Metric Sexual Dimorphism in Permanent Canines

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Abstract

The degree of sexual dimorphism of permanent human canines in cervical buccolingual and mesiodistal diameters was investigated through discriminant analyses. Measurements were recorded in 254 canines from 85 individuals in four populations and sex was estimated with multifactorial morphological methods. Age was similar assessed in order to rule it out as a factor. Tooth and body size were controlled for in three of the populations (56 individuals) by the greatest buccolingual diameter of the right first molar of the corresponding jaw and the coronal diameter of the right femoral head, respectively. Age and tooth and body size were statistically insignificant factor2s ($p > 0.05$). Inter-observer error varied from 0.04 to 0.17 mm or 0.7-3.0% and was largely insignificant. Student's t-tests found jaw was significant ($p<0.05$) but side was not ($p>0.05$) so measurements for both sides were averaged to increase the sample size. Sexual dimorphism was statistically insignificant for all four diameters individually or grouped with the exception of mandibular buccolingual width. Accuracy values ranged from 49-73% which, adjusted for a generous error margin from sexing techniques, became 39-58%. These results indicate that the landmarks, assemblages, or both do not exhibit significant sexual dimorphism. Future work should consider similar populations with different landmarks and/or the same landmarks on a different assemblage, preferably one of known sex.

Keywords: Sexual Dimorphism; Sex Estimation; Odontometrics; Dental Morphology; Dental Anthropology

Introduction

Amelogenesis is a sex-linked process and provides the basis for odontometric sexual dimorphism and so the means to estimate sex using solely the dentition. Approximately 90% of the genetic coding for ameloglobin (the organic component which constitutes 90% of enamel) is located on the X chromosome with the remaining 10% on the Y in males (1). The physiological manifestation of this coding is that males undergo a lengthier period of enamel formation than females, approximately 80 days or 0.56 mm diametrically in permanent canines according to some sources (1, 2). Others assert that male canines are some 3-9% larger than females and so metric sexual dimorphism in canines should be apparent within two standard deviations of variation (where $p < 0.05$) and so statistically identifiable (1). This premise is behind the research undertaken and presented here.

Several non-hominid primates as well as extinct hominid species also exhibit dimensional dental sexual dimorphism especially in the canines (5-7). This dimorphism is most likely a result of evolutionary selection for intra-species or single-sex competition for mates, territory, or other resources (6, 7). The canines exhibit the greatest divergence likely due to their function: they are designed for puncturing and tearing and so are the most efficient in both meat consumption and inflicting damage in competition (2, 7). Prominent canines are often visible protruding from or lying beneath the lips and so may serve as a deterrent to competitors (5).

Although most evident in the canines (2, 8), enamel metric dimorphism is also present in the other teeth, most notably the incisors (9) and premolars (10). Molars also exhibit metric dimorphism but to a lesser degree and recorded measurements (most often greatest buccolingual and mesiodistal lengths) may show more dimorphism in the morphological ratios rather than actual metrics (9-11). Due to an increase in morphological variability and complexity in multi-cusped and multi-rooted dentition increasingly complex methods are required for the posterior teeth which can introduce a higher inter-observer error value.

Inter-population (and also possibly significant inter-observer) variability have shown canine crown metrics to be reliable estimators of sex 77-88% of the time (9-13). Population variation is most apparent when distinct ethnic groups are compared (Europeans and Asians for example) but accuracy can still vary significantly even within somewhat related groups (10). Side and jaw may also influence reliability: Potter (14) asserts that the left side is more accurate than the right, for example, but usually side is considered to be irrelevant (9, 11, 13). Where jaw is concerned, several studies found greater dimorphism in mandibular canines (8, 9, 13, 14) but different populations exhibit the opposite (11, 13).

Previous studies usually considered greatest mesiodistal and/or buccolingual diameters with a few exceptions (9, 13, 14). Some projects found that the latter presented fewer errors in sex estimation (8, 14) but others came to the opposite conclusion (9). In short, it seems there is great variability as to which measurements, jaw, and even side provide the greatest accuracy.

The most noteworthy shortfall in previous experiments is the lack of precise landmarks. In a few cases they are not specified at all although in most (9, 14) the measurement recorded is simply the greatest diameter which provokes concerns regarding repeatability, particularly with reference to non-metric traits, interstitial wear facets, and substantial occlusal wear (15). The two diameters studied here have been included in previous studies and produced favourable results, but as greatest lengths rather than the more precise cervical diameter (9, 13).

In the first dimension, buccolingual diameter, non-metric traits (such as shovelling or a pronounced tuberculum) may interfere with the length recorded compared to a canine without such traits (15). In the second, mesiodistal diameter, there is the added challenge of interstitial facets: with the exception of an individual with an unusual amount of space in the dental arcade due to agenesis, impaction, or ante-mortem tooth loss, interstitial wear will have an effect upon the greatest mesiodistal diameter. The analysis of these two diameters specifically at the cervical region both avoids these limitations and provides specific points in order to assure high repeatability.

Materials and methods

Procedures

Cervical buccolingual and mesiodistal diameters (Figure 1) of 254 canines were recorded using Chronos digital sliding calipers to 0.01 mm precision. The buccolingual diameter was defined as the distance between the cervical-most midpoint of the crown on the buccal and lingual faces; the mesiodistal diameter was defined as the distance between the cervical-most midpoint of the crown on the mesial and distal faces. Each length was measured three times and the average was recorded; variation for a single measurement did not exceed 0.25 mm. Specimens were cleaned as necessary by dry brushing. It was preferable that the canines were loose but when necessary and where feasible they were measured in situ. Where calculus, caries, breakage, or other interference obstructed landmarks the corresponding measurement was abandoned, but where calculus had accumulated above or below the cervical region of the crown this was not a cause for exclusion.

The canines of one population were measured and recorded by the author and two additional observers with osteological experience. The second and third observers were supplied with written and pictoral instructions and calipers. Only the canines were displayed and visible with the exception of several cases where the dentition was in situ and so fragments or complete mandibles and maxillae (and occasionally more complete facial fragments) were observable. Efforts were made to obscure morphological sex indices from the observers.

Sex was estimated by the author from cranial, mandibular, and pelvic morphological indicators according to common standards (16-18). With few exceptions individuals under the age of 14 were not included due to problems with sex estimation accuracy (19, 20). Although published tests of multifactorial approaches to sex estimation performed on known-sex assemblages have reached as high as 90-95% accuracy, poor preservation sometimes resulted in some individuals in this study being sexed from only a few indicators or only one region. In these particular cases the landmarks and methods utilized have reliability rates of approximately 70-90% (17, 21, 22). Because of this range sex determinations were estimated to have a confidence score of 80%. Although this is likely a conservative estimate, this error adjustment is meant to indicate the imprecise basis rather than provide a precise error rating. In order to avoid observer bias individuals were sexed independently from the recording of dental measurements. Sex was divided into male, female, and indeterminate.

Age was not expected to be a factor but was tested in order to rule it out. Age was estimated using multifactorial methods including cranial suture fusion (23), dental attrition schedules (24, 25), and pubic symphysis (26) and auricular surface scores (27). For individuals still undergoing epiphyseal fusion or tooth calcification or eruption at the time of death schedules were employed according to Scheuer and Black (28) or the Workshop of European Anthropologists (29), respectively. Figure 2 displays the age distribution for the total sample; the large percentage of 16-30 year olds is due to this age group being both sexable according to the criteria outlined above and also less likely than older individuals to have obstructed landmarks or antemortem tooth loss.

Body size was also controlled in three populations. The coronal diameter of the right femoral head was measured although the left was substituted if the right was not present or was otherwise unsuitable due to damage or pathological reactions. The femoral head was selected as a standard for body size due to varying preservation among the different populations prohibiting the use of other standards such as femoral length or midshaft diameter. Femoral head control measurements were recorded in 38 of a possible 56 individuals.

Finally, tooth size was controlled in three populations. The greatest buccolingual crown diameter was measured for the right maxillary and mandibular first molars although the left was substituted if the right was not present or was otherwise unsuitable. This measurement was selected as the standard for tooth size proportions because it is unlikely to differ as greatly as others with morphological variation. First molar control measurements were recorded in 47 of 56 individuals.

Samples

Four populations were assessed for viable samples by the author and of these 254 canines from 85 individuals (31 males, 29 females, and 25 individuals of indeterminate sex) were deemed suitable for the study (see Figure 3). The four populations were drawn from collections from Black Gate, Newcastle-upon-Tyne (7th to 12th centuries); Exeter's Cathedral Green (12th to 16th centuries); Barbican, York (12th to 17th centuries); and Skriðuklaustur in eastern Iceland (15th to 18th centuries).

Statistical methods

Statistics were performed by the author with SPSS 15.0. Student's t tests were performed in order to assess the statistical significance of one side or jaw over the other. Each variable was tested against its opposite (e.g., right with left maxillary mesiodistal for side or right maxillary with mandibular mesiodistal for jaw). An insignificant t test resulted in the grouping of those two variables because they exhibit enough similarity that they do not need to be analysed individually (30). Uni- and multivariate discriminant analyses were utilized to group one or several independent variables (in this case maxillary buccolingual diameter or both maxillary buccolingual and mesiodistal diameters) by a dependent variable (sex). The program was run for each variable separately and also for certain combinations: grouped by jaw (maxillary buccolingual and mesiodistal; mandibular buccolingual and mesiodistal); by type (maxillary and mandibular buccolingual; maxillary and mandibular mesiodistal); and with all four variables. In all cases sex was the dependent variable except in tests where the influence of age was investigated.

In order to control for body size and tooth size each canine measurement was calculated as a ratio based on the control measurement (canine diameter ÷ femoral head diameter; canine diameter ÷ mandibular first molar diameter) and then tested by discriminant analysis with sex as the dependent variable. There were a total of 204 ratios in the body size-controlled dataset and 274 in the tooth size-controlled dataset.

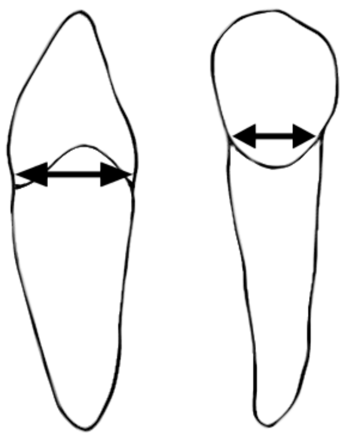

Figure 1 Dental dimensions

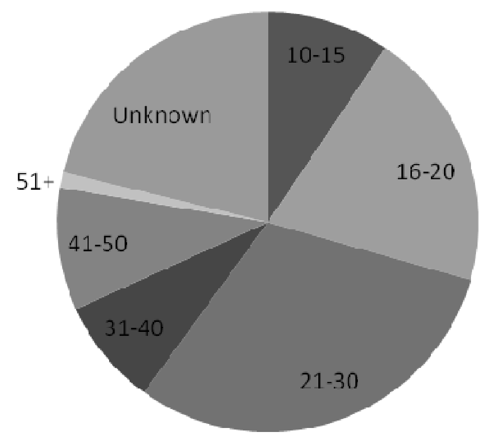

Figure 2 Age distributions for all populations

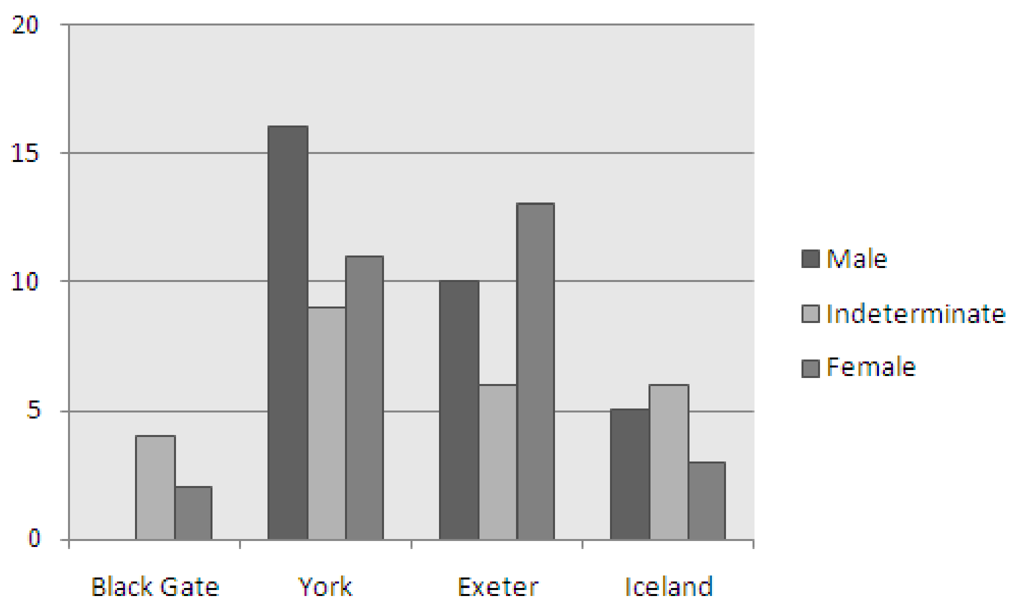

Figure 3 Population distributions by sex

Results

Canine metrics

Side for both jaws side was insignificant, so the data for right and left variables were merged (where only one side was recorded in a particular individual this measurement was the only one for a particular parameter; where both sides were recorded the lengths were averaged). This condensed the sample size from 398 data points to 281 (Figure 4). Jaw was significant however so maxillary and mandibular measurements were analysed independently.

Of the nine single or grouped variables tested, only mandibular buccolingual diameter was statistically significant ($p < 0.05$), but only presented a raw accuracy (before adjustment for sex estimation error) of 64%. The results are presented in Table 1. Although the accuracy rates are poor it is important to note that almost all of those individuals flagged by the statistics program as of misclassified sex (where the odontometric sex assignation was inconsistent with the predetermined skeletal sex assignation) were originally scored as only possible male/female.

Although statistically significant, a visual representation of mandibular buccolingual diameter (Figure 5) does not reflect an obvious divergence between males and females. The other analyses are similarly distributed, indicating not that there is identifiable inter-sex variation but instead a wide range of intra-sex variation, particularly within the female cohort. That the other variables and all combinations thereof are statistically insignificant indicates that the results are unreliable for the purposes of repetition.

Error and controls

The total average inter-observer error margin was 0.09 mm and ranged from 0.04 to 0.17 mm. The averages of the corresponding measurements which produced the least and greatest error were 5.54 mm and 5.65 mm; thus the error ranged from 0.7-3.0% and was insignificant where $p < 0.05$. All analyses controlling for age, body size, and tooth size were statistically insignificant. Age, body size, and tooth size did not significantly affect sexual dimorphic expression in this study.

Discussion

Interpretations of these results fall into two categories: a fault with the project design and/or data considered, or an actual lack of dimensional sexual dimorphism in the cervical crown of the canines. The low sample size and variable accuracy of sexing methods are the major flaws within the project design; indeed, interim discriminant analyses performed on the data by population would not yield results at all due to the low sample size. A much larger population would be much more likely to produce significant results, although the rate of accuracy may still not be very reliable.

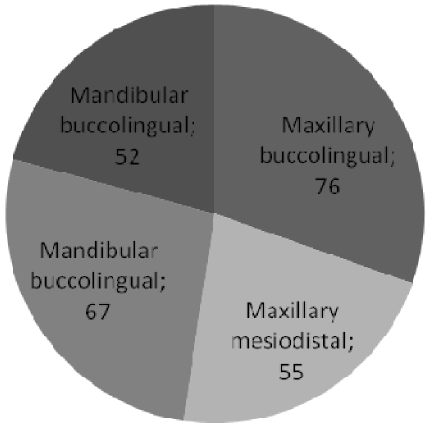

Figure 4 Data points by variable after grouping according to Student's t tests; number of samples

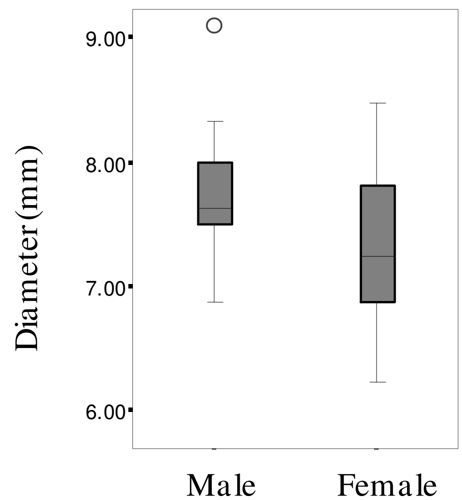

Figure 5 Mandibular buccolingual diameter ranges by sex

Table 1 Accuracy in sex estimation by variable, from discriminant analyses

	Accuracy	
Variables	**Raw**	**Adjusted for sex**
Maxillary buccolingual	64%	51%
Maxillary mesiodistal	49%	39%
Mandibular buccolingual	64%	51%
Mandibular mesiodistal	56%	45%
Maxillary and mandibular buccolingual	64%	51%
Maxillary and mandibular mesiodistal	59%	47%
Maxillary buccolingual and mesiodistal	49%	39%
Mandibular buccolingual and mesiodistal	66%	52%
All variables	73%	58%

In the latter category is primarily the consideration of metric sexual dimorphism: the British populations selected do not usually have very strong indicators of sex compared to some other populations, and due to the time period the individuals are likely to have been of somewhat homogenized British-European stock with similar genetic background. The small Icelandic assemblage, although separate from the British groups, is almost certainly all of Scandinavian background, which is also inherent in British populations. A population known to have more obvious morphological and/or metric sexual dimorphism could produce very different results. In addition, the insignificance of tooth and body size supports this possibility; the premise of odontometric dimorphism is based on males being larger and this size difference being proportional throughout the body (and dentition). That this principle is unsupported indicates the unsuitability of the assemblage tested.

Conclusion

In the assemblages tested, cervical mesiodistal and buccolingual diameters of permanent canines are not reliable indicators of sex. Findings indicate that canine odontometrics need not be side-specific, are not affected by age, and offer low inter-observer error. A repeat of this experiment on a different population, ideally of known sex, would further establish these dimensions as unreliable indicators of sexual dimorphism. Future research regarding odontometric sexual dimorphism should take these results into consideration as indicative of the lack of statistically significant metric sexual dimorphism in the cervical region of human permanent canines in the populations selected. The numerous previous studies have not considered the cervical region and so this study would benefit from being repeated for a comparative sample.

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