# A Growth Study of Chinese Ears Using 3D Scanning

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**Abstract.** Ears are important organs considering facial aesthetics and auditory function. Anthropometric data of ears can help in understanding the morphology, which can further be applied in medical and ergonomic research. The purpose of this study is to evaluate the variation of four selected ear dimensions along with other parameters such as gender, age and ear symmetry with the use of 3D scanned data. Sixty Chinese children (30 males and 30 females) aged 5 to 13 years were invited for the study. They were divided into three groups based on the age. Four dimensions (ear length, ear width, width from tragus to antihelix, and flipping angle from the base of the head to the helix) were measured for both ears from the point clouds data acquired from the 3D scans. Statistical analyses were performed to measure the growth and characteristics of ears' morphology. These results provide a better understanding of variation in ear morphology based on different demographic parameters. In addition, this research would assist in providing some basic 3D anthropometric data of ears for Chinese children, which can be helpful in deciding sizing, and grading parameters of ear related products for children.

**Keywords:** Growth study · Ear morphology · 3D scanning · Anthropometry Ergonomics

## 1 Introduction

Ears play a very crucial role in facial aesthetics as well as auditory capability of an individual. With the physical growth and development of an individual, the morphology and the shape of ears changes along with the body shape. The understanding of dynamic changes in the ear morphology and shape along with age can be of great use for anthropometric research, medical research and product design applications. Hence, it is very important to understand the growth pattern of ear.

Various researchers have tried to conduct ear growth studies on different populations, such as Turkish [1], American [2], Italian [3], and Japanese [4]. As for Chinese population, growth studies have concentrated on height, weight and sexual maturity of the whole body mainly [5–7], whereas there is hardly any growth study focusing on ear morphology. Previous study has shown that the ear growth pattern may vary based on ethnic group and sociocultural environment [1]. Therefore, there is a need for such


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anthropometric study to be conducted on Chinese population to understand the change in ear's morphology.

To measure ear dimensions, researchers have widely used traditional measurement techniques, like using calipers [8] and scales [9]. Researchers have also used 2D data acquired from images to obtain the ear dimensions [10]. However, the selected dimensions in these studies were very restricted due to the complex structure of human ear [9] and the variety among different individuals [11]. Development of 3D scanning technology has provided a new opportunity for ear related anthropometric research. 3D scanning is now being used to acquire the 3D point cloud for part of human body [12, 13], and there are several applications of specific 3D scanning devices available [14]. This technology can provide highly accurate information which can help in analysis of shape variance as compared to traditional measuring techniques [15]. Some researchers have tried to use 3D scanning for ear related research [16–18], but still there is a huge need for research in this area, as with the advancements in technology it has been made easier to acquire accurate data even with the complexity in ear's contour.

The main aim of this study was to explore the variation in different morphological features of ear and deduce their relationship with parameters like gender, age and symmetry with the use of 3D scanning, which could in turn help in understanding the growth of external ears in Chinese children.

## 2 Methods

### 2.1 Participants

Sixty Chinese children (30 males and 30 females) within the age range of 5 to 13 years were invited to participate in this study. The participants were further divided into 3 groups equally: 5 to 7 years of age (Group 1), 8 to 10 years of age (Group 2), and 11 to 13 years of age (Group 3). Each group had equal amount (10) of male and female participants. The demographic description of the participants is shown in Table 1.

**Table 1.** The demographic information of the population in this study.

| | | Group 1 (N = 20) | Group 2 (N = 20) | Group 3 (N = 20) |
|---|---|---|---|---|
| Height (cm) | Male | 116.75 ± 6.57 | 138.83 ± 4.06 | 158.11 ± 9.30 |
| | Female | 110.51 ± 6.58 | 138.35 ± 10.83 | 152.07 ± 7.79 |
| Weight (kg) | Male | 18.72 ± 1.79 | 33.75 ± 9.45 | 46.45 ± 10.15 |
| | Female | 20.56 ± 4.29 | 36.59 ± 9.62 | 46.00 ± 10.71 |

### 2.2 Procedure

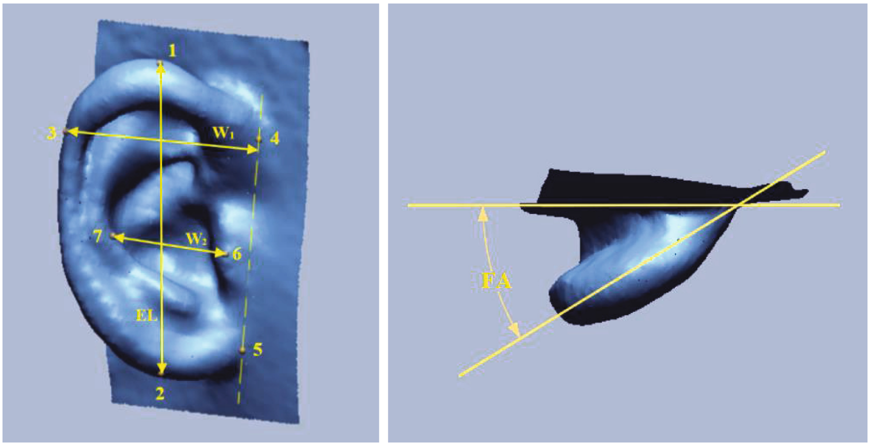
An informed consent form was signed by the participant before conducting the 3D scanning procedure. Since 3D scanners cannot scan hair accurately, participants were made to wear a specifically designed latex cap [12]. Also to avoid head movements during the scanning process, a head rest was used, where the participants were made to rest their chin. 3D scanning was performed by using a handheld Artec Eva 3D scanner with an accuracy of 0.1 mm. A point cloud data of the head including the ear region was captured for each participant as shown in Fig. 1.

**Fig. 1.** A point cloud of the children head including the ear region.

Seven landmarks were selected on the surfaces of the 3D scanning model using Rapidform 2006 software. Four anthropometric dimensions were calculated based on the positions of the selected reference points. The landmarks and measurements are indicated in Fig. 2. The landmarks include (1) Superaurale, (2) Subaurale, (3) Postaurale, (4) Preaurale, (5) Lobule anterior, (6) Tragus, and (7) Strongest antihelical curvature. The dimensions involve (EL) ear length from superaurale to subaurale; ($W_1$) ear width from postaurale to the ear base line; ($W_2$) the width from tragus to the strongest antihelical curvature; and (FA) flipping angle from the base of the head to helix.

### 2.3 Data Analysis

Statistical analysis was performed to systematically analyze the acquired data using SPSS 20.0 software. A within group descriptive statistical analysis was performed to evaluate the mean values and standard deviations of all the measured anthropometric dimensions. Correlation analysis was conducted to understand the relationships between measured anthropometric dimensions and other demographic parameters, such as age, gender, symmetry, body height and weight. Paired t-test was used to understand the influence of right left symmetry on the dimensions. Two-sample t-test was used to determine the existence of gender based effects on the measured values. One-way ANOVA was performed between groups to examine the differences of the measurements of the three age groups for both the ears separately.




(a) Front view of the right ear; (b) Top view of the right ear.

**Fig. 2.** Landmarks and measurements on the right ear.

## 3 Results

Tables 2, 3 and 4 provide general statistical description about all the measured dimensions under variables of gender, age and ear symmetry, respectively.

**Table 2.** General description of the dimensions for different gender groups (mm).

| | | | Mean | Standard deviation | 95% Confidence interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower | Upper |
| EL | Right ear | Male | 57.02 | 3.88 | 55.55 | 58.50 |
| | | Female | 53.13 | 3.28 | 51.88 | 54.38 |
| | Left ear | Male | 56.90 | 3.23 | 55.67 | 58.13 |
| | | Female | 53.86 | 3.29 | 52.61 | 55.12 |
| $W_1$ | Right ear | Male | 33.90 | 2.31 | 33.02 | 34.78 |
| | | Female | 31.84 | 2.22 | 31.00 | 32.68 |
| | Left ear | Male | 33.68 | 2.79 | 32.62 | 34.75 |
| | | Female | 31.68 | 2.68 | 30.66 | 32.69 |
| $W_2$ | Right ear | Male | 19.68 | 1.60 | 19.07 | 20.29 |
| | | Female | 18.41 | 1.84 | 17.71 | 19.11 |
| | Left ear | Male | 19.46 | 2.02 | 18.69 | 20.23 |
| | | Female | 18.85 | 1.84 | 18.15 | 19.55 |
| FA | Right ear | Male | 31.19 | 6.25 | 28.85 | 33.52 |
| | | Female | 28.96 | 5.85 | 26.78 | 31.15 |
| | Left ear | Male | 32.09 | 7.80 | 29.17 | 35.00 |
| | | Female | 30.99 | 6.76 | 28.46 | 33.51 |

**Table 3.** General description of the dimensions for different age groups (mm).

| | | | Mean | Standard deviation | 95% Confidence interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower | Upper |
| EL | Right ear | Group 1 | 52.53 | 2.89 | 51.18 | 53.89 |
| | | Group 2 | 55.80 | 3.77 | 53.98 | 57.61 |
| | | Group 3 | 57.03 | 4.20 | 55.00 | 59.05 |
| | Left ear | Group 1 | 53.32 | 3.02 | 51.91 | 54.73 |
| | | Group 2 | 55.79 | 3.04 | 54.33 | 57.25 |
| | | Group 3 | 57.14 | 3.68 | 55.37 | 58.91 |
| $W_1$ | Right ear | Group 1 | 31.92 | 2.24 | 30.87 | 32.96 |
| | | Group 2 | 33.15 | 2.58 | 31.90 | 34.39 |
| | | Group 3 | 33.60 | 2.40 | 32.44 | 34.75 |
| | Left ear | Group 1 | 31.68 | 2.73 | 30.40 | 32.95 |
| | | Group 2 | 32.95 | 3.01 | 31.50 | 34.41 |
| | | Group 3 | 33.46 | 2.78 | 32.12 | 34.80 |
| $W_2$ | Right ear | Group 1 | 18.77 | 1.27 | 18.18 | 19.37 |
| | | Group 2 | 19.70 | 2.14 | 18.67 | 20.73 |
| | | Group 3 | 18.69 | 1.90 | 17.77 | 19.60 |
| | Left ear | Group 1 | 19.21 | 1.79 | 18.37 | 20.05 |
| | | Group 2 | 19.59 | 2.04 | 18.61 | 20.57 |
| | | Group 3 | 18.66 | 1.99 | 17.71 | 19.62 |
| FA | Right ear | Group 1 | 29.76 | 5.53 | 27.17 | 32.35 |
| | | Group 2 | 29.64 | 6.44 | 26.63 | 32.65 |
| | | Group 3 | 30.83 | 6.54 | 27.77 | 33.90 |
| | Left ear | Group 1 | 30.96 | 7.50 | 27.45 | 34.47 |
| | | Group 2 | 31.42 | 5.93 | 28.64 | 34.19 |
| | | Group 3 | 32.23 | 8.44 | 28.28 | 36.19 |

**Table 4.** General description of the dimensions for right left symmetry (mm).

| | | Mean | Standard deviation | 95% Confidence interval | |
|---|---|---|---|---|---|
| | | | | Lower | Upper |
| EL | Right ear | 57.02 | 3.88 | 55.55 | 58.50 |
| | Left ear | 53.13 | 3.28 | 51.88 | 54.38 |
| $W_1$ | Right ear | 33.90 | 2.31 | 33.02 | 34.78 |
| | Left ear | 31.84 | 2.22 | 31.00 | 32.68 |
| $W_2$ | Right ear | 19.68 | 1.60 | 19.07 | 20.29 |
| | Left ear | 18.41 | 1.84 | 17.71 | 19.11 |
| FA | Right ear | 30.08 | 6.11 | 28.50 | 31.65 |
| | Left ear | 31.54 | 7.26 | 29.66 | 33.41 |

**Table 5.** Correlation coefficients of morphological symmetry between the two ears.

| | EL (right ear) | $W_1$ (right ear) | $W_2$ (right ear) | FA (right ear) |
|---|---|---|---|---|
| EL (left ear) | 0.907** | | | |
| $W_1$ (left ear) | | 0.739** | | |
| $W_2$ (left ear) | | | 0.729** | |
| FA (left ear) | | | | 0.754** |

**. p < 0.01; *. p < 0.05.

The correlation results in Table 5 suggested that there were strong relationships between right and left ear for all the measured dimensions. The correlation coefficients between the measured variables on each ear are separately presented in Tables 6 and 7. The correlation analysis showed that there were statistically significant relationships among dimension EL, $W_1$, $W_2$, body height and body weight, while dimension FA had little significant relationship with other variables. Considering the correlation coefficient values, there were significantly strong relationships between EL and $W_1$, between $W_1$ and $W_2$, between EL and body height, between EL and body weight, and between EL and age for both right and left ears, while the relationships between $W_1$ and body height, between $W_1$ and body weight, between $W_1$ and age were relatively weak with significance for both ears. It was also found that there were some relationships between EL and $W_2$ on right ear, $W_1$ and FA on right ear, as well as between EL and FA on left ear, but there was no significant relationship for the same dimensions on the opposite ear.

**Table 6.** Correlation coefficients between the dimensions on right ear.

| | EL (right ear) | $W_1$ (right ear) | $W_2$ (right ear) | FA (right ear) |
|---|---|---|---|---|
| $W_1$ (right ear) | 0.504** | | | |
| $W_2$ (right ear) | 0.343** | 0.580* | | |
| FA (right ear) | 0.190 | −0.289* | −0.174 | |
| Body height | 0.512** | 0.367** | 0.093 | 0.129 |
| Body weight | 0.475** | 0.308* | 0.132 | 0.087 |
| Age | 0.445** | 0.273* | 0.014 | 0.098 |

**. p < 0.01; *. p < 0.05.

**Table 7.** Correlation coefficients between the dimensions for left ear.

| | EL (left ear) | $W_1$ (left ear) | $W_2$ (left ear) | FA (left ear) |
|---|---|---|---|---|
| $W_1$ (left ear) | 0.522** | | | |
| $W_2$ (left ear) | 0.191 | 0.452** | | |
| FA (left ear) | 0.266* | −0.223 | −0.212 | |
| Body height | 0.535** | 0.338** | −0.050 | 0.078 |
| Body weight | 0.479** | 0.290* | −0.114 | 0.015 |
| Age | 0.440** | 0.326* | −0.142 | 0.066 |

**. p < 0.01; *p. < 0.05.

The results of paired t-test for the anthropometric dimensions under the variable of right left symmetry for are shown in Table 8. From the results, there was no significant difference between right and left ear on EL, $W_1$ and $W_2$. Only FA on right ear was significantly smaller than left ear.

**Table 8.** Comparison of the dimensions between left and right sides of ear.

| | Mean difference[a] | Standard error | t | df | p |
|---|---|---|---|---|---|
| EL | −0.33 | 0.22 | −1.52 | 59 | 0.14 |
| $W_1$ | 0.12 | 0.25 | 0.50 | 59 | 0.62 |
| $W_2$ | −0.09 | 0.18 | −0.51 | 59 | 0.61 |
| FA | −1.46 | 0.62 | −2.53 | 59 | 0.02* |

*. $p < 0.05$
Mean difference[a] = mean on right ear – mean on left ear

Table 9 demonstrates the results of two-sample T-test for which gender was independent variable and anthropometric dimensions were dependent variables. It was indicated that gender had significant effects on the mean values of EL and $W_1$ for both ears. Dimension EL and $W_1$ were greater for males than females for both the ears. Dimension $W_2$ on right ear was significantly larger for males as compared to females, whereas there was no significant difference between both the genders for dimension $W_2$ of left ear. For dimension FA, there was unclear difference between males and females for both ears.

**Table 9.** Comparison of the dimensions between male and female.

| | | Mean difference[b] | Standard error | t | df | p |
|---|---|---|---|---|---|---|
| EL | Right ear | 3.81 | 0.91 | 4.17 | 58 | 0.00* |
| | Left ear | 2.17 | 0.59 | 3.47 | 58 | 0.00* |
| $W_1$ | Right ear | 1.21 | 0.44 | 3.65 | 58 | 0.00* |
| | Left ear | 2.85 | 1.46 | 2.94 | 58 | 0.01* |
| $W_2$ | Right ear | 2.90 | 0.84 | 2.75 | 58 | 0.01* |
| | Left ear | 2.05 | 0.70 | 1.01 | 58 | 0.32 |
| FA | Right ear | 2.23 | 1.56 | 1.42 | 58 | 0.16 |
| | Left ear | 1.10 | 1.88 | 0.58 | 58 | 0.56 |

*. $p < 0.05$
Mean difference[b] = mean of male – mean of female

The results of one-way ANOVA revealed the differences of the mean values of all the dimension among the three age groups as shown in Table 10. It showed the existence of statistical significant difference amongst the three age groups of dimension EL for both sides of ears, while different age groups had no statistically significant influence on dimension $W_1$, $W_2$ and FA. Specifically, Table 11 compares the differences of dimension

**Table 10.** Comparison of the dimensions among age groups.

| | | F | $df^c$ | p |
|---|---|---|---|---|
| EL | Right ear | 8.232 | (2, 57) | 0.001* |
| | Left ear | 7.206 | (2, 57) | 0.002* |
| $W_1$ | Right ear | 2.203 | (2, 57) | 0.120 |
| | Left ear | 2.045 | (2, 57) | 0.139 |
| $W_2$ | Right ear | 1.955 | (2, 57) | 0.151 |
| | Left ear | 1.427 | (2, 57) | 0.248 |
| FA | Right ear | 0.227 | (2, 57) | 0.798 |
| | Left ear | 0.153 | (2, 57) | 0.858 |

*. $p < 0.05$
$df^c$ = (df(Between Groups), df(Within Groups))

**Table 11.** Comparison of dimension EL among age groups.

| | | Mean difference | Standard error | p |
|---|---|---|---|---|
| EL (right ear) | Group 1–Group 2 | −3.22 | 1.13 | 0.017* |
| | Group 1–Group 3 | −4.46 | 1.13 | 0.001* |
| | Group 2–Group 3 | −1.24 | 1.13 | 0.521 |
| EL (left ear) | Group 1–Group 2 | −2.54 | 1.01 | 0.040* |
| | Group 1–Group 3 | −3.77 | 1.01 | 0.001* |
| | Group 2–Group 3 | −1.23 | 1.01 | 0.448 |

*. $p < 0.05$.

EL between every age group. For both ears, dimension EL for Group 1 was significantly less than Group 2 and Group 3, while there was no significant difference between Group 2 and Group 3.

## 4 Conclusion and Discussion

Growth study about human ear provides a better understanding of the ear morphological changes which can be helpful for product design and medical applications. Previous ear growth studies have been performed on different populations [2, 3], but there are very few studies conducted on Chinese population. Hence, it is important to conduct similar research so as to help in better generalization and standardization of Chinese ear dimensions.

Previous studies [8, 19] indicated that male had significantly greater ear length and ear width than female in Turkish, Malaysian and Indian. Also in the current study, it was observed that ear length (EL) and ear width ($W_1$) for male were significantly greater than female for Chinese. Even though the relationships between right and left ear for ear length and width were similarly strong, the characteristics about the ear symmetry for different populations were not exactly the same [9, 20]. For Chinese population, a strong association between left and right side was found with coefficient of 0.91 in ear length (EL), 0.74 in ear width ($W_1$), 0.73 in ear width from the tragus to antihelix ($W_2$), and 0.76 in flipping angle from the base of the head to helix (FA), but no significant differences between the ear symmetry were discovered for all the dimensions in this study.

Liu [9] revealed that there was a weak association between ear length and body height among adults. Moreover, in this study, ear length (EL) appeared to be strongly related to body height, body weight and age, while ear width ($W_1$) had relatively weak relationships with these parameters. According to previous research [1, 2], there were continuous increments in ear length and width until the age of 18 years, and the growth rates became mild after certain ages with short period of no significant growth. In this study, the results were consistent with the past research. For both ears, there was a significant growth on ear length (EL) from group 1 to group 2 as well as from group 1 to group 3, but the increasing from group 2 to group 3 is not significant. Hence, the results showed that the ear length grew fast at earlier age and would turn slower after that. As to ear width ($W_1$) and the flipping angle (FA), the mean values were found to be increasing moderately without any significant differences from group 1, group 2 to group 3. Thus, the ear width and flipping angle were mildly growing. However, the width from the tragus to antihelix ($W_2$) was relatively stable without any trend of increase or decrease.

This study provides basic information about ear growth patterns for Chinese population. Based on these results, further studies can be conducted using large sample size which can help in better generalization of ear dimensions, which can help in understanding ear growth. This data can be very helpful for product design and medical application.

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