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Contents

# THE UNRELIABILITY OF SEX ALLOCATION BASED ON HUMAN ODONTOMETRIC DATA

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**Abstract**

In the present investigation we contrast the confidence with which individuals may be sexed and then reallocated on the basis of odontometric data. These data were derived from the maxillary mesiodistal and buccolingual diameters of 202 Lengua Indians (100 males, 102 females), 206 Negroes (106 males, 100 females) and 125 Caucasoids (59 males, 66 females). Multivariate intersex discrimination was actuated by means of stepwise discriminant analysis whilst allocation was evaluated by means of posterior and typicality probabilities. Bias was reduced by means of a jackknifing procedure. High levels of discriminatory confidence (each Wilks's Lambda, $p < 0.01$) were matched by high percentages of correct classification by sex (Amerindian, 87.5 — 93.5; Negro, 76.7 — 83.0; Caucasoid, 81.8 — 91.3). However, these high levels were unmatched by allocatory procedures, with only 30.4% of male Amerindians and 16.1% of females being confidently allocated. Similarly, 34% of male Negroes and 16.7% of female Negroes, and also 30.4% of Caucasoid males and 18.2% of Caucasoid females could be allocated with confidence. These results suggest that although multivariate discriminant techniques may be usefully employed in the separation of males and females, individuals cannot be assigned with the same degree of confidence, even with an *a priori* knowledge of their group membership.

*Key words:* Allocation, discrimination, Sex dimorphism.
*Running title:* Sex allocation.

## Introduction

The importance of multivariate techniques in an evaluation of sex differences in human tooth size has been established in several recent publications[1-5]. These authors have emphasized the significance of a consideration of intercorrelations among characters in the determination of those variables which contribute most to group separation. However, the usefulness of such discriminatory techniques in forensic analyses remains debatable. The forensic odontologist needs to be able to identify the affiliation of one or more specimens on the basis of available odontometric data. Yet the statistical methods available are concerned with discrimination rather than allocation. The essence of forensic identification, therefore, does not lie in traditional multivariate techniques.

Campbell[5] and more recently Kieser and Groeneveld[6], have stressed the importance of using appropriate statistical methods for the two independent, yet often confused, procedures of discrimination and allocation. In the present communication, we introduce the use for appropriate probabalistic techniques to the allocation of individuals in terms of odontometric data.

## Materials and Methods

The data for the present investigation were derived from three sources, the first of which consisted of artificial stone casts of the dental arcades of 100 male and 102 female Lengua Indians. Details of this population have been documented extensively elsewhere[3, 7]. A second sample, consisting of 125 Caucasoid school children (59 male, 66 females) has also been documented elsewhere[4]. The third sample consisted of 206 Negroes (106 male, 100 females) resident in the greater Johannesburg area[8].

Buccolingual and mesiodistal diameters were determined on the right side of the maxillary arcade of each individual, using a sliding caliper with a vernier scale (0.05 mm) on which the measuring tips had been sharpened. No measurements were attempted on malpositioned, carious, restored or fractured teeth, measurements on the antimere being substituted whenever possible. Loss of tooth material due to attrition, be it interproximal or occlusal, may have a confounding effect on dental measurements. Hence we were obliged to use those younger individuals who had experienced little or no dental wear. However, because a high percentage of these individuals had unerupted or partially erupted wisdom teeth, these were excluded from our analyses. The mesiodistal diameter (MD) of a tooth was defined as the distance between two parallel lines perpendicular to the mesiodistal axial plane of the tooth, taken tangential to the most mesial and distal points of the crown, along a line parallel to the occlusal plane. The BL crown diameter was taken as the greatest distance between the buccal and lingual surfaces of the tooth crown, with the arms of the caliper held parallel to the MD plane and tangential to the buccal and lingual surfaces[9]. Measurements were repeated on 25 randomly selected casts and yielded a mean within-rater difference of $0.05 \pm 0.32$ mm, and a reliability coefficient of 0.96, which compares favourably with the results reported by Kolakowski and Bailit[10].

Multivariate discrimination between the three populations was effected by means of canonical variate analysis, with Wilks's Lambda being used as a measure of cohesiveness within each group[11,12]. The relative contribution of each variable to overall separation was evaluated by means of stepwise discriminant analyses. Three methods were used to test the allocatory reliability of individuals. The first of these concerns the relative affinities of the assignee for each of the reference populations. Referred to as the posterior probability of membership[5], this measure is related to the probability density function of the given vector, for each of the populations. Campbell[5] has referred to such probabilities as typicality probabilities and has suggested that these may be seen as the probability of finding data vectors which have density values exceeding those of the given data vector for the individual to be assigned. In the present investigation, we employed two approaches in calculating typicality probabilities: the estimative approach which ignores sampling variation, and the predictive approach which actively considers sampling variation. Relevant statistical manipulations for the calculation of posterior probabilities, estimative and predicative typicalities are given by Kshirsagar[13], Campbell[5] and Kieser and Groeneveld[6].

Because it was felt that the direct determination of percentages of correct classification, posterior and typicality probabilities would result in an over simplification of the classificatory capabilities of the discriminant functions, a jackknife procedure was used. Briefly, the jackknife is a statistical method which was originally introduced by Quenoville[14] and further developed by Tukey[15]. It is used for the reduction of bias in an estimator of some population parameter and also for obtaining an estimate of the standard error of the improved estimate[16, 17]. In the present analysis, the jackknife removed the observation to be classified from the "learning" sample (i.e. the sample used to construct the discriminant function), whereafter the observation was classified according to its posterior probabilities. This procedure was then repeated for all the observations.

In the present investigation, confidence of allocation was examined by attempting to reassign individuals to one of the three populations from which they had originally been drawn. However, allocation schemes often have to be constructed for assignment to a number of groups, for which population parameters are usually not known. Although it is usually assumed that the underlying distributions are multivariately normal, Campbell[5] has stressed the importance of an impirical examination of such assumptions. Here quantile — quantile (Q — Q) plots of individual squared Mahalanobis distances were

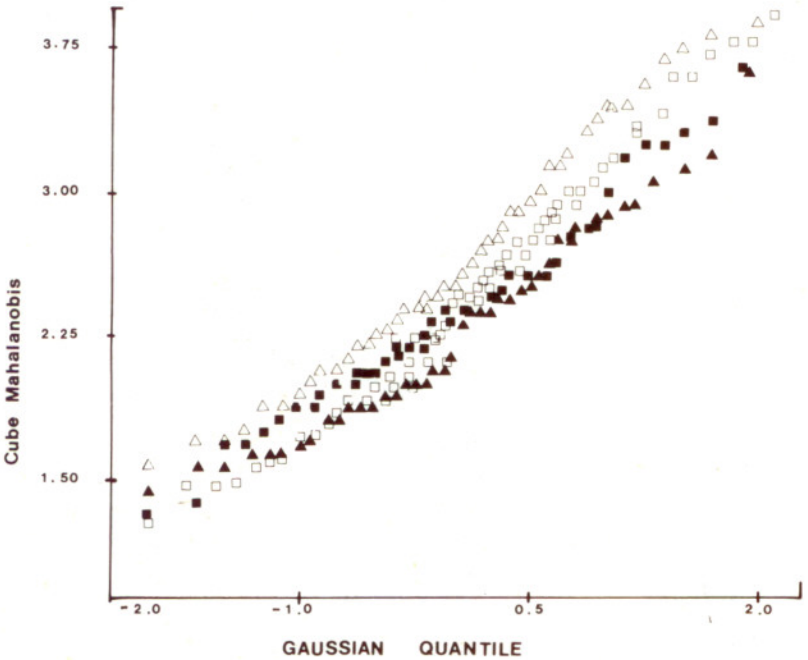


*Fig. 1.* Gaussian Q–Q plot of Mahalanobis distances for Amerindian males (black) and females (clear).

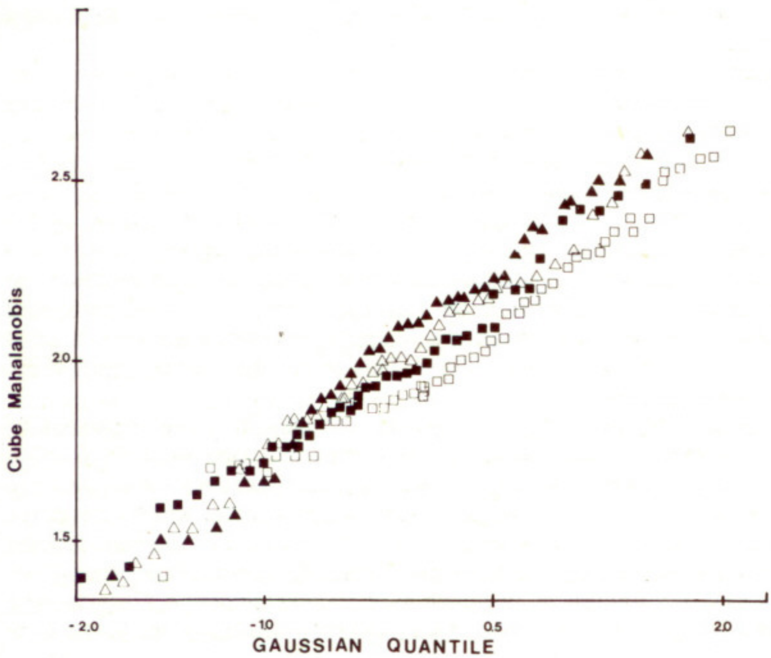


*Fig. 2.* Gaussian Q–Q plot of Mahalanobis distances for Negro males (black) and females (clear).

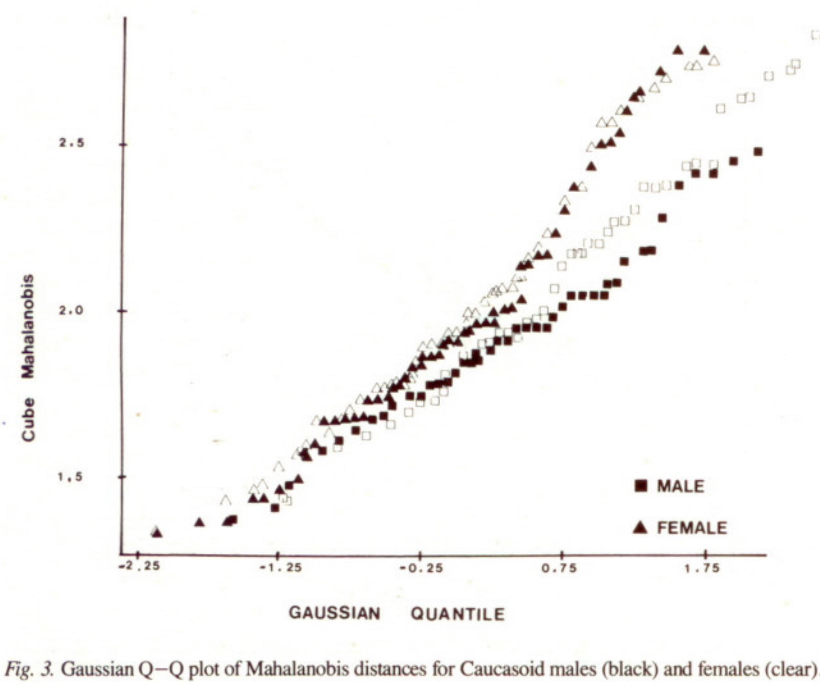


*Fig. 3.* Gaussian Q–Q plot of Mahalanobis distances for Caucasoid males (black) and females (clear).

used, as described by Gnanadesikan [18] and Campbell[5, 19]. Distances were calculated by resubstitution, using covariances and means, with Gaussian quantiles being plotted against cube roots of the squared Mahalanobis distances. Gaussian Q — Q plot for males and females of the three population groups are shown in Figures 1 — 3. Clearly, the assumption of multivariate normality is confirmed by the linearity of all these graphs.

## Results and Discussion

### Discrimination

Table 1 conveys the results of stepwise discriminant analyses for odontometric sex differences in male and female Amerindians, Negroes and Caucasoids. In Amerindians and Caucasoids, maximal multivariate intersex discrimination resided in the MD dimensions of the canines. In Negroes a different pattern was seen to emerge. The most reliable discriminator was P1 (MD), whilst the canine ranked third. Percentages of correct classification for males and females within each of the population groups are listed in Table 2, from which it appears that there is a range of 83,0%-91,3% in males and 76,7%-93,5% for females when raw data were used. Slightly lower percentages were recorded after

**Table 1. Results of stepwise discriminant analyses for maxillary odontometric sex differences in Amerindians, Negroes and Caucasoids.**

| *Population* | *Step* | *Variable Selected* | *F* | *Wilk's Lambda* |
|---|---|---|---|---|
| AMERINDIAN | 1 | C – MD | 50,01 | 0,629* |
| | 2 | M2 – MD | 8,61 | 0,571* |
| | 3 | P2 – MD | 5,52 | 0,535* |
| | 4 | M1 – MD | 4,23 | 0,509* |
| NEGRO | 1 | P1 – MD | 15,38 | 0,829* |
| | 2 | M1 – BL | 4,51 | 0,782* |
| | 3 | C – MD | 6,20 | 0,720* |
| | 4 | P2 – MD | 4,60 | 0,677* |
| CAUCASOID | 1 | C – MD | 43,02 | 0,641* |
| | 2 | M1 – MD | 14,06 | 0,576* |
| | 3 | I2 – MD | 8,51 | 0,485* |
| | 4 | P2 – BL | 1,28 | 0,477* |

* = $p < 0{,}01$.

**Table 2: Percentages of correct sex classification for male and female Amerindians, Negroes and Caucasoids, based on maxillary dimensions.**

| *Population* | *MALES* | | *FEMALES* | |
|---|---|---|---|---|
| | *Raw data* | *Jackknife* | *Raw data* | *Jackknife* |
| AMERINDIAN | 87,5 | 80,4 | 93,5 | 90,3 |
| NEGRO | 83,0 | 70,2 | 76,7 | 66,7 |
| CAUCASOID | 91,3 | 87,0 | 81,8 | 78,8 |

jackknifing, these results representing more realistic, unbiased estimates. In summary, our results indicate that males and females may be reliably separated by multivariate means. Even after reduction of bias, correct discrimination may be anticipated in 66,7%-90,3% of cases.

Arrays of percentages of sex dimorphism in the maxillary dental dimensions of the three population groups are given in Table 3. It is evident that, with the sole exception of the M1 (BL) in Caucasoids, there are measurable univariate differences between males and females. Highest levels of dimorphism were recorded in Caucasoids (mean percentage dimorphism MD = 6,1, BL = 4,8) whilst Lenguas were least dimorphic (mean percentage dimorphism MD = 3,8, BL = 3,3).

**Allocation**

Table 4 conveys the frequency percentages of posterior and typicality probabilities for maxillary teeth in Amerindians, Negroes and Caucasoids. These data are graphically displayed in Figures 4 to 6. Examination reveals that the values of posterior probabilities show a marked increase around midpoint 0,9. Posterior probabilities measure the relative affinities of individuals for their respective reference populations[5]. Hence these relatively high percentages underscore the high levels of discrimination achieved by stepwise discriminant analysis. Consideration of typicality probabilities, however, reveals a different and less sanguine pattern.

The typicality probability provides a measure of the closeness of a particular individual to the centroid of its reference population, and thus gives an idea of the ease with which an individual may be reassigned. It should be remembered, of course, that we have an *a priori* knowledge of the group

**Table 3: Percentages of sex dimorphism for MD and BL dimensions of maxillary teeth in Lengua Indians and South African Negroes and Caucasoids.**

| | | *Percentage Sex Dimorphism*[1] | | |
|---|---|---|---|---|
| *Dimension* | *Tooth* | *LENGUA* | *NEGRO* | *CAUCASOID* |
| Mesiodistal | I1 | 4,4 | 6,4 | 6,4 |
| | I2 | 3,6 | 8,9 | 6,9 |
| | C | 7,5 | 2,7 | 8,8 |
| | P1 | 3,7 | 1,7 | 3,5 |
| | P2 | 0,7 | 4,0 | 6,0 |
| | M1 | 1,8 | 2,0 | 4,4 |
| | M2 | 5,1 | 2,6 | 7,1 |
| Buccolingual | I1 | 3,4 | 2,9 | 3,0 |
| | I2 | 5,0 | 7,3 | 6,1 |
| | C | 7,1 | 4,8 | 6,3 |
| | P1 | 2,5 | 3,4 | 6,6 |
| | P2 | 0,2 | 5,6 | 7,0 |
| | M1 | 1,8 | 1,7 | 0,0 |
| | M2 | 3,4 | 1,7 | 4,8 |

1 $\left(\frac{xm}{xf} - 1\right) \times 100$

**Table 4: Frequency percentages of posterior probabilities, estimative typicalities and predictive typicalities for intersex distances between male and female Amerindians, Negroes and Caucasoids based on maxillary dimensions.**

| *Classification Probability Interval* | *AMERINDIAN* | | | *NEGRO* | | | *CAUCASOID* | | |
|---|---|---|---|---|---|---|---|---|---|
| | *Posterior Probability* | *Estimative Typicality* | *Predictive Typicality* | *Posterior Probability* | *Estimative Typicality* | *Predictive Typicality* | *Posterior Probability* | *Estimative Typicality* | *Predictive Typicality* |
| | | | | MALES | | | | | |
| 0,0 – 0,2 | 5,4 | 30,4 | 16,1 | 6,4 | 27,7 | 17,0 | 4,3 | 28,3 | 19,6 |
| 0,2 – 0,4 | 7,1 | 10,7 | 16,1 | 10,6 | 10,6 | 10,6 | 8,7 | 15,2 | 13,0 |
| 0,4 – 0,6 | 14,3 | 16,1 | 14,3 | 19,1 | 17,1 | 17,0 | 2,2 | 2,2 | 13,0 |
| 0,6 – 0,8 | 10,7 | 12,5 | 21,4 | 25,5 | 10,6 | 17,0 | 19,6 | 23,9 | 8,7 |
| 0,8 – 1,0 | 62,5 | 30,4 | 32,1 | 38,3 | 34,0 | 38,3 | 65,2 | 30,4 | 45,7 |
| | | | | FEMALES | | | | | |
| 0,0 – 0,2 | 6,5 | 35,5 | 3,2 | 13,3 | 26,7 | 3,3 | 9,1 | 21,2 | 0,0 |
| 0,2 – 0,4 | 0,0 | 22,6 | 3,2 | 10,0 | 10,0 | 6,7 | 9,1 | 18,2 | 6,1 |
| 0,4 – 0,6 | 9,7 | 12,9 | 16,1 | 16,7 | 20,0 | 20,0 | 9,1 | 12,1 | 27,3 |
| 0,6 – 0,8 | 25,8 | 12,9 | 16,1 | 13,3 | 26,7 | 26,7 | 18,2 | 30,3 | 21,2 |
| 0,8 – 1,0 | 58,1 | 16,1 | 61,3 | 46,7 | 16,7 | 43,3 | 54,5 | 18,2 | 45,5 |

membership of each assignee. Hence one would have anticipated that posterior and typicality probabilities should follow concordant patterns.

Evidence provided by the present study, however, suggests the opposite. Consider for instance, the highest probability interval for allocation in Table 4. Posterior probabilities for males indicate 62,5% Amerindians, 38,3% Negroes and 65,2% Caucasoids may be allocated with probabilities in excess of 80%.

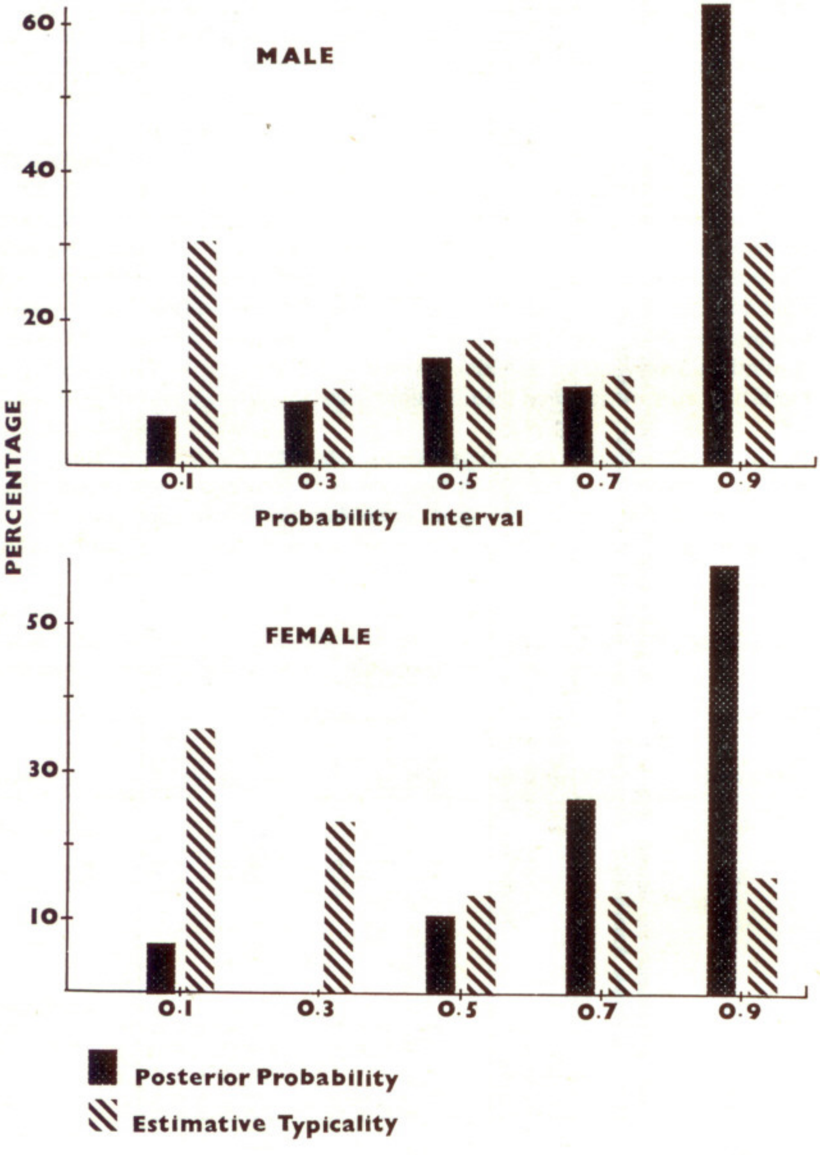


*Fig. 4.* Percentage distributions of the posterior probabilities and estimative typicalities in male and female Amerindians.

Typicalities by contrast, suggest that a mere 30,4% Amerindians, 34,0% Negroes and 30,4% Caucasoids could be reallocated with a probability exceeding 80%. In any consideration of allocatory reliability it is essential to take into account those individuals who could not be allocated with a reasonable degree of confidence. For instance, when comparing the least confident

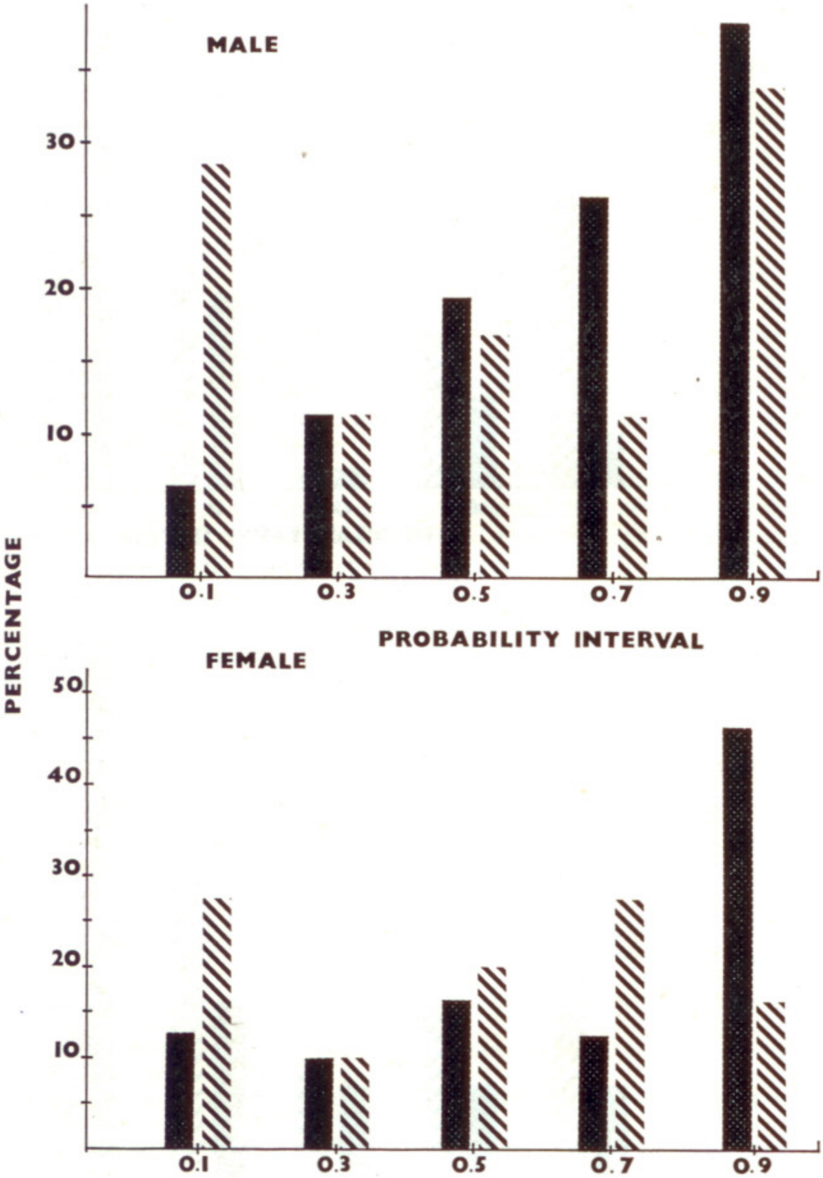


*Fig. 5.* Percentage distributions of the posterior probabilities and estimative typicalities in male and female Negroes.

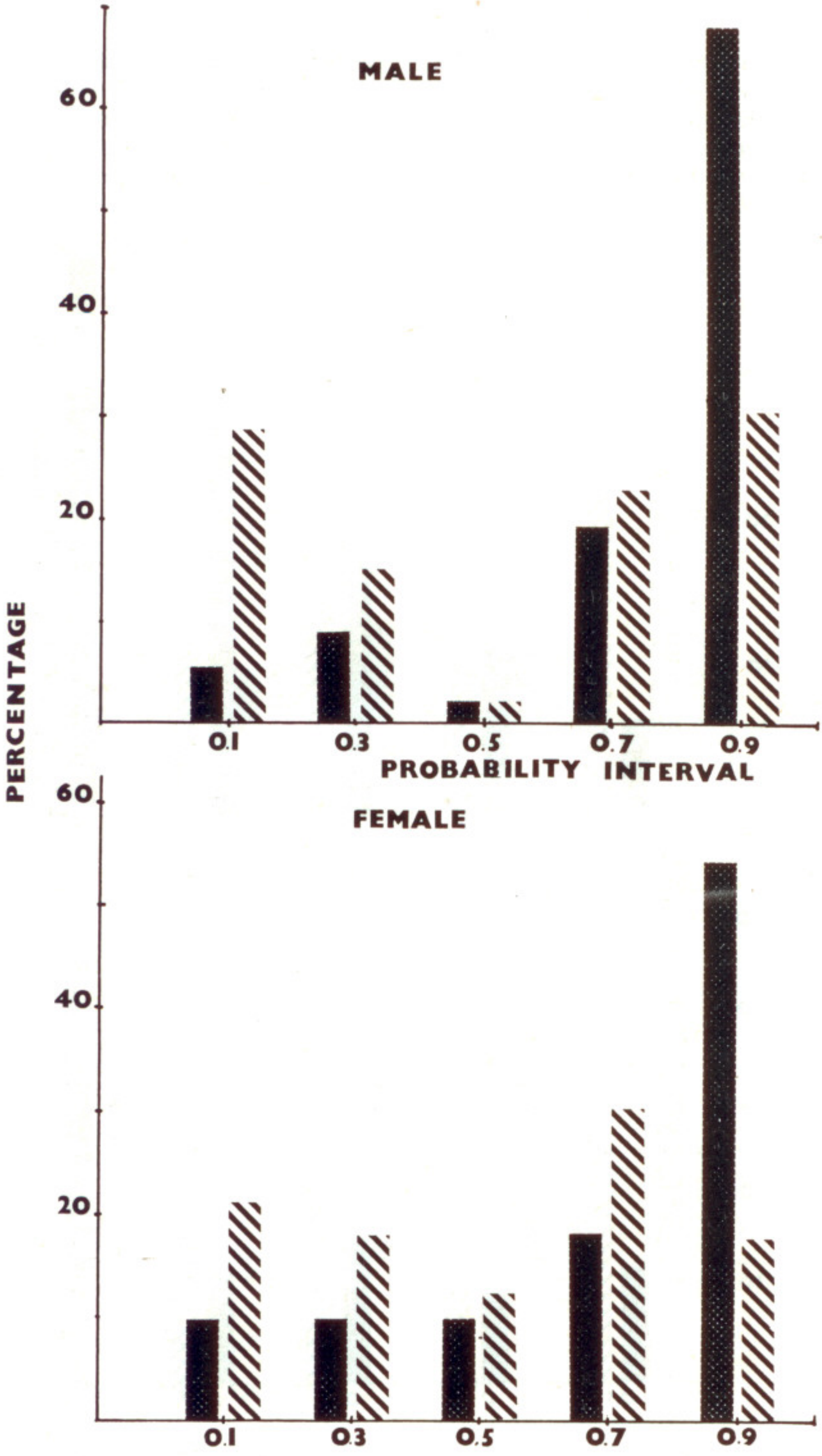


*Fig. 6.* Percentage distributions of the posterior probabilities and estimative typicalities in male and female Caucasoids.

allocatory intervals (0,0-0,2) posterior probabilities again support the results of stepwise discriminant analyses: 54% Amerindians, 6,4% Negroes and 4,3% Caucasoids could not be allocated. In contrast, typicality probabilities show that a full 30,4% Amerindians, 27,7% Negroes and 28,3% Caucasoids fell into the lowest level of allocatory confidence. From this comparison, it appears that nearly 30% of individuals may be considered atypical of their reference population, in spite of the fact that *a priori* their membership was known.

The tractability of discrimination as compared with allocation, may further be instanced by considering male Caucasoids. Multivariate discriminant analysis suggests that the total sample of caucasoids may be grouped into males and females with a 91,3% confidence. In contrast, however, if one male had to be drawn from this population, the ease with which he could be reallocated is reduced to a mere 30,4%. More alarming, perhaps, is the finding that a full 28,3% of Caucasoid males could not be reallocated at all, in spite of the fact that their reference population is known.

It is of interest that a similar study utilizing basocranial dimensions yielded comparable results[6]. Although multivariate discrimination was found to account for the correct classification of 71% of males and 74,4% of females, typicality probabilities indicated that 40% of individuals were atypical upon reassignment. These authors concluded that the description of differences between males and females was a great deal easier and statistically more meaningful than the allocation of group membership.

The present investigation suggests that males and females belonging to three major ethnic groupings may be reliably separated by multivariate means. However, up to 30% of these individuals could not be reassigned to the gender groups from which they had originally been drawn. Hence it is concluded that traditional discriminatory procedures may have overemphasized the ease with which an individual may be sexed based on odontometric data.

The emphasis in this report has been on the sexing of material based on dental measurements, but it is relevant that similar considerations might apply to the ethnic identification of skeletal remains.

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# GUSTAFSON'S METHOD FOR AGE DETERMINATION, REVISED

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## Abstract

Gustafson's method (1950) of age determination is widely applied in forensic odontology. As his regression line is often used with scepticism it was decided to subject his observations to a Pearson's correlation coefficient analysis and redraw his regression line. The revised line was compared with Gustafson's original. The recalculated formula was found to be y = 4,26x + 13,45, with a standard error of 7,03 years which differs from Gustafson's published results of y = 4,56x + 11,43 and 3,63 years respectively. Under 30 years-of-age Gustafson's regression line underestimates by between 1 and 2 years and above 60 years it overestimates by between 1 and 2 years. It is recommended that Gustafson's original regression line be replaced by the more accurate revised line.

**Keywords:** Age determination, dentinal translucency, forensic odontology
**Running title:** Gustafson's method revised

## Introduction

Forensic odontologists are often involved in the determination of the age of a deceased person. In children the stage of development and eruption of teeth make this a relatively simple procedure[1]. In adults however, where all teeth are fully developed and erupted, it is much more difficult to determine age as most clinical and radiographic methods are subjective. Gustafson was the first to devise a quantifiable microscopic method for age determination based on ground sections of fully developed teeth[2]. The six criteria he used were: degree of attrition, position of epithelial attachment, cemental thickness, amount of secondary dentine, degree of root resorption and root translucency.

A number of investigators have found difficulty in repeating Gustafson's results[3] using his data. Bang and Ramm[3] on the other hand, did studies on each of the six criteria and root translucency on its own was found to be more objective and accurate than when all six criteria were considered.

## Objectives

This study set out to reprocess Gustafson's data and compare the recalculated result with the original.

## Materials and Methods

Gustafson's original observations (Table 1) were reprocessed using standard

**Table 1: Gustafson's Raw Data**

| *Tooth Number* | *Total Point Values* | *Estimated Age* | *Actual Age* |
|---|---|---|---|
| 34 | 0 | 12 | 11 |
| 37 | 0 | 12 | 12 |
| 32 | 1 | 16 | 12 |
| 14 | 1 | 16 | 13 |
| 2 | 1 | 16 | 15 |
| 12 | 1 | 16 | 16 |
| 28 | 1 | 16 | 17 |
| 39 | 1 | 16 | 23 |
| 45 | 4 | 29 | 23 |
| 33 | 1 | 16 | 25 |
| 27 | 4 | 29 | 28 |
| 20 | 8 | 47 | 35 |
| 3 | 6 | 38 | 37 |
| 30 | 5 | 34 | 37 |
| 9 | 7 | 43 | 38 |
| 13 | 7 | 43 | 38 |
| 42 | 8 | 47 | 39 |
| 21 | 8 | 47 | 39 |
| 23 | 8 | 47 | 45 |
| 25 | 7 | 43 | 45 |
| 44 | 5 | 34 | 48 |
| 38 | 6 | 38 | 48 |
| 41 | 9 | 52 | 48 |
| 22 | 6 | 38 | 49 |
| 26 | 8 | 47 | 49 |
| 17 | 11 | 61 | 50 |
| 19 | 10 | 56 | 51 |
| 11 | 9 | 52 | 51 |
| 18 | 10 | 56 | 51 |
| 46 | 9 | 52 | 52 |
| 43 | 9 | 52 | 52 |
| 40 | 11 | 61 | 52 |
| 15 | 9 | 52 | 53 |
| 24 | 8 | 47 | 55 |
| 47 | 9 | 52 | 55 |
| 4 | 12 | 65 | 59 |
| 29 | 9 | 52 | 64 |
| 1 | 9 | 52 | 64 |
| 10 | 12 | 65 | 65 |
| 16a | 10 | 56 | 69 |
| 16b | 10 | 56 | 69 |

linear regression formulae. A revised regression line was then drawn and compared with the original. In addition, Pearson's correlation coefficient was used to calculate the value of 'r', from which the coefficient of determination ($r^2$) was deduced.

## Results

The recalculated regression line formula was $y = 4.26x + 13.45$ with a standard error of 7.03 years and standard deviation of 3.63 years (Table 2). As ages increased from 10 to 30 years Gustafson's regression line was found to

**Table: Gustafson's Original and Recalculated Formula**

| *Original Results* | *Recalculated Results* |
|---|---|
| y = 4,56x + 11,43 | y = 4,26x + 13,45 |
| STD ERR = 3,63 years | STD ERR = 7,03 years |
| | STD DEV = 3,63 years |
| | Pearson's Correlation Coeff: |
| | r = 0,9125 |
| | $r^2$ = 0,8327 |

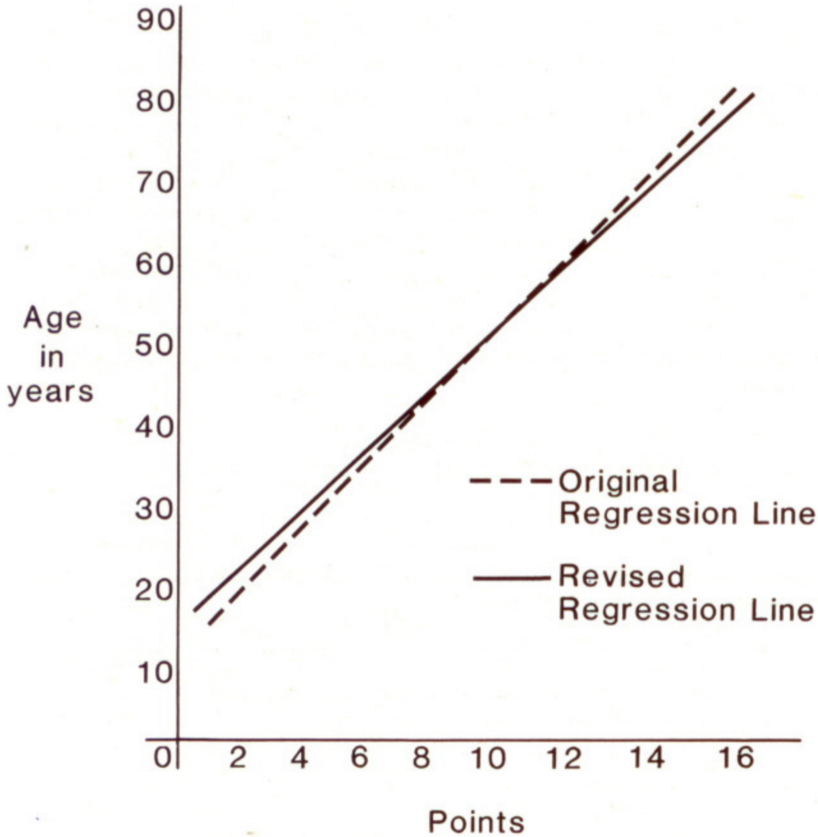


*Fig. 1:* Gustafson's original regression line plotted against the revised regression line.

underestimate decreasingly by 2 to 1 years. As ages increased from 60 to 80 Gustafson's line overestimated increasingly by 1 to 2 years (Fig. 1). Calculation of the correlation coefficient yielded a value of r = 0.9125 with a coefficient of determination value of $r^2$ 0.8327.

## Discussion

The regression line calculated by Gustafson does not correlate with his reprocessed data. Furthermore, the arguments he used to support the accuracy of his method are statistically invalid. According to our re-calculations standard error of the estimate was 7,03 years, regression formula $Y = 4{,}26x + 13{,}45$ and standard deviation was 3,63 years. Gustafson used standard deviation as a standard error of the estimate which made the method appear more accurate (Table 2).

Each variable measured by Gustafson has its own effect on the final score but because as many as six variables are used an occasional large variation in one of the factors will not influence the final results to any great extent. However, to utilize only one observation will not provide the required cushioning effect.

Bang and Ramm[3], claimed that in their sample, dentinal translucency in the root is the most accurate variable; however, the correlation coefficient in their sample of 978 roots was 0,70, where the coefficient of determination, $r^2 = 0{,}49$. This means that only 49% of the variation in the points scored can be explained, or attributed to the age variation within the sample. This is lower than the value of 83% obtained from Gustafson's recalculated results and lays open to question their assertion that dentinal translucency provides a better predictor on its own than Gustafson's six predictors taken together.

Gustafson's method of age determination is a significant contribution to forensic science, but due to inaccuracies in his calculations it has been discredited. His variables are however valid and future studies on dental age determination should be based on the revised regression line including all six observations.

## Acknowledgement

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# – ARE POINTS OF CORRESPONDENCE VIABLE?

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It is not unusual to hear forensic odontologists, giving evidence, say that there are "x" points of correspondence. They then express an opinion about the probability of the identification based upon the size of "x". At first sight this looks like an excellent idea but a closer examination reveals many imperfections and raises the question as to whether or not "points of correspondence" are either necessary or helpful.

In ideal circumstances there will be a match between the ante-mortem and the post-mortem charts of every tooth; but often this does not happen in practice for many different reasons. Dentists may not chart all of the teeth fully due to pressure of work or lack of time, and so the ante-mortem charting shows only the most recent treatment. When the dentition is examined at autopsy dental restorations are found that are not recorded. Some teeth may even be lost in an accident, which with other circumstances, may make it impossible to achieve a 100% match in each case.

This leads to the question of the value as evidence of a particular item of information. The rules of evidence and the standards of proof are no different in forensic odontology from those in other disciplines; the courts do not like having to reckon balances of probabilities, and some way of presenting otherwise confusing evidence, clearly and convincingly, is needed.

It would be very useful to have a numerical index of the frequency of particular fillings in individual teeth, especially in those cases where unusual restorations have been found.

Unfortunately this does not happen very often and in any one mass disaster the chances of making substantial numbers of identifications by this means are low in spite of the large number of possible variations. More importantly, the frequency of different types of filling in the teeth is not known in even one population, although as an example it would certainly be true to say that mesial-occlusal-distal fillings are common in the first permanent molars in the United Kingdom. However, there seems little doubt that this will not be true in years to come as children today enjoy better dental health than their parents. Also, dental practice varies in different countries, though perhaps not so much as it has done in the past. The chances of being able to work out a reliable index of frequency which would be equally applicable in all circumstances are therefore remote.

Points of correspondence ought to be an easy answer to this problem but unfortunately they may be measured in more than one way. Some forensic odontologists only consider teeth which are noted as being either decayed, missing or filled, and intact teeth are ignored. Others consider the whole dentition, and this gives two widely differing values. The latter approach is the more logical one because the object of the exercise is to compare a given mouth with the condition stated in the ante-mortem record. Most operators however tend to use the former approach which can lead to confusing anomalies. In a recent case an investigator suggested that a match he was making could not be considered good as he had only found two points of correspondence. The identification in question was pivotal to a number of others which meant that a lot of work had to be repeated. When it was completed it was found that the dentition in question was particularly characteristic as the victim was middle aged and had only two fillings in a full dentition. This led to the same conclusions. The point here is not so much that a mistake was made, but that the numerical value of the points of correspondence was taken as an absolute indicator of identity without full consideration of the circumstances.

Another difficulty with this technique is that there may be confusion about the relative values of such numerical, indices when a number of people have been identified. The legal profession may remember that in a previous case the forensic odontologist testified that he was satisfied that a particular identity was proven because there were 23 points of correspondence. If however he were to express an equally firm opinion the following week on only 12 points of correspondence, what should the layman think? The large numerical imbalance can only confuse and it would not be surprising were the legal profession to express some scepticism. More importantly, in cases with multiple deaths, relatives might hear such variations expressed in court which would create some doubt concerning the identity of the victims with low numerical scores.

There are many potential pitfalls for the unwary in medico-legal and dento-legal practice and it has to be asked whether a system with all these intrinsic faults has any place in contemporary practice? The answer must surely be "No". However, it is idle to criticise something if one cannot offer a better alternative with none of the faults of the original and able to be understood easily and used by everyone. One such scheme exists already and is used widely.

Ante- and post- mortem charts are produced and are published one below the other. This pictorial representation of the two is easily understood by all concerned and any anomalies are readily observed . The forensic odontologist can then explain the reasons why these do not invalidate the identification in the text of the report where they can be easily read and understood. If they are sound then the case will be accepted in court as proven and the relatives will be convinced that all doubts as to the identity have been resolved. They may very reasonably feel that there should not have been any anomalies at all and that it would have been much better if the ante-mortem chart had been full and accurate; but at least they will not have been confused and upset by doubtful numerical assessments.

There may be a place for those who feel comforted by numbers in the future, when all the existing disadvantages of a poorly defined system have been removed. There is a need to investigate this subject in order to resolve the mathematical imbalances and to establish a consistent and reproducible mathematical index of probability of identity which would always be applicable. Until this becomes practicable however I would urge that spurious numbers should be abandoned.

# THE SCIENTIFIC INVESTIGATION OF CRIME

## S. S. KIND

In his acknowledgement Stuart Kind thanks various people for helping in the preparation of this book, in particular those who assisted in making his prose literate. Thankfully they did not remove the individuality, which makes this book a production by none other than S S Kind. As in the writings of Lord Denning, the author's personality shines through a lifetime's experience, adding to the reader's delight and education. Many journals and textbooks seem to be intent upon publishing sterile prose and so it is refreshing to read a book like this.

Some people may be disappointed that this is not at first glance another "how to do it book", but if they examine the subject matter more closely, they will see that it is a carefully disguised handbook. However, it is a handbook with a difference. It is a philosophy of forensic science, not an easy thing to write, especially in the present climate, where the utilitarian approach is apparently preferable to the academic. Nevertheless, this is an extremely valuable approach and, for those who read the text carefully, there is much of value therein which is highly relevant to everyday forensic practice. Those who only peruse the pages superficially may well think that these are the leisurely musings of a retired forensic scientist. They would have missed the point. Superficial readers will sadly miss the many lessons in the book and they will be the poorer for that. Hopefully they do not carry out their everyday practice.

The often devious nature of forensic science practice is adequately illustrated by case No. 2-2, in which a Santa Claus Model burst into flames and set fire to a large store. Other findings, such as reversed stair treads suggested at one stage another cause, thus showing that in the forensic world an open mind is essential. Other cases are well chosen to illustrate the various aspects of the theme which is developed through the book. Many are possibly better than Santa Claus, but that one appeals to me. This is important, because there is something to suit all forensic tastes in this book. It ought not to be an addition to people's shelves, they should read it and note its contents. Some may cavil at the production, its having been done photographically from a word-processor typescript, but that is not really an issue, it is the contents that matter. Perhaps the illustrations could have been more photogenically reproduced, but they convey the message, and that is what counts.

There is sometimes a tendency to disregard books which are not manuals, one argument being that life is short and time is precious. This philosophy should not be applied to this book, which is a valuable contribution to the literature. Please read it and note the contents. You will enjoy it and benefit from it.

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