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ORIGINAL ARTICLE

Morphometric sex estimation using mastoid triangle: A prospective study

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Abstract
In the evaluation of unidentified skeletal remains one important step is to estimate the sex of the remains. The morphometric analysis of the mastoid triangle for sex estimation in and around Mangaluru District was the objective of the study. The present study was conducted on 50 male and 50 female bodies subjected to medico-legal autopsy at Justice K. S. Hegde Charitable Hospital. The quantitative variables, and the area were expressed in terms of mean and standard deviation along with the utility of measurements which was evaluated for sensitivity and specificity of using ROC curve. The study confirms the low accuracy of the mastoid triangle with respect to sex estimation.

Keywords
Anthropology; Craniometry; Mastoid Triangle; Morphometric sex estimation.

Introduction

Establishing identity, is an imperative aspect in any investigating procedure. The estimation of the identity of the person based on certain physical characteristics amounts to identification and is of utmost importance in the medico-legal field as it holds many social, economic and legal corollaries.[1,2] Out of the innumerable data to be established, a few important aspects include; positive determination of sex, age, anthropometric measurements like stature, built, dental morphology, foot prints, iris scan, dactylography, lip prints and DNA profiling etc; wherein sex estimation is an important part in forensic investigations and is a decisive feature of identification.[3] It is most often the first component of the biological profile to be assessed because other components like stature, age and race are dependent on sex estimation.[3] Once the sex of the skeleton or bone fragment is determined, it reduces the search for identity by half. Out of the numerous available parameters for sex estimation, following are the few noteworthy methods that are followed routinely[4]-physical morphology, radiographs, microscopic study of sex chromatin-gonadal biopsy, DNA profiling, gonadal biopsies.

Among these, morphological study is the most simple, dependable, economical and non-invasive method. Numerous researches have been piloted across the world on sex estimation based on various human bones mainly focusing on long bones[5,6], skull[7,8,9], pelvis[10,11,12], clavicle[13], sternum[14-17] etc.

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When it is about the estimation of sex, as per Krogman and Iscan skull and pelvis provide the most precise results in estimation of sex.[18] Various isolated regions on the skull such as teeth[19,20], frontal bone[21], nasal bone[22], palate[23,24] and foramen magnum[25] have been subjected to various studies to differentiate sex

Due to its compact structure and anatomical position the mastoid region along with the mastoid process, is highly resilient to physical damage, remains unharmed even in the ancient and damaged skulls.[22-26] Few researchers[19-21] recently have shown that the mastoid triangle formed by joining the three osteological landmarks namely Porion, Asterion and Mastoidale have legitimately aided in determining the sex of the given skull. Pioneers Paiva and Segre conducted the study by using the three landmarks in the population of Sao Paulo, Brazil.[27]

The growth of Forensic anthropology in general has been wide-reaching with major research and publications stirring all over the world. More than a few scientific papers and researches have been published on morphometric measurements of the mastoid triangle, a few on dry skulls and few on X-rays, for sex estimation all over the world including India and it as well established that results vary from region to region.[22-26]

Studies have not been undertaken on morphometric analysis of the mastoid triangle for sex estimation in this region of our country and hence the study was aimed at using this to gauge sex differences.

Materials and Methods

The required data for the study was collected, analysed and studied, for the cases above 18 years of age, subjected to medico-legal autopsy at Justice K. S. Hegde Charitable Hospital. 50 male and 50 female bodies were included in the study. Bodies with skull fractures, deformities, wormian bones and below the age group of 18 years of age were excluded. The study was conducted from Sept 15, 2015 to Sept 16, 2017. Following the dissection and reflection of the scalp, the related anatomical structures were dissected to expose the skull, the following bony landmarks, which constitute the mastoid triangle were identified.

Porion: Uppermost lateral point of the external auditory meatus

Asterion: Meeting point of the lambdoid, occipitomastoid and parietomastoid sutures.

Mastoidale: The lowest point of the mastoid process.

An imaginary triangle is drawn by joining the above three anatomical landmarks; and the following measurements were taken using digital vernier calipers with 0.00 mm precision.

The readings were carefully noted for both right and the left side and were carefully tabulated. The area of each triangle i.e., triangle on the right side and on the left side is calculated using the Heron's formula[5]:

Area = $\sqrt{s(s-a)(s-b)(s-c)}$ where s is (a+b+c)÷ 2

After which, areas of both sides are added. Quantitative variables such as age, measurements of the sides of the triangle on right and left (porion to asterion, porion to mastoidale and asterion to mastoidale) was expressed in terms of mean and standard deviation after ascertaining normality distribution using Shapiro–Wilk test. Quantitative variables of age group and gender were expressed in terms of percentages and proportions. Utility of the measurements to identify the sex of the skulls in terms of sensitivity and specificity of the measured variables was determined using Receiver Operator Characteristic (ROC) curve.[7,8] Statistical significance was assumed at <0.05. Data was entered into MS Excel 2010 and analyzed using SPSS version 16.0

Results

In the present study; about 30(60%) of males and 25 (50%) of females were in the age group of 18- 40 years, followed by 13(26%) males and 16 (32%) females were in the age group of 41-60 years and 7 (14%) males and 9 (18%) females were in the age group of 61%.

The values of right porion to asterion and the left porion to asterion of both males and females are presented in Table 2. Mean differences in porion to asterion on right side between males and females i.e. 43.14 ± 3.97 and 39.15± 3.90 respectively, was found to be statistically significant (p<0.05%). Mean differences in porion to asterion on left side between males and females i.e. 43.24± 3.62 and 38.63± 4.09 respectively was found to be statistically significant (p<0.05%).

The values of right porion to mastoidale and left porion to mastoidale of both males and females are presented in Table 3. Mean values of male skulls were found to be 35.46± 4.67 and 33.20± 3.79 and mean values of female skulls were found to be 31.32± 3.75 and 30.44± 2.85, respectively. The mean differences between the measurements on both sides in both males and females was found to differ significantly.

The mean values of right asterion to mastoidale and left asterion to mastoidale of both males and females are presented in Table 4. Mean values of male skulls i.e. 43.00± 3.44 was significantly higher when compared to the female sex i.e. 41.19± 5.04 in left asterion to mastoidale measurements. However, in the right asterion to mastoidale the mean value in females 43.81± 5.17 was found to be higher compared to males 43.28± 4.38 and these differences were not significant statistically. The values of right, left and total area of both males and females are presented in Table 5.

The mean area of the mastoid triangle on the right side in males was found to be 699.06± 125.61 and 581.60± 81.36 in females. The mean are of the mastoid triangle on the left side in males (656.2±85.99) and in females (552.62± 69.95) was also found to differ significantly.

Total mean area of the mastoid triangle on right and left side was 1346.2±195.0 in males and 1132.4±140.6 in females. This too was found to differ significantly between males and females.

Figure 1: Distance between Porion and Asterion

Figure 2: Distance-between-Porion-and-Mastoidale

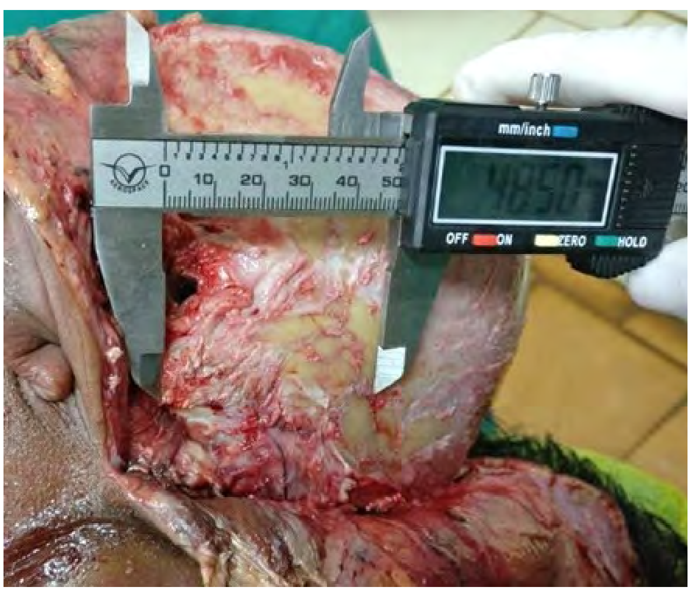

Figure 3: Distance-between-Asterion-and-Mastoidale

Figure 4 shows the ROC7,8 (Receiver Operating Characteristic Curve for the various parameters used for the determination of the sex on both right and left side. The cut off for all the values in terms of area under the curve, along with 95% confidence interval is shown in the Table 6.

The table shows the area of the left triangle (83.4%), area of the right triangle (80.9%), total area of both left and right triangle (81.2%), and the distance between the left porion to asterion (81.1%) had moderate discriminatory ability based on the area under the curve cut off to distinguish between male and female skulls.

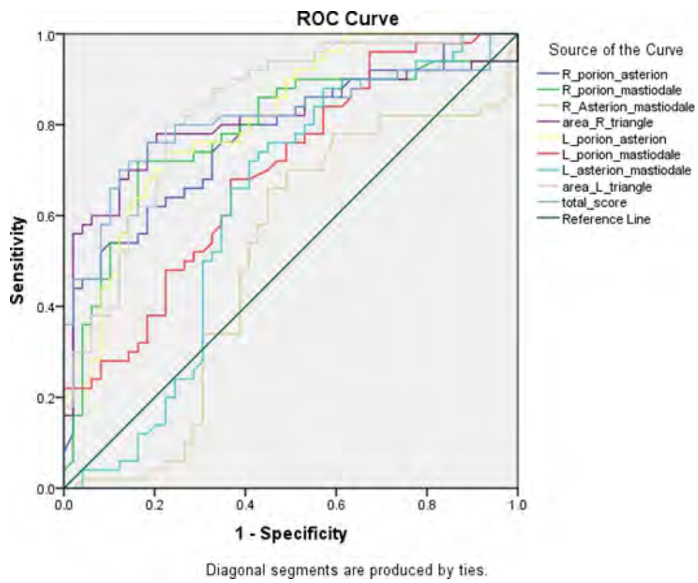

Figure 4: ROC for various parameters of mastoid triangles on both sides

The test result variable(s): R_porion_asterion, R_porion_mastiodale, R_Asterion_mastiodale, area_R_triangle, L_porion_asterion, L_porion_mastiodale, L_asterion_mastiodale, area_L_triangle, total_score has at least one tie between the positive actual state group and the negative actual state group. Intra observer error was addressed by taking mean of measurements three times consecutively and averaging the readings.

Table 1: Sex distribution of the study population

Age in years	Male n (%)	Female n (%)
<40	30 (60)	25 (50)
41-60	13 (26)	16 (32)
>61	7 (14)	9 (18)
Total	50 (100)	50 (100)

Table 2: Measurements of porion to asterion (right and left) between males and females

Dimensions	Males (mm)		Females (mm)		t value
	Range	Mean±SD	Range	Mean±SD	
Right porion to asterion	34.00-49.00	43.14±3.97	30.89-47.13	39.15±3.90	5.07
Left porion to asterion	36.00-50.00	43.24±3.62	31.00-46.69	38.63±4.09	5.97

$p<0.05$

Table 3: Measurements of porion to mastoidale (right and left) between males and females

Dimensions	Males (mm)		Females (mm)		t value
	Range	Mean±SD	Range	Mean±SD	
Right porion to mastoidale	20.00-42.00	35.46±4.67	23.00-41.00	31.32± 3.75	4.88
Left porion to mastoidale	28.00-44.00	33.20±3.79	23.00-35.83	30.44± 2.85	4.11

SD = standard deviation; p<0.05

Table 4: Measurements of asterion to mastoidale (right and left) between males and females

Dimensions	Males (mm)		Females (mm)		t value
	Range	Mean±SD	Range	Mean±SD	
Right porion to mastoidale	34.00-49.00	43.28±4.38	34.53-53.96	43.81±5.17	-0.56
Left porion to mastoidale	35.00-49.00	43.00±3.44	31.26-50.79	41.19±5.04	2.099

SD = standard deviation; p<0.05

Table 5: Measurements of area (right and left) between males and females

Dimensions	Male (mm^2)		Female (mm^2)		t value
	Range	Mean±SD	Range	Mean±SD	
Right area	332.0-884.0	699.06±125.61	429.18-796.75	581.60±81.36	5.55
Left area	478.0-866.0	656.2±85.99	419.86-727.94	552.62±69.95	6.61
Total area	1215.7-1455.9	1346.2±195.0	1021.8-1215.5	1132.4±140.6	6.27

Table 6: Area under the curve for various parameters

Area Under the Curve					
Test Result Variable(s)	Area	SE	p-value	Asymptotic 95% Confidence Interval	
				Lower bound	Upper bound
R_porion_asterion	0.778	0.047	<0.001	0.687	0.869
R_porion_mastiodale	0.783	0.048	<0.001	0.688	0.877
R_Asterion_mastiodale	0.507	0.061	0.911	0.387	0.626
area_R_triangle	0.809	0.047	<0.001	0.718	0.900
L_porion_asterion	0.811	0.043	<0.001	0.728	0.895
L_porion_mastiodale	0.694	0.052	0.001	0.592	0.797
L_asterion_mastiodale	0.621	0.059	0.038	0.506	0.737
area_L_triangle	0.834	0.041	<0.001	0.754	0.914
total_score	0.812	0.045	<0.001	0.723	0.901

SE = standard error

Discussion

Identification is the basis of the individuality of a person.[23] Skeleton is an important part of the body which resists all environment insults for maximum time and thus can be a valuable tool in identification.[24] In the field of Forensic medicine as well as anthropology, skull has a distinctive role in differentiating the sex of the skeletal remains. As discussed previously in the review of the literature, morphological methods and morphometric methods are the two primary ways of differentiating sex of a human skeleton.[18]

At all times, mastoid region has drawn the interest of investigators for its effectiveness in sex estimation. Size of the mastoid being one of Krogmans trait is significant in distinguishing male from female skulls both morphologically and morphometrically.[27]

In this study, an attempt was made to determine the efficacy of the distance between the three craniometric parameters and the calculated areas of the triangles, compare the data with existing literature and to establish the standards for the local population. The lack of study in reference to sex estimation from dimensions and mastoid triangle area in this region underlines the importance of the present study.

The three dimensions (porion to asterion, asterion to mastoidale and porion to mastoidale) of the mastoid triangle were measured for both, left and right sides and the areas of each mastoid triangle was calculated by substituting the above measurements in Heron's formula.

In present study, all the three dimensions and the area of the mastoid triangle on both right and left sides were found to be larger in males when compared to the females which is in accordance with the studies done by Kemke et al.[22], Galdames et al.[24], Manoonpol et al.[25], Madadin et al.[26], Bhagya et al.[28], Kanchan et al.[29], Blessing et al.[31], Singh et al.[33] This is probably due to the larger size of male skulls when compared to the female skulls as well as it is in response to the stronger muscle actions, thereby resulting in greater development of the mastoid process in males.

In the present study, statistically significant values ($p < 0.05$) were detected for the distance between porion to asterion and porion to mastoidale on right and the left mastoid triangles and it was in agreement with the studies done by Kemke et al.[22], Galdames et al.[24], Manoonpol et al.[25], Madadin et al.26, Bhagya et al.[28], Kanchan et al.[29], Blessing et al.[31], Singh et al.[33]

In our prospective study, the distance between the asterion to mastoidale was the longest of the other two mastoid dimensions (porion to asterion and porion to mastoidale), which is agreed upon the similar studies done by Galdames et al.[24], Manoonpol et al.[25], Madadin et al.[26], Singh et al.[33] However, no statistically significant difference was observed for asterion to mastoidale on both left and right mastoid triangles which is supported by the studies conducted by Kemke et al.[22] and Kanchan et al.[29] The confounder for this, could be the anatomical relationship of the asterion with other cranial structures as well as the position of the asterion which differs with the advance of the age in a population specific manner.[21,29]

The results of the current study specify that there exist a statistically significant difference in the areas of the mastoid triangle between males and females and thus agree with the observations made by Kemke et al.[22], Manoonpol et al.[25], Madadin et al.[26], Paiva and Segre[27], Bhagya et al.[28], Kanchan et al.[29], Blessing et al.[31], and Singh et al.[33]

When the area of the mastoid triangle calculated in our prospective study was compared (Table 8) with other similar studies done by foreign researchers like Kemke et al.[22], Manoonpal et al.[25], Madadin et al.[26], Paiva and Segre[27], Blessing et al.[31], it was observed that the mastoid triangle area in our study was comparatively lesser. As a matter of fact; the mean mastoid triangle area amid males in our study was by far less than the mean area of mastoid triangle in females just as in the studies of foreign researchers.[25,26,27] The discrepancies in the observations of aforementioned studies[25,26,27], thus prove the existence of population specific dissimilarities exhibited in the skull. This can be a result of the nutritional, environmental effects, sociocultural practices and racial differences as well as the inconsistency in the location of the landmarks of the skull in various populations.

Likewise, when our study was compared with other Indian studies done by Saini et al.[21], Bhagya et al.[28], Kanchan et al.[29], Singh et al.[33]; it was noted the incongruities still existed between the regions. These variations could be due to the fact that India is a diversified country where substantial population and ethnic diversity exists leading to intermixing of populations.

In the present study, the sexing aptitude of the mastoid triangle dimensions was low, when it was subjected to Receiver Operating Characteristic Curve analysis (ROC).[32] And it was similar to the study done by Kanchan et al.[29] Our observations that are indicative of a lower accuracy level of mastoid triangle dimensions are similar to those stated by Kemke et al.[22] and Kanchan et al.[29]

It is a well known fact that the criterions established on the skulls for one population should not be used on another population owing to the population variations.[22,29] In the modern world due to the intermixing of populations and due to the migration of population, it may not be virtually possible to consign a population reference when a skull is brought for the examination, thereby plummeting the applicability of the mastoid triangle in the estimation of sex from an unknown skull.

Conclusion

All the dimensions (porion to asterion, porion to mastoidale and asterion to mastoidale) of the mastoid triangles were higher in males than the females. All the dimensions (porion to asterion, and porion to mastoidale) were statistically significant except the distance between the asterion to mastoidale. The AUC (area under the curve) had a moderate sensitivity of (above 80%) for area of the left triangle(0.834), area of the right triangle (0. 809), total area of both left and right triangle (0.812) and distance between porion to asterion on the left side (0.811). It can be established from the study as well as from the comparative analysis with other studies that, the mastoid triangle is a poor indicator of sex and of limited significance in the absence of population reference. The AUC (area under the curve) had a moderate sensitivity (above 80%)- 0.834, 0. 809, 0.812 and 0.811 for area of the left triangle, area of the right triangle, total area of both left and right triangle and distance between porion to asterion on the left side, respectively. However; a cut-off point to distinguish between male and female skulls could not be arrived without significant compromise in the specificity. The study sample was insufficient to derive standards for the population.

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Conflict of interest: None to declare

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References

1. Vij K. Identification. In, Textbook of Forensic Medicine and Toxicology: Principles and Practice 6th Ed New Delhi: Elsevier 2014.35-73
2. Shetty M, Premalatha K. Study of palatal rugae pattern among the student population in Mangalore. J Indian Acad Forensic Med. 2011;33(2):112–5.
3. Aggrawal A. Text book of Forensic Medicine and Toxicology. 1st ed. New Delhi: Avichal publishing company; 2014. 58, 59, 60 p.
4. Mant AK. Identification of the living and dead. In, Taylor's Principles and Practice of Medical Jurisprudence 13th Ed London: Churchill Livingstone: 1984.156-63
5. Srivastava R, Saini V, Rai RK, Pandey S, Tripathi SK. A study of sexual dimor-phism in the femur among North Indians. J Forensic Sci. 2012;57:19-23.
6. Robinson MS, Bidmos MA. An assessment of the accuracy of discriminant function equations for sex determination of the femur and tibia from a South African population. Forensic Sci Int. 2011;206:212:1-5.
7. Raghavendra Babu YP, Kanchan T, Attiku Y, Dixit PN, Kotian MS. Sex estimation from from foramen magnum dimensions in an Indian population. J Forensic Leg Med. 2012;19:162-7.
8. Gonzalez RA. Determination of sex from juvenile crania by means of discrim-nant function analysis. J Forensic Sci. 2012;57:24-34.
9. Spradley MK, Jantz RL. Sex estimation in forensic anthropology: skull versus postcranial elements. J Forensic Sci. 2011;56:289-96.
10. Biwasaka H, Aoki Y, Sato K, Tanijiri T, Fujita S, Dewa K, et al. Analyses of sexual dimorphism of reconstructed pelvic computed

tomography images of contemporary Japanese using curvature of the greater sciatic notch, pubic arch and greater pelvis. Forensic Sci Int. 2012;219:288.1-8.

11. Steyn M, Becker PJ, L'Abbé EN, Scholtz Y, Myburgh J. An assessment of the repeatability of pubic and ischial measurements. Forensic Sci Int. 2012;214: 210.1-4.
12. Nagesh KR, Kanchan T, Bastia BK. Sexual dimorphism of acetabulum-pubis index in South- Indian population. Leg Med (Tokyo). 2007;9:305-8.
13. Papaioannou VA, Kranioti EF, Joveneaux P, Nathena D, Michalodimitrakis M. Sexual dimorphism of the scapula and the clavicle in a contemporary Greek population: applications in forensic identification. Forensic Sci Int. 2012;217(1- 3):231:1-7
14. Hunnargi SA, Menezes RG, Kanchan T, Lobo SW, Binu VS, Uysal S, et al. Sexual dimorphism of the human sternum in a Maharashtrian population of India: a morphometric analysis. Leg Med (Tokyo). 2007;10(1):6-10.
15. Franklin D, Flavel A, Kuliukas A, Cardini A, Marks MK, Oxnard C, et al. Estimation- of sex from sternal measurements in a Western Australian population. Forensic Sci Int. 2012;217:230:1-5.
16. Bongiovanni R, Spradley MK. Estimating sex of the human skeleton based on metrics of the sternum. Forensic Sci Int. 2012;219:290.1-7.
17. Ramadan SU, Türkmen N, Dolgun NA, Gökharman D, Menezes RG, Kacar M, et al. Sex determination from measurements of the sternum and fourth rib. Forensic Sci Int. 2012;197(1-3):120.e1-5.
18. Krogman WM, Iscan YM. The human skeleton in forensic medicine. 2nd ed. Springfield, Illinois, U.S.A.: Charles C. Thomas Pub Ltd; 1986.
19. Yokosawa S, Innami T, Takei T. Studies on sex determination from palate and canine and on palatal development by the moiré topograph. Acta Med Legal Society (Liege). 1985;35:313-8.
20. Uthman AT, Al-Rawi NH, Al-Timimi JF. Evaluation of foramen magnum in gender determination using helical CT scanning. Dentomaxillofac Radiol. 2012;41:197e202.
21. Saini V, Srivastava R, Rai RK, Shamal SN, Singh TB, Tripathi SK. Sex estimation from the mastoid process among North Indians. J Forensic Sci. 2012 Mar;57(2):434–9.
22. Kemkes A, Gobel T. Metric assessment of the “mastoid triangle” for sex determination: a validation study. J Forensic Sci. 2006;51:985-9.
23. Nagaoka T, Shizushima A, Sawada J, Tomo S, Hoshino K, Sato H, et al. Sex determination using mastoid process measurements: standards for Japanese human skeletons of the medieval and early modern periods. Anthropol Sci. 2008;116(2):105-13.
24. Galdames ICS, Matamala DAZ, Smith RL. Sex determination using mastoid process measurements in Brazilian skulls. Int J Morphol. 2008;26:941-4.
25. Manoonpol C, Plakornkul V. Sex determination using mastoid process mea-surement in Thais. J Med Assoc Thai. 2012;95:423-39.
26. Madadin M, Menezes RG, Dhafeeri O Al, Kharoshah MA, Ibrahim R Al, Nagesh KR, et al. Evaluation of the mastoid triangle for determining sexual dimorphism: A Saudi population based study. Forensic Sci Int. 2015 Sep;254(244):1–4
27. Paiva LAS de, Segre M. Sexing the human skull through the mastoid process. Revista do Hospital das Clínicas. 2003;58(1):15–20.
28. Bhagya B, Hema N. 2013. Validation metrics of the mastoid triangle. Nitte University Journal of Health Sciences.14-18.
29. Kanchan T, Gupta A, Krishan K. Estimation of sex from mastoid triangle - a craniometric analysis. J Forensic Leg Med. 2013;20(7):855–60.
30. Shah Swati et al. Sexing the human skull using the mastoid process. NHL J Med Sci. 2013;2:5: 75-78
31. Blessing N R Jaja et al. Mastoid triangle for sex determination in adult Nigerian Population: A Validation study. J Forensic Sci. 2013; 58,6.
32. Fan J et al. Understanding receiver operating characteristic curves. CJEM. 2006;8(1): 19-20
33. RP Singh et al. Determination of sex by measurement of area of the mastoid triangle in human skull. Indian Internet J Forensic Med Toxicol. 2008; 6:29-43