I-O-F-O-S

JOURNAL of FORENSIC ODONTO-STOMATOLOGY

VOLUME 30 Number 1 July 2012

SECTION ANTHROPOLOGY ARCHEOLOGY

Sex determination by linear measurements of palatal bones and skull base

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The authors declare that they have no conflict of interest.

ABSTRACT

Genetically determined sexual dimorphism is not restricted to reproductive organs. All body structures show sexual differences which emerge during puberty and persist lifelong. The aim of this study is to obtain a reliable method for sex determination through the analysis of linear measurements of palate bones and skull base. One hundred skulls of both sexes, 50 from males and 50 from females, aged between 22 and 55 years, from the São Gonçalo Cemetery of Cuiabá, capital of Mato Grosso state, Brazil, were analyzed. Distances between the incisive foramen, right and left greater palatine foramens and the basion were measured with a digital caliper. Finally, data were tabulated and statistically analyzed. Measurements showed significant sexual dimorphism, except the distance between the right and the left greater palatine foramens. The superior expression of sex dimorphism corresponded to the distance from the basion to the incisive foramen. The authors obtained two mathematical models for sex determination, with a reliability rate of 63% and 65% respectively.

***KEYWORDS*:** Forensic anthropology, anthropometry, forensic dentistry, sex, skull, palate

JFOS. July 2012, Vol.30, No.1 Pag 37-44
ISSN :2219-6749

INTRODUCTION

Anatomic differences between men and women go much beyond body physiognomy or the presence of primary and secondary sexual characters. Male and female human skeletons, despite having the same bones, exhibit a number of differences. However, they are not always apparent and are sometimes difficult to identify in the sex differentiation process.[1,2]

Before puberty it is virtually impossible to diagnose sex by visual examination of the human skull. After this period, as a result of hormone action, distinctive sexual characteristics become more apparent, male muscles gain mass and power, and bones begin to exhibit significant differences between sexes.[3,4] However, there is no single male skull trait that identifies a skull as being male or female. Rather, it is a set of traits that determines one sex or the other. [4, 5, 6]

Male skulls are significantly larger, heavier, and thicker in addition to having greater cranial capacity, whereas in women, protuberances, crests and processes tend to be smaller and smoother. [6, 7, 8]

It is well known that the credibility and reliability of human identification processes is directly related to the amount of data available for the individual. Thus, assessment of all truly dimorphic bones in the human skeleton, would be an ideal condition for determining sex. However, there are numerous cases in which a complete skeleton is unavailable, hindering this type of identification.

The verification of dissimilar features and dimensions involving the sexes, in addition to facilitating the human identification process, makes it more reliable since correct sex determination reduces the pool of evaluated persons by one half. [2,9]

Given that male proportions are larger than their female counterparts, we sought to establish a sex differentiation parameter,

based on relevant anatomic points present when the skull base is visualized, since the male palate is larger than the female's[7, 10, 11] and the skull base is very important in determining sex.[12]

The aim of this paper is to develop an accurate sex determination method using linear measurements of the palatal bones and skull base.

MATERIALS AND METHODS

Sampling

The sample consisted of 100 skulls (50 males and 50 females), aged between 22 and 55 years, with no malformations, apparent abnormalities, severe pathologies or traumatic sequelae, from persons who died in the second half of the 20th century. The skulls were obtained from the São Gonçalo Cemetery of Cuiabá, capital of Mato Grosso state, Brazil.

Data collection

The following linear measurements of the palatal bones and skull base, expressed in millimeters, were taken by a single investigator using a digital caliper (Digimess®, São Paulo, Brazil).(Figure 1):

- incisive foramen - right greater palatine foramen (IF-RGPF);
- incisive foramen - left greater palatine foramen (IF-LGPF);
- right greater palatine foramen – left greater palatine foramen (RGPF-LGPF);
- basion - incisive foramen (Ba-IF); and
- incisive foramen - point located at the center of an imaginary line joining the right and the left greater palatine foramens (IF-RGPF/LGPF).

To evaluate the intra-examiner reliability, 25 skulls were re-measured after seven days.

Statistical analysis

Data were entered into an Excel file and analyzed using Statistical Package for the

Social Sciences (SPSS) software, version 13.0. Intra-examiner reliability was checked by the paired t-test (systematic error) and Dahlberg's index (casual error), and the remaining data by the Kolmogorov-Smirnov test (normal distribution of the measurements), t-Student test (statistically significant difference between the sexes), and stepwise discriminant analysis model

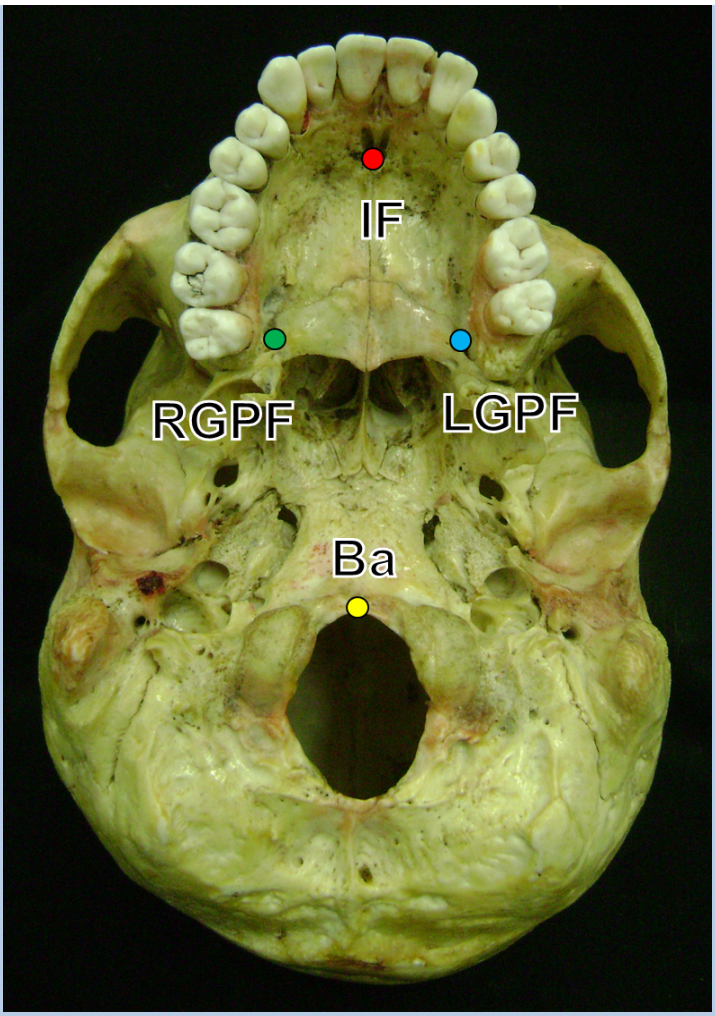

Fig.1: Illustration of anthropometric points used in this research: Incisive foramen (IF, red), right greater palatine foramen (RGPF, green), left greater palatine foramen (LGPF, blue) and basion (Ba, yellow)

RESULTS

With regard to differences between the averages obtained for each sex (Table 1), IF-RGPF, IF-LGPF, Ba-IF and IF-RGPF/LGPF showed statistically significant differences between males and females ($p<0.05$), while RGPF-LGPF did not.

The cut-off value for the most significant measurements is shown in Table 2; numbers above this value represent males and below it, females. Although IF-LGPF showed a higher overall percentage of sex differentiation than Ba-IF(65%), the latter best discriminated between sexes, due to the mean difference observed (3.66mm) (Table 2), demonstrating greater difference between males and females (Table 1).

The highest expression of sexual dimorphism corresponded to the Ba-IF variable ($p=0.004$); values less than 87.0 mm indicate females while those above this value represent males.

The analysis of all possible measurement combinations displayed a similar

discriminatory power to Ba-IF, considered separately. Thus, two logistic regression models for sex determination, with an accuracy rate of 63% and 65% respectively, were obtained and expressed by the formulas below:

Sex=-0.194xIF-RGPF+0.268xIF-LGPF+0.141xBa-IF–0.034xIF-RGPF/LGPF– 14.264

Sex = Ba-IF – 87. 0

In both functions, results less than zero indicate females and those above zero suggest males.

Table 1: **Mean values of variable measurements**

Variable	Female		Male		P-value[1]
	mean	*SD*	*mean*	*SD*	
IF-RGPF	41.78	3.40	43.32	3.10	0.020 *
IF-LGPF	42.19	3.53	43.96	2.96	0.008 *
RGPF-LGPF	34.69	2.46	34.95	2.26	0.593 ns
Ba-IF	85.10	6.45	88.76	5.85	0.004 *
IF-RGPF/LGPF	37.13	3.70	38.99	3.83	0.015 *

(1): t *Student*testsignificance level
(*): statistically significant difference (p<0.05)
(ns): not statistically significant difference (p>0.05)
Measurements in mm

Table 2: Cut-off value that maximizes the accuracy and percentage of correct classification among the sexes.

Measurement	Cut-off value	% of correct classification		
		General	*Female*	*Male*
IF-RGPF	43.27	65%	76%	54%
IF-LGPF	43.03	67%	70%	64%
Ba-IF	86.92	65%	64%	66%
IF-RGPF/LGPF	38.32	64%	66%	62%

DISCUSSION

Human identification consists of a series of steps to individualize individuals and establish their identity.[8] In this respect, forensic anthropology plays an important role in reconstructing the biological profile, taking into consideration its four main components: ancestry, age, stature and sex.[13,14] These factors can be determinants in a unique subject or a large number of unidentified corpses and skeletal remains. Such is the case of mass disasters, where correct sex identification reduces the pool of possible missing persons to just 50% of the population. [2,9]

Over the years, several scientific methods have been used to diagnose sex: visual inspection, anthropometric measurements, time and sequence of dental eruption, X-rays, microscopic observation of internal bone structures, physical and chemical analysis of calcified dental and bone tissues, sex-chromatin and DNA examinations. The choice of one or more of these will depend primarily on the quantity and state of preservation of human remains available for study. The degree of simplicity, practicality and accuracy, as well as costs, must also be considered. [15]

Adult human skulls are composed of a set of bones that are extremely rich in information concerning sexual dimorphism, which can be assessed both qualitatively and quantitatively. The robustness, size and cranial capacity in men are larger than in women. Methods based on visual morphological examination and anthropometric measurements are practical, easy to apply, inexpensive and reliable, as demonstrated by numerous and prestigious international studies.[6, 16] With the measures proposed, we sought to quantify this difference in order to establish parameters that can reliably determine the sex of an unidentified skull.

The sample analyzed was composed of skulls from the São Gonçalo Cemetery of Cuiabá, capital of Mato Grosso state, in Midwest Brazil. As to ancestry, the country contains one of the largest mixed populations in the world.[17] After more than five centuries of interethnic admixture between Amerindians, Europeans, Africans and Asians, Brazilians should be considered authentic members of an ancestral group, whose genetic traits have been reported by Pena et al.[18]and Santos et al.[19] It is important to remember that there is an enormous variability among peoples, making it essential to use sex determination methods grounded in the parameters of each population. [20, 21,22]

The present study focused on palatal bones and skull base measurements of 50 males and 50 females in order to verify the existence of sexual dimorphism. The Ba-IF linear distance was the most statistically significant measurement (p=0.004), corroborating the findings obtained by Francesquini Júnior et al. [23]

With respect to incisive foramen to left and right palatine foramen measurements, the results observed here agree with those obtained by Moreira et al.[10] who found sex differentiation for both the left and right greater palatine foramen. This was not observed by Teixeira,[7] who obtained a statistical difference only for the distance between the incisive foramen and the right greater palatine foramen.

In contrast to the findings of the present study, Saliba[24] found sex differentiation when measuring the distance from the right greater palatine foramen to the left greater palatine foramen. Methathrathip et al.[11]and Teixeira[7] also found statistically significant intersex differences in the

distance between the palatine foramen and the interpalatine suture, which represents half the distance proposed here.

Finally, it is important to draw attention to the fact that sex determination and human identification are fundamental individual rights and that, according to Brazilian law, dentists are ethically and legally qualified to perform such a task.[25]

CONCLUSION

Sex is a helpful tool in the human identification process and its determination is a complex task. The measurements analyzed in this study exhibited sexual dimorphism, excepting for the distance between the right and left greater palatine foramens. The most statistically significant was the distance from the basion to the incisive foramen.

Two logistic regression models for sex determination were developed, with a reliability rate of 63% and 65% respectively.

The method proved to be valid, simple, reproducible and inexpensive, but not foolproof. For this reason, it should only be used exclusively when more accurate techniques cannot be applied, in accordance with the anthropological premise of using the largest possible number of identification methods.

It should also be noted that any human identification method must be tested and validated on local samples due to the increasing level of human variation and interethnic admixture.

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