ORIGINAL RESEARCH

Efficacy of Mastoid Morphometry in Sex Determination Using Cone-beam Computed Tomography: A Retrospective Analysis in Dakshina Kannada Population

Junaid Ahmed[1], Anwesha Saha[2], Archana Muralidharan[3], Nanditha Sujir[4], Nandita Shenoy[5]

Received on: 05 June 2024; *Accepted on:* 10 July 2024; *Published on:* 05 August 2024

Abstract

Aim: To evaluate the morphology of the mastoid process and its role in sex determination with the help of cone-beam computed tomography (CBCT).

Materials and methods: A retrospective study was conducted on 200 adults who were subjected to full FOV CBCT scans (100 males and 100 females). Eight parameters of the mastoid process were assessed for sex determination. The study measured eight parameters of the mastoid process, including mastoid length (ML), mastoid width, mastoid height (MH), intermastoidale distance (IMD), intermastoidale lateral surface distance (IMLSD), mastoid medial convergence angle, mastoid size (MS), and mastoid surface area (MSA). Data were recorded and statistically analyzed.

Results: Statistics revealed a significant value for MH ($p < 0.001$), IMD ($p < 0.001$), IMLSD ($p < 0.001$), MSA ($p < 0.001$), MS ($p < 0.001$), and ML ($p = 0.032$). A highly significant value was noted for MH ($p < 0.001$), IMD ($p < 0.001$), IMLSD ($p < 0.001$), MSA ($p < 0.001$), MS ($p < 0.001$), followed by ML, all of which were found to be greater in males. Out of the eight parameters, IMD was found to be the best sex determinant among all the eight parameters, with an accuracy of 70%. The study showed a significant difference between the mastoid process morphometric measurements for males and females.

Conclusion: It can be concluded from the present study that IMD can be used as a good index for sex determination. The combined parameters that were found to be the most accurate were right MH, left ML, and IMLSD, with an accuracy of 75%.

Clinical significance: The three-dimensional imaging techniques can contribute significantly towards disaster victim identification and sex determination in the fields of forensic odontology and anthropology.

For the recognition of victims, sex determination becomes one of the most difficult parameters to assess. In such events, the mastoid process can become an important anatomical landmark for the estimation of sex. This is due to the condensed nature of the petrous bone and its protected position in the skull.

Keywords: Cone-beam computed tomography, Forensic, Identification, Mastoid, Morphometry, Sex.

The Journal of Contemporary Dental Practice (2024): 10.5005/jp-journals-10024-3700

Introduction

Forensic anthropology deals with the identification of human remains in a legal setting. The primary role of a forensic anthropologist is to evaluate human skeletal remains and to use their expertise to assist medical examiners as well as law enforcement agencies.[1,2]

In an individual, sex determination can be done with human skeletal remains. The dimorphic variation of sex develops during intrauterine life and later can be manifested as variations seen in the weight of bone along with its morphometric and volumetric dimensions. The accuracy of skeletal remains varies according to the bones and their fragmentary condition. The accuracy of sex determination is greatest when an intact skeleton is available. Pelvis, skull, and long bones are generally used for sex determination in an unrecognized skeleton and have good rates of accuracy.[3] Sex determination can also be done through the size of the tooth, fingerprints, and DNA analysis.[1] Morphological features of the skull, like size and architecture, frontal eminence, parietal eminence, supraorbital ridges, glabella, orbits, nasal aperture, zygomatic arch, occipital bone, mastoid process, foramen magnum, palate, condyles, gonial angle, mandibular body, and nuchal crest, can be used in the identification of sex. Out of these bones, the zygomatic arch and supraorbital ridge showed the maximum accuracy, followed by the nuchal crest and mastoid process.[4]

Two mastoid processes are present bilaterally and are conical in shape, protruding from the bottom of the temporal bone. It is located beyond the external acoustic meatus and along the side of the styloid process. It is filled with air sinuses, or mastoid

[1–5]Department of Oral Medicine and Radiology Manipal College of Dental Sciences Mangalore Manipal Academy of Higher Education Manipal, Karnataka, India, 576104

Corresponding Author: Archana Muralidharan, Department of Oral Medicine and Radiology Manipal College of Dental Sciences Mangalore Manipal Academy of Higher Education Manipal, Karnataka, India, 576104, Phone: +91 9840322708, e-mail: m.archana@manipal.edu

How to cite this article: Ahmed J, Saha A, Muralidharan A, *et al*. Efficacy of Mastoid Morphometry in Sex Determination Using Cone-beam Computed Tomography: A Retrospective Analysis in Dakshina Kannada Population. J Contemp Dent Pract 2024;25(5):453–458.

Source of support: Nil

Conflict of interest: None

cells. It serves as an attachment for various muscles, including the sternocleidomastoid muscle, the posterior belly of the digastric, the splenius capitis, and the longissimus capitis. The mastoid process assumes a protected position and is the most dimorphic part of the skull. Most of the current methods based on skeletal remains have inherent disadvantages like fragmentation of the bone in disasters, inability to retrieve intact bones in mass disasters, and higher error when individual bones are used for sex determination. Numerous researchers have previously considered radiographs as an integral source in forensic anthropology. The introduction of cone-beam computed tomography (CBCT) has ushered in a paradigm shift in oral and maxillofacial radiology, as well as forensic radiology.[5,6] Cone-beam computed tomography provides for an affordable and accurate assessment of the maxillofacial skeleton. There were limited studies in the literature on sex determination using mastoid morphometry in the Dakshina Kannada population. The present study aimed to evaluate the morphology of the mastoid process and its role in sex determination with the help of the CBCT.

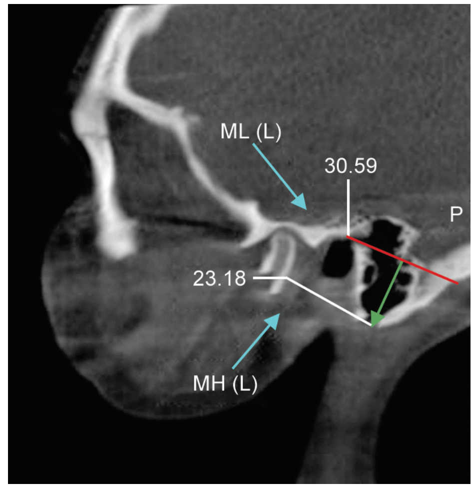

Fig. 1: Cone-beam computed tomography (CBCT) image: Measurement of mastoid length (ML) and mastoid height (MH) of the left side of the mastoid

Materials and Methods

The retrospective study was approved by the Institutional Ethical Committee of Manipal College of Dental Sciences, Mangaluru. (Protocol number: 21003) A sample size of 200 adults (100 males and 100 females) was selected. The retrospective data were retrieved over a period of 11 months, from March 2021 to February 2022. The analysis of the data was done in March 2022 for a period of 3 months. The study was done on the population of the Dakshina Kannada region due to the location of the institute.

Sample Size Calculation

Based on the study of the article by Deepa et al.,[5] the sample size was calculated as follows:

$$N = \frac{2\left(Z_{1-\frac{\alpha}{2}} + Z_{1-\beta}\right)^2 \sigma^2}{d^2}$$

N = population size
d = 1.25
σ^1 = 2.97, which is the standard deviation of group I
σ^2 = 2.26, which is the standard deviation of group II
σ = 2.62, which is the average standard deviation
$Z\ (1-\alpha/2)$: Z score for the alpha error chosen = 1.959964
$Z\ (1-\beta)$: Z score for the power chosen = 1.281552

Using the above formula, at an alpha error of 5% and a power of 90%, a sample size of 200 was calculated.

The study was conducted on the available CBCT records of subjects from Dakshin Kannada district who had undergone routine CBCT investigations for various dental conditions. The CBCT scan with a large field of view (FOV) of 20 × 17 mm dimensions (90 kV, 8 mA, 27 s, voxel size: 400) was taken using the Planmeca ProMax 3D Mid CBCT machine (Planmeca, Helsinki, Finland).

Patients over the age of 20 years were included in the study. Patients less than 20 years of age, images with gross artifacts, images that did not reveal anatomical details of the base or the lateral sides of the mastoid, and images with developmental anomalies or fractures were excluded from this study.

The images were viewed on an HP Compaq 8200 Elite CMT PC light-emitting diode backlit liquid crystal display (LCD) monitor measuring 48.3 cm (19 inches) with a viewable area display of 1280 × 1024. The present study measured eight parameters of the mastoid process, including mastoid length (ML), mastoid width (MW), mastoid height (MH), intermastoidale distance (IMD), intermastoidale lateral surface distance (IMLSD), mastoid medial convergence angle (MMCA), mastoid size (MS), and mastoid surface area (MSA). The multiplanar reconstructed images were aligned in three planes such that the axial orientation was aligned with the Frankfort horizontal plane. The coronal orientation was aligned to a plane along the anterior margins of the right and left external acoustic meatus, and the sagittal orientation was aligned to the mid-sagittal plane, as described by Balachandran et al.[6] The maximal ML and MH were measured using the sagittal view, while the axial view was used to measure the MW. On coronal view, the IMD, IMLSD, and MMCA were measured. The sagittal section and coronal sections were initially scanned to identify the maximum dimension of the mastoid process. The section with the maximum length and height was utilized for measurements.

- ML: The length of the mastoid process was measured from the porion to the posterior end of the incisura mastoidea (antero-posterior diameter) in the sagittal plane (Fig. 1).
- MH: The height of the mastoid process was measured by drawing a line perpendicular from ML to the tip of the mastoid process in the sagittal plane (Fig. 1).
- MW: The MW was measured as the distance between the highest point on the surface of the mastoid process within the digastric fossa and the most protruding point on its lateral surface (medio-lateral diameter) in the axial plane (Fig. 2).
- IMD: It is the linear distance between right and left mastoidale, wherein mastoidale is the lowest point on the tip of the mastoid process in the coronal plane (Fig. 3).
- IMLSD: It is the distance from the most prominent point on the convex lateral surface of the left and right mastoids in the coronal plane (Fig. 3).
- MMCA: The angle formed between the line starting from the most laterally prominent point on the mastoid surface, passing through the right mastoidale, and a similar line on the left side in the coronal plane (Fig. 3). The angle was measured at the level of C2.
- MS: The size of the mastoid process was measured by using the formula = (MH*ML*MW)/100.

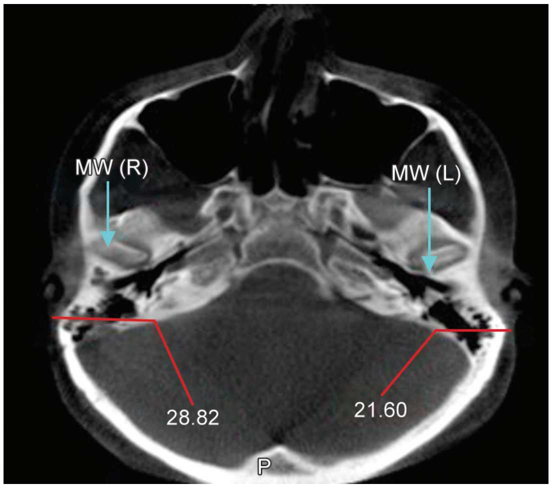

Fig. 2: CBCT image: Measurement of mastoid width (MW) of both sites

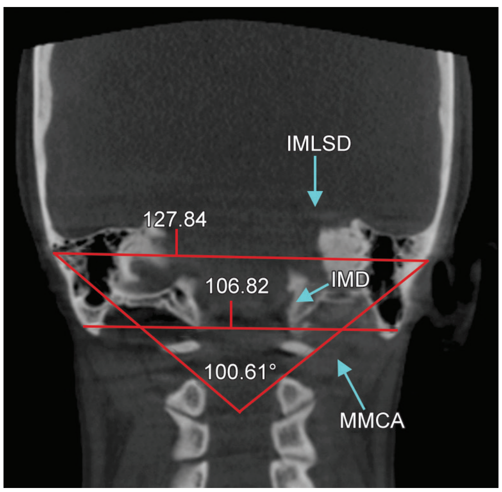

Fig. 3: CBCT image: Measurement of intermastoidale distance (IMD), intermastoidale lateral surface distance (IMLSD), and mastoid medial convergence angle (MMCA)

- MSA: The surface area (SA) of the mastoid process was measured using the formula = π (ML/2)*MH.

All measurements were carried out by two experienced maxillofacial radiologists at different time intervals. The radiologists were unaware of the sex of the patient. The principal investigator repeated measurements from 20 scans after 2 months. Each of the scans was number-coded, and the measurements of the scan were correlated to the sex of the individual by another investigator. Intra- and inter-observer reliability were calculated.

Statistical analysis of the collected data was carried out using SPSS version 2.5 (IBM SPSS® Statistics). The Intraclass correlation coefficient was used to determine the inter- and intra-observer reliability. The comparison of differences between males and females among the examined parameters was done using an independent *t*-test. Equations predicting the sex difference using the examined parameters were derived by discriminant analysis.

Results

A total of 200 scans were recorded (100 males and 100 females). The mean age of the study population was 27. The mastoid morphometric parameters were compared between males and females. The mean MH for males on the right side was 35.52 ± 4.54 and for females was 30.98 ± 4.4. The mean ML for males was 25.73 ± 4.04 and for females was 25.83 ± 3.83, on the right side. The mean MW for males was 25.81 ± 4.56, and for females, it was 25.19 ± 5.56, on the right side. On the left side, the mean MH for males was 35.05 ± 5.01 and for females, it was 31.3 ± 4.67. The mean ML on the left side for males was 25.57 ± 3.85, and for females, it was 26.73 ± 3.71. On the left side, the mean MW for males was 24.21 ± 3.93, and for females, it was 23.71 ± 4.93.

Table 1: Comparison of the morphometric measurements of two groups using independent *t*-test

	Male (n = 100)	*Female (n = 100)*		
	Mean ± SD	*Mean ± SD*	*t*	*p-value*
AGE	27.76 ± 7.68	26.23 ± 6.58	1.512	0.132
RMH	35.52 ± 4.54	30.98 ± 4.4	7.191	**<0.001**
RML	25.73 ± 4.04	25.83 ± 3.84	–0.193	0.847
LMH	35.05 ± 5.01	31.3 ± 4.67	5.466	**<0.001**
LML	26.73 ± 3.71	25.57 ± 3.85	2.16	**0.032**
RMW	25.81 ± 4.56	25.19 ± 5.56	0.867	0.387
LMW	24.2 ± 3.93	23.73 ± 4.93	0.746	0.457
IMLSD	130.32 ± 5.92	124.91 ± 5.89	6.481	**<0.001**
IMD	122.91 ± 5.72	118.14 ± 6.26	5.617	**<0.001**
MMCA	109.55 ± 5.22	109.62 ± 5.19	–0.088	0.93
RMS	237.27 ± 69.31	202.4 ± 64.11	3.693	**<0.001**
LMS	217.79 ± 61.1	199.74 ± 63.57	2.047	**0.042**
RSA	1438.76 ± 313.43	1262.54 ± 283.87	4.167	**<0.001**
LSA	1408.54 ± 301.65	1315.59 ± 279.23	2.261	**0.025**

p-value < 0.05 is considered statistically significant

For IMD, the mean value for males was 122.89 ± 5.7 and for females was 118.15 ± 6.25. IMLSD for males was 130.31 ± 5.92 and for females, it was 124.91 ± 5.86. MMCA for males was 109.57 ± 5.22, and for females, it was 109.61 ± 5.18. The right MS was 237.27 ± 69.31 for males and for females, it was 202.4 ± 64.11. Whereas, for the left MS, it was 217.79 ± 61.1, and for females, it was 199.74 ± 63.57. For males, the SA on the right side was 1438.76 ± 313.43 and for females it was 1262.54 ± 283.87. The SA on the left side for males was 1408.54 ± 301.65, and for females, it was 1315.59 ± 279.23 (Table 1).

Statistical analysis revealed a highly significant value for MH on the left and right side ($p < 0.001$), IMD ($p < 0.001$), IMLSD ($p < 0.001$), MS on the left ($p = 0.042$) and right side ($p < 0.001$), and MSA on the left ($p = 0.025$) and the right side ($p < 0.001$), all of which were found to be greater in males. Also, the left ML ($p = 0.032$) was found to be significantly greater in males. Discriminant function analysis was used to classify sex. It was found that IMD was the best sex determinant among all the eight parameters, with an accuracy of 70% (Table 2).

In order to find the best combination of parameters, forward stepwise discriminant function analysis was applied. The combined parameters that were found to be the most accurate were right MH, left ML, and IMLSD, with an accuracy of 75%.

The study showed a notable difference between the mastoid processes of males and females.

Discussion

Cone-beam computed tomography is a recently developed 3D imaging technology that has applications to assess the anatomy

Table 2: Discriminant function analysis to classify gender

Parameter	*Male mean values*	*Male SD*	*Female mean values*	*Female SD*	*Equation*	*Percentage of females correctly classified*	*Percentage of males correctly classified*	*Overall accuracy*	*Male centroid*	*Female centroid*	*Sectioning point*	*Demarcating point*
RMH	35.5193	4.535478	30.9754	4.400042	Discriminant function (D) = −7.441 + (0.224) × (RMH)	68	70	69.00%	0.508	−0.508	0	33.21875
RML	25.7291	4.044707	25.8329	3.830339	Discriminant function (D) = −6.545 + (0.254) × (RML)	44	50	47.00%	−0.014	0.014	0	25.75984
LMH	35.046	5.006557	31.3026	4.672291	Discriminant function (D) = −6.851 + (0.207) × (LMH)	66	64	65.00%	0.387	−0.387	0	33.09662
LML	26.7278	3.707026	25.5729	3.853339	Discriminant function (D) = −6.916 + (0.264) × (LML)	54	55	54.50%	0.153	−0.153	0	26.19697
RMW	25.8116	4.558494	25.1882	5.558467	Discriminant function (D) = −5.017 + (0.197) × (RMW)	58	54	56.00%	0.061	−0.061	0	25.46701
LMW	24.207	3.934835	23.7078	4.934177	Discriminant function (D) = −5.369 + (0.224) × (LMW)	49	50	49.50%	0.056	−0.056	0	23.96875
IMLSD	130.3068	5.92183	124.9124	5.861212	Discriminant function (D) = −21.66 + (0.17) × (IMLSD)	65	69	67.00%	0.458	−0.458	0	127.4118
IMD	122.8906	5.695416	118.1466	6.250805	Discriminant function (D) = −20.155 + (0.167) × (IMD)	70	70	70.00%	0.397	−0.397	0	120.6886
MMCA	109.5684	5.2168	109.6142	5.18295	Discriminant function (D) = −21.076 + (0.192) × (MMCA)	54	47	50.50%	−0.004	0.004	0	109.7708
RMS	237.2675	69.31093	202.4038	64.10922	Discriminant function (D) = −3.293 + (0.015) × (RMS)	56	60	58.00%	0.261	−0.261	0	219.5333
LMS	217.7857	61.10031	199.7372	63.57402	Discriminant function (D) = −3.348 + (0.016) × (LMS)	47	56	51.50%	0.145	−0.145	0	209.25
RSA	1438.757	313.43	1262.54	283.8655	Discriminant function (D) = −4.517 + (0.003) × (RSA)	53	57	55.00%	0.295	−0.295	0	1505.667
LSA	1408.539	301.6503	1315.587	279.2272	Discriminant function (D) = −4.686 + (0.003) × (LSA)	55	58	56.50%	0.16	−0.16	0	1562
RMH LML IMLSD	–	–	–	–	Discriminant function (D) = −14.189 + 0.154 (RMH)–0.127 (LML) + 0.097 (IMLSD)	78	74	75.0%	0.685	−0.685	–	–

and various pathologies of the head and neck region. The precision of measurements with CBCT is commendable since there are negligible chances of superimposition and positioning errors, thus improving the applicability of Cranio morphometric analysis in forensic odontology.

The mastoid process is the most dimorphic part of the skull, with a compact nature assuming a protected position, making the petrous bone the second-best region in the skeleton to predict sex, following the pelvic bone. Mastoid morphometry was chosen for this study as it is resistant to physical damage, remains intact in old age due to its anatomical position, and thus could be a potential predictor to determine sex. Most of the studies that were conducted on the mastoid process for sex determination were done on a dry skull. Vernier calipers were used to measure the length, height, and width, whereas measurements of the IMD, IMLSD, and MMCA were done using computed tomography. To evaluate the use of the mastoid process as a tool for sex determination, Passey et al. and Madhumathi et al. conducted studies on unidentified skeletons and human dry skulls, respectively. Passey et al. concluded that both right and left ML were significantly greater in males. In the present study, left ML was significantly greater in males when compared to females.[7] In a study conducted by Madhumathi et al., the height, length, and width of the mastoid process were used for sex determination, and it was concluded that ML was greater in males and the mastoid process can be used as an indicator for sex dimorphism.[8] In the present study, left ML and MH were greater in males than in females, which was in concordance with other studies.

In the present study, CBCT was used as a 3D modality to measure all the parameters of the mastoid process. The mastoid process is a conical prominence present behind the ear. It is the second-most common region for sex determination.[3] Amala Manivanan et al. carried out a retrospective study with a sample size of 100 adult CBCT images. Height, length, and width of both right and left mastoids were radiographically measured using CBCT. It was found that the length and height of the mastoid process in males were larger in size, whereas the width was greater in females. They concluded that the mastoid process can be a well-founded index for the determination of sex.[2] The findings of this study were in agreement with the present study. Mastoid length on the left side was significant and was greater in males. In a retrospective study using CBCT by Gopal et al., five parameters, namely ML, MH, angle, MSA, and IMD, were included. Out of the five parameters, only the intermastoid angle was not statistically significant, and the mastoid process was found to be lengthier in males, which was in accordance with the results of the present study.[9]

Amin et al. conducted a study on the Jordanian population to determine the sex by estimating the mastoid process in terms of height, length, width, IMD, MMCA, MSA, IMLSD, and mastoid flare using computer tomography. It was concluded that the IMD was found to be the best parameter for sex determination, which was correlating with the findings of the present study.[10]

Farhadian et al., conducted a retrospective study on a sample size of 190 CBCT scans to determine sex in terms of the distance between the porion and mastoidale; ML, height, and width; distance between the mastoidale and mastoid incision; the IMD distance between the lowest point of the mastoid triangle and the most prominent convex surface of the mastoid (MF); the distance between the most prominent convex mastoid point (IMSLD); and the intersecting angle drawn from the most prominent right and left mastoid point (MMCA). It was concluded from the study that IMSLD and IMD made the largest contributions to predict sex. IMD was found to be the best parameter in the present study also.[11]

In a descriptive retrospective study on the Mysore population, carried out by Patil et al. on a sample size of 64, to analyze the determination of sex using mastoid triangle area, area of the inter mastoid triangle, mastoid volume, bimastoid distance, and MH, all the parameters were significant. Area of the mastoid triangle, the volume of mastoid, and the bimastoid length are highly significant, whereas MH is less significant ($p = 0.452$). In contrast to the current study, MH was highly significant ($p < 0.001$).[12]

Mondal et al. conducted a retrospective study on 60 CBCT skull images. Radiographic measurements of the length, width, height, and volume were made using customized software. It was concluded that MH was a good indicator for gender determination, with an accuracy of 76.7%. In the current study, MH was also significant, having an accuracy of 75%.[13]

In the retrospective study conducted by Salemi et al. on 190 CBCT scans, nine parameters were included: the distance between the porion and the mastoid, ML, the distance between the mastoidale and the mastoid incision, ML, MH, and MW, mastoidale flare, IMD, the lateral surfaces of the left and right mastoids, and the MMCA measured on both the right and the left. It was concluded from his study that IMD and the lateral surfaces of the left and right mastoids had the most influence on sex determination. IMD was found to be the best parameter in the current study as well.[14]

In the present study, the combined parameters that were found to be the most accurate were right MH, left ML, and IMLSD, with an accuracy of 75%. The combination of skeletal parameters gives better accuracy in the estimation of sex than relying on individual parameters.[15]

For the recognition of victims, sex estimation becomes one of the most difficult parameters to assess. In such events, the mastoid process can become an important anatomical landmark for the determination of sex. This is due to the condensed nature of the petrous bone and also its protected position in the skull. Because of the unique position of the mastoid within the skull, it has been noted that it will remain intact even if the skull fragments.[7]

Further research studies with a multi-centric arrangement, an increased sample size, and the inclusion of various ethnic populations are needed to validate and generalize the present study findings. Studies on different populations will help to derive population-specific formulas for sex estimation and will also aid in generalizing the results of this study to the general population.

Conclusion

From the present study, it can be concluded that there is a significant variance between the mastoid processes of males and females. Out of the eight parameters assessed, IMD can be used as a good index for sex estimation. Statistically, it was revealed that the MH, IMD, ML, IMLSD, MS, and MSA were significant, which were found to be greater in males than females.

Authors' Contributions

JA: Conception, design of the work; acquisition, interpretation of data; substantively revised it; approved the submitted version. AS: Conception, design of the work; acquisition, drafted the work interpretation of data; preparation of tables and figures, substantively revised it; approved the submitted version.

AM: Analysis, interpretation of data; preparation of tables and figures, substantively revised it; approved the submitted version. NS: Design of the work, interpretation of data, drafted the work substantively revised it; approved the submitted version. NS: Design of the work; interpretation of data, drafted the work substantively revised it; approved the submitted version.

Ethical Approval

Ethics approval and consent to participate: Approval for the study was taken before conducting the study from the Institutional Ethics Committee, Manipal College of Dental Sciences, Mangaluru (Protocol no 21003).

References

1. Baryah N, Krishan K, Kanchan T. The development and status of forensic anthropology in India: A review of the literature and future directions. Med Sci Law 2019;59(1):61–69. DOI: 10.1177/002580 2418824834.
2. Divakar KP. Forensic odontology: The new dimension in dental analysis. Int J Biomed Sci 2017;13(1):1. PMID: 28533730.
3. Manivanan A, Saraswathi GK, Sai A. Osteometric assessment of the mastoids for gender determination: A retrospective CBCT study. Am J Otolaryngol Head Neck Surg 2019;2(3):1044. DOI: 10.24941/ajohs.2019.2.3.1044.
4. Nagare SP, Chaudhari RS, Birangane RS, et al. Sex determination in forensic identification, a review. J Forensic Dent Sci 2018;10(2):61. PMID: 30745778.
5. Deepa Gaayathri D, Kanmani R, Anandi MS, et al. Role of mastoid process in gender determination – A retrospective analysis using computed tomography. Int J Curr Res 2017;9(09):57323–57326. DOI: 10.24941/ijcr.2017.9.9.57323-57326.
6. Balachandran R, Kharbanda OP, Sennimalai K, et al. Orientation of cone-beam computed tomography image: Pursuit of perfect orientation plane in three dimensions—A retrospective cross-sectional study. Annals of the National Academy of Medical Sciences (India) 2019;55:202–209. DOI: 10.1055/s-0040-1701144.
7. Passey J, Mishra SR, Singh R, et al. Sex determination using mastoid process. Asian J Med Sci 2015;6(6):93–95. DOI: 10.3126/ajms.v6i6.12406.
8. Madhumathi D, Thenmozhi MS, Gurunathan D, et al. Determination of sex by measuring mastoid process. Drug Invent Today 2019;12: 2355–2357. DOI: 10.7897/2277-7695.120325.
9. Gopal SK, Sushmitha S, Kumar M. Mastoid and magnum – Hidden key in forensics – A retrospective three-dimensional cone-beam computed tomographic study. Int J Forensic Odontol 2020;5(2):62. DOI: 10.4103/ijfo.ijfo_20_20.
10. Amin W, Saleh M-W, Othman D, et al. Osteometric assessment of the mastoids for gender determination in Jordanians by discriminant function analysis. Am J Med Biol Res 2015;3(4):117–123. DOI: 10.12691/ajmbr-3-4-7.
11. Farhadian M, Salemi F, Shokri A, et al. Comparison of data mining algorithms for sex determination based on mastoid process measurements using cone-beam computed tomography. Imaging Sci Dent 2020;50(4):323. DOI: 10.5624/isd.2020.50.4.323.
12. Patil K, Sanjay CJ, Christopher VS, et al. Morphometric analysis of the mastoid process using cone beam computed tomography. Eur J Anat 2024;28(3):331–337. DOI: 10.52083/XIOD6609.
13. Mondal B, Vaishali MR, David MP, et al. Assessment of the usefulness of morphometric and volumetric analysis of mastoid process for gender determination in forensic odontology: A retrospective cone beam computed tomographic study. J Indian Acad Oral Med Radiol 2022;34(1):82–86. DOI: 10.4103/jiaomr.jiaomr_229_21.
14. Salemi F, Farhadian M, Shokri A, et al. Sex determination by osteometric assessment of the mastoid process using Cone Beam Computed Tomography. Braz Dent Sci 2021;24(1):1–9. DOI: 10.14295/bds.2021.v24i1.2075.
15. Madadin M, Menezes RG, Al Dhafeeri O, et al. Evaluation of the mastoid triangle for determining sexual dimorphism: A Saudi population based study. Forensic Sci Int 2015;254:244.e1–e4. DOI: 10.1016/j.forsciint.2015.06.019.