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Gender Determination by Measuring the Mandibular Ramus and Body of the Mandible: A Retrospective Radiographic Study

Dr. Kirti Saharan ^α, Dr. Shivaprasad S. ^σ & Dr. Ashok L. ^ρ

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Statistical analysis used: The measurements of the mandibular ramus and body were subjected to ROC curve analysis and Bland Altman analysis.

Results: The best parameter in determining gender were the Condylar Height followed by the Coronoid Height and the Projective Height of Ramus. The overall prediction accuracy for mandibular ramus parameters came out to be 80.5% and for the body of the mandible parameter it came out to be 76.7%.

Conclusion: Mandibular ramus has a better potential than the body of the mandible in terms of gender determination.

Keywords: forensic odontology, gender determination, identification, mandibular ramus, digital orthopantomograms, height of the body of mandible.

I. INTRODUCTION

Skeleton has always helped in genetic, anthropological, odontological and forensic investigation of living and dead individuals. Skull bones and pelvis are the most commonly used bones in gender and age determination.¹ The mandible is the most dimorphic and strongest bone of the skull and therefore, it is useful for gender and race determination

in forensic and archaeological cases where intact skull is not found.² Sexual dimorphism in the mandible is noticed in its shape and size. Previous studies have shown that the difference between sexes are generally more significant in the mandibular ramus than the body because the relative development (size, strength, and angulation) of the muscles of mastication affects the gender expression of mandible as the masticatory forces exerted are different for men and women³

Panoramic radiography has been used as an important tool in forensic anthropology and studies have been conducted to make a biometric system for human identification. It is commonly used for obtaining a comprehensive overview of the maxillofacial complex and the image quality of the panoramic radiograph is increased by the digital panoramic radiography. The advantages of digital images are their broad anatomical coverage, low patient exposure, and less time required for image acquisition and the disadvantages are magnification, geometric distortion and positioning errors.^{4,5}

Normally morphological and metric methods are used to estimate the gender of a mandible. The mandibles of males and females are differentiated by their size, chin shape, muscular markings, and gonial angle or flare. Determining sex using metric parameters like condylar breadth, coronoid breadth, gonial breadth, ramus breadth and height, height of the body of mandible, etc. are easy and more reliable compare to traditional non-metric methods.⁶ Therefore, by combining the reliable metric parameters and digital radiography we can get a more accurate gender estimation.

II. AIMS & OBJECTIVES

1. To compare the measurements on the mandibular ramus & body of the mandible and use them in gender determination among various age groups.
2. To measure the width & height of mandibular ramus and height of the body of mandible on digital orthopantomograms among various age groups.

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III. MATERIALS AND METHODS

A retrospective study was conducted on 120 digital orthopantomograms of the Indian individuals, which were later divided into three age groups of age between 21-30 years, 31-40 years and 41-50 years respectively. 40 digital orthopantomograms were taken under each age group consisting of 20 males and 20 females. Ideal Orthopantomograms of the patients with full set of permanent teeth, minimal alveolar bone loss and without any artefacts were included in the study whereas radiographs with developmental disturbances of the skull, mandibular deformities, pathologies, fractures and distorted digital images were excluded from the study.

The Digital OPG images that was obtained using PLANMECA PROLINE XC machine were measured using PLANMECA ROMEXIS 2.3.1.R software. The following measurements were taken on the right side of OPG's digitally (Fig.1 & Fig.2):

1. *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.
2. *Minimum ramus breadth*: Smallest anterior-posterior diameter of the ramus.
3. *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.
4. *Projective height of ramus*: Projective height of ramus between the highest point of the mandibular condyle and lower margin of the bone.

5. *Coronoid height*: Projective distance between coronion and lower wall of the bone.⁷
6. *Height of the body of mandible*: The distance from the inferior surface of the mandibular body to the height of the alveolar crest.

To eliminate the inter-observer variations and determination of reliability and reproducibility of the measurements, the images were evaluated by two qualified Oral Radiologist under standard conditions in a semi-dark room with ambient light & using magnifying lens icon.

IV. STATISTICAL ANALYSIS

Mean comparison between the age groups were done using Independent Student t-test. ANOVA test was used to compare the difference in the means of three groups for individual parameter for both the observers. ROC (Receiver operating characteristic) curve analysis was used to estimate the cut-off value for males and females, sensitivity and specificity for individual parameters among various age groups. This analysis has not been done in the literature before for similar kind of studies. Bland Altman analysis was used estimating agreement between observer 1 and observer 2.

V. RESULTS

Statistical analysis showed that each variable was a significant predictor in classifying a given sample ($P < 0.001$). The mean values for all the measurements were higher for the males as compared to the females. (Table 1)

Table 1: Total Mean and Standard Deviation for All the Parameters among Males and Females (Observer 1 & 2)

Parameters	Sex	Sample Size	Ob 1			Ob 2		
			Mean (mm)	Std. Deviation (mm)	P-Value	Mean (mm)	Std. Deviation (mm)	P-Value
Maximum Ramus Breadth	M	60	37.2	2.79	0.027	37.9	2.68	0.131
	F	60	34.3	2.80	0.075	34.6	2.86	0.310
Minimum Ramus Breadth	M	60	29.0	2.14	0.810	28.0	2.12	0.883
	F	60	27.3	2.58	0.342	26.3	2.48	0.383
Condylar Height	M	60	62.9	4.11	0.293	62.8	4.10	0.343
	F	60	55.9	3.14	0.109	56.0	3.02	0.165
Projective Height of Ramus	M	60	60.7	4.17	0.171	60.8	4.10	0.310
	F	60	54.0	3.55	0.168	53.9	3.47	0.321
Coronoid Height	M	60	56.7	4.45	0.963	56.2	4.35	0.911
	F	60	50.2	2.88	0.756	49.8	2.87	0.546
Height of the Body of Mandible	M	60	28.9	2.40	0.635	28.8	2.50	0.776
	F	60	26.0	2.09	0.821	25.9	2.18	0.884

The Bland & Altman analysis for inter-observer agreement showed statistically significant evidence of agreement between both the observers.

According to ROC curve analysis the decreasing order of various parameters for the sensitivity for cut-off values in males and females was:

Projective Height of Ramus > Condylar Height > Minimum Ramus Breadth = Coronoid Height > Maximum Ramus Breadth > Height of the Body of Mandible.

The decreasing order of various parameters for the specificity for cut-off values in males and females was: Height of the Body of Mandible > Coronoid Height > Condylar Height > Projective Height of Ramus > Maximum Ramus Breadth > Minimum Ramus Breadth.

The decreasing order of various parameters on mandibular ramus and body according to prediction accuracy was: Condylar Height > Coronoid Height = Projective Height of Ramus > Height of the Body of Mandible > Maximum Ramus Breadth > Minimum Ramus Breadth.

The overall prediction accuracy for mandibular ramus parameters came out to be 80.5% whereas the overall prediction accuracy for mandibular body parameter came out to be 76.7%.

VI. DISCUSSION

In the present study a total of six parameters were measured namely; maximum ramus breadth, minimum ramus breadth, condylar height, projective height of ramus, coronoid height and height of the body of mandible which were similar to the study carried out by *Saini V et al.*⁷ (2011), *Indira AP et al.*⁴ (2012), *Samantha K et al.*⁸ (2016), *Sairam V et al.*⁹ (2016), *Jambunath U et al.*¹⁰ (2016), *Kartheeki B et al.*¹¹ (2017).

1. Maximum ramus breadth

In the present study, the average cut-off point for Maximum Ramus Breadth in males and females of all the groups came out to be 34.9mm which was similar to that in the study conducted by *Sikka A et al.*¹² (2016) in which it was 35mm and lesser than the cut-off point taken in the study conducted by *Vinay G et al.*¹³ (2013) in which it was 39.5mm.

In the present study, the accuracy of Maximum Ramus Breadth for males was 83.3% and for females was 66.7% which was greater than in the study conducted by *Vinay G et al.*¹³ (2013) in which it was 72.08% for males and 63.64% for females. It was also greater than the male accuracy and lesser than the female accuracy in the study conducted by *Dong H et al.*⁶ (2015) in which it was 69.8% and 76.6%. The combined accuracy for Maximum Ramus Breadth was 75% which was greater than in the study done by *Saini V et al.*⁷ (2011) in which it was 65.3% and *Dong H et al.*⁶ (2015) in which it was 73.4%.

2. Minimum ramus breadth

In the present study, the average cut-off point for Minimum Ramus Breadth in males and females of all the groups came out to be 27.1mm which was lesser than the cut-off point taken in the study conducted by *Saini V et al.*⁷ (2011) and *Vinay G et al.*¹³ (2013) in which it was 30.5mm.

In the present study, the accuracy of Minimum Ramus Breadth for males was 85% and for females was 55% which was greater than the male accuracy and lesser than the female accuracy noted in the study conducted by *Vinay G et al.*¹³ (2013) in which it was 68.18% for males and 62.12% for females. The combined accuracy for Minimum Ramus Breadth was 70% which was greater than in the study done by *Saini V et al.*⁷ (2011) in which it was 63.2%.

3. Condylar height

In the present study, the average cut-off point for Condylar Height in males and females of all the groups came out to be 57.7mm which was lesser than the cut-off point taken in the study conducted by *Datta A et al.*¹⁵ (2015) in which it was 61.5mm and greater than the cut-off point taken in the study conducted by *Franklin D et al.*¹⁶ (2008) in which it was 53.8mm. But it was similar to the cut-off value given by *Saini V et al.*⁷ (2011) in which it was 57.6mm.

In the present study, the accuracy of Condylar Height for males was 93.3% and for females was 81.7% which was nearly similar to the accuracy noted in the study conducted by *Datta A et al.*¹⁵ (2015) in which it was 96% for males and 84% for females. But our accuracy was greater than the accuracy noted in the study conducted by *Saini V et al.*⁷ (2011) in which it was 73.9% of males and 66.7% for females, *Dong H et al.*⁶ (2015) in which it was 72.9% for males and 80.4% for females. The combined accuracy for Condylar Height was 87.5% which was greater than in the study done by *Franklin D et al.*¹⁶ (2008) in which it was 73.8%, *Saini V et al.*⁷ (2011) in which it was 72.4% and *Dong H et al.*⁶ (2015) in which it was 76.8%.

4. Projective height of ramus

In the present study, the average cut-off point for Projective Height of Ramus in males and females of all the groups came out to be 55.6mm which was greater than the cut-off point taken in the study conducted by *Saini V et al.*⁷ (2011) in which it was 50.7mm and also greater than the cut-off point taken in the study conducted by *Datta A et al.*¹⁵ (2015) in which it was 50.1mm.

In the present study, the accuracy of Projective Height of Ramus for males was 95% and for females was 75% which was greater than the accuracy noted in the study conducted by *Saini V et al.*⁷ (2011) in which it was 65.2% for males & 79.2% for females and also greater than the male accuracy in the study conducted by *Wankhede KP et al.*¹⁷ (2015) in which it was 76.4% but lesser than the female accuracy which was 81.5%. The combined accuracy for Projective Height of Ramus was 85% which was greater than in the study done by *Saini V et al.*⁷ (2011) in which it was 68.1% and *Wankhede KP et al.*¹⁷ (2015) in which it was 78%.

5. Coronoid height

In the present study, the average cut-off point for Coronoid Height in males and females of all the groups came out to be 52.8mm which was lesser than the cut-off point taken in the study conducted by *Saini V et al.¹⁷ (2011)* in which it was 58.3mm and also lesser than the cut-off point taken in the study conducted by *Datta A et al.²⁵ (2015)* in which it was 56.7mm. But our value is somewhat near to the value given in the study conducted by *Franklin D et al.¹⁶ (2008)* in which it was 55.5mm

In the present study, the accuracy of Coronoid Height for males was 83.3% and for females was 86.7% which was greater than the accuracy noted in the study conducted by *Saini Vet al.⁷ (2011)* in which it was 73.9% for males & 75% for females. But it was lesser than the male accuracy and greater than the female accuracy in the study conducted by *Datta A et al.¹⁵ (2015)* in which it was 84% for both males and females. The combined accuracy for Coronoid Height was 85% which was greater than in the study done by *Franklin D et al.¹⁶(2008)* in which it was 73.3% and *Saini V et al.⁷ (2011)* in which it was 74.1%.

6. Height of the body of mandible

In the present study, the average cut-off point for the Height of the Body of Mandible in males and females of all the groups came out to be 28.3mm which was greater than the cut-off point taken in the study conducted by *Sikka A et al.¹² (2016)* in which it was 23.0mm and almost close to the cut-off point taken in the study conducted by *Datta A et al.¹⁵ (2015)* and *Wankhede KP et al.¹⁷ (2015)* in which it was 25.7mm.

In the present study, the accuracy of the Height of the Body of Mandible for males was 63.3% and for females was 90%. It was lesser than the male accuracy and greater than the female accuracy noted in the study conducted by *Wankhede KP et al.¹⁷ (2015)* & *Datta A et al.¹⁵ (2015)* in which it was 70.9% & 88% for males & 51.9% & 76% for females. The combined accuracy for the Height of the Body of Mandible was 76.7% which was greater than in the study done by *Saini V¹⁴ (2013)*, *Wankhede KP et al.¹⁷ (2015)* and *Sikka A et al.¹² (2016)* in which it was 67.4%, 64.6% and 69.2%.

In the present study, the highest sexual dimorphism was seen with Condylar Height followed by Projective Height of Ramus and Coronoid Height which was similar to the study conducted by *Indira AP et al.⁴ (2012)* & *Kartheeki B et al.¹¹ (2017)* in which all variables showed strong sexual dimorphism with the mandibular ramus in terms of condylar height, coronoid height followed by projective height of ramus. In the present study least sexual dimorphism was noticed with the Minimum Ramus Breadth similar to the study conducted by *Saini V et al.⁷ (2011)* and *Samantha K et al.⁸ (2016)*.

In the present study, the overall prediction accuracy for Mandibular Ramus parameters in males was 88% and in females was 73% with a combined accuracy of 80.5% which was almost similar to the study conducted by *Saini V et al.⁷ (2011)* the overall prediction rate using five variables was 80.2% and also similar to the study conducted by *Kartheeki B et al.¹¹ (2017)* where overall prediction rate using all the five variables was 80.4%.

The overall prediction accuracy for the Height of the Body of Mandible in males was 63.3% and in females was 90% with a combined accuracy of 76.7%. This proved that the Mandibular Ramus parameters are more significant than the Height of the Body of Mandible measurement parameter in determining gender on the digital orthopantomograms.

Limitations of the present study are the inability to reliably estimate gender in the sub-adult range, edentulous patients, and severely deformed mandibular ramus.

VII. CONCLUSION

In conclusion, the ramus of the mandible has a better potential than the body of the mandible in determination of sex. However, larger sample size and more diverse population would enhance the reliability of this parameter.

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Table 2: Cut-Off Value for Males, Sensitivity and Specificity for Maximum Ramus Breadth in Various Age Groups (Observer 1 & 2)

Age Groups (years)	Ob 1			Ob 2		
	Cut off value (mm)	Sensitivity	Specificity	Cut off value (mm)	Sensitivity	Specificity
Group I (21-30)	> 34.5	70%	75%	> 36.5	70%	90%
Group II (31-40)	> 36.9	75%	85%	> 37	90%	70%
Group III (41-50)	> 33.4	100%	40%	> 36.9	55%	90%

Table 3: Cut-Off Value for Males, Sensitivity and Specificity for Minimum Ramus Breadth in Various Age Groups (Observer 1 & 2)

Age Groups (years)	Ob 1			Ob 2		
	Cut off value (mm)	Sensitivity	Specificity	Cut off value (mm)	Sensitivity	Specificity
Group I (21-30)	> 27.5	80%	75%	> 26.2	85%	65%
Group II (31-40)	> 26	100%	25%	> 28.5	45%	90%
Group III (41-50)	> 27.9	70%	65%	> 26.8	70%	65%

Table 4: Cut-Off Value for Males, Sensitivity and Specificity for Condylar Height on Right Side in Various Age Groups (Observer 1 & 2)

Age Groups (years)	Ob 1			Ob 2		
	Cut off value (mm)	Sensitivity	Specificity	Cut off value (mm)	Sensitivity	Specificity
Group I (21-30)	> 56.4	95%	80%	> 59.2	85%	95%
Group II (31-40)	> 60.1	85%	90%	> 60	80%	95%
Group III (41-50)	> 56.6	100%	75%	> 56.7	95%	80%

Table 5: Cut-Off Value for Males, Sensitivity and Specificity for Projective Height of Ramus on Right Side in Various Age Groups (Observer 1 & 2)

Age Groups (years)	Ob 1			Ob 2		
	Cut off value (mm)	Sensitivity	Specificity	Cut off value (mm)	Sensitivity	Specificity
Group I (21-30)	> 55.6	95%	80%	> 55.6	95%	80%
Group II (31-40)	> 57.3	90%	80%	> 58.8	75%	90%
Group III (41-50)	> 53.8	100%	65%	> 53.7	100%	70%

Table 6: Cut-Off Value for Males, Sensitivity and Specificity for Coronoid Height on Right Side in Various Age Groups (Observer 1 & 2)

Age Groups (years)	Ob 1			Ob 2		
	Cut off value (mm)	Sensitivity	Specificity	Cut off value (mm)	Sensitivity	Specificity
Group I (21-30)	> 51	100%	75%	> 51.5	100%	75%
Group II (31-40)	> 53	80%	85%	> 53	85%	85%
Group III (41-50)	> 54.3	70%	100%	> 52.5	80%	90%

Table 7: Cut-Off Value for Males, Sensitivity and Specificity for Height of the Body of Mandible on Right Side in Various Age Groups (Observer 1 & 2)

Age Groups (years)	Ob 1			Ob 2		
	Cut off value (mm)	Sensitivity	Specificity	Cut off value (mm)	Sensitivity	Specificity
Group I (21-30)	> 28.7	50%	100%	> 25.8	90%	55%
Group II (31-40)	> 28.2	65%	90%	> 25.9	90%	55%
Group III (41-50)	> 27.9	75%	80%	> 28.3	65%	90%

Table 8: Bland & Altman Analysis for Inter-Observer Agreement for Maximum Ramus Breadth among Various Age Groups

Age Groups (years)	Sample Size	Arithmetic Mean (mm)	95% Confidence Interval (mm)	Lower limit (mm)	95% Confidence Interval (mm)	Upper Limit (mm)	95% Confidence Interval (mm)	p-value
Group I (21-30)	40	-1.03	-1.37 to -0.69	-3.11	-3.70 to -2.53	1.05	0.47 to 1.64	< 0.0001
Group II (31-40)	40	-0.32	-0.72 to 0.09	-2.79	-3.48 to -2.09	2.16	1.46 to 2.85	0.122
Group III (41-50)	40	-0.07	-0.49 to 0.35	-2.63	-3.35 to -1.91	2.49	1.77 to 3.20	0.727

Table 9: Bland & Altman Analysis for Inter-Observer Agreement for Minimum Ramus Breadth among Various Age Groups

Age Groups (years)	Sample Size	Arithmetic Mean (mm)	95% Confidence Interval (mm)	Lower limit (mm)	95% Confidence Interval (mm)	Upper Limit (mm)	95% Confidence Interval (mm)	p-value
Group I (21-30)	40	0.94	0.73 to 1.14	-0.32	-0.67 to 0.04	2.19	1.83 to 2.54	< 0.0001
Group II (31-40)	40	0.91	0.76 to 1.07	-0.04	-0.31 to 0.23	1.87	1.60 to 2.14	< 0.0001
Group III (41-50)	40	1.06	0.87 to 1.25	-0.12	-0.45 to 0.21	2.24	1.91 to 2.57	< 0.0001

Table 10: Bland & Altman Analysis for Inter-Observer Agreement for Condylar Height among Various Age Groups

Age Groups (years)	Sample Size	Arithmetic Mean (mm)	95% Confidence Interval (mm)	Lower limit (mm)	95% Confidence Interval (mm)	Upper Limit (mm)	95% Confidence Interval (mm)	p-value
Group I (21-30)	40	-0.22	-0.66 to 0.22	-2.93	-3.69 to -2.16	2.49	1.73 to 3.25	0.326
Group II (31-40)	40	0.15	-0.20 to 0.49	-1.98	-2.58 to -1.38	2.28	1.68 to 2.87	0.396
Group III (41-50)	40	0.06	-0.36 to 0.47	-2.49	-3.20 to -1.77	2.61	1.89 to 3.32	0.781

Table 11: Bland & Altman Analysis for Inter-Observer Agreement for Projective Height of Ramus among Various Age Groups

Age Groups (years)	Sample Size	Arithmetic Mean (Mm)	95% Confidence Interval (Mm)	Lower Limit (Mm)	95% Confidence Interval (Mm)	Upper Limit (Mm)	95% Confidence Interval (Mm)	p-Value
Group I (21-30)	40	-0.23	-0.56 To 0.10	-2.24	-2.80 To -1.67	1.78	1.22 To 2.35	0.168
Group II (31-40)	40	0.30	0.10 To 0.49	-0.89	-1.23 To -0.56	1.48	1.15 To 1.82	0.004
Group III (41-50)	40	-0.12	-0.54 To 0.31	-2.72	-3.45 To -1.99	2.49	1.76 To 3.22	0.587

Table 12: Bland & Altman Analysis for Inter-Observer Agreement for Coronoid Height among Various Age Groups

Age Groups (years)	Sample Size	Arithmetic Mean (mm)	95% Confidence Interval (mm)	Lower limit (mm)	95% Confidence Interval (mm)	Upper Limit (mm)	95% Confidence Interval (mm)	p-value
Group I (21-30)	40	-0.01	-0.28 to 0.27	-1.72	-2.20 to -1.24	1.71	1.23 to 2.19	0.971
Group II (31-40)	40	0.61	0.33 to 0.90	-1.14	-1.63 to -0.65	2.36	1.87 to 2.85	0.0001
Group III (41-50)	40	0.65	0.37 to 0.92	-1.03	-1.50 to -0.56	2.32	1.85 to 2.79	< 0.0001

Table 13: Bland & Altman Analysis for Inter-Observer Agreement for Height of the Body of Mandible among Various Age Groups

Age Groups (years)	Sample Size	Arithmetic Mean (mm)	95% Confidence Interval (mm)	Lower limit (mm)	95% Confidence Interval (mm)	Upper Limit (mm)	95% Confidence Interval (mm)	p-value
Group I (21-30)	40	-0.01	-0.12 to 0.09	-0.66	-0.84 to -0.48	0.63	0.45 to 0.82	0.812
Group II (31-40)	40	0.18	-0.02 to 0.38	-1.02	-1.36 to -0.68	1.38	1.04 to 1.72	0.071
Group III (41-50)	40	0.13	-0.00 to 0.27	-0.68	-0.91 to -0.45	0.95	0.72 to 1.18	0.051

Table 14: Prediction Accuracy for Various Parameters on Mandibular Ramus and Body Among Males and Females of Various Age Groups (Observer 1 & 2)

S.No.	PARAMETERS	Ob 1			Ob 2		
		Males	Females	Total	Males	Females	Total
1.	Maximum Ramus Breadth	83.3%	66.7%	75%	73.3%	83.3%	78.3%
2.	Minimum Ramus Breadth	85%	55%	70%	68.3%	75%	71.7%
3.	Condylar Height	93.3%	81.7%	87.5%	90%	90%	90%
4.	Projective Height of Ramus	95%	75%	85%	90%	81.7%	85.8%
5.	Coronoid Height	83.3%	86.7%	85%	88.3%	83.3%	85.8%
6.	Height of the Body of Mandible	63.3%	90%	76.7%	81.7%	68.3%	75%

Table 15: Comparison of Prediction Accuracy for Various Parameters on Mandibular Ramus and Body of the Mandible among Males and Females of Various Age Groups (Observer 1 & 2)

S.No.	PARAMETERS	Ob 1			Ob 2		
		Males	Females	Total	Males	Females	Total
1.	Mandibular Ramus	88%	73%	80.5%	82%	82.7%	82.3%
2.	Body of the Mandible	63.3%	90%	76.7%	81.7%	68.3%	75%

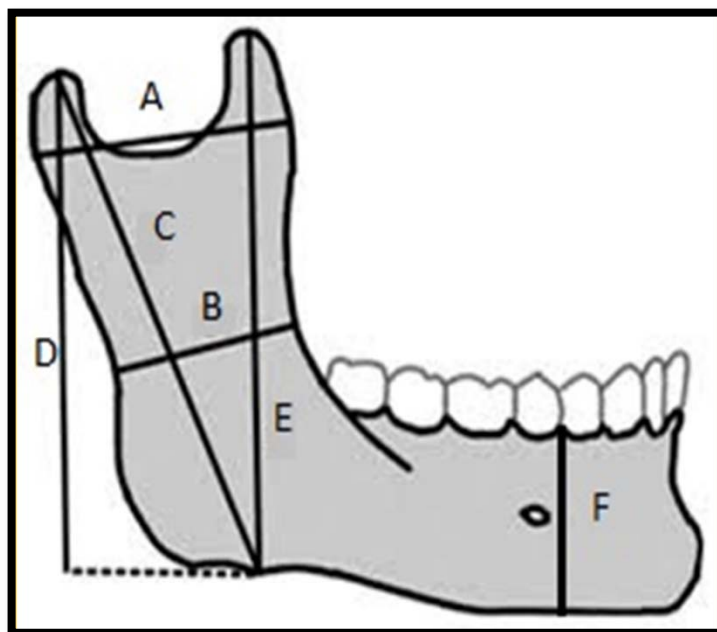


Fig. 1: Image showing measurement from the reference lines drawn from the anatomic landmarks of the mandible. (Diagram showing mandibular ramus measurements adapted from Saini et al. (17))

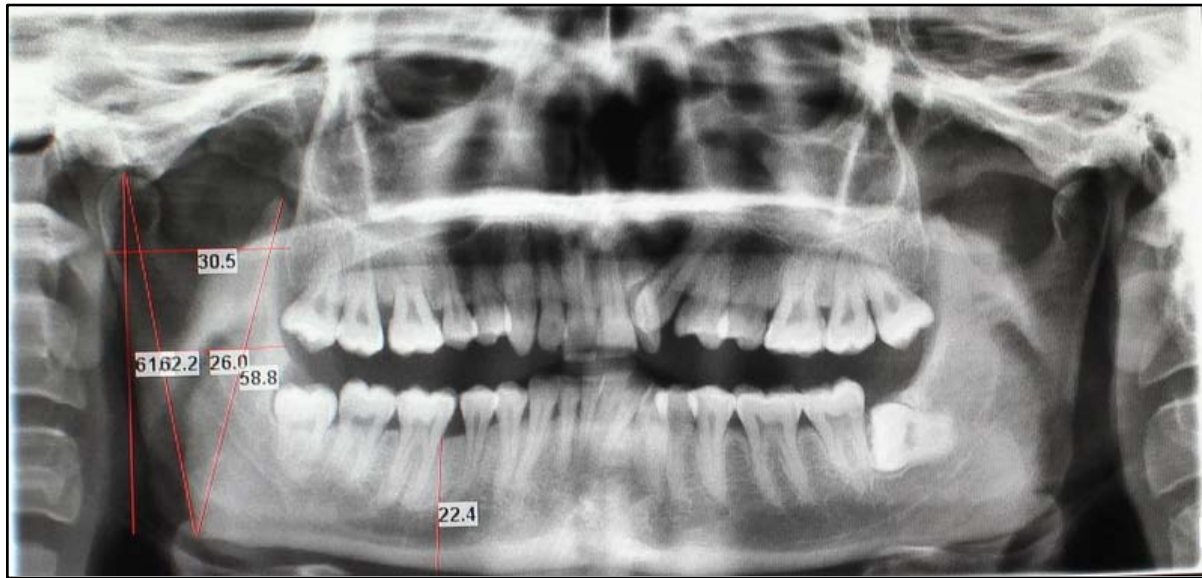


Fig. 2: OPG image showing measurements taken on the right side of the mandible.