Original Article

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Sex determination in Uruguayans by odontometric analysis

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Abstract

Sex assessment plays an important role in the forensic and bioarchaeological spheres. Teeth are invaluable elements in non-living populations for sex determination, since they commonly resist post-mortem damages and are latent sources of information about dimorphism. **Aim:** The present study consisted in an odontometric analysis willing to examine sexual dimorphism in Uruguayans. **Methods**: One hundred and twelve inferior dental stone casts, 56 from males and 56 from females, aged between 21 and 60 years, from one orthodontic clinic of Montevideo, capital of Uruguay, were analyzed. Several measurements and calculations were made, such as mesiodistal diameter and gingivoincisal length of mandibular canines, intercanine distance, mandibular canine index and the area of a virtual triangle. **Results:** Only mesiodistal diameter and gingivoincisal length of right canine, and the area of the triangle showed statistically significant differences between both sexes. The authors obtained a logistic regression model for sex determination with a reliability rate of 72.3% and a classification and regression tree with an accuracy of 77.7%. **Conclusions:** The results revealed that this method can be applied in forensic anthropology, as an auxiliary tool in human identification.

Keywords: forensic anthropology, odontometry, sex dimorphism.

Introduction

Positive identification of human remains requires the participation of a qualified and multidisciplinary forensic staff. In fact, it will be the consequence of the coordinated action of the largest possible number of disciplines related with this scientific activity[1].

Sex appraisal is the foremost stage in reconstructing the biological profile of unidentified bodies, as it allows to limit the pool of searching individuals to just one half of the population[2-3].

Additionally, the teeth are routinely used in postmortem comparative and reconstructive investigations by virtue of their extreme hardness and resistance to physical, chemical and bacterial decomposition[2-6] and the existence of some anatomical features that express sexual dimorphism[4,7-8]. This is why they may be used for sex determination with the aid of odontometric analysis. This kind of quantitative evaluation takes into consideration mostly the mesiodistal (MD), buccolingual (BL), mesiobuccal-distolingual (MB-DL) and distobuccal-mesiolingual

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(DB-ML) diameters, the gingivoincisal (GI) height and the intercanine (IC) distance, either individually or as part of indexes[9-11].

In view of these facts, the aim of this study was to estimate the level of sexual dimorphism in Uruguayans and to procure an accurate method in diagnosing sex from the dentition.

Material and methods

Sampling

The sample consisted of mandibular dental arches from 112 patients, 56 males and 56 females, aged between 21 and 60 years, assisted at the orthodontic clinic of IUCEDDU (Spanish acronym for Uruguayan University Institute for the Study and Diagnosis of Malocclusions), situated in Montevideo, capital of Uruguay. Exclusively subjects with an undamaged permanent dentition, without pathologies, proximal restorations, antecedents of extractions or orthodontic treatment, and canines fully erupted with minimal attrition, were selected.

Methods

After informed written consent had been obtained, impressions of the teeth were taken via dental plastic trays (O-Tray®; Dentaurum, GmbH & Co., Ispringen, Germany) and alginate material (Orthoprint® - Zhermack SpA, Via Bovazecchino, 100 45021 Badia Polesine, RO, Italy) and immediately poured in type 3 stone (Elite®ortho - Zhermack SpA, Via Bovazecchino, 100 45021 Badia Polesine, RO, Italy) to minimize dimensional alterations.

It should be mentioned that the research project was elaborated according to the recommendations of the Ethics Committee in Research of the School of Dentistry of Piracicaba, University of Campinas, São Paulo, Brazil, and approved at 24th August 2009 (register number 022/2009).

Definition of the measurements

Mesiodistal and gingivoincisal dimensions of canines. The mesiodistal diameter (MD) is defined as the greatest distance between the approximate surfaces of the crown, whereas the gingivoincisal length (GI) as the maximum distance among the middle of gingival margin and the cusp of the tooth crown. They were measured in both lower canines (33 and 43) with the divider of the Orthodontic Diagnostic Instrument designed by Prof. Dr. Korkhaus[12], positioned perpendicularly to the long axis of the tooth or coinciding with it, respectively (Figure 1).

Intercanine distance. The intercanine distance (IC) is the dimension between the cusp tips of right and left canines (on this opportunity, 33 and 43). It was measured using a digital calliper calibrated to 0.01 mm (150mm - Digimess®, São Paulo, SP, Brazil), as revealed in Figure 1.

Measures A, C, B and H. Measure A is the distance among the most prominent point in the union of the buccal and distal faces of the lower first left molar (36) and the interincisor point (IP), contact point between the lower central incisors (31 and 41). Measure C is the distance from the interincisor point (IP) to the most prominent point in the union of the buccal and distal faces of the lower first right molar (46). Measure B is the distance among the most prominent points in the union of the buccal and distal faces of the lower first molars (36 and 46). Measure H is perpendicular to B passing through the interincisor point (IP). The first three measures (A, C and B) bounded a virtual triangle and were taken by means of a digital caliper with calibration 0.01 mm (150 mm - Digimess®, São Paulo, SP, Brazil). The last (H), that correspond to its height or altitude, was measured with the divider and the transparent plastic millimeter scale of the Orthodontic Diagnostic Instrument designed by Prof. Dr. Korkhaus[12] , as shown in Figures 2, and 3. In order to reduce the operator-dependent bias, all measurements were performed by a single researcher, on three occasions, after a seven days interval, on a set of 25 randomly selected casts.

In turn, the mandibular canine index (MCI), conceptualized by Rao et al.[9] (1989) as the ratio between the maximum crown width (mesiodistal diameter) of lower canines and canine arch width (intercanine distance), and the area of the aforesaid polygon were calculated.

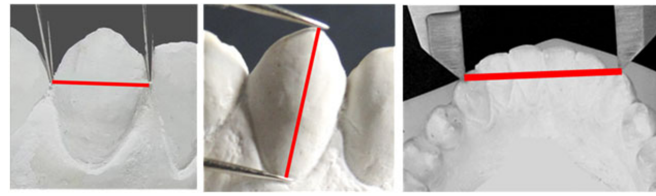

Fig. 1. Measurement of mesiodistal and gingivoincisal dimensions of canines and intercanine distance

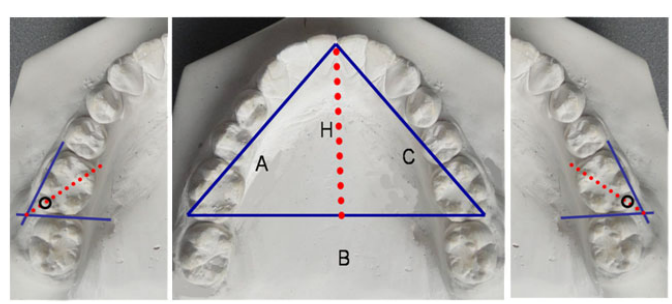

Fig. 2. Determination of the most prominent points in the union of the buccal and distal faces of the lower first molars, coinciding with the bisector of the angles formed by the tangents to those surfaces (circles, dotted lines and filled lines respectively). Virtual triangle bounded by segments A, C and B (filled lines) and segment H, its height (dotted line).

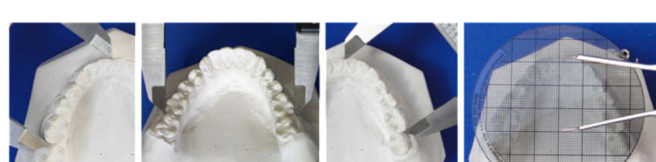

Fig. 3. Measurement of segments A, C, B and H.

Table 1. Intra-observer reliability in conformity with intra-class coefficient

	MD33	GI33	MD43	GI43	IC	A	B	C	H	Area
Agreement	0.832	0.809	0.780	0.792	0.930	0.966	0.926	0.987	0.745	0.895

Table 2. Variables with high correlation with sex.

	MD33	GI33	MD43	GI43	IC	A	B	C	H	Area
MD33	1	0.38	0.7	0.37	0.3	0.44	0.27	0.46	0.28	0.38
GI33	0.38	1	0.3	0.8	0.07	0.21	0.24	0.2	0.02	0.16
MD43	0.7	0.3	1	0.43	0.35	0.5	0.37	0.45	0.27	0.44
GI43	0.37	0.8	0.46	1	0.13	0.26	0.22	0.18	0.09	0.2
IC	0.3	0.07	0.35	0.13	1	0.45	0.35	0.49	0.27	0.42
A	0.44	0.21	0.5	0.26	0.45	1	0.13	0.77	0.57	0.75
B	0.27	0.24	0.37	0.22	0.35	0.53	1	0.6	0.08	0.65
C	0.46	0.2	0.45	0.18	0.49	0.77	0.6	1	0.54	0.78
H	0.28	0.02	0.27	0.09	0.27	0.57	0.08	0.54	1	0.85
Area	0.38	0.16	0.44	0.2	0.42	0.75	0.65	0.78	0.81	1

Table 3. Coefficients of the logistic model.

	Coefficient	*p* - value*
Constant	13.990867	0.0001
Area	-0.006259	0.0168
MD43	-0.841414	0.0605
GI43	-0.343839	0.0624

* Statistically significant at *p*-value <0.10 level.

Statistical analysis

All data were inserted in an Excel file and analyzed using R statistical software[13]. The intra-observer reliability was checked by the intra-class correlation coefficient (ICC), which demonstrated that there was no statistically significant difference among the three series of measurements (Table 1).

For this survey, two statistical models (logistic regression and Classification and Regression Tree - CART) were chosen and customized by the prior determination of their variables. These were evaluated firstly, according to their degree of correlation with sex (Table 2). Therefore, the mesiodistal and gingivoincisal dimensions of tooth 43, the intercanine distance and the area of the triangle were selected, whilst the remaining variables were discarded for attaining values greater than 0.65 (65%). The intercanine distance was disregarded making use of box plot graphic and Wilcoxon test.

Hence, the logistic regression model was ultimately built with a constant (x_0 = 1) and three explanatory variables (x_1 = Area, x_2 = MD43 and x_3 = GI43), whose parameters or coefficients (β_0, β_1, β_2 and β_3) are displayed in Table 3.

In view of substitution of the respective symbols for the estimated values, a definite mathematical expression (formula below) was obtained.

$$logit(p) = L = Ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k$$

$$logit\ (p) = \beta_0 + \beta_1 \text{ x Area} + \beta_2 \text{ x MD43} + \beta_3 \text{ x GI43}$$

logit(p) = 13.9908 + (-0.0062 x Area) + (-0.8414 x MD43) + (-0.3438 x GI43)

In this equation, results major than zero are indicative of feminine sex and minor than zero are indicative of masculine sex. In addition, the classification and regression tree (Figure 4) employed identical variables as the abovementioned model.

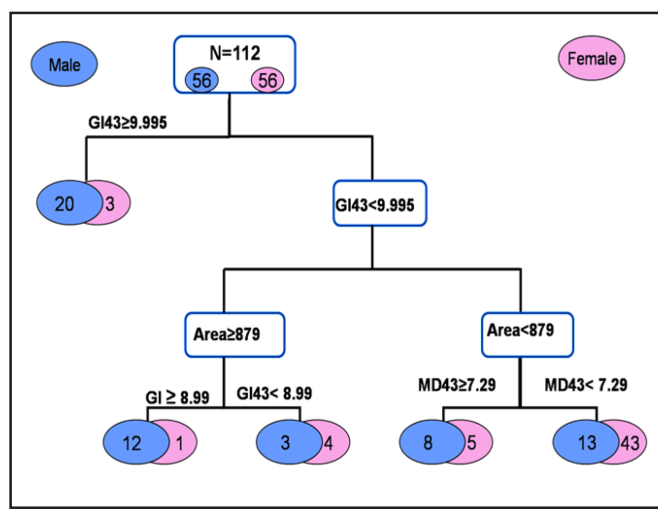

Fig. 4. Classification and regression tree.

Results

The sample evaluation through logistic regression model (Table 4) permitted to arrive at the following conclusions:

- 41 males and 40 females were correctly classified (success rate of 72.3%);
- 57 subjects were sorted as males and 55 as females, with an accuracy of 72% (41 of 57) and 73% (40 of 55) respectively;
- the reliability with regard to sex was 73.2% for males and 71.4% for females; and
- the total classification error was 27.7%, 28% for males and 27% for females when considered by sex.

When the sample was submitted to the classification

Table 4. Cataloging of sample members by means of the logistic regression model

		Observed	
		M	F
Predicted	M	41	16
	F	15	40

Table 5. Categorization of examined persons according to classification and regression tree

		Observed	
		M	F
Predicted	M	40	9
	F	16	47

Table 6. Classification of group memberships using mandibular canine index

		Observed	
		M	F
Predicted	M	30	40
	F	26	16

and regression tree (Table 5) the subsequent outcomes were obtained:

- 40 males and 47 females were correctly classified (success rate of 77.7%);
- the model has predicted that 49 individuals were males and 63 females, with an accuracy of 81.6% (40 of 49) and 74.6% (47 of 63) respectively;
- the reliability in relation to sex was 71.4% for males and 84% for females; and
- the total classification error was 22.3%, 18.4% for males and 25.4% for females when considered by sex.

Finally, the mandibular canine index (quotient between mesiodistal diameter of tooth 43 and intercanine distance) was applied in an attempt to validate it to the universe of this research (Table 6), with the following results:

- 30 males and 16 females were correctly classified (success rate of 41%);
- 70 subjects were sorted as males and 42 as females, with an accuracy of 43% (30 of 70) and 38% (16 of 42) respectively;
- the reliability in respect to sex was 54% for males and 29% for females; and
- the total classification error was 59%, 57% for males and 71% for females when considered by sex.

Then, it was established a standard value of the mandibular canine index (0.267); numerical quantities above this value belonged to masculine sex and below this value to feminine sex.

Discussion

Human identification requirement has its genesis in the social nature of man and his irreducible aspirations to differentiate himself from his peers. Certainly, in front of evolutionary changes that happened in collective organizations, it is no wonder that there is a noticeable need for individualizing creatures, establishing their identity, to respond to civil, administrative, commercial and criminal demands of modern life[5,14].

A positive identification depends largely on an appropriate reconstruction of the biological profile, taking into account its four main components: ancestry, age, stature and sex[8,10]. Correct sex determination is a crucial step for forensic purposes[15], particularly in presence of a huge amount of fragmented corpses or skeletal remains, where it would exclude about 50% the population in search operations[2-3].

Teeth constitute a splendid material for anthropological, genetic, dental and forensic examinations because of their easy accessibility[16], almost unbreakable structure[2,4-5,7] and their anatomical and volumetric discrepancies amongst sexes[4,7-8]. Indeed, dental sex dimorphism has been referred by many authors in studies of diverse populations around the world[7,9-11,17-23]. Nevertheless, Krogman and Iscan[24] (1986) underlined that although tooth size was slightly greater in males than in females, it represented an awfully changeable characteristic. Someway, they agreed with Gustafson[25] (1966) who alleged the inconvenience in determining sex merely by teeth. Thereby, any technique derived from tooth dimensions should always be contemplated as an appendage rather than the primary option[21].

In the course of time, several international researches have coincided in emphasizing the usefulness of odontometric analysis to estimate human sexual dimorphism. The dimensions most frequently used were the mesiodistal, buccolingual, mesiobuccal-distolingual and distobuccal-mesiolingual diameters, the gingivoincisal height and the intercanine distance, which can be weighed separately or as part of indexes[7,9-11]. However, very few odontometric standards exist for Uruguayans for use in forensic sex prediction.

In parallel, numerous researchers have pointed out the mandibular canines as the most dimorphic teeth of the permanent dentition, especially at their mesiodistal diameter[7,18,23]. Others have accomplished linear measurements of dental arches on stone casts of the volunteers[2,3,8-10,16,19-23,26].

The sample in question was formally comprised of stone casts from one orthodontic clinic of Montevideo, capital of Uruguay. As to the ancestry, this small South American country has historically been distinguished to host one of the most European populations in the new continent, but novel scientific inquiries have confirmed the incontestable genetic influence of Amerindians and Africans in moulding the Uruguayan identity[27]. In this scenario, we must keep in mind that, in consequence of the enormous variability among peoples, it is mandatory to use methods for sex determination based on parameters of each population[19], whose accuracy rate will depend on the mathematical symbols and procedures engaged[28].

The present work consisted in measuring lower canines and segments delimited by unlike dental groups of 56 males and 56 females, for the sake of confirm the existence of sexual dimorphism. Thus, the area of the triangle was the most statistically significant variable (p – value = 0.0168), having just found correspondence with data provided by Picapedra[26] (2010) for a set of 118 upper stone casts belonging to subjects, 59 males and 59 females, with similar origin, age and traits. Conversely, the mandibular canine index, ascribed by Rao et al.[9] (1989) and Reddy, Saxena and Bansal[22] (2008) as a quick, uncomplicated, economical, utilitarian and dependable system, presented no significant sexual dimorphism, coinciding with the outcomes observed by Muller et al.[17](2001) and Acharya and Mainali[2] (2009). In the opinion of these scientists, this condition should respectively be due to an incorrect anterior dental alignment or to it being a relative value (ratio of two absolute measurements: mesiodistal diameter of canines and intercanine distance), does not reflect sex differences that exist in the values *per se*.

In another vein, a good statistical analysis requires the application of flexible methodologies to render the results more easily comprehensible. In this objective, it should detail the selection process of variables and indicate the performance prediction of mathematical models. On this instance, two multivariate appliances of uncontroversial utility in health sciences, one of logistic regression and one more of classification and regression tree, were expressly created to assort cluster memberships. The first introduces itself as an influential statistical approach for forecasting a binary dependent variable such as sex, albeit still insufficiently explored in forensic dentistry[29]. In essence, it represents a widespread alternative that has proven to be very adaptable in its hypotheses and able of manipulating both discrete and continuous variables, which demand not be normally distributed, linearly related, or of equal variance within each ensemble[30]. Moreover, the second is a predictive and exploratory instrument that facilitates the explanation of a numerical response variable (regression) or categorized (classification), by means of a bunch of covariables and their possible interactions. In other words, it appears as an unsophisticated and versatile scheme, with no restrictions regarding the type and distribution of the considered variables, either dichotomous or not.

At last, it is vital to observe that sex allocation and human identification are held as fundamental individual rights and also that, pursuant to the legal framework of many nations, dental surgeons are ethically and legally enabled to perform identification expertises in their field of competence[28].

In conclusion, sex is a practical appurtenance in human identification process and its diagnosis is not an easy chore. The measurements and variables examined in this study disclosed sexual dimorphism, excluding the intercanine distance and the mandibular canine index. The most statistically significant of them was the area of the virtual triangle bounded by segments A, C and B. Two mathematical models for sex determination were formulated, one of logistic regression and another of classification and regression tree, with an accuracy rate of 72.3% and 77.7%, respectively. The procedure was found to be feasible, standardized, valid, simple, reproducible and inexpensive. Notwithstanding, it would be convenient not to use it as the sole indicator of sex, conforming to the anthropological principle of using the largest possible number of identification means. Likewise, it should be remarked that any identification method must be tested and validated on local samples in light of the growing degree of human variation and interethnic admixture.

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