Sex estimation in Indians by digital analysis of the gonial angle on lateral cephalographs

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ABSTRACT

Objective: Sex estimation of skeletons is important in forensic reconstructive identification. The mandible is a durable component that is suitable to discriminate the sexes while lateral cephalometry is a standardised radiographic technique accepted as a tool in personal identification. Limited data is available for the mandibular/gonial angle as a parameter for sex assessment using lateral cephalometric radiographs. The aim of this study is to determine the gonial angle's accuracy in sexing Indians using a new digital method and statistical approach.

Method: The sample comprised of 304 digital lateral cephalometric radiographs (155 females and 149 males, age between 18-30 years) of Indian subjects. The mandibular/gonial angle was measured on these radiographs using Adobe Photoshop software using tools available therein. The obtained angles for the sexes were subjected to logistic regression analysis (LRA), which forms a composite of weighted independent variables using a multivariate strategy.

Results: The average angle was 122.7° for females and 121.1°for males. LRA produced an accuracy rate of 56.3% in sex assessment, with females being more accurately identified (61.9%) than males (50.3%).

Conclusion: The study demonstrated significant univariate sexual dimorphism among males and females in this population. However, the sex prediction value of this approach was low and thus may not be useful in sex estimation involved in human identification of Indians.

INTRODUCTION

Sex estimation is an important part of post-mortem profiling in human identification. For this purpose, human skeletal material is of prime importance among which the pelvis and skull are two of the more characteristic parts which can aid in the sex identification of an individual. However, in cases where intact skull is not found, mandible alone may play a vital role in sex prediction as it is the most dimorphic bone of the skull. It is durable, resists any type of mutilation and is commonly preserved in forensic, osteological and anthropological contexts.[1,2] Since the mandible is the last skull bone to complete growth, genetic, hormonal or environment factors influence the sexual variations in the mandible. At the age of 14 years mandibular growth becomes stable in females, while it continues for two more years in males.[3] Several sexual

dimorphic criteria have been reported in mandibular bone including mandibular ramus height, bi-gonial width, etc., as well as the gonial angle in a few populations.[4] The mandibular/gonial angle is formed by the ramus line which is the tangent to the posterior border of the mandible, and the mandibular line which is the horizontal portion of the inferior border of the mandible through the gnathion.[5,6] The angle of mandible in infants and children is obtuse i.e., 140° or more. In adults it reduces to about 120°-130° because the ramus becomes almost vertical and in old age, the angle again becomes obtuse.[7] Thus, the angle of mandible is frequently used for age estimation of remains recovered from, for example, mass graves. But the significance of mandibular angle as a tool in forensic odontology for sex estimation has seldom been investigated.[8] A few studies on South Africans, Europeans, Americans and Egyptians exist in which the gonial angle has been shown to be sexually dimorphic and demonstrated good sex discrimination accuracy which was in contrast to an Indian study.[4,5,6] Since, skeletal attributes vary among different populations, a need arises for specific standards of assessment.

Radiographic examinations are commonly used for bony structures which are decomposed, cremated or mutilated.[9] Radiologic cephalometric examination of mandible may provide an easy and accurate method in sex estimation by linear and angular measurements. Various studies have claimed skull radiographs as a reliable method for sex estimation with accuracy up to 80% to 100%. Standard cephalometric radiographs allow identification of race and sex of an individual using simple measurements.[10] Limited information is available for the mandibular/gonial angle as a parameter for sex estimation using lateral cephalometric radiographs. A digital method for age estimation on orthopantomographs was conducted and concluded that digital age estimation can be used as a last resort, especially for geriatric age prediction.[11] The aim of this study is to determine how accurate the gonial angle is in sexing Indians; the measurements will be obtained using a digital methodology previously not used in sex assessment as well as a robust statistical approach.

MATERIALS AND METHODS:

After obtaining institutional ethical clearance (Sl. No. 1069 Dated – 25/04/2016), a total of 304 digital lateral cephalometric radiographs (155 females and 149 males) of Indian subjects aged between 18-30 years, which were archived in our department, were used in the study. The radiographs were available in the department as part of a previous study and were taken based on convenience sampling. Individuals with a history of orthodontic treatment or orthognathic surgery, trauma, any systemic disturbance or hereditary facial asymmetry were excluded from the study. The mandibular/gonial angle was measured on these radiographs using Adobe Photoshop CS3 (Adobe Systems Inc., Mountain View, USA) software using a methodology developed by one of the co-authors (ABA), which is briefly described below:

1. Using Ruler Tool (previously called the Measure Tool) in Photoshop a tangential line is marked along the lower border of the body of the mandible.
2. Next go to Image>Rotate Canvas>Arbitrary and click on the latter.
3. The rotation may be done clock-wise (CW) or counter clock-wise (CCW), as appropriate (Photoshop gives its suggestion) which orientates the mandible's lower border horizontally.
4. Activate Photoshop's inbuilt rulers (Ctrl+R in Windows computers; Cmd+R in Macintosh systems); click the cursor within the horizontal ruler at the top of the image and drag to position a line (called 'guide') onto the lower border of the mandible.
5. Next use the Ruler Tool (previously called the Measure Tool) to mark a tangential line along the posterior border of the ramus.
6. The angle 'A' may be noted in the Options bar. Angle between the horizontal line on the lower border of mandible and the tangential line along the posterior border of the ramus gives the Mandibular angle (Figure 1). If the angle is negative, the value must be subtracted from 180 to derive the true gonial angle.

The obtained angle for all subjects was separated for males and females, and descriptive statistics were generated. The sexual dimorphism of the gonial angle among the males and females was assessed using student T-test. The inter- and intra-observer variability were assessed on 50 randomly selected lateral cephalometric radiographs and the readings were subjected to paired t-test. Further, the measurements were subjected to logistic regression analysis (LRA) in SPSS software programme. Bivariate LRA allows predicting group membership (in this case, sex) and forms a composite of weighted independent variables using a multivariate strategy; it also provides a probability of the predicted sex. The level of significance was set at 5% and confidence interval at 95%.

Figure 1: Horizontal line onto the lower border of mandible and tangential line along the posterior border of ramus .

RESULTS

The results demonstrated a mean gonial angle of 122.7° for females and 121.1° for males which were statistically significant i.e. females had a larger gonial angle as compared to the males (Table 1). The results of the paired t-test showed no significant difference between repeat measurements by the same or by different observers (Table 2). The obtained angle for the sexes were subjected to logistic regression analysis (LRA), and an equation was obtained and sex classification accuracy was evaluated (Tables 3 and 4). The results of the logistic regression analysis are depicted in Tables 3 and 4. These include the gonial angle coefficient and the constant for the model in Table 3, which produced an overall accuracy rate of 56.3% in sex

assessment, with females being more accurately identified (61.9%) than males (50.3%) (Table 4).

Groups	Mean	Std. Deviation	t value	P value
Male	121.1°	6.4	2.122	0.035
Female	122.7°	6.3		

Table 1 – Descriptive statistics and t-value for the gonial angle in males and females

Test		Mean (Degree)	Difference	t-value	P value
Intraobserver	Evaluation 1	120.7	0.1460	0.280	0.78
	Evaluation 2	120.6			
Interobserver	Observer 1	120.7	-0.1620	-0.312	0.76
	Observer 2	120.9			

Table 2 – Paired sample t-test to assess potential observer variation

	B	S.E.	Wald statistic	df	Sig.	Exp (B)
LRA Coefficient	-0.038	0.018	4.305	1	0.038	0.963
LRA Constant	4.606	2.242	4.222	1	0.040	100.114

Table 3 - LRA equation for the gonial angle

Table 4 – Sex estimation efficacy of gonial angle using logistic regression

Parameter	Males		Females		
Gonial angle	Total No.	Correctly identified	Total No.	Correctly identified	Total Correctly Identified
	149	75 (50.3%)	155	96 (61.9%)	171/304 (56.3 %)

DISCUSSION

The gonial angle is a representation of the form of the mandible. This angle has an important role in predicting growth and it also has specific effects initially on growth, profile changes and the condition of the anterior teeth of the lower jaw.[12] Various studies have been conducted on the gonial angle for age and sex but with contradictory and variable results. There are either environmental or genetic factors controlling the mandibular angle configuration within each population. In previous studies conducted on African, including modern Egyptian populations, the gonial angle of the two sexes was found to be greater in males than females.[6] Usually the mean angle is 3-5 degrees greater in males. The reason for this sex difference may be explained by the fact that men have greater masticatory force than women and generally males have larger mandibles.[13,14] In the present study, the average gonial angle on digital lateral cephalographs was found to be 122.7° for

females and 121.1° for males. In this particular population, low sex estimation accuracy (56.3%) was noted which is in contrast to studies done on Egyptians, European- and African-Americans, Anatolians, Australian Aborigines and South Africans but was in agreement with another Indian study and a Lebanese sample.[7] This emphasises the population-specific differences present and the need for further evaluation in the context of genetic and environmental influences.

Sex estimation efficacy of the gonial angle was evaluated using stepwise logistic regression analysis, which demonstrated an accuracy of 56.3%, with females being more accurately identified (61.9%) than males (50.3%). This is in contrast to a study on a European population where discriminant function analysis (another multivariate statistical analysis) defined the gonial angle as one of the best predictors of sex with an accuracy ranging from 83% to 84%.[6] A similar study on European-Americans demonstrated an accuracy rate of 84%-86%. This difference between Indian and European groups may be attributed to geographic/population variation in the gonial angle.

Various studies have measured the gonial angle on dry mandible with use of mandibulometer and on x-ray images with goniometer.[15,16] X-ray imaging is certainly a useful method of carrying out proper comparisons and identifications. One of the most widespread anthropological methods for identification purposes is based on x-ray images of mandible. The determination of the gonial angle has been studied using panoramic radiography and the results have shown that the gonial angle measurement on the panoramic radiographs is an accurate and repeatable measure. A study done by Maryam et al on agreement between panoramic and lateral cephalometric radiographs for measuring the mean gonial angle was found to be insignificant for the sex and age groups.[12] Larheim and Svanaes also stated that both panoramic radiographs and lateral cephalograms were accurate in determining the gonial angle and there was no significant difference between the right and left sides in panoramic radiography.[16] However, most studies believe that lateral cephalograms are a more standardised form of radiograph for skull and mandible measurements. Interestingly, limited data is available for the mandibular/gonial angle as a parameter for sex assessment using lateral cephalometric radiographs.

It is for these reasons that, in the present study, digital lateral cephalometric radiographs were used. The gonial angle was measured in Adobe Photoshop, which provided a simple and an accurate tool for evaluation of the gonial angle on lateral cephalograms. The advantages of this method include the parallelism ensured throughout the technique which simulates as much as possible the measurements that are done on a dry mandible.

Despite several advantages in this method, the accuracy of sex estimation obtained was low, so this approach is not recommended for post-mortem profiling in human identification in Indians. However, it may be useful when no other parameter is available for this purpose.

CONCLUSION

This study demonstrated statistically significant univariate sexual dimorphism in the mandibular angle in a young adult Indian population and a low (males) to moderate (females) sex estimation accuracy using a new digital methodology on lateral cephalograms which is easy to apply and user friendly.

However, since the prediction value of the gonial angle demonstrated a low accuracy rate, it is not recommended for human identification among Indian population.

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