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Assessing Ramus Dimorphism of Jordanian Mandibles

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Abstract This investigation deals with descriptively examining the mandibular rami of young Jordanian adults for the presence or the lack of it of a flexure at the posterior border of a ramus; and evaluating the role of ramus flexure in sex identification. Three-dimensional (3D) rendered Cone Beam Computed Tomography (CBCT) images of a normative sample comprising 270 images were selected, of which 147 belonged to male patients and 123 images to females. Strict exclusion criteria were applied in selecting images. Each image was examined for the presence of a flexure on the posterior border of the ramus, which was carefully delineated and the occlusal plane marked, guided by the height of cusp tips of the mandibular molars. The results indicated that the ramus flexure method of sex prediction was more accurately diagnostic for females (85.1%), than for males (78.9%); this gave rise to an overall diagnostic accuracy of 82.2% which is below the reported 90.6-99.0% by Loth & Henneberg. Our results, however, agreed with the reported findings of other researchers. In conclusion, ramus flexure provides an acceptable predictive accuracy and could be considered as a supplementary rather than a definitive mean of sex determination.

Keywords: *sex dimorphism, ramus flexure, morphologic trait, predictive accuracy, forensic fossils, skeletal remains*

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1. Introduction

Sex determination of unknown skeletal remains is the most challenging, among other targets, such as, identification of age, stature and ethnic origin. The pelvic bone and mandible reflect anatomical differences between male and female; therefore they were used in many past studies, which centered on morphological differences that arise from genetically sex-linked growth and development [1,2,3]. The mandible was used in most studies since it is one of the most durable bones and persists in a well preserved state longer than other bones. There have been many publications dealing with sexual differentiation according to morphological traits of the mandible. In some early reports, Loth and Henneberg [4,5,6,7] described a flexure in the posterior border of the mandibular ramus that was present in males’, but absent in females’ mandibles, and used the flexure in sex determination. They claimed sexing accuracy ranging from 90.6% to 99% that the ramus is flexed in males at the same level of the occlusal plane whereas in females the ramus border is either straight or flexed near the neck of condyle or in association with gonial prominence. In a counter argument, other researchers reported that the association between ramus flexure and sex was weak; and that Loth and Henneberg’s method was based on a trait that, they believed, cannot be reliably or consistently identified, thus, threw doubt on the accuracy and reliability of that method of sex identification [8,9,10]. They reported that although the ramus flexure seemed to be greater and more constant in males, the overlap between the shapes of male and female rami was too substantial to make the ramus flexure method a valid means of sex determination. Some researchers tried Loth and Henneberg method of sex identification on their sample and reported that about two-thirds of the Orthopantomographic (OPT) images of females were correctly sexed, whereas the prediction accuracy was less than 50% for males [11,12]. Those were much lower than the success rates reported by Loth and Henneberg, which raised suspicion on the predictive accuracy and reliability of mandibular ramus flexure as a morphological indicator of sex. The literature contains varying reports, some argued for and some against the ramus flexure method of sex identification. Those researchers who supported the method had tried it on their test sample and claimed an overall prediction accuracy rate of 83% [13], whereas, those who were not in favor of the method reported a relatively lower prediction rate (76%) [14]. The general belief of all reported studies that using this sex dimorphic predictor may not attain a high confidence level, and, therefore, it should be coupled with other indicators of sex dimorphism.

Many past studies were carried out directly on dry mandibles. However, it is probably, because of the difficulty involved in getting access to dry skulls in the numbers required by the studies, researchers sought alternatives to dry skulls and employed “OPT” images of their patients’ mandibles in their analyses [15]. However, the alternative method, i. e., “OPT” being a two-dimensional (2D) diagnostic rendering from a three-dimensional (3D) structure, it is bound to yield images subject to projection, landmark identification, and measurement errors. Attempts to develop a 3D imaging technique to improve diagnosis has intensified during the late 1990s, and culminated during the last decade by achieving alternative protocols for facial bone visualization and modeling, referred to as Cone Beam Computed Tomography (CBCT) [16].

The aim of the present study was to investigate the validity of mandibular ramus flexure in sex differentiation among Jordanian young adults using three-dimensional 3D rendered Cone Beam Computed Tomography (CBCT) images of mandibles.

2. Materials and Methods

The present investigation was conducted on a sample consisting of 270 randomly selected Cone Beam Computed Tomography images (CBCT) of mandibles of young adult patients, the age of whom ranged between 27 to 55 years, who attended clinics of the dental department of the Jordan University Hospital (JUH). The exclusion criteria used in selecting the test sample involved excluding images that showed excessive loss of mandibular posterior teeth, over erupted, tilted, anomalous molars and teeth or mandibles associated with pathology.

The CBCT images were acquired with a WhiteFox scanner (WhiteFox, de Götzen SrL ITALY). The preset parameters of the scanner are shown in Table 1.

Table 1. Preset scanning parameters for the WhiteFox CBCT scanner

Scanner	kV	mAs	Scanning time (s)	FOV (mm)
CBCT (WhiteFox)	105	9.00	9.0	120 X 80 (w X h)

kV: Kilovolts, mAs: Milliampere/second, FOV: Field of view.

The CBCT data were exported from the WhiteFox software (WhiteFox Control 3D-00022, version 2.11.1, master version 1.46, inverter version 1.35, de Götzen, Germany) in (Digital Imaging and Communication in Medicine) "DICOM" multi-file format and imported into the customized "SolidPlanner Pro" software version 3.2, (Solid Models Co., Amman Jordan) on a Pavilion dv6 Laptop (HP USA) with a dedicated 1GB video card (Rad con HD 6750 AMD). The SolidPlanner software designed for the purpose of this study converted the DICOM images into 3D models using the marching cubes algorithm based on surface rendering [17]. The 3D surface models of all mandibular images were generated by the preset threshold value for bone (250-3071 Hounsfield units) as specified by the rendering software.

The obtained three-dimensional (3D) surface model images provided researchers the freedom of moving, sectioning, rotating a mandible's image around any preferred axis and viewing all its surfaces. This facility was of a great importance to this particular investigation, because it made it possible of rotating a mandible's image around its vertical axis to discloses the posterior border of its ramus and detect the presence of a flexure (Figure 1).

Prior to conducting the investigation, and in compliance with the policy of the Clinical Research Authority at the JUH, signed written informed consents were obtained from all the subjects selected for the study. All subjects were made aware that their OPT images were included in the investigation. The experimental protocol was examined and approved by the Ethics Committee and was, therefore, performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki (WMA, Helsinki, 1964) [18].

The 3D CBCT images were examined and analyzed according to the guidelines described by Loth & Henneberg (1996) [4]. Each image was examined, firstly, for a possible presence of a flexure at the posterior border of the ramus, and if present, the height of flexure was carefully marked. Secondly, the occlusal plane level was delineated as guided by the height of cusp tips of the mandibular molars. A decision was made whether or not the ramus flexure coincided with the occlusal plane level.

Examination of the images and careful digitization of their landmarks was facilitated by graphical tracing of the posterior border of the ramus; the deepest flexure point on the curving border was traced on both sides. A tangent line was drawn passing through two points, the first was the most prominent point on the posterior profile of the condylar head and the second point marked the maximum convexity of the posterior margin of the mandibular angle. A line passing through the most prominent cusp tips of the first and second mandibular molars marked the height of the occlusal plane. Third molars, if present, were not used in the determination of the occlusal plane height (Figure 2.).

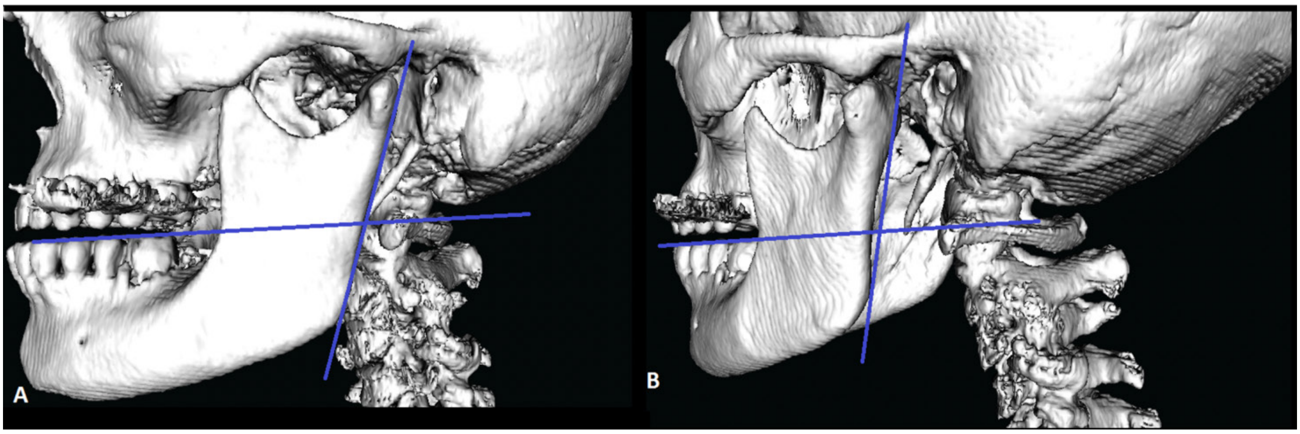

Figure 1. A rendered CBCT image of a patient's skull illustrating the left ramus when examined in a true lateral view (A) it showed straight posterior border having no flexure, but after the image was rotated to the right around the vertical axis (B) the ramus clearly exposed a definite flexure at it's posterior border

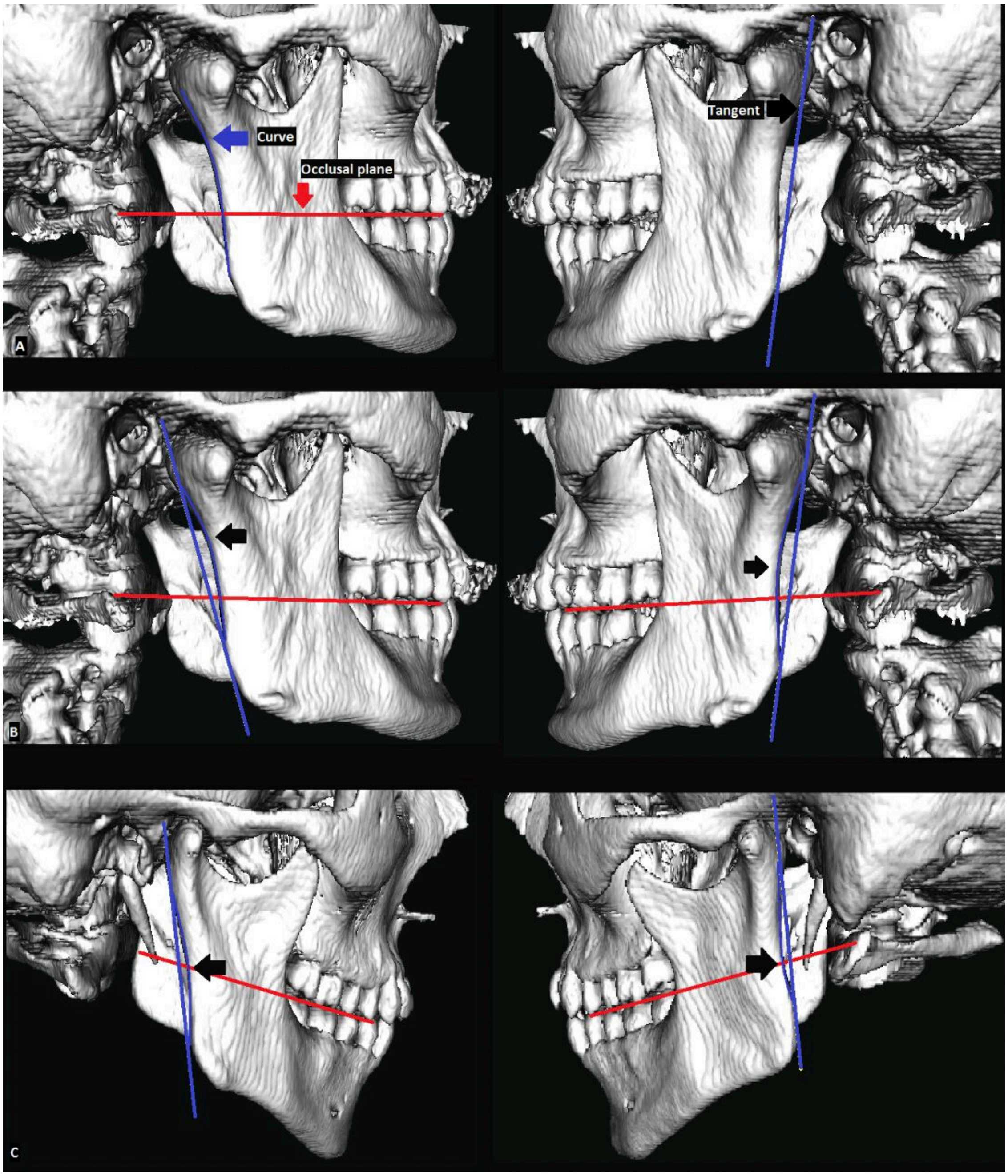

Figure 2. Showing 3D rendered CBCT images of three patients' skulls, illustrating in (A-top) flexed left and right rami marked by a blue curve (right ramus), a tangent along the ramus posterior border (left ramus), and the occlusal plane marked by a red line. (B-middle) illustrating flexed left and right rami at points higher than the occlusal plane. (C-bottom) illustrating flexed left and right rami at the same level of the occlusal plane

The images of the entire sample were scored according to the method advocated by Loth & Henneberg (1996) [4]. Score points were given for the left and right rami of each image, and then added together and the total score was used in sex prediction.

A score of (+1) was given when one side ramus was flexed at the occlusal plane level at that side; a score of (-1) was given to a straight posterior border ramus and to a ramus in which the flexure of its posterior border did not coincide with the height of the occlusal plane, but located either above or below the occlusal plane level, i. e., near the condyle or the mandibular angle; score (0) was given to a ramus the posterior border of which was neither flexed nor straight.

When scores of both rami were added, a total score of (+2) was assigned to the image in which both rami had a flexure coincided with the occlusal plane; a score of (-2) was given when both rami had straight posterior borders or to rami the flexure of which did not coincide with the occlusal plane but were high near the condyle or low near the mandibular angle; a total score of (+1) was given when one ramus was flexed at occlusal level and the other was indeterminate; a total score of (0) was assigned to the image in which either both rami were indeterminate or one ramus was flexed at the occlusal level and the other was straight; a total score of (-1) was given to the image in which one ramus was straight while the other was indeterminate. Images of total scores of (0, +1, +2) indicated male subjects, whereas images of total sores of (-1, -2) indicated female subjects. The examiner who carried out examination of the entire sample was unaware of the sex of the subjects whose images were being examined. The results of examination were statistically analyzed using the appropriate statistical tests.

2.1. Statistical Treatment

The examination results were analyzed using SPSS version-21 (Statistical Package for Social Studies; SPSS Ltd, Fountain Valley, CA 92708 USA); the "Chi-squared test," of the package, was employed at a probability level of $p<0.01$, indicating significant differences would be evaluated at 99% level of confidence.

3. Results

The sex prediction of the subjects was noted following the method suggested by Loth & Henneberg (1996) [4]. Distribution of subjects and their predicted sex, indicated by the shape of their mandibular ramus, is presented in Table 2 and Figure 3. Those individuals whose 3D CBCT images revealed total scores of -1 and -2 of both rami were classified as female subjects, and those whose rami attained added scores of 0, +1, and +2 were counted as males.

Table 2. Distribution of ramus shape scores in Jordanians

Score (*)	Percent (%) of Total
-2	48.5
-1	12
0	15.5
+1	9
+2	15

(*) [+2]= both rami flexed at the occlusal plane level; [+1] = one ramus flexed at the occlusal plane level and the other indeterminate; [0] = either both rami indeterminate or one flexed and the other one straight; [-1] = one ramus flexed but not at the occlusal plane level and the other indeterminate; [-2] = both rami straight.

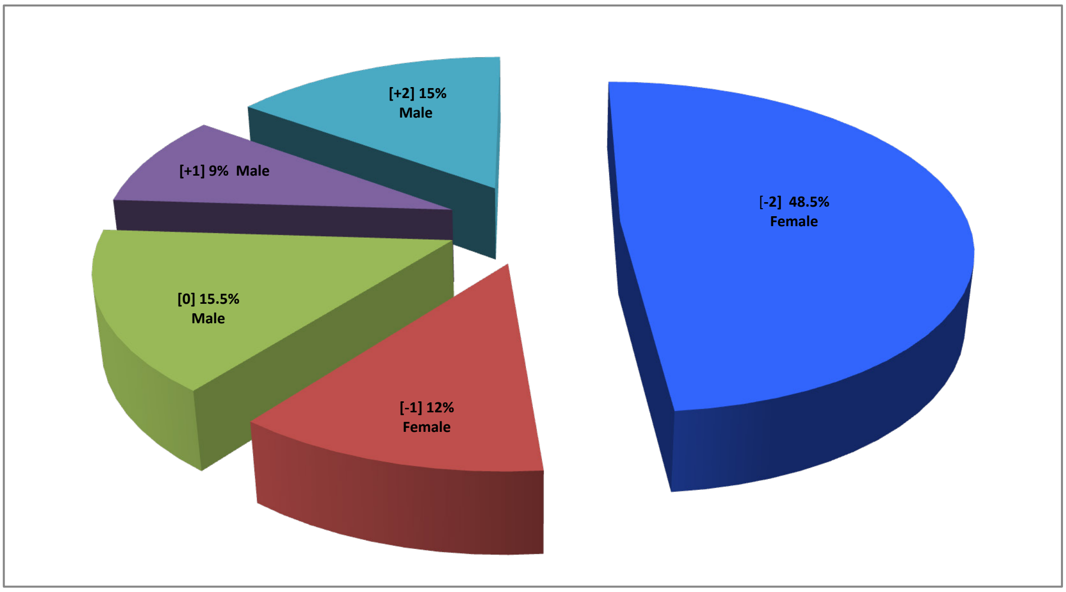

Figure 3. Distribution of predicted sex (%) indicated by ramus shape

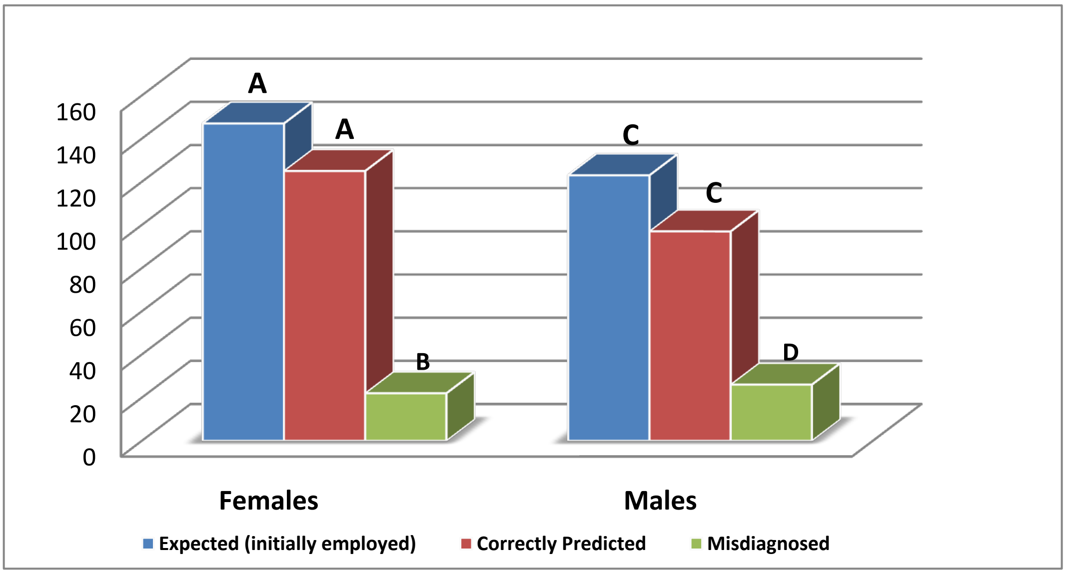

Figure 4. Number and gender of the initially employed subjects, those whose sex correctly predicted, and subject of misdiagnosed gender. Different alphabets denote statistically significant differences ($p<0.001$)

The number of images that scored -2 and were counted as females was 22 images less than that of females, originally included in the sample. This small difference was found to be statistically insignificant (Chi-squared "X^2 "= 0.986 at p>0.411). Likewise, the number of correctly predicted male images was 26 images less than that initially employed in the sample (Figure 4). The difference, 97 out of 123, was statistically insignificant (Chi-squared "X^2"= 0.93 at p>0.411).

The results presented in Table 2 and Figure 3 and Figure 4 demonstrated that when employing Loth & Henneberg (1996) [4] scoring method for sex identification of the investigated subjects, the ramus flexure was more accurately diagnostic for females (85.1%%), but the accuracy for male identification (78.9%) was slightly inferior to that for females; this gave rise to an overall diagnostic accuracy of 82.2%.

4. Discussion

This study established an overall predictive rate of accuracy of 82.2%, which is comparable to some previously reported rates [1,4,13,19,20]; but higher than other reported predictive rates, [8,9,10,11,12,14,21]. The differences among researchers in the predictive accuracy rate of ramus flexure they achieved could be ascribes, to the differences in the nature of the employed samples and to how strict exclusion criteria they followed. Some may have worked on samples that comprised 'pathological' cases that increased the risk of misdiagnosis and compromised the accuracy of sex prediction. The differences in the reported findings may also be attributed to the differences in the researchers' identification of the anatomical landmarks and the subjective assumption of the exact location of flexure of the posterior border of mandibular ramus.

It is clearly obvious that the strict exclusion criteria employed in selecting the sample in the present study, and the use of the 3D rendered CBCT images had helped eliminate all guesswork and attain precise and accurate outcome.

The results of this study demonstrated that the employed sex prediction method was more diagnostic for females. This was in agreement with the findings of some previous studies [12,13] that also found the ramus flexure method was more diagnostic for females than males. It should be noted that the age of the patients evaluated in this study, as well as in the other two studies [12,13], was the "young adulthood", that is, after the puberty period during which growth of bones is sex-linked and controlled by the influence of hormonal changes. Since the puberty period in females starts and ends earlier than in males, this means that females reach a state of hormonal stability faster than males. Thus, at young adulthood, females are hormonally more stable, i. e., the influence of hormones on growth of their bones has ceased. Whereas, in males the state of hormonal stability reached at a relatively later stage. As is the case with most sites of the skeleton, sex-based variation in growth rates and pattern is also reflected in the mandible, whereby the major hormonal influences triggered to initiate sexual maturation at puberty targets receptors in the mandible [7]. These, in turn, incur significant sex differences in shape and dimensions of the mandible, influenced by the configuration of the masticatory muscles.

The creation of the flexure is likely to result from a change in the size, strength or angulation of the muscles of mastication, specially the masseter and the medial pterygoid muscles, which attach just below the level of flexure on the ramus. In males, where rugosity of the medial pterygoid muscles attachment is noticeably more pronounced than that of the masseter, the ramus appears much more vertical. The temporalis and the lateral pterygoid muscles attach well above the flexure [4].

Musculoskeletal maturation at older age is rare and not expected to incur any significant change in the shape of mandibular ramus flexure in males as well as females. This was substantiated by the comparison made between the results of the present study and those reported by Tamer (2012) [13], who investigated an Egyptian sample whose average age was nearly double that of the sample evaluated in this study, albeit both studies indicated superiority of the predictive accuracy of female subjects compared to that of males.

Several researchers attributed the differences in their findings regarding the degree of trait expression between sexes or the overall rate of sex predictive accuracy to population specific factors influenced by environmental functional variables such as chewing habits and food type. The present study did not substantiate that argument, but provided evidence showing that comparable results could arise in studies conducted on samples of people living in different countries, some are neighbors while others are geographically distant, despite differences in food type and eating habits among peoples of these countries. This is evident by comparing the overall sex predictive accuracy rate of 82.2% reached in the present study with the rates of (85.5%), (83%), and (80.2%), reported by researchers from Turkey [1], Egypt [13], and India [20], respectively.

The findings of the present study as well as the above mentioned reports confirmed that the ramus flexure sex prediction method is more diagnostic for females than for males same as reported by Loth and Henneberg [4]. However, all those studies controverted the extremely high overall predictive accuracy of ramus flexure trait (90.6-99.0%) reported by Loth & Henneberg [4].

5. Conclusion

Mandibular ramus flexure may be useful in sex identification; our results showed that it provides an acceptable overall predictive accuracy and could be considered as a supplementary rather than a definitive mean of sex determination. In sexing unknown skeletal remains, it is necessary to employ as many methods or traits as possible instead of relying on one morphological trait.

Disclosure

The author has no conflicts of interest to declare.

Ethical Approval

The ethics committee of the University of Jordan-Faculty of Dentistry approved the present study. The Faculty committee approval was granted after considering the written consent that was obtained from all the subjects of the study sample who were made aware that their CBCT images were going to be included in this study before the investigation started.

Consent

All patients were made aware that their cone beam computed tomography images were selected for inclusion in the present investigation. Accordingly, they all signed written informed consents in compliance with the policy of the Clinical Research Authority at the Jordan University Hospital.

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