OPEN ACCESS
Saudi Journal of Oral and Dental Research
Abbreviated Key Title: Saudi J Oral Dent Res
ISSN 2518-1300 (Print) |ISSN 2518-1297 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: http://scholarsmepub.com/sjodr/

Original Research Article

Gender Based Variations in Morphological Features of Mandible in Digital Panoramic Radiographs - A Comparative Study

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| **Received:** 18.01.2019 | **Accepted:** 28.01.2019 | **Published:** 30.01.2019
DOI:10.21276/sjodr.2019.4.1.7

Abstract

Background: Identification of skeletal remains is of utmost importance in medico- legal investigations. Skeletal components are often investigated for gender determination the skull and pelvis along with the mandible being a practical element to analyze gender variation in the fragmented bones of a dense layer of compact bone makes it very durable and well preserved than any other bone. When sex determination using skeleton is considered, metric analyses on the radiographs are often found to be of superior value owing to their objectivity, accuracy and reproducibility. ***Aims And Objectives:*** The following were the aims and objectives of our study:- 1) To measure the various morphometric parameters of the mandible in digital panoramic radiographs, determine variations in the morphometric parameters of the mandible, based on gender. 2) To correlate these findings in gender determination. 3) To find out which are the most reliable parameters in gender determination. ***Materials And Methods:*** A retrospective study was conducted using panoramic radiographs of 100 males and100 females, which were taken using Orthophos XG machine 64 KV, 8mA and 14.1 seconds). Twelve parameters such as maximum ramus breadth, minimum ramus breadth, condylar height, projective height of ramus, coronoid height, height of mandible, superior margin of mental foramen to inferior border, inferior margin of mental foramen to inferior border, superior margin of mental foramen to alveolar crest, gonial angle, antegonial angle and antegonial depth were measured on both sides on digital panoramic radiographs .Measurements were made using mouse driven methods and anatomical landmarks. Statistical analysis was done. ***Results:*** There was significant difference in these parameters with p value < 0.05. ***Conclusion:*** This study shows strong evidence that mandibular measurements using panoramic radiographs were reliable for gender determination and the projective height of the ramus is the most significant of all the parameters, which may be used for gender determination using the mandible.

Keywords: Mandible, Sexual dimorphism, Gender determination, Panoramic radiographs.

INTRODUCTION

Forensic odontology is that branch of dentistry that deals with the proper handling and examination of dental evidence and with the proper evaluation and presentation of dental findings in the interest of justice [1]. This branch has been of high practical significance for many years in the identification of victims and suspects in mass disasters, abuse and organized crimes [2].

Determination of sex using skeletal remains poses a great problem for forensic experts especially when only fragments of the body are recovered [3]. The identification of human skeletal remains is considered an initial step in forensic investigations and is crucial for further analysis [4]. In the adult skeleton, sex determination is usually first step of the identification processes subsequent methods for age and stature estimation are sex dependent. The reliability of sex determination depends on the completeness of the remains and the degree of sexual dimorphism inherent in the population [4]. When the entire adult skeleton is available for analysis, sex can be determined up to 100% accuracy, but in cases of mass disasters where usually fragmented bones are found, sex determination with 100% accuracy is not possible and it depends largely on the available parts of skeleton.

The relative development (size, strength, and angulation) of the muscles of mastication is known to influence the expression of mandibular dimorphism as masticatory forces exerted are different for males and females [5]. Humphrey *et al.,* showed that the sites associated with the greatest morphological changes in size and remodeling during growth, mandibular condyle, and ramus tend to show higher sexual dimorphism, and differences between the sexes are generally more marked in the mandibular ramus than in the mandibular body [6].

Dry skull orthopantomography (OPG) is frequently used for scientific research or forensic investigations. Dental methods are considered to be a reliable tool when other identification methods fail [9]. Sex determination analysis can be done either by morphological analysis or by molecular analysis. Morphological analysis can be done on hard tissues (odontometric,orthometric, and miscellaneous) of oral and paraoral regions or soft tissue (lip prints‑ Cheiloscopy, palatal rugae pattern‑ Rugoscopy).

Dentofacial radiography has become a routine procedure in the dental, medical, and hospital clinics. The radiographs are taken at different periods during the lifetime of large segments of the population [7]. In forensic anthropology, comparison of ante mortem and postmortem radiographs is one of the cornerstones of positive identification of human remains. Ante mortem orthopantomograms may be of great value in the identification of human remains [8].

Mandible is the largest, strongest and movable part of the skull. Identification of mandible is important in medico-legal and anthropological work [9]. But in cases where intact skull is not found, mandible may play a vital role in sex determination as it is the most dimorphic, largest, and strongest bone of skull [3-5, 10]. The morphological features of mandible are commonly used by anthropologists and forensic dentists in the determination of sex [11].

The mental foramen is fairly well depicted in panoramic radiographs [12]. Panoramic radiographs provides the ability to view the entire body of the mandible and allows a more accurate location of the mental foramen in both horizontal as well as in vertical dimensions. Digital panoramic radiographs can be used to determine vertical height measurements of the mandible [13]. Measurements of the mandibular ramus tend to show higher sexual dimorphism and differences between the sexes are more marked in the mandibular ramus than mandibular body[6].Methods based on measurements and morphometry are accurate and can be used in determination of sex [14].

A search into the review of published literature showed that earlier studies have been conducted with only few selected parameters for analysis for the purpose of gender determination. Hence a study conducting all morphometric parameters related to mandible was decided to be conducted.

This study was conducted with an aim to evaluate the usefulness of morphological features of the mandible as seen in digital panoramic radiographs in sex determination and propose the use of the same in forensic analysis.

Aim

To study the various morphometric variations in the mandible using digital panoramic radiographs in male and female subjects and its application in gender determination.

The Objectives of the Study Where

- To measure the various morphometric parameters of the mandible in digital panoramic radiographs, determine variations in the morphometric parameters of the mandible, based on gender.
- To correlate these findings in gender determination.
- To find out which are the most reliable parameters in gender determination.

MATERIALS AND METHODS

The study population was selected from the Outpatient Department of Oral Medicine and Radiology, Tamilnadu Government Dental College and Hospital, Chennai, Tamilnadu, India. Patients who were referred to the Radiology Department for digital panoramic radiograph were selected for the study. Institutional Ethical committee approval was obtained prior to the beginning of the study. Patients from age 18 years till 65 years both dentulous and edentulous were included in the study. Patients with congenital anomaly of mandible, pathological lesions of mandible and patients with history of mandibular fracture or, major surgical procedures involving the mandible were excluded from the study.

The selected patients were seated comfortably in the dental chair and the details specified in the case history proforma were recorded. Oral cavity was examined under adequate light of the dental chair by a single examiner using mouth mirror probe, disposable gloves and mouth mask.

Digital panoramic radiographs were taken using digital panoramic system Orthophos XG machine (64KV,8mA,14.1seconds). The measurements were measured using SIDEXIS XG software with mouse driven method. Each radiograph was viewed digitally. Measurements were made using the reference lines drawn from anatomical landmarks. Totally twelve parameters were taken for the study as follows

- **Maximum ramus breadth:** The 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 jaw.
- **Minimum ramus breadth:** Smallest anterior–posterior diameter of the ramus.
- **Condylar height:** Height of the ramus of the mandible from the most superior point on the mandibular condyle to the tubercle, or most

protruding portion of the inferior border of the ramus.

- **Projective height of ramus:** Projective height of ramus between the highest point of the mandibular condyle and lower margin of the bone.
- **Coronoid height:** Projective distance between coronion and lower wall of the bone.

A line joining the most prominent point on the chin the 'menton' and the most prominent point of the angle of the mandible 'joining' was marked using mouse driven method.

The mental foramen was identified and marked on both sides. A line perpendicular to this tangent was marked from the inferior mandibular border to the alveolar crest such that it intersected the inferior edge of the mental foramen on the right side.

- The distance from the inferior surface of the mandibular body to the height of the alveolar crest on the right side (height).
- The distance between the superior margins of the mental foramen to the inferior border of the mandible on the right side (SM to IB).
- The distance between the inferior margins of the mental foramen to the inferior border of the mandible on the right side (IM to IB).
- The distance between the superior margin of the mental foramen to the alveolar crest on the right side (SM to AC) – were measured.
- The mandibular line was constructed as a tangent to the two lowest points on the anterior and posterior borders of the mandible. The ramus line was constructed through the two most distal points of the ramus. The intersection of these lines formed the gonial (mandibular) angle.
- Gonial angle is measured by the intersection of these lines.
- The antegonial angle was measured by two lines parallel to the antegonial region that will intersect at the deepest point of the antegonial notch.
- The antegonial depth was measured as the distance along a perpendicular line from the deepest point of the notch concavity to a tangent through the inferior border of the mandible. The following measurements were measured after taking orthopantomogram.

Statistical analysis

Statistical Analysis were done using SPSS version 17.Students unpaired t test was used.

Results

A total of 200 patients who satisfied the inclusion criteria were included in the study. They were divided into two groups. Group A consisted of 100 male patients Group B consisted of 100 female patients (Table-1).

The distribution of age group among 100 male patients included in the study were 40 patients (40%) in the age group of 18-28 years,22 patients(22%) in the age group of 29 -38 years,19 patients(19%) in the age group of 39-48 years,8 patients (8%) in the age group of 49-58 years,11 patients (11%)in the age group 59-65 group (Table-2 and Graph-1).

The distribution of age group among 100 female patients included in the study were 28 patients(28%) in the age group of 18-28 years,20 patients(20%) in the age group of 29 -38 years,28 patients(28%) in the age group of 39-48 years,17 patients (17%) in the age group of 49-58 years, 7 patients (7%)in the age group 59-65 group (Table-3 and Graph-2).

Digital panoramic radiograph was taken for the patients using Orthophos XG machine .The following measurements such as maximum ramus breadth, minimum ramus breadth, condylar height, projective height of ramus, coronoid height, height of mandible, superior margin of mental foramen to inferior border, inferior margin of mental foramen to inferior border, superior margin of mental foramen to alveolar crest, gonial angle, antegonial angle and antegonial notch were measured on both sides on digital panoramic radiographs using mouse driven method and statistical analysis were done using SPSS version 17. Students unpaired t test was used.

Significant difference in maximum ramus breadth was found between males and females. Maximum ramus breadth in males were found to be 45.3092±4.06995 where as in females were found to be 43.0910 ±3.59791 (p value<0.05) (Table-4 and Graph-3).

Significant difference in minimum ramus breadth was found between males and females .Minimum ramus breadth in males were 33.2252±.50578 and in females were 31.5619±3.12655 with p value < 0.05 (Table-5 and Graph-3).

Significant difference in condylar height was observed with males having values of 71.5530±5.61006 and females having the values of 66.2183±4.9030 with p value <0.05 (Table-5 and Graph-3).

Significant difference in projective height of ramus was found between males and females. Projective heights of ramus in males were 74.4057±5.43548 and in females were 66.2315±5.60217 with p value < 0.05 (Table-5 and Graph-3).

Significant difference in coronoid height was found with males having values of 67.2466±4.74079 and females having the values of 61.6321±4.49901 with p value < 0.05 (Table-5 and Graph-3).

Significant difference in height of mandible was found between males and females. The mean values of males were 33.2379±3.4526 and females were 30.6157± 3.46668 with p value <0.05 (Table-6 and Graph-4).

Significant difference in Superior Margin (SM) of Mental Foramen (MF) to Inferior Border (IB) was achieved. The mean values of SM-IB in males were 17.9864±1.63099 and in females were 15.9901±1.41340 with p value < 0.05 (Table-6 and Graph-4).

Significant difference in Inferior margin (IM) of Mental Foramen (MF) to inferior border (IB) of mandible was observed. The mean values of IM-IB in males were 14.8795±3.33484 and in females were 12.9411±1.32816 with p value < 0.05 (Table-6 and Graph-4).

There was no statistical significant difference observed in Superior Margin to Alveolar Crest (AC). The mean values of SM- AC in males were 19.6971+-2.84475 and in females were 18.4303± 6.13953 with p value = 0.63 (Table-6 and Graph-4).

Significant difference in Gonial angle was found between males and females. The mean value of gonial angle in males were 124.25±6.79838 and in females were 130.28±6.81115 with p value <0.05) (Table-7 and Graph-5).

Significant difference in Antegonial angle was found between males and females. The mean values of antegonial angle in males were 152.40±12.14595 and in females were 159.94± 7.67674 with p value <0.05 (Table-7 and Graph-5).

Significant difference in antegonial depth was achieved between male and female. The mean values of antegonial depth in males were 2.9552±.53715 and in females were 2.8126± .23638 with p value =0.016 (Table-7 and Graph-6).

In the present study, significant differences of these parameters among the age groups were also analysed. Comparison of these parameters did not show significant difference.

Among all these paramaters eleven parameters such as maximum ramus breadth, minimum ramus breadth, condylar height, projective height of ramus ,coronoid height, height of mandible, superior margin of mental foramen to inferior border, inferior margin of mental foramen to inferior border, gonial angle, antegonial angle and antegonial notch showed statistically significant difference .

Among all these parameters, projective height of ramus showed highly significant difference between males and females with a mean difference of -8.17420.

FIGURES, TABLES AND GRAPHS

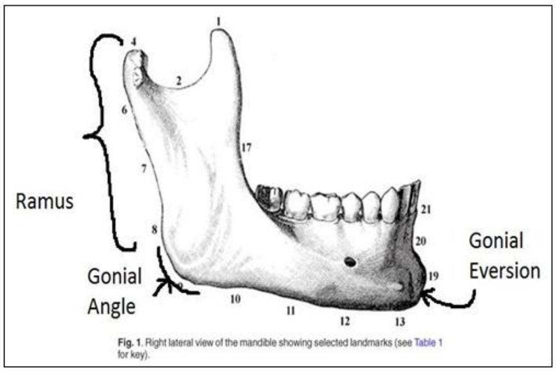
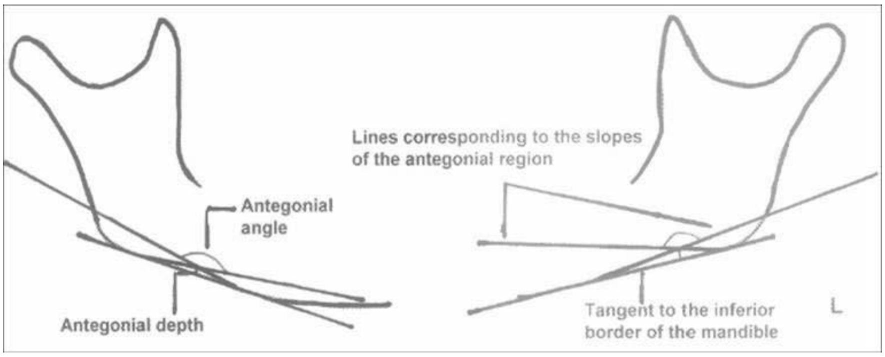


Fig-1: Gonial Angle



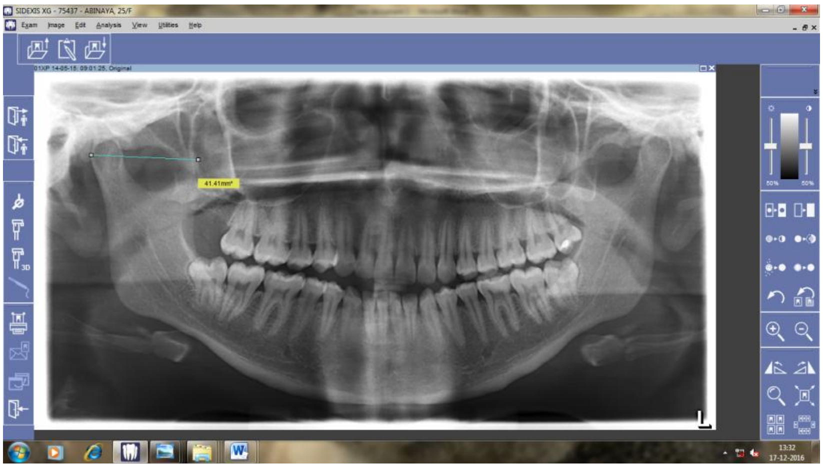


Fig-2: Digital OPG showing measurement of maximum Ramus breadth on Right side

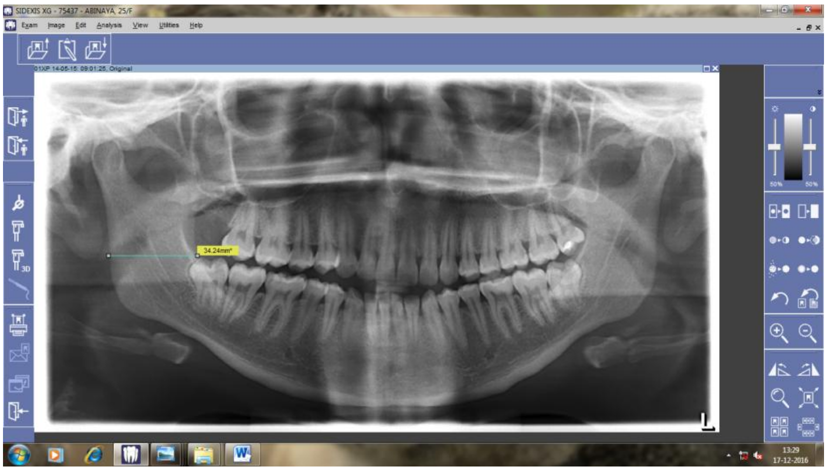


Fig-3: Digital OPG showing measurement of minimum ramus breadth on Right side

Fig-4: Digital OPG showing measurement of Condylar height on right side

Fig-5: Digital OPG showing measurement of Projective height of ramus on right side

Fig-6: Digital OPG showing measurement of coronoid Height on right side

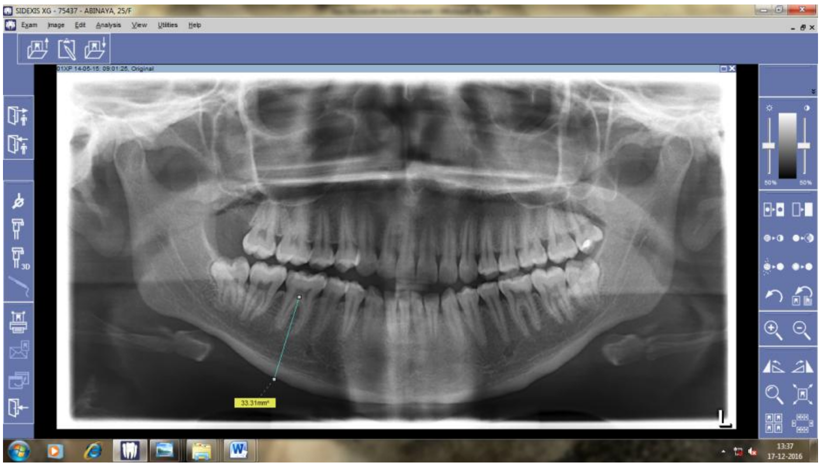


Fig-7: Digital OPG showing measurement of height of mandible on right side

Fig-8: Digital OPG showing identification of mental foramen on right side

Fig-9: Digital OPG showing measurement of superior margin of mental foramen to inferior border of mandible on right side

Fig-10: Digital OPG showing measurement of inferior margin of mental foramen to inferior border of mandible on right side

Fig-11: Digital OPG showing measurement of superior margin of mental foramen to alveolar crest on right side

Fig-12: Digital OPG showing measurement of gonial angle on right side

Fig-13: Digital OPG showing measurement of antegonial angle on right side

Fig-14: Digital OPG showing measurement of antegonial depth on right side

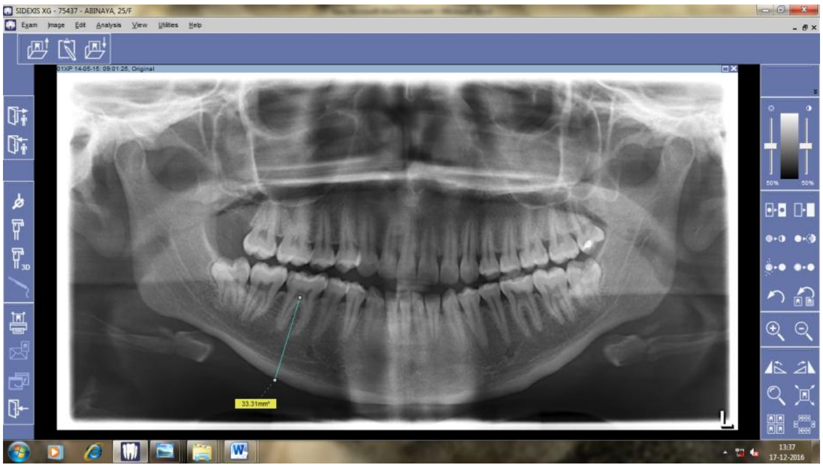


Fig-15: Digital OPG showing measurement of height of mandible on right side

Fig-16: Digital OPG showing identification of mental foramen on right side

Fig-17: Digital OPG showing measurement of superior margin of mental foramen to inferior border of mandible on right side

Fig-18: Digital OPG showing measurement of inferior margin of mental foramen to inferior border of mandible on right side

Fig-19: Digital OPG showing measurement of superior margin of mental foramen to alveolar crest on right side

Fig-20: Digital OPG showing measurement of gonial angle on right side

Fig-21: Digital OPG showing measurement of antegonial angle on right side

Fig-22: Digital OPG showing measurement of antegonial depth on right side

Tables

Table-1: Distribution of gender

Gender	No. of patients	Percentage
Male	100	50
Female	100	50

Table-2: Distribution of age group in Male (Group A)

Age group	No. of Patients	Percentage
18 to 28 years	40	40.0
29 to 38 years	22	22.0
39 to 48 years	19	19.0
49 to 58 years	8	8.0
59 to 65 years	11	11.0
Total	100	100

Table-3: Distribution of age group in Female (Group B)

Age group	No. of Patients	Percentage
18 to 28 years	28	28.0
29 to 38 years	20	20.0
39 to 48 years	28	28.0
49 to 58 years	17	17.0
59 to 65 years	7	7.0
Total	100	100

Table-4: Mean and Standard Deviation of Maximum Ramus Breadth and Minimum Ramus Breadth in Males (Group A) and Females (Group B)

Parameters	Groups	Mean	Standard Deviation	p value
Maximum Ramus Breadth	Male	45.3092	4.06995	.0001
	Female	43.0910	3.59791	
Minimum Ramus Breadth	Male	33.2252	2.50578	.00001
	Female	31.5619	3.12655	

Table 5: Mean and Standard deviation of Condylar Height, Projective Height of Ramus, Coronoid Height in Males (Group A) and Females (Group B)

Parameters	Groups	Mean	Standard Deviation	p value
Condylar Height	Male	71.5530	5.61006	.0001
	Female	66.2183	4.90305	
Projective Height of ramus	Male	74.4057	5.43548	.0001
	Female	66.2315	5.60217	
Coronoid Height	Male	67.2466	4.74079	.0001
	Female	61.6321	4.49901	

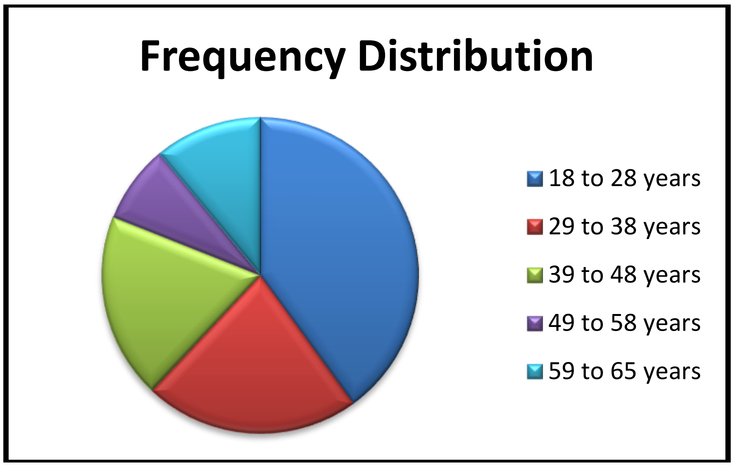
Table-6: Mean and Standard deviation of Height of Mandible, Superior Margin of mental foramen to inferior border, Inferior Margin of mental foramen to inferior border, Superior margin to alveolar crest in Males (Group A) and Females (Group B)

Parameters	Groups	Mean	Standard Deviation	p value
Height of Mandible	Male	33.2379	3.42526	.0001
	Female	30.6157	3.46668	
Superior Margin of mental foramen to inferior border	Male	17.9864	1.63099	.0001
	Female	15.9901	1.41340	
Inferior margin of mental foramen to inferior border	Male	14.8795	3.33484	.0001
	Female	12.9411	1.32816	
Superior margin to alveolar crest	Male	19.6971	2.84475	0.63
	Female	18.4303	6.13953	

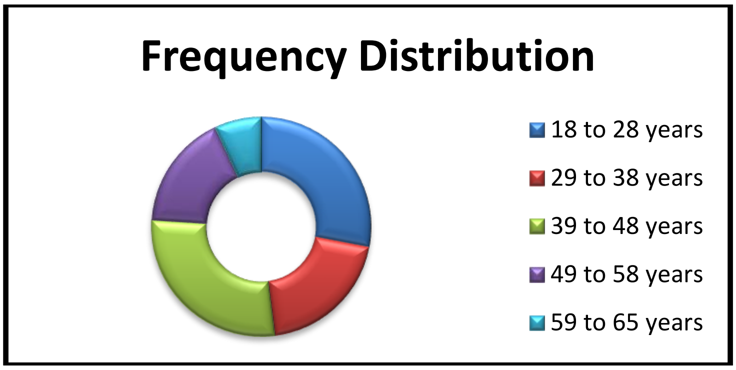
Table-7: Mean and Standard Deviation of Gonial Angle, Antegonial Angle, Antegonial depth in Males (Group A) and Females (Group B)

Parameters	Groups	Mean	Standard Deviation	p value
Gonial Angle	Male	124.25	6.79838	.0001
	Female	130.28	6.81115	
Antegonial angle	Male	152.40	12.14595	.0001
	Female	159.94	7.67674	
Antegonial Depth	Male	2.9552	.53715	.063
	Female	2.8126	.23638	

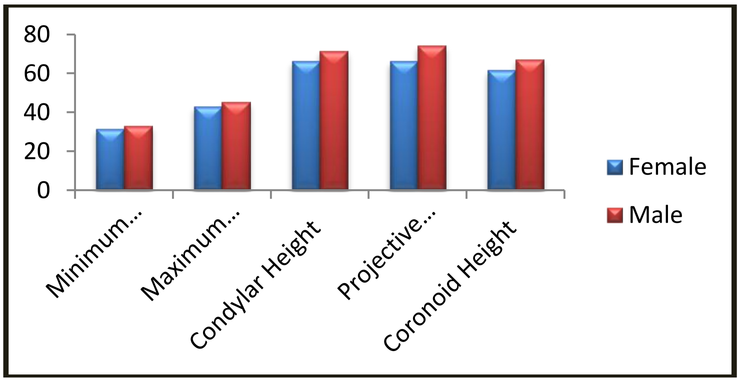
Bar Charts



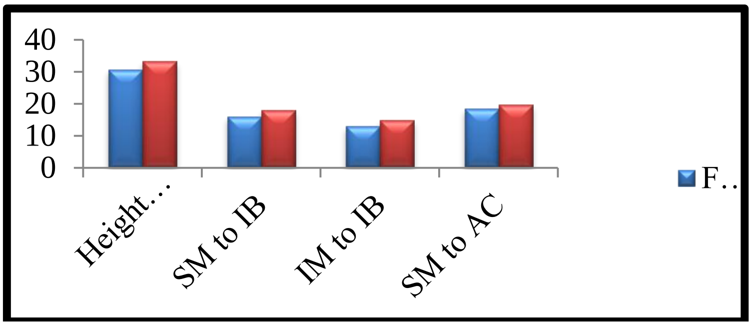
Graph-1: Frequency distribution in males



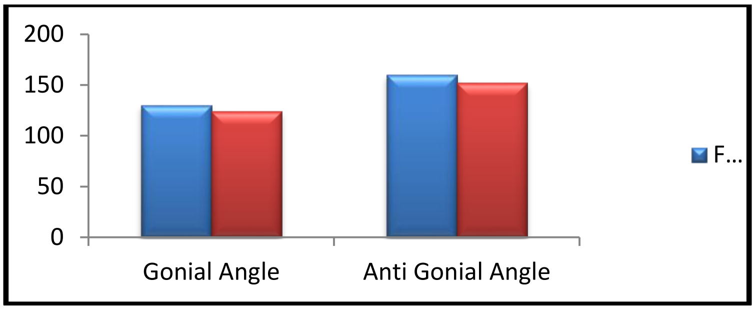
Graph-2: Frequency distribution in females



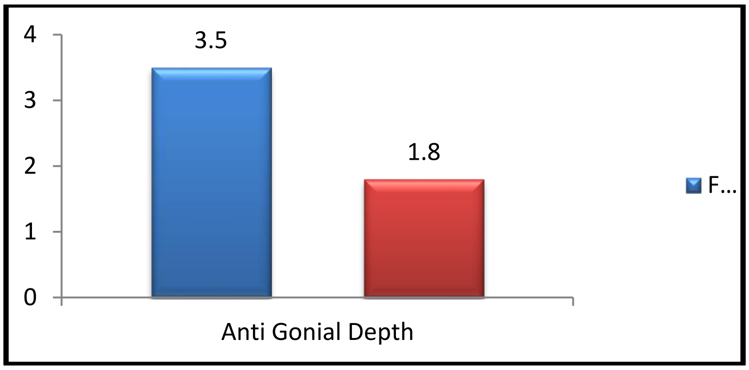
Graph-3:



Graph-4:



Graph-5:



Graph-6:

DISCUSSION

One of the important aspects of forensics is to determine gender from fragmented jaws and dentition [6].

Mandible plays a vital role in sex determination in cases where intact skulls are not found [3, 4, 14]. Mandible was used for this study for two simple reasons: Firstly there appears to be paucity of standards utilizing these elements and secondly the bone is largely intact[5].

The accuracy of panoramic radiographs in providing anatomic measurements has already been established. Panoramic Radiograph has been used by the clinicians as an accurate screening tool for the diagnosis of oral diseases. Principal advantages of panoramic radiographs include broad coverage, low patient radiation dose, short time required for image acquisition[15]. Other advantages are that interference of superimposed images is not encountered. The contrast and brightness enhancement and enlargement of images in digital panoramic radiographs provide an accurate and reproducible method of measuring the chosen points [16, 17]. The limitations of panoramic radiographs are magnification and geometric distortion, the vertical dimension in contrast to the horizontal is little altered and positioning errors can also occur due to positioning errors because of relatively narrow image layer [15].

Humphrey *et al.*, [5] emphasized that almost any site of mandibular bone deposition or resorption, or remodeling seems to have a potential for becoming sexually dimorphic. Hence mandibular condyle and ramus are generally the most dimorphic as these are the sites associated with the greatest morphological changes in size and remodeling during growth.

Wical and Swoope [18] reported that inspite of the resorption above the mental foramen, the distance from the foramen to the inferior border of the mandible remains constant throughout life. Lindh et al and Guler *et al.*, also suggested that the stability of this region does not depend on resorption of alveolar process above the foramen. Because of the stability of the basal bone and mental foramen, these landmarks were selected as a point of reference for our study.

Significant difference was found between males and females in the following parameters such as maximum ramus breadth, minimum ramus breadth, condylar height, projective height of ramus, coronoid height, height of mandible, superior margin of mental foramen to inferior border, inferior margin of mental foramen to inferior border, gonial angle, antegonial angle and antegonial notch. The mean values of superior margin to alveolar crest did not show any significance between males and females.

Our results correlated with Huumonen *et al.*, [19] who found significantly larger gonial angle in females as compared to males. In our study values of gonial angle in females (130.28±6.81115) were higher than males (124.25± 6.79838).

Our study correlated with Ghosh *et al.*, [20] with respect to antegonial angle, females had higher antegonial angles when compared to males. In our study females had higher antegonial angles when compared to males. The mean values of antegonial angles in females (159.94 ± 7.67674) were higher than males (152.40± 12.14595).With respect to antegonial depth, females (2.8126±.23638) had smaller values as compared to males (2.9552± .53715).

Our study did not correlate with Baydas [21] who found no statistically significant differences between males and females in gonial angle and antegonial depth .This was not consistent with our study since our study showed significant differenence in gonial angle and antegonial depth.

Our results correlate with Dutra *et al*., [22] who concluded that males had significantly smaller values of antegonial angle than females and males have higher values of antegonial depth than female. This was consistent with our study. In our study, mean values of antegonial angle in males were 152.40± 12.14595 and in females were 159.94 ± 7.67674.

Our results were consistent with Chole *et al*., [23] who concluded that males had significantly smaller antegonial angle and antegonial depth than females. In our study, males had smaller antegonial angle and higher antegonial depth than females.

Giles [24] measured mandibles of known sex using anthropometric measurements in American Whites and Negroes and reported that mandibular ramus height, maximum ramus breadth and minimum ramus breadth are highly significant with an accuracy of 85%. Our study was consistent with this study since all these paramaters are significant the mean values of projective height of ramus in males (74.4057±5.43548) were higher than females (66.2315±5.60217). The mean values of maximum ramus breadth were higher in males (45.3092±4.06995) than females (43.0910± 3.59791). The mean values of minimum ramus breadth were higher in males (33.2252±.50578) than females (31.5619±3.12655).

Our results were consistent with Dayal *et al*., [21] who reported mandibular ramus height to be the best parameter in the study, since our study showed significant difference between males and females.

Saini *et al*., [3] conducted a study on dry adult mandibles in Northern part of India and found that ramus expressed strong sexual dimorphism in that population, the best parameters were coronoid height, condylar height and projective height of ramus and breadth measurements were not very dimorphic study in their sample. But in our study breadth measurements were also showed dimorphism.

In the present study the mean values SM-IB was found to be higher in males (17.9864±1.63099) than females (15.9901±1.41340) and the mean values of IM-IB were found to be higher in males (14.8795±3.33484) than females (12.9411+1.32816). Our study was consistent with the study done by Thomas *et al*., [25] and Catovie *et al*., [26] and Moni Thakur *et al*., [27]. Our study was not consistent with the study done by Vodanovic[14]since in his study he concluded that IM-IB does not show sexual dimorphism. In our study IM-IB was significant.

In the present study, the mean values of the height of the mandible were significantly higher in males (33.2379±3.4526) than females (30.6157±3.4666).These studies were consistent with Cagri Ural *et al*., [13], Ortman *et al*., [28] and Moni Thakur *et al*., [27].

In the present study, the mean values of maximum ramus breadth, minimum ramus breadth, condylar height, projective height of ramus, coronoid height, height of mandible, superior margin of mental foramen to inferior border, inferior margin of mental foramen to inferior border and antegonial depth were found to be higher in males (Group A) than females (Group B).Whereas Gonial angle, antegonial angle were found to be higher in females (Group A) than males (Group B).

In our study variations between different age groups of the following parameters were also analysed. There was no statistically difference between different age groups.

In our present study, among the twelve parameters, projective height of the ramus showed highest significant difference. The mean values of superior margin to alveolar crest did not show any significance. In our study variations between different age groups of the following parameters were also analysed. There was no statistically difference between different age groups.

In our present study, among the twelve parameters, projective height of the ramus showed highest significant difference. The mean values of superior margin to alveolar crest did not show any significance.

Conclusion

This study was conducted to determine gender variations in various morphometric parameters in the mandible, in male and female patients in 200 subjects, using digital panoramic radiographs The highest significant difference was found in projective height of ramus. The mean values of superior margin of mental foramen to alveolar crest did not show significance.

We found that mandibular measurements using panoramic radiographs were reliable for gender determination. According to the results obtained from our study we conclude that the projective height of the ramus is the most significant and reliable of all the parameters, which may be used for gender determination using the mandible. However we believe further studies involving more sample size would be useful in reinforcing the findings of our study.

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