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# Odontometrics: a useful method for sex determination in an archaeological skeletal population?

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**Abstract**

Determining sex is one of the most important steps in the procedure of identification of the unknown person. Teeth are a potential source of information on sex.

The research is performed on the total of 86 skulls excavated in the late 19th and early 20th century from the mediaeval cemetery (10th and 11th century) at the archaeological site of Bijelo Brdo near Osijek. The material is stored in the Museum of Archaeology in Zagreb. Sex is determined on the basis of 20 osseal craniofacial, as well as odontometric features. Sexual dimorphism of the odontometric features is tested by the Students' *t*-test method.

Determining sex on the basis of craniofacial features is possible in 55.8% of the cases. Combining the craniofacial and odontometric features it is possible to determine sex in 86% of the cases.

In cases where ante-mortem data on sex are not available it is best to combine a number of different methods in order to raise the level of confidence and the level of success in sex determination.


*Keywords:* Archaeology; Medieval; Sex determination; Odontometrics; Croatia

## 1. Introduction

During forensic and archaeological excavations, it is often the case that not all the bones of an individual are collected. Therefore, the skull and the teeth often provide the only identification material. Because skeletal remains that come from archaeological series are very often poorly preserved and fragmentary, demanding careful handling to prevent further damage, sex determination can be particularly complex. Numerous methods with a satisfying level of confidence have been developed to determine sex in poorly preserved human remains (Slaus and Tomicic, 2005; Graw et al., 1999; Rissech and Malgosa, 2005; Patriquin et al., 2003; Walrath et al., 2004; Kemkes-Grottenthler, 2005; Rissech et al., 2003; Graw et al., 2005; Vodanović, 2006; Kemkes-Grottenthaler et al., 2002; Stone et al., 1996; Marino, 1995; Hoyme and Iscan, 1989; Brkić, 2000).

Normally, the nature and range of sex characteristics variation are determined by using large skeletal collections of known sex. Sex may be determined either from the cranium or from the bones of the postcranial skeleton. Sex determination from postcranial skeleton is often based merely on observed differences in size and ruggedness of the bones. Specific postcranial landmarks appropriate for sexing include overall breadth of the pelvis, the width of sciatic notch and subpubic angles, the presence of a ventral arc on the anterior surface of the pubis and the contour of the medial part of the ischiopubic ramus. Sex determination from the cranium and mandible relates to their size, robustness and some metrical characteristics. Male and female skulls may be distinguished by general size, supraorbital ridges, mastoid processes, occipital region, frontal eminences, parietal

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eminences, orbits, forehead, cheekbones, palate, occipital condyles, mandible, chin shape, gonial angle and gonial flare. Metrical characteristic of the cranium should be used to support the visual assessment of sex characteristics. Best metrical variables for classification by sex for Caucasians are bizygomatic breadth, maximum length glabella–opisthocranion, nasal breadth, subnasal height, palatal length and angle opisthion–nasion. The reliability of metrical analysis depends on the bony features used, but it usually lies between 70% and 95%. Generally, evaluation of the pelvis provides more reliable sex estimation than cranial measurements do. When an entire skeleton is available for inspection, sex determination is usually immediately possible with 95–100% accuracy. Accuracy of prediction decreases to approximately 95% with the pelvis alone, 90% with the skull alone and 80–90% with bones of the postcranial skeleton (Briggs, 1998).

In archaeological investigations, data on sex are not more reliable than their sources. There are many collections from old, unmarked burial grounds that are limited due to lack of information on sex, age, race or life history. Although they are not ideal, these bone collections are our only source of biological information on these populations. There were no antemortem data available for the skeletal collection examined in this paper. Additionally, all postcranial bones were destroyed during the excavation more than hundred years ago. This means that only partially preserved skulls were available for sex estimation.

Teeth are known to be unique organs made of the most enduring mineralized tissues in the human body (Brkić, 2000). As such, teeth are resistant to mechanical, chemical, physical and thermal types of destruction. Therefore, teeth are very important elements in the identification of skeletal remains, especially in cases when, due to the poor preservation of skeletal remains, the identification is not possible by standard methods. Sex determination using dental features is primarily based upon the comparison of tooth dimensions in males and females, or upon the comparison of frequencies of non-metric dental traits, like Carabelli's trait of upper molars, deflecting wrinkle of lower first molars, distal accessory ridge of the upper and lower canines or shovelling of the upper central incisors (Teschler-Nicola and Prossinger, 1998). Therefore, odontometrics provide information on sex. There are numerous studies in which differences in male and female odontometric features have been identified (Teschler-Nicola and Prossinger, 1998; Muller et al., 2001; Alt et al., 1998; Rao et al., 1989). Considering the fact that there are differences in odontometric features in specific populations (Iscan and Kedici, 2003), even within the same population in the historical and evolutional context, it is necessary to determine specific population values in order to make identification possible on the basis of dental measurements. These values can be of use in determining sex in specific cases: in individual, as well as in group (mass disasters, archaeological sites, etc.) (Iscan and Kedici, 2003; Lukacs and Hemphill, 1993; Balciuniene and Jankauskas, 1993; Lew and Keng, 1991; Sharma, 1983; Potter et al., 1981; Harris and Nweeia, 1980; Ghose and Baghdady, 1979; Perzigian, 1976).

The purpose of this paper is to determine sex on the basis of craniofacial features of the skeletal remains excavated at the early mediaeval Bijelo Brdo site, located near Osijek, to make an odontometric analysis of permanent teeth of the Bijelo Brdo population, and finally to determine sex on the basis of odontometric features. It is well known that skeletal characteristics vary by population and that there is a need for population specific standards for sex determination. Standards developed for one population are not useful for other populations. In archaeological investigations where no ante-mortem data is available, exact conclusions about sex are rather impossible. If we exclude DNA analysis, an expensive and time-consuming method, the most reliable information about sex can be obtained from special statistical procedures like discriminate function analysis. Discriminate function analysis provides data about sex employing specific bone measurements which are further used for the classification of new cases. Although discriminate analysis is a reliable method, for researchers who are not familiar with multifactorial statistics it is not so simple to interpret its results. The present study is an attempt to present odontometrics as an easy-to-use additional technique to determine sex in archaeological circumstances without need for complicated statistical software.

## 2. Materials and methods

Research has been carried out on the skeletal remains of 86 skulls excavated in the late 19th and early 20th centuries at the mediaeval cemetery of the Bijelo Brdo site near Osijek, dated to the 10th and 11th century. Sex determination of these skulls was a part of a multidisciplinary project focused on the reconstruction of life of medieval Croatians. The osteological material is stored in the Archaeological Museum of Zagreb and was temporarily moved to the Department of Dental Anthropology, School of Dental Medicine, University of Zagreb for the purpose of this research.

Sex is determined on the basis of the 20 craniofacial features shown in Table 1 (Slaus and Tomicic, 2005; Brkić, 2000). The male skull tends to be larger and heavier than the female, and it is more rugged, with prominent landmarks for muscular and ligamentous attachments. The male supraorbital ridges are better defined. The mastoid process and external occipital protuberance are well developed in the male, whereas parietal and frontal eminences are not prominent. The upper margin of the orbit in the male is more rounded (in the female it is sharper), and the cheekbones are heavier. The male palate is large and broad. The male mandible is more robust, with a U-shaped chin, broad ramus and flared gonial regions. These features are considered to be the best for sex assessment, providing accuracy of 80–90% (Briggs, 1998). The skulls for which, due to high level of damage, the determination of sex was not possible are included with the remark "sex – not determined".

Measurements of permanent teeth are taken with a sliding calliper. Mesiodistal diameter of the tooth crown is taken as the greatest mesiodistal dimension parallel to the occlusal and facial surface. Mesiodistal diameter of the tooth cervix

Table 1
Craniofacial features used for sex determination

| Craniofacial features | |
|---|---|
| 1. Overall skull shape and size, | 11. Robustness of the nuchal crest, |
| 2. Robustness of the brow ridges, | 12. Presence or absence of the external occipital protuberance, |
| 3. Sharpness of the superior orbital border, | 13. Robustness of the temporal line, |
| 4. Presence or absence of superciliary arches, | 14. Robustness of the zygomatic process, |
| 5. Shape of the glabellar region, | 15. Robustness of the mastoid process, |
| 6. Eye orbit shape, | 16. Configuration of the chin, |
| 7. Shape of forehead, frontal bossing, | 17. Size of the teeth, |
| 8. Shape of the nasal bone, | 18. Shape of the palate, |
| 9. Width of the mandibular ramus, | 19. Shape and size of the mandibular condyles, |
| 10. Gonial angle, | 20. Shape and size of the occipital condyles. |

is taken as the greatest mesiodistal dimension parallel to the occlusal and facial surface measured in the cervical part of the tooth crown. Buccolingual crown diameter is the greatest distance between the facial and lingual surfaces of the crown, taken at right angles to the plane in which the mesiodistal diameter is taken. Crown height is defined as the distance from the tip of the highest cusp to the cervical line on the buccal side. All the measurements are shown in Fig. 1. To avoid the possibility of incorrect measurements caused by abrasion, only teeth with a low level of abrasion and without exposed dentine were included. Robustness is taken as the product of multiplication of the mesiodistal and buccolingual diameter of the tooth crown (Pettenati-Soubayroux et al., 2002; Taylor, 1978).

The measurements were performed by one person (MV) and all values were rounded to two decimal places. In order to assess the reliability of the measurements, intraobserver error was tested. Same measurements were obtained from 100 randomly selected teeth from the original sample at a different time by the same author to assess intraobserver error. Another observer measured same randomly selected teeth in order to test the interobserver error. Their measurements were analyzed using Student's *t*-test.

Anthropological tooth labelling system was used (Briggs, 1998). Statistically significant sexual dimorphisms in male and female odontometric features were tested by the Students' *t*-test. The level of statistical significance was set at $p < 0.05$.

After the sex of the skulls was assessed on the basis of craniofacial features and after the sex specific ranges of measured dental values were established, the final sex assessment was performed.

## 3. Results

Out of the total of 86 skulls sex could be determined on the basis of craniofacial features in 55.8% of the cases, while in 44.2% of the cases it was not possible, mostly due to the poor preservation of the material. Out of the total sample, males as well as females each presented 27.9% of the skulls on which the sex was determined (Table 2). Robustness of the zygomatic process, configuration of the chin, shape and size of the mandibular condyles, shape and size of the occipital condyles were the variables at least used for sex determination, because they were very often damaged or missing.

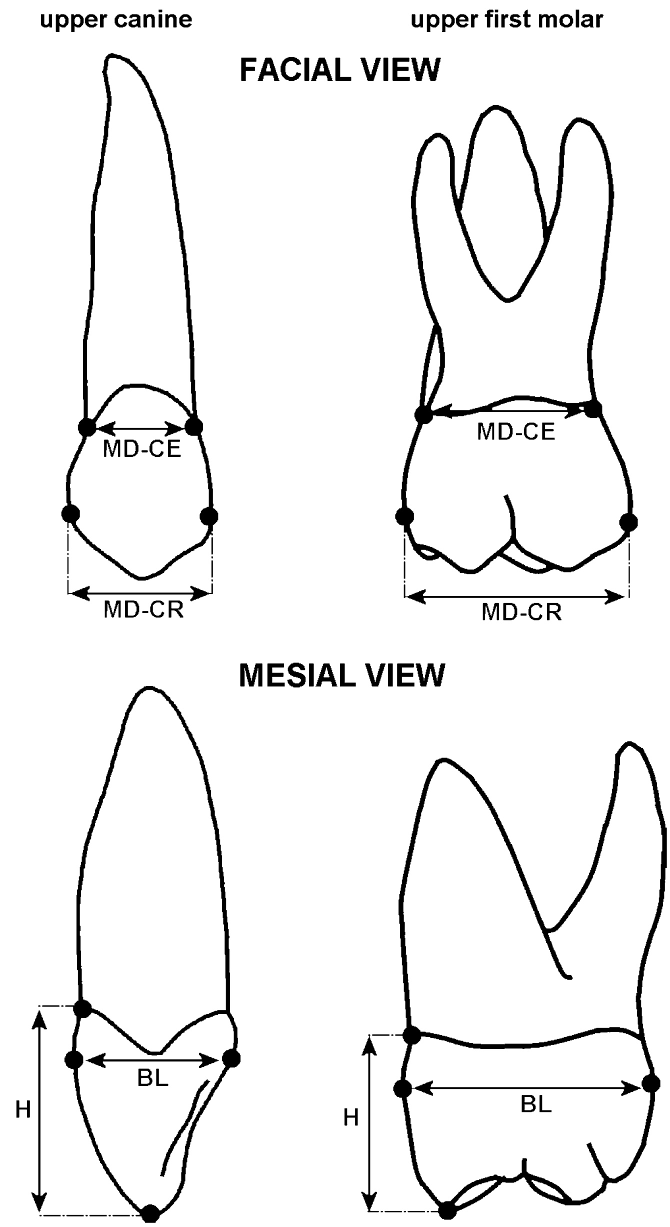


Fig. 1. The locations of the measurements. MD-CE - mesiodistal diameter of the tooth cervix, MD-CR - mesiodistal diameter of the tooth crown, BL - buccolingual crown diameter, H - crown height.

Table 2
Results of the sex determination using craniofacial features

| *N* total (%) | *N* sex − determined: male + female (%) | | *N* sex − undetermined (%) |
|---|---|---|---|
| 86 (100.0) | 48 (55.8) | | 38 (44.2) |
| | *N* male (%) | *N* female (%) | |
| | 24 (27.9) | 24 (27.9) | |

*N*, number of individuals.

Measurements of permanent teeth were only taken from teeth that have a low level of abrasion. Teeth that showed a high level of abrasion that could affect the measurements were not included in the research. Differences in the parameters of the left and the right side of the jaws were statistically tested, but statistically significant differences were not found.

The measurement of the mesiodistal diameter was conducted on a total of 946 permanent teeth. There was a statistically significant difference in the mesiodistal diameter of the crown of the mandibular second premolar. In males the measured value was $6.90 \pm 0.50$ mm, and in females $6.50 \pm 0.50$ mm ($p < 0.026$), Table 3.

The mesiodistal diameter of the tooth cervix was measured on a total of 977 permanent teeth. There was a statistically significant difference between males and females in the mesiodistal diameter of tooth cervix of the maxillary canine (males $6.00 \pm 0.45$ mm, females $5.45 \pm 0.50$ mm, $p < 0.000$) and the mandibular third molar (males $8.80 \pm 0.65$ mm, females $8.20 \pm 0.60$ mm, $p < 0.022$), Table 4.

The buccolingual diameter of the tooth crown was measured on a total of 953 permanent teeth. There were statistically significant differences between males and females in the buccolingual diameter of the crown of the maxillary canine (males $8.50 \pm 0.70$ mm, females $7.90 \pm 0.60$ mm, $p < 0.003$), mandibular central incisor (males $6.30 \pm 0.45$ mm, females $5.85 \pm 0.45$ mm, $p < 0.014$), and the mandibular third molar (males $9.50 \pm 0.75$ mm, females $8.65 \pm 0.50$ mm, $p < 0.004$), Table 5.

The height of the tooth crown was measured on a total of 697 permanent teeth. There were statistically significant differences between males and females in the crown height of the maxillary central incisor (males $8.20 \pm 1.70$ mm, females $10.35 \pm 1.65$ mm, $p < 0.024$), maxillary second incisor (males $8.15 \pm 1.50$ mm, females $9.30 \pm 1.25$ mm, $p < 0.040$), maxillary first premolar (males $6.80 \pm 1.15$ mm, females $7.65 \pm 0.65$ mm, $p < 0.020$), maxillary second premolar (males $6.05 \pm 0.75$ mm, females $6.65 \pm 0.65$ mm, $p < 0.26$), maxillary first molar (males $6.30 \pm 0.45$ mm, females $7.35 \pm 0.75$ mm, $p < 0.000$), mandibular central incisor (males $6.85 \pm 1.80$ mm, females $8.50 \pm 1.40$ mm, $p < 0.003$), and the mandibular first molar (males $5.50 \pm 1.00$ mm, females $6.85 \pm 1.25$ mm, $p < 0.002$), Table 6.

Table 4
Mesiodistal diameter of the tooth cervix

| | Male | | | Female | | | *p*-level |
|---|---|---|---|---|---|---|---|
| | *N* | *A* (mm) | SD (mm) | *N* | *A* (mm) | SD (mm) | |
| Upper jaw | | | | | | | |
| I1 | 13 | 6.32 | 0.49 | 17 | 6.15 | 0.65 | 0.441 |
| I2 | 22 | 5.11 | 0.50 | 21 | 4.81 | 0.52 | 0.060 |
| C | 28 | 6.00* | 0.48 | 23 | 5.47* | 0.50 | 0.000* |
| P1 | 27 | 4.90 | 0.40 | 25 | 4.73 | 0.28 | 0.087 |
| P2 | 28 | 4.73 | 0.36 | 27 | 4.86 | 0.42 | 0.211 |
| M1 | 26 | 7.93 | 0.87 | 34 | 7.90 | 0.62 | 0.884 |
| M2 | 24 | 7.47 | 0.70 | 28 | 7.43 | 0.53 | 0.808 |
| M3 | 14 | 6.66 | 0.66 | 7 | 6.71 | 0.95 | 0.887 |
| Lower jaw | | | | | | | |
| I1 | 20 | 3.68 | 0.35 | 16 | 3.53 | 0.24 | 0.152 |
| I2 | 22 | 4.05 | 0.60 | 20 | 3.97 | 0.41 | 0.597 |
| C | 28 | 5.43 | 0.59 | 21 | 5.24 | 0.61 | 0.271 |
| P1 | 28 | 5.02 | 0.38 | 24 | 4.89 | 0.32 | 0.205 |
| P2 | 27 | 5.31 | 0.44 | 22 | 5.13 | 0.37 | 0.134 |
| M1 | 27 | 9.26 | 1.06 | 23 | 8.90 | 0.56 | 0.154 |
| M2 | 31 | 9.13 | 0.66 | 21 | 9.05 | 0.77 | 0.664 |
| M3 | 24 | 8.80* | 0.65 | 10 | 8.21* | 0.64 | 0.022* |

*N*, number of teeth; *A*, average; SD, standard deviation; *, statistically significant; I1, central incisor; I2, lateral incisor; C, canine; P1, first premolar; P2, second premolar; M1, first molar; M2, second molar; M3, third molar.

Table 3
Mesiodistal diameter of the tooth crown

| | Male | | | Female | | | *p*-level |
|---|---|---|---|---|---|---|---|
| | *N* | *A* (mm) | SD (mm) | *N* | *A* (mm) | SD (mm) | |
| Upper jaw | | | | | | | |
| I1 | 11 | 8.20 | 0.77 | 17 | 8.11 | 0.78 | 0.759 |
| I2 | 22 | 6.43 | 0.56 | 21 | 6.54 | 0.58 | 0.514 |
| C | 26 | 7.52 | 0.63 | 22 | 7.41 | 0.51 | 0.541 |
| P1 | 24 | 6.38 | 0.56 | 25 | 6.51 | 0.25 | 0.328 |
| P2 | 26 | 6.30 | 0.48 | 27 | 6.45 | 0.53 | 0.266 |
| M1 | 22 | 10.45 | 0.71 | 34 | 10.25 | 0.70 | 0.304 |
| M2 | 22 | 9.26 | 0.99 | 28 | 9.39 | 0.66 | 0.591 |
| M3 | 13 | 8.05 | 1.17 | 8 | 8.51 | 1.13 | 0.387 |
| Lower jaw | | | | | | | |
| I1 | 18 | 5.23 | 0.32 | 15 | 5.28 | 0.32 | 0.695 |
| I2 | 19 | 5.70 | 0.59 | 19 | 5.83 | 0.29 | 0.389 |
| C | 22 | 6.70 | 0.62 | 20 | 6.64 | 0.32 | 0.692 |
| P1 | 27 | 6.56 | 0.42 | 22 | 6.62 | 0.36 | 0.613 |
| P2 | 26 | 6.91* | 0.54 | 21 | 6.54* | 0.54 | 0.026* |
| M1 | 24 | 10.65 | 1.09 | 23 | 10.57 | 0.69 | 0.759 |
| M2 | 27 | 10.30 | 0.70 | 20 | 10.18 | 0.93 | 0.600 |
| M3 | 22 | 10.19 | 0.87 | 9 | 9.67 | 0.60 | 0.110 |

*N*, number of teeth; *A*, average; SD, standard deviation; *, statistically significant; I1, central incisor; I2, lateral incisor; C, canine; P1, first premolar; P2, second premolar; M1, first molar; M2, second molar; M3, third molar.

Table 5
Buccolingual diameter of the tooth crown

| | Male | | | Female | | | *p*-level |
|---|---|---|---|---|---|---|---|
| | *N* | *A* (mm) | SD (mm) | *N* | *A* (mm) | SD (mm) | |
| Upper jaw | | | | | | | |
| I1 | 12 | 6.92 | 0.55 | 17 | 6.85 | 0.46 | 0.732 |
| I2 | 22 | 6.42 | 0.65 | 21 | 6.48 | 0.37 | 0.717 |
| C | 26 | 8.52* | 0.70 | 22 | 7.91* | 0.62 | 0.003* |
| P1 | 25 | 9.01 | 0.63 | 25 | 8.77 | 0.55 | 0.173 |
| P2 | 26 | 8.97 | 0.63 | 27 | 9.01 | 0.58 | 0.822 |
| M1 | 23 | 11.26 | 0.44 | 34 | 10.96 | 0.79 | 0.105 |
| M2 | 22 | 11.20 | 0.80 | 28 | 10.82 | 1.06 | 0.161 |
| M3 | 13 | 10.04 | 1.23 | 8 | 10.44 | 1.49 | 0.508 |
| Lower jaw | | | | | | | |
| I1 | 18 | 6.32* | 0.49 | 15 | 5.87* | 0.48 | 0.014* |
| I2 | 19 | 6.33 | 0.62 | 19 | 6.22 | 0.34 | 0.523 |
| C | 23 | 7.73 | 0.71 | 20 | 7.44 | 0.56 | 0.153 |
| P1 | 27 | 7.69 | 0.72 | 22 | 7.45 | 0.46 | 0.185 |
| P2 | 26 | 8.09 | 0.68 | 21 | 7.95 | 0.77 | 0.523 |
| M1 | 25 | 10.49 | 0.83 | 22 | 10.26 | 0.41 | 0.252 |
| M2 | 28 | 9.95 | 0.52 | 21 | 9.69 | 0.50 | 0.092 |
| M3 | 22 | 9.54* | 0.78 | 10 | 8.69* | 0.54 | 0.004* |

*N*, number of teeth; *A*, average; SD, standard deviation; *, statistically significant; I1, central incisor; I2, lateral incisor; C, canine; P1, first premolar; P2, second premolar; M1, first molar; M2, second molar; M3, third molar.

Table 6
Height of the tooth crown

| | Male | | | Female | | | $p$-level |
|---|---|---|---|---|---|---|---|
| | $N$ | $A$ (mm) | SD (mm) | $N$ | $A$ (mm) | SD (mm) | |
| Upper jaw | | | | | | | |
| I1 | 5 | 8.23* | 1.74 | 15 | 10.39* | 1.69 | 0.024* |
| I2 | 11 | 8.18* | 1.51 | 16 | 9.34* | 1.26 | 0.040* |
| C | 13 | 8.95 | 1.60 | 16 | 8.66 | 1.28 | 0.585 |
| P1 | 14 | 6.84* | 1.18 | 17 | 7.68* | 0.67 | 0.020* |
| P2 | 15 | 6.06* | 0.78 | 17 | 6.65* | 0.66 | 0.026* |
| M1 | 15 | 6.32* | 0.48 | 26 | 7.35* | 0.79 | 0.000* |
| M2 | 16 | 6.69 | 0.43 | 20 | 7.15 | 0.88 | 0.065 |
| M3 | 10 | 6.18 | 1.18 | 4 | 6.76 | 0.21 | 0.354 |
| Lower jaw | | | | | | | |
| I1 | 11 | 6.88* | 0.84 | 11 | 8.54* | 1.43 | 0.003* |
| I2 | 11 | 7.77 | 1.26 | 14 | 8.90 | 1.53 | 0.059 |
| C | 14 | 9.88 | 1.69 | 15 | 10.17 | 1.49 | 0.624 |
| P1 | 16 | 7.76 | 0.99 | 15 | 7.58 | 1.57 | 0.705 |
| P2 | 17 | 6.96 | 0.92 | 14 | 7.15 | 1.55 | 0.670 |
| M1 | 17 | 5.50* | 1.04 | 18 | 6.85* | 1.28 | 0.002* |
| M2 | 19 | 6.42 | 0.88 | 16 | 6.94 | 1.44 | 0.201 |
| M3 | 16 | 6.43 | 1.07 | 8 | 6.50 | 0.90 | 0.882 |

$N$, number of teeth; $A$, average; SD, standard deviation; *, statistically significant; I1, central incisor; I2, lateral incisor; C, canine; P1, first premolar; P2, second premolar; M1, first molar; M2, second molar; M3, third molar.

Measurements needed to calculate the robustness of a tooth were performed on a total of 945 permanent teeth. There were statistically significant differences between males and females in the maxillary canine (males $65.00 \pm 10.05$ mm, females $58.70 \pm 7.05$ mm, $p < 0.017$), the mandibular second premolar (males $56.10 \pm 8.40$ mm, females $51.30 \pm 6.20$ mm, $p < 0.036$), the mandibular first molar (males $115.85 \pm 9.55$ mm, females $108.90 \pm 10.50$ mm, $p < 0.028$), and the mandibular third molar (males $97.80 \pm 16.60$ mm, females $84.15 \pm 8.70$ mm, $p < 0.028$), Table 7.

Table 7
Robustness of the teeth

| | Male | | | Female | | | $p$-level |
|---|---|---|---|---|---|---|---|
| | $N$ | $A$ (mm) | SD (mm) | $N$ | $A$ (mm) | SD (mm) | |
| Upper jaw | | | | | | | |
| I1 | 11 | 57.14 | 8.08 | 17 | 55.79 | 8.13 | 0.670 |
| I2 | 22 | 41.40 | 6.68 | 21 | 42.39 | 4.63 | 0.574 |
| C | 26 | 65.03* | 10.06 | 22 | 58.72* | 7.04 | 0.017* |
| P1 | 24 | 57.90 | 7.41 | 25 | 57.16 | 4.97 | 0.682 |
| P2 | 26 | 56.70 | 7.69 | 27 | 58.32 | 7.58 | 0.444 |
| M1 | 22 | 117.60 | 9.75 | 34 | 112.57 | 12.79 | 0.122 |
| M2 | 21 | 102.72 | 14.59 | 28 | 101.92 | 14.88 | 0.852 |
| M3 | 13 | 81.82 | 18.65 | 8 | 88.64 | 15.69 | 0.400 |
| Lower jaw | | | | | | | |
| I1 | 18 | 33.05 | 3.27 | 15 | 31.05 | 3.76 | 0.112 |
| I2 | 18 | 36.60 | 5.96 | 19 | 36.30 | 3.19 | 0.848 |
| C | 21 | 51.88 | 8.96 | 20 | 49.40 | 5.28 | 0.291 |
| P1 | 27 | 50.63 | 7.36 | 21 | 49.45 | 4.49 | 0.520 |
| P2 | 26 | 56.12* | 8.44 | 21 | 51.33* | 6.23 | 0.036* |
| M1 | 23 | 115.87* | 9.57 | 23 | 108.94* | 10.53 | 0.024* |
| M2 | 27 | 102.86 | 11.35 | 20 | 99.08 | 13.53 | 0.304 |
| M3 | 22 | 97.82* | 16.60 | 9 | 84.19* | 8.70 | 0.028* |

$N$, number of teeth; $A$, average; SD, standard deviation; *, statistically significant; I1, central incisor; I2, lateral incisor; C, canine; P1, first premolar; P2, second premolar; M1, first molar; M2, second molar; M3, third molar.

There was no statistically significant difference between the findings of the two observers. Table 8 shows the $t$ values of intra- and interobserver error test.

The percentage of sexual dimorphism was calculated for all odontometric features that showed a statistically significant difference between males and females, Table 9 .The greatest difference was observed in the central incisor crown height. Females had higher value of tooth height by 20.80%. However, tooth height is an odontometric feature that is characterized by individual variations due to tooth abrasion. Not taking tooth height into consideration, the greatest difference in male and female odontometric features was evident in the robustness of the third molar. In males the third lower molar was for 16.19% more robust. The mesiodistal diameter of the tooth crown showed least difference between sexes, with only 5.58%.

Odontometric features that show sexual dimorphism are used in sex determination in cases where sex could not be determined using craniofacial features. On the basis of mean values and standard deviation the ranges of values are determined that can be attributed only to males and only to females, Table 10. Comparing the odontometric data on the remains of individuals of the unknown sex with the ranges of odontometric features shown in Table 10, sex can further be determined on 26 individuals more; 19 females and 7 males. The new distribution of sex in the Bijelo Brdo series is shown in Table 11.

By including the odontometric parameters in the procedure of determining sex, efficiency of determining sex is raised from 55.8% (on the basis of craniofacial features alone) to 86.0% (combining craniofacial and odontometric features), which presents a 30.2% increase in the success of determining sex.

## 4. Discussion

The Bijelo Brdo culture group, named after the most important site in Bijelo Brdo near Osijek (eastern Croatia), developed from an older Avaro-Slavic culture, dated 7–9 century AD. The Bijelo Brdo culture lasted from 10th to 12th century AD, at places even longer (early mediaeval period). Archaeological sites belonging to the Bijelo Brdo culture group can be found in northern Croatia, Austria, Bosnia and Herzegovina, Hungary, Romania, Slovakia, Slovenia, and Serbia. The origin of this culture is considered to be in the Pannonian Valley. The Pannonian Slavs are considered to be the main carriers of the Bijelo Brdo culture, which according to some theories spread to all south Slavic countries (Demo, 1996).

Even though the skeletal remains of the Bijelo Brdo series are well preserved (Vodanović et al., 2004), skeletal remains in archaeology are very often poorly preserved and fragmentary which makes analysis very complicated, at times even impossible. Sex determination, one of the basic features of identification, is a much more demanding task. Unfortunately, it is also much less reliable if performed on poorly preserved material. For that reason it is best to combine several methods in order to raise the level of confidence and the percentage of success in determining sex.

Table 8
$t$ values of intra- and interobserver error tests

| | Intraobserver | Interobservers |
|---|---|---|
| *Mesiodistal diameter of the tooth crown* | | |
| Upper jaw | | |
| I1 | 0.31 | −0.11 |
| I2 | 0.41 | −0.55 |
| C | 0.13 | 0.67 |
| P1 | 0.17 | 1.26 |
| P2 | 0.26 | 0.42 |
| M1 | 0.34 | 0.09 |
| M2 | 0.28 | 0.26 |
| M3 | 0.34 | 0.57 |
| Lower jaw | | |
| I1 | 0.62 | 0.67 |
| I2 | 0.61 | 0.19 |
| C | −0.22 | −0.97 |
| P1 | 0.66 | 0.64 |
| P2 | 0.58 | 0.96 |
| M1 | −0.50 | −1.07 |
| M2 | −1.05 | −0.89 |
| M3 | 0.98 | 1.15 |
| *Mesiodistal diameter of the tooth cervix* | | |
| Upper jaw | | |
| I1 | 0.73 | 0.11 |
| I2 | 0.79 | −0.72 |
| C | −0.71 | −0.76 |
| P1 | 0.65 | −0.89 |
| P2 | −0.07 | −1.23 |
| M1 | 1.10 | −0.74 |
| M2 | 0.49 | 0.55 |
| M3 | 0.44 | 0.70 |
| Lower jaw | | |
| I1 | −0.57 | 0.51 |
| I2 | 0.08 | 0.54 |
| C | 0.10 | 0.55 |
| P1 | −0.42 | 0.40 |
| P2 | −0.50 | 0.14 |
| M1 | −0.37 | −0.18 |
| M2 | 0.32 | 1.00 |
| M3 | 0.05 | 0.51 |
| *Buccolingual diameter of the tooth crown* | | |
| Upper jaw | | |
| I1 | −0.43 | −0.09 |
| I2 | −0.46 | −0.07 |
| C | −0.42 | −0.02 |
| P1 | −0.70 | 0.21 |
| P2 | −1.30 | 0.49 |
| M1 | −0.42 | 0.40 |
| M2 | −0.27 | 0.30 |
| M3 | −0.05 | 0.42 |
| Lower jaw | | |
| I1 | 0.34 | 0.88 |
| I2 | 0.08 | 0.95 |
| C | −0.12 | 1.07 |
| P1 | −0.94 | 0.79 |
| P2 | −0.82 | 0.83 |
| M1 | −0.12 | 1.35 |
| M2 | 0.48 | 1.84 |
| M3 | 0.69 | 1.06 |
| *Height of the tooth crown* | | |
| Upper jaw | | |
| I1 | −0.21 | −0.22 |
| I2 | −0.14 | −0.17 |
| C | 0.10 | −0.12 |
| P1 | 1.12 | 0.65 |
| P2 | 0.96 | 0.98 |
| M1 | −0.67 | −0.91 |
| M2 | 0.48 | 0.68 |
| M3 | 0.35 | 0.49 |
| Lower jaw | | |
| I1 | 0.10 | −0.03 |
| I2 | 0.22 | −0.16 |
| C | 0.13 | −0.18 |
| P1 | −0.08 | −0.19 |
| P2 | −0.04 | −0.27 |
| M1 | −0.03 | 0.23 |
| M2 | 0.47 | 0.99 |
| M3 | 0.55 | −0.57 |

None of the $t$ values are significant at the $p < 0.05$ level.
I1, central incisor; I2, lateral incisor; C, canine; P1, first premolar; P2, second premolar; M1, first molar; M2, second molar; M3, third molar.

As a means of determining sex, odontometric features have been the subject of research for a long time (Iscan and Kedici, 2003; Pettenati-Soubayroux et al., 2002). Ditch and Rose (1972) were the first to prove that teeth diameters can be successfully used in determining sex in poorly preserved and fragmentary skeletal remains in archaeology.

Crowns of permanent teeth are formed at an early stage and their dimensions remain unchanged during further growth and development, except in cases when specific changes and disorders in terms of functionality, pathology and nutrition can have affect on the normal dimensions of a tooth (Teschler-Nicola and Prossinger, 1998). Because of that odontometric features of teeth can be used in determining sex after the tooth has erupted even in children whose osseous features of the sex are not yet defined (Teschler-Nicola and Prossinger, 1998). Chromosomes responsible for the sexual difference are in direct connection to growth and development of teeth. Alvesalo and Tammisalo (1981), Alvesalo et al. (1985, 1987) found that the Y chromosome increases the mitotic potential of the tooth germ. It induces dentinogenesis, while the X chromosome induces amelogenesis. The research preformed by Stroud et al. (1994) showed that males have larger mesiodistal diameters of single teeth, which is due to a thicker dentin layer.

Mesiodistal and buccolingual diameters of the permanent tooth crown are the two most commonly used and researched features used in determining sex on the basis of dental measurements (Teschler-Nicola and Prossinger, 1998). Muller et al. (2001) performed an investigation of French students and confirmed the difference between males and females in the buccolingual diameter of the mandibular canine. They concluded that odontometrics is a quick and easy method for determining sex which should be tested by other sex determination methods, dental or not, since the percentage of exact odontometric results does not exceed 84–87%. Researching the Chinese population, Lew and Keng, 1991 discovered a statistically significant difference between males and females in

Table 9
Degree of sexual dimorphism of the odontometric features in the Bijelo Brdo sample

| | Male | | | Female | | | Sexual dimorphism | | |
|---|---|---|---|---|---|---|---|---|---|
| | *N* | *A* (mm) | SD (mm) | *N* | *A* (mm) | SD (mm) | *p*-level | *X*[a] | %[b] |
| Mesiodistal diameter of the tooth crown (mm) | | | | | | | | | |
| L-P2 | 26 | 6.91* | 0.54 | 21 | 6.54* | 0.54 | 0.026* | 0.37 | 5.58 |
| Mesiodistal diameter of the tooth cervix (mm) | | | | | | | | | |
| U-C | 28 | 6.00* | 0.48 | 23 | 5.47* | 0.50 | 0.000* | 0.52 | 9.55 |
| L-M3 | 24 | 8.80* | 0.65 | 10 | 8.21* | 0.64 | 0.022* | 0.58 | 7.12 |
| Buccolingual diameter of the tooth crown (mm) | | | | | | | | | |
| U-C | 26 | 8.52* | 0.70 | 22 | 7.91* | 0.62 | 0.003* | 0.61 | 7.71 |
| L-I1 | 18 | 6.32* | 0.49 | 15 | 5.87* | 0.48 | 0.014* | 0.44 | 7.56 |
| L-M3 | 22 | 9.54* | 0.78 | 10 | 8.69* | 0.54 | 0.004* | 0.85 | 9.81 |
| Height of the tooth crown (mm) | | | | | | | | | |
| U-I1 | 5 | 8.23* | 1.74 | 15 | 10.39* | 1.69 | 0.024* | −2.16 | −20.80 |
| U-I2 | 11 | 8.18* | 1.51 | 16 | 9.34* | 1.26 | 0.040* | −1.16 | −12.40 |
| U-P1 | 14 | 6.84* | 1.18 | 17 | 7.68* | 0.67 | 0.020* | −0.83 | 10.85 |
| U-P2 | 15 | 6.06* | 0.78 | 17 | 6.65* | 0.66 | 0.026* | −0.59 | −8.90 |
| U-M1 | 15 | 6.32* | 0.48 | 26 | 7.35* | 0.79 | 0.000* | −1.02 | −13.95 |
| L-I1 | 11 | 6.88* | 0.84 | 11 | 8.54* | 1.43 | 0.003* | −1.66 | −19.46 |
| L-M1 | 17 | 5.50* | 1.04 | 18 | 6.85* | 1.28 | 0.002* | −1.35 | −19.66 |
| Robustness of the teeth | | | | | | | | | |
| U-C | 26 | 65.03* | 10.06 | 22 | 58.72* | 7.04 | 0.017* | 6.31 | 10.75 |
| L-P2 | 26 | 56.12* | 8.44 | 21 | 51.33* | 6.23 | 0.036* | 4.79 | 9.33 |
| L-M1 | 23 | 115.87* | 9.57 | 23 | 108.94* | 10.53 | 0.024* | 6.93 | 6.36 |
| L-M3 | 22 | 97.82* | 16.60 | 9 | 84.19* | 8.70 | 0.028* | 13.63 | 16.19 |

*N*, number of teeth; *A*, average; SD, standard deviation; *, statistically significant.
U, upper teeth; L, lower teeth; I1, central incisor; I2, lateral incisor; C, canine; P1, first premolar; P2, second premolar; M1, first molar; M2, second molar; M3, third molar.
[a] $X = A$ male $- A$ female.
[b] $\% = (A$ male$/A$ female $- 1.0) \times 100$.

Table 10
Range of measured odontometric values that show sexual dimorphism

| | Range of values characteristic only for males | Range of values characteristic only for females |
|---|---|---|
| Mesiodistal diameter of the tooth crown (mm) | | |
| L-P2 | 7.08–7.45 | 6.0–6.37 |
| Mesiodistal diameter of the tooth cervix (mm) | | |
| U-C | 5.97–6.48 | 4.97–5.52 |
| L-M3 | 8.85–9.45 | 7.57–8.15 |
| Buccolingual diameter of the tooth crown (mm) | | |
| U-C | 8.53–9.22 | 7.29–7.82 |
| L-I1 | 6.35–6.81 | 5.39–5.83 |
| L-M3 | 9.23–10.32 | 8.15–8.76 |
| Height of the tooth crown (mm) | | |
| U-I1 | 6.49–8.70 | 9.97–12.08 |
| U-I2 | 6.67–8.08 | 9.69–10.60 |
| U-P1 | 5.66–7.01 | 8.02–8.35 |
| U-P2 | 5.28–5.99 | 6.84–7.31 |
| U-M1 | 5.84–6.56 | 6.80–8.14 |
| L-I1 | 6.04–7.11 | 7.72–9.97 |
| L-M1 | 4.46–5.57 | 6.54–8.13 |
| Robustness of the teeth | | |
| U-C | 65.76–75.09 | 51.68–54.97 |
| L-P2 | 57.56–64.56 | 45.10–47.68 |
| L-M1 | 119.47–125.44 | 98.41–106.30 |
| L-M3 | 92.89–114.42 | 75.49–81.22 |

U, upper teeth; L, lower teeth; I1, central incisor; I2, lateral incisor; C, canine; P1, first premolar; P2, second premolar; M1, first molar; M2, second molar; M3, third molar.

the mesiodistal and the buccolingual crown diameter of the permanent canine. Researching the buccolingual diameter of permanent dentition in Turkish students Iscan and Kedici (2003) discovered a statistically significant difference between males and females in the maxillary and mandibular canine, and the mandibular second premolar, providing the accuracy of correct classification of about 77%.

According to the time of death, ante-mortem and post-mortem teeth abrasion are possible. Ante-mortem teeth abrasion is caused by diet, jaw size and chewing stresses during the life. Post-mortem teeth abrasion is caused mostly by mechanical or chemical damages that affect the teeth after death. Ante-mortem and post-mortem teeth abrasion can easily be recognized according to different wear patterns. Ante-mortem abrasion mostly affects the occlusal and approximal teeth surfaces and is highly positive correlated with age. There are many different classification methods of teeth abrasion, based on macroscopic or microscopic examination of the changes on tooth surface. Macroscopic changes are often visible (localized facets of smooth and shiny enamel, areas of exposed dentine). In order to avoid mistakes, in this study all teeth exhibiting macroscopic changes on the surface were excluded from further measurements.

A number of researches show that males have larger teeth than females (Teschler-Nicola and Prossinger, 1998; Muller et al., 2001; Lew and Keng, 1991; Perzigian, 1976). This is also confirmed by this research. All measured parameters (with the exception of tooth height) on average have higher values in males. Previous researches of the Bijelo Brdo population (Vodanović et al., 2003, 2004, 2005) showed that males have a higher level of tooth abrasion that affects the tooth crown height. The difference is statistically significant. Only teeth with a low level of abrasion are included in the measuring of tooth crown height (the sample on which the tooth height is measured is by 30% smaller than the sample on which other odontometric parameters are measured), but there is still a noticeable difference between males and females in tooth height.

It is argued that only intact teeth and teeth after immediate eruption should be included in measuring the tooth crown

Table 11
Results of the sex determination using craniofacial and odontometric features in the Bijelo Brdo sample

| *N* total (%) | *N* sex − determined: male + female (%) | | *N* sex − undetermined (%) |
|---|---|---|---|
| 86 (100.0) | 74 (86.0) | | 12 (14.0) |
| | *N* male (%) | *N* female (%) | |
| | 31 (36.0) | 43 (50.0) | |

*N*, number of individuals.

height, considering the fact that females show higher values in tooth crown height, which is statistically significant. Even though this seems correct, it may also manipulate the results by eliminating the specific features of a population. Tooth abrasion, most commonly due to hard food consumption, is one of the dental characteristics of ancient peoples.

Although there is an obvious sexual dimorphism in human crown dimensions, the level of dimorphism is lower than that of the non-metric dental traits like Carabelli's trait of upper molars, deflecting wrinkle of lower first molars, distal accessory ridge of the upper and lower canines or shovelling of the upper central incisors. Many non-metric dental traits are highly positive correlated with tooth size because they are both genetically determined (Scott and Turner, 1997). This can be helpful during sex determination of skeletal remains, because some of dental traits can disappear due to tooth abrasion, but the mesiodistal and buccolingual crown dimensions can still be unchanged. On the other hand, at times crown dimensions can be useless for sex determination due to pathological conditions like caries, while presence of some dental treatment can yet be helpful for sex identification.

It is considered that odontometric features of teeth are population specific (Iscan and Kedici, 2003), and that direct comparison and non-critic analyses can lead to false conclusions. Statistically significant differences that are established in the Bijelo Brdo series are consistent with results of other authors who showed that the greatest difference between males and females is in the tooth dimensions of the canine (Teschler-Nicola and Prossinger, 1998; Muller et al., 2001; Iscan and Kedici, 2003; Lew and Keng, 1991). This research shows that there is a high level of sexual dimorphism in the mesiodistal cervix diameter, the buccolingual crown diameter, and the robustness of the mandibular third molar.

## 5. Conclusion

The advantages in determining sex on the basis of odontometric features are simplicity, speed, and low cost, while the greatest disadvantage is the possibility of mistake in the cases where the normal dimensions of teeth is altered. Such cases include abrasion of the incisal, occlusal and approximal surfaces, very common in ancient people. Apart from abrasion, mistakes are possible in the procedure itself. This is because the lack of referent odontometric values needed for comparison leaves room for mistakes in determining sex. Therefore, in order to raise the level of confidence and percentage of success in determining sex, it is best to combine several different methods when the ante-mortem data on sex are not available (most commonly in archaeological series).

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