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THE MANDIBULAR RAMUS FLEXURE IN THE BYZANTINE SKELETONS OF NICEA REMAINS: A SINGULAR MORPHOLOGICAL INDICATOR

ABSTRACT: Loth and Henneberg (1996) described the flexure of the posterior margin of the mandibular ramus at the level of the occlusal plane as a single morphological indicator of sexual dimorphism. Using only this feature, Loth and Henneberg were able to predict sex with 94.2% accuracy in a large sample of mandibles. To test the accuracy of their method, mandibles (n=24), which are of known sex (male) and age, from the Nicea remains (13th century) were assessed for the presence or absence of mandibular ramus flexure. The results of this study indicated that the mandibular ramus flexure was diagnostic for 91.7% of the males. These results suggest that the presence of the posterior border's flexure of the mandibular ramus can be used as a singular morphological indicator in sex determination.

KEY WORDS: Mandibular ramus – Morphology – Sex assessment – Late Byzantine period

INTRODUCTION

Correct sex identification of the human skeleton is important in both bioarchaeological and forensic anthropology studies (Bruzek 2002). The traits of the bones are used as a morphologic indicator for visual determination of sex (Sawyer *et al.* 1998). The researcher's ability to properly identify and score a morphologic trait is crucial to any method's predictive potential (Haun 2000). In studies of skeletal biology, the frequently cited drawbacks of visual assessment for determining the sex of an individual are: 1) a high degree of observer subjectivity, 2) a lack of consistency in the evaluation of traits, and 3) a strong dependence on the observer's level of experience. Nonetheless, there are advantages to visual examination techniques, which include their relative ease of use and when incomplete preservation precludes complete sets of measurements from being made (Bruzek 2002).

Loth and Henneberg (1996) have proposed that a single morphological indicator, the presence or absence of flexure on the posterior border of the mandible, can be used to determine sex in the human mandible. These same authors have stated that this trait rivals the predictive accuracy of the complete pelvis at 94.2% for all samples as an indicator of human sexual dimorphism. According to Loth and Henneberg (1996), a distinct angulation (flexure) of the posterior ramus border at the level of the occlusal plane is present in adult male mandibles (Loth, Henneberg 1996). Adult female mandibles are not flexed at this point, having straighter posterior borders. When flexure occurs in female mandibles, it is above or below the occlusal plane (Hill 2000). Mature males exhibit flexure at the level of the molar occlusal plane on the posterior border of the ramus, while females of all ages and many subadult males display a straight border at that level (Haun 2000). The presence of this flexure is hypothesized to result from "a change in the size, strength, or angulation of the muscles of mastication, especially the masseter and pterygoid", which occurs during puberty as a response to hormonal changes (Loth, Henneberg 1996). These same researchers further claim that children of both sexes possess a straight ramus and that "flexure is not consistent in males until the end of adolescence" (Loth, Henneberg 1996).

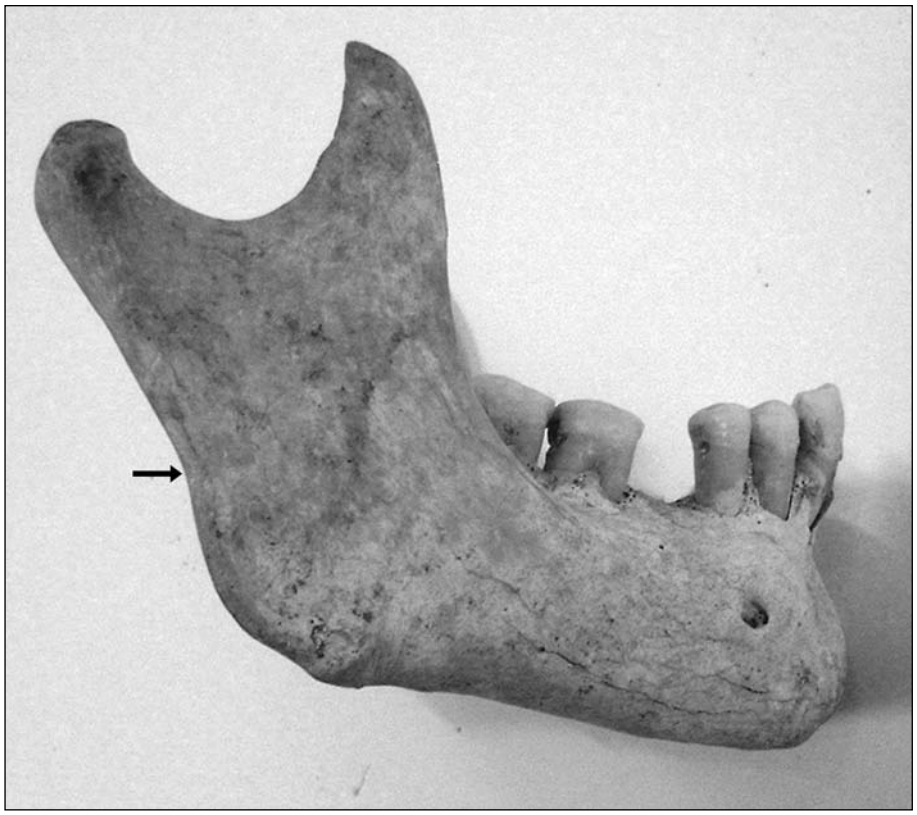

FIGURE 1. The flexure of the posterior border of the ramus at the molar occlusal plane on a Late Byzantine mandible.

Koski (1996), Indrayana *et al.* (1998), Donnelly *et al.* (1998), Hill (2000) and Haun (2000) have tested the accuracy of Loth and Henneberg's (1996) method in mandibles from the different groups. Koski (1996) using radiographs of 80 young adult females, questioned the reliability of ramus flexure as an indicator of sex, noting that very often it is difficult to distinguish its location and degree. Loth and Henneberg (1998) countered, suggesting that Koski (1996) confused other kinds of flexure with the sexual dimorphic flexure they described, and that he limited his sample to radiographs. Subsequently, Indrayana *et al.* (1998), Donnely *et al.* (1998), Hill (2000) and Haun (2000) have investigated the presence of the mandibular ramus flexure and they reported this trait to be diagnostic for 90.0%, 76.8%, 91.9%, and 92.9% of the adult male mandibles, respectively. However, their results have indicated that the predictive accuracy of mandibular ramus flexure was lower in females than in males.

In this article, our aim is to test the predictive accuracy of Loth and Henneberg's (1996) method on a sample (Late Byzantine period, 13th century AD) with known sex and age.

MATERIALS AND METHODS

A total of 24 adult male mandibles, which were excavated from a Byzantine (13th century) burial site near Iznik (Nicea), Turkey, were studied. They were derived from adult male skeletons (sexed by pelvic and cranial morphology) with healthy teeth and the mean age at death was calculated as approximately 35 years using the morphology of the symphyseal surface of the pubis and the degree of closure of the cranial structures (Ozbek 1984). It is believed that these individuals were killed during a battle given the presence of traumatic injuries in the majority of the skeletons. Only complete mandibles were included in the study. Visual assessments were made by Ari.

Mandibles were visually assessed for the presence or absence of posterior mandibular ramus flexure following the guidelines established by Loth and Henneberg (1996). Posterior mandibular ramus flexure noted at the level of the occlusal surface of the molars (*Figure 1*) was scored +1, a straight border or flexure which is not at the occlusal plane was scored –1, while ambiguous borders were scored 0. The scores of both right and left rami were then added to yield a score of +2, +1, 0, –1, or –2. Mandibles receiving scores of +2, +1, and 0 were designated to be males; scores of –1 and –2, females.

RESULTS

Our results are presented in *Tables 1* and *2*. In this study, the results indicate that the posterior mandibular ramus flexure was diagnostic for 22/24 or 91.7% of the adult male mandibles. Flexure of the posterior border of the mandible was scored bilaterally in 15 mandibles (62.5%) and

TABLE 1. The presence of the mandibular ramus flexure on the mandibles rami.

The flexure of the posterior border of mandible ramus	Mandibles rami		Total rami
	Right ramus n (%)	Left ramus n (%)	n (%)
Absence (–)	–	2 (4.1%)	2 (4.1%)
Unambiguous (0)	5 (10.4%)	7 (14.6%)	12 (25%)
Presence (+)	19 (39.6%)	15 (31.3%)	34 (70.9%)
Total rami n (%)	24 (50%)	24 (50%)	48 (100%)

TABLE 2. Total (left + right) ramus flexure scores of the Late Byzantine period mandibles. (Mandibles with total scores of –2 or –1 are identified as female, mandibles with total scores of 0, 1, or 2 are identified as male.)

Total score	Mandibles n (%)
–2	–
–1	2 (8.3%)
0	3 (12.5%)
+1	4 (16.7%)
+2	15 (62.5%)
Total mandibles n (%)	24 (100%)

unilaterally in four mandibles (16.7%). Three mandibles (12.5%) were scored as having bilaterally ambiguous posterior borders. Interestingly, the absence of flexure, indicating female, was found in two mandibles (8.3%). These mandibles both had a straight posterior border on the left rami and an ambiguous posterior border on the right rami.

DISCUSSION

The results of the studies of Loth and Henneberg (1996), Indrayana *et al.* (1998), Donnelly *et al.* (1998), Hill (2000), and Haun (2000) have indicated that ramus shape was diagnostic for 94.2%, 91.5%, 60.8%, 79.1%, and 78.2% of all samples, respectively. However, the results reporting the accuracy of determining male sex in previous studies and this study were higher than those. Loth and Henneberg (1996), Indrayana *et al.* (1998), Hill (2000), and Haun (2000) have reported that the predictive accuracy of the ramus flexure were 99%, 90%, 91.9%, and 92.9% for males, respectively. Only Donnelly *et al.* (1998) have found this accuracy range to be 76.8% for males. The result of this study (91.7%) is consistent with all the previous studies with the exception of Donnelly *et al.* (1998).

Loth and Henneberg (1996) analyzed 200 mandibles from adults of known sex from the Dart Collection and stated that the usefulness of mandibular ramus flexure is enhanced by the survivability of the mandible and the fact that preliminary investigations show that the trait is clearly evident in fossil hominids. They have suggested that mandibular ramus flexure should be applied to "fragmented mandibles from historic archaeological finds, rare fossil hominids, and modern forensic cases" (Loth, Henneberg 1996).

Indrayana *et al.* (1998) have applied Fourier analysis to radiographs of 150 individuals and reported 91.5% and 90.0% accuracy for all samples and males respectively. They have explained that the differences in the shape of the mandible may occur between individuals and populations due to their dietary habits (i.e. eating soft and hard foods). Donnelly *et al.* (1998) have examined 96 mandibles from a forensic collection of known sex and a Native American sample where sex was estimated from the pelvis. They reported the prediction accuracy results of 64.3% (from forensic sample) and 85.7% (from Native American sample) for males, results that are below those reported in Loth and Henneberg (1996) and Indrayana *et al.* (1998). In addition, Donnelly *et al.* (1998) have reported the prediction accuracy to be 56.3% (from forensic sample) and 63.8% (from Native American sample) for all samples. Donnelly *et al.* (1998) further concluded that: a) the association between ramus flexure and sex is weak; b) the predictive accuracy of Loth and Henneberg's method is better than the chance for only one sex, males; and c) the method is based on a trait that cannot be reliably or consistently identified. More recently, Hill (2000) and Haun (2000) have investigated the presence of the mandibular ramus flexure in 158 mandibles from the Hamann-Todd Collection and 150 mandibles from the Tepe Hissar Skeletal Collection, respectively. The results of Hill's (2000) and Haun's (2000) studies indicated that ramus shape was diagnostic for 91.9% and 92.9% of the males (with an overall prediction accuracy of 78.7% and 78.2%) respectively. Hill (2000) concluded that the low overall accuracy, an invalid scoring system, and high intra-observer error indicate that mandibular ramus flexure is an unreliable technique for estimation of sex. However, Haun (2000) has questioned the predictive potential of mandibular ramus flexure as a single indicator of sexual dimorphism and suggested caution when applying

this method, especially in the case of fragmentary forensic and fossil remains.

In summary, previous work has suggested that the presence or absence of posterior mandibular ramus flexure may lack the degree of accuracy predicted by Loth and Henneberg and should be used with caution when it is the only available indicator of sex. It is difficult to admit that the sexual traits of the skeleton could be more clearly expressed in one sex than the other. The total degree of sexual dimorphism of any bone is a function of the interaction of the partial dimorphism of certain main regions of the bone. Thus, according to the concept of functional integration, lower levels of sexual dimorphism in one morpho-functional complex can be functionally compensated by higher levels of dimorphism in the other morpho-functional complex. The inter-segment size relationships are sex- and population-specific. With both genetic and functional components the existence and degree of trait expression appears to be population specific (Haun 2000; Bruzek 2002).

In conclusion, previous studies and the present study question the predictive accuracy of mandibular ramus flexure as a single indicator of sexual dimorphism and suggest that caution be used when applying this technique in the absence of other morphological and osteometric indicators, especially in the case of fragmentary forensic or rare fossil remains. However, these results do not negate the potential applicability of the Loth and Henneberg technique to other ancient and modern populations, particularly where additional indicators of sex and age are present (Haun 2000). It should be noted that the results achieved in the studies of Hill (2000), Haun (2000), and the present study are based on the skeletal remains from individual archaeological sites.

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