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# External Ear Morphometry of the Adult Binis in Southern Nigeria and Assessment of its Significance

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## ABSTRACT

**Introduction:** the external ear is a prominent part of cephalofacial phenotype that contribute to the human physiognomy. This study was conducted to assess the external ear morphometry of the adult Bini tribe in Southern Nigeria and to elaborate its significance and application.

**Methods:** This was a cross-sectional study was carried out among the Bini Tribe residents in Benin City, Nigeria. Three hundred and fifty subjects between ages 25 to 50 years old were recruited for this study. Using standard anatomical landmarks and formulae, the external ear morphometry of the subjects was assessed. This include the ear height and width, lobular height and width as wells as the ear and lobular indices.

**Results:** The mean age of male subjects was 43.85±3.55; female subjects was 39.89±3.44 and the entire study population was 42.35±4.65. Some external ear parameters (ear width and index) showed bilateral variation with the mean values significantly ($p<0.05$) higher on the right side. All parameters except ear index and lobular height showed sexual dimorphism with ear height and width significantly ($p<0.05$) higher in males while lobular width and index was significantly ($p<0.05$) higher in females. The comparison across different population showed population-specificity in some auricular parameters.

**Conclusion:** The findings of this study on the external ear morphometry of the Nigerian Binis indicated certain similarities and differences from proximate and distant population respectively. It also indicated the reference values of the study population for application in forensic anthropology, reconstructive surgeries, and other clinical procedures.

**Keywords:** External ear morphometry; Sexual dimorphism; Bini tribe, Nigeria.

## Introduction

The human ear is morphologically and functionally divided into three parts namely external, middle and inner ear. The external and middle ear collect and transfer sound to the internal ear which in turn functions as the organ of hearing and equilibrium.[1] The external ear comprises mainly the auricle which is composed of irregular plate of elastic cartilage covered by thin, hairless skin.[1] The morphological features of the auricle include elevated areas such as helix and antihelix as well as depressed areas such as concha, scapha and others.[2] Other distinguishing features include auricular shape, lobular shape and attachment, tragus shape and helix shape.[3]

Essentially, the external ear is a prominent part of cephalofacial phenotype that contribute to the human physiognomy. Therefore, external ear anomalies or deformities resulting from congenital malformations, trauma, infections or injuries lead to apparently unsatisfactory look, social discrimination, physical and psychological stress.[4] Currently, there are different reconstructive procedures designed to correct the anomalies or deformities. These procedures, like the reconstructive surgeries for other cephalofacial structures, essentially involve the application of cephalometric parameters which are derived through scientific measurements of cephalofacial dimensions including those of the auricle.[2]

Generally, cephalometric parameters have wide range of applications in plastic and reconstructive surgery, forensic medicine, orthodontics, clinical diagnosis and treatment planning.[5,6] They are also applied for the determination of inter-racial and intra-racial variation in human population.[7,8] These parameters are generally influenced by factors such as age, sex, race, hereditary and climate.[8,9] The variability of the cephalometric parameters including auricular dimensions often necessitate population-specific morphometric assessment. This would in turn enable the determination of reference values that are of significance during the aforementioned application procedures.

Due to the dearth of data among the study population, this study was conducted to assess the external ear morphometry of the adult Bini tribe in Southern Nigeria and to describe its diverse significance.

## Materials and Methods

### Study population

This cross-sectional study was carried out among the Bini tribe (a minority ethnic group), predominantly resident in Benin City ($6^0$20"7'N, $5^0$37"33'E), Edo State,

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Nigeria. It involved 350 randomly selected participants (180 male and 170 female subjects) between ages 25 to 50 years old.

### Measurements of parameters

The subjects were in anatomical positions while measurement of the external ear parameters was taken by an observer to avoid inter-observer error, and according to the standard anatomical landmarks (Figure 1). The ear height (or length) was measured as the distance between the most superior point of the helix and most inferior point of the lobule; the ear width was measured as the distance between the most anterior and posterior points of the auricle; the lobular height (or length) was measured as the distance from the most inferior point of the lobule to the base of tragal notch while the lobular width was measured as the transverse distance at the mid-level of the lobule.[10,11] All measurements were taken using digital sliding caliper and measured to the nearest 0.1mm. For each participant, the ear index was calculated as the percentage ratio of the ear width to the ear height while the lobular index was calculated as the percentage ratio of the lobular width to the lobular height.[11] The study was approved by the Research and Ethical Committee of School of Basic Medical Sciences, Igbinedion University, Okada, Edo State, Nigeria (08/009169/HSC).

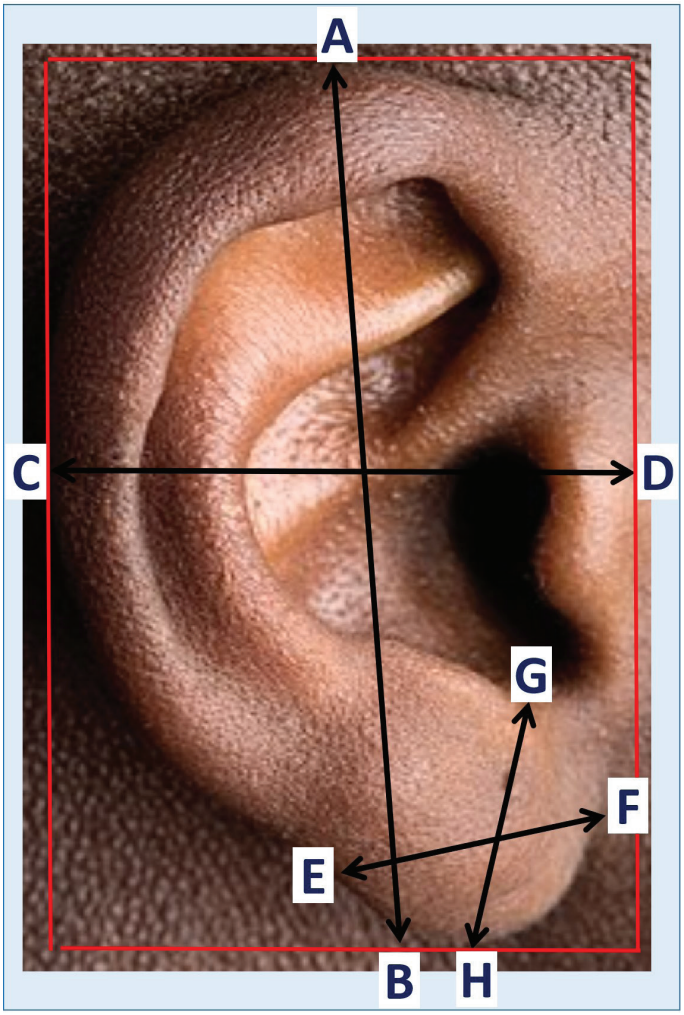


**Figure 1.** External ear morphometric landmarks (AB: Ear height; CD: Ear width; GH: Lobular height; EF: Lobular width).

### Inclusion and exclusion criteria

Only prospective participants whose paternal and maternal parents and grand-parents are descendants of the Bini tribe, without anomaly, deformity, pathology and asymmetry of external ear on both sides were included in the study. Any prospective participants with any anomaly, deformity, pathology and asymmetry of external ear on both sides, or having mixed parentage or parentage from other tribes other than Bini tribe were excluded from the study.

### Statistical analysis

The data recorded was analyzed using the IBM-SPSS software (version 22) and presented as mean and standard deviation (SD). The comparison of the measurements among male and female participants was conducted using the independent samples *t*-test and comparison of measurements on contralateral side was conducted using a paired samples *t*-test. The statistically significant level was $p<0.05$.

## Results

The mean age of male subjects was 43.85 ± 3.55; female subjects was 39.89 ± 3.44 and the entire study population was 42.35 ± 4.65. The external ear morphometry among the male subjects (Table 1) showed bilateral non-significant difference in all the parameters assessed except the ear width and ear index. The right ear width (27.33 ± 3.11) was significantly higher ($p<0.05$) than the left ear width (26.34 ± 3.77). Similarly, the right ear index (47.99 ± 4.45) was significantly higher ($p<0.05$) than the left ear index (46.15 ± 5.23).

The bilateral ear morphometry among the female subjects (Table 2) also showed similar outcome to those of the males. The right ear width (25.33 ± 2.89) was significantly higher ($p<0.05$) than the left ear width (24.22 ± 3.56). Similarly, the right ear index (47.69 ± 4.89) was significantly higher ($p<0.05$) than the left ear index (45.49 ± 6.12).

The right ear morphometry among the subjects (Table 3) also showed significant difference ($p<0.05$) in all the parameters assessed except the ear index and lobular height. This results further showed that the existence of sexual dimorphism in most of the auricular exhibited an alternating pattern. The male right ear height and width (57.55 ± 5.65 and 27.33 ± 3.11) were significantly higher ($p<0.05$) than the female right ear height and width (53.23 ± 3.55 and 25.33 ± 2.89). Conversely, the female right lobular width and index (16.45 ± 3.16 and 115.14 ± 12.34) were significantly

higher ($p$<0.05) than the male right lobular width and index (14.97 ± 2.85 and 104.33 ± 10.33).

Similar to findings regarding the right ear morphometry above, the left ear morphometry (Table 4) showed significant difference ($p$<0.05) in all parameters assessed except the ear index and lobular height. In addition, the results further showed sexual dimorphism of left ear morphometry in an alternating pattern. The male left ear height and width (56.95 ± 5.87 and 26.34 ± 3.77) were significantly higher ($p$<0.05) than the female left ear height and width (53.12 ± 4.99 and 24.22 ± 3.56). However, the female left lobular width and index (16.76 ± 2.23 and 114.56 ± 11.65) were significantly higher ($p$ < 0.05) than male left lobular width and index (15.11 ± 3.11 and 103.23 ± 12.53).

The comparison of the findings among different population revealed population-specific results (Table 5). The bilateral ear index among Bini subjects were lower than the values reported among proximate tribes (Hausas and Igbos) in Nigeria and other European or Asian population. However, the lobular index showed divergent comparison with the values among Bini subjects higher or lower than values of other tribe or population.

The comparison of the auricular morphometry across different population generally revealed population specificity. Based on the results (Table 6), the bilateral ear length of the Binis showed similarity with the Nigerian Hausas and Ijaws), significantly higher than those of the Igbos and significantly lower than those of other population assessed. This variable trend of auricular morphometry across different population were also observed for other parameters assessed which include the ear width, lobular height and lobular width.

**Table 1.** The external ear morphometry among male Bini subjects.

| VARIABLES | Male (n = 180) | |
|---|---|---|
| | Right Ear (Mean ± SD) | Left Ear (Mean ± SD) |
| Ear height (mm) | 57.55 ± 5.65 | 56.95 ± 5.87 |
| Ear width (mm) | 27.33 ± 3.11 | 26.34 ± 3.77* |
| Ear index (%) | 47.99 ± 4.45 | 46.15 ± 5.23* |
| Lobular height (mm) | 14.32 ± 2.39 | 14.65 ± 3.44 |
| Lobular width (mm) | 14.97 ± 2.85 | 15.11 ± 3.11 |
| Lobular index (%) | 104.33 ± 10.33 | 103.23 ± 12.53 |

SD = Standard deviation; n = Number of participants; * indicates significant difference at $p$<0.05

**Table 2.** The external ear morphometry among female Bini subjects.

| VARIABLES | Female (n = 170) | |
|---|---|---|
| | Right Ear (Mean ± SD) | Left Ear (Mean ± SD) |
| Ear height (mm) | 53.23 ± 3.55 | 53.12 ± 4.99 |
| Ear width (mm) | 25.33 ± 2.89 | 24.22 ± 3.56* |
| Ear index (%) | 47.69 ± 4.89 | 45.49 ± 6.12* |
| Lobular height (mm) | 14.28 ± 2.45 | 14.65 ± 3.12 |
| Lobular width (mm) | 16.45 ± 3.16 | 16.76 ± 2.23 |
| Lobular index (%) | 115.14 ± 12.34 | 114.56 ± 11.65 |

SD = Standard deviation; n = Number of participants; * indicates significant difference at $p$<0.05

## Discussion

Human morphometry are veritable indicators of variation within the same or different gender of the same or different population which can be applied to determine sex, age or age-related morphological variation, physical fitness and health status.[21,22] Generally, paired structures often exhibit morphometric variation bilaterally. The bilateral variation of some ear parameters, observed in the current study (Table 1 and 2), was similarly reported among proximate or distant population. Among the Nigerian Igbos, significant bilateral difference existed for ear height in both sexes but for lobular index only in females.[16] Furthermore, the study among Indians showed bilateral differences of the ear dimensions such as ear height, ear width, lobular height, lobular width among males and lobular width in females.[23]

Essentially, the external ear morphometry has been described to exhibit sexual dimorphism in different

**Table 3.** The external ear morphometry of the right ear among the male and female subjects.

| VARIABLES | Right Ear (Mean ± SD) | |
|---|---|---|
| | Male (n = 180) | Female (n = 170) |
| Ear height (mm) | 57.55 ± 5.65 | 53.23 ± 3.55* |
| Ear width (mm) | 27.33 ± 3.11 | 25.33 ± 2.89* |
| Ear index (%) | 47.99 ± 4.45 | 47.69 ± 4.89 |
| Lobular height (mm) | 14.32 ± 2.39 | 14.28 ± 2.45 |
| Lobular width (mm) | 14.97 ± 2.85 | 16.45 ± 3.16* |
| Lobular index (%) | 104.33 ± 10.33 | 115.14 ± 12.34* |

SD = Standard deviation; n = Number of participants; * indicates significant difference at $p$<0.05

**Table 4.** The external ear morphometry of the left ear among the male and female subjects.

| VARIABLES | Left Ear (Mean ± SD) | |
|---|---|---|
| | Male (n = 180) | Female (n = 170) |
| Ear height (mm) | 56.95 ± 5.87 | 53.12 ± 4.99* |
| Ear width (mm) | 26.34 ± 3.77 | 24.22 ± 3.56* |
| Ear index (%) | 46.15 ± 5.23 | 45.49 ± 6.12 |
| Lobular height (mm) | 14.65 ± 3.44 | 14.65 ± 3.12 |
| Lobular width (mm) | 15.11 ± 3.11 | 16.76 ± 2.23* |
| Lobular index (%) | 103.23 ± 12.53 | 114.56 ± 11.65* |

SD = Standard deviation; n = Number of participants; * indicates significant difference at $p$<0.05

**Table 5** Comparison of the ear indices in different study population.

| Author(s) | Country (Tribe) | Study Participants | Ear Index (Mean ± SD) | | Lobular Index (Mean ± SD) | |
|---|---|---|---|---|---|---|
| | | | Right | Left | Right | Left |
| Kent *et al.*[11] | Turkey | Male (n = 56) | 54.10 ± 6.84 | 54.27 ± 13.32 | 110.44 ± 26.37 | 120.70 ± 47.11 |
| | | Female (n = 59) | 52.42 ± 6.53 | 50.93 ± 4.88 | 111.37 ± 20.23 | 115.32 ± 15.60 |
| Petrescu *et al.*[12] | Romania | (n = 14) | 54.40 ± 5.77 | 53.93 ± 4.54 | 92.59 ± 17.48 | 93.56 ± 20.67 |
| Singh *et al.*[13] | India | Male (n = 78) | 52.69 ± 6.12 | 52.79 ± 5.87 | 109.55 ± 20.42 | 115.34 ± 22.16 |
| | | Female (n = 52) | 50.91 ± 5.51 | 51.70 ± 6.21 | 110.24 ± 20.87 | 115.39 ± 21.86 |
| Swati *et al.*[14] | India | Male (n = 250) | 48.60 ± 4.60 | 48.40 ± 4.30 | 155.40 ± 36.10 | 151.60 ± 34.4 |
| | | Female (n = 250) | 50.00 ± 3.90 | 49.60 ± 3.80 | 166.20 ± 40.80 | 157.10 ± 36.8 |
| Mustapha *et al.*[15] | Nigeria (Hausa) | Male (n = 200) | 51.04 ± 6.15 | 51.88 ± 6.39 | 135.80 ± 32.89 | 133.77 ± 34.18 |
| | | Female (n = 200) | 49.59 ± 5.88 | 51.36 ± 9.18 | 124.97 ± 22.07 | 121.90 ± 8.35 |
| Oladipo *et al.*[16] | Nigeria (Igbo) | Male (n = 142) | 53.47 ± 7.23 | 53.28 ± 6.69 | 95.17 ± 18.12 | 96.80 ± 18.56 |
| | | Female (n = 158) | 52.50 ± 6.85 | 50.93 ± 7.05 | 94.60 ± 19.59 | 94.30 ± 16.63 |
| Current Study | Nigeria (Bini) | Male (n = 180) | 47.99 ± 4.45 | 46.15 ± 5.23 | 104.33 ± 10.33 | 103.23 ± 12.53 |
| | | Female (n = 170) | 47.69 ± 4.89 | 45.49 ± 6.12 | 115.14 ± 12.34 | 114.56 ± 11.65 |

SD = standard deviation; n = number of participants

population thereby underscoring its significance for sex determination. Similar to the current study (Table 3 and 4), the findings among Nigerian Igbos indicated sexual dimorphism of some external ear parameters (ear height, lobular height and width and ear index) which were significantly higher in females than in males.[16] In addition, the lobular height showed sexual dimorphism among the Nigerian Hausas with the values significantly higher in females than in males.[15] Among the Turkish population, external ear dimensions (ear height, ear width, lobular height and lobular width) were significantly higher among males than females.[19] Similar outcome was reported among the Indians where external ear parameters were significantly higher among males than females.[10]

Furthermore, external ear morphometry have been widely reported to exhibit variation across different ethnic groups, race or population. The comparison of external ear morphometry across different population (Tables 5 and 6) showed contrasting outcomes. The findings of the current study showed similarity with the external ear dimensions of proximate Hausa and Igbo tribes of Nigeria. Such inter-tribal similarities of external ear morphomtery was similarly reported among the proximate Turk and Far tribes in Iran.[24] However, the differences observed in the results of the current study and those of distant population further highlighted the influence of racial, climatic, dietary and genetic factors on auricular morphometry across different population.

Moreover, human identification remains a critical aspect of forensic anthropology which typically employs anthropometric parameters. The application of anthropometry including external ear morphometry for human identification was firstly conducted by Alphonse Bertillon.[25] However, the modern biometric system, which also employs anthropometric parameters such as the ear parameters, has become a reliable technique for human identification.[26] This application of ear biometrics for the purpose of human identification constitutes the branch of forensic science known as the forensic otoscopy.[3] Previous studies have also described the uniqueness of external ear morphology and indicated that no two individuals have the same morphology.[10,27] Moreso, the study by Fakorede *et al.*[28] elaborated the applicability of auricular morphometry as for identification among the Nigerian Yoruba, Hausa, and Igbo tribes. Hence, the findings of the current study further provide the reference values for the identification and distinction of the Bini tribe from other population.

Essentially, the size, shape and symmetry of the external ear contributes to the aesthetic attributes of the human face.10 Hence, the normal morphometry and symmetry are important factors that determine successful reconstruction during auricular anomalies.[29] These anomalies could result from malformations characterized by underdevelopment of auricular cartilage and partial absence of skin or deformations characterized by fully developed but amorphous auricular cartilage.[30] Hence, cartilage grafting can be described as the foundation of auricular construction.[2] Hence, the findings provided by the current study offers the vital reference values for external ear reconstructive procedures among the study population.

In addition, the estimation of age, height and sex of individuals had been undertaken using the external

**Table 6.** Comparison of the external ear dimensions in different adult population.

| Author(s) | Country (Tribe) | Gender | Ear height (Mean ± SD) | | Ear width (Mean ± SD) | | Lobular height (Mean ± SD) | | Lobular width (Mean ± SD) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Right | Left | Right | Left | Right | Left | Right | Left |
| Kumari *et al.*[10] | India | Male (n = 100) | 60.77 ± 3.74 | 59.99 ± 3.83 | 30.60 ± 2.81 | 30.81 ± 2.69 | 16.48 ± 2.37 | 17.04 ± 2.30 | 18.21 ± 2.75 | 18.08 ± 2.31 |
| | | Female (n = 100) | 56.59 ± 3.04 | 55.55 ± 3.68 | 28.55 ± 3.12 | 28.81 ± 2.80 | 15.97 ± 1.77 | 16.53 ± 1.57 | 15.93 ± 2.18 | 16.31 ± 2.10 |
| Kent *et al.*[11] | Turkey | Male (n = 56) | 62.30 ± 3.60 | 62.00 ± 5.40 | 34.10 ± 5.60 | 34.00 ± 9.00 | 18.50 ± 6.20 | 18.10 ± 6.20 | 19.20 ± .80 | 20.50 ± 5.90 |
| | | Female (n = 59) | 58.30 ± 4.20 | 58.50 ± 3.80 | 30.40 ± 3.30 | 29.70 ± 2.70 | 16.10 ± 2.20 | 16.50 ± 2.10 | 17.60 ± 2.60 | 18.80 ± 2.10 |
| Petrescu *et al.*[12] | Romania | (n = 14) | 59.27 ± 4.09 | 60.69 ± 4.55 | 32.16 ± 3.57 | 32.71 ± 3.66 | 18.45 ± 2.32 | 18.58 ± 2.34 | 17.04 ± 3.52 | 17.31 ± 3.99 |
| Singh *et al.*[13] | India | Male (n = 78) | 62.90 ± 4.80 | 62.30 ± 4.80 | 33.10 ± 4.50 | 32.80 ± 3.90 | 17.60 ± 3 .10 | 17.70 ± 3.00 | 19.00 ± 3.40 | 20.20 ± 3.60 |
| | | Female (n = 52) | 59.90 ± 4.00 | 59.10 ± 3.90 | 30.40 ± 3.40 | 30.50 ± 3.80 | 16.70 ± 2.90 | 17.50 ± 3.10 | 18.20 ± 3.50 | 19.80 ± 3.50 |
| Farhan *et al.*[17] | Iraq | Male (n = 157) | 53.30 ± 6.80 | 53.40 ± 6.90 | 33.60 ± 4.30 | 33.50 ± 4.20 | 7.60 ± 1.70 | 7.80 ± 1.60 | 20.30 ± 3.40 | 20.10 ± 3.10 |
| | | Female (n = 154) | 52.20 ± 5.60 | 52.20 ± 5.70 | 33.00 ± 4.50 | 33.00 ± 4.40 | 8.00 ± 2.10 | 8.40 ± 1.90 | 20.00 ± 3.30 | 20.30 ± 3.00 |
| Tatlisumak *et al.*[18] | Turkey | Male (n = 200) | 64.46 ± 3.43 | 65.49 ± 3.45 | 35.33 ± 3.14 | 33.96 ± 3.38 | 18.40 ± 2.11 | 18.37 ± 2.24 | 19.21 ± 3.40 | 17.33 ± 3.23 |
| | | Female (n = 200) | 60.29 ± 3.19 | 61.33 ± 3.15 | 32.96 ± 2.81 | 32.28 ± 2.86 | 17.33 ± 2.01 | 17.31 ± 1.93 | 18.73 ± 3.48 | 17.07 ± 3.13 |
| Prasetyo and Putri[19] | Indonesia | Male (n = 96) | 61.70 ± 3.90 | 61.30 ± 4.20 | 26.80 ± 2.40 | 26.30 ± 2.30 | 19.30 ± 3.60 | 19.60 ± 4.20 | 19.10 ± 4.60 | 18.70 ± 4.10 |
| | | Female (n = 428) | 58.10 ± 2.70 | 57.80 ± 2.80 | 24.00 ± 3.40 | 24.10 ± 2.60 | 16.60 ± 2.20 | 16.80 ± 3.00 | 15.90 ± 2.40 | 16.00 ± 2.30 |
| Mustapha *et al.*[15] | Nigeria (Hausa) | Male (n = 200) | 54.83 ± 4.12 | 54.24 ± 4.10 | 28.00 ± 4.11 | 28.17 ± 4.25 | 14.22 ± 3.14 | 13.84 ± 3.15 | 18.69 ± 3.81 | 17.80 ± 3.63 |
| | | Female (n = 200) | 54.90 ± 3.76 | 54.01 ± 4.69 | 27.25 ± 3.86 | 27.52 ± 3.35 | 15.28 ± 2.81 | 14.82 ± 2.58 | 18.77 ± 3.28 | 17.91 ± 3.17 |
| Oladipo *et al.*[16] | Nigeria (Igbo) | Male (n = 142) | 47.01 ± 6.30 | 46.24 ± 5.85 | 25.06 ± 4.14 | 24.68 ± 4.32 | 13.92 ± 2.61 | 13.99 ± 2.18 | 12.99 ± 2.30 | 13.30 ± 1.94 |
| | | Female (n = 158) | 48.25 ± 6.83 | 48.25 ± 6.24 | 25.19 ± 3.93 | 24.57 ± 4.21 | 14.44 ± 2.67 | 14.89 ± 2.55 | 13.37 ± 2.26 | 13.78 ± 2.04 |
| Edibamode *et al.*[20] | Nigeria (Ijaw) | Male (n = 58) | 58.40 ± 0.45 | 58.14 ± 0.60 | 28.21 ± 0.68 | 27.41 ± 0.37 | 14.32 ± 0.31 | 14.47 ± 0.27 | 13.04 ± 0.32 | 13.50 ± 0.34 |
| | | Female (n = 54) | 56.66 ± 1.10 | 57.90 ± 0.46 | 27.51 ± 0.65 | 27.45 ± 0.65 | 15.58 ± 0.29 | 15.41 ± 0.31 | 13.28 ± 0.34 | 13.43 ± 0.38 |
| Current Study | Nigeria (Bini) | Male (n = 180) | 57.55 ± 5.65 | 56.95 ± 5.87 | 27.33 ± 3.11 | 26.34 ± 3.77 | 14.32 ± 2.39 | 14.65 ± 3.44 | 14.97 ± 2.85 | 15.11 ± 3.11 |
| | | Female (n = 170) | 53.23 ± 3.55 | 53.12 ± 4.99 | 25.33 ± 2.89 | 24.22 ± 3.56 | 14.28 ± 2.45 | 14.65 ± 3.12 | 16.45 ± 3.16 | 16.76 ± 2.23 |

SD = Standard deviation; n : Number of participants. All measurements are presented in millimeters (mm)

ear morphometry such as the ear height, ear width, lobule height and lobule width.[10,31] Among the South Indian population, Yadav *et al*[32] demonstrated the application of anthropometric parameters including ear length and width for stature and sex estimation. Similar to other cephalometric parameters, another

significance of the external ear morphometry include its application in ergonomics with regards to the design and production of products such as hearing aids, earphones, earrings, helmets, earmuffs and personal protective equipment.[24,33] Hence, findings of the current study offer more significance and applications among the study population.

## Conclusion

The external ear parameters is an important components of cephalometry that contribute to human physiognomy as well as several other applications. This study provided the reference values of external ear morphometry of the Nigerian Bini tribe which would be of significance during diverse forensic, clinical and ergonomic procedures.

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