Incus Morphometry: A Possible Tool in Sex Determination

Kamal Singh*, Aarti Rohilla and Jyoti Rohila

Department of Anatomy, Pt. B. D. Sharma Post Graduate Institute of Medical Sciences, Rohtak-124001, Haryana, India

*Corresponding author: Dr. Kamal Singh, Assistant Professor, Department of Anatomy, 18/CH, Medical Campus, Pt. B. D. Sharma PGIMS, Rohtak-124001, Haryana, India, Tel: +91-9812531007; E-mail: drkamalanatomy@gmail.com

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Abstract

The adult human skeleton is sexed using morphological and metrical traits of big intact bones like skull, mandible, pelvis and long bones etc. The Incus is housed in the middle ear, so it remains well protected even in the mutilated bodies. Morphometry of the 120 human Incus bones from 60 cadavers have been studied with the aim to know the sexual dimorphism in north Indian population. It is observed that study of normal dimensions and indices will provide insight for the surgeons and will have surgical implications in reconstruction of ossicular chain, which may have been congenitally absent, malformed, fixed, disrupted or destroyed by trauma or disease. These are the results for guidance and future manipulation in the field of ENT and Forensic Medicine.

Keywords: Ear ossicles; Incus; Indices; Ossiculoplasty; Middle ear cavity; Prosthesis

In the present study we attempt to evaluate the applicability of Incus Morphometric indices as a potential tool for determination of sex.

Material and Method

The study was conducted on sixty unidentified cadavers ("Unidentified" means that the cadaver is not belonging to any person or family) in different stages of decomposition during medicolegal postmortem examination. The ossicles were procured manually after dissection of the petrous part of temporal bone by using Cobbler’s Cut Method [17] and 120, Incus bones were retrieved as the Ossicles attain the stage of maturity within the 4th-5th Month of Intrauterine life [2]. So, it does not imply any advantage to classify them as Young, Middle and Older Adult. So, the following parameters of cleaned and dried bones were studied from selected points as depicted in the diagrams (Figure 1).

**Figure 1:** Cleaned and dried temporal bone. Total length (d-e) mm: Maximal distance between the superior edge of the body and the end of the long process. Total width (d-f) mm: Maximal distance between the superior edge of the body and the end of the short process. Maximal distance top of the processes (e-f) mm: Maximal distance between the tips of the processes. Angle (y): Angle between the processes. Index: Total width × 100/total length of incus. Weight of Incus (mg).
These Morphometric parameters were measured by the digital vernier caliper with the least count of 0.01 mm. The weights of the bones were measured by the electronic micro-balance of 'Sartorius CP224S' model with the minimal readability of 0.1 mg.

The angles were measured with the standard ruler and protractor on the photographs of the ossicles taken by fujiﬁlm 10.0 megapixel camera with 5x optical zoom.

The bones and camera were ﬁxed in same position, distance, and orientation with respect to each other for each measurement. All the measurements were taken by one setup. Each reading was taken thrice and a mean of all three was taken to rule out any error.

The results of the study were computed and analyzed with SPSS software. Normal descriptive statistics i.e., means, standard deviation & P-Value as well as Canonical discriminant function coefficients in discriminant function analyses were performed. The discriminant function formula is as follows:

\[ F(X) = A_1X_1 + A_2X_2 + \ldots + A_NX_N + C \]

Where \( F(X) \) represents the discriminant function score, \( X_1 \) to \( X_N \) are the measured variables, \( A_1 \) to \( A_N \) are the unstandardized coefficients of each variable and \( C \) is the function’s constant. The sectioning point (\( Z_0 \)) for each Discriminant function is calculated from the weighted mean of values at the group centroids for males and females using the formula provided by Xavier [18].

\[ Z_0 = \frac{(Z_m \times N_f) + (Z_f \times N_m)}{N_m + N_f} \]

Where \( Z_m \) and \( Z_f \) are the group centroids for male and female groups, \( N_m \) and \( N_f \) being the number of Incus bones of males and females respectively. Any value above the sectioning point will be classiﬁed as male and the values below the sectioning point will be classiﬁed as female.

**Observations and Results**

Descriptive statistics of both the sexes for Left & Right sides of Incus Bone were analyzed and compared respectively (Tables 1 and 2). We observed no statistical signiﬁcance on comparison of morphometric parameters of incus of both the sexes for left & right side respectively. But, Discriminant Function Analysis of the different parameters of incus showed that these parameters provides us a good criteria in determining the group Centroids and signiﬁcance of percentage accuracy in determination of sex (Tables 3-6).

| Sr. No. | Morphometric Parameter | Male Left Side Mean ± SD | Female Left Side Mean ± SD | P-Value |
|---------|------------------------|--------------------------|---------------------------|---------|
| 1       | Total Length (mm)      | 6.682 ± 0.498            | 6.666 ± 0.334             | 0.88    |
| 2       | Total Width (mm)       | 5.112 ± 0.396            | 4.942 ± 0.281             | 0.061   |
| 3       | Maximal distance between Top of Processes (mm) | 5.985 ± 0.447 | 6.031 ± 0.313 | 0.646 |
| 4       | Angle (\( \gamma_0 \)) | 75.000 ± 8.878           | 72.800 ± 8.198            | 0.323   |
| 5       | Index                  | 76.714 ± 8.176           | 74.270 ± 4.717            | 0.09    |
| 6       | Weight (mg)            | 26.833 ± 4.539           | 25.857 ± 2.654            | 0.313   |

**Table 1**: Descriptive statistics of the left Incus bone measurements.

| Sr. No. | Morphometric Parameter | Male Right Side Mean ± SD | Female Right Side Mean ± SD | P-Value |
|---------|------------------------|---------------------------|-----------------------------|---------|
| 1       | Total Length (mm)      | 6.691 ± 0.419             | 6.656 ± 0.330               | 0.718   |
| 2       | Total Width (mm)       | 5.104 ± 0.394             | 5.013 ± 0.279               | 0.303   |
| 3       | Maximal distance between Top of Processes (mm) | 6.039 ± 0.459 | 5.993 ± 0.290 | 0.647 |
| 4       | Angle (\( \gamma_0 \)) | 74.500 ± 8.982           | 75.067 ± 7.492              | 0.792   |
| 5       | Index                  | 76.429 ± 5.828           | 75.445 ± 4.810              | 0.479   |
| 6       | Weight (mg)            | 26.747 ± 4.615           | 25.777 ± 3.053              | 0.341   |

**Table 2**: Descriptive statistics of the right incus bone measurements.

On applying DFA on the individual parameters for the left side has produced a sex determination accuracy of 66.7% in males with maximal distance top of the process, and 66.7% in females with weight of the left incus bone.

Whereas a 60% accuracy for sex determination was being observed with total width for males, females & both (Table 3).

On applying DFA on the individual parameters for the right side has produced a sex determination accuracy of 60% in males with total width, and 56.7% in females with total length & weight of the right incus bone.

Whereas a 56.7% accuracy for sex determination was being observed with total width for males, females & both (Table 4).
Table 3: Discriminant function analysis showing % accuracy for sex determination by taking individual parameters of left incus.

| Sr. No | Parameters | Unstandardized Coefficients | DF's Constant | Wilk's Lambda | Group Centroids | Correctly Assigned |
|--------|------------|-----------------------------|---------------|---------------|-----------------|-------------------|
|       |            |                             |               |               | M F             | M F T             |
| A     | Total length (d-e) mm | 2.358                        | -15.736       | 1             | 0.02 -0.02     | 16.70% 43.30% 30% |
| B     | Total width (d-f) mm   | 2.911                        | -14.636       | 0.941         | 0.247 -0.247   | 60% 60% 60%       |
| C     | Maximal distance top of the processes (e-f) mm | 2.589                   | -15.557       | 0.996         | 0.06 -0.06     | 66.70% 50% 58.30% |
| D     | Angle (y0)             | 0.117                        | -8.649        | 0.983         | 0.129 -0.129   | 60% 43.30% 51.70% |
| E     | Index                  | 0.182                        | -13.738       | 0.951         | 0.222 -0.222   | 50% 60% 55%       |
| F     | Weight                 | 0.269                        | -7.085        | 0.982         | 0.131 -0.131   | 53.30% 66.70% 60% |

Table 4: Discriminant function analysis showing % accuracy for sex determination by taking individual parameters of right incus.

| Sr. No | Parameters | Unstandardized Coefficients | DF's Constant | Wilk's Lambda | Group Centroids | Correctly Assigned |
|--------|------------|-----------------------------|---------------|---------------|-----------------|-------------------|
|       |            |                             |               |               | M F             | M F T             |
| A     | Total length (d-e) mm | 2.653                        | -17.703       | 0.998         | 0.047 -0.047   | 50% 56.70% 53.30% |
| B     | Total width (d-f) mm   | 2.929                        | -14.818       | 0.982         | 0.134 -0.134   | 60% 53.30% 56.70% |
| C     | Maximal distance top of the processes (e-f) mm | 2.604                   | -15.663       | 0.996         | 0.059 -0.059   | 43.30% 46.70% 45% |
| D     | Angle (y0)             | 0.121                        | -9.042        | 0.999         | -0.034 0.034   | 36.70% 43.30% 40% |
| E     | Index                  | 0.187                        | -14.212       | 0.991         | 0.092 -0.092   | 46.70% 46.70% 46.70% |
| F     | Weight                 | 0.256                        | -6.712        | 0.984         | 0.124 -0.124   | 43.30% 56.70% 50% |

On applying DFA on the different combination of parameters for the left side it is observed that has produced a sex determination with maximum accuracy of 53.3% can be carried out by taking parameters in serial no. 5 of Table 5 in males. Whereas a maximum of 66.7% can be accurately classified by using serial no. 3, 4, 5 and 6 (Table 5).

A total of 60% accuracy for sex can be defined for sex determination while taking serial no. 5 alone implying that length, width, maximal distance & weight can best classify the left incus as male or female.

On applying DFA on the different combination of parameters for the right side it is observed that has produced a sex determination with maximum accuracy of 53.3% can be carried out by taking parameters in serial no. 8 of Table 6 in males; whereas a maximum of 56.7% can be accurately classified by using serial no. 1 & 8 (Table 6). A total of 55% accuracy for sex can be defined for sex determination while taking serial no. 8 alone implying that width & weight could be the best parameter for determination of sex of an individual by using right incus bone.
Table 5: Discriminant function analysis showing % accuracy for sex determination by taking different combinations of parameters of left incus.

| Sr. No. | Parameters                                                                 | Unstandardized Coefficients | DF's Constant | Wilk's Lambda | P-Value | Group Centroids | Correctly Assigned |
|---------|-----------------------------------------------------------------------------|------------------------------|----------------|---------------|---------|-----------------|--------------------|
| 1       | D+F (Angle + Weight)                                                        | -0.039+ 0.247               | -3.561         | 0.983         | 0.606   | -0.131          | 43.30%             |
| 2       | A+C (Length + Maximum Distance)                                            | 0.924+ 2.012                | -18.266        | 0.996         | 0.892   | 0.062           | 33.30%             |
| 3       | A+F (Length + Weight)                                                      | -1.257+ 0.319               | 0.008          | 0.982         | 0.598   | 0.133           | 46.70%             |
| 4       | A+B+C+D+F (Length + Width + Maximum Distance + Angle + Weight)            | -1.624+ 0.169+ 1.088+ 1.972+ 0.046 | -6.698      | 0.967         | 0.869   | 0.181           | 40%                |
| 5       | A+B+C+F (Length + Width + Maximum Distance + Weight)                       | -1.537+ 0.187+ 0.663+ 1.998 | -8.742         | 0.971         | 0.799   | 0.17            | 46.70%             |
| 6       | A+B+C (Length + Width + Maximum Distance)                                  | -0.661+ 2.839+ 1.166        | -16.971        | 0.979         | 0.749   | 0.145           | 46.70%             |
| 7       | A+B (Length + Width)                                                       | 0.003+ 2.928                | -14.832        | 0.982         | 0.591   | 0.134           | 36.70%             |
| 8       | B+F (Width + Weight)                                                       | 1.913+ 0.139                | -13.333        | 0.976         | 0.496   | 0.155           | 53.30%             |

Table 6: Discriminant function analysis showing % accuracy for Sex Determination by taking different combinations of parameters of right incus.
Discussion

Morphometric analysis of ear ossicles had been the subject of interest since the mid fifteenth century [8] and earlier researchers have observed insignificant variations in the morphology of incus not only in both the sexes but also on both sides. Studies on embryogenesis of the hearing [19] have shown that the ear differs from one individual to another with a saying that “No two ears are the same” [20]. The review of Indian as well as international literature revealed that morphometry of ossicles has been studied by many investigators more so in males [21-23].

This study represents an endeavour by the investigators to provide a comprehensive coverage of measurement of the various parameters of the incus. The literature, so far as available, is remarkably devoid of extensive observations even on the gross anatomy of the ossicles. Earlier studies by Natekar et al. reveal various morphometric measurements of malleus and incus [24].

Auditory ossicles specially regarding incus was under consideration for study by a group of research workers. Even though the total length of incus, total width and angle of incus was studied widely only a few have studied the maximum distance between tip of process [8,11,12,24-28].

The study of index of incus was carried out in three different population Natufian, En Gedi and Recent India [8,26]. The incus weight was exclusively done and reported by Harneja and Chaturvedi; Natekar and De Souza [23,24].

These reported studies from Indian and other research workers throughout the world have studied the parameters of the ear ossicles particularly in males [26,29-32]. The various morphometric results of bisexual and bilateral values of incus were compared with previous researchers are shown in Table 7.

Although results of Morphometric analyses did not reveal a statistically significant level of sexual dimorphism, but on Discriminant functional analysis it is found that Incus bone can be used a tool for determination of sex with maximum accuracy up to 66.7%.

| Sr. No. | Authors                      | Morphometric Parameters of Incus | Angle (º) | Index | Weight (mg) |
|---------|------------------------------|---------------------------------|-----------|-------|-------------|
| 1       | Present Data (2010)          | 6.674 5.043 6.01               | 74.342    | 75.714 | 26.303      |
| 2       | Natekar & De Souza (2006)    | 6.52 5.06 5.86                 |           |       |             |
| 3       | Unur, Ulger, Ekinci (2002)   | 6.5 4.9 6.1                    |           |       |             |
| 4       | Siori et al (1995)           | Gebelen/Asiut* 4.69 4.89 6.02 |           |       |             |
|         | Antinoe*                     | 6.78 5.14 6.15                |           |       |             |
| 5       | Unur et al (1993)            | 6.7 5.1 6.1                    |           |       |             |
| 6       | Arrensburg et al. (1981)     | Natufian* 6.5 5.1              |           |       |             |
|         | Roman (En Gedi)*             | 6.6 5.3 95                    |           |       |             |
|         | Recent India*                | 6.4 5.1 95                    |           |       |             |
| 7       | Harneja & Chaturvedi (1973)  | Natufian* 6.5 5.1              |           |       |             |
|         | Roman (En Gedi)*             | 6.6 5.3 95                    |           |       |             |
|         | Recent India*                | 6.4 5.1 88                    |           |       |             |
| 8       | Angel (1972)                 | 6.8 4.9                       |           |       |             |
| 9       | Arrensburg & Nathan (1972)   | 6.8 5.1 94                    |           |       |             |
| 10      | Harada (1972)                | 6.8 4.8 4.2                   |           |       |             |
| 11      | Bouchet & Giraud (1968)      | 6.5 5.1 95                    |           |       |             |
| 12      | Masali (1968)                | 6.4 4.8                       |           |       |             |
| 13      | Heron (1923)                 | 5.2                            |           |       |             |

Table 7: Comparison of Morphometric data of incus from present study and some previous studies.
Conclusion

The findings in our study revealed subtle sex differences by accuracy and suggested that the assumptions of previous investigators in this regard need to be reassessed. Thus, this study may turn out to be a potential source of forensic investigation for evaluation of sex in severely mutilated and decomposed bodies during postmortem examination. The dimensions of the incus will provide insight to the otolaryngologist surgeons for implications in reconstruction of ossicular chain to regain the original mechanics. This study will also give a basis for teaching the medical students about the basic and detailed structure of the ear (external, middle, internal) as well as its related significance in Clinical Medicine, ENT and Forensic Science.

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