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Review

Variability in Mastoid Triangle Area Measurements for Sex Estimation: A Critical Narrative Review of Studies from Brazil, India, and Turkey

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Abstract

Background/Objectives: The mastoid triangle, defined by porion, asterion, and mastoidale, has been used to investigate sexual dimorphism for sex estimation. This critical narrative review aimed to describe and compare variability in reported mean mastoid triangle areas for males and females among studies using samples from the same country and to assess limitations affecting comparability. **Methods:** PubMed, Google Scholar, SciELO, and resources accessible through EBSCOhost were searched in 2024 and updated in 2026. Thirteen eligible studies from Brazil (five), India (six), and Turkey (two) were included. Sex-specific right and left areas were extracted; directly reported bilateral means were distinguished from descriptive sums of lateral means. Findings were synthesized narratively without meta-analysis. **Results:** Mastoid triangle areas were generally larger in males than in females, but values varied among studies within the same country. Reported or descriptively derived male bilateral values ranged from 1316.50 to 1535.30 mm^2 in Brazil, 1151.30 to 1475.69 mm^2 in India, and 1455.20 to 1472.19 mm^2 in Turkey. Differences in sample characteristics, reference sex ascertainment, measurement techniques (including direct measurements and computed tomography-based reconstructions), and the reporting of bilateral values limited comparability. **Conclusions:** Differences among reported measurements did not allow reliable identification of consistent within-country patterns of anatomical variability in male and female crania. Limited comparability and insufficient chronological information precluded inferences about secular morphological changes. Standardized protocols, well-documented, chronologically comparable samples, and independently established reference sex are needed to strengthen future research in human anatomy and forensic anthropology.

Keywords: mastoid triangle; morphometric variability; sexual dimorphism; sex estimation; forensic anthropology

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1. Introduction

Sex estimation from skeletal remains is a fundamental component of forensic anthropological analysis [1]. Krogman, as reported by İşcan and Steyn [2], described historical sex-estimation accuracy rates of 100% when the complete skeleton was available, 95% using the pelvis alone, 92% using the skull alone, and 98% when the skull and pelvis were assessed together. These findings highlight the potential value of the skull for sex estimation when

other skeletal elements are unavailable. However, these historical accuracy rates should be interpreted with caution, as the marked predominance of male individuals in the skeletal collections used for these early assessments may have biased the reported results, limiting their generalizability. More recent investigations have demonstrated that sex-classification accuracy based on nonmetric cranial traits varies across population samples [3], while observer-related differences in trait scoring can also influence classification outcomes [4].

Cranial sex estimation has been investigated using both anatomical and computational approaches [5]. When preserved, cranial remains can provide anatomical information relevant to forensic sex estimation. Although cranial morphology exhibits sexually dimorphic characteristics, their expression varies among populations, and cranial traits are generally less reliable for sex estimation than pelvic traits [3,4]. The petrous portion of the temporal bone frequently survives skeletal fragmentation [6]. Another structure of the temporal bone, the mastoid process, exhibits sexual dimorphism and is routinely examined in forensic sex estimation [7,8]. Variation in the mastoid process has been investigated using different approaches, including nonmetric visual assessments, linear measurements, and three-dimensional analyses. These methods examine different aspects of mastoid size and shape and are not necessarily interchangeable [3,4,8].

Building upon this premise, in 2003, De Paiva and Segre [9] investigated sexual dimorphism through the measurement of the mastoid triangle area, defined by three craniometric landmarks: porion, asterion, and mastoidale. Their methodology involved obtaining xerographic projections of both sides of the skull, identifying the corresponding landmarks, and transferring the delineated triangles to tracing paper for area calculation. However, the authors did not specify the mathematical formula used to determine these areas. Subsequently, Suazo et al. (2008) assessed the mastoid triangle using direct craniometric measurements obtained with a digital caliper and explicitly calculated the triangular areas using Heron's formula [10]. The craniometric landmarks defining the mastoid triangle are illustrated in Figure 1.

Following these investigations, mastoid triangle measurements have been examined in studies involving cranial specimens or radiological reconstructions from Brazil [10–13], India [14–19], Turkey [20,21], Thailand [22], and Bulgaria [23], among others. Complementary investigations have examined broader aspects of mastoid morphology using approaches that differ from mastoid triangle area measurements. Jung and Woo (2016) [24] applied geometric morphometrics to 200 modern White American crania and demonstrated that both mastoid size and shape exhibited sexual dimorphism, with size accounting for a substantial proportion of the observed shape variation. Petaros et al. (2021) [25] examined mastoid volumes using three-dimensional models of 170 medieval Croatian crania and found that different anatomical definitions of the mastoid region influenced measurement outcomes and sex-estimation performance. More recently, Celebrini et al. (2025) [26] investigated linear, angular, and volumetric mastoid measurements using cone-beam computed tomography in a Brazilian sample. Together, these investigations demonstrate that mastoid morphology can be assessed through different quantitative approaches, which are not directly interchangeable with the geometric area defined by porion, asterion, and mastoidale. Accordingly, the present review focuses specifically on mastoid triangle area measurements while considering these broader investigations as anatomical and methodological context.

Previous investigations have primarily focused on the discriminatory performance of mastoid triangle measurements for sex estimation, whereas the variability and comparability of mean areas reported across studies using samples from the same country have received less attention. Examining these differences may help identify methodological and sample-related limitations that affect the interpretation and comparison of published morphometric data.

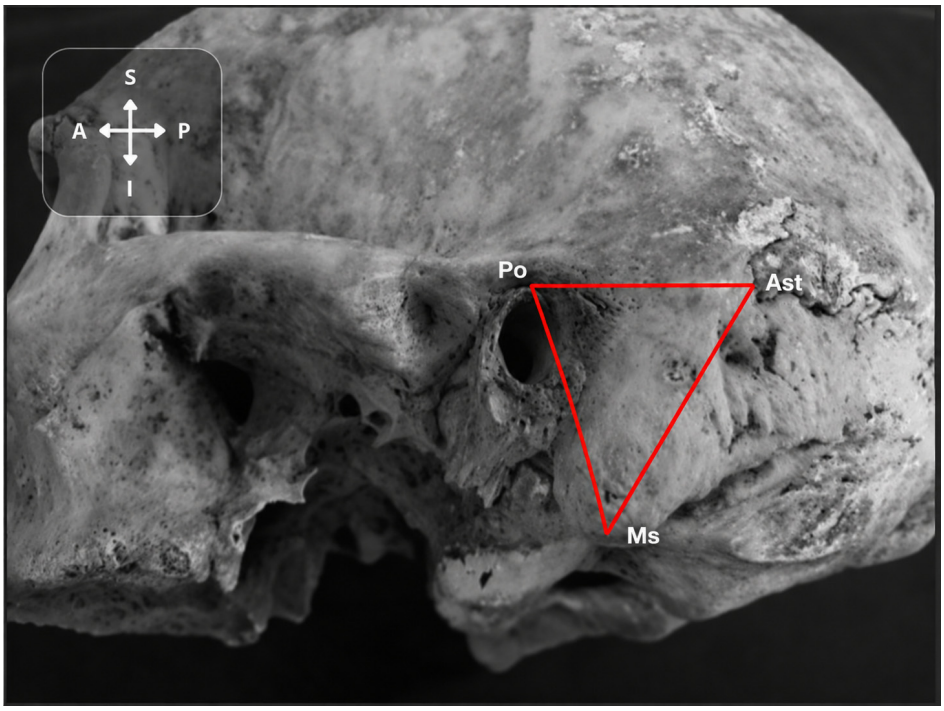


Figure 1. Oblique lateral view of a human skull showing the approximate locations of the craniometric landmarks defining the mastoid triangle: porion (Po), asterion (Ast), and mastoidale (Ms). The red lines outline the mastoid triangle. The landmark positions are approximate and are provided for illustrative purposes. The orientation cross indicates superior (S), inferior (I), anterior (A), and posterior (P). Original photograph of a cranial specimen from the Human Morphology Laboratory at San Sebastian University, Valdivia Campus, Chile.

To address this gap, studies involving samples from the same country can be examined descriptively, without assuming that these samples represent a homogeneous biological population. In the present review, the literature search was conducted without predefined geographical restrictions, and Brazil, India, and Turkey were identified as countries with at least two studies meeting the established eligibility criteria. Accordingly, this critical narrative review aims to describe and compare the variability in mean mastoid triangle areas reported for males and females across studies using samples from the same country, while considering methodological and sample-related limitations that may affect the interpretation of the observed differences.

2. Materials and Methods

2.1. Study Design and Search Strategy

A critical narrative review of the scientific literature was conducted to examine within-country variability and comparability of reported mastoid triangle area measurements.

The initial literature search was performed between June and October 2024 and updated between April and July 2026, with additional searches and eligibility verification conducted in November 2026. PubMed, Google Scholar, SciELO, and bibliographic resources accessible through EBSCOhost were searched. EBSCOhost was accessed through the institutional library of San Sebastian University (Chile), using the databases and academic resources automatically selected by the platform's default configuration, without applying subject-area restrictions or manually modifying the database selection. Search terms included "mastoid triangle", "triángulo mastoideo", "sexual dimorphism" AND "mastoid process", and "dimorfismo sexual" AND "proceso mastoides". Additional searches were subsequently performed by combining "mastoid triangle" with the names of countries identified during

the initial search. The updated search and subsequent eligibility verification identified additional relevant studies, including research involving Turkish samples.

2.2. Selection Criteria

Original studies involving adult human crania, assessed through direct examination of osteological specimens or radiological imaging, were considered eligible if they examined both sexes, assessed the area of the mastoid triangle defined by the craniometric landmarks porion, asterion, and mastoidale, and reported right and left mastoid triangle areas separately for males and females.

To allow within-country comparisons, studies were selected from countries for which at least two eligible investigations were identified. This criterion was established during the literature search, as no geographical restrictions had been applied initially. Following the updated literature search and eligibility assessment, Brazil, India, and Turkey were identified as the countries meeting this criterion.

Studies were excluded if they did not assess mastoid triangle area, if the available information was insufficient to verify their eligibility, or if inconsistencies in the reported measurements or units prevented reliable interpretation or standardization of the results in square millimeters (mm^2).

2.3. Study Selection and Data Analysis

After duplicate removal, 39 unique publications were retained for screening. Following title and abstract screening, seven publications were excluded because they did not assess mastoid triangle area, leaving 32 publications for further eligibility assessment. Of these, 19 publications were excluded for not meeting one or more eligibility criteria, including the availability of sex-specific right- and left-side mastoid triangle area measurements and the requirement of at least two eligible studies per country, or because insufficient methodological information or inconsistencies in reported measurements or units prevented reliable interpretation. The final selection comprised 13 studies: five from Brazil, six from India, and two from Turkey.

Among the 19 publications excluded during the eligibility assessment, several studies required particular consideration because their eligibility or reported measurements could not be reliably verified or interpreted. Chaudhary et al. (2018) [27], Lahiri et al. (2023) [28], and Sasani et al. (2024) [29] were excluded because their full texts could not be obtained, preventing sufficient verification of their methodological procedures and reported results. Senthil Kumar and Ashik (2020) [30] were excluded due to internal inconsistencies among the reported linear measurements, triangle perimeters, and areas. Kiran et al. (2021) [31] were excluded because inconsistencies between the reported lateral and bilateral measurements, together with discrepancies involving the reported dispersion statistics, prevented reliable interpretation of the results. Çeri et al. (2022) [32] were excluded because the measurement units could not be reliably established and inconsistencies in the reported statistical analyses prevented adequate verification of the findings.

Data were extracted on publication year, sample characteristics, measurement methods, and sex-specific right and left mastoid triangle areas. The findings were organized by country and publication year and examined through a descriptive and critical comparison. When bilateral mean areas were not directly reported, the right and left mean areas were summed for descriptive purposes. These values were identified as derived calculations rather than directly reported bilateral means.

Publication year was used solely to establish the chronological order of the studies and was not considered indicative of the chronological characteristics of the individuals represented in each sample. Given the heterogeneity in sample characteristics and measure-

ment methods, no meta-analysis was performed. Furthermore, the limited chronological information prevented any conclusions regarding secular changes in mastoid triangle area.

During the initial preparation of the manuscript, Gemini 1.5 Pro (Google) was used to assist with Spanish-to-English translation and language refinement. During subsequent revisions, ChatGPT (OpenAI, GPT-6) was used to assist with academic writing, translation, language revision, the organization of information extracted from the included studies, and the identification of potential inconsistencies in reported measurements. The authors reviewed the AI-assisted content and verified relevant information against the original publications. The authors retain full responsibility for the accuracy, interpretation, and integrity of the manuscript.

3. Results

The findings from studies involving Brazilian osteological samples are presented below, in chronological order by year of publication:

In a 2003 study, a sample of 60 skulls from São Paulo (30 males, 30 females), all belonging to individuals over 18 years of age, was analyzed. The mean areas in male skulls were 752.10 mm^2 (right) and 753.22 mm^2 (left). Conversely, female skulls exhibited mean values of 608.70 mm^2 (right) and 602.54 mm^2 (left) [9].

Subsequently, in 2008, Suazo et al. examined 81 Brazilian skulls (50 males, 31 females) sourced from the Laboratory of the Escola Paulista de Medicina in São Paulo, belonging to individuals aged 40 to 70 years. They reported mean areas of 703.35 mm^2 (right) and 674.45 mm^2 (left) for males, whereas females presented mean areas of 624.09 mm^2 (right) and 685.64 mm^2 (left) [10].

In another Brazilian study published in 2019, 100 adult skulls (47 males, 53 females) from individuals over 18 years of age were analyzed. The mean age at death was 53.88 years for males and 59.95 years for females. The mean mastoid triangle areas in male skulls were 780.50 mm^2 (right) and 754.70 mm^2 (left), whereas in female skulls, these values were 641.50 mm^2 (right) and 614.80 mm^2 (left) [11].

In 2021, De Castro et al. examined 80 skulls (46 males, 34 females) from individuals aged 18 to 60 years, all sourced from an osteological biobank at the University of Campinas. In male skulls, they reported mean areas of 661.00 mm^2 (right) and 655.50 mm^2 (left), while female skulls yielded mean areas of 609.50 mm^2 (right) and 616.70 mm^2 (left) [12].

Finally, Fonseca et al. (2023) [13] examined a sample of 244 adult skulls (212 male and 32 female) from central-western Brazil, which had been incorporated into a forensic osteological collection between 1990 and 2021. The mean right and left mastoid triangle areas in male skulls were 684.11 mm^2 and 668.94 mm^2, respectively, compared with 588.93 mm^2 and 582.88 mm^2 in female skulls.

De Paiva and Segre [9] proposed bilateral mastoid triangle area thresholds of $\geq$1447.40 mm^2 for males and $\leq$1260.36 mm^2 for females in their study sample. Values between these thresholds were not assigned to either sex category. These reference values were derived from a specific osteological sample and should not be considered universally applicable without external validation. The findings from the included Brazilian study samples are summarized in Table 1.

Regarding the Indian osteological samples, six studies were included. The findings are presented chronologically by publication year, with the geographic provenance of each sample identified when reported by the authors. This approach was adopted because some studies included skulls from different locations, making classification into broad geographic regions less appropriate.

Table 1. Mean values of the mastoid triangle area in male and female skulls from Brazil (565 skulls).

	Male			Female		
Year	**Right**	**Left**	**Total Area**	**Right**	**Left**	**Total Area**
2003 (60 skulls) [9]	752.10 mm^2	753.22 mm^2	1505.32 mm^2	608.70 mm^2	602.54 mm^2	1211.24 mm^2
2008 (81 skulls) [10]	703.35 mm^2	674.45 mm^2	1389.56 mm^2	624.09 mm^2	685.64 mm^2	1296.22 mm^2
2019 (100 skulls) [11]	780.50 mm^2	754.70 mm^2	1535.30 mm^2	641.50 mm^2	614.80 mm^2	1256.40 mm^2
2021 (80 skulls) [12]	661.00 mm^2	655.50 mm^2	1316.50 mm^2 *	609.50 mm^2	616.70 mm^2	1226.20 mm^2 *
2023 (244 skulls) [13]	684.11 mm^2	668.94 mm^2	1353.05 mm^2 *	588.93 mm^2	582.88 mm^2	1171.81 mm^2 *

Note: All values are presented to two decimal places for consistency. Values reported with greater precision in the original studies were rounded to two decimal places, while trailing zeros were added where necessary. * Values were calculated by summing the mean right and left mastoid triangle areas reported in the original studies. These derived values were used for descriptive purposes and do not necessarily represent mean bilateral areas calculated from paired measurements of the same skulls. The bilateral values reported by Suazo et al. (2008) [10] were taken directly from the original publication and differ from the sums of the corresponding right and left means. The original study reported different sample sizes for right- and left-side measurements (males: $n = 49$ and 48, respectively; females: $n = 30$ and 31, respectively), which may contribute to this discrepancy. However, the available data do not allow its exact cause to be established.

In 2013, Bhagya et al. examined 80 adult skulls (40 males and 40 females), aged 35–60 years, from a medical college in Mangalore, Karnataka. The mean mastoid triangle areas in male skulls were 726.76 mm^2 (right) and 734.30 mm^2 (left), whereas female skulls exhibited mean areas of 607.63 mm^2 (right) and 615.16 mm^2 (left) [14].

In the same year, Gangrade et al. analyzed 100 adult skulls (50 males and 50 females) obtained from anatomical collections in Nagpur, Maharashtra, and Udaipur, Rajasthan. The reported mean areas were 749.60 mm^2 (right) and 726.10 mm^2 (left) for males, compared with 650.30 mm^2 (right) and 638.60 mm^2 (left) for females [15].

Also in 2013, Shah and Patel examined 100 adult skulls collected from medical colleges in Gujarat. Mean mastoid triangle areas were 663.66 mm^2 (right) and 662.54 mm^2 (left) in males and 595.92 mm^2 (right) and 589.29 mm^2 (left) in females [16].

In 2016, Ajay Kumar et al. [17] analyzed 100 adult skulls (50 males and 50 females) from a medical college in Kolar, Karnataka. Mean right and left mastoid triangle areas were 684.75 mm^2 and 709.13 mm^2 in males, respectively, compared with 549.24 mm^2 and 546.64 mm^2 in females.

Subsequently, Chavan et al. (2018) [18] examined 132 adult skulls (80 males and 52 females) obtained from osteological collections in the Marathwada region of Maharashtra. The reported mean areas were 586.05 mm^2 (right) and 565.30 mm^2 (left) for males and 508.47 mm^2 (right) and 436.37 mm^2 (left) for females.

Finally, Passey et al. (2021) [19] analyzed 300 adult skulls (190 males and 110 females) from an institutional osteological collection described as representing a North Indian population. Mean right and left mastoid triangle areas were 650.29 mm^2 and 648.97 mm^2 in males, respectively, compared with 590.61 mm^2 and 582.19 mm^2 in females.

The findings from the six studies involving Indian osteological samples are summarized in Table 2, arranged by year of publication.

Regarding the Turkish samples, two studies were included. In 2021, Başaloğlu et al. [20] examined 60 adult dry skulls (30 males and 30 females) from an anatomical collection at Aydın Adnan Menderes University, Turkey. The mean mastoid triangle areas in male skulls were 723.90 mm^2 (right) and 731.30 mm^2 (left), whereas female skulls exhibited mean areas of 545.60 mm^2 (right) and 556.80 mm^2 (left).

Table 2. Mean values of the mastoid triangle area in male and female skulls from India (812 skulls). The years are referenced, along with the number of skulls examined.

	Male			Female		
Year	**Right**	**Left**	**Total Area**	**Right**	**Left**	**Total Area**
2013 (100 skulls) [15]	749.60 mm^2	726.10 mm^2	1475.69 mm^2	650.30 mm^2	638.60 mm^2	1288.90 mm^2
2013 (100 skulls) [16]	663.66 mm^2	662.54 mm^2	1326.20 mm^2 *	595.92 mm^2	589.29 mm^2	1185.21 mm^2 *
2013 (80 skulls) [14]	726.76 mm^2	734.30 mm^2	1461.06 mm^2	607.63 mm^2	615.16 mm^2	1222.79 mm^2
2016 (100 skulls) [17]	684.75 mm^2	709.13 mm^2	1393.88 mm^2	549.24 mm^2	546.64 mm^2	1095.88 mm^2
2018 (132 skulls) [18]	586.05 mm^2	565.30 mm^2	1151.30 mm^2	508.47 mm^2	436.37 mm^2	944.85 mm^2
2021 (300 skulls) [19]	650.29 mm^2	648.97 mm^2	1299.26 mm^2 *	590.61 mm^2	582.19 mm^2	1172.80 mm^2 *

Note: All values are presented to two decimal places for consistency. Values reported with greater precision in the original studies were rounded to two decimal places, while trailing zeros were added where necessary. * Values were calculated by summing the mean right and left mastoid triangle areas reported in the original studies. These derived values were used for descriptive purposes and do not necessarily represent mean bilateral areas calculated from paired measurements of the same skulls. All bilateral values without an asterisk were extracted directly from the original publications. In Chavan et al. (2018) [18], the reported bilateral means differ slightly from the sums of the corresponding right and left means. The available data do not allow this discrepancy to be resolved.

Subsequently, Açar and Aydoğdu (2025) [21] analyzed three-dimensional reconstructions from computed tomography scans of 152 adults (75 males and 77 females), obtained from a radiology database at Necmettin Erbakan University in Konya, Turkey. The mean right and left mastoid triangle areas in male skulls were 726.40 mm^2 and 745.79 mm^2, respectively, compared with 598.50 mm^2 and 588.88 mm^2 in females.

The mastoid triangle area measurements reported in both Turkish studies are summarized in Table 3.

Table 3. Mean values of the mastoid triangle area in male and female samples from Turkey (212 individuals). The years are referenced, along with the number of individuals examined.

	Male			Female		
Year	**Right**	**Left**	**Total Area**	**Right**	**Left**	**Total Area**
2021 (60 skulls) [20]	723.90 mm^2	731.30 mm^2	1455.20 mm^2	545.60 mm^2	556.80 mm^2	1102.30 mm^2
2025 (152 CT scans) [21]	726.40 mm^2	745.79 mm^2	1472.19 mm^2 *	598.50 mm^2	588.88 mm^2	1187.38 mm^2 *

Note: All values are presented to two decimal places for consistency. Values reported with lower precision in the original studies were displayed with trailing zeros. * Values were calculated by summing the mean right and left mastoid triangle areas reported in the original studies. These derived values were used for descriptive purposes and were not reported directly as bilateral means in the original publication. The bilateral values reported by Başaloğlu et al. (2021) [20] were extracted directly from the original publication. The reported female bilateral mean (1102.30 mm^2) differs slightly from the sum of the corresponding rounded right and left means (1102.40 mm^2).

The characteristics of the included studies, including sample provenance, age range, sex distribution, reference sex ascertainment, and mastoid triangle measurement techniques, are summarized in Table 4.

Table 4. Characteristics of the included study samples and methods used to measure and calculate mastoid triangle area.

Study	Sample Provenance	Sample n (M/F)	Age (Years)	Reference Sex Ascertainment	Mastoid Triangle Measurement	Area Calculation Method
De Paiva and Segre (2003) [9]	Guarulhos, São Paulo, Brazil; identified skulls exhumed from a municipal cemetery.	60 (30/30)	≥18; range NR	Cemetery identification records.	Xerographic skull projections; traced triangles	NR
Suazo et al. (2008) [10]	Museum of the Federal University of São Paulo (UNIFESP), Brazil.	81 (50/31)	40–70	Documented osteological collection records.	Direct digital caliper (0.01 mm)	Heron's formula
Sinhorini et al. (2019) [11]	Institute of Education and Research in Forensic Sciences (IEPCF), Brazil; documented osteological collection.	100 (47/53)	≥18; range NR	Documented osteological collection records.	Direct digital caliper (0.01 mm)	Heron's formula
De Castro et al. (2021) [12]	Osteological biobank, Piracicaba Dental School, UNICAMP, Brazil.	80 (46/34)	18–60	Death certificates available; specific verification procedure NR.	Direct digital caliper (±0.03 mm)	Heron's formula
Fonseca et al. (2023) [13]	Forensic osteological collection, central-western Brazil; specimens incorporated between 1990 and 2021.	244 (212/32)	Adults; range NR	Genetic (DNA) analysis.	Anthropometric caliper	Heron's formula
Bhagya et al. (2013) [14]	Department of Anatomy, Yenepoya Medical College, Mangalore, Karnataka, India.	80 (40/40)	35–60	Departmental records of sex and age.	Vernier caliper (0.01 mm)	Heron's formula
Gangrade et al. (2013) [15]	Anatomical collections in Nagpur, Maharashtra, and Udaipur, Rajasthan, India.	100 (50/50)	Adults; range NR	Known-sex skulls; verification procedure NR.	Sliding Vernier caliper (0.01 mm)	Heron's formula
Shah and Patel (2013) [16]	Anatomy museums of medical colleges in Gujarat, India.	100 (49/51) *	≥18; range NR	Known-sex skulls; verification procedure NR.	Vernier caliper	Heron's formula
Ajay Kumar et al. (2016) [17]	Sri Devaraj Urs Medical College, Kolar, Karnataka, India.	100 (50/50)	>18; range NR	Known-sex skulls; verification procedure NR.	Mitutoyo digital Vernier caliper	Heron's formula
Chavan et al. (2018) [18]	Osteological collections from Aurangabad and the Marathwada region, Maharashtra, India.	132 (80/52)	Adults; range NR	Known-sex skulls; verification procedure NR.	Sliding Vernier caliper	Heron's formula
Passey et al. (2021) [19]	Institutional anthropology museum; sample described as North Indian.	300 (190/110)	Adults; range NR	Cranial morphological characteristics (Williams and Rogers criteria).	Digital Vernier caliper (0.01 cm)	Heron's formula
Başaloğlu et al. (2021) [20]	Dry skulls, Department of Anatomy, Aydın Adnan Menderes University, Aydın, Turkey.	60 (30/30)	Adults; range NR	Known-sex skulls; verification procedure NR.	Compass (0.01 mm precision)	Heron's formula
Açar and Aydoğdu (2025) [21]	Retrospective diagnostic CT dataset, Department of Radiology, Necmettin Erbakan University, Konya, Turkey.	152 (75/77)	18–81	Male/female categories reported; reference ascertainment procedure NR.	256-slice CT; 3D Slicer (v4.11.2021); landmark-based measurements	Heron's formula

Note: M, male; F, female; NR, not reported in the original publication. Values such as "≥18" or ">18" indicate the reported minimum eligibility age, not the observed age range. "Known-sex skulls" indicates that sex was stated to be known, although the independent verification procedure was not described. * Shah and Patel (2013) [16] reported 50 males and 50 females in Materials and Methods, but 49 males and 51 females in Results. The sex distribution shown in this table follows their Results Section.

4. Discussion

This critical narrative review examined the variability and comparability of mean mastoid triangle areas reported across 13 studies involving samples from Brazil, India, and Turkey [9–21]. Although males generally exhibited larger areas than females, the reported measurements differed among investigations within each country. Rather than reassessing the presence of sexual dimorphism, this review focuses on the differences in published mean areas and the methodological and sample-related considerations relevant to their interpretation.

Among the Brazilian studies [9–13], reported or descriptively derived bilateral mean areas ranged from 1316.50 to 1535.30 mm^2 in males and from 1171.81 to 1296.22 mm^2 in females. These values reflect differences among investigations involving samples with distinct characteristics and measurement procedures. The pattern of sexual dimorphism was not entirely uniform across sides: Suazo et al. [10] reported a slightly larger mean left mastoid triangle area in females (685.64 mm^2) than in males (674.45 mm^2), despite the generally larger male measurements reported across the included studies. Furthermore, differences in the number of available right- and left-side measurements in that investigation complicate the interpretation of the reported bilateral values. This finding highlights the importance of considering lateral measurements and sample composition when examining sex-related differences in mastoid triangle area.

A comparable pattern of between-study variability was identified in India [14–19], where reported or descriptively derived bilateral mean areas ranged from 1151.30 to 1475.69 mm^2 in males and from 944.85 to 1288.90 mm^2 in females. The included investigations involved osteological samples obtained from different institutions and geographical locations, with differences in sample composition and measurement procedures. Although the studies originated from the same country, their samples should not be considered representative of a homogeneous national population. The wide range of reported measurements emphasizes the importance of documenting sample provenance and characteristics when conducting within-country comparisons.

The two Turkish studies provide an additional perspective on the relationship between measurement procedures and reported mastoid triangle areas. Başaloğlu et al. [20] reported bilateral mean areas of 1455.20 mm^2 in males and 1102.30 mm^2 in females using direct measurements of dry skulls. In contrast, the sums of the mean right and left areas reported by Açar and Aydoğdu [21], based on three-dimensional computed tomography reconstructions, yielded descriptive bilateral values of 1472.19 mm^2 and 1187.38 mm^2, respectively. Although the male values were relatively similar, a greater difference was observed between the female values. Given the differences in sample characteristics and measurement approaches, the numerical similarities and differences between these investigations should be interpreted in relation to their respective methodological contexts.

Measurement acquisition and area calculation procedures are particularly relevant to the interpretation of the reported findings. De Paiva and Segre [9] determined mastoid triangle areas from two-dimensional xerographic projections, although the mathematical procedure used to calculate the areas was not explicitly described. Most of the other Brazilian and Indian studies obtained direct linear measurements using calipers and calculated the areas with Heron's formula. Similarly, Başaloğlu et al. [20] used direct measurements obtained with a compass and applied Heron's formula, whereas Açar and Aydoğdu [21] performed landmark-based measurements on computed tomography-derived three-dimensional reconstructions using 3D Slicer. These approaches differ in measurement acquisition, even when the same geometric landmarks and area calculation formula are used. The methodological characteristics summarized in Table 4 therefore provide essential context for assessing the comparability of the published measurements.

Differences in the reporting of bilateral measurements constitute an additional methodological consideration. Some studies directly reported bilateral mean areas, whereas others presented separate means for the right and left sides. When bilateral means were unavailable, the lateral means were summed for descriptive comparison in the present review. Although these sums would correspond to mean bilateral totals when both sides were measured in the same individuals, equivalence cannot be assumed when the numbers of available measurements differ or the pairing of observations is insufficiently documented. Furthermore, some directly reported bilateral means differed from the sums of the corresponding lateral means. Distinguishing these values, as indicated in Tables 1–3, helps preserve the original reporting characteristics of each investigation and supports a more transparent comparison of the available data.

The characteristics of the analyzed samples also require consideration. The investigations differed in sample size, institutional and geographic provenance, sex distribution, and the procedures used to establish reference sex. For example, Fonseca et al. [13] used genetic analysis to establish reference sex, whereas Passey et al. [19] relied on cranial morphological characteristics. In addition, the procedures used to establish reference sex were not clearly described in the two Turkish investigations [20,21]. These distinctions are particularly relevant when assessing the discriminatory performance of mastoid measurements, as reference sex established through cranial morphological assessment may not provide a fully independent standard for evaluating other cranial characteristics.

Although sex-classification accuracy was not the principal outcome of the present review, the differences reported among investigations provide additional context for interpreting the applicability of mastoid measurements. Suazo et al. [10] reported a classification accuracy of 64.2% using the porion–mastoidale distance, whereas Sinhorini et al. [11] reported 80.8% using bilateral mastoid triangle area. Among the Turkish studies, Başaloğlu et al. [20] reported 90% using total mastoid triangle area, while Açar and Aydoğdu [21] reported 77.0% and 69.7% for the right and left areas, respectively. These results reflect differences in the measurements evaluated, statistical procedures, and sample characteristics. Furthermore, the porion–mastoidale distance is a linear measurement rather than an area measurement. Accordingly, classification performance provides complementary information about the potential forensic application of mastoid measurements but should be distinguished from the analysis of variability in mean mastoid triangle areas.

In this context, Fonseca et al. [13] suggested that mastoid triangle measurements should be considered a complementary tool for sex estimation, given the relatively modest degree of morphometric sexual dimorphism observed in their study. The systematic review and meta-analysis by Stefanel et al. [33], involving 1604 human skulls, also highlighted limitations in the evidence supporting the application of the mastoid triangle for sex estimation. These findings reinforce the importance of distinguishing statistically significant differences between sexes from reliable individual classification. Furthermore, investigations using geometric morphometrics, three-dimensional volumetric assessments, and cone-beam computed tomography [24–26] examine aspects of mastoid morphology that are not fully captured by mastoid triangle area measurements. These complementary approaches broaden the anatomical context of the present review while emphasizing the importance of distinguishing the specific geometric area of the mastoid triangle from other measurements of mastoid size and shape.

Another important consideration concerns the chronological characteristics of the analyzed samples. Publication year does not necessarily correspond to the chronological origin of the individuals examined. For example, De Paiva and Segre [9] studied skulls collected in 1997, whereas Fonseca et al. [13] examined specimens incorporated into a forensic osteological collection between 1990 and 2021. Similarly, Açar and Aydoğdu [21]

analyzed computed tomography images obtained between July 2023 and May 2024. These dates describe the collection or acquisition of material and do not establish comparable birth cohorts or periods of anatomical development. Consequently, the available chronological information is insufficient to determine whether differences in mastoid triangle area measurements reflect secular morphological changes.

The present review has limitations associated with its narrative design, the retrospective reconstruction of the search strategy, and restricted access to the full texts of some potentially relevant investigations. Furthermore, the requirement of at least two eligible studies per country restricted the geographical scope of the analysis. The descriptive comparisons were also based on published aggregate measurements obtained from heterogeneous samples rather than standardized individual-level data. These limitations define the scope of the present synthesis, which identifies differences among published mean areas while recognizing the need for more comparable evidence to characterize anatomical variability within populations.

Future investigations should prioritize standardized measurement protocols, consistent definitions of craniometric landmarks, and transparent reporting of measurement instruments and area calculation procedures. Detailed documentation of sample provenance, chronological characteristics, reference sex ascertainment, and the number of individuals contributing to each measurement would further improve comparability. Studies should also distinguish directly reported bilateral means from values derived from lateral means and, when evaluating sex-estimation performance, incorporate independent reference standards and external validation. Greater methodological consistency would facilitate more reliable comparisons among investigations and provide a stronger foundation for investigating anatomical variability in the mastoid region and its potential applications in human anatomy and forensic anthropology.

5. Conclusions

This critical narrative review examined mastoid triangle area measurements reported across 13 studies involving male and female samples from Brazil, India, and Turkey. Although differences in mean mastoid triangle areas were observed among investigations conducted within the same country, the available evidence did not allow the reliable identification of consistent patterns of anatomical variability in male and female crania. Differences in sample characteristics, reference sex ascertainment, measurement techniques, and the reporting of bilateral measurements limited the comparability of the findings.

Furthermore, the lack of comparable chronological information prevented the determination of secular morphological changes based on these measurements. Publication year does not establish the chronological origin of the examined individuals; therefore, differences among studies cannot be interpreted as evidence of anatomical changes over time. These findings highlight the need for standardized measurement protocols, well-documented and chronologically comparable samples, and independently established reference sex information. Addressing these limitations would facilitate a more reliable assessment of anatomical variability and provide a stronger methodological basis for future investigations of potential secular changes in mastoid triangle area, contributing to research in human anatomy and forensic anthropology.

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