

SHORT COMMUNICATION

M. Schmittbuhl · J. M. Le Minor · F. Taroni
P. Mangin

Sexual dimorphism of the human mandible: demonstration by elliptical Fourier analysis

Received: 27 November 2000 / Accepted: 14 March 2001

Abstract A new quantitative approach of the mandibular sexual dimorphism, based on computer-aided image analysis and elliptical Fourier analysis of the mandibular outline in lateral view is presented. This method was applied to a series of 117 dentulous mandibles from 69 male and 48 female individuals native of Rhenish countries. Statistical discriminant analysis of the elliptical Fourier harmonics allowed the demonstration of a significant sexual dimorphism in 97.1% of males and 91.7% of females, i.e. in a higher proportion than in previous studies using classical metrical approaches. This original method opens interesting perspectives for increasing the accuracy of sex identification in current anthropological practice and in forensic procedures.

Keywords Sexual dimorphism · Anthropology · Biometry

Introduction

Sexing of an isolated skeletal element is a classical problem in forensic osteology. Elliptical Fourier methods allow the morphological quantification of any forms regardless of their degree of complexity (Ferrario et al. 1996; Lestrel 1997; Le Minor and Schmittbuhl 1999; Chen et al. 2000). A new quantitative approach of the mandibular sexual dimorphism, based on computer-aided image analysis and elliptical Fourier analysis of the mandibular outline in lateral view is presented and applied in this technical note.

Materials and methods

Osteological material

The study sample consisted of 117 dentulous mandibles from 69 male and 48 female individuals native of the area around the River Rhine (Rhenish countries comprising Alsace in eastern France, Baden State in western Germany and western Switzerland) which came from the skeletal collections of the Institute of Anatomy (Faculty of Medicine, Strasbourg, France), the Museum of Natural History (Basel, Switzerland) and the Department of Anthropology and Ecology (University of Geneva, Switzerland). Only mandibles with complete permanent dentition and without bone pathology were retained.

Elliptical Fourier analysis

Image capture of the mandibular outlines was performed with a digital camera Minolta RD-175 (resolution 1528×1146 pixels \times 24 bits) equipped with a 300 -mm telephoto lens (Minolta AF 300 mm F4 APO G). The image processing was performed with a microcomputer HP Vectra VE Pentium II, 400 MHz. Image visualisation and processing were made with the software package Adobe Illustrator 7.0.

A left lateral view of each dentulous mandible was captured photographically. The focal axis of the camera was perpendicular to the median sagittal plane and centred on the left first lower molar, the distance between this molar and the camera was 3.0 m. (Fig. 1). From the mandibular digital image, the teeth were removed by image processing, the segmentation line applied corresponded to a Bezier's curve connecting the mesial and distal points of the cemento-enamel junction (cervix) of each tooth and the mandibular outline was determined by image processing.

An original elliptical Fourier approach was used as developed by Schmittbuhl et al. (1997, 2001).

Statistical analysis was carried out using Statistica 6.0 (StatSoft, Inc.). A discriminant analysis was performed using an increasing number of elliptical Fourier harmonics and the significance of the discriminant function was evaluated from the Wilks' Lambda statistic (Klecka 1980) (level of significance set at $p = 0.05$). The statistical evaluation of a significant sexual dimorphism was realised using the Mahalanobis distances method (Klecka 1980). From the determination for each individual of its Mahalanobis distance with the centroid of each sex group, the numbers and proportions of individuals presenting a significant sexual dimorphism were calculated.

M. Schmittbuhl (✉) · F. Taroni · P. Mangin
Institut Universitaire de Médecine Légale,
Rue du Bugnon 21, 1005 Lausanne, Switzerland
e-mail: Mathieu.Schmittbuhl@hospvd.ch

J. M. Le Minor
Institut d'Anatomie Normale (EA 1315), Faculté de Médecine,
67085 Strasbourg, France

Fig. 1 Schematic representation of the image analysis system and of the reference position of the human mandible (left lateral view) used in the present study

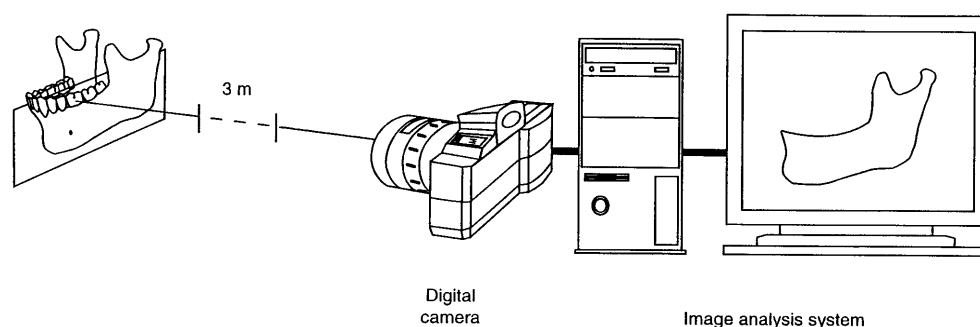


Table 1 Numbers and proportions of individuals presenting a significant sexual dimorphism of the mandibular outline

Sexual dimorphism	Males (n = 69)		Females (n = 48)		Total (n = 117)	
	n	%	n	%	n	%
Significant	67	97.1	44	91.7	111	94.9
Non-significant	2	2.9	4	8.3	6	5.1

Results

Significant differences between males and females were demonstrated by the discriminant analysis of the elliptical Fourier descriptors of the mandibular outlines and by the Mahalanobis distance between the male and female groups which was 12.94 ($p < 0.01$); the proportion of individuals presenting a significant sexual dimorphism was 97.1% in males and 91.7% in females (Table 1).

Discussion

Using conventional metrical measurements, a significant sexual dimorphism was observed for the mandible in 84.9% of individuals from black and white American samples (Giles 1964) and in 81.5% of individuals from a South African whites sample (Steyn and Iscan 1998; Iscan and Steyn 1999). These classical approaches using measurements between points of reference determined on the mandible provided only partial morphological information.

The present elliptical Fourier analysis is, on the contrary, based on all points of the mandibular outline (here 1024 sampled points are retained) and can be considered as taking into account all the shape information of the outline. This use of more information allows the demonstration of a significant sexual dimorphism of the human mandible in a higher proportion than in previous reports (mean 94.9%, Table 1).

The lateral view of the mandible has been retained here since this view can be applied on bony materials (dried bones or skeletal remains) as well as on profile head radiographs currently realised for cephalometric studies. The present method could also be directly applied to other mandibular outlines as outlines obtained from orthopanto-

mography currently used in identification processes (Du Chesne et al. 2000).

Among the interesting aspects of the present approach, the automation of the image analysis procedures for outline extraction and of the elliptical Fourier analysis allows a greater reproducibility and an easy use even by a non-specialist. The developed software is moreover adapted for a personal microcomputer and is thus easy to communicate and transport.

This original approach opens interesting perspectives for increasing the accuracy of sex identification in current anthropological practice and in forensic procedures.

Acknowledgements The authors thank, for access to collections and for help and hospitality, Prof. H. Sick (Institute of Anatomy, Medicine Faculty, Strasbourg, France), Prof. C. Simon and Mrs. S. Eades (Department of Anthropology and Ecology, University of Geneva, Switzerland), Prof. F. Wiedenmayer (Museum of Natural History, Basel, Switzerland). This work was supported by the Foundation for Medical Research (France).

References

- Chen SYY, Lestrel PE, Kerr WJS, McColl JH (2000) Describing shape changes in the human mandible using elliptical Fourier functions. *Eur J Orthod* 22:205–216
- Du Chesne A, Benthaus S, Teige K, Brinkmann B (2000) Post-mortem orthopantomography – an aid in screening for identification purposes. *Int J Legal Med* 113:63–69
- Ferrario VF, Sforza C, Guazzi M, Serrao G (1996) Elliptic Fourier analysis of mandibular shape. *J Craniofac Genet Dev Biol* 16: 208–217
- Giles E (1964) Sex determination by discriminant functions analysis of the mandible. *Am J Phys Anthropol* 22:129–135
- Iscan MY, Steyn M (1999) Craniometric determination of population affinity in South Africans. *Int J Legal Med* 112:91–97
- Klecka WR (1980) Discriminant analysis. Sage Publications, Beverly Hills London
- Le Minor JM, Schmittbuhl M (1999) Importance of elliptical Fourier methods for morphometry of complex outlines: application to the distal human femur. *Surg Anat Radiol* 21:387–391
- Lestrel PE (1997) Morphometrics of craniofacial forms. In: Dixon AD, Hoyte DAN, Rönning O (eds) *Fundamental of craniofacial growth*. CRC Press, Boca Raton New York, pp 155–185
- Schmittbuhl M, Allenbach B, Schaaf A, Le Minor JM (1997) Méthodes de Fourier elliptiques appliquées à la quantification de la forme de contours complexes. *Biom Hum Anthropol* 15: 233–241
- Schmittbuhl M, Allenbach B, Le Minor JM, Schaaf A (2001) Elliptical descriptors: some simplified morphometric parameters for the quantification of complex outlines. *Math Geol* (in press)
- Steyn M, Iscan MY (1998) Sexual dimorphism in the crania and mandibles of South African whites. *Forensic Sci Int* 98:9–16