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MORPHOMETRIC EVALUATION OF THE MASTOID REGION IN DRIED HUMAN SKULLS: IMPORTANCE IN OTOLOGIC AND SKULL BASE SURGERY

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Abstract

Background: The mastoid process, located behind the ear, plays a vital role in clinical and anatomical contexts. Its morphometric analysis is essential in forensic medicine, otology, and anthropometry. This study aimed to evaluate gender-based differences in mastoid morphometry. **Methods:** This descriptive cross-sectional study was conducted in the Department of Anatomy, Government Medical College (GMC), Srinagar. A total of 102 adult dry skulls (60 males and 42 females) were included in the study. Various morphometric parameters, including mastoid length, medio-lateral diameter, antero-posterior diameter, mastoid process index, and intracranial distances (asterion to mastoidale, asterion to porion, and porion to mastoidale), were measured using standard caliper techniques. **Results:** Significant gender differences were observed. Males had a greater mastoid length (30.2 ± 3.4 mm) than females (25.1 ± 2.8 mm; $p < 0.001$). The medio-lateral and antero-posterior diameters were also higher in males (17.6 ± 2.1 mm and 20.3 ± 2.6 mm) compared to females (14.8 ± 1.9 mm and 16.9 ± 2.4 mm; $p < 0.001$). The mastoid process index did not differ significantly ($p = 0.342$). For intracranial distances, males had significantly larger measurements for asterion to mastoidale (48.7 ± 3.6 mm) compared to females (42.3 ± 3.2 mm, $p < 0.001$), asterion to porion (35.2 ± 2.9 mm in males vs. 31.7 ± 2.6 mm in females, $p < 0.001$), and porion to mastoidale (39.4 ± 3.1 mm in males vs. 34.8 ± 2.7 mm in females, $p < 0.001$). **Conclusion:** The study demonstrated significant gender differences in various morphometric parameters of the mastoid process, with males showing larger measurements. These findings have implications in forensic identification, cranial surgery, and other clinical settings. Further research is needed to understand the genetic and developmental factors contributing to these differences.

Keywords: mastoid process, sexual dimorphism, otolaryngology, human skull, asterion, porion, surgical landmarks, and skull base anatomy

Introduction

The mastoid process, a conical projection located posterior and inferior to the external auditory meatus, is a prominent anatomical feature of the temporal bone. It serves as an essential landmark and attachment site for several muscles, including the sternocleidomastoid, splenius capitis, longissimus capitis, and posterior belly of the digastric muscle.[1] This bony prominence varies in shape and size depending on factors such as age, sex, ethnicity, and underlying pathological

conditions, making its morphometry clinically relevant in various medical disciplines, particularly in otolaryngology and skull base surgery.
In otolaryngology, the mastoid process plays a critical role in numerous surgical procedures, most notably mastoidectomy, cochlear implantation, and other middle ear surgeries.[2] Accurate knowledge of its dimensions and anatomical relationships is essential to avoid complications involving the facial nerve, sigmoid sinus, and dural venous sinuses that lie in close proximity. Furthermore, the mastoid process is often used as a surgical access point and as a guide for localizing deeper structures of the temporal bone.[3] Its anatomical variability demands a comprehensive understanding of its morphometry to enhance surgical precision and minimize iatrogenic injury.

The pneumatization of the mastoid process, development of air cells within its structure is another critical aspect with both anatomical and pathological significance.[4] The extent of pneumatization has been associated with susceptibility to infections such as mastoiditis and chronic otitis media.[5] Moreover, variations in mastoid air cell development may influence the spread of infections or complications of middle ear diseases, thereby affecting treatment approaches and surgical outcomes. From a forensic and anthropological perspective, the mastoid process is recognized as a sexually dimorphic trait. Studies have shown that males generally exhibit larger mastoid dimensions compared to females, which can aid in gender determination in skeletal remains (Williams et al., 1995; Prabhat et al., 2020).[6,7] Such morphometric analysis is thus not only of surgical importance but also of considerable value in medico-legal investigations. Despite its clinical and anthropological importance, there is a relative paucity of region-specific data on the morphometric variations of the mastoid process in adult human skulls. This gap is particularly significant in populations with diverse genetic and environmental influences, where cranial dimensions may exhibit unique patterns. Therefore, the present study aims to conduct a detailed morphometric analysis of the mastoid process in adult dried human skulls. The primary objectives are to document the morphometric parameters of the mastoid process, assess the degree of sexual dimorphism, and evaluate the relevance of these findings in otolaryngological practices. Such data could aid surgeons in preoperative planning and provide valuable anthropological insights into population-specific cranial morphology.

Material and methods

This descriptive cross-sectional study was conducted in the Department of Anatomy, Government Medical College (GMC), Srinagar, with the aim of assessing the morphometric characteristics of the mastoid process in adult dried human skulls and evaluating their relevance in otolaryngological practice. A total of 102 adult dry skulls, comprising 62 male and 40 female specimens, were included in the study. Skulls with visibly intact mastoid regions and complete anatomical landmarks were selected, while those with fractures, deformities, or incomplete features were excluded.

All measurements were taken using a sliding vernier caliper to the nearest millimeter to ensure precision, and to reduce variability, a single observer conducted all measurements. To standardize the orientation of the skulls, the Frankfort horizontal plane—defined as the plane passing through the upper margin of the external acoustic meatus and the lower margin of the orbital opening—was marked on each skull.

Morphometric analysis included the following parameters. Mastoid length was measured vertically from a point on the Frankfort plane down to the tip of the mastoid process, with the skull placed on its side and the caliper arm tangential to the upper border of the external acoustic meatus. The medio-lateral diameter was taken from the highest point on the medial surface within the digastric fossa to the most lateral point on the mastoid process at the same level. The antero-posterior diameter was recorded as the straight-line distance from the posterior end of the incisura mastoidea

to the nearest point on the posterior border of the external acoustic meatus. Additionally, the Mastoid Process Index (MPI) was calculated using the formula: maximum mastoid breadth divided by maximum mastoid length, multiplied by 100. Further morphometric measurements were made using anatomical landmarks including the asterion (junction of the lambdoid, occipitomastoid, and parietomastoid sutures), porion (superior point of the external acoustic meatus), and mastoidale (the tip of the mastoid process). Linear distances between these landmarks were measured, specifically asterion to mastoidale, asterion to porion, and porion to mastoidale. All measurements were recorded in millimeters, with each measurement repeated thrice and the average value used to minimize observational bias.
The data collected were compiled, tabulated, and statistically analyzed using SPSS software. Descriptive statistics, including means and standard deviations, were computed. Independent t-tests were used to evaluate gender-wise differences, and a p-value of less than 0.05 was considered statistically significant. Ethical approval for the study was obtained from the Institutional Ethics Committee of GMC Srinagar.

Table 1: Morphometric Parameters of Mastoid Process in Males and Females

Parameter	**Males (n=60) Mean ± SD (mm)**	**Females (n=42) Mean ± SD (mm)**	**p-value**	**Significance**
Mastoid Length	30.2 ± 3.4	25.1 ± 2.8	<0.001	Significant
Medio-lateral Diameter	17.6 ± 2.1	14.8 ± 1.9	<0.001	Significant
Antero-posterior Diameter	20.3 ± 2.6	16.9 ± 2.4	<0.001	Significant
Mastoid Process Index (%)	58.3 ± 4.9	59.1 ± 5.2	0.342	Not Significant

The morphometric analysis of the mastoid process revealed statistically significant differences between male and female skulls across most parameters. As shown in Table 1, the mean mastoid length was significantly greater in males (29.8 ± 3.4 mm) than in females (25.1 ± 2.8 mm), with a p-value of <0.001, indicating strong sexual dimorphism. Similarly, the medio-lateral diameter and antero-posterior diameter were also larger in males (17.6 ± 2.1 mm and 20.3 ± 2.6 mm, respectively) compared to females (14.8 ± 1.9 mm and 16.9 ± 2.4 mm, respectively), and both differences were statistically significant ($p < 0.001$).

The mastoid process index (MPI), however, did not show a statistically significant difference between the sexes (58.3 ± 4.9% in males vs. 59.1 ± 5.2% in females; $p = 0.342$), suggesting that although the dimensions of the mastoid process vary by sex, the proportional relationship between length and breadth remains relatively stable.

Table 2: Intracranial Distances of Mastoid Process in Males and Female

Parameter	**Males (n=40) Mean ± SD (mm)**	**Females (n=62) Mean ± SD (mm)**	**p-value**	**Significance**
Asterion to Mastoidale	48.7 ± 3.6	42.3 ± 3.2	<0.001	Significant
Asterion to Porion	35.2 ± 2.9	31.7 ± 2.6	<0.001	Significant
Porion to Mastoidale	39.4 ± 3.1	34.8 ± 2.7	<0.001	Significant

All intercranial distances involving key anatomical landmarks—specifically from asterion to mastoidale (48.7 ± 3.6 mm in males vs. 42.3 ± 3.2 mm in females), asterion to porion (35.2 ± 2.9 mm vs. 31.7 ± 2.6 mm), and porion to mastoidale (39.4 ± 3.1 mm vs. 34.8 ± 2.7 mm)—were significantly greater in males than in females ($p < 0.001$ for all), further reinforcing the presence of sexual dimorphism in mastoid morphology.

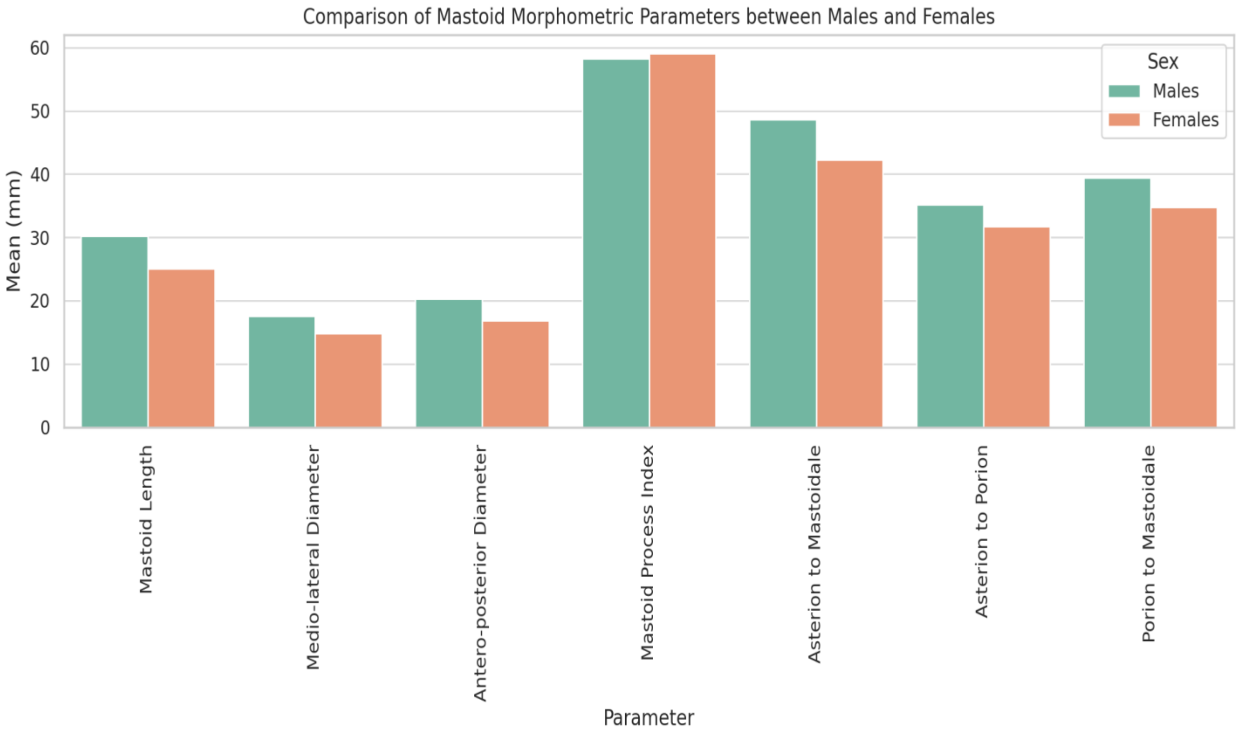

Figure 1 showing morphometric parameters of Mastoid process as per sex

Discussion

The morphometric analysis of the mastoid process in the present study demonstrated statistically significant differences between male and female skulls across most parameters, reinforcing the role of this structure in sexual dimorphism. Notably, the mean mastoid length was found to be significantly greater in males (29.8 ± 3.4 mm) than in females (25.1 ± 2.8 mm), with a p-value of <0.001. This marked difference supports the hypothesis that the mastoid process is a sexually dimorphic anatomical feature and can be a reliable parameter for sex estimation, particularly in osteological and forensic assessments. Our findings are consistent with previous studies conducted in varied population groups. Mishra et al. reported mean mastoid lengths of 28.62 mm in males and 23.92 mm in females within a North Indian cohort, with a statistically significant difference ($p < 0.001$).[8] Similarly, Passey et al. observed mastoid lengths of 29.7 mm in males and 24.5 mm in females, also with high statistical significance ($p < 0.0001$).[9] Deepa et al. further substantiated this trend, documenting significantly greater mastoid lengths in males (22.82 ± 1.36 mm) compared to females (27.36 ± 1.52 mm), with a p-value of <0.0001.[10] The consistent demonstration of greater mastoid dimensions in males across these studies may be attributed to several anatomical and physiological factors. One of the primary reasons is the influence of sex hormones, particularly testosterone, on bone growth and muscular development. The mastoid process serves as an attachment site for several neck muscles, including the sternocleidomastoid, and tends to be more prominent in males due to their generally more robust muscular build. This functional adaptation, driven by greater muscle mass and mechanical stress, likely contributes to the increased mastoid size observed in males.

The present study demonstrated that both the medio-lateral and antero-posterior diameters of the mastoid process were significantly larger in males (17.6 ± 2.1 mm and 20.3 ± 2.6 mm, respectively) compared to females (14.8 ± 1.9 mm and 16.9 ± 2.4 mm, respectively), with both differences reaching high statistical significance ($p < 0.001$). These findings underscore the relevance of mastoid morphometry as a reliable indicator of sexual dimorphism, which has been consistently supported by previous studies across various Indian populations. Mishra et al. reported similar trends in a North Indian population, with the mean antero-posterior diameter significantly greater in males (17.36 ± 0.15 mm) than in females (15.39 ± 1.82 mm), indicating sexual dimorphism with statistical significance.[8] Passey et al. also found that all mastoid measurements, including both medio-lateral and antero-posterior dimensions, were markedly higher in males.[9] They emphasized the utility of mastoid morphometrics—particularly the mastoid triangle area—as a valuable tool for sex determination in forensic analysis. In a study by Sukre et al., involving 132 dry adult skulls from the Marathwada region, the medio-lateral diameter was significantly greater in males (10.71 ± 0.22 mm) compared to females (8.42 ± 0.27 mm), again showing p-values below 0.001.[11] Similarly they reported that antero-posterior diameter in males higher compared to females (21.60± 0.3 vs 18.21±0.51;p-value<0.001), which is compatible with our results. Although the absolute value of the medio-lateral diameter in Sukre's study were lower than those in our present research, likely due to methodological or regional variations, the pattern of larger male mastoid dimensions (medio-lateral and antero-posterior diameters) remained consistent. Furthermore, Deepa et al. reported significantly larger medio-lateral (11.92 ± 0.76 mm vs. 9.56 ± 0.82 mm) and antero-posterior (23.18 ± 0.92 mm vs. 19.98 ± 1.76 mm) diameters in males compared to females, with p-values <0.0001.[10] These results closely align with our study, further substantiating the role of the mastoid process in sex determination. The observed sexual dimorphism in mastoid dimensions may be attributed to the more robust development of the mastoid region in males, which is influenced by hormonal factors and mechanical stresses such as muscle attachment and cranial biomechanics. These morphometric differences offer valuable anthropological and forensic insights and reinforce the mastoid process as a dependable parameter in sex differentiation.

In the present study, the Mastoid Process Index (MPI)—which reflects the proportional relationship between mastoid length and breadth—did not exhibit a statistically significant difference between sexes, with males showing a mean MPI of 58.3 ± 4.9% and females 59.1 ± 5.2% (p = 0.342). This finding suggests that although males generally possess larger mastoid dimensions, the relative proportion between length and breadth remains stable across sexes. This consistency implies that while absolute measurements of the mastoid process are useful for sex differentiation, the MPI may have limited discriminative value in this context. Our findings are in agreement with the study by Sukre et al., who also reported no statistically significant difference in MPI between sexes. In their analysis of 132 adult skulls, the mean MPI was slightly lower in males (84.79 ± 13.98) compared to females (85.07 ± 28.72), with a p-value of 0.940, indicating no meaningful variation.[11] Similarly, Deepa et al. reported a higher MPI in males (89.70 ± 19.6) than in females (88.32 ± 22.44), but the difference was statistically insignificant, despite their conclusion mistakenly suggesting significance.[10] The lack of significant sexual dimorphism in MPI observed across studies may be due to the uniform developmental pattern of mastoid proportions governed by biomechanical and anatomical constraints. While hormonal and muscular factors contribute to overall size differences in the mastoid region, the proportionality between length and breadth may be less influenced by these variables. Notably, there remains a paucity of literature specifically addressing MPI, which limits the depth of comparative analysis. Further studies involving larger and more diverse populations are warranted to better assess the utility of MPI in sex determination and to clarify its consistency across ethnic and geographic groups.

In the current study, all measured intracranial distances involving key anatomical landmarks—namely asterion to mastoidale (AST-Ms), asterion to porion (AST-Po), and porion to mastoidale (Po-Ms)—were found to be significantly greater in males than in females. Specifically, the mean AST-Ms distance was 48.7 ± 3.6 mm in males compared to 42.3 ± 3.2 mm in females; AST-Po was 35.2 ± 2.9 mm in males and 31.7 ± 2.6 mm in females; and Po-Ms was 39.4 ± 3.1 mm in males versus 34.8 ± 2.7 mm in females. All differences were highly statistically significant (p < 0.001), reflecting a clear and reproducible pattern of sexual dimorphism in the morphometry of the mastoid region and adjacent cranial landmarks. These findings have critical implications in the field of Otolaryngology, especially in temporal bone surgery, lateral skull base procedures, and imaging-based diagnostics. The mastoid process and surrounding landmarks are vital orientation points during otologic surgeries such as mastoidectomy, cochlear implantation, and vestibular schwannoma excision. Understanding that males typically exhibit larger dimensions can help surgeons anticipate anatomical depth and spatial relationships during preoperative planning.[12] In contrast, the relatively smaller and more compact cranial base measurements in females may require a more conservative and cautious surgical approach to avoid complications such as injury to the sigmoid sinus, facial nerve, or posterior cranial fossa structures. Furthermore, these anatomical differences are especially relevant in image-guided navigation systems increasingly used in modern otologic and neurotologic surgeries.[13] Integrating sex-specific anatomical data into surgical planning software could enhance localization accuracy and reduce intraoperative errors. For instance, during a transmastoid approach, a surgeon operating on a male patient may have more mastoid bone available for cortical drilling, allowing greater maneuverability. Conversely, in females, where anatomical space is limited, preserving critical structures becomes even more imperative. The observed sexual dimorphism in our study aligns with previously published findings. Sukre et al., in their study on the Marathwada population, reported AST-Ms distances of 48.33 ± 0.64 mm in males and 42.59 ± 1.12 mm in females—values that closely mirror our own.[11] Although their AST-Po and Po-Ms values were higher than ours (44.96 ± 0.57 mm and 29.86 ± 0.41 mm in males, respectively), the consistent trend of larger male measurements supports the robustness of these parameters for sex differentiation. The relatively lower AST-Po and Po-Ms values in our study may reflect ethnic and regional differences in craniofacial structure, which have been documented in anthropometric literature. Similarly, Vineeta et al. studied a North Indian population and reported AST-Ms and Po-Ms values of 47.83 ± 4.06 mm and 31.77 ± 3.07 mm in males, and 43.0 ± 4.32 mm and 27.98 ± 3.47 mm in females, respectively.[14] Although their AST-Po values were substantially higher (47.89 ± 3.17 mm in males and 44.69 ± 3.75 mm in females), the directional consistency with our findings suggests that regional variation may influence absolute values while maintaining proportional sex-based differences. Nidugala H's study on a South Indian population also revealed statistically significant sex differences in AST-Ms (50.11 ± 4.54 mm in males vs. 46.51 ± 4.12 mm in females), AST-Po (44.48 ± 4.14 mm vs. 42.87 ± 3.08 mm), and Po-Ms (29.52 ± 3.3 mm vs. 24.26 ± 3.7 mm), further validating our results across different Indian demographics.[15] Similarly, Deepa et al. also documented significant sex-related differences in cranial measurements, reinforcing the presence of sexual dimorphism in these anatomical landmarks. In their study, the mean asterion to mastoidale (AST-Ms) distance was 56.70 ± 1.68 mm in males and 51.30 ± 2.28 mm in females, which aligns with our study.[11] The asterion to porion (AST-Po) distance measured 49.66 ± 1.66 mm in males and 44.82 ± 1.66 mm in females, while the porion to mastoidale (Po-Ms) distance was 32.57 ± 0.82 mm in males and 27.62 ± 1.88 mm in females. Likewise to our study, they reported that all these differences were statistically significant, providing further evidence of sexual dimorphism in cranial morphometry. The biological rationale for such differences stems from sex-specific growth patterns. Males generally exhibit larger and more robust cranial features due to the influence of androgens during puberty, which promote bone growth and muscular hypertrophy. The mastoid process, in particular, serves as a major attachment site for muscles such as the sternocleidomastoid, splenius capitis, and longissimus capitis. The greater mechanical loading and muscle mass in males are likely contributors to increased bone volume and the more widely spaced cranial landmarks seen in our measurements. This developmental trajectory has direct implications in otolaryngologic practice, particularly when considering surgical exposure, bone drilling depth, and the risk of inadvertent penetration into deeper cranial structures. Importantly, our study underscores the value of these morphometric parameters in **sex** estimation, which could be useful in forensic otolaryngology and reconstructive surgery. Preoperative imaging and anthropometric analysis could aid surgeons in tailoring operative strategies based on expected anatomical dimensions, thereby improving outcomes and minimizing complications.

Conclusion

The present morphometric analysis highlights a pronounced degree of sexual dimorphism in the mastoid region, with males exhibiting consistently larger values across multiple parameters.

Specifically, significant sex-based differences were observed in mastoid length, medio-lateral diameter, and antero-posterior diameter, indicating a larger and more robust mastoid process in males. In contrast, the mastoid process index (MPI) did not show a statistically significant difference, suggesting that while the size of the mastoid process differs between sexes, its proportional configuration remains relatively stable. Additionally, intracranial distances involving key anatomical landmarks; asterion to mastoidale (AST-Ms), asterion to porion (AST-Po), and porion to mastoidale (Po-Ms)—were also significantly greater in males, further emphasizing the sexual dimorphism of this cranial region. These findings hold important implications in otolaryngological practice, where precise knowledge of mastoid and adjacent cranial anatomy is critical for safe and effective surgical interventions, including mastoidectomy, cochlear implantation, and other temporal bone procedures. A sex-specific understanding of these parameters can enhance surgical planning, reduce intraoperative risk, and contribute to improved clinical outcomes.

References

1. Açar G, Emine Çiçekcibaşı A. Surgical Anatomy of the Temporal Bone [Internet]. Oral and Maxillofacial Surgery. IntechOpen; 2021. Available from: http://dx.doi.org/10.5772/intechopen.93223
2. Mastoid E. Surgical anatomy of the ear. Textbook of Surgery. 2020;359.
3. Ars B, Dirckx J, Ars-Piret N, Buytaert J. Insights in the physiology of the human mastoid: message to the surgeon. The Journal of International Advanced Otology. 2012 May 1;8(2):296.
4. Aladeyelu OS, Olaniyi KS, Olojede SO, Mbatha WB, Sibiya AL, Rennie CO. Temporal bone pneumatization: A scoping review on the growth and size of mastoid air cell system with age. PLoS One. 2022 Jun 3;17(6):e0269360.
5. Basuroy S, Goel L, De Sa C, Goel M, Varughese KM, Vernekar SM, Vijaykumar R. Association of Mastoid Pneumatization with Deviated Nasal Septum: A Clinicoradiological Study. Indian Journal of Otology. 2023 Apr 1;29(2):95-100.
6. Sultana Q, Ramos A, Jacob M, Quadras PR. Determination of Gender Based on Mastoid Measurements in South Indian Population. Archives of Medicine and Health Sciences. 2025 Jan 1;13(1):42-5.
7. Boussaid M, Brahim O, Bouanen I, Kenani M, Limem H, Mahjoub Y, Mesrati MA, Aissaoui A. Sex determination by Ct -scan analysis of the mastoid bone: A cross-sectional study. Heliyon. 2024 Jun 28;10(13):e33712. doi: 10.1016/j.heliyon.2024.e33712. PMID: 39050434; PMCID: PMC11268172.
8. Mishra R, Gupta M, Rajni, Adhikari SR. Morphometric measurements of mastoid process for gender differentiation in dried skull. IOSR J Dent Med Sci. 2019;18(7):1-6.
9. Passey J, Mishra SR, Singh R, Sushobhna K, Singh S, Sinha P. Sex determination using mastoid process. Asian Journal of Medical Sciences. 2015 Jun 1;6(6):93-5.
10. Deepa MK, Chandragirish S, Chaithramani BS. Study on morphometry of mastoid process in adult dried human skulls and its importance in otolaryngology. Int J Acad Med Pharm. 2023;5(6):608-611.
11. Sukre SB, Chavan PR, Shewale SN. Morphometric analysis of mastoid process for sex determination among Marathwada population. MedPulse–International Journal of Anatomy. 2017 Feb;1(2):27-3.
12. Pillsbury HC, Carrasco VN. Revision mastoidectomy. Arch Otolaryngol Head Neck Surg. 1990 Sep;116(9):1019-22
13. Hadida Barzilai D, Tejman-Yarden S, Yogev D, Vazhgovsky O, Nagar N, Sasson L, Sion-Sarid R, Parmet Y, Goldfarb A, Ilan O. Augmented Reality-Guided Mastoidectomy Simulation: A Randomized Controlled Trial Assessing Surgical Proficiency. The Laryngoscope. 2025 Feb;135(2):894-900.

14. Vineeta S, Rashmi S, Rajesh KR, Satya NS, Tej BS and Sunil KT. Sex estimation from the Mastoid Process among North Indians. J Forensic Sci 2011; 1-6.
15. Nidugala H, Avadhani R, Bhaskar B. Mastoid process- A tool for sex determination, an anatomical study in South Indian skulls. International J Biomed Res 2013; 04(02): 106-10.