REVIEW ARTICLE

Is there enough evidence so that mandible can be used as a tool for sex dimorphism? A systematic review

Puja Hazari,
Rakesh S. Hazari[1],
Sunil Kumar Mishra[2],
Surendra Agrawal[2],
Mukesh Yadav[3]

Department of Maxillofacial Prosthodontics and Implantology, People's Dental Academy, [1]Department of Pathology, People's College of Medical Sciences, [2]Department of Maxillofacial Prosthodontics and Implantology, People's College of Dental Sciences and Research Centre, [3]Department of Maxillofacial Prosthodontics and Implantology, Bhabha Dental College, Bhopal, Madhya Pradesh, India

Address for correspondence:
*Dr. Puja Hazari,
Department of Maxillofacial Prosthodontics and Implantology, People's Dental Academy, Bhopal, Madhya Pradesh, India.
E-mail: hazaripuja@yahoo.in*

Abstract

Statement of Problem: One of the most challenging tasks for forensic science is to identify the unknown human skeletal remains of deceased individuals. Study of sex by distinguishing the various morphological characteristics of bones is utmost important in forensic anthropology and for medico-legal assessment. **Purpose:** The purpose of this article is to review the literature, to find if there is sufficient evidence to establish the use of mandible in sex identification. **Materials and Methods:** An electronic search was performed to identify suitable literature, using database of MEDLINE, PubMed, and EBSCOhost. Published articles in between January 2000 and April 2015 were searched. The main focus of search was on the various parameters of mandible studied in last 15 years for sex dimorphism. The focus was on the articles published on radiographic studies as well as on morphometric studies of dry mandible in which skeletal parameters were studied. The screening of titles and abstracts were done, suitable literature that fulfilled the inclusion criteria was selected for a full-text reading. **Results:** The initial literature search resulted in 89 articles, out of which only 36 articles fulfilled the inclusion criteria and were included in this systematic review. **Conclusion:** Out of 16 radiographic studies, 14 showed statistically significant results that the adult mandible could be used with increased sensitivity and objectivity to identify both sex and population affinity compared to other standard analytical techniques, whereas two studies showed insignificant results. Out of 20 morphometric studies of dry mandible 15 studies showed a positive correlation between sex dimorphism and mandibular parameters and five studies did not show any positive correlations between the two.

Key words: Anthropology, dry mandible, flexure, osteologic, radiographic, sex dimorphism

Introduction

The aim of osteology is to establish the attributes for an individual from their skeletal remains. In anthropological, archaeological, and forensic studies along with the ethnicity and stature, age determination, the identification of sex from human skeletal remains is an

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important element.[1] The pelvis is the most reliable source for sex dimorphism among human bones,[2] but when a complete pelvis is absent in such cases, other bones such as mandible can be an important aid in identification. Since mandible retains its shape better than other bones and as it is most durable facial bone, it is appropriate for study. Many researchers claim a sexing accuracy of 80% from the cranium alone, 90% from the skull and mandible, and 98% from the pelvis.[3] This review of literature is an attempt to summarize the morphometric parameters of dry mandible and radiographic parameters of mandibular bone, which can be used for sex dimorphism and to find out whether mandible can be used successfully as a tool for sex dimorphism?

Search strategy

A broad search of the literature in MEDLINE, PubMed, and EBSCOhost database was performed for articles published between January 2000 and April 2015. A focus was made on peer-reviewed journals. The key words searched were anthropology, dry mandible, flexure, sex dimorphism, radiographic, osteologic, morphometric. The search strategy included the combination of the following terms: "Mandible and sex dimorphism; radiograph in mandible sex dimorphism; osteologic studies, dry mandible and sex dimorphism; ramus in sex differentiation; mental foramen in sex differentiation, morphometric study of dry mandible." Manual searches of the references of all full-text articles and relevant review articles selected from the electronic search were also performed.

Selection criteria

To determine the studies to be included in this systematic review, the following inclusion criterias were decided. Articles related to mandible in sex dimorphism were only included. Only original articles were included. Both abstract and full text articles were included. Review articles and case reports were excluded. On articles with both maxilla and mandible parameters in sex dimorphism, only mandibular parameters were included. Studies that did not meet any of the inclusion criteria were excluded from the review. The literature search initially resulted in 89 articles out of which only 36 articles fulfilled the inclusion criteria and were included in this systematic review. A systematic review of available articles from the MEDLINE and PubMed on morphometric studies of dry mandible and radiologic studies was done. A synopsis of various radiographic studies on mandible in sex dimorphism was presented in Table 1.[4-19] And synopsis of skeletal parameters of morphometric studies on dry mandible in sex dimorphism was presented in Table 2.[1,2,20-37]

Results

Most of the studies reviewed showed statistically significant sex differentiations. Among the most prominent parameters showing sex dimorphism was the ramus of the mandible showing demarcating measurements in ramus breadth and ramus height. Other major parameters which showed statistically significant sex dimorphism were the bicondylar and bigonial width, position of the mental foramen, mandibular length, and chin height. Mandibular ramus flexure was one parameter which has been studied extensively but showed inconsistent results. Very few studies were available on factors such as condylar length and breadth, gonial angle, symphyseal height, and fossa inclinations, but those available showed higher values for males.

Discussion

This article reviewed the various parameters of mandible studied in last 15 years for sex dimorphism. Most of the studies done showed statistically significant sex demarcations. Among the most prominent parameters showing significant sex dimorphism was the ramus of the mandible which showed differences in minimum ramus breath and height. In the study by Ongkana and Sudwan[1] on Thai population minimum ramus breadth for male and females was 32.8 mm and 31.4 mm, respectively. In another study by Pokhrel and Bhatnagar[33] in Indian population, the ramus breadth values were 36.59 ± 6.01 and 28.71 ± 2.72 for male and female, respectively. Kharoshah *et al*.[7] also studied that the predictive accuracy for sex difference was 83.6% in males and 84.2% in females in Egyptian population using minimum ramus height as a factor. Using ramus height as study parameter in Jordanian population Al-Shamout *et al*.[14] concluded that the difference was statistically significant with right side values being 54.02 mm in males and 49.77 mm in females and the left side values for male, i.e., 52.62 mm in relation to females i.e. 48.44 mm. In another study using ramus height on Indian population, Thakur *et al*.[32] also concluded that ramus height can be successfully used as a tool for sex dimorphism with higher values for males. The right side values for male and female were 53 mm and 45.8 mm, respectively, and the left side values were 59.4 mm for male and 36.5 mm for female, respectively. The measured values for both the parameters were higher for male irrespective of the populations studied by many researchers.

Though ramus flexure has been widely studied it showed inconsistent results mainly due to improper grading system.[6,20,21,23,27] Coqueugniot *et al*.[20] and Saini *et al*.[27] concluded that ramus flexure can be successfully used to determine sex with an high average accuracy of up to 82%, while Hill[21] conclude that the results were not consistent as 79.1% accuracy was seen in first evaluation and only 64.7% of the scores were duplicated in the second session. Kemkes-Grottenthaler *et al*.[23] concluded an overall accuracy of 59%.

Table 1: Summary of various radiographic studies on mandible in sex dimorphism

Author	Year	Population	Number of subjects (male/female)	Group age (mean), years	Parameters for study	Study design	Observation (mm)	Conclusion
Saglam[4]	2002	Turkish	Dentate and edentulous group both (48, 48)	Dentate group=43-68 Edentulous group=43-83	Mandibular vertical measurements at three locations	Panoramic radiographs	The distance from the lower border of the mandibular to other locations were significantly greater in men in both the groups when compared to women	After tooth loss there was differences in alveolar ridge resorption between the sexes
Rai[5]	2007	Indian	103 (51/52)	55-76	Mandibular vertical measurements at four locations	Orthopantomography	Significant difference was seen in the distance between the superior margin of mental foramina to crest of the alveolar ridge	This distance decreases significantly with age, and rapidly in females
Galdames *et al*.[6]	2008	Chilean	188 (80/108)	Average age of 21.13 years	Mandibular ramus flexure	Orthopantomograph	Females were 63.25% (62-64.5%) correctly sexed, whereas the prediction accuracy was only 48.25% (46.5-50%) for men	Results were better for the diagnosis of sex in females than in males
Kharoshah *et al*.[7]	2010	Egyptian	330 (165/165)		Six mandibular parameters were evaluated	Spiral CT scan	Statistically significant sex differences were seen in bicondylar breadth, gonial angle, and minimum ramus breadth	The overall predictive accuracy of this study was 83.6% in males and 84.2% in females
Kalinowski and Rózylo-Kalinowska[8]	2011	Polish	877 (410/467)	20-95 (48.69)	Mandibular height in the mental foramen region	Digital panoramic radiograph	Mean height of the mandible on the right side was greater in males than in females	The differences for both parameters were statistically significant
Rashid and Ali[9]	2011	Iraqi	300 (150/150)	20-49	Four vertical measurements of mental and mandibular foramina	Digital panoramic radiography	Males almost have higher measurements than females	Statistically significant differences were observed in all linear measurements between sexes
Angel *et al*.[10]	2011		165 (55/110)	18-80	Location of inferior alveolar canal was assessed at three points	CBCT	The relative location of the inferior alveolar canal and associated foramina in adults remain fairly constant without regard to age and sex	The results were not statistical significant at ($P<0.05$)

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Table 1: Contd....

Author	Year	Population	Number of subjects (male/female)	Group age (mean), years	Parameters for study	Study design	Observation (mm)	Conclusion
Wu *et al*.[11]	2012	Asian	198 (103/95)	Female=11-88 Male=15-98	Mandibular fossa inclination was studied at different points	Computed tomography (sagittal view) LA , LP , RA	LA, LP and RA Male=41.7±8.9; 36.4±7.3; 41.2±8.7 Female=36.8±7.8; 34.1±6.6; 37.0±7.4 (degrees)	LA, LP, and RA were significantly steeper in males than in females
Sheikhi *et al*.[12]	2012	Isfahan	102 (57/55)	21-91 (52.37)	Locations, sizes, and length of LF were assessed	CBCT	Males had significantly larger distance between buccal end of lingual canal from inferior and buccal plate	Location of lingual canal and foramen can be used as a sex dimorphism tool
Felicita *et al*.[13]	2012	South Indian	120 (60/60)	17-28	Subspinale supramentale, superior and inferior prosthion	Lateral cephalograms	Significant difference of maxillary length at subspinale and superior prosthion and mandibular length at supramentale and inferior prosthion	There was a statistically significant sexual dimorphism in the aggregate lengths
Al-Shamout *et al*.[14]	2012	Jordanian	209 (103/106)	11-69 (33.51±14.5)	Ramus height Bigonial width Mandibular gonial angle	Digital panoramic radiography	Male subjects had higher values Sex differences in gonial angle were not statistically significant	Significant differences ($P<0.0001$) were seen in bigonial width and ramus height
Chole *et al*.[15]	2013	Indian	1060	15-66	Gonial angle, antegonial angle and antegonial depth	Panoramic radiographs	Males had smaller gonial and antegonial angle and greater antegonial depth than females	Significant sex difference was seen in mandibular angle at ($P<0.05$)
Chandra *et al*.[16]	2014	North Indians	100 (60/40)	18-62	Perpendicular distance from superior and inferior borders of mental foramen to lower border of the mandibular	Orthopantomograph	Tangents were made from superior (S-L) and inferior borders of the foramen (I-L), perpendiculars were drawn from the tangents to the lower border of the mandible	S-L and I-L between males and females showed a very high significant difference ($P<0.001$) and ($P=0.0022$) respectively on both the right and the left sides
Thakur *et al*.[17]	2014	South India	102 three groups each of 34 radiographs	Three groups <25 25-50 >50	Four parameters were studied	Digital orthopantomograph (right side)	Significant difference obtained between all the four parameters	Significant difference between males and females was seen

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Table 1: Contd....

Author	Year	Population	Number of subjects (male/female)	Group age (mean), years	Parameters for study	Study design	Observation (mm)	Conclusion
Genú *et al*.[18]	2014	Brazilian	142 (43.4%/56.6%)	21-79 (49.84)	MF AL IC	CBCT	One MF was found on each side in all subjects AL was seen in 18.9% of the images In 96.5% of the it was possible to identify the anterior extension of the IC	No significant difference ($P>0.05$) between sex was observed
Indira *et al*.[19]	2915	Indian	100 (50/50)		Ramus Breadth Condylar height Ramus height Coronoid height	Orthopantomograph	Each variable was a significant predictor in classifying a given sample ($P<0.001$)	The mean values showed that all dimensions were higher in males compared to females

MF: Mental foramen, AL: Anterior loop, IC: Incisive canal, LF: Lingual foramen, CBCT: Cone-beam computed tomography, LA: Left anterior, LP: Left posterior, RA: Right anterior

Table 2: Synopsis of skeletal parameters of morphometric studies of dry mandible in sex dimorphism

Author	Year	Population	Number of subjects (male/female)	Group age (mean), years	Parameter for study	Study design	Observation (mm)	Conclusion
Coqueugniot *et al*.[20]	2000	Palaeolithic hominids	06 Homo sapiens fossil	Late adolescence and adulthood	MRPF	Visual skeletal study	Score of 0 to+2 was identified as males, and−1 or−2 was identified as females	A visual assessment of MRPF as a sex indicator did not bring any high significant value
Hill[21]	2000		158		Mandibular ramus flexure	Visual skeletal study	79.1% accuracy was seen in first evaluation and only 64.7% in second	Low overall accuracy in sex dimorphism
Loth and Henneberg[22]	2001	South African whites and blacks	62	0-19	Symphyseal base and body shape	Mandible	Symphyseal base and body shape in female and male were compared	Males were consistently identified more accurately than females
Kemkes-Grottenthaler *et al*.[23]	2002		153		Mandibular ramus flexure and gonial eversion	Mandible	Ramus flexure Male=66% Female=32% Gonial eversion Male=75.4% Female=5.2%	Low accuracy for both the parameters due to age and localized tooth loss
Hu *et al*.[24]	2006	Korean	102		13 nonmetric items	Morphological characteristics	Rocker shaped mandibles, bilobate or square chin predominated in males	Nonmetric parameters could be used for sex dimorphism
Franklin *et al*.[25]	2007	African, American, South African Bantu and Caucasian	African American (18/19) South African Bantu (25/17) Caucasian (10/7)	African American =1-17 South African Bantu=1-17 Caucasian 2-17	Bilateral points and midline points of mandible	Subadult mandible Morphometric study	No significant sexual dimorphism in the subadult sample	The subadult mandible is not dimorphic

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Table 2: Contd....

Author	Year	Population	Number of subjects (male/female)	Group age (mean), years	Parameter for study	Study design	Observation (mm)	Conclusion
Ongkana and Sudwan[1]	2009	Thai population	102 (68/34)	Male/ female=67.35±12.0 /63.35±13.52	Nine parameters	Dried mandible Metric analysis	Chin height Male=64.8 Female=59.0 mm	Eight out of nine parameters (except chin height) showed significant difference
Galdames *et al*.[26]	2009	Brazilian	32 (20/12)	0-1	Eight mandibular parameters	Dried mandible	Most of the dimensions were higher in male	There were no statistically significant differences
Saini *et al*.[27]	2011	Indian	112 (88/24)		Mandibular ramus flexure	Dried Mandible	This trait can be used to diagnose gender with an average accuracy of up to 82%	Mandibular ramus flexure can be successfully used as a parameter for sex dimorphism
Carvalho *et al*.[28]	2013	Brazilian population	66 (34/32)	Older than 20 years	Bigonial distance and mandibular ramus height	Anthropology (skulls)	Accuracy of 76.47% for males and 78.13% for females	Parameters and methodology must be validated for the different groups
Marinescu *et al*.[29]	2013	Romanian	200 (100/100)	20-86 (39)	Chin height, bigonial width and bicondylar breadth	Adult dried mandible	The accuracy of discriminant function using all 3 variables is 84%, equal for male and female	Bigonial width provided 80.5% accuracy, slightly better for males
Vinay *et al*.[30]	2013	South Indian Bigonial width, bicondylar breadth, mandibular length	250 (175/75)		Bigonial breadth Bicondylar breadth Mandibular length and mandibular index	Metric analysis of mandible	Male=75.92, 71.39, 66.02% Female=71.16, 63.54, 53.01% respectively	The sex differences in mean values were significant
Kumar and Lokanadham[31]	2013	South India	80	18-60	22 parameters of mandible were evaluated	Dried mandible	Symphyseal height, body thickness, body length, anthropometric arch width, mandibular angle, bicondylar diameter	Mandible of unknown sex can be sexed to the extent of 75% accuracy by six dominating parameters
Thakur *et al*.[32]	2013	Indian	60 (30/30)		Mandibular angle and height of the ramus	Dried mandible (using mandibulometer)	Significant difference obtained between males and females	Significant difference between the ramus height of right and left side and mandibular angle of left side
Pokhrel and Bhatnagar[33]	2013	Pune (India)	158 rami from 79 intact mandibles		Minimum and maximum ramus breadth, maximum condylar length and breadth	Dried mandible	Measurements taken from rami and condyle were greater for males	All the values were greater for males, then for females
Raj and Sindhu[34]	2013	South Indian	120 (60/60)		Four mandibular parameters were evaluated	Adult mandible Digital Vernier caliper	Significant parameter for sex dimorphism seen was supero-inferior length (right side)	The ramus part of mandible has satisfactory potential for determination of sex
Kranioti *et al*.[2]	2014	Greek	70 (36/34)	>66 (55.3±8.8 /50.9±15.8)	Chin height, minimum ramus height, bicondylar, bigonial and bimental breadth	Dried mandible	Results indicate that in male mandibular produces greater values than female except bimental breadth	Bigonial breadth is most discriminatory factor with accuracy of 71% followed by bicondylar breadth with (69%)

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Table 2: Contd....

Author	Year	Population	Number of subjects (male/female)	Group age (mean), years	Parameter for study	Study design	Observation (mm)	Conclusion
Akhlaghi *et al*.[35]	2014	Iranian	45 (23/22)	Below the age of 20	Eight mandibular anthropometric parameters	Cadavers	No significant statistical difference was seen in the values between the two sex in samples below the age of 12	Symphyseal height and mandibular bigonial breadth could be used to determine the sex
Lin *et al*.[36]	2014	Koreans	240 (120/120)	Mean age 46.2	11 parameters	Discrimination function analysis using 3D mandible models	Mandibular flexure upper border, maximum ramus vertical height and upper ramus vertical height expressed the greatest dimorphism	Upper ramus above flexure holds larger potential than the mandibular ramus flexure itself to predict sexes
Pillai *et al*.[37]	2014	South India	88	18-60	Mandibular morphology was studied for 22 parameters	Dried mandible	Significant differences obtained in height of the ramus, body thickness, mandibular angle etc.	Six dominating characteristics could possibly help in identification of sex

P value: Prevalence, MF: Mental foramen, 3D: Three-dimensional, MRPF: Mandibular ramus posterior flexure

Other parameter showing consistently significant higher values for male was the bicondylar width. In the study by Ongkana and Sudwan[1] on Thai population bicondylar width for male was 123.8 mm and for females was found to be 116.1 mm. Marinescu *et al*.[29] also concluded similar results in Romanian population with males showing higher values, i.e., 120 mm and 113.1 mm for females. Similarly, Vinay *et al*.[30] in his study on Indian population showed similar results with male values of 129 mm and 96.9 mm for females, and Kranioti *et al*.[2] showed male values of 118.72 mm and 113.34 mm in females for Greek population, respectively. These results were further supported by the study of Kumar and Lokanadham[31] on Indian population who concluded the bicondylar diameters to be in range of 91–126 mm.

Bigonial breadth can also be considered as a statistically significant factor for sex dimorphism. In the study conducted by Vinay *et al*.[30] on Indian Population, the measured values were 103.5 mm for males and 78 mm for females, which were supported by the findings of Kranioti *et al*.[2] who found the male measurements to be 101.169 mm and female measurements to be 93.974 mm in Greek population.

A large number of studies were conducted on the position of the mental foramen. Rai[5] studied the Indian population and concluded that a statistically significant sex difference existed between the superior margins of mental foramina to crest of the alveolar ridge. These finding were further supported by the study conducted by Rashid and Ali[9] were the distance was 17.4 ± 0.119 mm for males and 16.01 ± 0.121 mm for females in Iraqi population. Thakur *et al*.[17] also studied the same parameter and found the distance to be statistically more in males and concluded that the distance between the superior margins of mental foramina to crest of the alveolar ridge can be used as a tool for sex dimorphism with high accuracy. The distance between the inferior margins of the mental foramen to the inferior border of the mandible also showed a high accuracy for sex dimorphism.[8,9,16,17] Chandra *et al*.[16] found the lower height to be 12.67 mm in males and 11.46 mm in females on the right side and 12.58 mm in males and 11.25 mm in females on the left side in Indian. Rashid and Ali[9] found these measurements to be 10.06 ± 0.101 mm in males and 9.24 ± 0.095 mm in female which coincided with other similar studies.

Mandibular length and chin height were also evaluated, and measurements were higher for males in all studies.[1,30] Ongkana and Sudwan[1] found the mandibular length to be 8.94 mm in males and 8.53 mm in females of Thai origin. Similar values were reported by Vinay *et al*.[30] in Indian population who found the male measurements to be 8.81 mm and female measurements to be 6.22 mm for mandibular length. Chin height values were 29.78 for males and 26.12 for females in the study conducts by Kranioti *et al*.[2] and 32.1 mm and 29.4 mm in the study conducted by Marinescu *et al*.[29] in Romanian population for males and females respectively.

Conclusion

The present review revealed that there was a statistically significant sex dimorphism in mandible. 87.5% of radiographic studies showed statistically significant results that the adult mandible could be used to identify both sex and population affinity compared to other standard analytical techniques. Out of twenty morphometric studies of dry mandible 75% of studies showed a positive correlation between sex dimorphism and mandibular parameters. The review further concludes that it is better to use more number of variables than single parameters for higher accuracy in identification of the mandible in sex dimorphism. Growing mandible cannot be used as a very accurate method in sex differentiation as its studies showed a lower rate of sex differentiation than adult bone. Hence, due to the differences in ethnic patterns parameters and methodology must be validated and standardized for the different groups of population.

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There are no conflicts of interest

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