DOI: 10.7860/JCDR/2022/59582.17242

Review Article

Anatomy Section

Mandibular Ramus as a Tool For Sexual Determination: A Systematic Review

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ABSTRACT

Introduction: Mandible being one of the sturdy bone resists damage and therefore its fragments are mostly available after mass disasters like explosions. After the pelvis, the mandible of the skull has significant sexual dimorphism. Many parameters of the mandible altogether make it suitable to identify sex from a given bone.

Aim: To determine sex with the help of parameters of the ramus of human mandible.

Materials and Methods: This systematic review included the articles from 2000 to 2020 and took one year duration. All studies were categorised under dry bone and radiological study. Only original articles of a cross-sectional study, cohort study and case-control study related to ramus and sex determinations were selected online by using available databases like Medline, Embase, and Google Scholar. All selected articles were then analysed for different types of ramus parameters studied. Studies that considered more than one parameter of ramus were included or otherwise rejected. Research articles that mentioned the efficacy of gender identification of bone by considering parameters of the ramus of the mandible, were tabulated.

Results: Commonly used ramus parameters by different researchers were maximum ramus breadth/width, minimum ramus breadth/width, ramus flexure and ramus height. In addition, coronoid height and projection height was also used by some. In most of the studies, parameters in males were higher than in females whereas gender predictive value was seen higher i.e, 70-83% when a combination of all ramus parameters was taken. In the case of consideration of a single parameter, gender predictive values ranged from 45-79%, and a higher sex predictive value was seen for males.

Conclusion: Only when the fragment of the mandible ramus is available, then it can be utilised for gender identification by using ramus width, ramus height along with other parameters based on availability. Ramus alone is a good tool for sex determination in the mandible.

Keywords: Panoramic, Radiographies, Sex dimorphism

INTRODUCTION

After the pelvis, the role of the mandible is considered significant in the identification of gender [1,2]. Being the strongest bone of the face, mandible is more resistant to degradation and has more possibility to get fragments as a piece of evidence. There is a number of metric and non metric traits of mandible utilised in gender determination due to their property of sexual dimorphism [3-5]. Mandible shape and size help to determine sexual dimorphism but the condyle and ramus part of the mandible have higher scores in the determination of gender [6]. The study of different parameters of the mandible showing relevant sexual dimorphism has an important role in the field of archeology, anthropology, and forensic science in relation to the identification of race, age, and gender. A combination of metric traits adds more reliability due to its measurable quantitative element. When sex determination of bone is done by osteometric or radiograph method, metric analysis by radiograph methods stands superior in terms of accuracy and reproducibility [7].

In anthropology, sex determination is one of the pillars among other components like age and population. Age-related changes include remodeling with the growth of an individual. Morphological changes in the mandible due to food habits have major effects on the dimension of parameters of the ramus and condyle of the mandible. Radiograph methods like Orthopantomography (OPG) and Digital Panoramic radiography (DPG) are common routine procedures in dental and medical clinical fields [5,6]. A large amount of data available due to these routine procedures can be easily utilised for gender identification after filtering specific parameter dimensions, which can be beneficial in the field of forensic anthropology and forensic investigation.

With the increasing incidence of mass disasters by explosions, natural calamities, air crashes, and crimes there has been increased demand for data, with the help of which, identification of an individual and their gender can be done from fragments of the bone that are available. In the present systematic review, an attempt was made to summarise the role of the ramus of the mandible as a fragment for gender determination.

MATERIALS AND METHODS

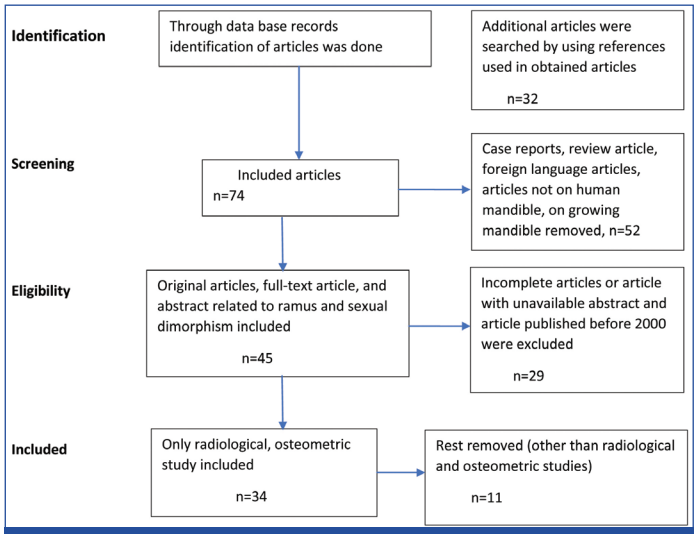
This systematic review included the articles from 2000 to 2020 and analysis was done in one year duration (March 2021 to February 2022). An online search was done on available databases like Medline, Embase and Google Scholar. Related literature of the last 20 years from 2000 to 2020, was searched that included keywords like dry mandible, ramus, gender determination, radiological, orthopantomography osteologic, anthropology, forensic, and sexual dimorphism. In order to get more related articles, Boolean operators such as AND/OR/NOT were utilised. A combination of the mandible and sexual dimorphism, dry mandible or osteological study, the panoramic study of the mandible, ramus and gender determination and ramus not gonial width were utilised to search more titles, abstracts and original articles. References of the related articles were searched to extract more data. For the purpose of collecting relevant articles, certain inclusion and exclusion criteria were formulated.

Inclusion criteria: Articles included were only those that came under the category of observational studies, cross-sectional studies, prospective and retrospective studies. Original articles, abstracts and full-text articles based on radiological and osteometric studies of the ramus of the mandible, with aim of study for sexual dimorphism were only included in the study.

Exclusion criteria: Case report and review article were not included in the study. Any article on mandibles, but not based on gender determination or not on human mandibles was excluded. Articles

about the growing mandible, irrespective of the aim for sexual dimorphism were also excluded from the study.

After the screening, 126 relevant articles were collected. After the application of inclusion and exclusion criteria, 34 articles were finalised for systemic review [Table/Fig-1].



[Table/Fig-1]: PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart for selection process.

All included materials were categorised into the radiological and osteological study, in relation to parameters of the ramus of the mandible and tabulated along with needful data. All the articles finalised were individually screened and analysed by the authors. Tabulation of studies with their population, parameters used, study tool, and conclusions were done.

Study of Risk of Bias

In case of any doubt in relation to exclusion or inclusion, the article was discussed among authors to reach a common consensus on excluding or including the article. A checklist for qualitative research by Munn Z et al., was used to assess the quality of articles. This tool assessment was based on review question clarity, inclusion criteria, appropriateness of the extent of use of resources, criteria of appraising studies, methods used to minimise errors, the combination of different studies, publication bias, and any directive for new ideas given or not [8]. Any disagreement over any article was tried to finalise following the above leading questions to reach common consensus of exclusion and inclusion. This reduced bias of selection, but still selection bias could not be totally neglected .

RESULTS

Considering all Indian studies, Max RB was 38.2 mm in males and 35.8 mm in females whereas Min RB ranged from 27.7 mm to 30.11 mm in males and 20.2 mm to 30.11 mm in females with overall accuracy 83.9% [5-7,9-17] [Table/Fig-2,3]. In [Table/Fig-3], the study on the population of Thailand shows that the Min RB in them was closer to the lower value of Min RB of the Indian population. Among all other countries,ramus height in Indians was in the range of 60.1 mm to 67.9 mm for males and 40.9 mm to 55.7 mm for females [11,12,17,18-28] [Table/Fig-4,5]. The ramus height of Thailand people [Table/Fig-5] was closer to the lower value of the ramus height range observed in the Indian population and it was a much lower value range from 44.18 to 49.94 mm seen in the population of Tanzania [28]. The overall accuracy of sex determination was seen higher with parameter ramus breadth. There was a big range of accuracy of gender identification for ramus flexure noticed, ranging from 32 to 92%, but it was found that the percentage of accuracy was higher in males in comparison to females [29-37] [Table/Fig-6,7].

Name of authors and year of publication	Sample size	Country	Parameters	Additional parameters	Study tool	Conclusion
Saloni et al., [5] 2020	200	India	Max RB Min RB	Condy Ht (Mx RH) Project Ht Corond Ht	Digital Panoramic Radiography (DPR)	All parameters higher in males Overall accuracy in sex determination 77.6% 78.4% in males, 76.8% in female
Mathew NS et al., [6] 2017	100	India	Min RB		Panoramic radiograph	Wider in male
Samatha K et al., [7] 2016	120	India	Max RB Min RB	Condy Ht Project Ht Corond Ht	Orthopantomogram (OPG) Analysed with Discriminant Function Analysis (DFA) using Fisher's-exact test	Max RB,Condy Ht, Project Ht Significant (p-value <0.05) Ramus useful for gender determination
Bhagwatkar T et al., [9] 2016	100	India	Max RB Min RB	Condy Ht (Mx RH) Project Ht Corond Ht	OPG	All parameters high in males
Kumar BN et al., [10] 2016	308	India	Max RB Min RB		OPG	Max RB M=3.82±0.38 cm F=3.58±0.33 cm Min RB M=2.92±0.32 cm F=2.77±0.31 cm
Kallali BN et al., [11] 2016	30	India	Min RB	RH	3D-CT	Min RB Male=2.4±0.25 cm Female=2.02±0.18 cm p-value=0.72
Jambunath U et al., [12] 2016	50	India	Max RB Min RB	Condy Ht Proj Ht Corond Ht	DPR	Min RB and Max RB=not significant
Kharoshah MA et al., [13] 2010	330	Egypt	Min RB		Spiral CT	Overall accuracy 83.9%

[Table/Fig-2]: Ramus breadth (Radiological study) [5-7,9-13].
Min: Minimum; Max: Maximum; DPR: Digital panoramic radiography; OPG: Orthopantomography; RH: Ramus height; RB: Ramus breadth; Project Ht: Projective height; Condy Ht: Condylar height; Corond Ht: Coronoid height; M: Male; F: Female; Mm: Millimeter; Cm: Centimeter

Name of authors and year of publication	Sample size	Country	Parameters	Additional parameters	Study tool	Conclusion
Kujur B et al., [14] 2017	47	India	Min RB		VrC	M=31.43±3.33 mm F=30.11±2.33 mm P=0.1273
Sharma M et al., [15] 2016	126	India	Min RB		VrC	M=30.92±2.55 mm F=29.56±2.86 mm

Pokhrel R and Bhatnagar R [16] 2013	79	India	Min RB Max RB		VrC	All measurements greater for males
Ongkana N and Sudwan P [17] 2009	68	Thailand	Min RB	RH	VrC	Min RB male: 30.28 mm female 30.14 mm

[Table/Fig-3]: Ramus breadth (Osteological study) [14-17].
Min: Minimum; Max: Maximum; RH: Ramus height; RB: Ramus breadth; M: Male; F: Female; Mm: Millimeter; Vrc: Vernier caliper

Name of authors and year of publication	Sample size	Country	Parameter	Additional parameters	Study tool	Conclusion
Abbas B and Najm AA [18] 2019	50	Iraq	RH		DPR	RH higher in males In Males RH=76.1±0.9 mm In Females RH=70.1±0.57 mm
Kallali BN et al., [11] 2016	30	India	RH	Min RB	3D-CT	RH male =60.1±0.98 mm RH female=40.9±0.52 mm (p-value <0.001)
Jambunath U et al., [12] 2016	50	India	Max RH	Min RB Max RB Condy Ht Proj Ht Corond Ht	DPR	Max RH higher in males (p-value <0.001)
Taleb NSA and Beshlawy DME [19] 2015	191	Egypt	Condy Ht Corond Ht	Upp RB Low RB Project Ht	DPR	All ramus variables higher in male Condy Ht and Corond Ht significant predictor of sex Corond Ht accuracy of 81% in male, 77.9% in female, overall 79.6%
Leversha J et al., [20] 2015	220	Queensland	RH		DPR	RH higher in males (p-value <0.0001)
Al-shamout R et al., [21] 2012	209	Jordan	RH		DPR	Male with higher value, Significant difference seen
Indira AP et al.,[22] 2012	100	India	RH	RB Condy Ht Corond Ht	OPG	Higher values in male Significant difference (p-value <0.001)

[Table/Fig-4]: Ramus height (Radiological study) [11,12,18-22].
Min: Minimum; Max: Maximum; DPR: Digital panoramic radiography; OPG: Orthopantomography; RH: Ramus height; RB: Ramus breadth; Project Ht: Projective height; Condy Ht: Condylar height; Corond Ht: Coronoid height; M: Male; F: Female; Mm: Millimeter

Name of authors and year of publication	Sample size	Country	Parameters	Additional parameters	Study tool	Observation/Conclusion
Datta A et al., [23] 2015	50	India	RH		VrC	M: 67.98 mm F: 55.72 mm
Kranioti EF et al., [1] 2014	70	Greek	Min RH		VrC	Higher value in male
Pillai TJ et al., [24] 2014	88	India	RH		Vr C	Significant difference seen
Kumar MP et al., [25] 2013	80	India	RH	Min RB	VrC	Based right ramus RH sexing 75M 5F, left RH sexing 70 M 10 F
Carvalho SP et al., [26] 2013	66	Brazil	RH		VrC	Accuracy of 76.47% for males and 78.13% for females
Ongkana N and Sudwan P 2009 [17]	68	Thailand	RH	Min RB	VrC	Max RH M: 60.81 mm F: 60.26 (significant)
Rai R et al., [27] 2007	117	India	RH		VrC	RH higher in males than in females
Fabian FM and Mpembeni R [28] 2002	50	Tanzania	RH		VrC	Higher in males (found significant), M=49.94 mm F=44.18 mm

[Table/Fig-5]: Ramus height (Osteological study) [1,23-28].
Min: Minimum; Max: Maximum; RH: Ramus height; RB: Ramus breadth; M: Male; F: Female; mm: Millimeter; VRC: Vernier caliper

Name of authors and year of publication	Sample no.	Country	Parameter	Study Tool	Conclusion
Badran DH et al., [29] 2015	419	Jordan	MRF	OPG	Moderately acceptable predictive accuracy
Galdemes IC et al., [30] 2008	188	Chilean	MRF	OPG	63.25% accuracy in females identification, 48.25% in male

[Table/Fig-6]: Ramus flexure (Radiological study) [29,30].
OPG: Orthopantomography; MRF: Mandibular ramus flexure

Name of authors and year of publication	Sample size	Country	Parameters	Additional parameters	Study tool	Observation/Conclusion
Lin C et al., [31] 2014	240	Korean	MRF	Max RH	3D model Discrimination functional analysis	Upper RH expressed the greatest dimorphism
Saini V et al., [32] 2011	112	Indian	MRF		Sliding calipers	82% accuracy
Franklin D et al., [33] 2008	225	Africa	MRF		Microscribe G2X portable digitizer	Posterior ramus significant difference seen
Balci Y et al., [34] 2005	120	Turkey	MRF		Morphology observation	Accuracy identification male 92.6%, female 60%

Haun SJ, [35] 2000	150	Iran	MRF		Morphology observation	Overall accuracy in sex determination 78.2%
Kemkes GA et al., [36] 2002	153	Germany	MRF		Morphology observation	Ramus flexure Male=66% Female=32%
Hill CA [37] 2000	158	Kansas	MRF		Morphology Observation	64.1% to 79.1% accuracy low accuracy

[Table/Fig-7]: Ramus flexure (Osteological study) [31-37].
RH: Ramus height; MRF: Mandibular ramus flexure

DISCUSSION

Many related articles showed that more than 22 parameters were studied in the mandible to understand their correlation with sexual dimorphism. The total article reviewed in the last 20 years showed that the most common parameters utilised for gender determination in the mandible were a gonial angle, ramus height, ramus breadth, ramus flexure, and bigonial width. Among these, correlations of parameters like gonial angle, ramus flexure and ramus breadth were more in accuracy alone or in combination, for sex determination through the mandible. Kharoshah MA et al., in their radiological study with a sample of 330 people in Egypt population concluded that, the overall predictive accuracy of sex prediction was 83.9% by using parameters bicondylar breadth, gonial angle, and minimum ramus breadth whereas it was 83.6% in males and 84.2% in females [13].

Saini V et al., took 116 mandibles of north Indian origin for their osteometric study over the different parameters of ramus only that included condylar height, projected height, coronoid height, minimum, and maximum ramus breadth. They found significant sexual dimorphism with an overall accuracy of 80.2% [32]. Lin C et al., did a study of 240 mandibles of the Korean population to determine sex from ramus flexure parameters only, and found that, sex determination accuracy ranges from 50.4 to 77.1% by using discrimination functional analysis. They further added that accuracy increases up to 88.8%, if all variables of mandibular flexure were input in stepwise discriminant analysis [31].

Ercan I et al., took 415 samples of Turkish origin, to study of virtual assessment of sex by a linear and angular trait of mandibular ramus, using three-dimensional CT concluding an accuracy range of 51-95.6% in sex determination by using mandibular ramus. They further pointed out that accuracy increased to 89.7-98.6% if mandibular flexure upper border and max ramus breadth was utilised by applying bivariate analysis [38]. A 99% accuracy rate was noticed by them when stepwise discrimination analysis was done. Saloni et al., in their study of ramus and gender determination by the radiological method using digital panoramic film of 200 Indian origin samples found significant differences and thus were able to get overall accuracy of sex determination by ramus parameters upto 77.6%, which was individually up to 78.4% in male and 76.8% in female respectively [5].

Kaur R et al., did a digital radiological study on 100 samples of the Indian Haryana region to find mandibular ramus and sex determination using ramus parameters like minimum and maximum ramus width, condylar height, and projection height of ramus. They found significant differences between male and female parameters [39]. Indira AP et al., their radiographic study of 100 mandibles of Indian origin concluded that the mandibular ramus was a strong parameter for sex determination [22].

The above study was supported by a similar study done by Damera A et al., [40]. Loth SR and Henneberg M, found mandibular ramus flexure help to determine the sex of the mandible with an accuracy of up to 91% due to a significant difference [3]. Pokhrel R and Bhatnagar R 2013 [16] concluded that, a fragment of a mandible having a ramus can be used for gender determination when they found significant differences in the parameter of the ramus and were able to determine the sex of the mandible with an overall accuracy of 82.9% with help of ramus breadth and 70.9% with condylar length and breadth by using discriminate functional analysis method [16]. For this study, they took 158 rami of 79 mandibles of Indian origin. Kronoiti EF et al., found significant differences and sexual dimorphism in the ramus of the mandible by using discriminate functional analysis by taking 70 adult Greek population mandibles [1].

The collection of huge data over years on different parameters related to the ramus of the mandible enables anthropologists to identify the gender of an individual with the help of fragments of the mandible. Predictive accuracy increases as parameters like ramus height, ramus width, and ramus flexure, when combined all together to identify gender through the ramus of the mandible. In addition to gender identification, these parameters data could be utilised in the field of cosmetic surgery like reconstruction of the face. Comparative study over parameters of different populations and ethnicity would help to understand anthropological connections among them, if any or to evaluate factors, that lead to changes in morphometric dimensions of the mandible. The development of more aesthetic prostheses could be possible, if the compilation of all related parameters was done and analysed based on age, population, and gender.

Limitation(s)

The non availability of sufficient data, based on a cadaveric study was a big limitation and could not be well-blended, with studies based on radiological and osteometric studies.

CONCLUSION(S)

Different parameters like ramus breadth, ramus height and ramus flexure all together play a significant role in sexual dimorphism identification of the mandible and can be utilised in combination to identify the sex of fragment of ramus of the mandible with predictive accuracy, ranging from 64-84%. Considering the fact that, most of the studies included were on the Indian population which showed the same trend as those of another geographical area i.e most parameters were on the higher side in males. The parameters like ramus breadth, were comparatively lower in people of Thailand and ramus height of Tanzania population was toward the lower end of the range seen in the Indian population. Validated measurements based on different gender, ethnic patterns, and populations should be kept in mind during anthropological studies, forensic applications, and surgical reconstruction of faces.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Aug 22, 2022
- Manual Googling: Nov 15, 2022
- iThenticate Software: Nov 17, 2022 (7%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? No
- Was informed consent obtained from the subjects involved in the study? NA
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Aug 09, 2022**
Date of Peer Review: **Sep 19, 2022**
Date of Acceptance: **Nov 20, 2022**
Date of Publishing: **Dec 01, 2022**