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A Comparison of Traditional and 3D Scanning Measurement in Ear Anthropometry

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Abstract. Ear anthropometry is important in physical ergonomics for ear-related products. With various anthropometric methods, comparisons between different measuring techniques have not been sufficiently studied especially for ear dimensions. This study aimed at comparing traditional measurement and 3D scanning method for ear anthropometry, with addressing their usages in practice. For thirty participants, ear length and ear width were measured by the same investigator with two measuring methods. Traditional measurement was directly conducted with a caliper, whereas dimensions using 3D scanning technique were extracted from the point cloud acquired from a structured light scanner. Statistical results showed the differences between traditional and 3D scanning measurement, which can provide empirical evidences of differences between different measuring techniques for ear anthropometry. Additionally, the usages of different methods were discussed so that proper method can be selected to match specific goals for future research.

Keywords: Anthropometry · Comparison · Ear measurement

1 Introduction

Anthropometry can provide valuable information in physical ergonomics. Particularly, ear anthropometry has been conducted to provide size and shape reference for ear-related ergonomic design. Researchers have applied different measuring techniques to conduct ear anthropometry in the past, including direct measurement [1–3], 2D photogrammetry [4,5] and 3D modelling method [6,7]. Hence, comparison between different methods is necessary to gain a comprehensive understanding of these

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methods. Some researchers have reviewed different measuring methods involving particular body parts, such as human body [8], feet [9], head and face [10]. However, comparison between traditional measurement and 3D measuring techniques in ear anthropometry has not been sufficiently studied.

Among the measuring methods, traditional measurement was the mostly used method to obtain ear dimensions, with direct measuring selected dimensions with tools, such as caliper, tape and protractor [1-3]. With the development of computer-aided design techniques, 3D scanning was extensively used in anthropometry for research and industrial use. Researchers have tried to use 3D scanning technology to study external ear [6,11], even though some challenges occurred when applying 3D scanning techniques in ear anthropometry due to the complex structure of external ear. Based on the consideration, the study selected direct measurement using caliper and indirect measurement through 3D scanning technique as the compered objectives.

The main aim of the study was to compare traditional measurement and 3D scanning method for ear anthropometry, with addressing their usages in practice. The comparisons in the study provided a statistical verification and usage discussion, so that proper measuring method can be selected to match specific goals for future research.

2 Methods

Thirty Chinese adults (15 males and 15 females) aged between 20 to 30 years were recruited in Hong Kong. Participants with deformities of bone and soft tissue around the ear region were not included. The demographic information was shown in Table 1.

Table 1. Demographic information of participants.

	Age (years)	Body height (cm)	Body weight (kg)
Male	23.7 ± 3.3	172.2 ± 4.9	64.2 ± 9.2
Female	23.4 ± 2.9	159.3 ± 6.2	63.1 ± 6.5

For each participant, ear length and ear width were acquired through both traditional and 3D scanning measurement. Only right ear was involved in the study. A caliper was used to directly measure the two dimensions, and a structured-light scanner (Artec Eva ® Artec) was used to scan the ear region. After scanning, a point cloud of the ear was acquired for dimension extraction. Four landmarks, including Superaurale, Subaurale, Postaurale, Preaurale, and Lobule anterior, were positioned on the 3D ear model, and then the ear length and ear width were calculated accordingly [12]. The landmarks and dimensions are demonstrated in Figure 1.

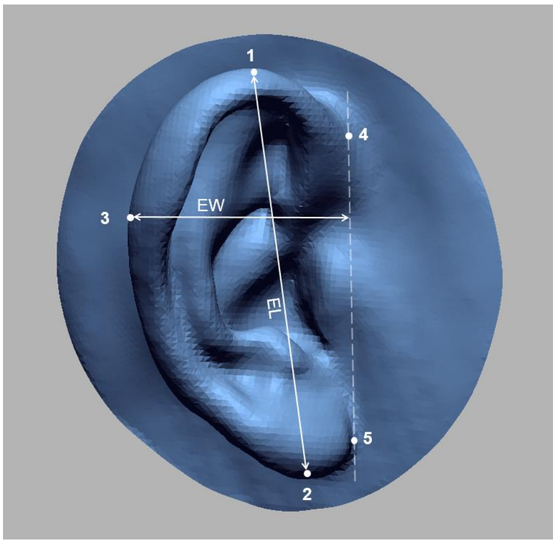

Fig. 1. Landmarks and dimensions involved in the study. Landmarks are (1) Superaurale, (2) Subaurale, (3) Posraurale, (4) Preaurale, and (5) Lobule anterior; Dimensions include (EL) ear length from Superaurale to Subaurale, and (EW) ear width from Postaurale to the ear base.

Statistical analysis was conducted to compare the ear dimensions in SPSS software. Descriptive statistics demonstrated the overall information of ear dimensions using different measurements. Paired t-test was used to compare the mean values through different anthropometric methods. Correlation coefficient and mean absolute difference were computed to compare the reliability of the two measuring methods.

3 Results

Descriptive statistics provided general information of selected ear dimensions measured with caliper and 3D scanning technique. The means, standard deviations (SD), minimums (Min), Maximums (Max) and 95% confidence intervals were listed in Table 2.

Table 2. Ear dimensions by direct and 3D scanning measurement (mm)

		Mean	SD	Min	Max	95% confidence	
						Lower	Upper
Ear length	Direct measurement	61.44	3.98	54.10	71.10	59.95	62.93
	3D scanning measurement	59.92	3.88	54.39	68.70	58.48	61.37
Ear width	Direct measurement	30.77	2.49	26.40	36.50	29.84	31.70
	3D scanning measurement	31.50	2.81	26.76	37.40	30.45	32.56

Ear dimensions through traditional and 3D scanning measurement were compared with paired t-test. The analysis results indicated the differences between traditional and 3D scanning measurement, as shown in Table 3. Specifically, 3D scanning measurement provided slightly smaller ear length and slightly larger ear width than traditional measurement with significant differences.

Table 3. Comparison of mean value between traditional and 3D scanning measurement

	Mean diffference[a]	Std. error mean	t	df	p
Ear length	1.51	0.22	6.81	29	0.000*
Ear width	-0.73	0.22	-1.18	29	0.003*

*. $p<0.05$
Mean difference[a] = traditional measurement – 3D scanning measurement

To compare the inter-observer reliability, correlation coefficients and mean absolute difference of the ear dimensions were calculated. As shown in Table 4, the results indicated the correspondence of the two anthropometric methods. The correlation results suggested an excellent agreement between traditional and 3D scanning measurement for both ear length and ear width. Additionally, the absolute values of MD (mean difference) and MAD (mean absolute difference) were similar, even though the difference of ear width is slightly larger than ear length.

Table 4. Inter-observer reliability between traditional and 3D scanning measurement

	Correlation coefficient (r)	p	Mean absolute difference
Ear length	0.952	0.000*	1.74
Ear width	0.903	0.000*	1.16

*. $p<0.05$

4 Discussion and conclusion

In previous studies, traditional and 3D scanning measurements were compared for different body components, including human body [8], feet [9], head and face [10,13,14]. As for ear anthropometry, Coward compared computerized tomography (CT), magnetic resonance imaging (MRI) and laser scanning for selected ear dimensions [16]. However, with various anthropometric methods, the comparative studies between these methods have not been adequately conducted in ear anthropometry. Therefore, this study statistically compared traditional measurement with structured light scanning measurement, with addressing the using conditions for specific methods.

Researchers have compared the mean values between using traditional and 3D scanning measurements for human body [8,9], head and face [10,13]. In these studies, differences between the two measuring methods were discovered to vary upon particular dimensions. Compared with direct measurement, 3D scanning measurement provided larger values for most of the circumferences and lengths for human body, and smaller values for armscye circumference, ann length and cerival height, with significant differences, while no significant difference was found for neck base circumference, bust circumference, waist back length [8], shoulder breath and abdominal depth [9]. Moreover, the differences of mean values between traditional and 3D scanning measurement were found to differ along with specific scanner for head and face dimensions [13]. In the study, traditional measurement of ear length was slightly larger than 3D scanning measurement, the reason could be the influence of hair near Superaurale landmark. As for ear width, traditional measurement provided slightly smaller value than 3D scanning measurement, which can be interpreted by the limitation of traditional measurement, that is, the ear baseline cannot be exactly located with the direct measuring method. The mean differences between traditional and 3D scanning measurement were 1.51 mm and 0.73 mm for ear length and ear width individually, which are considered as acceptable error (2 mm) in ISO 20685 [14].

Additionally, mean absolute difference (MAD) and mean difference (MD) are commonly compared to test discrepancy between different measuring methods [15]. Bougourd [16] compared the inter-observer variability of selected body dimensions based on MAD, while Han [8] associated the values between MD and MAD with interpretation for distinguished dimensions. In the study, the absolute values of MD and MAD for both dimensions were similar, even though the difference between the two absolute values for ear width was slightly larger than ear length. This was due to the obstacles of hair around Preaurale, despite that hair around the region was taken care with hairpins and covered with a cap.

Previous research suggested that 3D scanning measurement provided reliable data for specific dimensions, such as selected body dimensions [16], head and face dimensions [17]. Consistently, the inter-observer reliability, tested with correlation coefficient (ear length: r=0.952; ear width: r=0.903), showed a strong relationship between traditional and 3D scanning measurement, which meant that structured light scanning was as reliable as traditional measurement for selected ear dimensions.

Other than above quantitative comparisons, the usages of traditional and 3D scanning measurements also needed to be compared for ear anthropometry. As the mostly used method in previous ear anthropometric research, traditional measurement is convenient to conduct with selected or specific designed equipment. Limitations of the method exist obviously, such as time-consuming procedure, restricted information of dimensions and difficulty to acquire certain dimensions. Without providing the shape information and particular dimensions, ear anthropometry using traditional measurement may not fit with current lifestyle requirements for ear-related ergonomic design. Based on the considerations, 3D scanning technology provided an opportunity to overcome these limitations. Nowadays, 3D scanning was widely used to reconstruct the 3D model of the surface for a target item in research and industry. However, limitations still exist under certain conditions when applying 3D scanning techniques in ear anthropometry. Due to the principle of light, 3D scanning encounters problem when scanning surface covered by hair and with complex structures [18]. Some regions near hairline or posterior part of pinna mostly encounter scanning issue, and ear canal is difficult to be directly scanned. In addition, small movement of head may influence the scanning results, so it may be challenging to acquire scanning results with good quality for children or other related population [12]. Therefore, researchers need to pay critical focus on these areas and consider the physical condition of the participant, when apply 3D scanning in ear anthropometry.

Overall, even though there were significant differences between traditional and 3D scanning measurement for ear dimensions, the values of mean differences and mean absolute differences were relatively small. With the high correlation coefficients, the 3D scanning measurement can be considered as reliable as direct measurement for selected ear dimensions. The study provided statistical verification for comparison between traditional and 3D scanning measurement for ear length and ear width, with addressing the advantages and disadvantages of different measurements. Limitations of the study include relatively small sample size and restricted ear dimensions considering the variation of ear size and shape. Therefore, further study can be conducted more systematically with a larger sample size, further dimensions, and additional measuring methods.

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