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A Radiomorphometric Study of Mandibular Morphological Changes Associated with Sexual Dimorphism

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ABSTRACT

Introduction: the determination of sex from unknown skeletal remains is an essential role in the field of forensics and anthropology. In the field of forensics, sex determination is the first step in personal identification. Apart from the pelvis, the skull appears to be the most reliable element of the skeleton in determining sex. The mandible is the biggest and toughest face bone, concerning sexual dimorphism. The study aimed to measure, compare, and distinguish the sex-related changes in the mandible in South Indian population on digital panoramic radiographic images and to evaluate their reliability in sex determination that might serve as evidence in forensics.

Methods: digital panoramic images were obtained for 420 patients, which included 210 males and 210 females. Various parameters were measured and evaluated across the body and the ramus of the mandible, including one angular measurement (gonial angle) and four linear measures (condylar length, ramus length, cortical bone thickness, and ramal notch width). The data obtained was subjected to descriptive statistical analysis and a two-way ANOVA test.

Results: comparison between males and female groups showed statistically significant differences in all parameters with $p < 0.05$ except the ramal notch width. The mean value of all parameters was found to be comparatively higher in males. Thus, all parameters except the ramal notch width were found to be reliable in sex determination. It was found that males had greater value when compared to females.

Conclusion: this study recommends the use of these parameters for the purpose of sex determination.

Keywords: Forensic science; Sex Determination; Digital Panoramic Images; Mandibular Morphology; Measurements; Mandibular Ramus.

Introduction

Establishing one's identity is critical for the unknown deceased person in homicide, accidents, suicide, and catastrophic disasters such as terrorist attacks, explosions, earthquakes, and plane accidents, as well as for criminals who are concealing their identities[1]. Identification of the sex of the human skeleton remains of an unknown deceased person is regarded as the difficult first step in Forensics[2]. Few studies have focused on using several skeleton traits to determine variation related to sex and ethnicity to improve forensic identification[3]. Many studies have proven that the pelvis and skull bones demonstrate the highest sexual dimorphism of around 98% and could be used for this purpose[4]. Bones change at a constant rate throughout a person's life, and those changes in the skeleton follow a chronological pattern. Knowing what changes take place in the bones can help determine sex from the skeleton. The mandible is the largest, strongest, and movable component of the skull, and identifying it is crucial in anthropological research and medico-legal matters.

Radiology plays a vital role in determining an individual's age and sex[3]. No two radiographs are alike, and this ideology is implicated in determining individual's sex. Panoramic radiography is a common modality in routine dental check-ups[5] and an employed method in scientific research and criminal investigations[6]. Even though there are a variety of ways of determining sex, OPG can provide anatomical measurements with accuracy when the exterior features are damaged[7].

The current study aims to evaluate the morphological alterations in the mandible by considering one angular and four linear measurements across the body and ramus of the mandible.

Materials and Methods

This study was a prospective observational study that included 420 apparently healthy subjects aged 12 - 70 years of age attending the outpatient department of Oral Medicine and Radiology who required OPG for diagnostic purpose. The subjects were divided into four age groups: 1 - 18 years of age, 19 - 40 years of age, 41 - 60 years of age, 61 - 70 years of age. Of the 420 subjects, 210 (50%) were males and 210 (50%) were females. Each age group was comprised of 120 (28.6%) individuals, of which 60 (14.3%) were males and 60 (14.3%) were females, except for the age group of 61 - 70, which comprised of 60 (14.3%) individuals, of which

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30 (7.15%) were males and 30 (7.15%) were females. The mean age for males was 43.1333 and 41.8667 for females.

Table 1. Cross table showing Distribution of study subjects according to age and sex with the mean values 7.

Ages	sex		Total
	Male	Female	
12-18	60 (14.3%)	60 (14.3%)	120 (28.6%)
19-40	60 (14.3%)	60 (14.3%)	120 (28.6%)
41-60	60 (14.3%)	60 (14.3%)	120 (28.6%)
60+	30 (7.15%)	30 (7.15%)	60 (14.3%)
Total	210 (50.0%)	210 (50.0%)	420 (100.0%)
Mean	37.7857	35.1619	36.4738

Inclusion criteria:

- Subjects aged 12 - 70 years old.
- Ideal digital panoramic radiographic images with optimum diagnostic quality and clearly showing all the reference landmarks.

Exclusion criteria:

- Subjects with any systemic disease affecting the jawbone.
- Patients with history of temporomandibular joint disorders, maxillofacial trauma surgery, orthognathic treatment.
- Patients with congenital maxillofacial malformations or syndromes.
- Completely edentulous mandibular arch.
- Digital panoramic images with any artefacts.

Method

After obtaining written consent from the selected cases, the clinical examination was carried out, and the clinical findings were recorded on an individual proforma specially designed for the study. The institutional ethical committee clearance was obtained before the conduct of study. Individuals satisfying the eligibility criteria were subjected to OPG examination at fixed operating parameters based on the built of the subject by adopting the requisite radiation protection measures. Linear and angular measurements were performed on digital panoramic images for all parameters on both sides using Planmeca Romexis software (3D Software).

The parameters that were measured in our study were as follows:

1. Gonial angle (GA): It is formed by drawing a line between two imaginary lines that extend from lower border of the mandible to the ramus of the mandible.
2. Condyle length (CL): It is the distance measured between two tangential lines that are drawn at the superiormost point of the condylar head and the deepest point of the concavity of the sigmoid notch.
3. Ramus length (RL): It is calculated by drawing two lines, both parallel to the ramus tangent line one at the level of the most lateral image of condyle and the other at the level of the most lateral image of ramus. The distance between these two lines is RL.
4. Cortical bone thickness: The thickness of the radiopaque band is measured at lower border of the mandible's body, where antegonial notch begins mesially.
5. Ramal notch depth (RND): It is calculated by drawing a line from ramus tangent line to the ramus notch concavity's deepest point.

Figure - 1 is a panoramic image showing gonial angle (red line), condylar length (yellow line), ramus length (green line), ramal notch width (light blue line) and cortical bone thickness (dark blue line) that are measured using Planmeca Romexis Software.

All the obtained data were tabulated and analyzed statistically and compared between the sex groups respectively using SPSS software version 22.0. All obtained data was then subjected to descriptive statistics, Paired t-test and Two-way ANOVA test to arrive at the results.

Results

All subjects were divided into 4 categories i.e., 12 - 18 years of age, 19 - 40 years of age, 41 – 60 years of age, and 60 - 70 years of age. Descriptive statistics of all the mandibular ramus parameters on OPG is shown in Table 1. All the parameters have higher male measurements than females and hence each variable was a significant predictor in classifying the sex. All the measurements except ramal notch width (p value= .114) were found to be statistically significant (P value < 0.001). [Table 2,3,4]

The mean value of gonial angle among 210 males was 181.0514, and among 210 females it was 179.8998. A statistically significant difference was noted between the right and left gonial angles (p =0.000), with the right side depicting comparatively higher values than the left in both males and females of all age groups.

The mean value of the condylar length among 210 males was 22.3318 and among 210 females it was 21.3350. A significant difference in the mean value of condylar length was noted on both the right and left sides, with males depicting comparatively higher values than females. No significant difference was noted between the right and left condylar lengths (p = 0.767).

The mean value of the ramus length among 210 males was 71.1225 and among 210 females was 66.8413. A statistically significant difference was noted between the right and left ramus length (p = 0.003), with the right side depicting comparatively higher values than the left in both males and females of all age groups.

The mean value of the cortical bone thickness among 210 males was 3.6712 and among 210 females it

Table 2. Comparison of the mean values of males and females in all parameters.

Parameters	Gender	12-18 years	19-40 years	41-60 years	60+ years	Total Mean	P
Gonial angle	Male	181.6615	180.6968	181.0040	180.6350	181.0514	.025*
	Female	180.0130	179.3363	180.2044	180.1912	179.8998	
Condylar length	Male	20.4402	23.0337	22.6100	24.1550	22.3318	.001*
	Female	21.4392	21.3025	21.8392	20.1833	21.3350	
Ramus length	Male	66.2783	71.6304	72.9633	76.1133	71.1225	.000*
	Female	65.6437	68.1577	67.3633	65.5600	66.8413	
Cortical bone thickness	Male	3.2467	3.6467	4.0667	4.0533	3.6712	.048*
	Female	3.4300	3.6467	4.0667	4.0533	3.5988	
Ramal notch depth	Male	2.2583	3.0658	3.0542	3.6883	2.9207	.114
	Female	2.8675	2.6983	2.8092	3.0833	2.8333	

*$P<0.05$ significance at 5% level of significance.

Table 3. Comparison of the mean values of the right and left gonial angles according to gender.

Parameter	Sides	sex	Mean	Std. Deviation
Gonial angle	Right	Male	237.2703	6.75731
		Female	234.9221	9.29245
	Left	Male	124.8325	11.74227
		Female	124.8775	7.29529
Condylar length	Right	Male	22.3792	4.49094
		Female	21.2486	3.80511
	Left	Male	22.2844	4.71649
		Female	21.4214	3.91457
Ramus length	Right	Male	71.3717	10.22537
		Female	67.0469	6.37968
	Left	Male	70.8733	10.22272
		Female	66.6358	6.37097
Cortical bone thickness	Right	Male	3.6319	.80761
		Female	3.6038	.70500
	Left	Male	3.7105	.82884
		Female	3.5938	.69234
Ramal notch depth	Right	Male	2.8324	1.09059
		Female	2.7600	.97506
	Left	Male	3.0090	1.19190
		Female	2.9067	.93607

was 3.5988. A significant difference in the mean value of cortical bone thickness was noted on the left side, with males depicting comparatively higher values than females, and on the right side, no significant difference was noted between males and females. No significant difference was noted between the right and left cortical bone thickness (p = 0.133).

The ramal notch width was greater on the left side than on the right. However, this was statistically not significant.

Table 4. Comparison of mean values of right and left sides in each parameter. Paired T-test values on pairing right and left values.

Paramete rs	Side	Mean	Std. Deviatio n	Paired t-test (Paired Differences)		
				Mean	Std. Deviatio n	Sig. (2-tailed)
Gonial angle	Righ t	236.0962	8.19937	111.24123	15.46445	.000*
	Left	124.8550	9.76338			
Condyla r length	Righ t	21.8139	4.19556	-.03900	2.69601	.767
	Left	21.8529	4.35044			
Ramus length	Righ t	69.2093	8.78312	.45469	3.06425	.003*
	Left	68.7546	8.76774			
Cortical bone thickness	Righ t	3.6179	.75727	-.03429	.46712	.133
	Left	3.6521	.76497			
Ramal notch depth	Righ t	2.7962	1.03384	-.16167	.69174	.000*
	Left	2.9579	1.07159			

*$P<0.05$ significance at 5% level of significance.

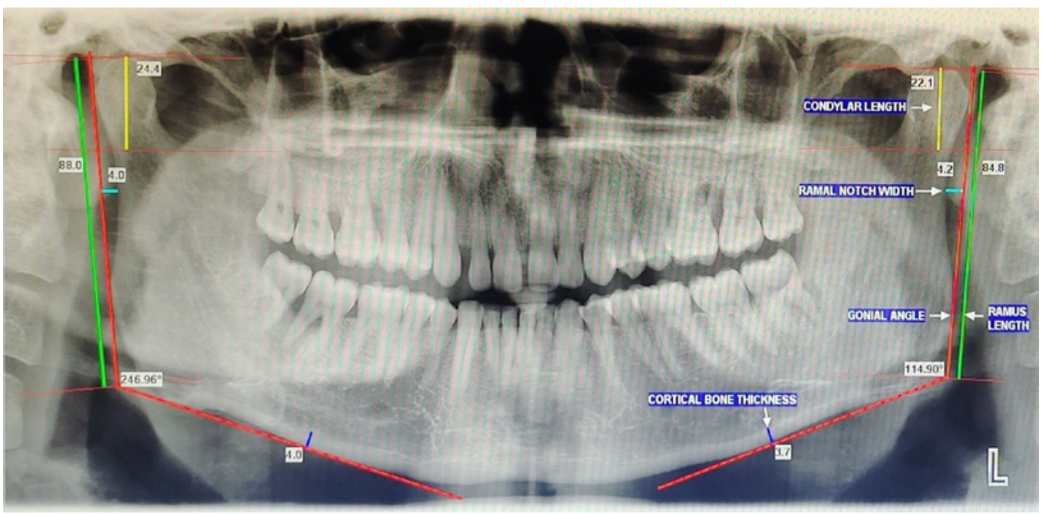

Figure 1. Bilateral angular and linear measurement of mandible on OPG.

Discussion

In forensic anthropology, human osteological remains are frequently utilised for estimation of various traits of every person to help in identification or to utilise as evidence in a suspected identification[8]. Identification of sex based on morphological traits is subjective and likely to be inaccurate, but methods based on measurements and morphometry are accurate and can be used in the determination of sex from the skull[9]. It has previously been proven that panoramic radiographs are accurate in providing anatomical measurements. Clinicians have embraced panoramic radiographs as a reliable screening method for identifying oral diseases. Broad coverage, minimal patient radiation exposure, and quick imaging acquisition are some of the main benefits of panoramic radiography. Magnification and geometric distortion are the limitations of panoramic radiography. However, this limitation did not affect our results since all images were uniformly magnified.

In our study, we discovered a significant difference in gonial angle between both sides of the jaw. This is in correlation with the findings of Revant H. Chole *et al.*[10], who also discovered a significant difference in the gonial angle between right and left sides of the jaw. However, this factor is not in agreement with the findings of Larheim *et al.*[11] (1986), who observed no significant difference betwe en the right and left gonial angles. This disagreement might be due to a disparity in sample size and the age group (14–28 years) of their study population.

The study by Humphrey *et al.*[12] (1999), found the length of the condyle showed a significant difference between males and females. In contrast to this, a study conducted by Jeong-Ki Joo *et al.*[13] (2012) with the help of digital panoramic radiography for the determination of sex revealed no significant differences in condyle length between males and female groups. In our study, a difference in condylar length was found between males and females. Males showed higher condylar length than females. The studies that are in disagreement with our study might be due to differences in sample size, ethnicity, and also much older individuals (60 – 69) involved compared to our study. Overall, this parameter (condylar length) was found to be a promising parameter for sex determination.

In our study, differences in ramus length were also found between males and females. This statement is correlated with a few of the other studies by Morant *et al.*[14] (1936), Humphrey *et al.*[12] (1999), Hrdlicka[15] (1940), and Mangla *et al.*[16] (2011). In our study, the ramus length in males was found to be higher thanfemales. This statement goes in accordance with the study executed by Mangla *et al.* (2011), who also found males have a higher ramus length than females. Overall, this parameter (ramus length) was found to be a promising parameter for sex determination. A difference in ramal notch width was found between males and females. In which higher ramal notch width was found among males than that of females. Overall, the ramal notch width was found to be statistically not significant for sex determination.

As this was a time-bound study, a statistically qualified minimum sample size was assessed. In future, further studies are recommended to validate our hypothesis with a larger sample size, including various ethnicity and socioeconomic groups for age determination.

Overall results obtained in our present study revealed that all parameters cannot be used as a tool for sex determination as the gonial angle, condyle length, ramus length, and cortical bone thickness except the ramal notch width show anatomic variations between males and female groups and are found to be statistically significant. Therefore, it is concluded that one angular measurement and three linear measurements on digital panoramic images can be used in forensic anthropology as a valuable tool for sex determination. Hence, these measurements are advocated varyingly for providing evidence in forensics, especially when other bones of the skeleton are unavailable.

Conclusion

Numerous studies have shown that each group has unique bone traits and have stressed the necessity for population-specific osteometric criteria for determining sex[17,18]. No one skeletal indication should be relied upon primarily if additional verified dimorphic regions are available; the maximum chance of a sex determination comes from a thorough study of all known bones belonging to a specific individual.

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Mini Curriculum and Author's Contribution

1. Dr Karthikeya Patil – Concepts, Design, Definition of intellectual content, Literature search, Data analysis, Statistical analysis, Manuscript preparation, Manuscript editing, Guarantor.

2. Dr Harshitha N - Concepts, Design, Literature search, Clinical studies, Data acquisition, Data analysis, Statistical analysis, Manuscript preparation, Guarantor

3. Dr Sanjay C J - Concepts, Design, Definition of intellectual content, Literature search, Data acquisition, Manuscript editing, Guarantor

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