J Forensic Sci, November 2006, Vol. 51, No. 6
doi:10.1111/j.1556-4029.2006.00270.x
Available online at: www.blackwell-synergy.com

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Sex Determination Using Nonmetric Characteristics of the Mandible in Koreans*

ABSTRACT: The mandible is the largest and hardest facial bone and retains its shape better than other bones in the forensic and physical anthropologic field. The mandible can be used to distinguish among ethnic groups and between sexes. We examined the morphological characteristics of the mandibles of 102 Koreans of either sex. Of 13 nonmetric items of the mandible, the characteristic that best allowed the sexes to be distinguished was the contour of the lower border of the mandible: rocker-shaped mandibles predominated in males (68.1%), whereas most females (84.6%) exhibited a straight mandible. In addition, the mental region was shaped differently between the sexes: the shape of the chin in most males was generally bilobate or square (91.7%), whereas the chin in females was either square (45.5%) or pointed (54.5%). In this study, the positive predict values of male and female were 92.5% and 73.7%, respectively. Therefore, the nonmetric method used to analyze the mandible in this study can be used for sex discrimination.

KEYWORDS: forensic science, forensic anthropology, mandible, nonmetric characteristics, sex determination

The mandible is the largest and strongest bone in the face. The temporomandibular joint that is formed between the mandibular head and the temporomandibular fossa allows free movement of the mandible, which facilitates the chewing of food and digestion (1). The mandible is inserted by the masticatory muscles, which include the masseter muscle, the temporal muscle, the medial pterygoid muscle, and the lateral pterygoid muscle. The shape of the mandible can vary according to the different lifestyles and chewing habits (2). Therefore, the morphological characteristics of the mandible vary among different ethnic groups.

There are several causes of differences in the shape of the mandible between the sexes (3). The shape and size of the mandible appear to differ between the sexes from the development of the deciduous tooth. Also, the size of the masticatory muscles and mandible appear to differ between males and females before birth (4). The size of the ramus differs between males and females according to the stage of mandibular development and muscle growth (5,6). Furthermore, the mandible grows at a different rate in males and females (7,8). Because puberty occurs earlier in females than in males, sexual differences may manifest themselves in the skull and jaws of females earlier than in the later and longer-maturing males (9).

There have been many attempts to establish metric standards for the determination of the mandibles of males and females (10–12). However, metric methods are limited by the requirement of a complete mandible. Using nonmetric methods, Bass (13) found that the shape of the chin could be used to distinguish between males and females. In addition, Loth and Henneberg (14) reported that there is a large difference in the flexure of the ramal posterior border between male and female Africans that can be used to distinguish the sexes with 99% reliability. In addition, it was reported that there are distinct differences in the gonial flaring of the mandible between the sexes (15).

In this study, we investigated the criteria that can be used to distinguish between male and female Koreans by investigating the nonmetric characteristics of the mandible.

Materials and Methods

We examined mandibles from 107 modern Koreans (74 males, 33 females) with a mean age of 55.9 years (males: 53.9, females: 60.3 years; range: 18–86 years). The soft tissues were removed and the mandibles were dried before being examined.

We examined 13 nonmetric characteristics, including the shape of the chin, for both the left and right side of the mandible. To avoid subjective judgments, several researchers reached a consensus regarding the following nine items by examining several mandibles together: the shape of the chin according to the thickness of the mandible in front of and beneath the chin (item 1), the profile of the chin according to amount of protrusion of the chin observed from the side (item 2), the contour of the lower border of the mandible according to the depth of the antegonial notch (item 3), the shape of the ascending ramus that formed the middle part of the ramus (item 4), the profile of the ascending ramus according to the curvature of the ramus against the mandibular plane (item 5), the divergency of the gonial angle according to whether it was bent inward or outward (item 6), the inversion of the posterior edge of the ramus (item 8), the shape of the mental spine according to the extent of protrusion and the fusion pattern (item 12), and the flexure of the ramal posterior border (item 13).

The form of the mylohyoid bridge (item 10) was classified into three types according to the extent of the bridge formation: no

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*This work has been presented in poster form at 16th meeting of the International Association of Forensic Sciences in Montpellier, France.

Received 4 Sept. 2005; and in revised form 18 Dec. 2005, 22 April 2006, 9 June 2006; accepted 25 June 2006; published 8 Nov. 2006.

formation, incompletely formation (type I), and complete formation (type II). Type I was subdivided into two categories characterized either by a slight rising of the bridge together with the presence of spines (type Ia) or by protrusive areas of the bridge that were almost in contact with each other (type Ib).

The shape of the mental spine (item 12) was classified into four types according to the shape and the fusion pattern of the left and right sides: sharp separation into two parts, dull separation into two parts, sharp fusion, and dull fusion. We also examined cases in which the superior mental spine and the inferior mental spine were fused.

The nonmetric items were classified as follows:

1. The shape of the chin
   bilobate/square/pointed.
2. The profile of the chin
   vertical/prominent.
3. The contour of the lower border of the mandible
   straight/rocker/undulating.
4. The shape of the ascending ramus
   pinched/wide.
5. The profile of the ascending ramus
   vertical/slanted/inverted.
6. The divergency of the gonial angle
   inverted/straight/everted.
7. The presence of the mandibular torus
   present/absent.
   single/multiple.
8. The inversion of the posterior edge of the ramus
   absent/slight/somewhat strong/strong.
9. The presence of the accessory mental foramen
   present/absent.
10. The form of the mylohyoid bridge
    absent/partial (type Ia)/partial (type Ib)/complete (type II).
11. The presence of the retromolar foramen
    present/absent.
12. The shapes of the superior mental spine and the inferior mental spine
    sharp separation/dull separation/sharp fusion/dull fusion/triple separation/sharp fusion of superior mental spine and inferior mental spine/dull fusion of superior mental spine and inferior mental spine.
13. The flexure of the ramal posterior border
    straight/flexure.

Data were analyzed using a χ^2 test (SAS ver. 6.12; The SAS Institute, Cary, NC). We took $p<0.01$ to indicate statistical significance.

Results

The shape of the chin and the contour of lower border of the mandible were significantly different between males and females ($p<0.01$). In the contour of the lower border of the mandible, most males (72.2%) had a rocker-shaped lower border of the mandible, whereas most females (84.9%) had a straight lower border. None of the mandibles had an undulating lower border (Table 1, Fig. 1). In the shape oh the chin, the chin in males was mainly bilobate or square (91.6%), whereas the chin in females was either square (45.5%) or pointed (54.5%, Table 1, Fig. 2).

The pattern of the ascending ramus profile was slanted in both sexes (74.1%), although more females (84.6%) than males (69.2%) exhibited this characteristic (Table 1). Approximately 25% of both sexes exhibited the mandibular torus, which was observed between the first and second premolar (78.0%). While the percentage of males with a single mandibular torus (51.5%) was similar to the percentage of males with a multiple mandibular torus (48.5%), most females had a single mandibular torus (87.3%). A wide ascending ramus (81.8%) was present in more mandibles than the pinched form (18.2%), and there was no difference between the sexes in the expression of these two characteristics (Table 1).

The percentage of mandibles from females that exhibited strong inversion of the posterior edge of the ramus (33.4%) was higher than the percentage of males that exhibited this characteristic (25.0%). Similarly, more females (30.3%) than males (20.8%) exhibited an accessory mental foramen, and there was no difference between the percentage of mandibles with accessory mental foramens on the left (54.2%) or right (45.8%) side (Table 1, Fig. 3).

Examination of the shape of the mental spines revealed that most males and females exhibited sharp separation of the superior mental spine (males: 51.4%, females: 60.6%). The inferior mental spine in males exhibited sharp fusion (36.1%) or dull fusion (31.9%), whereas more females had a dully fused inferior mental spine (48.5%) than a sharply fused spine (21.2%). Surprisingly, one male had a superior mental spine that was divided into three parts (Table 2).

The everted gonial angle was the most divergent characteristic in both sexes, followed in decreasing order of divergency by a straight and an inverted gonial angle (Table 1, Fig. 4). Approximately 5.3% of the mandibles exhibited a complete canal of mylohyoid bridge, and the partial type (Ib) was observed in very few mandibles (0.9%, Table 1, Fig. 5).

Five examiners (excluding the authors) examined the mandibles to test the reliability and reproducibility of the classification of 8 (items 1, 2, 3, 4, 5, 6, 8, 13) of 13 items. The κ values of the inter- and interexaminer agreement were 0.8536 (95% confidence limits: 0.7808–0.9264) and 0.8892 (95% confidence limits: 0.8236–0.9542), respectively. The washout period was 90 days.

Discussion

Distinguishing males from females and the differences ethnic groups by analyzing the morphological characteristics of bone is important in the fields of physical and forensic anthropology. Sound bone is difficult to obtain because the quality of bone deteriorates over time due to factors such as environment-induced erosion. Examination of the pelvic bone is the most accurate means of sex discrimination, but this bone is rarely found intact. The mandible is the strongest bone in the human body and persists in a well-preserved state longer than any other bone. Therefore, mandibular characteristics are extremely useful for determining sex and race.

Loth and Hennberg (14) carried out a nonmetric study of the degree of curvature of the posterior border of the ramus in Africans. They reported that this characteristic was significantly different between the sexes and could be distinguished with 99% reliability. Using the same method, Indrayana et al. (16) reported that male and female Indonesians could be distinguished with

TABLE 1—*Comparison of the 13 mandibular nonmetric traits between male and female.*

Items	Male	Female	Total
The shape of the chin			
Bilobate	33.3	0.0	22.9
Square	58.3	45.5	54.2
Pointed	8.4	54.5	22.9
The profile of the chin			
Vertical	29.2	36.4	31.4
Prominent	70.8	63.6	68.6
The contour of the lower border of the mandible			
Straight			
Lt	27.8	84.4	48.1
Rt	27.8	84.9	48.6
Rocker			
Lt	72.2	15.6	51.9
Rt	72.2	15.1	51.4
Undulating			
Lt	0.0	0.0	0.0
Rt	0.0	0.0	0.0
The shape of the ascending ramus			
Pinched			
Lt	19.7	15.6	18.4
Rt	19.4	15.2	18.1
Wide			
Lt	80.3	84.4	81.6
Rt	80.6	84.8	81.9
The profile of the ascending ramus			
Vertical			
Lt	31.0	15.6	26.2
Rt	30.6	15.2	25.7
Slanted			
Lt	69.0	84.4	73.8
Rt	69.4	84.8	74.3
Inverted			
Lt	0.0	0.0	0.0
Rt	0.0	0.0	0.0
The divergency of the gonial angle			
Inverted			
Lt	6.9	12.5	8.7
Rt	6.9	12.1	8.6
Straight			
Lt	15.3	18.7	16.3
Rt	9.7	21.2	13.3
Everted			
Lt	77.8	68.8	75.0
Rt	83.3	66.7	78.1
The presence of the mandibular torus			
Absent			
Lt	72.2	72.7	72.4
Rt	76.4	78.8	77.1
Present			
Lt	27.8	27.3	27.6
Rt	23.6	21.2	22.9
Single			
Lt	50.0	88.9	62.1
Rt	52.9	85.7	62.5
Multiple			
Lt	50.0	11.1	37.9
Rt	47.1	14.3	37.5
The inversion of the ramal posterior edge			
Absent	19.4	15.1	18.1
Slight	55.6	51.5	54.3
Somewhat strong	19.4	27.3	21.9
Strong	5.6	6.1	5.7
The presence of the accessory mental foramen			
Absent	79.2	69.7	76.2
Present	20.8	30.3	23.8
The form of the mylohyoid bridge			
Absent			
Lt	81.9	84.4	82.7
Rt	84.7	75.8	81.9
Partial Ia			
Lt	11.1	9.4	10.6
Rt	11.1	15.2	12.4

TABLE 1—*Continued.*

Items	Male	Female	Total
Partial Ib			
Lt	0.0	3.1	0.9
Rt	0.0	3.0	0.9
Total II			
Lt	6.9	3.1	5.8
Rt	4.2	6.0	4.8
The presence of the retromolar foramen			
Absent			
Lt	68.1	71.9	69.2
Rt	65.3	75.8	68.6
Present			
Lt	31.9	28.1	30.8
Rt	34.7	24.2	31.4
The flexure of the ramal posterior border			
Straight			
Lt	29.6	31.3	30.1
Rt	31.9	30.3	31.4
Flexure			
Lt	70.4	68.7	69.9
Rt	68.1	69.7	68.6

All values are expressed by percentage.
Rt, right side; Lt, left side.

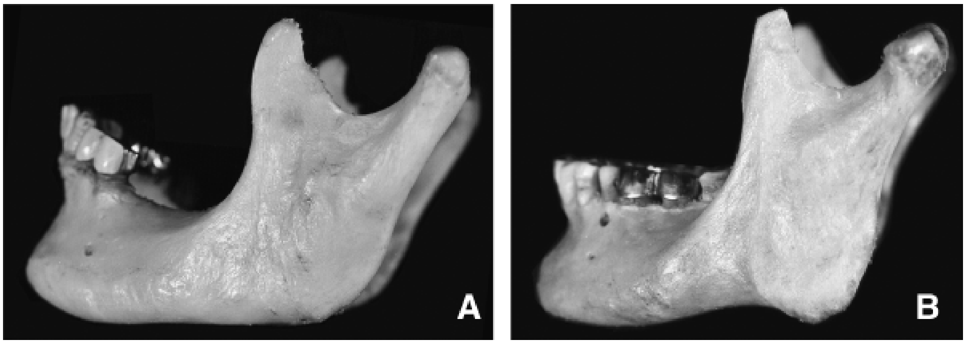

FIG. 1—*The contour of the lower border of the mandible. The anterior border anterior to the gonion was classified as straight if the antegonial notch had not been formed (A) and rocker-shaped if the antegonial notch was present (B).*

90% and 94% reliability, respectively. However, the aforementioned studies are controversial, and Koski (17) concluded that this method could not be used to determine sex. In this study, we failed to find any difference between the sexes in the degree of curvature of the posterior border of ramus. Specifically, the posterior border of the ramus was curved in most males (69.3%) and females (69.2%), which made this characteristic unsuitable for determining sex.

The shape of the chin and the lower border of the mandible had a different shape between males and females in the present study. The shape of the chin is used widely to distinguish between the sexes (13), because the male chin is usually bilobate or square whereas the female chin is more pointed. Similar observations were made in the present study; specifically, 91.7% of males had either a bilobate or square chin, whereas 54.5% of females had a pointed chin. However, while the shape of the chin is more dis-

FIG. 2—*The shape of the chin. The anterior and inferior sides of the mandible were examined to classify the shape of the chin as bilobate (A), square (B), or pointed (C).*

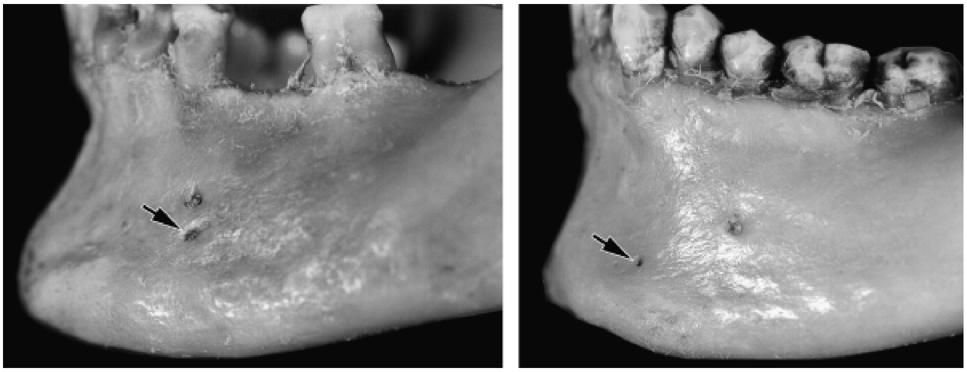

FIG. 3—*The presence of the accessory mental foramen (arrows).*

TABLE 2—*Frequency according to the type of the superior and inferior mental spine in Koreans.*

Type	Superior Mental Spine			Inferior Mental Spine		
	Male	Female	Total	Male	Female	Total
Sharp separation	51.4	60.6	54.3	5.6	6.1	5.7
Dull separation	9.7	12.2	10.5	2.8	3.0	2.9
Sharp fusion	9.7	3.0	7.6	36.1	21.2	31.4
Dull fusion	4.2	3.0	3.8	31.9	48.5	37.1
Triple separation	1.4	0.0	0.9	0.0	0.0	0.0

	Male	Female	Total
Sharp fusion of superior mental spine and inferior mental spine	18.1	18.2	18.1
Dull fusion of superior mental spine and inferior mental spine	5.5	3.0	4.8

All values are expressed by percentage.

tinctive in males than in females, sex discrimination based only on the shape of the chin is not sufficiently reliable.

The characteristic that was the most distinguishable between the sexes in the present study was the shape of the lower border of the mandible. The lower borders of mandibles from males tended to be rocker shaped (72.2%), whereas lower borders of mandibles from females tended to be straight (84.9%). Therefore, the shape of the lower border of the mandible may be used as a reliable index for sex discrimination. However, we believe that using only this characteristic is not sufficiently reliable for sex discrimination; instead, evaluating both the shape of the chin and the shape of the lower border of the mandible improve the precision of sex discrimination. When these two items were combined, 69.4% of males exhibited the characteristics of male mandibles (a bilobate or square chin and a rocker-shaped lower border of the mandible), whereas 48.5% of females exhibited the characteristics of female mandibles (a pointed chin and a straight lower border of the mandible, Table 3). Few males (5.6%) had a pointed chin and a straight lower border, which are characteristics of females, while 9.1% of the females exhibited mandibular characteristics that were characteristic of males (Table 3). Therefore, the probability of assigning the incorrect sex to a mandible when examining both the shape of the chin and the shape of the lower border of the mandible is very low. Moreover, the shape of the chin is the most distinctive characteristic in males (91.6%), whereas the lower border of the mandible is the most distinctive characteristic in females (84.9%). Therefore, we can determine the sex using the following two-step approach. During the first step in determining sex based on the characteristics of the mandible, if the lower border of the mandible is rocker shaped, it is likely to be the mandible of a male, but if the lower border is straight, it is likely to be the mandible of a female; during the second step, if the chin of the mandible that has a straight lower border is bilobate, it is likely to be the mandible of a male. Using this method to discriminate between the sexes, the positive predict values of males and females were 92.5% and 73.7%, respectively (Table 4).

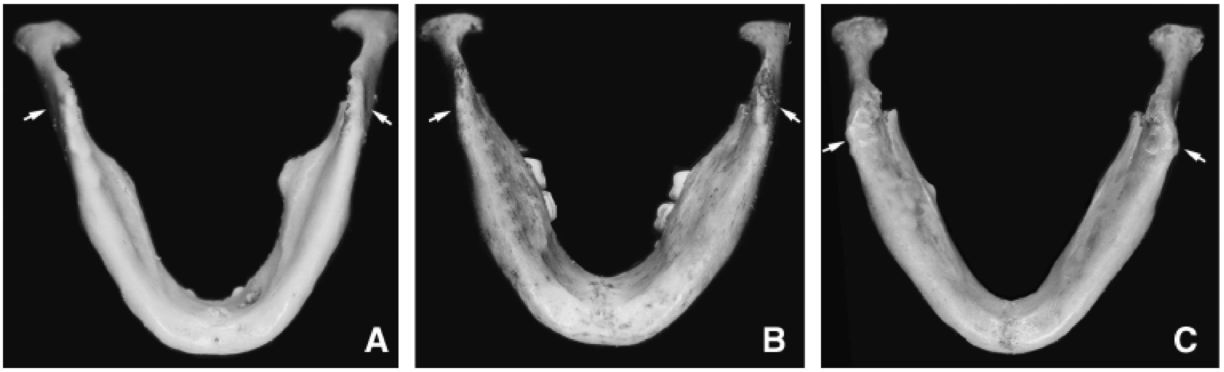

FIG. 4—*The divergency of the gonial angle. The arrows indicate the divergency. The divergency of the gonial angle was classified as inverted (bent inward; A), straight (unbent; B), or everted (bent outward; C).*

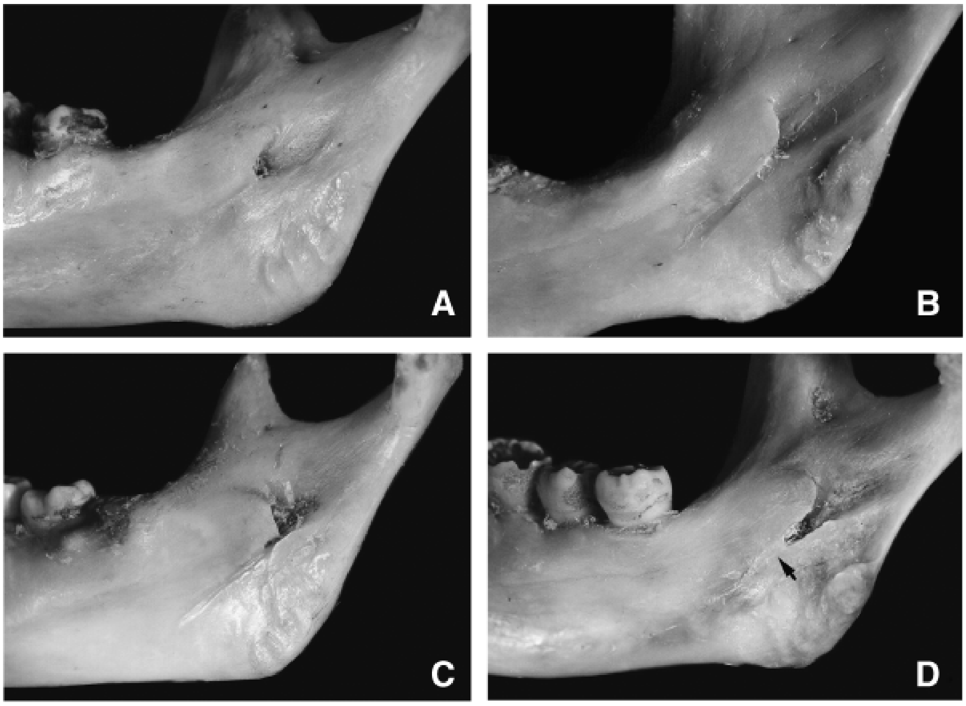

FIG. 5—*The form of the mylohyoid bridge. The form of the mylohyoid bridge was classified according to the extent of the bridge formation. (A) Mylohyoid groove only. (B) Slightly rising bridge. (C) Protrusive areas of the bridge almost in contact with each other. (D) Complete formation of the mylohyoid canal. The arrow indicates the mylohyoid canal.*

TABLE 3—*Comparison of the shape of the chin and the lower border of mandible between males and females.*

Shape of Chin/Contour of Lower Border of Mandible	Male	Female
Bilobate/straight	13.9	0
Bilobate/rocker	19.4	0
Square/straight	8.3	36.4
Square/rocker	50.0	9.1
Pointed/straight	5.6	48.5
Pointed/rocker	2.8	6.0

All values are expressed by percentage.

The surfaces of the mandibles of males are often rough, whereas those of females tend to be smooth (as is the case for mandibles of children). Aitchison (9) suggested that this difference was caused by the earlier onset of puberty in females compared with males, which leads to an earlier cessation of growth in females. Thus, differences between the sexes in the various mandibular characteristics occur during the extended growth period in males.

In conclusion, the differences between the sexes and among ethnic groups in the morphological characteristics of the mandible are determined by the environment and different growth patterns. Therefore, males and females can be distinguished based on the shapes of various parts of the mandible. We found that the simultaneous use of the shape of the lower border of the mandible and the shape of the chin is the best method of predicting sex with a rate of accuracy that is higher than 90%.

TABLE 4—*The positive values of the male and female.*

	True Sex of the Mandible	
	Male	Female
Experimental sex of the mandible		
Male	62	5
Female	10	28

Male positive predictive value: 62/62+5 = 92.5%.
Female positive predictive value: 28/10+28 = 73.7%.

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