

Establishment of gender in forensic odontology

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Abstract

Sex determination of skeletal remains is part of the archaeological, anthropologic and many medico-legal examinations. The methods vary and depend on the available bones and their condition. The only method that can give a totally accurate result is the DNA technique, but in many cases for several reasons it cannot be used. Teeth are excellent material for anthropological, genetic and forensic investigations and can be used in the determination of sex.

Key words: Forensic odontology, Sexual dimorphism, DNA analysis

Introduction

Determining the sex, or sexing, of unknown human remains is the second step in the triad of building a dental profile. Forensic odontology plays an important role in establishing the sex of the victims with bodies mutilated beyond recognition due to major mass disaster. Sex can be determined based on data from morphology of skull and mandible, metric features, as well as by DNA analyses of teeth.

Sexing From Craniofacial Morphology and Dimensions

The use of morphological features of the skull and mandible is a common approach used by anthropologists in sexing¹. A number of features are known to show variation between the sexes. The use of multiple features tends to be more accurate. Botha as well as Chandra Sekaharan, however, cautions that most of these features are not reliable before puberty. Until puberty there is little sexual difference in the skulls. During this time only pelvis can be used for sex determination. After puberty, other bones used for determination of sex are sternum, long bones, craniofacial bones scapula and metacarpal bones². Moreover, they are affected by old age changes. Hence, their application in sexing may need to be confined to young adults and the middle-aged.

Williams and Rogers got 96% success in determining the sex using different features of the skull and the

mandible. They also observed that using a constant 6 traits – mastoid, supraorbital ridge, size and architecture of skull, zygomatic extension, nasal aperture and mandibular gonial angle – the accuracy was 94%. This indicates that craniofacial morphology can be used to determine sex of skeletal specimen with a high degree of precision³.

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. In a study, Hu K S et al examined the morphological characteristics of the mandibles of 102 Koreans of either sex. Of 13 non-metric 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 authors concluded that non-metric method used to analyze the mandible in this study can be used for sex discrimination⁴.

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Numerous studies have clearly demonstrated that skeletal characteristics vary by population. Steyn M and Iscan M Y conducted a study to establish population specific standards for sex determination from the skull in South African whites. Five functions were developed from the complete cranium, vault, face, mandible and bizygomatic breadth. Dimensions from the complete cranium provided the best accuracy. In the mandible, bigonial breadth was the most dimorphic of the measurements taken. Average accuracies ranged from 80% (bizygomatic breadth alone) to 86% (cranium). Diagnostic accuracy, however, was lower than that obtained from femur and tibia⁵.

Sex Differences in Tooth Size

Teeth may be used for differentiating sex by measuring their mesiodistal (MD) and buccolingual (BL) dimensions. Lund and Mornstad state "this is of special importance in young individuals where skeletal secondary sexual characters have not yet developed". Various studies have shown significant differences between male and female permanent and deciduous tooth crown dimensions. However, tooth measurements are population specific and vary from region to region. In most studies, the canines have consistently shown the maximum sex difference. Premolars, maxillary molars as well as maxillary incisors are also known to have significant differences. In a study, Iscan and Kedici could accurately establish sex in 77% of the cases using maxillary and mandibular canines, and mandibular second molar⁶.

Presently, sex can be determined from tooth measurements using a statistical method called *discriminant function analysis*. Using this analysis, sex was determined correctly in 92.5% of cases³.

Sexual dimorphism refers to the differences in size, shape or, color between males and females and is useful tool to distinguish them. The canines are favoured as ideal teeth to study these differences. A study was performed by Boaz K and Gupta C on 100 dental casts of South Indian population in the age group of 14-20 years. The study revealed that the mean values of buccolingual (BL) and mesiodistal (MD) dimensions of mandibular left canines (33) were greater in females than in males and also the mean values of mesiodistal (MD) dimensions of mandibular right canines (43) were greater in females. Authors concluded that the finding could be attributable to evolution resulting in a reduction in sexual dimorphism, causing an overlap of tooth dimensions in modern males and females⁷.

Soubayroux IP, Signoli M and Dusour D conducted a study to evaluate the relevance of lower canine measurements used for sex determination. Sexual

dimorphism was tested on 89 well preserved burials, dating back from plague outbreak in Marscilles (1722). The results showed that there is a relative dental dimorphism (males > females mesiodistal diameters) in humans, and lower canines and upper lateral incisors are the useful teeth in dimorphic dental determination. The lower canine is the most accurate tooth for the analysis of dental sexual dimorphism⁸.

Acharya A B and Mainali S conducted a study to explore the utility of buccolingual (BL) and mesiodistal (MD) measurements in sex differentiation when used independently. BL and MD measurements of 28 teeth (third molars excluded) were obtained from a group of 53 Nepalese people (22 women and 31 men) aged 19–28 years. Stepwise discriminant analyses were undertaken separately for both types of tooth crown variables and their accuracy in sex classification compared with one another. MD dimensions had recognizably greater accuracy 25/31 (83%) in sex identification than BL measurements 19/31 (64%). The results were consistent with previous reports. However, the higher accuracy levels have been obtained when both types of dimensions were used concurrently, implying that BL variables contribute to sex assessment to some extent. Hence, it is inferred that optimal results in dental sex assessment are obtained when both MD and BL variables are used together⁹.

Rai B and Anand SC investigated the accuracy with which gender can be differentiated by odontometric analyses in a North Indian population. Dental casts of 445 subjects (M:F 233:212) in the age group of 17-57 years were obtained. Measurements were made on the mesio buccal, distolingual and distobuccal mesiolingual diameters by digital vernier caliper. The mean values and standard deviation of all recorded dimensions were larger in males than in females. Mandibular canine ($p < 0.001$) had significant mean differences in all measurements. It also showed high significant dimorphic values¹⁰.

Dental Index

In addition to absolute tooth size, tooth proportions have been suggested for differentiating males and females. Aitchison presented the 'Incisor index' (Ii), which is calculated by the formula $Ii = [MDI 2 / MDI 1] \times 100$, where MDI 2 is the maximum mesiodistal diameter of the maxillary lateral incisor and MDI 1 is the maximum mesiodistal diameter of the central incisor. This index is higher in males, confirming the suggestion of Schrantz and Bartha that the lateral incisor is distinctly smaller than the central incisor in females⁶.

Since canines exhibit the greatest sexual dimorphism and are also highly resistant to disease and postmortem insults, Rao and associates developed the 'Mandibular

Canine Index' (MCI) :

$$\text{MCI} = \frac{\text{Mesiodistal crown width of mandibular canine}}{\text{Mandibular inter - canine arch width}}$$

Further, the mean and standard deviation (S.D.) of the MCI was derived separately for males and females and a cut off point to distinguish the sexes- termed the 'Standard MCI' calculated as:

$$\text{Standard MCI} = \frac{(\text{Mean female MCI} - \text{SD}) + (\text{Mean female MCI} + \text{SD})}{2}$$

The cut-off point, or standard MCI value, obtained by Rao and associates was 0274. If the MCI Value of a skull specimen is less than or equal to standard MCI, the individual is categorized as female; a value more than the standard MCI would group the person as male. The success rate of determining sex using the standard MCI was almost 86%. However, the accuracy from tooth measurements is lower to the near 100% success obtained using pelvis and skull. This can be attributed to an overlap existing between male and female tooth dimensions, which make accurate diagnosis of sex, challenging. The success is usually greater when all available teeth are used. Nevertheless, teeth should be used as an adjunct and not as the sole indicator of sex³.

Acharya A B and Mainali S conducted another study to describe the sexual dimorphism by dental indices derived from the permanent dentition. Three dental indices- 'crown area,' 'crown module' and 'crown index' were calculated from the buccolingual (BL) and mesiodistal (MD) measurements of 123 permanent dentitions (58 females and 65 males) belonging to age-range 19–28 years. Sex differences in the dental indexes were assessed using univariate and multivariate statistics and compared to that of linear measurements reported previously on the same sample. Stepwise discriminant analyses undertaken for the indices gave moderate to high accuracy rates in sexing (69.8–81.1%). However, this is lower to the classification accuracy reported for linear measurements. Therefore, authors concluded that dental indexes have no added utility in forensic sex assessment¹¹.

Sex Determination by DNA Analysis

Forensic DNA analysis for sex determination can give highly accurate results. Microscopic examination of the cells from the pulp can reveal the presence of Barr bodies in females. Modern DNA extraction methods can isolate genomic DNA from dental cells and the gene *Amelogenin*, a sex linked gene¹.

Sex can be determined with very minute quantities of

DNA and from very old specimens of teeth. *Amelogenin* (AMEL) is one of the major matrix proteins secreted by the ameloblasts of the enamel³.

The AMEL gene, coding for a highly conserved protein, is located on the X and the Y chromosomes in humans. The two alleles are similar for the exonic sequences but differ in the intronic sequences. Thus the females (XX) have two identical AMEL genes but the males (XY) have two non identical genes. The fact that the X and Y specific AMEL genes are 106 and 112 base pairs, or bp, in length, respectively, provides a relatively direct procedure to discriminate between male and female AMEL^{1,12}.

On a bar-code type of display, a male DNA sample appears as two discrete bands of 106 and 112 bp. A female DNA sample appears as a single band of 106 bp for the gene AMEL. This distinction between human male and female AMEL genes is remarkably specific, sensitive and cost-effective for modern forensics¹².

Polymerase chain reaction (PCR) is a method amplifying small quantities of relatively short target sequences of DNA using sequence- specific oligonucleotide primers and thermostable Taq DNA polymerase. Preparing DNA from teeth by ultrasonication, and subsequent PCR amplification, Sivagami and coworkers obtained 100 per cent success in determining the sex of the individual¹³.

Conclusion

Determination of sex using skeletal remains presents a great problem to forensic experts especially when only fragments of the body are recovered. Forensic dentists can assist other experts to determine the sex of remains by using teeth and skull. The durability of teeth in the fire and bacterial decomposition makes them invaluable for identification and sex determination.

Various methods of sex determination have been described but in the emerging field of forensic odontology, forensic DNA analysis seems to be a useful technique as it is the most accurate and can be performed on minute quantities of DNA. But at the same time it is more time consuming and expensive. Therefore in developing countries, the establishment of gender of fragmented skeletons, grossly destroyed, charred and mutilated bodies relies on the other methods also which are easy, inexpensive and accurate.

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