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Mandibular ramus- a tool for gender determination. A retrospective study using digital panoramic radiographs

Dave Gunjan T[1], Parikh Neelampari[2]

1 PhD Scholar, Oral Pathology, Gujarat University, Ahmedabad, Gujarat, India

2 Department of Oral and Maxillofacial pathology, Faculty of Dental Sciences, Dharamsinh Desai University, Nadiad, Gujarat, India

Abstract

Gender identification is one of the prefatory procedure of forensic examination. Skull along with mandible is the most sexually dimorphic bone after pelvis and is reliable for gender identification. Mandible is indeed a durable and robust facial bone being often used for anthropological and forensic studies because it retains its shape well over time making a valuable tool for identifying individuals. Being advantageous from various aspects, calibrated panoramic radiographs (OPG) have been employed in this study for performing measurements. The primary objective is to investigate the potential of using linear measurements of left and right side of mandibular ramus on OPG for gender identification within the Gujarat population. Specifically the study aims to assess whether the left or right side of mandibular ramus provides more reliable data for gender identification. Material and method: 193 panoramic radiographs were chosen randomly from archives of Oral Medicine and Radiology Department of Karnavati School of Dentistry, Gandhinagar after obtaining ethical committee clearance and applying set of inclusion and exclusion criteria. The study comprised of 111 females and 82 males spanning an age range of 16-75 years. Image j software was employed for measuring linear parameters like Condylar length, Coronoid length, maximum & minimal ramal breadth. Data was obtained and gender determination regression equations were developed for right as well as left side based on these measurements. statistical analysis performed using SPSS 23 software. Results: t test conducted for all 4 parameters on left and right side between males and females indicated statistically highly significant difference with a p-value of 0.0001. Furthermore, the discriminant functional analysis yielded prediction accuracy of 79.3% for the right side of ramus and 80.8% for left side in terms of gender identification. Sectioning points for distinguishing between females and males on right side was 0.1315 and that on left side were 0.13 respectively. This results lead to conclusion that mandibular ramus can be a viable tool for gender determination with left side of ramus being more accurate predictor of gender than right side of ramus.

Keywords: Forensic odontology, Gender determination, Digital panoramic radiogrpahs, Mandibular ramus, Discriminant analysis.

INTRODUCTION

Forensic odontology plays a pivotal role within a multidisciplinary framework to determine the identity of individuals, particularly in the aftermath of catastrophic events like terrorist attacks, plane crashes, train and road accidents, fires, mass homicides and natural clamities such as tsunamis, earthquakes and flood among others [1]. When dealing with such mass disasters or accidents resulting in skeletal remains or burnt human remains, the process of identifying individuals becomes particularly challenging. One of the initial steps in the identification process is determining the gender of the unknown person [2]. Gender determination often relies on examining such skeletal components, with pelvis, skull, and mandible being commonly utilized [3]. It’s fascinating how the mandible plays a crucial role in forensic odontology, aiding in the identification of individuals in various challenging scenarios. The durability and resilience of the mandibular bone indeed makes it a valuable tool for such purposes [2,4]. Mandibular morphology analysis, as part of this process, offers valuable insights into gender estimation. In this study, we have focused on utilizing different morphological features of the mandible to assess the accuracy of gender determination when only the mandible is available.

The method of doing gender estimation using bones can be done by direct measurements either on dry skeleton or on radiographs [5]. Historically Studies done have shown that gender determination using skull and mandible can be done up to 90% [2]. Present study has used precalibrated digital panoramic radiographs or OPGs to estimate gender from mandible as OPG is a straight forward, non-intrusive, relatively cost effective, dependable approach to get broad coverage area consisting of mandible maxilla and all teeth [6]. It also has advantage of low radiation dose, lesser superimposed images, short time required for image acquisition. They do help in getting accurate linear & angular measurements which are reproducible [3,7].

***Corresponding author:**
Dr. Gunjan T. Dave
PhD Scholar, Oral Pathology, Gujarat University, Ahmedabad, Gujarat, India
Email:
gunjan_dave29@rediffmail.com

This retrospective study included four linear parameters such as Condylar length, Coronoid length, ramal maximum breadth, ramal minimum breadth on right and left side of mandible of both gender with the aim of determining whether mandible can be used for gender determination, using OPG and that whether left or right side of mandibular ramus is better for gender identification specifically for the Gujarat population

MATERIALS AND METHODS

Sample collection

The retrospective study was conducted in Department of Oral and Maxillofacial Pathology (OMP) Karnavati School of Dentistry, Uvarsad, Gandhinagar. Panoramic radiographs of both genders were randomly selected from the data of OMR Department of Karnavati School of Dentistry after obtaining ethical committee clearance. 193 {82 males (42.48%) and 111 females (57.52%) } panoramic radiographs taken in Genoray Papaya digital machine, (90 Kvp and 8mA), were selected. Exclusion criteria considered were pathologies, fractures, developmental disturbances of the mandible, surgeries (fracture & orthognathic), subjects undergoing orthodontic treatment and edentulous mandible.

Method

Calibration of radiographs: Precalibrated radiographs were obtained in JPEG format as shown in figure.

Procedure for measurements on radiographs:

Image J software: Image j © software (a public domain Java image processing and analysis program.) was used for measurement of all parameters.

Defining parameters:

Condylar Length: Height of the ramus from the most superior point on the mandibular condyle to the tubercle or most protruding portion of the inferior border of the ramus

Coronoid Length: Projective distance between coronion and lower border of the bone

Maximum Ramal Breadth: The distance between the most anterior point on the mandibular ramus and a line connecting the most posterior point on the condyle.

Minimum Ramal Breadth: Smallest anterior–posterior diameter of the ramus [7].

All the Parameters were measured on left and right side of ramus by using mouse driven method. 386 rami were measured bilaterally. Tabulation was done in Microsoft excel ©.

Statistical Analysis

t-test & discriminant functional analysis were done using SPSS ver 23 ©.

RESULTS

The t- test showed that all parameters of males have higher mean values than female mean values with statistically highly significant difference. (Table 1 and Table 2)

Discriminant function analysis of right side and left side

Table 3 shows box's M statistical test is used to assess the equality of population covariance matrices for right as well as left side parameters suggested that there are significant differences in covariance matrices among both genders.

Canonical discriminant test in table 4 & 5 shows eigen value of right side and left side to be 0.760 and 0.744 respectively. There is strong canonical correlation on both sides between all 4 parameters in between both genders. Also significance level of the relation is 0.000 suggesting that these parameters are effective in discriminating male from female.

Table 6 and 7 show centroid value and sectioning point of discriminant equation of right and left side parameters. This suggests that if value of equation is between -0.746 and 0.1315 individual is female and if value is between 0.1315 and 1.009 the individual is male on right side. Similarly Centroid value of left side parameters is between -0.738 and 0.13 individual is female and if value is between 0.13 and 0.998 person is male. Accuracy of equation on right side is calculated 79.3% and on left side to be 80.8%.

The ROC analysis represents reliability of individual parameter to discriminate between males and females. The larger the ROC value, away from 0.5, more valid the variable was in predicting gender (Table 9; Figure 1 and 2).

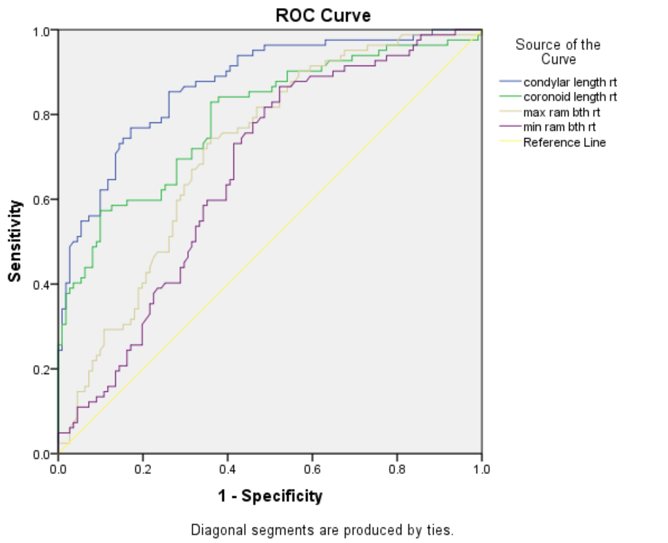

Figure 1: ROC curve for right side

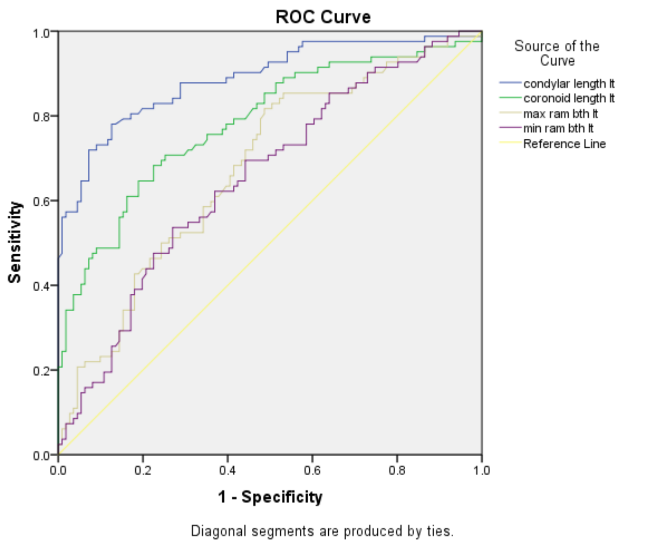

Figure 2: ROC curve for left side

Table 1: Mean + S.D. of all Parameters of the Right side of ramus

Parameters	Male Mean ± S.D.	Female Mean ± S.D.	Standard error	Significance (t test)
Condylar length	6.3720 ± 0.44234	5.6867 ± 0.39858	0.061	0.0001
Coronoid length	5.6686 ± 0.54719	5.1133 ± 0.40539	0.069	0.0001
Ramal maximum breadth	3.6894 ± 0.35503	3.4295 ± 0.34944	0.051	0.0001
Ramal minimum breadth	2.7293 ± 0.25876	2.5650 ± 0.29786	0.041	0.0001

Table 2: Mean + S.D. of all Parameters of the Left side of ramus

Parameter	Males Mean ± S.D.	Females Mean ± S.D.	Standard error	Significance (t test)
Condylar length	6.3803 ± 0.49357	5.6923 ± 0.37973	0.063	0.0001
Coronoid length	5.7287 ± 0.64948	5.2400 ± 0.41569	0.077	0.0001
Ramal maximum breadth	3.7159 ± 0.38865	3.4952 ± 0.33768	0.052	0.0001
Ramal minimum breadth	2.8186 ± 0.50404	2.6091 ± 0.31654	0.059	0.0001

Table 3: Box's M statistic for right side and left side

Right side		Left side	
Box's M	31.284	Box's M	69.909
F approx	3.056	F approx	6.828
Df1	10	Df1	10
Df2	143347.541	Df2	143347.541
Sig.	.000	Sig.	.000

Tests null hypothesis of equal population covariance matrices.

Table 4: Canonical Discriminant Functions for right side

Discriminant function/test	Eigen value	Canonical Correlation	Wilks' Lambda	Chi-square	Df.	Sig.
Value	0.760	0.657	0.568	106.890	4	0.000

Table 5: Canonical Discriminant Functions for left side

Discriminant function/test	Eigen value	Canonical Correlation	Wilks' Lambda	Chi-square	Df.	Sig.
Value	0.744	0.653	0.573	105.131	4	0.000

Table 6: Standardized discriminant And Classification Coefficients, Structure Matrix And Group Centroids For Variables of Right side

Variables	Standardized discriminant Function Coefficients	Structure Matrix	Classification Function Coefficients		Functions at Group Centroids	Sectioning point
			Male	Female	Female : -0.746 Male : 1.009	0.1315
Condylar Length	0.790	0.935	22.001	25.321		
Coronoid Length	0.239	0.672	10.697	11.589		
Ramal Maximum Breadth	0.443	0.421	23.281	25.493		
Ramal Minimum Breadth	-0.260	0.332	-1.210	-2.830		
Constant			-128.966	-157.378		

Table 7: Standardized discriminant And Classification Coefficients, Structure Matrix And Group Centroids For Variables of Left side

Variables	Standardized discriminant Function Coefficients	Structure Matrix	Classification Function Coefficients		Functions at Group Centroids	Sectioning point
			Male	**Female**	Female : -0.738 Male : 0.998	0.13
Condylar Length	0.956	0.918	24.367	28.213		
Coronoid Length	-0.035	0.534	7.681	7.566		
Ramal Maximum Breadth	0.153	0.353	18.263	19.000		
Ramal Minimum Breadth	0.292	0.297	12.242	13.487		
Constant			-137.915	-166.840		

Table 8: Classification results

		Gender	Predicted Group Membership right side		Total	Predicted Group Membership left side		Total
			female	male		female	male	
Original	Count	female	92	19	111	97	14	111
		male	21	61	82	23	59	82
	%	female	82.9	17.1	100.0	87.4	12.6	100.0
		male	25.6	74.4	100.0	28.0	72.0	100.0
Cross-validated	Count	female	90	21	111	95	16	111
		male	22	60	82	24	58	82
	%	female	81.1	18.9	100.0	85.6	14.4	100.0
		male	26.8	73.2	100.0	29.3	70.7	100.0

a. 79.3% of original grouped cases correctly classified on right side and 80.8% of original grouped cases correctly classified on left side.
b. 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.
c. 77.7 % of of cross-validated grouped cases correctly classified on right side. 79.3% of cross-validated grouped cases correctly classified on left side.

Table 9: ROC area for parameters of left and right side when used to predict gender

Right side			Left side		
Parameters	Area	Significance	Parameters	Area	Significance
Condylar length	0.871	0.000	Condylar length	0.888	0.000
Coronoid length	0.793	0.000	Coronoid length	0.784	0.000
Maximal ramus breadth	0.716	0.000	Maximal ramus breadth	0.678	0.000
Minimal ramus breadth	0.664	0.000	Minimal ramus breadth	0.653	0.000

DISCUSSION

In cases where human DNA is not accessible for the purpose of human identification, skeletal remains play a vital role [8]. Among these remains, skeletal and dental components are of primary importance, as they tend to endure the longest after an individual's death. Forensic anthropologists rely on these structures to establish crucial aspects of a person's identity, such as their age, sex, ancestral background, and any potential physical abnormalities or injuries. Moreover, dental records can be compared to the dental features of the remains, providing a more precise means of identification [1]. This is especially valuable when conventional methods like fingerprinting or DNA analysis are not viable options for identification [1,8].

Over the years, numerous studies, whether based on dry mandibles or orthopantomograms (OPG), have consistently confirmed that mandibles exhibit sexual dimorphism. Following in their footsteps, many researchers have explored various parameters of mandibular morphology, revealing that the mandibular ramus exhibits a greater degree of sexual dimorphism compared to the mandibular body [7]. Moreover, according to Basic Z et al., metric studies, which involve objective bone measurements, have highlighted distinct differences across various populations, reducing the subjectivity associated with examiner interpretations [8].

Indeed, studies have indicated that environmental and social factors like climate, nutrition, genetic influences, and pathologies can significantly impact bone size and shape. This has been observed in various studies that highlight variations in skeletal morphology among different populations, emphasizing the need for population-specific standards when determining gender [3].

In our research, we have endeavored to establish gender determination equations tailored to the Gujarat population. In our study, we incorporated a total of 193 subjects, consisting of 82 males and 111 females, as our study subjects. We utilized a comprehensive set of four parameters Condylar length, Coronoid length, and the maximum and minimum breadths of the ramus on both the left and right sides for analyzing sexual dimorphism in the mandible within the Gujarat population.

The use of multiple parameters, as opposed to a single one, can enhance the accuracy of gender prediction. Furthermore, our study revealed that the measurements of male parameters held greater significance compared to female parameters. The application of a t-test yielded a highly statistically significant result, with the difference between male and female measurements showing a p-value of less than 0.0001. This underlines the robustness of the findings in distinguishing gender based on these mandibular parameters.

The observed differences in mandibular morphology, as noted by Hazari et al., can be attributed to the contractile activity of masticatory muscles and the influence of bite force on craniofacial skeletal transformations. In general, men tend to have stronger muscles and greater bite force capabilities compared to women [2]. Moreover, from a hormonal perspective, sexual hormones, including androgens and estrogen, play a significant role in shaping morphological distinctions in craniofacial structures, leading to variations in musculoskeletal growth during puberty between different genders, as discussed by Asrani et al [9]. Therefore, it is the interplay of sexual hormones and varying strengths of masticatory muscles that collectively contribute to the differences in mandibular morphology between males and females.

It's clear that the accuracy rates for gender determination using mandible can vary between different studies and populations. Here are some of the accuracy rates from various studies: Giles et al: 85% [10], Sandeepa NC et al 92% [11], Abu-talesb NS and El Beshlawy taleb: 79.6% [12], Markande A et al: 76% [7], Sambhana et al: 75.8% [5], Jambunath et al: 72% [3], Nagraj et al 71 % [13], More et al: 69% [4], Samantha et al: 60% [14]. In present study, which involved 386 rami from 193 Digital OPGs, the accuracy was determined to be 79.3% on the right side of the mandible and 80.8% on the left side of the mandible. These variations in accuracy rates can be attributed to differences in sample size, population characteristics, measurement techniques, and other factors across these studies.

In alignment with prior research conducted by Sambhana et al [5], Sandeepa et al [11] and Singh B et al [15], our study has revealed that individual parameters within the ramus of the mandible have capability to exhibit sexual dimorphism. This assertion is substantiated through the utilization of ROC curve analysis in our study.

Present study observed that the left side of the mandibular ramus is a better predictor of gender than the right side. It's not uncommon for studies to yield contrasting results, and this variance can be due to differences in sample populations, measurement methods, or other factors. The study by Sairam et al [16], which suggests the opposite, highlights the need for continued research and analysis in this area to better understand the factors contributing to these discrepancies in gender prediction accuracy. This ongoing exploration can help refine our knowledge of mandibular morphology as a predictor of gender.

CONCLUSION

In conclusion, our study has demonstrated the utility of measurements on the mandibular ramus from digital panoramic radiographs for gender determination provides gender-specific equations. the findings in our study suggest that the left side of the mandibular ramus is a more reliable predictor of gender than the right side in the Gujarat population. This study lays path for broader studies involving a larger number of subjects and additional parameters which can contribute to achieve higher accuracy rates for both gender determination and age estimation. This ongoing research is essential for refining and enhancing the techniques used in forensic anthropology and identification.

Conflict of Interest

The authors declare no conflict of interest.

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ORCID ID

Dave Gunjan T: https://orcid.org/0009-0002-4911-2719
Parikh Neelampari: https://orcid.org/0009-0008-2622-9045

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