Prediction of gender by odontometric data using logistic regression analysis

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Abstract

Introduction: Determination of gender by anthropologists can be done by various methods e.g. skull bones, pelvic bones and other skeletal determinants. Assessment of odontometric data is a promising tool for gender prediction, which is usually preserved due to its robust nature.

Aim and Objectives: The objective of the study was to predict the gender of an individual, using the odontometric data with powerful statistical tools like Logistic Regression Analysis (LRA) and Discriminant Analysis (DA).

Materials & Method: 100 subjects were selected (50 male and 50 female) within the age group of 18-28 years. An alginate impression was made and models were prepared. The odontometric data was collected in the form of various mesiodistal and buccolingual measurements with Vernier calipers which was subjected to statistical analysis, using the two tests LRA and DA. Thereafter, results were compared for accurate gender prediction.

Results: The statistical analysis of the measurements obtained was done by using two tests logistic regression analysis and discriminant analysis. After analysis and comparisons of the two methods for gender prediction, it was observed that LRA provides more accurate prediction than DA in determining the gender. Also, when data from both the arches was analyzed, it was more accurate in predicting the gender as in comparison to the analysis from either of the arch.

Conclusion: The study has revealed that LRA may be better than DA for odontometric sex prediction. Overall, the results depict that the complete dentition, when used as a unit and through the application of flexible multivariate statistics such as LRA, has potential for its use as a prominent and sole indicator of sex prediction.

Keywords: Forensic Odontology; Logistic Regression Analysis; Discriminant Analysis; Gender Prediction; Odontometric Data.

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Introduction

To establish the identity of a person, one of the most essential factor is gender determination. Gender determination is a procedure adopted by anthropologists, archaeologists and forensic scientists[1]. The determination of sex from the femur has been the subject of many studies which have been conducted both on well-preserved bones and poorly preserved skeletal remains. Measurements at the midpoint of the shaft, the femoral head diameter, and the femoral distal breadth are taken, for the determination of sex from the femur and multivariate and univariate analyses are performed.[2,3,4]

During a forensic investigation, dentition is routinely used and the application ranges from postmortem comparative identification to estimation of age among children, juvenile and adults[3]. The teeth form a unique part of human body as they are the most durable and resilient part of the skeleton. The science dealing with establishing the identity of a person by teeth is known as Forensic odontology or Forensic dentistry.[1]

Measurement of dimensions of the permanent dentition are extremely helpful adjunct in assessment of an individual's gender and their value is enhanced as teeth are highly resistant to postmortem destruction.[5] Assessment of gender using orodental dimensions is primarily based upon the comparison of tooth dimensions in males and females or upon the comparison of frequencies of non-metric dental traits, like Carabelli's trait of upper molars, deflecting wrinkle of lower first molars, distal accessory ridge of the upper and lower canines or shovelling of the upper central incisors (Teschler-Nicola and Prossinger, 1998).[6] Therefore, odontometrics provide quite sufficient information on the gender of the individual.[7]

The term "regression" had its origin with the 19th century statistician Francis Galton. He used it to describe his observation that the sons of short fathers tended to be taller and sons of tall fathers shorter, so that the height of sons "regressed" to the mean height of all men. Galton's friend Karl Pearson developed the mathematical basis for what has come to be termed regression analysis, a statistical technique used to describe and quantify the relationship between two or more variables. In linear regression, the term "simple" refers to the fact that only two variables are to be

related. The technique is therefore said to be bivariate. The term "linear" indicates that the relationship can be described by a straight line. The relationship between variables is one of change, that is, as one variable increases or decreases in magnitude, the other also changes in magnitude.[8]Albanese et al.[9,10] used logistic regression analysis (LRA) to assess gender from the hipbone and femur and obtained accuracy rates of up to 98.5%. Steyn and İşcan[11] recently suggested that it would be interesting to see whether results of LRA and DA are at par with respect to their accuracy.[5]

Application of discriminant function analysis (DA) resulted in about 95% accuracy in odontometric sex identification[12,13], further enhancing the dentition's role. However, these results are exceptions, for other studies have found that dental measurements predict the gender with a precision ranging between 77% and 87%.[5]

LRA is considered to be better than the discriminant function models since the former is more flexible in its assumptions and it can handle both discrete and continuous variables, which need not be normally distributed, linearly related or of equal variance within each group. Furthermore, even when DA satisfies the assumptions required of it, logistic regression, comparatively, still performs well. That is, the assumptions which DA must fulfill, need not be met by LRA, in order to optimize its prediction accuracy.[14] Therefore, one would expect a 'natural' improvement in gender assessment using LRA. While LRA has been a useful adjunct in other areas of forensic odontological investigations such as race prediction and age estimation[15], its utility in sex prediction using teeth is unexplored. The present study has, therefore, ventured to evaluate the usefulness of LRA in odontometric sex prediction by comparing the outcome with that of DA.[5]

Materials & Method

The study sample comprised of dentitions from 100 individuals (50 females and 50 males), all young adults between 18 and 28 years of age. All subjects were either enrolled as students or employed as faculty in our institution and originated from this region. Following informed verbal consent, impressions of the teeth were made using alginate material and the casts poured in dental stone (Fig. 1, 2).

Fig. 1: Materials used for impression making

Fig. 2: Final impression of both the arches

Mesiodistal (MD) and buccolingual (BL) dimensions of all teeth, except third molars, were measured on the casts using a Vernier caliper device calibrated to 0.01 mm. The third molars were excluded for an obvious reason of having a wide range of anatomical variations. The MD dimension was defined as the greatest distance between contact points on the approximate surfaces of the tooth crown and was measured with the caliper beaks placed occlusally along the long axis of the tooth.[16] In cases where teeth were rotated or misaligned, measurements were taken between points on the approximate surfaces of the crown where it was considered that contact with adjacent teeth would normally occur. The BL measurement was defined as the greatest distance between the labial/buccal surface and the lingual surface of the tooth crown measured with the caliper held at right angles to the MD dimension.[17]

Following measurement and data entry into an MS Excel spreadsheet, three discriminant and logistic regression analyses (one for teeth of both jaws, one each for the maxillary and mandibular teeth) was performed using a statistical software program named SPSS version 11.5 as suggested by the department of statistical analysis of the institute. The three analyses were undertaken with a view to compare prediction accuracy of teeth in both jaws taken together with teeth

from a single jaw, as may be encountered in forensic contexts.[5]

Results

In both DA and LRA, coefficients and constants were derived and the variables multiplied with the respective coefficient and added to the constant. In DA, it results in a discriminate score, which is compared to the cut-off or sectioning point (the average of group centroids). A score which was less or more than the sectioning point would categorize the case as female or male, respectively. The default cut-off in logistic regression is 0.5, so a case with a probability >0.5 would be categorized as male, while P<0.5 would be considered a female.[18] The closer the value is to 1, the greater the probability that the case is male, while a value closer to 0 indicates a greater probability of the case being female.[5]

The accuracy of sex prediction of DA and LRA are depicted in Table 1. Entering all 56 tooth variables (i.e., 28 MD and 28 BL dimensions) yielded 84% and 89% success rates for DA and LRA, respectively. Accuracy levels from LRA fell when consideration is limited to only the maxillary or only mandibular teeth (Table 1).

Table 1: Cross-validated classification results of the discriminant analysis (DA) and logistic regression analyses (LRA)

	Male		Female		All	
	n	%	n	%	n	%
Discriminant Analysis						
Both Jaws	43 / 50	86.0	41 / 50	82.0	84 / 100	84.0
Maxillary Teeth	40 / 50	80.0	37 / 50	74.0	77 / 100	77.0
Mandibular Teeth	20 / 50	40.0	32 / 50	64.0	52 / 100	52.0
Logistic Regression Analysis						
Both Jaws	47 / 50	94.0	42 / 50	84.0	89 / 100	89.0
Maxillary Teeth	42 / 50	84.0	40 / 50	70.0	82 / 100	82.0
Mandibular Teeth	30 / 50	60.0	43 / 50	86.0	73 / 100	73.0

Table 2 shows the **Goodness of fit statistic**, the −2Log likelihood and **Nagelkerke R Square statistic**. Lower the −2LL statistic, better the fit of the model to the data, whereas, in Nagelkerke R Square statistics, higher the value better is the fit of model to the data. Thus, both the statistical analysis concludes that when data from both the jaws are analyzed using LRA it gives a more accurate prediction of the gender (Graph 1). Table 3 shows the **Test of significance statistic** which also concludes that when odontometric data from both the jaws are taken into account it is more accurate in the sex prediction of the model.

Table 2: Goodness of fit Statistic (LRA)

	-2 Log likelihood	Nagelkerke R Square
Both Jaws	62.862	0.708
Maxillary Teeth	89.228	0.520
Mandibular Teeth	138.172	0.006

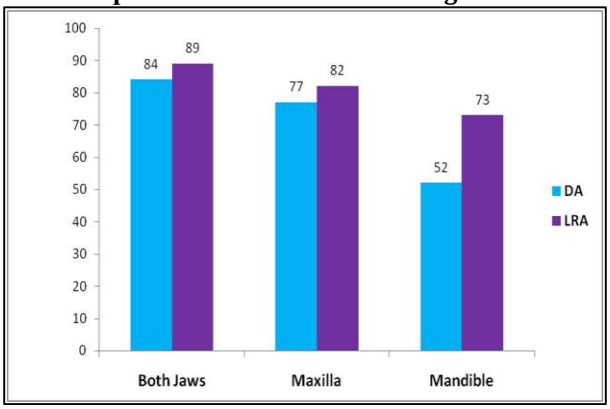
Note: Lower the – 2 Log likelihood, better is the fit of the model to the data and vice-versa.

Table 3: Test of significance (DA)

	Wilk's Lambda	P-value	Significance
Both Jaws	0.515	0.001	Significant
Maxilla	0.633	0.001	Significant
Mandible	0.995	0.802	Not Significant

Note: Lower the Wilk's lambda, better is the prediction from the data and vice-versa

Graph 1: The graph showing the columnar representation of the percentage accuracy of the two tests methods i.e. Cross-validated classification results of the discriminant (DA) and logistic regression analyses (LRA) as well as the comparisons of both and each single arch



Discussion

The accurate gender assessment of skeletal remains has important ramifications in forensic and bioarchaeological investigation. It has been suggested that, for optimal sex prediction, as many criteria as available should be utilized.[19,20] Sex determination, one of the basic features of identification, is a much more demanding task. Unfortunately, it is also much less reliable if performed on poorly preserved material. Therefore, due to this reason, it is best to combine several methods in order to raise the level of confidence and the percentage of success in determining sex.[7]

As a means of determining the gender, odontometric features have been the subject of research for a long time (Iscan and Kedici, 2003; Pettenati-Soubayroux*et al*., 2002).Ditch and Rose (1972)[12] were the first to prove that teeth diameters can be successfully used in determining sex in poorly preserved and fragmentary skeletal remains in archaeology. Crowns of permanent teeth are formed at an early stage and their dimensions remain unchanged during further growth and development, except in cases when specific changes and disorders in terms of functionality, pathology and nutrition can have affect the normal dimensions of a tooth (Teschler-Nicola and Prossinger, 1998).[6] Due to this odontometric features of teeth can be used in determining sex after the tooth has erupted even in children whose osseous features of the sex are not yet defined (Teschler-Nicola and Prossinger, 1998).[6,7]

Albanese believed that LRA is a powerful, albeit underused, statistical approach for predicting a binary dependent variable such as sex. In addition to the advantages of logistic regression stated in the introduction, a major benefit over DA is that the probability of sex allocation is calculated.[5] Logistic regression is the statistical technique used when we wish to estimate the probability of a dichotomous outcome such as the presence or absence of a disease or of death. The probability of the outcome is the dependent variable and the various factors that influence it are the independent variables, sometimes termed risk factors. One may think of the probability of the outcome as a proportion or a percentage. However, the results of logistic regression are presented in terms of the odds, rather than the probability, of the outcome.[8]

A practical issue that is seldom addressed in most odontometric sex assessment studies is that of the influence of age on tooth dimensions.[5] Tooth abrasion, most commonly due to hard food consumption, is one of the dental characteristics of ancient peoples. Although there is an obvious sexual dimorphism in human crown dimensions, the level of dimorphism is lower than that of the non-metric dental traits like Carabelli's trait of upper molars, deflecting wrinkle of lower first molars, distal accessory ridge of the upper and lower canines or shovelling of the upper central incisors. Many non-metric dental traits are highly positive correlated with tooth size because they are both genetically determined (Scott and Turner, 1997). This can be helpful during sex determination of skeletal remains, because some of dental traits can disappear due to tooth abrasion, but the mesiodistal and buccolingual crown dimensions can still be unchanged. On the other hand, at times crown dimensions can be useless for sex determination due to pathological conditions like caries, while presence of some dental treatment can yet be helpful for sex identification.[7]

It would, therefore, be interesting to test the use of LRA in odontometric sex differences in samples that include subjects from diverse age groups. This would give an indication of sex differences in a 'normal' population, in contrast to sex differences depicted in 'ideal' populations such as the one used here and previously.[11,13]

Another factor which can influence the determination of gender is absence or loss of teeth due to any physiological or pathological causes. For such cases, appropriate grouping of teeth present, which are morphologically and dimensionally similar, could be an adjunct in conclusion. For example, a group consisting of maxillary lateral incisor and both mandibular central and lateral incisors could be considered one group which is more or less morphologically and dimensionally similar. Similarly both maxillary and mandibular premolars can be included in a group because of morphological and dimensional resemblance. Thus any loss of tooth from this group can give a rough idea of the dimension of the missing tooth when compared to the average dimensional range of the group.

Conclusion

The advantages in determining sex on the basis of odontometric features are simplicity, speed and low cost, while the greatest disadvantage is the possible inaccuracy in cases where the normal dimensions of teeth is altered.[7] The present study has revealed that LRA may be better than DA for odontometric sex prediction. In fact, a perfect fit of the logistic regression model to the odontometric data was derived using the entire dentition, although there was a tendency for allocation accuracy to reduce when maxillary/ mandibular teeth were assessed separately and when teeth are missing. Overall, the results show that the dentition, when used as a unit and through the application of flexible multivariate statistics such as LRA, has potential for its use as the sole indicator of sex prediction.[5]

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