Original Article

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Mandibular Ramus as Dimorphic Tool in Age and Sex Determination-A Cross Sectional Radio-Anthropometric Study on Digital Panoramic Radiograph

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Abstract

Objective: This research article focuses on prediction of age on the basis of maximum ramus breadth, minimum ramus breadth, condylar height, projective height of ramus and coronoid height. (Linear regression analysis). However it also determine sex of individual on the basis of discriminant function analysis using Fischer exact test using maximum ramus breadth, minimum ramus breadth, condylar height, projective height of ramus and coronoid height. *Material and Methods:* The orthopantomograms of 200 subjects were taken from planmeca promax-dimax4 OPG machine at 66 Kvp, 8mA and exposure time 16 sec. All the measurements are done on digital orthopantomograms using planmeca Romexis 3.2.0R software. The measurements of the mandibular ramus will be subjected to Discriminant function analysis. *Results:* The study sample consists of 200 subjects aged between 8 to 82 years with a mean age of 38.21±17.12 years. The persons correlation coefficient (r) between age and minimum ramus breadth was not significant correlation however the maximum ramus breadth, condylar height, coronoid height and projective height were directly associated with age and demonstrate a significant positive relation in maximum ramus breadth, condylar height, coronoid height and significant positive relation in projective height. The maximum ramus breadth, min ramus breadth, condylar height, coronoid height and projective height values were greater in males than females. The difference in maximum ramus breadth, minimum ramus breadth, condylar height, coronoid height and projective height values in males and females were statistically significant ($P<0.05$). *Conclusion:* Mandibular ramus can be a useful tool for age and sex determination in forensic science.Thus medicolegal cases having age and sex issues can be resolved with measurements of mandibular ramus if panoramic radiograph is available.

Keywords: Mandibular Ramus; Ramus Breadth; Condylar Height; Projective Height of Ramus and Coronoid Height.

Introduction

Dentofacial radiography has become a routine procedure in the dental, medical and hospital clinics.Where in radiographs are taken at different periods during the lifetime of large segments of the population [1] .Whereas the determination of sex is an important aspect of forensic anthropology and vital in medicolegal investigations. Among various measures mandibular ramus can be used to differentiate between male and female strongly expresses univariate sexual dimorphism. When skeletal sex determination is considered, metric analyses on the radiographs are often found to be of superior value owing to their objectivity, accuracy and reproducibility.

Mandible is the largest, strongest and movable part of the skull. Mandible identification is important in medicolegal and anthropological work [2]. The teeth along with skull are best preserved part of human remains. Sex can be more accurately determined after the attainment of puberty. The differences are well marked in bony pelvis and skull. Mandible next to the pelvis in human remains will help us in identification of age, sex and race [3,4]. To evaluate the mandibular angle and to analyze the relationship of the angle and height and breadth

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of the ramus of the mandible to the gender so as to study its role in the anthropological diagnosis [5]. Sex determination based only on characteristics of teeth and their supporting structures had been a difficult task where as X-ray examination of the mandible gives definitive information about the sex. The mandibular condyles are smaller in females. By radiological examination sex determination of skull is possible to the extent of 88 percent [6]. Mandible and its variations in age, sex and race will help physicians, surgeons, medico-legal authorities and anthropologists to give correct interpretations for the results of diagnostic procedures in living [2,4].

Panoramic radiography is a very popular and most widely accepted that conveniently provides the clinician with a comprehensive view of maxillofacial complex with relatively reduced radiation dose [7,8]. However the limitation being is its inability to confirm the dimensions of the structures shown on the radiographs correspond to real dimensions of the exposed structures [8-10]. The inherent property of panoramic radiographs is magnification and distortion. Distance of the object between the X-ray source and film is responsible for the magnification of the filmed structures. In the sharply depicted layer, the image is free of distortion [9-11].

The identification of human skeletal remains is considered an initial step in forensic investigations and is crucial for further analysis [12]. In the adult skeleton, sex determination is usually the first step of the identification process as 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 [13]. 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 [12,13].

As evident from the earlier studies, skull is the most dimorphic and easily sexed portion of skeleton after pelvis, providing accuracy up to 92%.[12] 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 [12-15]. Presence of a dense layer of compact bone makes it very durable, and hence remains well preserved than many other bones. Dimorphism in mandible is reflected in its shape and size [12]. Male bones are generally bigger and more robust than female bones [13].

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 [16]. Humphrey *et al.* showed that the sites associated with the greatest morphological changes in size and remodeling during growth, mandibular condyle, and ramus in particular are generally the most sexually dimorphic. Measurements of the mandibular 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 [17]. Methods based on measurements and morphometry are accurate and can be used in determination of sex [18].

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 [19]. Rotational panoramic radiography is widely used for obtaining a comprehensive overview of the maxillofacial complex [20]. In forensic anthropology, comparison of antemortem and postmortem radiographs is one of the cornerstones of positive identification of human remains. Antemortem orthopantomograms may be of great value in the identification of human remains [21]. Several studies have been conducted on dry adult mandibles for sex determination [12,15-18], but a literature search did not reveal any studies with regard to measurements on ramus of the mandible using a digital panoramic radiograph.

Materials and Methods

The orthopantomograms of 200 subjects were taken from planmeca promax-dimax4 OPG machine at 66 Kvp, 8mA and exposure time 16 sec. All the measurements are done on digital orthopantomograms using planmeca Romexis 3.2.0R software.The subject was positioned properly in the panoramic machine set up so that the jaws were within the focal trough as per the methodology described by Langland, Langlais and Morris (1982). The subject was made to stand erect with back straight. The height was adjusted by pressing the adjustable knob. The subjects were explained about the working of the machine. The operation of the panoramic machine was demonstrated to the subjects and the subjects were appraised of the need to be still during the procedure.Jacket, sweater and bulky dress materials were removed so that there could be sufficient space between the bottom of the cassette holder and patients shoulder. The subject was made to wear a lead apron and was positioned carefully in the focal through with the help of bite block covered with occlusal disposable envelope and head holder of the machine so that the lower border of mandible was equidistant on each side from the chin support and perpendicular to the Frankfurt horizontal plane.Frankfurt horizontal plane was maintained parallel to the floor of the clinic. The patient's midsagittal plane was positioned in the center of the focal trough of the x-ray unit by asking the patient to bite with his central incisors (upper and lower). The patient was asked to close the lip and place the tongue against the palate. Automatic exposure parameters were selected. After all the adjustments were made, appropriate 66 Kvp and 8mA were selected and exposure were made at 16 sec of exposure time by depressing the control switch of the panoramic machine. The orthopantogram is displayed on console computer. The image is saved and stored in computer. Then image of orthopantogram is opened with inbuilt planmeca Romexis 3.2.0R software for measurement of study parameters. The study parameters are measured using mouse-driven method by moving the mouse and drawing lines using chosen points on the digital panoramic radiograph as follows (Figure 1& Figure 2)-

- 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/maximum ramus 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.

Statistical Analysis

Categorical variables will be presented in number and percentage (%) and continuous variables will be presented as mean and SD. Qualitative variables will be compared using Chi-Square test /Fisher's exact test as appropriate. The data were analyzed by the discriminant function analysis using Fischer exact test. Pearson correlation coefficients were used to determine the relationship between two scale parameters, while correlation was defined as a measure of the strength of a linear relationship between two variables. A p value of <0.05 will be considered statistically significant. The data will be entered in MS EXCEL spreadsheet and analysis will be done using Statistical Package for Social Sciences (SPSS) version 21.0.

Results

The study sample consists of 200 subjects aged between 8 to 82 years with a mean age of 38.21±17.12 years (Table 1). Majority of the study subjects were between 18 to 35 years of age(Table 2). The sex ratio in our study population showed that male patient proportion was higher than female i.e. 51.0 % and 49.0% respectively (Table 3). The pearsons correlation coefficient (r) between age and minimum ramus breadth shows no obvious significant correlation(r=-.040) however the maximum ramus breadth, condylar height, coronoid height and projective height were directly associated with age and demonstrate a significant positive relation in Maximum ramus breadth(r=0.182, p=0.010), condylar height(r=0.192, p=0.006), coronoid height(r=0.274, p=<0.001) and significant positive relation in projective height(r=0.193, p=0.006) (Table 4). On the basis of strong positive correlation between maximum ramus breadth, condylar height, coronoid height and projective height and age it was concluded that age plays an important role in determination of maximum ramus breadth, condylar height, coronoid height and projective height. The linear regression analysis has been done for all parameters in relation to age and mathematical equation derived are used in prediction of age if value of any study parameter is known (Figure 1,2,3,4). Table 5 shows the mean comparison of study parameters according to gender of study population using discriminant function analysis and Fisher exact test. Higher mean values were observed in male population in comparision to females i.e the maximum ramus breadth, min ramus breadth, condylar height, coronoid height and projective height values were greater in males than females. The difference in maximum ramus breadth, minimum ramus breadth, condylar height, coronoid height and projective height values in males and females were statistically significant (P<0.05). The standard deviation was greater in females than males. The F-statistic values indicated that highest sexual dimorphism was seen with condylar height and least with minimum ramus width. The sex could be determined from calculations using the equations given below(Table 6).

D of Male: 82.455+ 1.173 (Max Ramus breadth) + .315 (Min Ramus breadth) - 0.569 (Condylar Height)+ .802 (Coronoid Height) + 1.345 (Projective Height)

D of Female: 73.158+ 1.075 (Max Ramus breadth) + .320 (Min Ramus breadth) - 0.732 (Condylar Height)+ .772 (Coronoid Height) + 1.435 (Projective Height)

The sex was accurately determined in 74 cases out of 102 male mandibular measurements with prediction accuracy rate of 72.5% and sex was accurately determined in 66 cases out of 98 female mandibular measurements with an accuracy rate of 67.3%.

Table 1: Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Age	200	74	8	82	38.98	17.116

Table 2:

Age Intervals	N	%
<18 years	26	13.0
18 to 35 years	66	33.0
36 to 50 years	60	30.0
51 to 65 years	33	16.5
>65 years	15	7.5
Total	200	100.0

Table 3:

Sex	N	%
Male	102	51.0
Female	98	49.0
Total	200	100.0

Table 4: Pearson correlation with age of study subjects

	Pearson Correlation Coefficients (R)	P value	Equations Derived by Linear Regression Analysis
Max Ramus breadth	.182**	.010	Age =10.320+0.808*(Max Ramus breadth)
Min Ramus breadth	-.040	.574	Age =43.898+(-0.164)*(Min Ramus breadth)
Condylar Height	.192**	.006	Age =10.408+(0.430)*(Condylar Height)
Coronoid Height	.274**	<0.001	Age =(-6.947)+(0.779)*(Coronoid Height)
Projective Height	193**	.006	Age =6.813+(0.440)*(Projective Height)

** Correlation is significant at the 0.01 level (2-tailed)

Table 5:

	Male		Female		F value	P value
	Mean	Std. Deviation	Mean	Std. Deviation		
Max Ramus breadth	36.302	3.7023	34.558	3.8297	10.720	0.001
Min Ramus breadth	30.642	4.7322	29.202	3.3391	6.139	0.014
Condylar Height	69.149	6.9221	63.740	7.4105	28.482	<0.001
Coronoid Height	60.941	5.8306	56.810	5.4894	26.568	<0.001
Projective Height	75.700	6.6853	70.529	7.4265	26.831	<0.001

Table 6: Fisher's linear discriminant functions

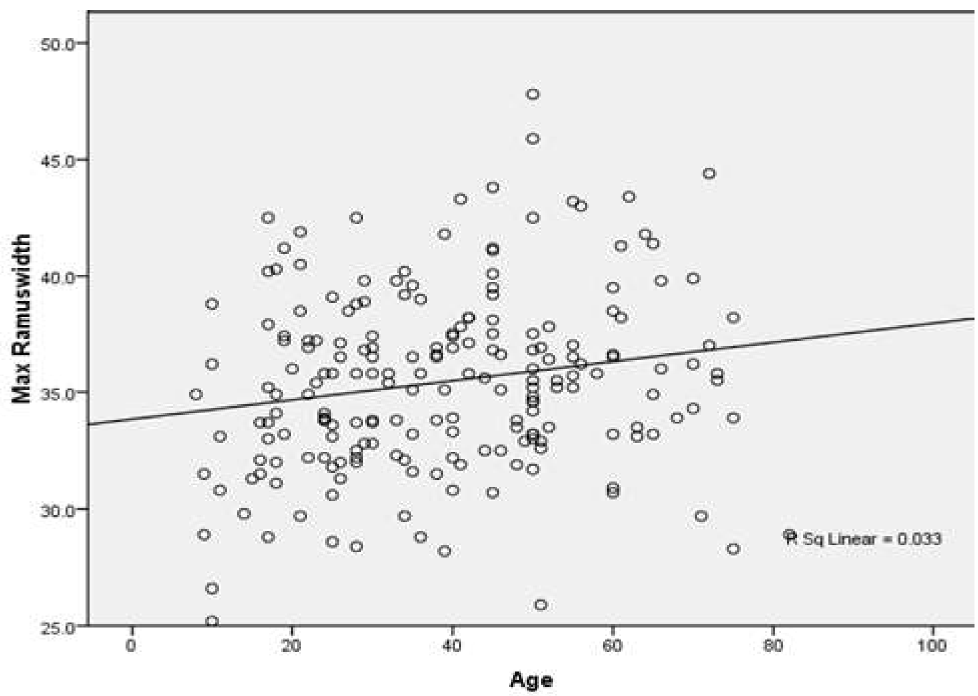
	Sex	
	Male	Female
Max Ramus breadth	1.173	1.075
Min Ramus breadth	.315	.320
Condylar Height	-.569	-.732
Coronoid Height	.802	.772
Projective Height	1.345	1.435
(Constant)	-82.455	-73.158

Table 7: Classification Results[a,b,c]

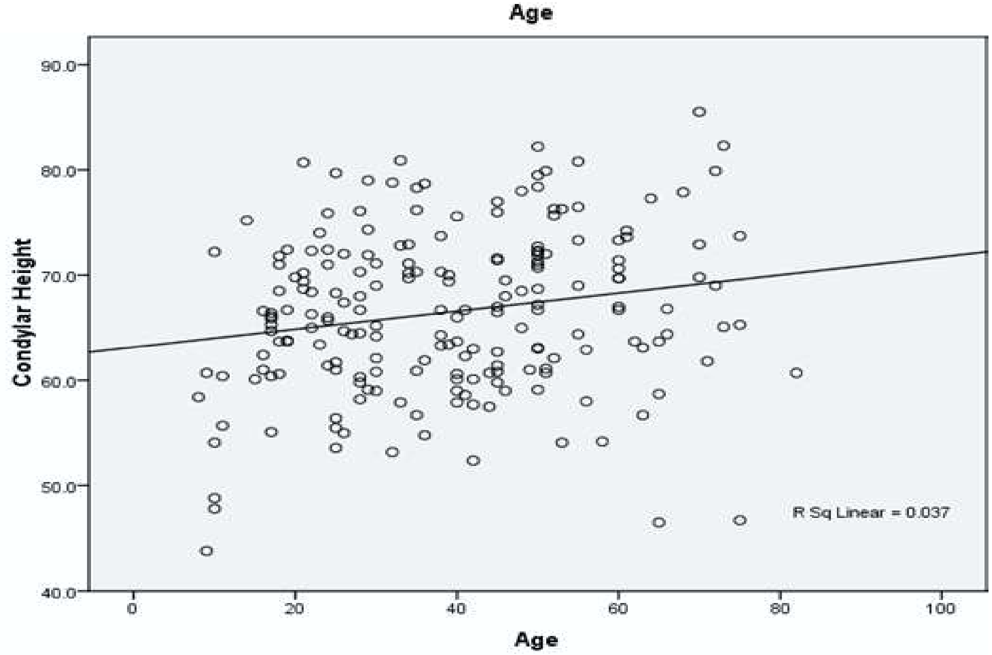
		Sex	Predicted Group Membership		Total
			Male	Female	
Original	Count	Male	74	28	102
		Female	32	66	98
	%	Male	72.5	27.5	100.0
		Female	32.7	67.3	100.0
Cross-validated[a]	Count	Male	72	30	102
		Female	33	65	98
	%	Male	70.6	29.4	100.0
		Female	33.7	66.3	100.0

a. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.
b. 70.0% of original grouped cases correctly classified.
c. 68.5% of cross-validated grouped cases correctly classified.

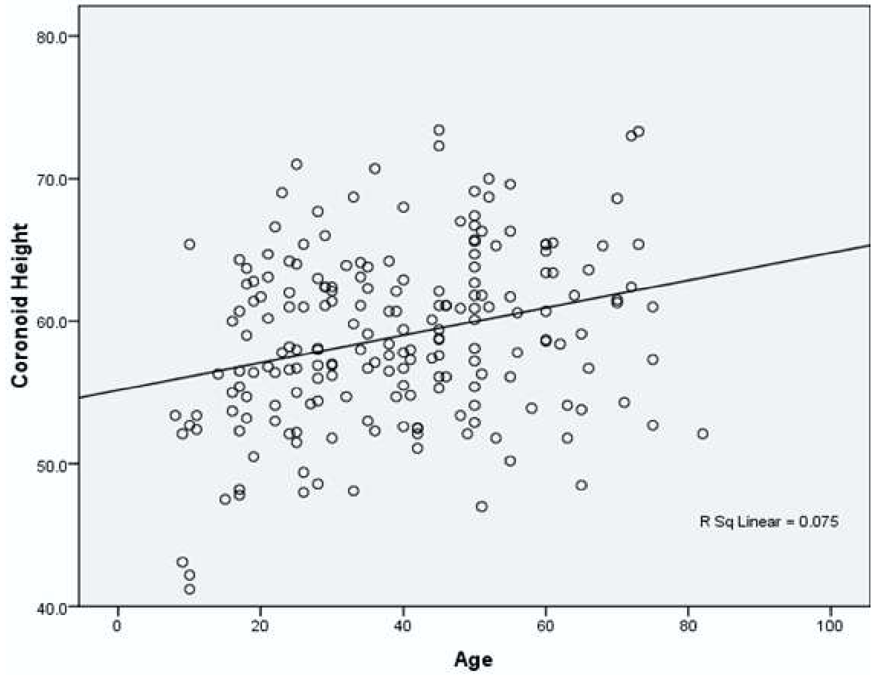
Graph 1:



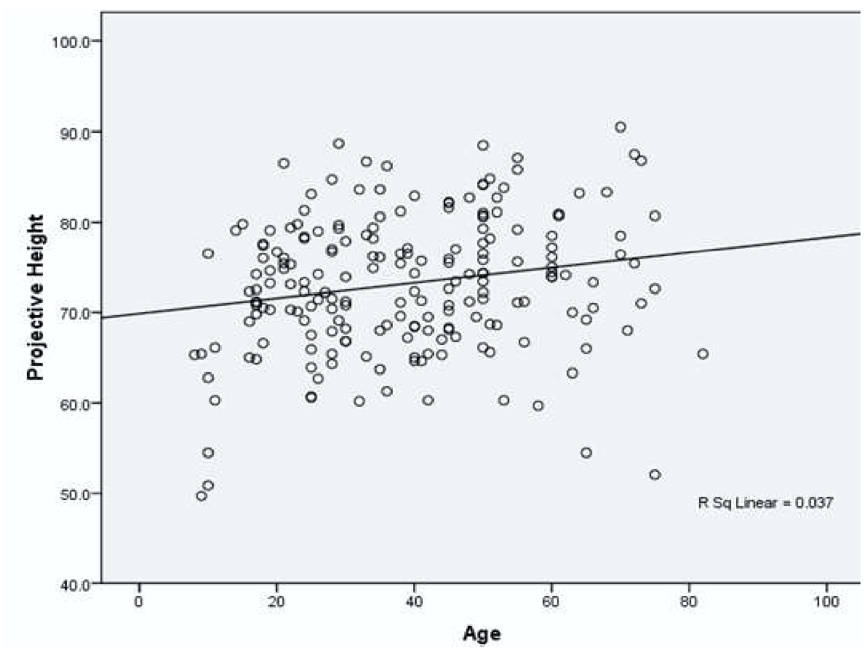
Graph 2:



Graph 3:



Graph 4:



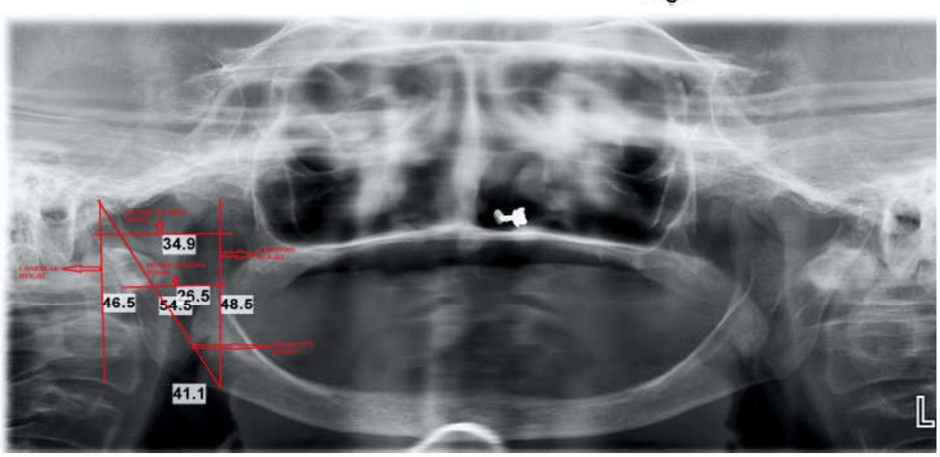


Fig. 1: Measurements of study parameters on right side of mandibular ramus

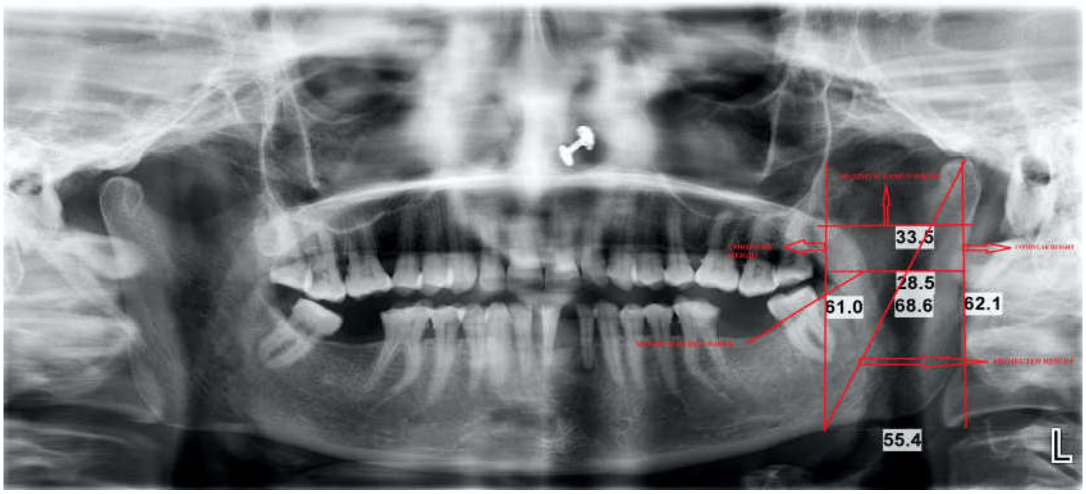


Fig. 2: Measurements of study parameters on left side of mandibular ramus

Discussion

Determination of sex by morphological assessment has remained as one of the oldest approaches in forensic anthropology and medico legal examinations. The method may vary and depend on the available bones and their conditions. The identification of sex is of significance in cases of mass fatality incidents where bodies are damaged beyond recognition. When entire adult skeleton is available for analysis, sex can be determined up to 100% accuracy (pelvis). However 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 [22]. Skull is the most dimorphic and easily remarked portion of skeleton after pelvis. However in cases where intact skull is not found mandible may play a vital role in sex determination as it is the most dimorphic bone of skull. Anthropometry of the face and intraoral regions can help in the field of forensic odontology when common forensic data are unavailable [23]. The disadvantages OPG technique is unequal magnification and geometric distortion which causes many problems.The vertical dimension as compared to the horizontal dimension is little altered. These distortions are the result of the horizontal movement of the film and X ray source [24,25].

A study conducted by Kambylafkas et al [26] concluded that the evaluation of total ramal height is reliable and an asymmetry of more than 6% is an indication of a true asymmetry using panoramic radiograph. Dayal et al [27] found mandibular ramus height to be the best parameter in their study with 75.8% accuracy. A study conducted by Saini et al [28] showed that coronoid height possessed the best potential for sex determination in Indian people with the accuracy of 74.1% and the combination of it with minimum ramus breadth, maximum ramus breadth and/or mandibular ramus length will show significant sexual dimorphism with an overall accuracy of 80.2%. Another study conducted by Indira et al [29] on mandibular ramus measurements were subjected to discriminant function analysis. Each of the five variables measured on mandibular ramus using orthopantomograph showed statistically significant sex differences between sexes indicating that ramus expresses strong sexual dimorphism. The mandibular ramus demonstrated greatest univariate sexual dimorphism in terms of minimum ramus breadth, condylar height, followed by projective height of ramus. Overall prediction rate using all five variables was 76%.

D. N Kawale et al [30] concluded that minimum ramus breadth of mandible in males having mean 3.1346 cm, standard deviation 0.3243,standard error of mean is 0.0463 with values of female mandible have mean 2.9 cm, standard deviation 0.23,standard error of mean 0.0542.The p value is 0.006 which decreases the importance of minimum ramus breadth in sex determination of mandible.He also stated that maximum ramus breadth in males having mean 3.8938 cm, standard deviation 0.335, standard error of mean 0.0478 while in females mean is 3.6666 cm, standard deviation 0.3067 and standard error of mean is 0.0723 and p value is 0.013.He also deduced that maximum ramus height of mandible in males is having mean 6.0061 cm, standard deviation 0.5249 and standard error of mean is 0.0749 while in females mean is 5.0888 cm, standard deviation is 0.3878 and standard error of mean 0.0914. Sexual dimorphism of mandible with help of maximum ramus height is highly significant as p value is 0.000. Skull and pelvis are the exclusively studied bones for determination of sex. Although mandible is a part of skull, it is not investigated as vigorously as the rest of the cranium [31]. Sex differences in the mandible have been described based on traditional morphological and features or statistical analysis of metrical system. However in recent times Franklin *et al* [32] have tried to utilize the principles of geometric morphometric method and data were analyzed using specific software and three-dimensional configuration. While the study appears modern and valuable it requires highly technical and expensive morphometric equipment and therefore the results are less helpful at most of the forensic or anthropologic centers. Consequently it is imperative to use the conventional morphological or anthropometric measurements to arrive at a conclusion.

Giles et al [33] measured mandibles of known sex using anthropometric measurements and reported mandibular ramus height, maximum ramus breadth and minimum ramus breadth as highly significant with an accuracy of 85% in American Whites and Negroes.

Whereas in our study we concluded that the pearsons correlation coefficient (r) between age and minimum ramus breadth shows no obvious significant correlation(r=-.040) however the maximum ramus breadth, condylar height, coronoid height and projective height were directly associated with age and demonstrate a significant positive relation in maximum ramus breadth (r=0.182, p=0.010), condylar height(r=0.192, p=0.006), coronoid height (r=0.274, p=<0.001) and significant positive relation in projective height (r=0.193, p=0.006).

On the basis of strong positive correlation between maximum ramus breadth, condylar height, coronoid height and projective height and age it was concluded that age plays an important vital role in determination of maximum ramus breadth, condylar height, coronoid height and projective height.

We compared the study parameters according to gender of study population using discriminant function analysis and Fisher exact test. We observed higher mean values in males in comparision to females i.e the maximum ramus breadth, minimum ramus breadth, condylar height, coro noid height and projective height values were greater in males than females. The difference in maximum ramus breadth, minimum ramus breadth, condylar height, coronoid height and projective height values in males and females were statistically significant (P<0.05). The standard deviation was greater in females than males. The F-statistic values indicated that highest sexual dimorphism was seen with condylar height and least with minimum ramus width.We accurately determined the sex in 74 cases out of 102 male mandibular measurements with prediction accuracy rate of 72.5% and sex was accurately determined in 66 cases out of 98 female mandibular measurements with an accuracy rate of 67.3%.

Conclusion

Mandibular ramus can be a useful tool for age and sex determination in forensic science.Thus medicolegal cases having age and sex issues can be resolved with measurements of mandibular ramus if panoramic radiograph is available.

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