Determination of Sex of Dry Human Mandible by its various Parameters (A Morphometric Study)

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ABSTRACT

Determination of sex from the human remains is very much important and necessary in both living and dead persons for medico-legal and anthropological perspectives. Bones often survive by the long process of decay and provide the major evidence of age and sex of human remains. The mandible is the best material for this study because mandible takes more time to decay. The present study is based on (125) adult dry human mandibles of known sex. Out of (125) dry mandibles (80) were of male and (45) were of female individuals. These mandibles are collected from the Department of Anatomy of Maharishi Markandeshwar Medical College and Hospital, Kumarhatti District Solan, Himachal Pradesh, India. Various measurements are taken from its selected points as described in the paper and recorded in tables. Mean value of measurements of right and left side of male and female mandibles are taken separately. The average value of the width between mandibular foramen to mandibular foramen and the difference between male and female is 3.30 mm which is more in male than in female mandibles. The average width between medial poles of right and left condyles is 2.22 mm more in case of male mandible than in female. The average heights of coronoid process, condyloid process, height of notch of mandibles from base of the mandible, distance between mental foramen and the base of the mandible are 4.86 mm, 3.38 mm, 6.14 mm and 2.03 mm respectively more in males than in females . The average angle of the mandible is 5.28^0 more in female mandible than male. The mandibular index is 93.27% and 98.09% in male and female respectively. The mandibular index is more in female as compared to male. All these differences in measurements will help in the determination of the sex of the mandible which is a major aim of our study. The present study is compared with standard literature and studies done by other authors. The present study will be helpful for forensic medicine, forensic dentistry, anthropologists and maxillofacial surgeons.

Key words: *Mandibular foramen, mental foramen, coronoid process, condyloid process, angles of mandible, genial tubercles, lingula, mandibular notch, Temporo-mandibular joint*

INTRODUCTION

Mandible is the largest and strongest bone of face which gives the shape to the face. It is only bone of skull which is mobile and moves during eating and chewing process. All the four muscles of mastication get insertion on the mandible on its different places. It consists of a horse shoe shaped body and two rami. The rami are having two processes i.e. coronoid and condyloid processes. The condyloid process is having the head and neck. The head articulates with the mandibular fossa of temporal bone to form the Temporo-mandibular joint. The neck gives the insertion to the lateral pterygoid muscle in its pterygoid fovea on the anterior side of the neck. The coronoid process is a conical process, on which the temporalis muscle gets insertion. In between two processes there is a notch called mandibular notch through which the nerves and vessels pass to the masseter muscles on both (right and left) sides. Outer surface of rami give the insertion to the masseters muscle near the angle, while the inner surface of rami give the insertion to the medial pterygoid muscles near the angle of the mandible. There are foramina called mandibular foramina on the medial surface of both the rami, through which the inferior alveolar nerves and vessels pass to the mandibular canals. On the anterior boundary of mandibular foramen there is conical projection called the lingula, on which there is attachment of spheno-mandibular ligament. On the posterior border of the rami there are attachment of the stylo-mandibular ligament. These ligaments give the strength to the temporo-mandibular joint along with other ligaments of the joint. In the arch of body of mandible there are three or four genial tubercles which give the attachment to genioglossis and geniohyoid muscles. On the antero-lateral surfaces of body of the mandible there are two small foramina called mental foramina through which the mental nerves and vessels pass, which are terminal branches of the inferior alveolar nerves and vessels. (Standring 2008, Snell 2012).

Mandible may play a vital role in sex determination as it is most dimorphic, largest and strongest bone of skull. Presence of a dense layer of compact bone, makes it very durable, and hence remains well preserved that of many other bones. Dimorphism in mandible is reflected in its shape and size. Male bones are generally bigger and more robust than female bones (Saini et al. 2011, Scheuer-2002).

Mandible is the largest and strongest bone of the face. There are less chances of its damage during disaster and accidents. The mandible bone is very helpful in investigations like age and sex because it is having many points for determination of age and sex. In these days when there is increase in atrocities on women, the mandible bone is very much helpful in determining the sex of the bones of deceased. So the mandible is very much helpful for forensic medicine, anthropological workers and maxilla-facial surgeons who can use the coronoid process for grafting purpose (Harrison 1995).

According to Hu et al. (2006) the mandible is the largest and hardest facial bone and remains its shape better than other bones in the forensic and physical anthropologic field. This is of particular importance in relation to human identification as its durability can be the only reason a skeletal remains true identity is known. This quality can be exploited to distinguish ancestry and to identify gender also.

Franklin et al. (2007), Johnson et al. (1990), Naccarato and john (2008), Heereshechadra and Malaviya (1972) noted that the dimensions of male mandible is considerably larger and longer especially body than female. In addition male mandibles typically have squarer chins and thicker, rougher muscle attachments than female mandibles. There are variations in the mandible according to sex, age and race which can be helpful to the physicians, surgeons, medico legal authorities and anthropologists to give correct interpretations for the results of diagnostic procedures in the living (Williams et al. 2000, Dutta 2002, Singh 2009 and Saini et al. 2011).

The head or condyloid process of the mandible is markedly convex from front to back and slightly convex from side to side. The medico legal axis is longer than the antero-posterior and projects beyond the neck as medial and lateral poles are more prominent. This axis is directed medially and slightly backward. The head is bent slightly to the anterior on the neck, such that the articular surface faces upward and forwards (Sinnatamby 2011).

Anthropologists worked in different regions to evaluate the angle of the mandible and to analyze the relationship of the angle and height and breadth of the ramus of the mandible to the gender, as to study its role in the anthropological diagnosis (Rai et al. 2007). Several studies have been conducted on dry adult mandibles for sex determination but literature search did not reveal any study with regard to measurements on ramus of the mandible using as digital panoramic radiograph (Saini et al. 2011, Hu et al. 2006, and Vodanovic et al. 2006). A broken mandible usually involve two fractures, which frequently occur on opposite side of the mandible, thus, if one fracture is involved, a search should be made for another. For example, a hard blow to the jaw often fractures the neck and body of the mandible in the region of the opposite canine tooth (Moore et al. 2010).

MATERIALS AND METHODS

The present study is conducted on (125) adult dry human mandibles of known sex (80) mandibles of male and (45) mandibles of female which are collected from the Department of Anatomy of Maharishi Markandeshwer Medical College and Hospital, Kumarhatti, Solan, Himachal Pradesh, India. All the mandibles are of adult age and known sex. (125) adult dry human mandibles are the material for this study. Any deformed or broken mandible is discarded. The measurements are taken from different points of all the mandibles as given below in the list. These measurements of the mandibles are taken with the help of digital vernier caliper, metallic scale and goniometer in both the sexes differently and recorded in the tables. The mean of the measurements of both the sexes are taken separately and compared with each other to see the differences in male and female to identify the sex of the mandibles. The present study will be compared with the standard literature and studies done by other authors.

The list of measurements and their abbreviations used for the calculations and given in tables are given below: -

1. Width between right mandibular foramen and left mandibular foramen (rmf - lmf)

2. Width between right mental foramen and left mental foramen (rmnf - lmnf)
3. Width between medial poles of right and left condyles of the mandible (rcdp - lcdp)
4. Width between right mandibular foramen and center of genial tubercles (rmf -gt)
5. Width between left mandibular foramen and center of genial tubercles (lmf -gt)
6. Height of right coronoid process from the base of the mandible (rcp -b)
7. Height of left coronoid process from the base of the mandible (lcp -b)
8. Height of right condyloid process from the base of the mandible (rcdp -b)
9. Height of left condyloid process from the base of the mandible (lcdp -b)
10. Height of right mandibular notch from the base of the mandible (rmn-b)
11. Height of left mandibular notch from the base of the mandible (lmn -b)
12. Height of right mental foramen to the base of the mandible (rmf- b)
13. Height of left mental foramen to the base of the mandible (lmf- b)
14. Right angle of the mandible (ranm)
15. Left angle of the mandible (lanm)
16. Mandibular index (MI)

Formula for the calculation of mandibular index (MI): -

$$\text{Mandibular Index (MI)} = \frac{\text{Avg. width between (right and left) mf and gt}}{\text{Avg. width between (rmf and lmf)}} \times 100$$

OBSERVATIONS

Sex determination

In the present study the measurements are taken from different points as given in the material and methods. The measurements of (125) dry adult human mandibles of both the sexes are given in the table 1 and table **2.** Out of 125 dry human mandibles, 80 mandibles were of male and 45 mandibles were of female.

Table - I Mean values of various measurements of male and female mandible

S.No	Name of Measurements	Measurements in Male in mm (Mean ± SD)	Measurements in Female in mm (Mean ± SD)	Male vs Female	
				Difference (mm)	t-value
1	Mf – mf	76.28± 1.5273	72.98± 0.6929	3.30	16.56*
2	Mnf – mnf	43.93 ± 0.8626	43.59± 0.7070	0. 34	2.40*
3	Rmcdp – lmcdp	74.74 ± 1.6597	72.52± 3.5638	2.22	3.95*
4	Rmf – gt	71.63 ± 1.6404	71.59± 1.1879	0.04	0.16
5	Lmf - gt	71.61 ± 0.4242	71.59 ± 0.2969	0.02	0.31
6	Rcp - b	61.32 ± 0.0212	55.54 ± 0.8909	5.78	43.56*
7	Lcp – b	59.95 ± 0.7566	56.01± 0.4525	3.94	36.39*
8	Rcdp – b	64.82 ± 1.5414	61.22 ± 0.7424	3.60	17.61*
9	Lcdp – b	64.28 ± 0.6788	61.12± 0.6858	3.16	24.94*
10	Rmn – b	51.02 ± 0.6646	45.62± 1.3293	5.40	25.53*
11	Lmn – b	50.91 ± 0.1767	44.04± 0.5798	6.87	77.39*
12	Rmnf – b	13.79 ± 0.0494	11.79± 0.1414	2.01	92.56*
13	Lmnf - b	14. 21 ± 0.2969	12.17± 0.3252	2.04	13.20*
14	Ranm^0	119.5^0 ± 0.0070	125.4^0 ± 1.4142	5.9^0	**28.06***
15	Lanm^0	120.33^0 ±0.0070	125.0^0± 0.7071	4.67^0	**44.75***

* $p<0.05$, mandibular foramen (rmf - lmf), mental foramen (rmnf - lmnf), poles of right and left condyles of the mandible (rmcdp, lmcdp), mandibular foramen and center of genial tubercles (rmf -gt), (lmf-gt), height of coronoid process from the base of the mandible (rcp -b), (lcp-b), height of right condyloid process from the base of the mandible (rcdp -b), (lcdp-b), height of

right mandibular notch from the base of the mandible (rmn-b). (lmn-b), height of right mental foramen to the base of the mandible (rmf- b), (lmf-b), Right angle of the mandible (ranm), (lanm)

Table 2. Side differences in different measuremnets of the mandible of dry bones of males and females

Measurements Left vs right	Males t-value	Females t-value
Rcp-Lcp	12.14*	3.15*
Rcdp-Lcdp	2.70*	0.66
Rmn-Lmn	1.39	7.31*
Rmnf-Lmnf	4.41*	7.19*

* $p<0.05$

The mean width between the mandibular foramen to mandibular foramen (mf-mf) **(Photograph – II)** in males is 76.28 mm, whereas in female mandibles the mean width is 72.98 mm **(Table - 1).** Thus there is a difference of 3.30 mm between the two sexes which shows that male rami are wider than the female mandibular rami. The difference is statistically significant indicating a real sex differences. This measurement is helpful in determination of sex from the measurement of mandibular foramen to mandibular foramen (Table 2).

Photograph - I. Goniometer and vernier caliper (Lt) Mandibular foramen to mandibular foramen (Rt)

The difference in width between mental foramen to mental foramen in male and female is very small only of 0.34 mm **(Table - 1) (photograph – III),** this difference is however non-significant (Table 2). The external features of the mandible are different between the two sexes. From this width it is not possible to identify the sex of the mandible. The arches of the male and female mandibles are almost same but the shapes are different. The shape of the male mandible is rectangular and less prominent whereas female mandible is rounded, prominent and pointing forward. Through morphological features of the mandibles we can determine the sex of the mandible but not from the measurements of width between mental foramen to mental foramen.

(Photograph-III). Mental foramen to mental foramen

(Photograph-IV) Width between right and left medial poles of condyloid processes

The mean width between the medial poles of right and left condyles of the mandibles (**Photograph - IV)** is 74.74 mm in males and 72.52 mm in females **(Table - 1).** It means that the condyles in males are wider than those in females by a margin of 2.22 mm. This seems to be a suitable measure for the determination of sex of the mandible.

The width between right and left mandibular foramen to genial tubercles measured on both sides separately in both the sexes (**Photograph – V)** has a mean value of 71 .62 mm in males whereas in female it is 71.59 mm **(Table - 1**). The difference between male and female is of 0.03 mm which is non-significant, it shows that the width between the mandibular foramen to genial tubercles of male and female mandibles are almost equal. Therefore this measurement is not suitable for the determination of the sex of the mandible.

(Photograph-V) Width between mandibular foramen to genial tubercle **(Photograph -VI) Height of coronoid process**

The heights of the right and left coronoid processes were measured separately in both the sexes (**Photograph** – VI). Mean height of male coronoid processes is 60.64 mm and in female it is 55.78 mm. If we compare the heights of male and female coronoid process there is a difference of 4.86 mm. the males show significantly larger values it means the coronoid processes of males are longer as compared to the coronoid processes of female. This measurement is significant and helpful in estimation of the sex of the mandible.

Height of notches of the mandibles are measured from the base of the mandible **(Photograph - VIII).** It is found that average height of notch in males was (50.97) mm and in females is (44.83) mm **(Table - I),** the height of notch of the ramus of the mandible is significantly more in male as compared to that of the female mandible. and hence has a profound use in the determination of the sex of the mandible.

The height of the symphysis manti is difficult to measure because the height of the inferior alveolar process varies from mandible to mandible It is better if we measure the distance between the mental foramen and the base of the mandible on both sides i.e. right and left and in both the sexes because the mental foramen remains at same distance from the base of the mandible.. So we have done this. The average height in males is (14. 0) mm while in females it is found to be (11.98 mm) **(Table - 1).** It shows that the body of the mandible is significantly broader in male than in female mandible **(Photograph - IX).**

(Photograph-VII). Height of Condyloid process

(Photograph - VIII) Height of mandibular notch

(Photograph - IX) Height of mental foramen to base of the mandible

(Photograph - X) Angle of the mandible

The angles of both male and female mandibles are measured with the help of goniometer, in males it is 119.92^0 and in the females it is 125.2^0 **(Table - 1) (Photograph - X).** The angles found in female mandibles are significantly larger in degree as compared to the angles of mandibles found in male mandibles. The angle is everted in males and inverted or rounded in females. The muscle attachment is more prominent in male than in female. The difference in the size of angles is due to the presence of smaller skulls in female. With the help of difference in angles of both male and female mandibles and morphological features we can determine the sex of the mandible.

Table 3. Mandibular index in male and female dry bones

Mandibular Index	
In Male	In Female
71.62/76.78 x 100 = 93.27%	71.59/72.98 x 100=98.09%

The mandibular index is calculated with the help of width between right mandibular foramen to left mandibular foramen and width between center of genial tubercles and right and left mandibular foramina and their average values **(Table -3).** The mandibular index calculated is 93.27 % in male whereas in female it is 98.09%.. From mandibular index we can estimate or determine the sex of mandible even if we have the broken or fragmented mandibles which are having the mandibular foramen and genial tubercles.

With the help of all these measurements, except a few, it is reasonable to estimate and determine the sex of the mandible from its fragments also even if the morphological features are not very clear by which we can determine the sex of the dry human mandible. This study will be helpful in the forensic dentistry, forensic medicine, maxilla-facial surgeons and anthropologists in their diagnosis and treatment, and also in determination of sex of the mandible.

Side differences

The mean height of right coronoid process in males is 61.32 mm and left coronoid process is 59.95 mm. There is a difference of 1.37 mm between heights of right and left coronoid processes. This can be due to eating and chewing habits. Some persons have the habit of chewing and eating only on the right side and vice versa. In that case his/her coronoid process will be developed more and will be longer on the side frequently used **(Table - 1).** In females the right coronoid process measured is as 55.54 mm and left coronoid process as 56.01 mm. Though in female the right coronoid process is a little smaller than on the left but the difference is non-significant (**Table - 1).** The eating and chewing habits among these females may be the uniform use of both the sides of the jaw.

DISCUSSION: -

The present study has been conducted in the department anatomy of Maharishi Markandeshwer Medical College and Hospital, Kumarhatti, District: Solan, Himachal Pradesh, India. All the above shown measurements are taken and recorded on dry mandibles stored and compared with the standard literature and studies done by other authors.

According to **Rai *et al*. (2007),** one of the main differences of the genetic male and female is the individual characteristic of their skeleton. The skeleton is referred to as an excellent material in living and nonliving population for genetic, anthropological, odontology and forensic investigations. The identification of skeletal remains as male or female are particularly important as it can help to confirm or exclude an individual's identity. They found that the mean mandible angle in Indian population was about 119 degree, if considered according to gender then for male it was 118 degree and for female it was 121 degree. The height of ramus in male was about 5.39 cm and in female it was 5.18 cm. In the present study the average height of rami of mandibles found are 50.97 mm in male mandible and 44.83 mm in female mandible. There is a difference in heights of male and female rami. This reading is helpful in determination of the sex of the bone.

In a study by Shultz (1933) mandibular angle ranges from 104^0 - 137^0 with a mean value of 123^0 by which 62 mandibles have greater and everted gonial angle. Eversion of angle is characteristic of male and inversion in that of female (Lockhart, 1965). Prakash and Abdi, (1987) observed that the mean value of mandibular angle was more in female i.e. (118.6^0 to 123^0). In Males the lateral aspect of the angle of the mandible shows rough or rigid appearance. In females the angle of the jaw is often more rounded and gracile in construction. The attachment surface of the masseter muscle is often much smoother in female (Whittaker, 1989). In the present study, the average of angles of mandibles found are 119.92^0 in males and 125.2^0 in females. The marked male and female differences in measurements on mandibles of th present study are helpful in determination of the sex of the mandible.

As per Kemkes-Grotternthaler (2002), determination of gender can be conducted by using two methods, metrically (using previous statistics) or descriptively (morphologically). As the cranial features vary between the two genders, and the differentiation usually based on the features that are typically more prominent and well defined in the males as compared to those found in the females **(Rai *et al*. 2007).** It is possible to exploit this differentiation for the purposes of identification.

Vodanovic *et al*. (2006) suggested along with others that the mandible of the male is more robust and defined, in other terms chiseled, than that of the female. The study conducted by **Suazo *et al*. (2008),** noted that the mandible of a female appears filed, smooth to touch and look and had an overall general small dimensions when measured. **Franklin *et al*. (2007), Johnson *et al*. (1990) and Naccarato and Johson (2008)** all noted that the dimensions of the male mandible is considerably larger and longer especially in the length and height of the mandible body. In addition, male mandibles typically have squarer chin and thicker, roughened muscle attachments than female mandible. An adult mandible can be used to identify both sex and population affinity with increased sensitivity and objectivity as compared to other standard analytical techniques **(Franklin *et al*., 1996).** Sex may even be determined from lower jaw fragments **(Potsch-Schneider *et al*., 1985).** In the present study the width between right and left mental foramina are almost equal in both the mandibles of male and female, which are negligible and insignificant and are not helpful in identification of sex of the mandible except the morphological features of the mandible which are different in male and female mandible.

There is statistically significant sex difference in the mandibular angle and length in context to gender and race for example the average angle of the black Zimbabweans is greater than the value reported for some African population (**Mbjiorgn *et al*., 1997).** Anthropologists worked in different regions to evaluate the mandibular angle and to analyze the relationship of the ramus of mandible to the gender, so as to study its role in the anthropological diagnosis **(Rai *et al*., 2007).**

The identification of sex from human remains is of fundamental importance in forensic medicine and anthropology, especially in criminal investigations as well as in the identification of missing persons and in attempts at reconstructing the lives of ancient populations. One of the important aspects of forensics is to determine the sex from the fragmented jaws and dentitions **(Vodanovic *et al*., 2006).** The determination of sex based on morphological marks is subjective and likely to be inaccurate, but the methods based on measurements and morphometry are accurate and can be used in determination of sex from the skull **(Humphrey *et al*., 1999; Franklin *et al*., 2007, Franklin *et al*., 2008).** The mandibles were used for analysis for two simple reasons; firstly, there appears to be a panicity of standards utilizing this element and secondly, this bone is often recovered largely intact **(Franklin *et al*. 2008).** The mandible contributes immensely to the determination of sex**. Winson (2004)** suggests that direct observation of certain features help in the preliminary identification, however to confirm sex a number of other measurements must be taken of the mandible, skull and pelvic.

Khan and Sharieff, (2011) observed that overall triangular type of coronoid process (67%) more prevalent than hook shape (30%) and rounded (3%). Triangular type more prevalent in males (72.2%) than females (51.1%), whereas hook shape more prevalent in females (44.9%) than males (25.2%) and rounded more prevalent in females (4.1%) than males (2.6%). **Isaac and Holla, (2001)** studies (157) dry human mandibles and showed (49%) triangular, (27.4%) hook shaped and (23.6%) rounded. Overall triangular type is more prevalent in males, whereas hook and rounded shaped are seen more in females.

The present study in conformation with the studies done by **Vodanovic *et al*. (2006), Suazo *et al*. (2008), Franklin *et al*. (2007), Johnson *et al*. (1990), Naccarato and Johnson (2008).** They reported that the dimensions of male mandibles are considerably larger and longer in lengths and heights of the body of mandible as compared to mandible of female. The present study has shown siginificant sex differences in different measurments on the mandible and hence it is very useful in the sex determination of the manible which will be helpful in the forensic medicine, forensic dentistry, anthropological investigations and maxilla-facial surgeons in their diagnosis and treatment and also in determination of the sex of the mandible.

CONCLUSION

The mandible bone is the largest and strongest bone of the face. It can easily be available after the disasters. It is destroyed very less and decays very late. It is the bone by which we can easily determine the sex by its external features and by its various measurements and parameters. The variations in external features and various measurements of the human mandibles of both the sexes will help in determination of sex of an individual. By keeping in mind all the variations and differences of the studies we can identify the sex of the person from the unknown mandible. This study will be helpful to the forensic dentistry, forensic medicine, anthropologists and maxilla-facial surgeons to give there correct identification of sex of an individual in medico legal cases and also in their diagnosis and treatment.

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