*Original Article*

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# Role of Skeletal Landmarks in Sex Determination: A Panoramic Radiographic Study

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**Abstract**

*Background:* Digital panoramic radiographs can be used as a simple and reliable tool to assess the sexual dimorphism of skull bones for forensic purposes. *Aims and Objectives:* To compare the measurements of various skeletal landmarks on maxilla and mandible between the genders using digital panoramic radiographs and to evaluate the role of panoramic radiographs in the identification of sex using these landmarks. *Materials and Methods:* This retrospective study consisted of evaluation of digital panoramic radiographs of 25 male and 25 female patients performed using Planmeca machine and analyzed using DBSWIN software. Various skeletal landmarks were recorded and compared between males and females. *Results:* Certain variables like height of body of mandible, distance of mental foramen to inferior cortex, inferior cortical width, condylar head width and height, antegonial depth, ramus width and height , articular eminence inclination and height were found to be significantly more in males than females. However, there was no significant difference in variables like gonial angle, fossa depth, maxillary sinus and nasal fossa width. Based on these parameters, a discrimnant functional equation was derived to determine sex. *Conclusion:* The present study confirms the role of various radiological landmarks on orthopantomograph (OPG) in identification of sex, therefore emphasizing its significance in forensics and research.

**Keywords**: Articular Eminence; Discrimnant Function; Orthopantomograph; Nasal Fossa; Sexual Dimorphism.

## Introduction

The forensic and anthropological research is based on certain physical characteristics that are unique to every individual [1]. These characteristics are important for personal identification, especially for the age or sex determination of any individual. Sex determination can be done by new molecular methods like DNA fingerprinting as well as by using non-metric discrete traits to more objective anthropometric methods. In cases, where entire skeleton is not available, skull can be used for sex determination as it is usually well preserved during mass disasters [2]. Earlier anthropometric studies using dimorphic character of skull have shown accuracy up to 92% and the studies using skull radiographs have shown accuracy upto 90% in determination of sex [3].

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The comparison of antemortem and postmortem dental records like dentures, dental radiographs etc has become an important component of modern day forensic investigations for personal identification especially in criminal cases, mass disasters, grossly decomposed bodies and in the situations where visual identification is neither possible nor desirable [4,5].

Dentofacial radiography has been routinely performed in dental clinics and hospitals. Panoramic radiographs reveals morphological and architectural details of skull including both the maxillary and mandibular arches on a single radiograph, thereby providing additional characteristics and multiple points for comparison [6]. Furthermore, digital panoramic radiography is commonly accessible, cost effective, easy to perform, quick and easily implemented (in any special training for the forensic examiner) technique, used to assess orofacial vital structures and can serve as an important antemortem record [4,6].

Thus, in our study, we used digital panoramic radiographs as a simple and reliable tool to assess the sexual dimorphism of skull bones for forensic purposes.

**Aims and Objectives**

Based on the above, the aims and objectives of the study were to compare the measurements of various skeletal landmarks on maxilla and mandible between the genders using digital panoramic radiographs and to evaluate the role of panoramic radiographs in the identification of sex using these landmarks.

**Materials and Methods**

This retrospective study was conducted in the Department of Oral Medicine and Radiology of the institute. It consisted of evaluation of digital panoramic radiographs of 25 male and 25 female patients, retrieved from the data from the Department of Radiology, performed using Planmeca machine (planmeca proline ec) and analyzed using DBSWIN software. The ethical clearance from institute ethical committee was obtained. Digital OPGs of subjects between 20-40 years and prescreened for quality were included for the study. Radiographs showing unclear landmarks, radiographic/magnification errors, pathologies of jaw, fractures, developmental disturbances, deformed or edentulous mandible were excluded from the study. All the readings were observed by single observer (oral radiologist) and reexamined by same observer after one month.

The following parameters were measured. (Figure 1,2)

1. Height of the mandibular body (ht bd): Direct distance from the alveolar process to the inferior border of the mandible perpendicular to the base at the level of the mental foramen.
2. Height of upper alveolar border to mental foramen(ht ac mf): Distance of upper alveolar border to superior border of mental foramen
3. Distance of mental foramen to inferior cortex (mf ic): Distance from lower border of mental foramen to inferior cortex of mandible.
4. Cortical width (cw): Width of inferior cortex as seen in OPG.
5. Antegonial notch depth (agn dt): Distance from highest point on the notch to tangent drawn at lower border of mandible.
6. Maximum ramus breadth (rw max): Distance between the most anterior point on the mandibular ramus and a line connecting the most posterior point on the condyle and the angle of the jaw.
7. Minimum ramus breadth (rw min): Least breadth of the mandibular ramus measured perpendicular to the height of the ramus.
8. Condylar height (con ht): Height of the ramus of the mandible from the most superior point on the mandibular condyle to the most protruding portion of the inferior border of the ramus.
9. Coronoid height (cor ht): Height of the ramus of the mandible from the most superior point on coronoid process to the most protruding portion of the inferior border of the ramus.
10. Condylar head height (ch ht): Distance from highest point of condylar head till neck of condyle.
11. Condylar head width (ch wd): Maximum width of head of condyle.
12. Depth of sigmoid notch (fos dt): Distance from line joining highest points on coronoid and condylar process to deepest point on the notch.
13. Gonial angle (gn a): Angle between tangent drawn to inferior border of mandible to tangent to posterior surface of ramus.
14. Inclination of articular eminence (art a): Angle between posterior slope of articular eminence and frankfort horizontal plane.
15. Depth of articular eminence (art dt): Perpendicular distance between lowest point of the articular eminence and highest point of the fossa.
16. Maxillary sinus width (max sinus wd): Maximum width of maxillary sinus.
17. Nasal fossa width (nw): Distance of nasal septum to lateral nasal wall.

*Statistical Analysis*

To test the difference in parameters among genders, independent t test was used. Level of statistical significance was set at<0.05. Discrimnant functional analysis was used to derive equation for gender determination. To check the intraobserver variability, Cronbach alpha test was used. Statistical analysis was done using SPSS Version 16.

## Results

In the present study, a total of 50 OPGs were selected of patients between 20-40 years including 25 males and 25 females. Certain variables like height of body of mandible, distance of mental foramen to inferior cortex, inferior cortical width, condylar head width, condylar head height, antigonial depth, ramus width (max and min), ramus height (condylar and coronoid height), articular eminence inclination and height were found to be significantly more in males than females. However, there was no significant difference in variables like gonial angle, fossa depth, max sinus width and nasal fossa width.(Table 1, Graph 1) Based on the above a discrimnant functional equation was calculated using Canonical Discriminant Function coefficient. (Table 2) Following formula was derived to determine sex.

D=-39.631+.529(ht bd md)-.401(ht ac mf)-.109(mf ic)-.230(cw)-.102(ch ht)+.410(ch wd)+.885(agn dt)+.017(gn a)+.279(rw mx)+.019(rw min)-.04(cor ht)+.163(con ht)-.241(fos dt)+.104(art a)-.014(art dt)+.164(nw)-.038(max sin wd)

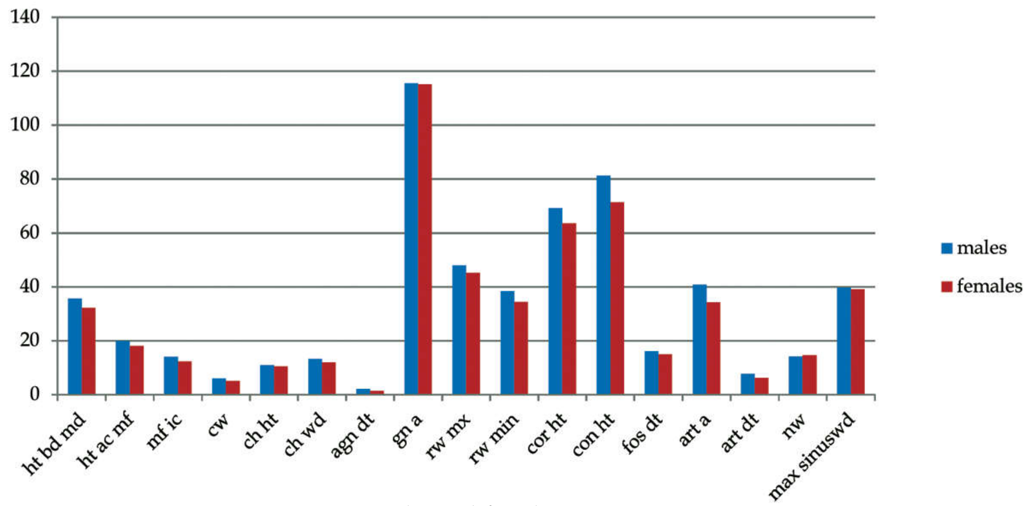
For males the values lies between 1 to 2.168 and for females it lies between 1 to -2.168 (Table 3). 74% of the cases were found to be correctly classified using the formula. The intraobserver aggrement was found to be 81%.

**Table 1:** Various parameters among males and females

| Variable | Male<br>Mean ± S.D. | Female<br>Mean ± S.D. | p value |
|---|---|---|---|
| HT BD MD | 35.700± 2.6870 | 32.240 ± 2.8333 | **.000** |
| HT AC MF | 19.905 ± 2.9215 | 18.085±.7336 | .072 |
| MF IC | 14.060±.3774 | 12.340±.3505 | **.002** |
| CW | 6.020±.1665 | 5.050±.2553 | **.003** |
| CH HT | 10.885±.3034 | 11.540±.4616 | **.05** |
| CH WD | 13.335±.3231 | 11.965±.2664 | **.002** |
| AGN DT | 2.040±.2202 | 1.425±.1487 | **.026** |
| GN A | 115.595±1.3968 | 115.265±5.6864 | .955 |
| RW MX | 47.990±.7142 | 45.210±.7833 | **.012** |
| RW MIN | 38.460±.8314 | 34.345±1.3931 | **.015** |
| COR HT | 69.250±1.3048 | 63.675±1.5608 | **.009** |
| CON HT | 81.375±.9620 | 71.380±1.3349 | **.000** |
| FOS DT | 16.135±.5139 | 14.990±.4096 | .090 |
| ART A | 40.790±1.2429 | 34.215±1.6502 | **.003** |
| ART DT | 7.7650±.34153 | 6.2400±.28658 | **.002** |
| NW | 14.4250±2.32263 | 14.1750±2.51352 | .650 |
| MAX Sinus WD | 39.6600±5.13157 | 39.1650±6.09212 | .783 |

**Table 2:** Discriminant function coefficients for various parameters

| Canonical Discriminant Function Coefficients<br>Variable | Function |
|---|---|
| HT BD MD | .529 |
| HT AC MF | -.401 |
| MF IC | -.109 |
| CW | -.230 |
| CH HT | -.102 |
| CH WD | .410 |
| AGN DT | .885 |
| GN A | .017 |
| RW MX | .279 |
| RW MIN | .019 |
| COR HT | -.040 |
| CON HT | .163 |
| FOS DT | -.241 |
| ART A | .104 |
| ART DT | -.014 |
| NW | .164 |
| MAX SINUSWD | -.038 |
| (Constant) | -39.631 |




**Graph 1:** Various parameters among males and females

**Table 3:** Discrimnant function for males and females

| Functions at Group Centroids | |
|---|---|
| **Sex** | **Function** |
| Male | 2.168 |
| Female | -2.168 |

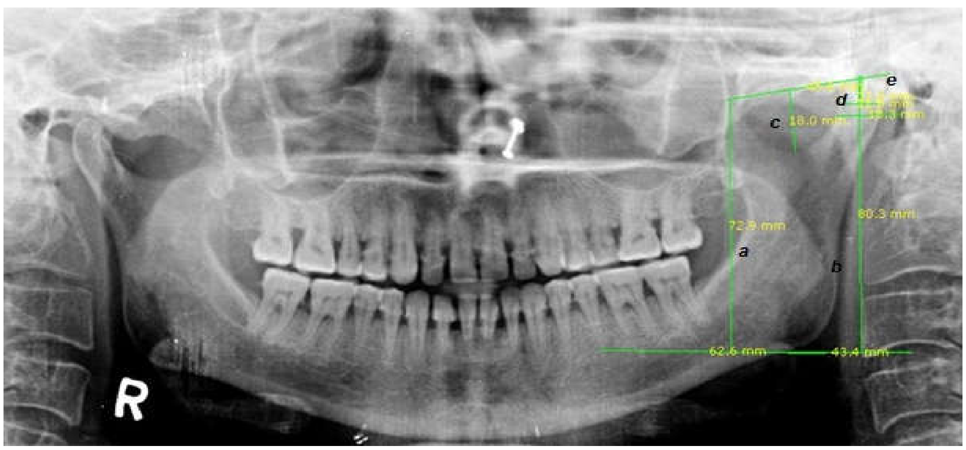



**Fig. 1:** Measurement of various parameters on OPG. a. Coronoid height b. Condylar height c. Sigmoid notch depth d. Condylar head width e. Condylar head height

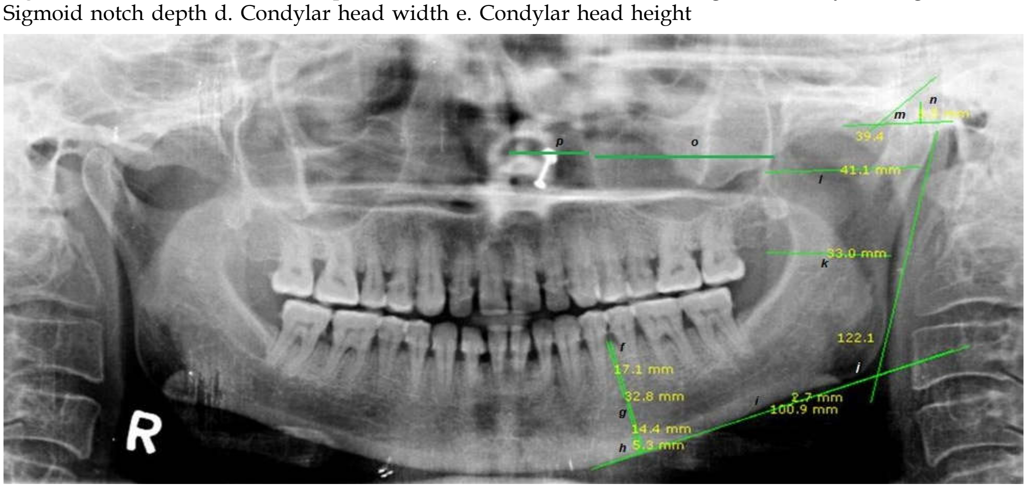



**Fig. 2:** Measurement of various parameters on OPG. f. height of body of mandible g. distance of mental foramen to inferior cortex h. width of inferior cortex i. antigonial notch depth j. gonial angle k. min ramus width l. max ramus width m. slope of articular eminence n. articular eminence depth o. max sinus width p. nasal width

## Discussion

Identification of sex of an individual is one of the most important aspects of medicolegal cases and anthropological research. Availability of simple, economical, quick and accurate modalities can drastically reduce the time taken in the identification of individuals, thus shortening the legalities associated with the same. The use of dentofacial radiography has been an established method for personal identification and has made forensic odontology as emerging branch in the field of forensics [5].

We used digital pantomographs for the study as they are more objective, standardized and have broad coverage with low patient radiation dose. Moreover, features like enhancement of image contrast and sharpness make the measurements easy, clear and reproducible [6]. However, this technique has limitations like geometric distortion and magnification. But this did not affect our results as images with geometric distortion and positioning errors were excluded from the study and the magnification was generalised over all the parameters and subjects. Also, only one side (left) was used for all the measurements.

It has been reported that the skeletal characteristics are age-related phenomena which appear or become pronounced at puberty and are affected by senility [3,7]. Hence, in the present study the age limit was set between 20 and 40years.

Variations in skull morphology is indicated by genetic, environmental and developmental factors [8]. Male skulls are significantly larger, heavier, and thicker in addition to having greater cranial capacity, whereas in women; protuberances, crests and processes tend to be smaller and smoother [9]. The relative development (size, strength and angulation) of the muscles of mastication is known to influence the expression of skull dimorphism as masticatory forces exerted are different for males and females.Though external factors such as diet and lifestyles etc also play an important role in growth and development [10].

In this study, mandibular landmarks like height of body of mandible, cortical width, condylar head width, condylar head height, ramus width, ramus height, condylar and coronoid height were found to have more mean value ($p<0.05$) than females. The usefulness of mandible for sex determination has been established by Pokherel et al. (2012) using dry intact mandibles and by Indira et al. (2013) using digital panoramic radiographs [10,11]. They found that ramus width, ramus height, condylar width, condylar height and coronoid height were significantly high in males than females. Male skulls are generally larger, heavier and robust than females.

The mean values of the height of the mandibular body and distance of mandibular body to inferior cortex were significantly high in males as compared to females. Similar results were found by Chkoura A et al. and Thakur M et al. in their radiologic studies on panoramic radiographs [12,13]. However, no significant difference in distance of alveolar crest and superior border of mental foramen was found between males and females. The height of alveolar crest is chiefly dependent on the periodontal/dentulous status of individual, but the distance from the foramen to the inferior border of the mandible remains relatively constant and not affected by the dental status [14].

Certain previous studies have shown change in gonial angle in males and females and different age groups. No difference was found in our study between males and females. Upadhayay et al. and Raustia et al. also showed no difference in gonial angle among sexes.The difference in studies could be related to different study populations and variability in sample size [15,16].

Articular eminence inclination and articular height values of males were higher as compared to females, similar to results by Lewis et al. (2001) and Sumbullu et al. (2012). Difference in articular eminence morphological features can be due to sex hormones, metabolic activity differences between male and female patients during the adolescent period, difference in the amount of functional force affecting the TMJ and gender differences in the shapes of condylar pathways [17,18].

The width of nasal fossa and maxillary sinus was found to be more in males than females, but this was not found to be statistically significant. Oladipo et al in their study on 500 males and 500 females of different age groups found significant difference in nasal width in males and females [19]. Jasim et al showed significantly more maxillary sinus width in males than females in 120 patients [20]. However, in their study, CT images were used for calculation which are more accurate than two dimensional OPG images used in our study.

In the present study, 50 digital OPGS were used to study difference in various landmarks in skull in males and females. Previous studies have reported an accuracy of 80-100% using skull radiographs are used for sex determination. Patil showed an accuracy of 99% using lateral cephalograms on central Indian population [20]. Binnal A et al reported a reliability of 86% using descrimnant functional equation using cephalometric landmarks [3]. Indira et al found that 76% cases were classified correctly using mandibular landmarks on OPG [10]. In this study, accuracy was found to be 74% using the derived functional equation. The reason can be attributed to the small sample size.

## Conclusion

This study is first of its kind using 15 parameters together on a digital OPG for establishing sexual dimorphism, thereby suggesting increased accuracy of results. Based on these parameters, a discrimnant functional equation can be derived to determine sex. The findings of present study confirm the role of various radiological landmarks on OPG in identification of sex, therefore emphasizing its significance in forensics and research. However, further studies with large sample size and different study populations should be carried out to increase validity of the results.

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