Introduction

Sex estimation is the cornerstone for establishing a biological profile of a human skeleton during physical and forensic anthropological analyses. When estimating sex, the accuracy depends on the different osteological elements analysed (Krishan et al. 2016; Meindl & Russell 1998; Spradley & Jantz 2011), although the pelvis is the anatomical region that is most widely considered to be the best indicator due to its high level of sexual dimorphism (Bružeket al. 2017; Murail et al. 2005). However, problems arise when the skeleton is incomplete, or when the pelvis has been damaged. In such cases, the cranium has historically been considered the second-best indicator of sex (Cox et al. 2008; Luo et al. 2013; Muckle 2014). Some textbooks highlight the cranium as the most useful anatomical region for estimating sex when the pelvis is not available, including Cox et al. (2008), Muckle (2014) and Langley & Tersigni-Tarrant (2017); however, these do not provide supporting references. Several studies that were based in cranial morphological traits have achieved correct sex classification rates of 83% to 90% (Konigsberg & Hens 1998; Ramamoorthy, Pai, Prabhu, Muralimanju & Rai 2016; Walker 2008) and 85.7% to 94.1% (Amores-Ampuero & Alemán 2016; Saini et al. 2011; Small et al. 2018; Steyn & Işcan 1998) using metric data. At present, some debate still persists, and there is evidence that postcranial bones have more discriminatory power than the cranium.

Bello & Andrews (2006) analysed the frequencies of the availabilities of the different skeletal elements of immature and adult human remains in burial sites from medieval and post-medieval collections, to determine the specific anatomical patterns of their preservation. They evaluated these according to two indices: the Anatomical Preservation Index, as a preservation score that defines the quantity of osseous material present, expressed as the ratio between the proportions of the bones preserved for each single bone element and the total number of bones of the skeleton; and the Bone Representation Index, as the frequency of the presence of each bone element in a sample. Their data showed that the cranium was generally well represented and the clavicle was reasonably abundant, while the scapula was generally poorly preserved, and the sternum was often fragmented and poorly preserved. Further, the patella was under-represented, although it was almost complete when it was present, and the small bones of the hands and feet were generally not present, but also tended to be well preserved and almost complete when they were present. Finally, the presence of the long bones appeared to be related to either their size (the bigger the long bone, the better preserved) or their position (proximal limb elements better preserved than distal elements). Thus, humeri were more often preserved than radii and ulnae, and femora were better preserved than tibiae and fibulae. The relative abundance of the teeth was not evaluated as these were not available at the time of the observations.

Several studies have provided evidence that estimation of sex using long-bone measurements can provide success rates ≥90% (Charisi et al. 2011; Patterson & Tallman 2019; Spradley & Jantz 2011), and have thus concluded that long bones are to be preferred to the cranium for estimating sex when the pelvis is not available. However, in medicolegal death investigations and for archaeological sites, skeletal remains are often recovered in a poor state of preservation due to the effects of environmental conditions and the activities of carnivores and/or other scavengers. Thus, sex can be more difficult to determine given that the long bones can be incomplete, fragmentary and/or too fragile to be manipulated and analysed.

Teeth are known for being the hardest and most durable and resistant biological remains, as these can survive a variety of destructive effects caused by chemical, physical, mechanical and thermal variations (Fereira et al. 2008; Schmidt 2008; Viciano et al. 2012;

Viciano et al. 2015a). Sex estimation from dental characteristics is primarily based on comparisons of dental dimensions (odontometrics) between males and females, and numerous studies have identified sex differences in such metric characteristics of the permanent dentition (Adams & Pilloud 2019; De Angelis et al. 2015; Peckmann et al. 2015; Tardivo et al. 2015; Zorba et al. 2012; Viciano et al. 2011; Viciano et al. 2013; Viciano et al. 2015b). However, odontometrics is only used as a supplementary tool for sex estimation in the forensic and archaeological contexts when sex estimation is not possible by standard methods. The percentages of correct sex classification using odontometrics ranges from 61.3% to 100% (Angadi et al. 2013; Khamis et al. 2014; Mitsea et al. 2014; Peckman et al. 2015; Peckman et al. 2016; Viciano et al. 2013; Zorba et al. 2012; Zorba et al. 2014), depending on the tooth and measurements used. Nevertheless, to raise the level of accuracy of sex classification, it is maybe best to combine several different methods when a skeleton is fragmentary and/or in a poor condition (Patterson & Tallman 2019). Lavelle (1974) established a relationship between tooth and skull size, suggesting the possibility that the combination of cranial and dental measurements might increase the percentages of correct sex classification. Following this premise, Thapar et al. (2012) evaluated the extent of sexual dimorphism of tooth and cranial size in a living Indian population and their potential in sex estimation using logistic regression analysis. Their study demonstrates that cranial anthropometry along with odontometrics give a better accuracy in estimating the sex of an individual rather than using them individually. Nevertheless, their study presents two limitations: (i) they only analysed three cranial parameters (maximum head length, maximum head breadth, and cephalic index), and (ii) they consider the dentition as a unit instead of measuring individual teeth. Thus, through logistic regression analysis, they took into consideration the combination of cranial measurements with all maxillary teeth, all mandibular teeth and all teeth for sex estimation.

Considering previous research, the aim of this study was to analyse the level of sexual dimorphism in cranial and dental measurements to evaluate whether the combination of them provides greater sex discriminatory power compared to only the cranial or dental methods. For this purpose, compared to the study of Thapar et al. (2012), a greater number of cranial measurements were analysed and, to maximize the technique's applicability in archaeological and forensic cases where the dentitions are incomplete or in poor condition, the functions were calculated for each tooth separately. Finally, the results were compared to previously published studies to see if the combination of cranial and dental measurements suggest greater sex discriminatory power compared to the postcranial bones.

Materials and methods

This study was based on the Granada osteological collection of identified adult individuals from the Granada Municipal Cemetery of San José, Spain (Alemán et al. 1997). These individuals are housed in the Laboratory of Anthropology of the University of Granada, Spain. Reliable antemortem information was obtained from the burial and death certificates in the Registry Office, which yielded detailed data on the sex, birth and death dates, and immediate and underlying causes of death, among other information.

The study sample consisted of 70 individuals (41 males, 29 females). Their ages at death ranged from 24 to 94 years (mean age, 65±14 years). Their deaths occurred during the five decades from 1961 to 2001 (74.4% before 1975; thus, the sample was largely dated from the second third of the 20th century).

Due to the advanced age of many of the individuals and the resulting alterations in the mandibular region (e.g., antemortem tooth loss, and consequent alveolar remodelling), and to the frequent presence of pathological conditions, the measurements of this anatomical region were not considered in the present study. Likewise, because of the exclusion of the mandible from analysis, the mandibular teeth were also excluded. Only the maxillary teeth were included in this analysis. The limiting factors of the dental specimens for exclusion from the analysis were: notable wear; pathological processes, such as antemortem tooth loss, caries, calculus deposits and hypoplastic defects; dental anomalies, such as number, volume, shape and position of the teeth; trauma and fractures; and taphonomic/ diagenetic effects.

Data collection for the crania

Thirty direct measurements were taken on each cranium, according to the standard measurement techniques recommended by Martin & Knussmann (1988). The full list for the neurocranial and splanchnocranial measurements and their abbreviated forms are given in Table 1. All the variables were measured to the nearest 0.1 mm using a non-digital vernier sliding caliper, a spreading caliper and a non-stretchable measuring tape. Measurements from the left side were used, substituting the right side only when measurements from the left side were missing.

Data collection for the teeth

Forty-four measurements were taken for the maxillary incisors (four measurements), canines (four measurements), premolars (four measurements) and molars (eight measurements) according to the definitions provided by Hillson et al. (2005), with the mesiodistal cervical diameters measured following the criteria outlined by Vodanović et al. (2007). The full list for the maxillary crowns and the measurements at the level of the cementoenamel junction and their abbreviated forms are also given in Table 1. A digital dental caliper (Masel Orthodontics Inc, USA) with a precision of 0.01 mm was used to collect crown and cervical measurements. Measurements were performed on either the left or right side depending on their availability. If both contralateral teeth were available, to avoid the use of more sophisticated techniques for the analysis of asymmetry, the average was calculated to adjust the values.

Statistical analysis

The statistical analyses were carried out using the statistical package for social sciences IBM SPSS Statistics 22.0 software for Windows (Chicago, IL, USA). First, the cranial and dental measurements were assessed for normality in their distributions using the Kolmogorov–Smirnov one-sample tests, and for homoscedasticity using Levene’s tests. Next, the general descriptive statistics were determined for all of the measurements of the cranium and maxillary teeth, to provide means and standard deviations separately for both male and female individuals. Next, Student’s *t*-tests were performed to define significant differences between the sexes when large sample size ($N \geq 30$), normality and homoscedasticity were fulfilled ($p > 0.05$) and otherwise (when assumptions of *t*-Student’s parametric test are violated) with non-parametric Mann–Whitney *U*-tests. Finally, binary logistic regression analysis was performed to identify the most useful sex discriminant functions. The equations were determined for pairs of measurements (i.e., one cranial measurement, one dental measurement) to maximize the applicability of the technique for forensic and archaeological cases in which the cranium and dentition are incomplete and/or poorly preserved. Binary logistic regression analyses were used instead of the more commonly employed linear discriminant function analysis for metric sex estimation methods, as the former is more robust and was best suited for our dataset (Albanese 2003; Pohar et al. 2004). The –2 log likelihood was calculated to determine the fits of the logistic regression models to the datasets (lower –2 log statistic = better fit). To test the consistency of prediction accuracy, the data were subjected to leave-one-out cross-validation.

Binary logistic regression analysis produces coefficients for each measurement included in a model as well as a constant. In order to use this information to predict the sex of an individual, a logit must first be calculated using the following formula:

$$L_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \qquad (1),$$

where the logit (L_i) is a linear function of the independent variable(s) X_n, β_0 is the value for the constant, β_1 is the first coefficient, X_1 is the first measurement, and so on. The logit value can also be used to calculate the probability of female sex (P_f) using the function:

$$P_f = \frac{1}{1+e^{-Li}} \qquad (2).$$

The probability of male sex is simply $P_m = 1 - P_f$. In the present study, a P_f-value <0.5 indicates male sex and P_f-value >0.5 indicates female sex. As an illustrative example, if $P_f = 0.913$, the individual was classified as female sex, with a sex allocation accuracy of 91.3% probability for the combination of cranial and dental measurements ($P_m = 1 - 0.913 = 0.087$; 8.7% probability of being male sex). Conversely, if $P_f = 0.067$, the individual was classified as male sex ($P_m = 1 - 0.067 = 0.933$), with a sex allocation accuracy of 93.3% probability for the combination of cranial and dental measurements (6.7% probability of being female sex).

Finally, sex bias was calculated by subtracting the percent of females correctly classified from the percent of males correctly classified. Positive sex bias indicate that more males are correctly classified whereas negative sex bias indicate that more females are correctly classified.

Results

Descriptive statistics and univariate sexual dimorphism

The Kolmogorov–Smirnov tests showed that 13 of the 30 measurements of the cranium and 36 of the 44 measurements of the dentition were normally distributed within sex ($p > 0.05$). The results of homoscedasticity indicated that the sample was homogeneous in 25 of the 30 measurements of the cranium and 26 of the 44 measurements of the dentition ($p > 0.05$). Regarding the dentition, in nine cases it was not possible to perform the homoscedasticity test (Tables 2 and 3).

Tables 2 and 3 give the means and statistics for all of the cranial and dental dimensions, along with the significance analyses using Student's *t*-tests and Mann–Whitney *U*-tests, and the significance values (*p*-values) for the differences between male and female measurements.

These data show that the male crania have higher means than the female crania for all of the measurements except OSA, LIA, LIC, OB, OH, NB and MAL. Comparisons of standard deviations suggest that the male crania show more variability than the female crania for all of the measurements except LDB, MB, LFB, ABH, TA, FSA, PSA, LIA, LIC, BPL, BizB, OH, BioB and NH. Student's *t*-tests and Mann–Whitney *U*-tests revealed statistically significant differences ($p \leq 0.05$) between the sexes in 11 of the 19 neurocranial measurements, and in six of the 11 splanchnocranial measurements (Table 2).

For the dentition, these data show that the male teeth have higher means than the female teeth for all of the measurements except MDcrnM^2, MDcrnM^1 and MDcrnPM^1. The comparisons of the standard deviations also suggest that the male teeth show more variability than the female teeth for all of the measurements except MDcrnM^2, MDcrnPM^2, BLcrnM^2, BLcrnM^1, BLCrnPM^2, MBDLcrnM^2, MBDLcrnM^1, MLDBcrnM^1, MDcervPM^2, MDcervPM^1, MDcervI^1, BLcervPM^1 and MBDLcervM^2. Due to the small sample sizes (N < 30) for the dental measurements, only the Mann–Whitney *U*-tests were performed. These data showed statistically significant differences ($p \leq 0.05$) between the sexes in five of the 22 crown measurements, and in 10 of the 22 cervical measurements (Table 3). Taking the maxillary dentition as a whole, the most sexually dimorphic tooth is the canine, represented by mesiodistal and buccolingual diameters of the crown and cervix, followed by the first and second molars.

Logistic regression analysis

Tables 4 and 5 give the logit equations and their sex allocation accuracies for both original data and the leave-one-out classification, where equations with a discriminant power <75% have been excluded (as these have little utility for reliable sex estimation). Furthermore, only the logit equations in which a minimum of 25 cases were used for their construction are shown.

Table 5 shows the allocation accuracies for correct sex estimation obtained from these equations. It can be seen that the sex allocation accuracies here ranged from 63.6% to 100% for the females, and from 71.4% to 93.8% for the males. Out of 38 logit equations, males show higher correct classifications than females in the original sample for 22 equations (sex bias ranging from –8.0% to 12.4%), and in 18 equations for the cross-validated sample (sex bias ranging from –10.0% to 12.4%). Therefore, overall, the males were classified more accurately than the females for these logit equations. For the pooled sexes, the overall sex allocation accuracies ranged from 76.0% to 92.3% in the original sample and from 72.0% to 88.5% in the cross-validated sample.

Analysis for the 38 logit equations obtained show that the combination of the neurocranial and canine measurements were the best predictor of sex in this sample. For the cranium, all of the 38 logit equations were defined by the measurements of the neurocranium. For the maxillary dentition, of the 38 logit equations, 31 were defined by one measurement of the canines (i.e., all except L_9, L_{19}, L_{24}, L_{27}, L_{30}, L_{33}, L_{36}), six were defined by one measurement of the first molars (i.e., for equations L_9, L_{19}, L_{24}, L_{30}, L_{33}, L_{36}), and one was defined by one measurement of the second molars (i.e., equation L_{27}).

Discussion

Intra- and inter-observer error analyses were performed by the same authors for the same osteological collection and the same cranial and dental measurements as used in the present study, and these were published previously (Amores-Ampuero & Alemán 2016; Viciano et al. 2013). The intraclass correlation coefficient (ICC) was used by Amores-Ampuero & Alemán (2016) to determine the levels of agreement between repeated measurements collected by the same observer and by the different observers. The ICC results demonstrated that the cranial measurements were highly reproducible and with an elevated precision and accuracy within and between the observers. Viciano et al. (2013)

followed a different approach using the Lin's concordance correlation coefficient (CCC) to assess the intra- and inter-observer errors. The CCC results showed that the different dental measurements collected by the same observer were highly reproducible. In the inter-observer error analysis, the CCC results showed lower concordance values. The differences between different observers were attributed to the second observer, who had no prior training in odontometrics and had difficulties in measuring certain tooth diameters (e.g. the crown diameters of molars, which showed a variation in form and often presented difficulties in the application of some of the measurement definitions).

The analyses in the present study show that measurements of the neurocranium and the maxillary canines show high levels of sexual dimorphism, and sex estimation methods based on the combination of measurements from these anatomical elements can yield high levels of sex allocation accuracy. The logit equations developed yielded percentages of correct assignment of sex ranging from 76.0% to 92.3%. However, the results of correct sex allocation accuracy may be overestimated due to the small samples sizes used for the construction of these equations. There is no consensus on the number of variables needed for logistic regressions; however, it has been proposed that a minimum of 10 observations be used to develop binary logistic regression equations (Peduzzi et al. 1995; Peduzzi et al. 1996). Below 10 observations, the results should be interpreted cautiously as the statistical model may not be valid. Other authors, including Vittinghoff and McCulloch (2007), relax the rule and propose a minimum of five observations. Nevertheless, our results are reassuring because each logit equation is developed with only two predictor variables, and only logit equations with a minimum of 25 cases were constructed. In addition, the logit equations showed better efficacy in predicting sex in males as compared in females. This may be due to the composition of the sample for the construction of these logit equations because the study sample was comprised of more males than females.

Concerning sexual dimorphism of the neurocranium, the findings here are in agreement with other studies. For example, the basion–bregma height has been considered useful for sex estimation in numerous studies (e.g., Franklin et al. 2005; Giles & Elliot 1963; Song et al. 1992; Steyn & Işcan 1998; Zabando et al. 2009), while Steyn & Işcan (1998), Song et al. (1992), Zabando et al. (2009) and Fernández (2007) highlighted the maximum cranial length as a measurement with high sexual dimorphism. In the same way, the data in the present study have revealed that the canine is the tooth with the greatest level of sexual dimorphism, followed by the first and second molars, as also highlighted by Angadi et al. (2013), Pettenati-Soubayroux et al. (2002), Pereira et al. (2010), Hassett (2011) and Zorba et al. (2011).

Table 6 shows the overall sex allocation accuracies of the combinations of cranial and maxillary dental measurements that were obtained in the present study as compared to other studies of cranial and postcranial sex estimation methods that have analysed the same osteological collection of identified adult individuals from the Granada Municipal Cemetery of San José, Spain. Amores-Ampuero & Alemán (2016) studied only the cranial measurements, and they reported correct sex allocation accuracies from 58.9% to 80.9% using discriminant function analysis, and from 60.5% to 94.1% using logistic regression analysis. On the other hand, Viciano et al. (2013) analysed only the dental measurements and obtained correct sex allocation accuracies from 79.4% to 92.6%. In the present study, the combinations of the cranial and dental measurements provided higher correct sex allocation accuracies than for the cranial method of Amores-Ampuero & Alemán (2016). However, the dental method of Viciano et al. (2013) provided similar correct sex allocation accuracies as the present combination of cranial and dental measurements.

It is necessary to highlight that in the present study postcranial elements were not included, so we can only compare the percentages of correct sex allocation of our study with those previously published by other researchers on the same osteological collection analysed (i.e. Alemán 1997; Amores-Ampuero & Alemán 2016; García-Parra et al. 2014; Mastrangelo et al. 2011; Peckman et al. 2016; Viciano et al. 2013). However, the actual individuals analysed in the present study are included in these cited studies. In this way, the cranial method provided lower correct sex allocation accuracies than for both the different anatomical elements of the postcranial skeleton and the combination of the cranial and dental measurements, which had similar correct sex allocation accuracies. There have not been any studies based on the cranial morphological traits for this same osteological collection of identified adult individuals, and therefore no comparisons can be made here.

Despite the limitations of excluding the postcranial elements, the findings of the present study suggest that metric analyses of the cranium alone fail to improve classification accuracies over postcranial elements when the pelvis is missing or damaged. Furthermore, the findings of this study demonstrate that statistical models that include both the dentition and cranium produce classification accuracies that are on par with those of the postcranial skeleton.

In forensic practice, the skeletal remains of immature and adult individuals are often limited in their completeness when recovered. From a medico-legal point of view, the absence of key skeletal elements for the reconstruction of the biological profile of the recovered skeletonised individual can hinder and even prevent identification (Kanchan & Krishan 2011). For this reason, several methods based on different anatomical areas have been developed over the last few decades to facilitate the deduction of biological profiles in cases where few dental and skeletal elements are recovered, and/or where these are not well preserved and/or are fragmented (e.g., Adams & Pilloud 2019; D'Anastasio et al. 2014; González-Reimers et al. 2000; Irurita et al. 2014a; Irurita et al. 2014b; Klales & Burns 2017; Kubicka & Piontek 2016; Lee 2009; López-Lázaro et al. 2018; Navega et al. 2012; Patterson & Tallman 2019; Spradley & Jantz 2011; Tallman & Blanton 2020; Viciano et al., 2013; Viciano et al. 2018).

The underrepresentation of specific skeletal remains in medico-legal contexts can be attributed to human behavior or natural/ taphonomic processes, although they can also reflect the characteristic preservation patterns of a skeleton due to the inherent structural properties of the bone. Where bone mineral density is low, the absence of specific anatomical elements might be expected when environmental conditions are particularly destructive (e.g., Pilloud et al. 2016; Ross & Cunningham 2011). Conversely, the absence of more densely constructed bones might suggest a form of selection process (e.g., opportunistic scavenging of the remains when they are left exposed in an outdoor context —e.g., Moraitis & Spiliopoulou 2010; Spradley et al. 2012—, or mass disasters with mutilated bodies —e.g., Barbería et al. 2015; Seleye-Fubara et al. 2012). Furthermore, this might reflect deliberate human modification of the remains (e.g., decapitation or dismemberment of a corpse in a homicide case, to hinder its identification —Konopka et al. 2016; Zerbo et al. 2018).

Therefore, improved sex allocation accuracies can be achieved by the use of the combination of cranial and dental measurements for sex estimation of skeletal remains in comparison to the cranium only. This is further supported by the following: (i) the cranium is a skeletal region that is generally well preserved due to its relative high mineral density; (ii) the teeth are the hardest and most durable and resistant structures of a skeleton against the various agents of destruction; and (iii) when a cranium is present, it will generally also have some teeth remaining (although single-rooted teeth can be easily lost postmortem). As a result, this combination of cranial and dental measurements can increase the correct sex classification in comparison with only the use of the cranium. On the other hand, the present study suggests that this combination of cranial and dental measurements provides similar correct sex allocation accuracy to that of postcranial elements when compared to other studies. However, the present study only included the maxillary dentition in the analysis. Therefore not including the mandible and mandibular teeth, no the postcranial skeleton. Thus, this similar correct sex allocation accuracy achieved by this combination of cranial and dental measurements might be skewed, and so further analysis is necessary to include also the mandible and mandibular teeth. Coquerelle et al. (2011) investigated whether the mandible was sexually dimorphic during early postnatal development and whether early dimorphic features persist during subsequent ontogeny. They found that sexual dimorphism already exists by birth, concentrated at the ramus and the mental region, with these differences decreasing between the ages 4 and 14. From puberty to adulthood, males were characterized by a continuation of allometric shape changes whereas the shape of the female mandible continued to change even after size had ceased to increase. Thus, some researchers have shown that mandible is sexually dimorphic, demonstrating its usefulness for sex estimation in some populations (Bertsatos et al. 2019; Patterson & Tallman 2019; Villanueva et al. 2017). Furthermore, mandibular teeth also show sexual dimorphism, specially the canine. As Eimerl and De Vore (1965) postulated, the sexual dimorphism of canines is based on functional (non-masticatory) activity. They postulated that canines in primates were related to the threat of aggression which later shifted to the upper limbs in the evolutionary process. Until this evolutionary change, canines played an important role for survival in males. Alvesalo (2009) suggests that sexual dimorphism in tooth size is explained by differential effects of the X and Y chromosomes on dental growth. The Y chromosome promotes both tooth crown enamel and dentine growth, whereas the effect of the X chromosome on crown growth seems to be restricted to enamel formation. Thus, males have larger tooth crowns than females in contemporary human populations, which can be attributed to dentine thickness. Thus, because the mandible and mandibular teeth are anatomical elements that show great sexual dimorphism, further research is necessary to include in the analysis these elements to have a global view on whether the combination of cranial and dental measurements provides greater sex discriminatory power compared to only the cranial or dental methods, and subsequently, also with the postcranial skeleton.

Conclusions

The present study suggests that the combined method of cranial and maxillary dental measurements was more accurate than the cranial method alone, although it provided similar correct sex allocation accuracy to the dental method. Furthermore, this study suggests that only the combination of the cranial and the maxillary dental measurements can provide similar correct sex allocation accuracies to those of the postcranial skeleton.

However, findings presented here should be taken with caution, since the present study presents some limitations, such as: (i) small sample size, so that the data likely do not capture the range of variation within this population (particularly evident with the dental measurements); (ii) mandible and mandibular teeth were not included in the analysis, so all the anatomical elements of the skull were not analysed; (iii) postcranial bones were not directly measured and analysed, so the percentages of correct sex allocation of the present study were compared with those of previously published studies, and (iv) specific origin of the sample, as skeletal attributes vary among different populations.

The results of the present study show that the combination of cranial and maxillary dental measurements gave very good correct sex allocation accuracy (up to 92.3%). This finding could be particularly important when skeletal remains are in a poor state of preservation and only crania are recovered, and the use of only these two parameters (cranial anthropometry and odontometrics) may provide sex discriminatory power. Nevertheless, despite of the aforementioned limitations, more research is needed in different populations to evaluate whether the combination of cranial and dental measurements provides greater sex discriminatory power compared to postcranial skeleton.

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Table 1. Definitions of the cranial and maxillary dental measurements and abbreviations used in this study following Hillson et al. (2005), Martin & Knussmann (1988) and Vodanović et al. (2007).

Region	**Abbreviation**	**Definition**
Neurocranium	MCL	Maximum cranial length
	LSB	Length of the skull base
	MB	Maximum breadth
	LFB	Least frontal breadth
	MFB	Maximum frontal breadth
	BB	Biasterionic breadth
	BBH	Basion–bregma height
	ABH	Auriculo–bregmatic height
	HC	Horizontal circumference
	TA	Transverse arc
	TSA	Total sagittal arc
	FSA	Frontal sagittal arc
	PSA	Parietal sagittal arc
	OSA	Occipital sagittal arc
	LIA	Lambda-inion arc
	FSC	Frontal sagittal cord
	PSC	Parietal sagittal cord
	OSC	Occipital sagittal cord
	LIC	Lambda-inion cord
Splanchnocranium	BPL	Basion–prosthion length
	BioB	Biorbital breadth
	BizB	Bizygomatic breadth
	UFH	Upper facial height
	IB	Interorbital breadth
	OB	Orbital breadth
	OH	Orbital height
	NB	Nasal breadth
	NH	Nasal height
	MAL	Maxillo–alveolar length
	MAB	Maxillo–alveolar breadth
Maxillary dental crown	MDcrn	Maximum mesiodistal crown diameter
	BLcrn	Maximum buccolingual crown diameter
	MBDLcrn	Mesiobuccal–distolingual crown diameter
	MLDBcrn	Mesiolingual–distobuccal crown diameter
Maxillary cement–enamel junction	MDcerv	Mesiodistal cervical diameter
	BLcerv	Buccolingual cervical diameter
	MBDLcerv	Mesiobuccal–distolingual cervical diameter
	MLDBcerv	Mesiolingual–distobuccal cervical diameter
Maxillary teeth notation	I^1/ I^2	First/ second incisors
	C	Canine
	PM^1/ PM^2	First/ second premolars
	M^1/ M^2/ M^3	First/ second/ third molars

Table 2. Descriptive statistics for the cranial measurements, and Student's *t*-test and Mann–Whitney *U*-test for the mean differences between the sexes.

	Measurements according to sex (in mm)											
	Male			Female			Statistic					
Skull measurement	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	***KS***	***L***	***t***	***U***	***p***	**Sig.**
Neurocranium												
MCL	41	181.842	6.251	27	175.741	4.044	N	N	—	227.00	0.000	*
LDB	38	99.842	3.956	28	96.821	4.456	N	Y	—	306.00	0.003	*
MB	39	132.154	5.234	29	131.138	5.604	N	Y	—	496.50	0.391	
LFB	40	92.375	4.168	29	92.345	4.312	N	Y	—	535.50	0.587	
MFB	40	115.675	5.859	28	114.000	5.491	N	Y	—	459.00	0.207	
BB	40	107.850	7.131	28	105.786	6.602	N	Y	—	432.00	0.110	
BBH	38	133.053	5.337	27	126.444	4.051	Y	N	—	159.50	0.000	*
ABH	36	65.294	4.600	27	59.462	4.679	N	Y	—	758.00	0.000	*
HC	40	509.175	20.521	29	501.172	15.598	N	Y	—	387.00	0.019	*
TA	37	305.730	12.233	28	298.393	18.578	N	Y	—	417.50	0.183	
TSA	38	370.158	15.374	28	364.519	14.514	N	Y	—	407.00	0.105	
FSA	38	128.553	6.429	27	123.963	6.931	N	Y	—	338.00	0.020	*
PSA	39	127.487	9.265	27	121.407	9.532	N	Y	—	324.00	0.008	*
OSA	37	114.054	11.465	27	115.926	7.364	N	Y	—	473.50	0.723	
LIA	39	58.795	6.736	27	62.074	8.827	Y	Y	–1.711	—	0.092	
FSC	38	110.724	5.135	27	107.672	4.126	Y	N	—	1272.00	0.000	*
PSC	39	114.092	6.848	27	108.913	6.764	Y	Y	4.327	—	0.000	*
OSC	38	96.144	5.496	27	94.132	4.951	Y	Y	2.159	—	0.033	*
LIC	39	57.487	6.591	27	60.190	7.063	Y	Y	–2.268	—	0.025	*
Splanchnocranium												
BPL	26	92.692	4.848	20	90.300	5.192	N	Y	—	190.50	0.122	
BizB	37	125.432	3.693	28	119.643	4.218	N	Y	—	150.00	0.000	*
UFH	26	69.474	5.036	20	66.361	4.568	Y	Y	3.094	—	0.003	*
OB	38	35.745	1.999	28	35.997	1.510	N	N	—	1906.00	0.307	
OH	38	34.610	1.923	28	35.103	2.045	Y	Y	–1.429	—	0.156	
IB	38	23.963	2.349	28	22.755	2.146	Y	Y	3.051	—	0.003	*
BioB	38	93.764	3.134	28	91.655	3.617	Y	Y	3.606	—	0.000	*
NB	38	21.831	1.806	28	21.928	1.628	Y	Y	–0.320	—	0.750	
NH	38	51.061	2.800	28	49.003	3.122	Y	Y	4.006	—	0.000	*
MAL	25	49.170	3.554	19	49.272	2.612	Y	Y	–0.151	—	0.881	
MAB	11	60.121	4.178	6	54.430	2.630	N	N	—	32.00	0.000	*

N, number of individuals; SD, standard deviation; *KS*, Kolmogorov-Smirnov test (Y=yes, normality; N=no, no normality); *L*, Levene test (Y=yes, homoscedasticity; N=no, no homoscedasticity); *t*, Student's *t*-test; *U*, Mann–Whitney *U*-test; *p*, *p*-value; Sig., significance: * $p \leq 0.05$

Table 3. Descriptive statistics for the maxillary teeth measurements, and Student's *t*-test and Mann–Whitney *U*-test for mean differences between the sexes.

	Measurements according to sex (in mm)											
Tooth	**Male**			**Female**			**Statistic**					
measurement	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	***KS***	***L***	***t***	***U***	***p***	***Sig.***
Maxillary dental crown												
MDcrnM^3	7	8.969	0.631	1	8.890	—	Y	—	—	3.00	0.827	
MDcrnM^2	10	9.567	0.355	13	9.612	0.479	Y	Y	—	53.00	0.457	
MDcrnM^1	9	10.347	0.778	4	10.370	0.245	Y	Y	—	17.50	0.938	
MDcrnPM^2	10	7.043	0.271	8	6.815	0.364	Y	Y	—	25.00	0.183	
MDcrnPM^1	12	7.218	0.470	5	7.270	0.189	Y	Y	—	29.50	0.958	
MDcrnC	14	7.982	0.376	11	7.574	0.331	N	Y	—	21.00	0.002	*
MDcrnI^2	7	7.244	0.343	3	6.560	0.227	Y	Y	—	2.00	0.053	
MDcrnI^1	8	8.548	0.261	—	—	—	Y	—	—	—	—	
BLcrnM^3	10	11.225	1.142	1	9.740	—	Y	—	—	1.00	0.206	
BLcrnM^2	15	11.883	0.562	11	11.512	0.661	Y	Y	—	56.00	0.169	
BLcrnM^1	14	11.839	0.591	11	11.026	0.671	Y	Y	—	28.00	0.007	*
BLcrnPM^2	16	9.299	0.546	8	8.694	0.603	Y	Y	—	26.50	0.022	*
BLcrnPM^1	14	8.996	0.677	5	8.870	0.328	Y	Y	—	28.00	0.517	
BLcrnC	17	8.465	0.429	12	7.787	0.274	Y	Y	—	22.00	0.000	*
BLcrnI^2	12	6.721	0.478	5	6.490	0.142	Y	N	—	19.00	0.246	
BLcrnI^1	11	7.586	0.325	6	7.000	0.461	Y	Y	—	9.50	0.018	*
MBDLcrnM^3	11	11.609	0.922	1	10.320	—	N	—	—	1.00	0.192	
MBDLcrnM^2	16	12.165	0.591	11	11.843	0.740	Y	Y	—	66.00	0.278	
MBDLcrnM^1	13	12.552	0.529	9	12.300	0.631	Y	Y	—	45.50	0.385	
MLDBcrnM^3	10	9.951	0.889	1	9.190	—	Y	—	—	1.00	0.206	
MLDBcrnM^2	14	10.992	0.920	12	10.982	0.732	Y	Y	—	80.00	0.837	
MLDBcrnM^1	11	11.373	0.755	11	10.754	0.868	Y	Y	—	33.00	0.071	
Maxillary dental cervix												
MDcervM^3	5	7.102	0.209	—	—	—	Y	—	—	—	—	
MDcervM^2	10	7.944	0.407	8	7.483	0.141	N	N	—	19.00	0.062	
MDcervM^1	3	8.090	0.678	3	7.657	0.136	Y	Y	—	3.00	0.513	
MDcervPM^2	12	4.826	0.343	6	4.392	0.115	N	N	—	13.50	0.035	*
MDcervPM^1	10	4.760	0.322	6	4.352	0.329	Y	Y	—	10.00	0.030	*
MDcervC	13	6.367	0.363	9	5.384	0.559	Y	Y	—	8.00	0.001	*
MDcervI^2	9	4.677	0.449	4	4.273	0.083	Y	N	—	6.00	0.064	
MDcervI^1	6	6.450	0.210	5	6.292	0.342	Y	Y	—	8.00	0.201	
BLcervM^3	4	9.428	1.158	—	—	—	N	—	—	—	—	
BLcervM^2	9	11.320	0.547	11	10.745	0.452	Y	Y	—	19.00	0.020	*
BLcervM^1	9	11.081	0.590	7	10.333	0.291	Y	N	—	7.00	0.010	*
BLcervPM^2	14	8.585	0.701	6	7.827	0.481	Y	Y	—	17.00	0.039	*
BLcervPM^1	11	8.423	0.491	8	7.796	0.525	Y	Y	—	15.00	0.017	*
BLcervC	16	8.141	0.443	11	7.303	0.393	Y	Y	—	16.00	0.000	*
BLcervI^2	10	6.110	0.417	6	5.603	0.162	Y	N	—	8.50	0.020	*
BLcervI^1	8	6.416	0.236	7	6.044	0.438	N	Y	—	13.00	0.083	
MBDLcervM^3	6	10.930	1.442	—	—	—	Y	—	—	—	—	
MBDLcervM^2	8	11.360	0.533	9	11.097	0.632	Y	Y	—	25.00	0.290	
MBDLcervM^1	9	11.629	0.545	5	10.854	0.163	Y	N	—	1.00	0.004	*
MLDBcervM^3	4	8.758	0.453	—	—	—	N	—	—	—	—	
MLDBcervM^2	11	10.107	0.910	11	9.898	0.516	Y	N	—	50.50	0.511	
MLDBcervM^1	4	9.760	0.548	7	9.441	0.373	N	N	—	6.00	0.131	

N, number of individuals; SD, standard deviation; *KS*, Kolmogorov-Smirnov test (Y=yes, normality; N=no, no normality); *L*, Levene test (Y=yes, homoscedasticity; N=no, no homoscedasticity); *t*, Student's *t*-test; *U*, Mann–Whitney *U*-test; *p*, *p*-value; Sig., significance: * $p \leq 0.05$

Table 4. Logistic regression equations[a].

Cranial measurement	**Maxillary tooth measurement**	**Tooth aspect**	**Logit equation**
Maximum cranial length	Canine	Crown	$L_1 = 119.758 - 0.515(\text{MCL}) - 3.474(\text{MDcrnC})$
		Crown	$L_2 = 86.222 - 0.264(\text{MCL}) - 4.901(\text{BLcrnC})$
		Junction	$L_3 = 112.127 - 0.344(\text{MCL}) - 6.647(\text{BLcervC})$
Maximum breadth	Canine	Crown	$L_4 = 50.637 - 0.044(\text{MB}) - 5.525(\text{BLcrnC})$
Least frontal breadth	Canine	Crown	$L_5 = 52.516 - 0.174(\text{LFB}) - 4.525(\text{BLcrnC})$
		Junction	$L_6 = 51.594 - 0.144(\text{LFB}) - 4.998(\text{BLcervC})$
Maximum frontal breadth	Canine	Crown	$L_7 = 41.881 - 0.088(\text{MFB}) - 3.954(\text{BLcrnC})$
		Junction	$L_8 = 35.196 - 0.017(\text{MFB}) - 4.357(\text{BLcervC})$
Biasterionic breadth	First molar	Crown	$L_9 = 24.042 + 0.067(\text{BB}) - 2.741(\text{BLcrnM}^1)$
	Canine	Crown	$L_{10} = 32.718 + 0.023(\text{BB}) - 4.371(\text{BLcrnC})$
		Junction	$L_{11} = 32.929 + 0.011(\text{BB}) - 4.468(\text{BLcervC})$
Basion-bregma height	Canine	Crown	$L_{12} = 86.538 - 0.439(\text{BBH}) - 3.788(\text{BLcrnC})$
Horizontal circumference	Canine	Crown	$L_{13} = 78.985 - 0.089(\text{HC}) - 4.211(\text{BLcrnC})$
		Junction	$L_{14} = 76.738 - 0.078(\text{HC}) - 4.853(\text{BLcervC})$
Total sagittal arc	Canine	Crown	$L_{15} = 88.597 - 0.141(\text{TSA}) - 4.667(\text{MDcrnC})$
		Junction	$L_{16} = 58.492 - 0.061(\text{TSA}) - 4.469(\text{BLcrnC})$
Frontal sagittal arc	Canine	Crown	$L_{17} = 60.932 - 0.406(\text{FSA}) - 1.182(\text{MDcrnC})$
		Crown	$L_{18} = 78.038 - 0.278(\text{FSA}) - 5.309(\text{BLcrnC})$
Parietal sagittal arc	First molar	Crown	$L_{19} = 36.314 - 0.091(\text{PSA}) - 2.212(\text{BLcrnM}^1)$
	Canine	Crown	$L_{20} = 41.726 - 0.054(\text{PSA}) - 4.378(\text{BLcrnC})$
		Junction	$L_{21} = 58.293 - 0.133(\text{PSA}) - 5.533(\text{BLcervC})$
Occipital sagittal arc	Canine	Crown	$L_{22} = 33.889 - 0.019(\text{OSA}) - 3.949(\text{BLcrnC})$
		Junction	$L_{23} = 34.961 - 0.020(\text{OSA}) - 4.288(\text{BLcervC})$
Lambda-inion arc	First molar	Crown	$L_{24} = 22.891 - 0.092(\text{LIA}) - 2.514(\text{BLcrnM}^1)$
	Canine	Crown	$L_{25} = 31.622 + 0.020(\text{LIA}) - 4.106(\text{BLcrnC})$
		Junction	$L_{26} = 31.755 + 0.020(\text{LIA}) - 4.336(\text{BLcervC})$
Frontal sagittal cord	Second molar	Crown	$L_{27} = 181.468 - 1.385(\text{FSC}) - 2.606(\text{BLcrnM}^2)$
	Canine	Crown	$L_{28} = 230.411 - 1.808(\text{FSC}) - 4.032(\text{MDcrnC})$
		Crown	$L_{29} = 80.363 - 0.383(\text{FSC}) - 4.820(\text{BLcrnC})$
Parietal sagittal cord	First molar	Crown	$L_{30} = 35.960 - 0.086(\text{PSC}) - 2.326(\text{BLcrnM}^1)$
	Canine	Crown	$L_{31} = 41.201 - 0.070(\text{PSC}) - 4.173(\text{BLcrnC})$
		Junction	$L_{32} = 50.133 - 0.132(\text{PSC}) - 4.660(\text{BLcervC})$
Occipital sagittal cord	First molar	Crown	$L_{33} = 25.007 + 0.223(\text{OSC}) - 4.076(\text{BLcrnM}^1)$
	Canine	Crown	$L_{34} = 41.120 - 0.119(\text{OSC}) - 3.723(\text{BLcrnC})$
		Junction	$L_{35} = 53.357 - 0.219(\text{OSC}) - 4.292(\text{BLcervC})$
Lambda-inion cord	First molar	Crown	$L_{36} = 24.425 + 0.088(\text{LIC}) - 2.615(\text{BLcrnM}^1)$
	Canine	Crown	$L_{37} = 31.819 + 0.021(\text{LIC}) - 4.131(\text{BLcrnC})$
		Junction	$L_{38} = 36.264 - 0.039(\text{LIC}) - 4.458(\text{BLcervC})$

[a] See Table 5 for assessment of the fit of each logit equations

For abbreviations, see Table 1

Junction, cementoenamel junction

A P_f-value <0.5 indicates male sex and P_f-value >0.5 indicates female sex.

Table 5. Logistic regression equation[a] fits and classification accuracies of the original and cross-validated samples.

			Female correct		Male correct		Total	
Logit equation[b]	**N**	**–2LL**	**n/N**	**(%)**	**n/N**	**(%)**	**(%)**	**Sex bias**
L_1								
Original	25	11.291	9/11	81.8	13/14	92.9	88.0	6.2
Cross-validation			9/11	81.8	12/14	85.7	84.0	2.2
L_2								
Original	28	15.467	10/11	90.9	15/17	88.2	89.3	–1.6
Cross-validation			10/11	90.9	13/17	76.5	82.1	–8.8
L_3								
Original	26	10.452	8/10	80.0	15/16	93.8	88.5	8.5
Cross-validation			8/10	80.0	12/16	75.0	76.9	–3.1
L_4								
Original	26	17.043	10/12	83.3	12/14	85.7	84.6	1.3
Cross-validation			10/12	83.3	12/14	85.7	84.6	1.3
L_5								
Original	27	21.348	11/12	91.7	12/15	80.0	85.2	–6.5
Cross-validation			10/12	83.3	12/15	80.0	81.5	–1.8
L_6								
Original	25	17.722	9/11	81.8	11/14	78.6	80.0	–1.8
Cross-validation			8/11	72.7	11/14	78.6	76.0	3.3
L_7								
Original	27	21.971	10/12	83.3	12/15	80.0	81.5	–1.8
Cross-validation			10/12	83.3	12/15	80.0	81.5	–1.8
L_8								
Original	25	18.766	9/11	81.8	11/14	78.6	80.0	–1.8
Cross-validation			9/11	81.8	11/14	78.6	80.0	–1.8
L_9								
Original	25	24.017	7/11	63.6	12/14	85.7	76.0	12.4
Cross-validation			7/11	63.6	12/14	85.7	76.0	12.4
L_{10}								
Original	28	22.501	10/12	83.3	13/16	81.3	82.1	–1.2
Cross-validation			10/12	83.3	13/16	81.3	82.1	–1.2
L_{11}								
Original	26	18.749	9/11	81.8	12/15	80.0	80.8	–1.0
Cross-validation			9/11	81.8	12/15	80.0	80.8	–1.0
L_{12}								
Original	25	13.252	9/11	81.8	13/14	92.9	88.0	6.2
Cross-validation			9/11	81.8	13/14	92.9	88.0	6.2
L_{13}								
Original	27	17.704	11/12	91.7	13/15	86.7	88.9	–2.8
Cross-validation			11/12	91.7	12/15	80.0	85.2	–6.5
L_{14}								
Original	25	14.707	9/11	81.8	13/14	92.9	88.0	6.2
Cross-validation			9/11	81.8	12/14	85.7	84.0	2.2
L_{15}								
Original	25	15.928	9/11	81.8	13/14	92.9	88.0	6.2
Cross-validation			8/11	72.7	13/14	92.9	84.0	11.3
L_{16}								
Original	26	16.887	8/11	72.7	13/15	86.7	80.8	8.1
Cross-validation			8/11	72.7	13/15	86.7	80.8	8.1
L_{17}								
Original	25	15.451	9/11	81.8	12/14	85.7	84.0	2.2
Cross-validation			8/11	72.7	12/14	85.7	80.0	7.3

L_{18}								
Original	26	11.207	10/11	90.9	14/15	93.3	92.3	1.4
Cross-validation			10/11	90.9	13/15	86.7	88.5	–2.4
L_{19}								
Original	25	21.805	7/11	63.6	12/14	85.7	76.0	12.4
Cross-validation			7/11	63.6	12/14	85.7	76.0	12.4
L_{20}								
Original	28	21.959	8/11	72.7	14/17	82.4	78.6	5.9
Cross-validation			8/11	72.7	14/17	82.4	78.6	5.9
L_{21}								
Original	26	15.161	9/10	90.0	14/16	87.5	88.5	–1.5
Cross-validation			9/10	90.0	14/16	87.5	88.5	–1.5
L_{22}								
Original	27	22.171	9/11	81.8	13/16	81.3	81.5	–0.3
Cross-validation			9/11	81.8	13/16	81.3	81.5	–0.3
L_{23}								
Original	25	18.517	8/10	80.0	12/15	80.0	80.0	0
Cross-validation			8/10	80.0	12/15	80.0	80.0	0
L_{24}								
Original	25	22.342	8/11	72.7	12/14	85.7	80.0	7.3
Cross-validation			8/11	72.7	10/14	71.4	72.0	–0.7
L_{25}								
Original	28	22.667	9/11	81.8	14/17	82.4	82.1	0.3
Cross-validation			9/11	81.8	14/17	82.4	82.1	0.3
L_{26}								
Original	26	18.700	9/10	90.0	13/16	81.3	84.6	–5.4
Cross-validation			9/10	90.0	12/16	75.0	80.8	–9.2
L_{27}								
Original	25	9.187	11/11	100.0	12/14	85.7	92.0	–8.0
Cross-validation			10/11	90.9	12/14	85.7	88.0	–2.9
L_{28}								
Original	25	7.875	10/11	90.9	13/14	92.9	92.0	1.1
Cross-validation			9/11	81.8	13/14	92.9	88.0	6.2
L_{29}								
Original	26	12.533	9/11	81.8	13/15	86.7	84.6	2.8
Cross-validation			9/11	81.8	13/15	86.7	84.6	2.8
L_{30}								
Original	25	23.070	7/11	63.6	12/14	85.7	76.0	12.4
Cross-validation			7/11	63.6	12/14	85.7	76.0	12.4
L_{31}								
Original	28	22.091	8/11	72.7	14/17	82.4	78.6	5.9
Cross-validation			8/11	72.7	14/17	82.4	78.6	5.9
L_{32}								
Original	26	16.318	9/10	90.0	14/16	87.5	88.5	–1.5
Cross-validation			9/10	90.0	14/16	87.5	88.5	–1.5
L_{33}								
Original	25	20.589	9/11	81.8	10/14	71.4	76.0	–5.8
Cross-validation			9/11	81.8	10/14	71.4	76.0	–5.8
L_{34}								
Original	27	21.348	9/11	81.8	13/16	81.3	81.5	–0.3
Cross-validation			9/11	81.8	13/16	81.3	81.5	–0.3
L_{35}								
Original	25	15.948	8/10	80.0	13/15	86.7	84.0	4.0
Cross-validation			9/10	90.0	11/15	73.3	80.0	–10.0
L_{36}								

Original	25	23.132	8/11	72.7	11/14	78.6	76.0	3.3
Cross-validation			8/11	72.7	10/14	71.4	72.0	–0.7
L_{37}								
Original	28	22.684	9/11	81.8	14/17	82.4	82.1	0.3
Cross-validation			9/11	81.8	14/17	82.4	82.1	0.3
L_{38}								
Original	26	18.632	8/10	80.0	13/16	81.3	80.8	0.8
Cross-validation			8/10	80.0	13/16	81.3	80.8	0.8

N, total number of individuals used to develop the logit equations; *–2LL*, –2 log likelihood; n, number of individuals correctly classified compared with the total of individuals used for classification

[a] Only logit equations with a minimum of 25 cases used for their construction are included

[b] See Table 4 for the complete logit equations developed

Table 6. Overall sex allocation accuracies of the combination of cranial and maxillary dental measurements (cranium + maxillary teeth) obtained in the present study compared to other studies of cranial and postcranial sex estimation methods that have analysed the same osteological collection of identified adult individuals from the Granada Municipal Cemetery of San José, Spain.

		Overall sex allocation accuracy (%)			
Skeletal element	**Analysis**	**Original**	**Cross-validation**	**N° equations developed**	**Reference**
Cranium + maxillary teeth	Logistic regression	76.0–92.3	72.0–88.5	38	This study
Cranium	Discriminant function	58.9–80.9	58.9–78.2	7	Amores-Ampuero & Alemán (2016)
	Logistic regression	60.5–94.1		6	
Teeth	Logistic regression	79.4–92.6	80.0–87.5	10	Viciano et al. (2013)
Clavicle	Discriminant function	82.4–94.7		6	Alemán et al. (1997)
Scapula	Discriminant function	81.0–93.7		12	Alemán et al. (1997)
Humerus	Discriminant function	81.4–96.7		10	Alemán et al. (1997)
Ulna	Discriminant function	80.6–91.8		9	Alemán et al. (1997)
Radius	Discriminant function	84.0–93.5		10	Alemán et al. (1997)
Carpals	Discriminant function	80.0–98.9		54	Mastrangelo et al. (2011)
Metacarpals	Discriminant function	80.6–86.6		8	Alemán et al. (1997)
Upper extremity	Discriminant function	97.5–98.0		14	Alemán et al. (1997)
Sternum	Discriminant function	70.7–91.8	70.7–91.8	11	García-Parra et al. (2014)
Femur	Discriminant function	80.9–90.9		10	Alemán et al. (1997)
Tibia	Discriminant function	82.1–90.5		14	Alemán et al. (1997)
Fibula	Discriminant function	80.6–85.5		4	Alemán et al. (1997)
Patella	Discriminant function	75.5–83.8	75.5–81.9	3	Peckman et al. (2016)
Calcaneus and talus	Discriminant function	80.0–88.2		15	Alemán et al. (1997)
Metatarsals	Discriminant function	80.0–86.1		13	Alemán et al. (1997)
Lower extremity	Discriminant function	84.7–91.7		3	Alemán et al. (1997)