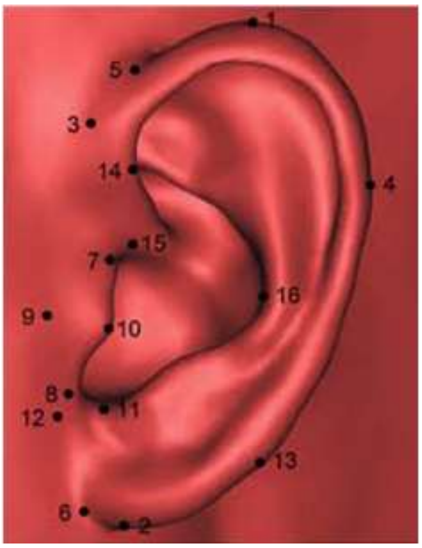


Figure 4: The landmarks location of the ear in 3D image

The landmark points shown in Figure 4 are as follows:

1. Superaurale
2. Subaurale
3. Preaurale
4. Postaurale
5. Otobasion superius
6. Otobasion inferius
7. Deepest point on the notch on upper margin of tragus
8. Lowest point on the lower border of tragus
9. Cardinal point of tragus
10. Protragion
11. Incisura intertragica inferior (the deepest point in the incisura intertragica)
12. Lobule anterior (ear attachment line is drawn joining the otobasion superior and inferior)

13. Lobule posterior (the most posterior point on the margin of lobule perpendicular to lobule anterior)
14. Concha superior (the intersection of the lower edge of the anterior end of the crus antihelices inferius and the posterior border of crus helicus)
15. Incisura anterior auris posterior (the most posterior point on the edge of incisura anterior auris)
16. Strongest antihelical curvature

Morphometric Measurement

Morphometric measurement in this study was carried out virtually using the measurement application module available in the software. Softwares MIMICS version 14.0 (Materialise, Leuven, Belgium) and Geomagic Qualify (Geomagic, U.S Corporate) were used to measure linear and angularity, respectively. A total of 15 parameters were measured. Of these, 12 were standard parameters (Figures 5 and 6) that were similarly measured by Wang *et al.*, (2011) in their study. The remaining 3 parameters were measured in order to see the symmetry between the face and the ear (Figure 7). Measurements were taken for both the left and the right ear of each sample.

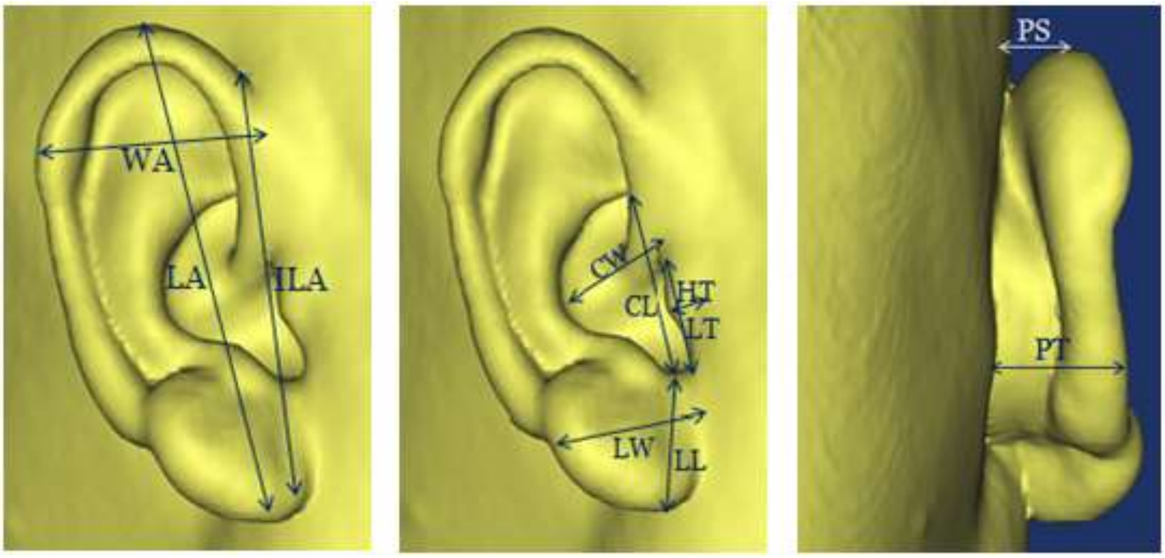


Figure 5: Linear measurement parameters of the ear.

Each parameter in Figure 5 is defined as follows:

LA: Length of auricle

WA: Width of auricle

ILA: Insertion length of auricle

CL: Conchal length

CW: Conchal width

LL: Lobular length

LW: Lobular width

HT: Height of tragus

LT: Length of tragus

PS: Protusion at Superaurale level

PT: Protusion at Tragus level

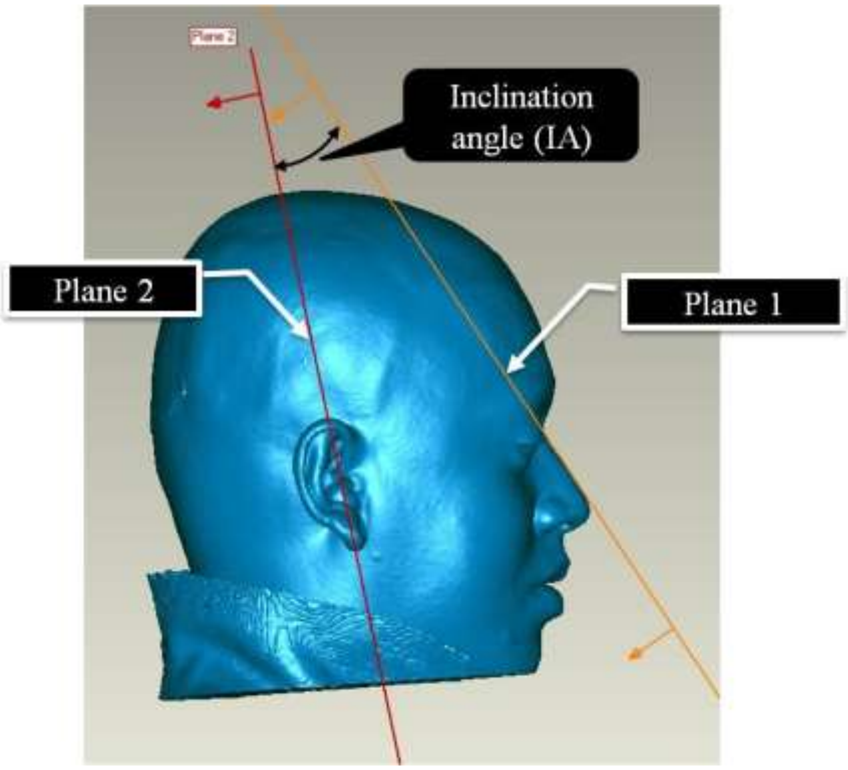


Figure 6: Inclination angle (IA) measurement of the ear

Angularity measurements

The inclination angle (IA), the angle between the axis of the auricle and the bridge of the nose was measured using Geomagic Qualify software. Figure 6 shows the creation of two planes, where Plane 1 refers to the bridge of the nose and Plane 2 refers to the axis of the auricle. Plane 2 was created by connecting landmarks 1 and 2. Inclination angles for both right and left ear were measured.

Symmetrical angles (SA) were also measured. SA refers to the angle between the right and the left ear taken from the frontal view (Figure 7). Plane 3 was created by connecting landmarks 1 and 2 of the left ear while plane 4 by connecting landmarks 1 and 2 of the right ear. Symmetrical angles between right and left ear with respect to the axis of the midface were also measured in this study (Figures 8a and 8b). For these measurements, plane 5 was created by connecting a few cephalometric landmark points identified for the midface (Figure 9).

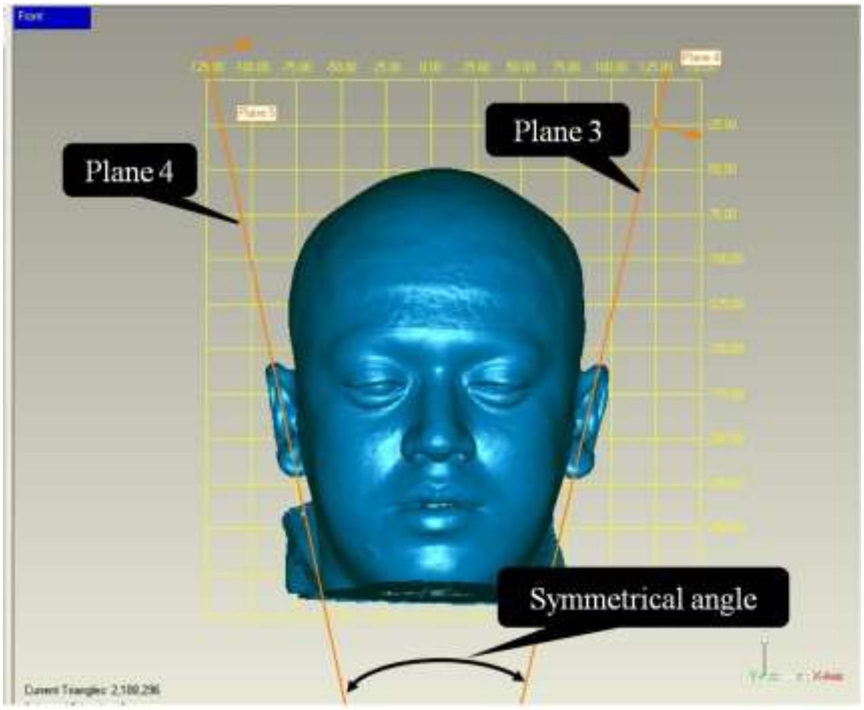
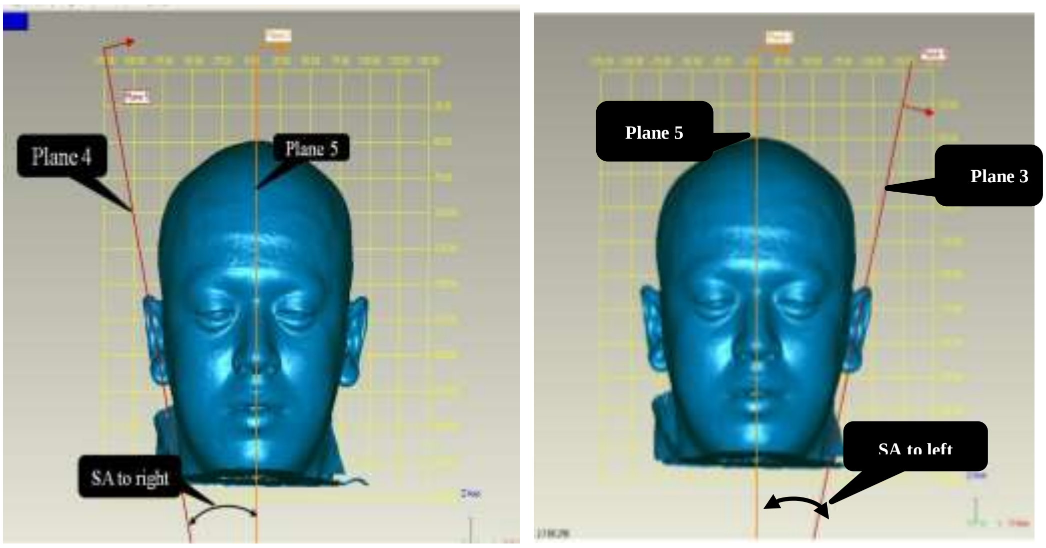


Figure 7: Symmetrical angle (SA) parameter



(a) *(b)*

Figure 8: Symmetrical angle for right ear (a) and left ear (b) with respect to the axis of the nose

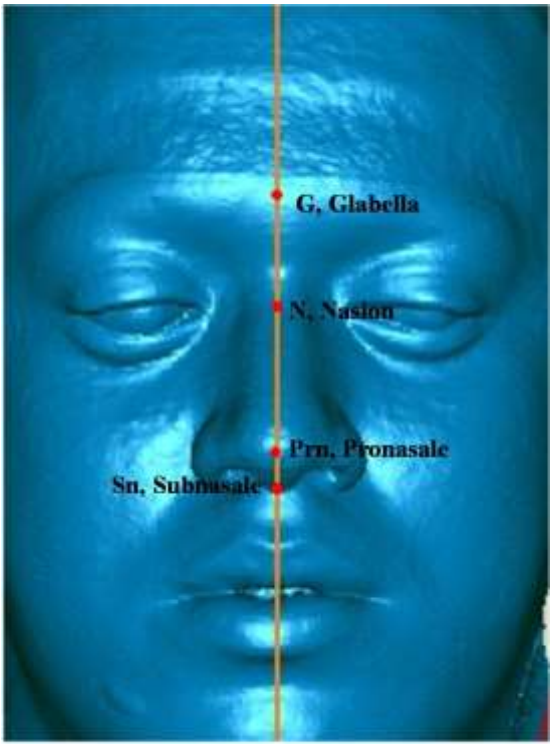


Figure 9: Cephalometric landmarks for midface

Measurement for symmetrical angles in relation to the anthropometric analysis of the ear had not been studied previously. However, it must be noted that these parameters play important roles in determining the correct location to place the prosthetic ear in relation to the facial asymmetry (personal communication with an anaplastologist).

Statistical Analysis

Descriptive statistics were described in terms of mean and standard deviations. Measurements of 68 samples with 15 normal ear parameters were carried out by one individual observer and validated by an expert. Each measurement was carried out 3 times, each at one month interval and the average value calculated. For confidentiality, scans were identified by codes instead of the actual name of the samples.

RESULTS AND DISCUSSION

Socio-Demographic Characteristic for Morphometric Analysis

A total of 68 samples were studied in this research of adult samples aged from 18 years old and above. The socio-demographic characteristics for all the samples are shown in Table 1 below.

Table 1: Socio-demographic characteristics of morphometric analysis samples

Variable	Mean (SD)	Frequency (%)
Age (Years)	40.57 (16.43)	
Gender		
Male		46 (67.6)
Female		22 (32.4)

The sample group consists of 67.6 % males and 32.4 % females. The mean age of the sample is 40.57 (16.43) with ages ranging from 18 to 90 years old.

Morphometric Analysis of Left and Right Ear

The results of morphometric analysis of both the left and the right ears for all 68 samples are presented in Table 2. A total 15 parameters of both the normal left and right ears were measured. The average and standard deviation for each parameter measured were calculated and tabulated (Table 2).

Table 2: The morphometric ear measurements of left and right ear (n=68)

Measurements (mm)	Right Ear Mean (SD)	Left Ear Mean (SD)
LA	62.35 (0.93)	62.24 (0.96)
WA	33.46 (1.37)	32.63 (1.47)
ILA	54.55 (1.64)	54.44 (2.22)
LT	15.41 (1.54)	15.07 (1.66)
HT	5.68 (1.07)	5.49 (0.88)
LL	18.79 (0.97)	18.84 (0.82)
LW	22.86 (2.52)	22.23 (3.03)

CL	26.79 (0.89)	26.68 (0.85)
CW	20.95 (2.01)	20.61 (1.88)
PS	10.43 (1.30)	10.91 (1.49)
PT	19.74 (0.90)	19.89 (0.91)
IA	23.64 (3.20)	23.04 (3.84)
SA	16.43 (2.65)	na
SA to the right ear	9.04 (2.31)	na
SA to the left ear	na	8.36 (2.06)

LA=Length of Auricle, WA= Width of auricle, ILA=Insertion length of the auricle, LT=Length of tragus, HT=Height of tragus, LL=Lobular length, LW=Lobular width, CL=Conchal length, CW=Conchal width, PS= Protusion at Superaurale level, PT= Protusion at Tragal level, IA= Inclination angle of the Auricle, SA= Symmetrical Angle, na=not applicable

The results show only a very small difference in measurement between the right and the left ear. Overall, measurements for right ear parameters have higher values compared to the left ear for the length and width of auricle (LA and WA), insertion length of auricle (ILA), length and width of tragus (LT and HT), length and width of conchal (CL and CW), inclination angle (IA) and symmetrical angle (SA). Similar results were also obtained by other authors (Ekanem *et al*., 2010, Coward *et al*., 2000, Deopa *et al.*, 2013).

Table 3 compares the values of ear parameters obtained from our study and those from other studies but with different ethnic groups. The values vary from one study to the other. However, the values obtained from our work are closer to those obtained by Sforza *et al.* (2009) and Wang *et al.* (2011) which shows that ear morphology differs from one ethnic group to the other. To date, there are no studies on the symmetrical angles that are available, hence our data from this study cannot be assessed and compared with those of other workers.

From Anatomical Landmarks to Digital Morphology Measurement

Conventional anthropometrics measurements identifies soft-tissue landmarks placing instruments such as calipers, angle meters, measuring tapes and protractors over measurement surface (in this case human) to measure the distance between a pair of landmarks, or the angle comprises three of them (Sforza, 2006). This conventional method limits the numbers of parameters to be measured as it is quite difficult to reach the landmarks at complex location for example, the conchal and tragus area. As a result not many studies are able to give the values of conchal and tragus parameters.

This study demonstrates the competency of using 3D image obtained from CT scan data to execute the measurement. The number of parameters that can be measured has increased and these include the inclination angle, protrusion at superaurale and tragal level. The 3D image data created in MIMICS that is exported to Geomagic software enable the measurement of the symmetrical angles to be performed. All these measurements do not need the presence of samples in their physical form thus allowing ample time to perform the required measurements. Another advantage of using a CT is that, the data captured are able to show the anatomy of the ear, both externaly and internally. The data image conversion from the CT scan not only gives information on the soft tissue but also the information on the bony area. With these data, medical doctors can easily diagnose and plan for implant surgery when necessary.

Table 3: Distribution of results obtained in the measurement of left and right ear compared to other studies of different ethnic

Measurements (mm)	**Our study Kelantan, Malaysia**		**Oludiran, Benin City**		**Wang *et al.*, (2011) North China**		**Sforza *et al.*, (2009) Italy**		**Deopa *et al.*, (2013) Uttarakhan, India**		**Ekanam *et al.*, (2010) Maiduguri, Nigeria**		**Bozkir *et al.*, (2006) Turkey**	
	n = 63		*n= 1462*		*n = 485*		*n = 843*		*n = 177*		*n = 217*		*n = 341*	
	18 - >60 yrs		8-30 yrs		18-74 yrs		4-73 yrs		17-25 yrs		18-65 yrs		18-25 yrs	
	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
LA	62.4 (0.9)	62.2 (1.0)	55.6 (6.0)	55.6 (6.0)	59.7 (3.6)	59.9 (3.8)	63.9 (3.9)	63.8 (4.0)	59.0 (4.0)	59.1 (3.8)	56.0 (4.0)	56.0 (6.0)	61.2 (3.3)	61.4 (3.3)
WA	33.5 (1.4)	32.6 (1.5)	32.4 (4.5)	32.0 (4.5)	32.8 (2.2)	32.4 (2.2)	37.4 (3.3)	37.2 (3.5)	29.5 (2.3)	29.7 (2.8)	11.1 (2.8)	11.2 (2.6)	32.1 (2.1)	32.3 (2.2)
LL	18.8 (1.0)	18.8 (0.8)	14.0 (3.8)	14.0 (3.8)	18.5 (2.6)	18.5 (2.5)			16.6 (2.2)	16.9 (2.1)	13.3 (2.5)	13.4 (2.3)	18.2 (1.6)	17.9 (1.6)
LW	22.9 (2.5)	22.2 (3.0)	16.0 (4.8)	16.0 (4.8)	19.6 (1.9)	19.6 (1.9)			19.4 (2.1)	19.6 (2.3)			19.4 (2.1)	19.0 (2.1)
ILA	54.6 (1.6)	54.4 (2.2)			45.6 (4.0)	45.9 (4.1)								
LT	15.4 (1.5)	15.1 (1.7)			14.1 (6.3)	14.4 (2.0)								
HT	5.68 (1.07)	5.49 (0.88)			5.3 (1.7)	5.6 (1.6)								
CL	26.8 (0.9)	26.7 (0.9)			25.5 (2.0)	25.5 (2.1)								
CW	20.9 (2.0)	20.6 (1.9)			18.0 (2.3)	18.0 (2.2)								
PS	10.4 (1.3)	10.9 (1.5)			14.5 (3.9)	14.4 (3.7)								
PT	19.7 (0.9)	19.9 (0.9)			20.0 (3.9)	19.7 (3.8)								
IA	23.6 (3.2)	23.0 (3.8)			15.1 (6.1)	15.1 (6.0)	29.3 (6.7)	30.7 (6.7)						

CONCLUSION

In conclusion, the knowledge of the normal ear dimensions is important in the diagnosis of congenital malformations, syndromes and deformities as well as in the planning of treatment. This study demonstrates the mean value and standard deviations of a few standard ear morphometric parameters from both left and right ear measurement for the population of Kelantan. It is hoped that the data obtained from this study will contribute to the knowledge and assist the experts working in this area to produce an anatomically correct ear during the process of its reconstruction.

ACKNOWLEDGEMENT

The author would like to express her deepest gratitude to SIRIM management for the financial support and to the personnel of Pusat Pengajian Sains Pergigian (PPSG), Universiti Sains Malaysia for the provision of facility, advice and guidance for the successful completion of this research.

REFERENCES

Azaria, R., Adler, N., Silfen, R., Regev, D. and Hauben, D. J. (2003). Morphometry of the Adult Human Earlobe: A Study of 547 Subjects and Clinical Application. *Plast Reconstr Surg., Vol 111, pp 2398-2402*

Brucker, M. J., Patel, J. and Sullivan, P. K. (2003). A Morphometric Study of The External Ear: Age- and Sex-Related Differences. *Plas Reconstr Surg*; *Vol 112, pp 647-652*.

Coward, T. J., Scott, B. J. J., Watson, R. M., Richards, R. (2000). Laser scanning of the ear identifying the shape and position in subjects with normal facial symmetry. *Int. J. Oral Maxillofac Surg*., Vol *29, pp 18-23*

Deopa D., Thakkar H. K., Chandra Prakash, Niranjan R., Barua M. P., (2013). Anthropometric measurements of external ear of medical students in Uttarakhan region, *Journal of the Anatomical Societyof India*, *Vol 62, pp 79-83*

Ekanem, A. U., Garba, S. H., Musa, T. S. and Dare, N. D. (2010). Anthropometric Study of the Pinna (Auricle) among Adult Nigerians Resident in Maiduguri Metropolis; *J.Med Sci*, 10(6) *pp 176-180*

Kalcioglu, M. T., Miman, M. C., Toplu, Y., Yakinci, C. and Ozturan, O., (2003). Anthropometric Growth Study of Normal Human Auricle; *International Journal of Pediatric Otorhinolaryngology, Vol 67, pp 1169-1177*

M. Gulhal Bozkir, Pinar Karakas, Metin Yavuz, Fahri Dere (2006). Morphology of the External Ear in Our Adult Population. *Aesthetic Plastic Surgery, Vol 30, pp 81-85*

Oludiran, O. O., Omotos, D. R., (2012). A Morphometric Study of The External Ear at Benin City

Purkait, R. Handbook of Anthropometry: Physical Measures of Human in Health and Disease. London: Springer. *pp 907*

Sforza, C., Grandi, G., Binelli, M., Tommasi, D. G., Rosati, R. & Ferrario, V.F. (2009). Age- and Sex-Related Changes in the Normal human Ear, *Forensic Science International* 187 110.e1-110.e7

Sforza & Virgilio, F. F., (2006). Soft-tissue facial anthropometry in three dimensions: from anatomical landmarks to digital morphology in research, clinics and forensic anthropology. *Journal of Anthropological Sciences. Vol.84, pp 97-124*

Wang, B., Dong, Y., Zhao, Y., Bai, S. and Wu, G., (2011). Computed Tomography measurement of The Auricle in Han Population of North China; *Journal of Plastic Surgery & Aesthetic Surgery, Vol 64, pp 34-40*

Fourie, Z., Janalt, D., Gerrits, P. O., Ren, Y., (2010). Evaluation of anthropometric accuracy and reliability using different three-dimensional scanning systems, *Forensic Sci. Int*, doi:10.1016/j.forsciint.2010.09.018