DISCRIMINANT ANALYSIS OF DECIDUOUS TEETH TO DETERMINE SEX

DISCRIMINANT FUNCTION ANALYSIS
OF DECIDUOUS TEETH
TO DETERMINE SEX

By

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ABSTRACT

Studies using deciduous tooth crown measurements have concluded that statistically significant differences between males and females are not as effective for discriminating between the sexes as are the results from permanent tooth measurements. The present study measured the mesiodistal and faciolingual crown diameters of the maxillary and mandibular deciduous teeth of 162 dental casts from children, age 3-4 years, and the permanent first molars of 84 casts from the same children, age 16 years, of the Burlington Growth Study. The data displayed significant differences between the sexes for all 40 deciduous diameters at the 5% level of significance, and for 37 diameters at the 1% level. Using 3 to 5 deciduous measurements, the discriminant analyses of several samplings of these children produced discriminant functions in which 76%-90% of holdout samples are correctly classified by sex. Using combinations of deciduous and permanent measurements, 83%-85% of the holdout samples are correctly classified. The results of the univariate and multivariate analyses of the Burlington sample were compared to several earlier studies of deciduous and permanent teeth of both modern and archaeological populations. The Burlington group proved to be the most dimorphic in the deciduous teeth and that dimorphism in the deciduous teeth was within the range published for the permanent teeth in several other

studies. The expression of sexual dimorphism in the deciduous teeth varies both within and among populations. The level of classification accuracy using discriminant analysis of the deciduous teeth approaches the accuracy levels for the permanent teeth.

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CHAPTER ONE

INTRODUCTION

While a variety of metric and morphological methods have been developed to determine the sex of adult human skeletons, reliable methods for determining the sex of subadult (preadolescent) remains have not been established. Only a very few studies have produced any standards for classification by sex using subadult skeletal features. Choi and Trotter (1970) used discriminant analysis in a study of 115 fetal skeletons ranging in age from 16 to 44 fetal weeks. They produced a classification accuracy of 72% with resulting discriminant functions which consist of age plus long bone weight and length ratios. Weaver (1980) examined iliac auricular surface elevation in fetal and infant (up to age 6 months) skeletons. Based on his observation of surface elevation being present in females and absent in males, he achieved a classification accuracy of 43%- 75% for females and of 73%-92% for males. Hunt and Gleiser (1955) used the relationship of hand-wrist developmental age (carpal age) to permanent dentition developmental age (permanent mandibular first molar formation stage), determined radiologically, to classify subadult skeletons. Accuracy levels ranged from 73% at age 2 to 81% at age 8, but Sundick (1977) determined that this method proved accurate only in individuals age 12 and older.

Bailit and Hunt (1964) analyzed permanent tooth (canines and posterior teeth) developmental stages radiographically in the mixed dentition of a modern subadult sample, but concluded that the methods used were not practical for determining sex. However, the fact that significant sexual dimorphism does occur in the permanent dentition (Garn, Lewis, & Kerewsky 1964; Garn et al. 1967; Potter 1972; Potter et al. 1981; Axelsson & Kirveskari 1983), suggests that there might be significant sexual dimorphism in the deciduous teeth which would prove useful in determining the sex of subadult remains.

Previous studies of human deciduous teeth (for example Black 1978; Lysell & Myrberg 1982; Axelsson & Kirveskari 1984) concluded that the expression of sexual dimorphism is less in the deciduous dentition than in the permanent dentition. Generally, though not always, male means for tooth crown diameters are greater than female means in both the deciduous and permanent teeth, and particularly in the mandibular canines (Garn et al. 1967; Moss & Moss-Salentijn 1977; Moss 1978; Anderson & Thompson 1973; Potter et al. 1981). Moss (1978; also Moss & Moss-Salentijn 1977) maintains that the greater male than female canine crown diameters result from differences in enamel thicknesses due to the longer period of amelogenesis in the male. Completion of tooth crown calcification (amelogenesis) occurs earlier in the female than in the male for both the deciduous and the permanent teeth (Fanning 1961: 212, 215; Moorrees, Fanning, & Hunt 1963: 1494-1495; Demerjian & Levesque 1980).

Using a sample group of 42 fetuses, 18 males and 24 females aged 28 to 38 weeks, Coughlin (1967) demonstrated the presence of sexual dimorphism prenatally in the deciduous molar tooth buds. Female means were actually larger than male means in 25 of the 28 dimensions measured mesiodistally and faciolingually, with differences being significant for 6 of those 25 dimensions, including the mesiodistal and faciolingual crown diameters. Coughlin (1967) attributes increased male tooth crown diameters postnatally to continued circumferential deposition of enamel.

In a review of the anthropometric and sexually dimorphic effects of the X and Y chromosomes, Varrela (1984) discusses the effect that both have upon tooth size. The Y chromosome influences body growth (but not shape), including tooth size, additively and to a greater extent than does the X chromosome (Varrela 1984). Females lacking one X chromosome (45, XO), have smaller teeth than do normal (46,XX) females (Kari, Alvesalo, & Manninen 1980), but females with an extra X chromosome (47,XXX) do not show an increased tooth size (Varrela 1984: 37). Males with an additional Y chromosome (47,XYY) exhibit larger deciduous and permanent teeth than do normal (46,XY) males, due possibly to the direct effect of the Y chromosome upon tooth development (Alvesalo & Kari 1977; Townsend & Alvesalo 1985). Tanner et al. (1959) have postulated that the Y chromosome influences the timing and rate of body development, producing slower male maturation compared to female maturation.

Classification by Sex through Discriminant Analysis

Using a sample of 171 modern white Canadian adults, Anderson and Thompson (1973) calculated discriminant functions for a variety of dental and skeletal features. With one function derived through the discriminant analysis of the mesiodistal diameter of the permanent mandibular canines, 74.3% of those cases, or 127 individuals, were accurately grouped by sex. Anderson and Thompson (1973) maintain that the permanent mandibular canine widths alone have value for sex determination in forensic dentistry (Anderson & Thompson 1973: 431).

Garn et al. (1977) used permanent crown measurements to derive the discriminant functions by which approximately 64-87% of their analysis sample of 204 modern American whites were correctly classified. Owsley and Webb (1983) reported an accuracy range of 61-81% in a discriminant function analysis which tested the misclassification potential of three different validation methods, the sample resubstitution, jackknife, and holdout sample methods. From a sample of 176 modern American whites, an analysis sample of 116 cases was used to derive the functions by which a holdout sample consisting of the remaining 60 cases was classified correctly with a range of 60.9%-79.5% (Owsley & Webb 1983).

Using the crown measurements of the permanent dentition, Ditch and Rose (1972) computed discriminant functions from one adult archaeological sample which had initially been classified by sex using long bones and the pelvis. They then applied those functions to a second related sample which had also first been classified using post-cranial features but which had an incomplete dentition. Depending upon the dental discriminant function used, they grouped this sample by sex with an accuracy ranging from 80-100%.

Sciulli, Williams, and Gugelchuk (1977) also used discriminant analysis in determining the sex of an adult archaeological sample through dental measurements. The use of the skull, pelvis, and long bones to classify the sample by sex yielded 57 females and 52 males. Mesiodistal and faciolingual diameters of the maxillary and mandibular canines were then measured. The discriminant function resulting from the analysis classified the sample with an accuracy of 79.4%, based on the initial determination of the sex of each specimen using skeletal features.

Krogman and Işcan (1986) state that the determination of sex using the teeth should be done only to verify a classification made using other features of the skeleton (Krogman & Iscan 1986: 366). Similarly, the 1972 Workshop of European Anthropologists maintains that "...because of...a broad overlapping of male and female measurements... sex diagnosis really cannot be based on teeth" (1980:525). However, one conclusion was that: "For children...the deciduous teeth represent the only factor useful for sex diagnosis" (Workshop of European Anthropologists 1980: 525). Sundick (1977), in an overview of the methods of age and sex determination of the subadult skeleton, also recommends that research on subadult material include an analysis of the deciduous dentition, given the durability of teeth in forensic and archaeological finds.

Several anthropological studies of the deciduous dentition of modern populations analyse the extent of sexual dimorphism but do not attempt to determine whether the application of a classificatory procedure, such as discriminant function analysis, would yield an effective method for separating the sexes. Margetts and Brown (1978) examined the crown size of the right deciduous teeth of Australian

Aborigines, measuring the mesiodistal and faciolingual diameters of 197 individuals, 78 female and 119 male, aged 4 to 11 years. Significant sex differences occurred in 12 of the 20 diameters used.

Lysell and Myrberg (1982) measured the deciduous mesiodistal tooth-crown diameters, using dental casts obtained from 1,110 Swedish children, 530 males and 580 females. They determined that small but statistically significant differences existed between the sexes for all tooth types. Lukacs, Joshi, and Makhija (1983) measured the crown diameters of the left deciduous dentition of 100 Hindu children from Western India, 50 female and 50 male. They reported significant differences by sex for all but one of the 20 diameters. Axelsson and Kirveskari (1984) examined the crown size of the right deciduous teeth of 540 Icelandic children, 254 females and 286 males, measuring the mesiodistal and faciolingual diameters. Significant differences were found in 11 of the 20 deciduous diameters.

One study of the crown diameters of the deciduous teeth did employ discriminant function analysis to classify a sample by sex. Black (1978) measured the mesiodistal and faciolingual diameters of the right deciduous dentition from casts of 133 white American children, 64 females and 69 males. Based on the observation that only 5 of the 20 diameters measured were significant, Black concluded that the deciduous teeth displayed much less sexual dimorphism than did the permanent dentition of a related adult sample. He also concluded that discriminant functions calculated from the deciduous diameters were much less accurate for sex classification than were the discriminant functions derived by Garn et al. (1977) from the <u>permanent</u> diameters of these same children (Black 1978: 81). Using several discriminant functions, and at the 5% significance level, Black correctly classified by sex 64-68% of the deciduous sample from which he had originally derived those functions. The correct grouping of 75% of that sample was achieved only by ignoring the 5% probability level.

To what extent does the degree of significant sexual dimorphism expressed in a sample affect the accuracy with which discriminant analysis will classify that sample by sex? As demonstrated by the results of the previous four deciduous dentition studies, patterns of sexual dimorphism in the crown diameters of the deciduous teeth differ for each group. Similarily, Garn et al. (1967) had observed that in the permanent teeth "...the magnitude and patterning of sexual dimorphism in permanent tooth size differs from population to population" (1967: 965). Only Black (1978) used discriminant analyses, and his deciduous sample displayed the lowest degree of significant sexual dimorphism. The classification accuracy proved to be much less than that achieved with the permanent dentition, and was obtained by applying the discriminant functions to the analysis sample, the group from which the functions had originally been derived. In discriminant analysis, however, the cases used in developing a discriminant function will be classified with a greater accuracy by that same function than if the function were applied to a related group of unknown sex (Frank, Massy, & Morrison 1965: 253; Owsley & Webb 1983).

The purposes of this study were to determine:

1. whether the mesiodistal and faciolingual deciduous crown diameters of a specific sample would display significant sexual

dimorphism, and to determine the extent of that dimorphism,

2. whether the groups of deciduous variables derived from the discriminant function analysis of those diameters would classify by sex a second sample with an accuracy of 75% or greater, as seen with the permanent dentition, and,

3. whether the addition of the permanent first molar (the '6-year molar') measurements would have an effect upon the classification accuracy of the discriminant function.

4. In addition to the discriminant analysis, the results of the univariate and multivariate analyses are compared to results presented in other published studies of the deciduous dentition.

CHAPTER TWO

MATERIALS AND METHODS

The Subsample

For this study, dental measurements were taken from 162 deciduous dental casts, 80 female and 82 male, of children aged 3 to 4 years, and from an additional 84 permanent dental casts, 45 female and 39 male, drawn from that same group of 162 children at 16 years of age. The casts were selected from the 315 cases of the Serial Experimental Group, a section of the sample group of 1,380 children involved in the Burlington Orthodontic, or Growth, Study. The Burlington Growth Study was a longitudinal study conducted annually from 1952-1972 in Burlington, Ontario, Canada and is considered to contain a sample representative of the majority population of children in Ontario at that time--described as being Caucasian and Anglo-Saxon (Popovich & Grainger 1954-59). The entire collection of orthodontic, periodontal, medical, and anthropological materials and records is housed at the Burlington Growth Centre, Faculty of Dentistry, University of Toronto, Toronto, Ontario.

The Growth Study structure allowed control for such variables as nutritional and health status, genetic relatedness, population background, age, and sex of the individuals selected for this present study (Popovich & Grainger 1954-59). During the time of the Growth

Study, the average household income for Burlington (above the national average) and its location (between Hamilton and Toronto), meant accessibility to an above-average number of health care practitioners and specialists, both medical and dental (Popovich & Grainger 1954-59). Theoretically, the Growth Study sample was drawn from an Ontario population well-situated financially and geographically for achieving and maintaining optimum levels of nutrition and health. The medical records for the individuals in the present study did not reveal any histories of malnourishment or serious illnesses which might have inhibited normal growth and development. The present study includes only two sets of sibs, one pair of sisters and one pair of fraternal twin brothers, with the pairs being unrelated to each other. None of the children were recorded as being first cousins or as being either an adopted or a foster child.

The 162 children chosen for this study are white and although all are Canadian, their parentage reflects the predominantly British structure of the Burlington and the Ontario population of the time, as does the Burlington Growth Study sample (Popovich & Grainger 1954-59). The parents of 68% of the children are recorded as being of British origin (more specifically, English, Scottish, or Irish), while of the remaining 32% of the children, 22% are of combined British and European origin, 6% are of European origin, and 4% are of unknown background. The study sample is, therefore, described as being of Northwest European origin, with only 10% (17 children) having parents who are of Southern or Eastern European origin or who have not recorded their origin.

The Cast Selection Criteria

For both the deciduous and the permanent dentition, dental casts were selected which ensured that a complete set of measurements of either the 40 deciduous or the 8 permanent diameters would be recorded for each individual. The dental casts had been obtained from children at either 3 or 4 years of age (although in 13 cases some measurements were made on casts taken at 5 years of age). For many cases, two casts, one at age 3 and one at age 4, were available, and where a diameter could not be accurately measured on one cast, the second cast was used.[2.1] For the permanent first molar measurements, the casts were obtained from the same 162 children used in the deciduous dentition study. The 84 casts finally chosen had been taken from these children at age 16.

The deciduous dentition had to be completely erupted to ensure that the full mesiodistal and faciolingual diameters of each tooth were measured. The narrow age range stipulated, while resulting in the elimination of a number of casts with incomplete eruption of the dentition, ensured a lower incidence of attrition, caries, or restoration changes to the crown diameters of the casts being assessed for inclusion in the study.

A cast which was of poor quality, broken, or chipped, which contained damaged, excessively crowded, or morphologically abnormal teeth, or which exhibited attrition, caries, or restorations which altered the natural dimensions of the teeth, was rejected. That case method described by Moorrees (1959):

> Mesiodistal crown diameter: the greatest distance between the contact points on the interproximal surface of each tooth, measured with the calipers held parallel to the occlusal surface. If the tooth being measured is not in 'normal' position in the arch, measurement is made between those points where contact would 'normally' occur (see Figure 2.1, page 14).

This definition has been employed in several studies involving the deciduous dentition (for example, Moorrees et al. 1957; Margetts & Brown 1978; Sawyer et al. 1982; Lukacs, Joshi, & Makhija 1983) and comparisons with these, and similar studies can be made. As detailed by Hunter and Priest (1960: 407), the mesiodistal measurements were made with the caliper points inserted from the facial aspect of the tooth (Figure 2.1), although in a very few cases the points were inserted from the occlusal aspect of individual teeth.

The faciolingual crown diameter measurements were made using the method detailed by Townsend (1976: 31), Margetts and Brown (1978: 434), and Hillson (1986: 233):

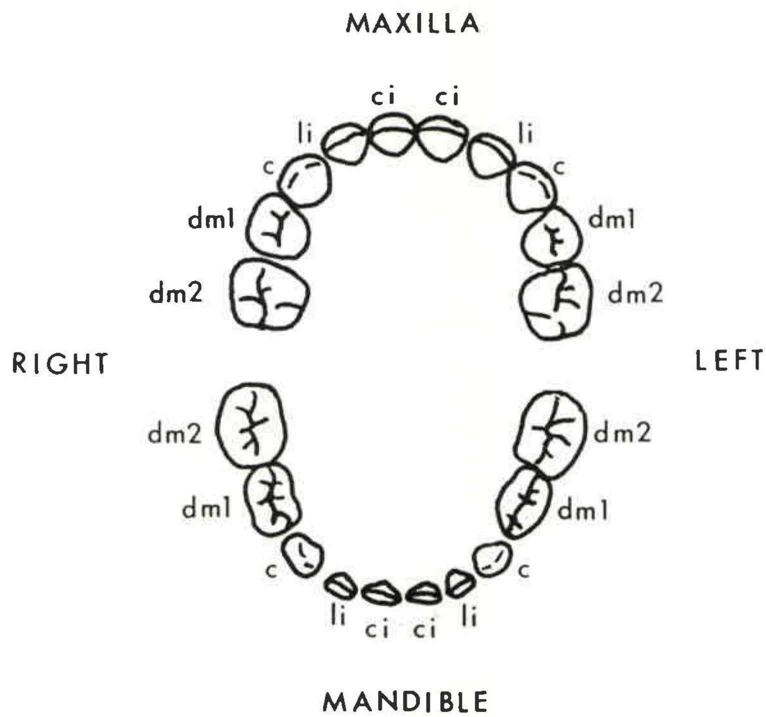
> Faciolingual crown diameter: the greatest distance between the facial surface and the lingual surface (including the cingulum of the anterior teeth) of the tooth crown, measured with the calipers held at right angles to the mesiodistal crown diameter of the tooth (see Figure 2.1, page 14).

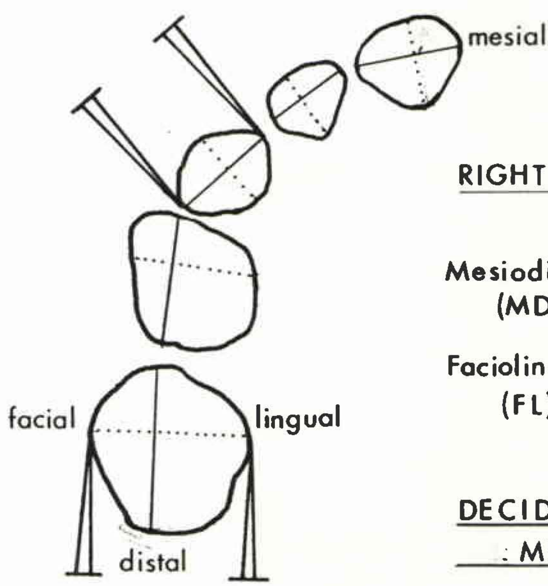
For the faciolingual measurements, the caliper points were inserted from the distal aspect of the tooth (Figure 2.1).

The measurement reference points for the mesiodistal crown diameter, as defined in this study, are the contact points, which are determined by the 'ideal' anatomical relationship between tooth position and the curve of the dental arch. An alternate measurement, the

FIGURE 2.1: MEASUREMENT OF THE DECIDUOUS CROWN DIAMETERS

DECIDUOUS DENTITION





RIGHT MAXILLA

Mesiodistal: ______
(MD)

Faciolingual: ....
(FL)

DECIDUOUS DIAMETER
: MEASUREMENT

maximum mesiodistal crown diameter, by definition, overlooks tooth rotation, abnormal contact point location, and individual variation in tooth morphology, in establishing the measurement reference points (Seipel 1946: 24; Hillson 1986: 233, 234). The maximum mesiodistal diameter measures the greatest distance between the interproximal crown surfaces along the curve of the dental arch, and therefore, does not consistently measure tooth length from contact point to contact point (see Seipel 1946:24; also Axelsson and Kirveskari 1984: 183). Hillson (1986: 233 & 234) has suggested that the difference in measurements obtained with the between-contact points and the maximum mesiodistal diameter methods would be more evident in the posterior dentition. The choice of measuring points for the mesiodistal diameter will affect the selection of measuring points for the faciolingual diameter, possibly producing differences in the results obtained depending upon the measurement method. Axelsson and Kirveskari (1983) point out that the maximum mesiodistal measurement is more relevant to anthropological studies, although Bass (1971: 226) mentions only the between-contact points measurement in his description of dental measurement methods.

The Statistical Procedures: Univariate Analysis

The statistical analysis of the deciduous and the permanent dentition data involved the use of both univariate and multivariate procedures. The error study methods and results are discussed in Chapter 3. The final data were analyzed using the computer package, SPSSX (SPSS Inc. 1986).

To determine whether the data were normally distributed by sex, the Kolmogorov-Smirnov one-sample test was run with the procedure, NPAR TESTS (SPSS Inc. 1986). The data were split by sex and the cumulative frequency distribution function of each study variable was compared to a normal distribution constructed from the standardized mean and standard deviation (SPSS Inc. 1986: 813-814; Norusis 1983: 222). The maximum difference between the actual and the theoretical distributions was used to establish whether or not the distributions for each variable were significantly different from normal (Norman & Streiner 1986: 87-88).

The univariate statistics, mean ($\bar{X}$), standard deviation (SD), standard error of the mean ($S_{\bar{x}}$), and range (R), as well as the Student's t-test for independent samples, were obtained with the SPSSx procedure, T-TEST (SPSS Inc. 1986), using the male, female, and pooled male and female data. To assess and compare the variability of tooth size for each tooth type, the coefficient of variation (CV) was determined for males and for females, using the formula:

$$CV = \frac{SD}{\bar{X}} \times 100$$

The standard deviation is expressed as a percent of the mean. The results for males and females were compared to establish whether there were a pattern of difference which might be attributed to sexual dimorphism.

Percentage sexual dimorphism was calculated by the method used by Garn et al. (1967):

$$\left(\frac{\text{MALE } \overline{X}}{\text{FEMALE } \overline{X}} - 1.0 \right) \times 100$$

The amount by which the male mean for each variable is greater than the female mean is expressed as a percentage of the female mean.

<u>The Statistical Procedures: Multivariate Analysis</u>

The goal of part of this study was to determine not only if the mesiodistal and faciolingual crown diameters of the deciduous dentition displayed significant sexual dimorphism, but also if combinations of certain diameters would prove effective in classifying by sex a sample of unknown sex. The study data, therefore, consists of the nominal variable, sex, into which individual cases would be grouped through the analysis of the metric variables, the crown diameters. The multivariate statistical technique, discriminant function analysis (specifically, two-group or two-way discriminant analysis), was used, through the procedure, DISCRIMINANT (SPSS Inc. 1986). The detailed explanations of the procedure were obtained from Norušis (1985) and Hair, Anderson, and Tatham (1987).

For the purposes of discriminant analysis, the nominal variable, sex, is termed the <u>categorical</u> variable and is a <u>dependent</u> variable composed of the two groups, female and male. The crown diameters, or metric variables, are the independent, classification variables. The portion of the study sample cases for which sex is known, and from which the discriminant function is calculated, is referred to as the analysis sample.

The discriminant function produced is a linear equation:

$$D = B_0 + B_1 X_1 + B_2 X_2 + . . . B_p X_p$$

(Norušis 1985: 80)

which consists of:

1. The independent variables ($X_1 . . . X_p$), which discriminate most effectively between the predefined groups,

2. The constant (B_0),

3. The discriminant weights or coefficients ($B_1 . . . B_p$), which are calculated from the original data and which maximize the ratio of between-groups sum of squares to within-groups sum of squares (the F-ratio), and,

4. The discriminant score (D), which is the sum of the equation for each case classified.

The discriminant function is structured so that, for each case, the raw measurement for each of the independent variables (crown diameters) selected as being the most effective discriminators is multiplied by the specific discriminant weight. The results and the constant are then summed to obtain the discriminant score for that case.

Based on the discriminant score, DISCRIMINANT (SPSS Inc. 1986) utilizes a Bayesian statistical formula to determine the probable group membership for each case. Cases with a discriminant score less than zero (0.0000), a negative score, are categorized as female and cases with a score greater than zero, a positive score, are categorized as male.

The analysis sample can be classified but the classificatory accuracy of the resulting discriminant function is better tested, or cross-validated, by applying it to a holdout sample, a separate set of cases from the study sample for which sex is deliberately entered as unknown. The accuracy with which the holdout sample is classified is then evaluated by comparing the predicted sex to the actual sex for each case. As well, Hair, Anderson, and Tatham (1987) suggest that "...the classification accuracy should be at least 25% greater than that achieved by chance" (Hair, Anderson, & Tatham 1987: 90). For a study sample which consists of 2 groups of equal size, there is a 50% chance of correctly classifying the cases by sex. The application of the 25% criterion would mean that a minimum classification accuracy of 62.5% would be the goal. For this study the criterion for classification accuracy was set at 50% better than chance, a 75% classification accuracy, given the level of accuracy achieved with the permanent dentition in other studies.

The value of having a holdout sample arises from the fact (previously stated in the Introduction, page 7) that a discriminant function will best classify the cases used in its derivation. The optimum size of the holdout sample is still subject to discussion (see Hair, Anderson, & Tatham 1987: 82-83), but for this study, the original study cases were ultimately split into four different groups (Groups A to D), each containing a holdout sample and one to two analysis samples

TABLE 2.1: STRUCTURE OF THE SAMPLE GROUPS USED FOR DISCRIMINANT FUNCTION ANALYSIS

GROUP	SAMPLE TYPE	TOTAL N	N USED FOR ANALYSIS	N USED FOR CLASSIFICATION
A	Analysis (Deciduous)	141	136	138
	Analysis (Deciduous & Permanent)	63	63	63
	Holdout	21	-	21
B	Analysis (Deciduous)	122	119	121
	Holdout	40	-	40
C	Analysis (Deciduous)	141	138	140
	Analysis (Deciduous & Permanent)	63	63	63
	Holdout	21	-	21
D	Analysis (Deciduous)	120	117	117
	Analysis (Deciduous & Permanent)	42	42	42
	Holdout	42	-	42

of varying sizes (Table 2.1, page 20). The sizes varied because only those cases having all the variables specified are utilized by the procedure, DISCRIMINANT, (SPSS Inc. 1986), in either the calculation of the discriminant function or the classification of the cases. The final selection of four groups resulted from a desire to see whether the level of classification accuracy achieved initially with Groups A and B could be repeated using a slightly different combination of cases in the holdout group and whether the same small cluster of variables would be included in the resulting discriminant functions.

The Group A holdout sample consisted of the 21 Error Study cases (see Chapter 3) which had permanent measurements, 12 females and 9 males, in order that a comparison could be made of results obtained with the deciduous variables alone and in combination with the permanent variables. The two analysis samples contained 136 cases in the deciduous diameters sample, drawn from the remaining 141 cases, and 63 cases in the combined deciduous and permanent diameters sample. Group B contained a holdout sample of the 40 Error Study cases, 20 females and 20 males, and an analysis sample drawn from the remaining 122 deciduous dentition cases, the 119 cases with measurements for the 40 deciduous diameters. Although only the deciduous variables were used in the discriminant analysis, the objective was to determine the results obtained using a larger holdout group than that used in Group A. Group C contained a holdout sample of 21 cases with permanent diameter measurements, 11 females and 10 males, not included in the Error Study, in order to see whether there would be any difference in the results obtained using cases which had not been remeasured. The two analysis samples contained the remaining 141 cases with deciduous diameter measurements and the 63 cases with both deciduous and permanent diameter measurements. Group D, a combination of Groups A and C, consisted of a holdout sample of 42 cases and two analysis samples, and again provided a large holdout sample. The deciduous diameter analysis sample contained 117 cases and the combined deciduous and permanent diameter analysis sample contained 42 cases.

The primary objective in running the discriminant analysis was to determine the classification accuracy of the discriminant function when applied to a holdout sample. However, two underlying assumptions of discriminant analysis are that the metric variables of each classification group are from multivariate normal distributions and that the variance-covariance matrices for the groups are equal (Hair, Anderson, & Tatham 1987: 76-77; Norušis 1985: 108-109). The resulting discriminant function scores for the cases being classified will then have normal distributions and equal variances. Within the SPSSX procedure, DISCRIMINANT (SPSS Inc. 1986), Box's M test is used as a multivariate test of the equality of the group covariance matrices. In addition, deviations from multivariate normal distributions can be revealed indirectly through Box's M test: the test can show covariance matrices to be unequal if the multivariate distributions are non-normal (Norušis 1985: 108).

The actual impact that violations of the assumptions have upon the discriminant analysis has been questionned, especially when large sample sizes are involved (for a discussion, refer to Harris 1975: 85-87, 231-233). Norušis (1985) has pointed out that large sample sizes may yield statistically significant Box's M test results when in fact the group covariance matrices are similar enough that the equality assumption is not violated (Norušis 1985: 108).

For the preliminary analyses no holdout samples were specified. Instead, the 162 deciduous cases, and the 84 permanent cases, were each used to construct two analysis samples for separate stepwise discriminant analyses. The 40 deciduous variables, coupled with the deciduous analysis sample, and then the 8 permanent variables, coupled with the permanent analysis sample, were each analyzed to derive two small clusters of variables that would prove effective in discriminating between females and males, using the method, MAXMINF (SPSS Inc. 1986). The variable, or diameter, which discriminates most effectively between the groups (the variable which has the largest F-ratio) is the first variable chosen for inclusion in the discriminant function. At each step in the procedure, only the variable with the highest F-ratio, at the 5% significance level, in relation to the variables already selected, is added. The discriminant function is computed for all of the variables which meet the criterion level for continued inclusion in the calculations and is then used to classify all the cases which have measurements for those fewer variables.

Because skeletal remains may contain only a few teeth, the number of deciduous classificatory variables was arbitrarily reduced to the first 5 variables of the cluster chosen for inclusion in the original discriminant function. A direct discriminant analysis was then run, using the 5 deciduous variables, 4 maxillary and 1 mandibular, to derive a discriminant function for the classification of the analysis sample cases. Direct discriminant analysis computes the discriminant function in one step using all of a specified group of independent variables.

A series of stepwise and direct discriminant analyses were then run using Groups A to D. For each Group, the cases of the holdout sample were entered as sex unknown and the first analysis sample consisted of the remaining cases with measurements for all 40 of the deciduous diameter variables. Stepwise discriminant analysis of the analysis sample produced a smaller group of classificatory variables with which the analysis sample was classified. The deciduous classificatory variables selected through stepwise analysis were then reduced to a cluster of 5 (or less) variables and direct discriminant analyses were conducted on Groups A, B, C, and D, using three combinations of those variables--maxillary and mandibular variables together, maxillary variables alone, and mandibular variable alone--to classify the holdout sample for each Group. Next, the 3 permanent variables selected through the preliminary stepwise analysis of Group D were combined with the small set of deciduous variables which had been selected in the previous deciduous stepwise analysis of that Group. A series of direct discriminant analyses were then run, using the analysis sample cases with both deciduous and permanent measurements, and the holdout sample for Group D was again classified using various combinations of the maxillary and mandibular variables.

CHAPTER THREE

THE ERROR STUDY

Introduction

In a study where the conclusions reached are based upon the analysis of measurements made of a sample group, the accuracy of the measurements must be established in order to ensure the accuracy of the conclusions. The potential sources of error must be defined and controlled for in order to decrease significantly the effect that errors of measurement might have upon the reliability of the results. Statistical manipulations cannot overcome the fact that inaccurate measurements are unrepresentative of the sample group being examined and that any conclusions drawn from the testing of inaccurate measurements will be useless.

Errors of measurement can be divided into two types: systematic errors and observer errors (as described by Hunter and Priest 1960). Systematic errors involve the occurrence of a consistent pattern of error throughout the body of measurement data. The calipers being used might, for example, make precise measurements for each case. However, an undetected miscalibration would mean that the measurements would be inaccurate to the same extent for each case. Equipment inaccuracy was controlled for in this study by having the Helios dial caliper calibration verified at the beginning of the data-gathering by a qualified individual who was not involved in the research. The calibration was then rechecked a minimum of three times daily during the data-gathering.

Observer errors result from the difficulties involved in developing and maintaining a consistently accurate measurement technique, and from mistakes made in reading and/or recording a measurement. Fundamental observer errors occur because the teeth are not geometrically perfect cubes. By definition, the measurement diameters used impose a geometric outline upon a structure which is actually highly variable and curved in shape (Hillson 1986: 232-233). The determination of the diameter measurement reference points on each tooth is actually a subjective decision on the part of the individual observer, but the chosen reference points must be replicable, especially in a subsequent error study where the goal is to determine whether or not significant errors have been introduced into the body of data. Following the definition specified in Chapter 2, careful determination of the mesiodistal contact points provided a mental reference line against which the caliper points were set at right angles to measure the faciolingual diameter of the tooth.

Additional observer errors can occur in the reading and recording of the measurements. Such errors can involve mistakes in reading the Helios dial or in transferring the measurements to the data sheets (figures could be entered incorrectly or be transposed). When the measurements were taken for this study, the dial was read and the measurement was recorded; then, the figures entered were compared to the dial reading again. Antimere measurements were also compared for each tooth and differences of greater than 0.20mm prompted remeasurement of the teeth, following Margetts and Brown (1978: 495).

In summary, attention was paid to specific factors which can introduce errors of measurements into the data. Only casts in which the teeth met the criteria for inclusion in the study were measured. The Helios dial caliper accuracy was verified and rechecked routinely. The crown diameter definitions (see Chapter 2) were used to determine caliper point placement for each dimension. Measurements were read, recorded, and compared back to the dial reading. An error study was then conducted to test the accuracy of the measurement data.

Methods

The error, or replicability, was assessed from 40 randomly selected casts, 20 female and 20 male, which were remeasured five weeks after the completion of the original data-gathering. To assess observer error, Hillson (1986: 234) has taken a maximum of 0.10mm difference as being the normal unit of permissible measurement difference between an original and a repeat measurement. In addition, the statistical test used specifically for the error study included Dahlberg's Method for Determining the Standard Deviation of a Single Determination (Townsend 1976: 40; Margetts and Brown 1978: 495). This method for calculating the standard deviation of a single determination (SD_s) (Figure 3.1, page 28) was used in order that the results of the error study might be compared with other researchers.

FIGURE 3.1: DAHLBERG'S METHOD FOR DETERMINING THE STANDARD DEVIATION OF A SINGLE DETERMINATION

$$SD_s = \sqrt{\frac{\sum d^2}{2N}}$$

where **d = the difference between the original and the error study measurement**

N = the number of double determinations (remeasured casts)

The significance of the difference between the repeated measures (the original measurement and the error study, or repeat, measurement), for each case in the error study, was assessed for each diameter or variable, using the <u>Direct Difference Method</u> (Christensen and Stoup 1986: 296-298). The greater statistical power of this method ensured a more precise estimation of the errors of measurement. The method involves the determination of the mean difference ($\bar{X}_d$), the standard deviation of the difference scores (S_d), the standard error of the estimate of the mean difference scores ($S_{\bar{d}}$), and the degree of significant difference from zero for each variable through Student's t-test calculated by the difference method (Figure 3.2, page 30).

<u>Sandler's A-Statistic</u> (Runyon & Haber 1984: 300-301; Christensen & Stoup 1986: 298-299), the formula for which is derived from Student's t-test, was also used to calculate whether the differences between the original and the error study measurements for each diameter were significant (Figure 3.3, page 31). The sum of the squares of the differences ($\sum D^2$) is divided by the square of the sum of the differences ($\sum D)^2$ to yield Sandler's statistic, A (where H_0 : $u_1 - u_2 = 0$). If the value obtained for A at (N-1) degrees of freedom and at a specific level of probability is equal to or less than the figure given in the <u>Table of Critical Values for A</u>, the null hypothesis is rejected. The conclusion would then be that a significant difference exists between the original and the error study measurement for the diameter being examined. The results obtained with Sandler's A Statistic were compared with those obtained with the more involved Direct Difference method.

FIGURE 3.2: THE DIRECT DIFFERENCE METHOD

Step 1.

$$\bar{X}_d = \frac{\sum d}{N}$$

Step 2.

$$S_d = \sqrt{\frac{\sum d^2 - \frac{(\sum d)^2}{N}}{N - 1}}$$

Step 3.

$$S_{\bar{d}} = \frac{S_d}{\sqrt{N}}$$

Step 4.

$$t = \frac{\bar{X}_d}{S_{\bar{d}}}$$

where d = the difference between the original and the error study measurements

N = the number of difference scores

FIGURE 3.3: SANDLER'S A-STATISTIC

$$A = \frac{\sum D^2}{(\sum D)^2}$$

where D = the difference between the original and the error study measurement

Results

The differences between the original and the error study measurements ranged from 0.00mm to 0.80mm, with 396 differences, or 24.75% of the total 1,600 repeat measurements, exceeding 0.10mm. A breakdown of those differences (Table 3.1, page 33) showed that all tooth groups were involved. The faciolingual diameter (with 215 differences) was only slightly more affected than was the mesiodistal (with 181 differences), and the maxilla (208 differences) was only slightly more affected than was the mandible (188 differences). The female cases accounted for 209 measurement differences and the male cases for 187 of the differences.

The standard deviations for a single determination calculated by Dahlberg's method (Table 3.2, page 34) ranged from 0.06mm to 0.15mm. Mesiodistal measurements averaged 0.08mm and faciolingual measurements averaged 0.09mm. When comparing the mesiodistal and faciolingual diameters of the 20 individual teeth, the mesiodistal standard deviations ranged from 0.06mm to 0.09mm, while the faciolingual ranged from 0.06mm to 0.15mm. The faciolingual right and left measurements for the mandibular first molar (dm1), 0.14mm and 0.15mm respectively, were the largest standard deviations for the single determinations.

The results obtained by the direct difference method (Table 3.3, page 35) and Sandler's A-Statistic method (Table 3.4, page 36) revealed significant differences at $p < 0.05$ between the original and the error study measurements for 10 variables, 3 mesiodistal diameters

TABLE 3.1: THE NUMBER OF MEASUREMENT DIFFERENCES GREATER THAN 0.10MM, BY TOOTH TYPE

TOOTH	DIAMETER			
	MESIODISTAL		FACIOLINGUAL	
	N		N	
Maxilla	Right	Left	Right	Left
ci	14	11	13	9
li	13	10	11	11
c	5	6	10	11
dm1	8	11	9	15
dm2	10	13	7	11
Total	50	51	50	57
Maxillary Total	208			
Mandible	Right	Left	Right	Left
ci	2	2	8	6
li	8	7	11	8
c	9	12	14	10
dm1	8	9	15	17
dm2	9	14	13	6
Total	36	44	61	47
Mandibular Total	188			
Mesiodistal Subtotal	181		Faciolingual Subtotal	215
Overall Total	396			

TABLE 3.2: THE RESULTS OBTAINED USING DAHLBERG'S METHOD FOR DETERMINING THE STANDARD DEVIATION OF A SINGLE DETERMINATION

	MESIODISTAL		FACIOLINGUAL	
TOOTH	RIGHT SD_s	LEFT SD_s	RIGHT SD_s	LEFT SD_s
<u>Maxilla</u>				
ci	.085	.076	.080	.073
li	.093	.080	.100	.096
c	.066	.068	.085	.100
dm1	.086	.089	.088	.089
dm2	.074	.090	.072	.088
<u>Mandible</u>				
ci	.059	.059	.061	.068
li	.064	.066	.079	.070
c	.079	.085	.105	.095
dm1	.073	.071	.143	.145
dm2	.077	.093	.074	.077
<u>Average</u>	.076	.079	.090	.090
	(.08)	(.08)	(.09)	(.09)

TABLE 3.3: THE RESULTS OBTAINED USING THE DIRECT DIFFERENCE METHOD

	MESIODISTAL		FACIOLINGUAL	
TOOTH	$\bar{X}_d$	t_d	$\bar{X}_d$	t_d
Maxilla				
Right				
ci	-.019	.987	-.031	1.803
li	-.036	1.797	-.029	1.299
c	-.013	.842	-.044	2.429* **
dm1	-.010	.516	-.026	1.207
dm2	-.035	2.210* **	-.026	1.581
Left				
ci	-.036	2.236* **	-.025	1.448
li	-.029	1.640	-.023	1.055
c	-.088	.572	-.069	3.467**
dm1	.010	.499	-.053	2.876**
dm2	-.026	1.317	-.065	3.844**
Mandible				
Right				
ci	-.005	.377	.873	.091
li	-.014	.953	-.114	.070
c	.006	.350	-.006	.264
dm1	-.053	3.667**	-.106	3.862**
dm2	-.025	1.472	-.046	3.058**
Left				
ci	-.011	.844	-.015	.993
li	-.011	.759	-.025	1.623
c	-.005	.259	-.009	.403
dm1	-.021	1.354	-.079	2.602* **
dm2	-.040	1.997	-.004	.216

* No significant difference at $p < 0.01$
** Significant difference at $p < 0.05$

TABLE 3.4: THE RESULTS OBTAINED USING SANDLER'S A-STATISTIC

	MESIODISTAL		FACIOLINGUAL	
TOOTH	RIGHT	LEFT	RIGHT	LEFT
Maxilla				
ci	1.027	.220* **	.325	.400
li	.327	.388	.603	.901
c	1.400	3.000	.190* **	.132**
dm1	3.688	3.938	.694	.142**
dm2	.224* **	.587	.415	.091**
Mandible				
ci	6.875	1.395	119.000	1.014
li	1.099	1.716	201.000	0.395
c	7.960	14.500	14.040	6.020
dm1	.098**	.557	.090**	.169**
dm2	.475	.270	.129**	21.000

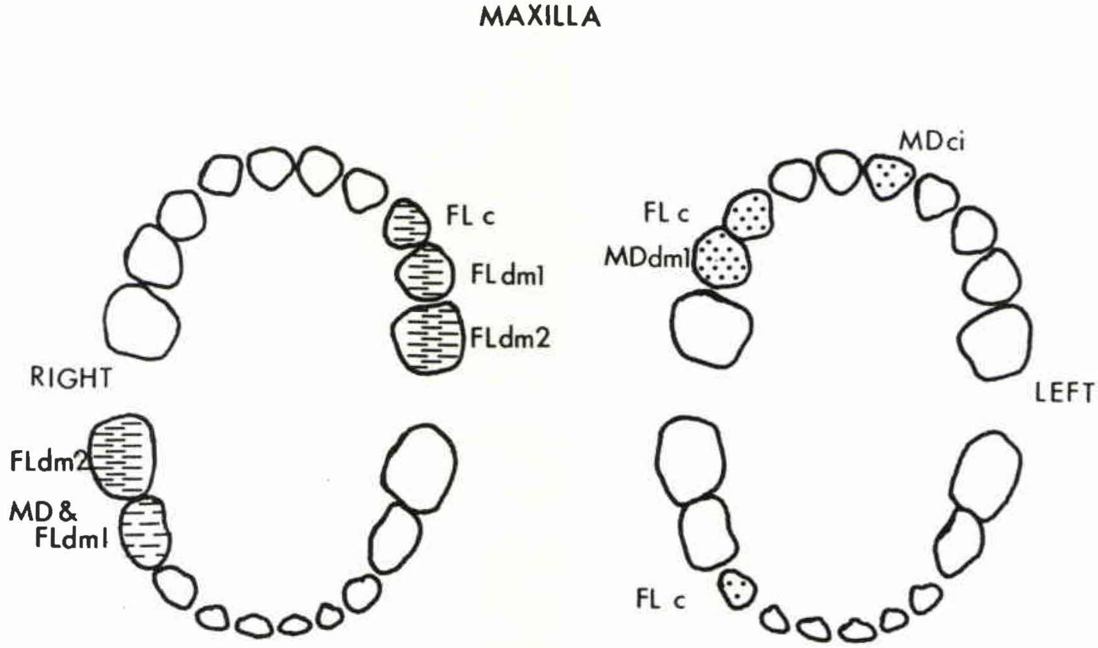
* No significant difference at $p < 0.01$
** Significant difference at $p < 0.05$

showed no significant difference at $p < 0.01$. Significant differences at both $p < 0.05$ and $p < 0.01$ occurred in the mesiodistal and facio-lingual diameters of the right mandibular second molar (dm2), and the left maxillary second molar (dm2), first molar (dm1), and canine (c) (Figure 3.4 (A.), page 38). Significant differences at $p < 0.05$, but not at $p < 0.01$, occurred in the mesiodistal diameters of the right maxillary first molar (dm1) and the left mandibular first molar (dm1) (Figure 3.4 (B.), page 38).

Discussion

Margetts and Brown (1978), in a replicability trial using 14 sets of casts, determined that the differences between the original and the repeat measurements ranged from 0.00mm to 0.29mm, with only 11 differences out of a total 560 scores (1.96%) being greater that 0.10mm. They reported significant differences at $p < 0.05$ between the mean values of the original and the repeat measurements for 5 variables, 2 mesiodistal diameters and 3 faciolingual, with each diameter specifically involving either a canine or an incisor. In comparison, in this error study, 396 of 1,600 measurements (24.75%) differed by greater than 0.10mm and the differences ranged from 0.00mm to 0.80mm. No significant pattern to the measurement differences emerged, although the mandible, mesiodistally, showed the least number of differences (80, or 20%, of the total 400 repeat measurements differed from the original study measurements). The standard deviations calculated by Dahlberg's method by Margetts and Brown (1978),

FIGURE 3.4: DECIDUOUS CROWN DIAMETERS SHOWING SIGNIFICANT DIFFERENCES IN MEASUREMENT REPLICATION



A. Diameters significantly different at $p \leq 0.05$ & 0.01

B. Diameters significantly different at $p \leq 0.05$ but not at $p \leq 0.01$

MANDIBLE

using a Helios dial caliper reading to 0.10mm and fitted to a linear potentiometer, ranged from 0.06mm to 0.27mm, with a mesiodistal average of 0.12mm and a faciolingual average of 0.15mm for the deciduous teeth (Table 3.5, page 40). Seipel (1946), using Dahlberg's method, reported standard deviations ranging from 0.09mm to 0.31mm for right deciduous mesiodistal maxillary and mandibular measurements. The standard deviations calculated for this error study, therefore, fall within the narrow ranges computed in other similar studies, and do not indicate the existence of significant differences between the original and the error study measurements.

However, the Direct Difference method and Sandler's A-Statistic did produce results which questionned the reliability of the measurement technique used to obtain the original measurements, especially for the faciolingual diameters of maxillary dm2 and dm1 and maxillary c, and for the mesiodistal diameter of mandibular right dm1. Accordingly, a case by case study, focusing upon those specific dimensions, was undertaken to determine whether the original or the repeat measurements were inaccurate.

Before the case by case study was begun, the Helios dial caliper points were resharpened and the calipers recalibrated. For the 10 variables to be remeasured (the faciolingual diameters of dm2, dm1, and maxillary c and the mesiodistal diameter of mandibular right dm1), a measurement difference of greater that 0.10mm between the original and the repeat measurement meant that the tooth should be remeasured for that particular variable. The case by case study involved 38 casts and 122 remeasurements.

TABLE 3.5: A COMPARISON OF RESULTS OBTAINED USING DAHLBERG'S METHOD TO DETERMINE ERRORS OF MEASUREMENT

	MESIODISTAL					FACIOLINGUAL			
	RIGHT			LEFT		RIGHT		LEFT	
TOOTH	A	B	C	B	C	B	C	B	C
Maxilla									
ci	.08	.12	.09	.09	.08	.12	.08	.12	.07
li	.14	.12	.09	.19	.08	.21	.10	.14	.10
c	.12	.11	.07	.18	.07	.22	.09	.15	.10
dm1	.31*	.13	.09	.14	.09	.27	.09	.19	.09
dm2		.15	.07	.14	.09	.18	.07	.20	.09
Mandible									
ci	.09	.08	.06	.06	.06	.06	.06	.06	.07
li	.08	.07	.06	.09	.07	.10	.08	.12	.07
c	.12	.13	.08	.10	.09	.12	.11	.18	.10
dm1	.17*	.18	.07	.16	.07	.13	.14	.18	.15
dm2		.11	.08	.14	.09	.13	.08	.11	.08

A = Seipel (1946): * dm1 and dm2 combined and averaged.

B = Margetts & Brown (1978)

C = De Vito (1987)

The results of the case by case study were examined in order to assess the reliability of the remainder of the error study data which had shown no significant differences at $p < 0.05$ but which contained 274 measurement differences greater than 0.10mm. If the remeasurement differed from the original measurement by 0.10mm or less, the original measurement was accepted as being an accurate score. If the remeasurement were equivalent to or within 0.10mm of the repeat measurement in the first error study, and greater than 0.10mm different from the original measurement, the repeat measurement was accepted as being an accurate score.

Hillson's (1986: 234) criterion of 0.10mm difference as the maximum permissible measurement difference between the original and the repeat measurement was used to assess observer error (see this study, page 26). Of the 122 measurements for which the measurement difference had been equal to or greater than 0.15mm (therefore displaying a difference of greater than 0.10mm), 99 remeasurement scores were equal to or within 0.10mm of the original measurement (Table 3.6, page 42). Two scores were within 0.15mm to 0.20mm of the original measurement but differed from the repeat measurement by greater than 0.20mm. Of the 21 remaining scores, 14 were equal to the repeat measurements and 7, which differed from the original by greater than 0.10mm, were within 0.10mm of the repeat measurement.

The 10 variables examined in the case by case study comprised a total of 400 measurements, of which 122, or 30% of that total 400, were remeasured. After remeasurement, 99 scores, or 25% of the total 400, approximated the original measurements, 21 or 5% approximated the

TABLE 3.6: CASE BY CASE REMEASUREMENT RESULTS FOR 10 DIAMETERS

	N CASES REMEASURED	N ≤ 0.10MM OF ORIGINAL MEASUREMENT	N ≥ 0.15- ≤ 0.20 MM OF ORIGINAL MEASUREMENT	N ≤ 0.10MM OF REPEAT MEASUREMENT
		MESIODISTAL		
Mandible				
Right				
dm1	8	7	-	1
		FACIOLINGUAL		
Maxilla				
Right				
c	10	9	-	1
dm1	9	5	-	4
m2	7	5	-	2
Left				
c	11	11	-	-
dm1	15	12	-	3
dm2	11	8	-	3
Mandible				
Right				
dm1	15	14	1	-
dm2	13	11	-	2
Left				
dm1	17	11	1	5
dm2	6	6	-	-
Total	122	99	2	21

repeat measurements, and 2 measurements, or 0.5%, were greater than 0.10mm different from the original measurements but did not approximate the repeat measurements. These results indicated that for the other 30 variables displaying a total of 274 measurement differences greater than 0.10mm, remeasurements should be done.

The remaining 30 variables were combined with the original 10 variables of the case by case study (Table 3.7, page 44). Of the total 396 remeasurements made, 311 were equal to or within 0.10mm of the original measurement. Three scores were within 0.15mm to 0.20mm of the original measurement but differed from the repeat measurement by greater than 0.20mm. Eighty-one scores were equal to or within 0.10mm of the repeat measurement. For one case, one score proved to be greater than 0.20mm different from either the original or the repeat measurement and remained unchanged upon subsequent remeasurement several days later.

Conclusions

The 40 deciduous variables examined in the error study involved a total of 1,600 measurement scores. For 396 measurements, or 24.75% of the total, there was a difference of greater than 0.10mm between the original and the repeat measurement. After remeasurement in the case by case study, 312 scores, or 19.5% of the total 1,600, equalled or approximated the original measurement and 80 scores, or 5.0%, equalled or approximated the repeat measurement. For those 80 scores, the error study measurements were used when the data were subsequently analyzed.

TABLE 3.7: CASE BY CASE REMEASUREMENT OF THE 40 DECIDUOUS VARIABLES

	N CASES REMEASURED		N ≤ 0.10MM OF ORIGINAL MEASUREMENT		N ≥ 0.15- ≤ 0.20 MM OF ORIGINAL MEASUREMENT		N ≤ 0.10MM OF REPEAT MEASUREMENT	
	Right	Left	Right	Left	Right	Left	Right	Left
				MESIODISTAL				
Maxilla								
ci	14	11	11	9	0	0	3	2
li	13	10	8	7	0	0	5	3
c	5	6	3	4	0	0	2	2
dm1	8	11	5	9	0	1	3	1
dm2	10*	13	8	11	0	0	1	2
Subtotal	101		75		1		24	
Mandible								
ci	2	2	0	1	0	0	2	1
li	8	7	7	5	0	0	1	2
c	9	12	9	11	0	0	0	1
dm1	8	9	7	8	0	0	1	1
dm2	9	14	9	12	0	0	0	2
Subtotal	80		69		0		11	
				FACIOLINGUAL				
Maxilla								
ci	13	9	11	7	0	0	2	2
li	11	11	7	10	0	0	4	1
c	10	11	9	11	0	0	1	0
dm1	9	15	5	12	0	0	4	3
dm2	7	11	5	8	0	0	2	3
Subtotal	107		85		0		22	
Mandible								
ci	8	6	7	4	0	0	1	2
li	11	8	10	4	0	0	1	4
c	14	10	9	6	0	0	5	4
dm1	15	17	14	11	1	1	0	5
dm2	13	6	11	6	0	0	2	0
Subtotal	108		82		2		24	
Overall Total	395*		311		3		81	

* One score remeasured >0.20mm different from both the original and the repeat measurement.

For 3 scores, or 0.1875% of the total, which were within 0.15mm to 0.20mm of the original measurement but which did not approximate the repeat measurement, the original measurements were used. For the 1 score, or 0.0625%, which was greater than 0.20mm different from both the original and the repeat measurements, the remeasurement score was used.

The results of the error study and the case by case study mean that only 5.25% of the original measurements had actually been incorrect. Possibly, if a longer period of time had been allowed to elapse between the completion date of the original data-gathering and the start of the error study, there might have been less discrepancy between the original measurements and the repeat measurements. Taking such measurements is a tiring procedure and perhaps requires a longer break in order to ensure the level of concentration necessary for accuracy. Alternatively, the error study could have been done at the beginning of the data-gathering.

Of the four methods used to determine measurement error, the quickest and most effective method proved to be the questionning of any repeat measurement which differed from the original by greater than 0.10mm. To calculate whether the differences for each tooth diameter were in fact significant, Sandler's A-Statistic formula proved to be both simple and reliable when compared to the other statistical methods.

CHAPTER FOUR

RESULTS

Univariate Analysis

The Kolmogorov-Smirnov test showed all of the diameters, both deciduous and permanent (Appendix Table 4.A, page 120; Table 4.B, page 21) to to be normally distributed by sex. Male means proved to consistently greater than female for the 40 deciduous diameters (Appendix Tables 4.C-4.F, pages 122-126; Figures 4.1-4.2, pages 47-48) and for the 8 permanent diameters (Appendix Table 4.G, page 121), although there is considerable overlap in the ranges.

The independent t-test revealed significant differences between males and females for all 40 of the deciduous diameters at the 5% significance level, for 37 of the diameters at the 1% significance level, and for 25 of the diameters at the 0.1% significance level (Table 4.1, page 49; Table 4.2, page 50). Overall the maxillary deciduous dentition displayed more significant differences, especially faciolingually. However, the most significant individual differences occurred mesiodistally, in the mandibular canines, and then faciolingually, in the maxillary right central and lateral incisors and the maxillary left second molar (Figure 4.3, page 51). The 8 permanent diameters were all significantly different at the 5% level or less (Table 4.3, page 52).

FIGURE 4.1: COMPARISON OF MALE & FEMALE MEANS FOR THE MESIODISTAL DECIDUOUS CROWN DIAMETERS

(Right Side — Rounded to one decimal place)

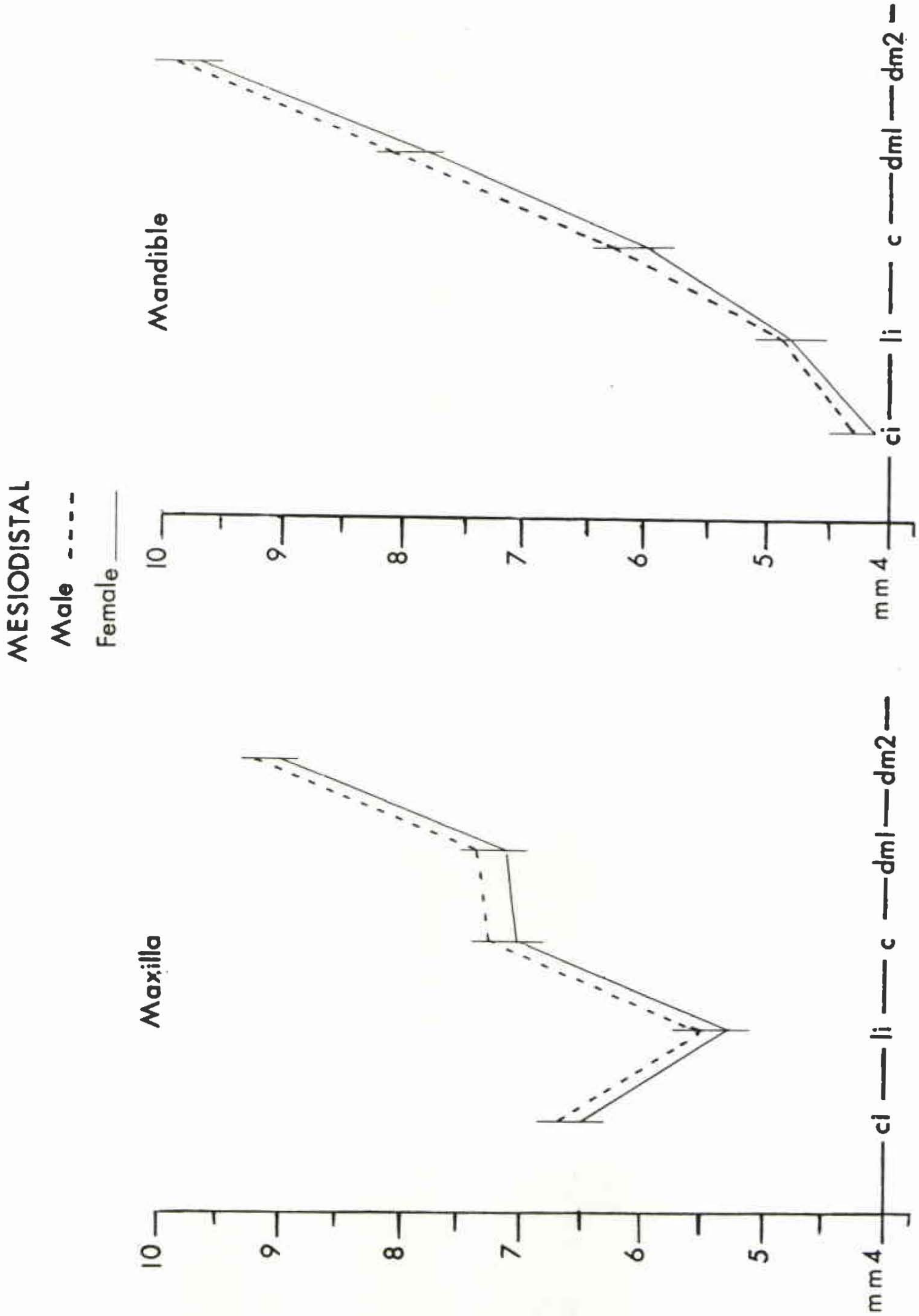


FIGURE 4.2: COMPARISON OF MALE & FEMALE MEANS FOR THE FACIOLINGUAL DECIDUOUS CROWN DIAMETERS

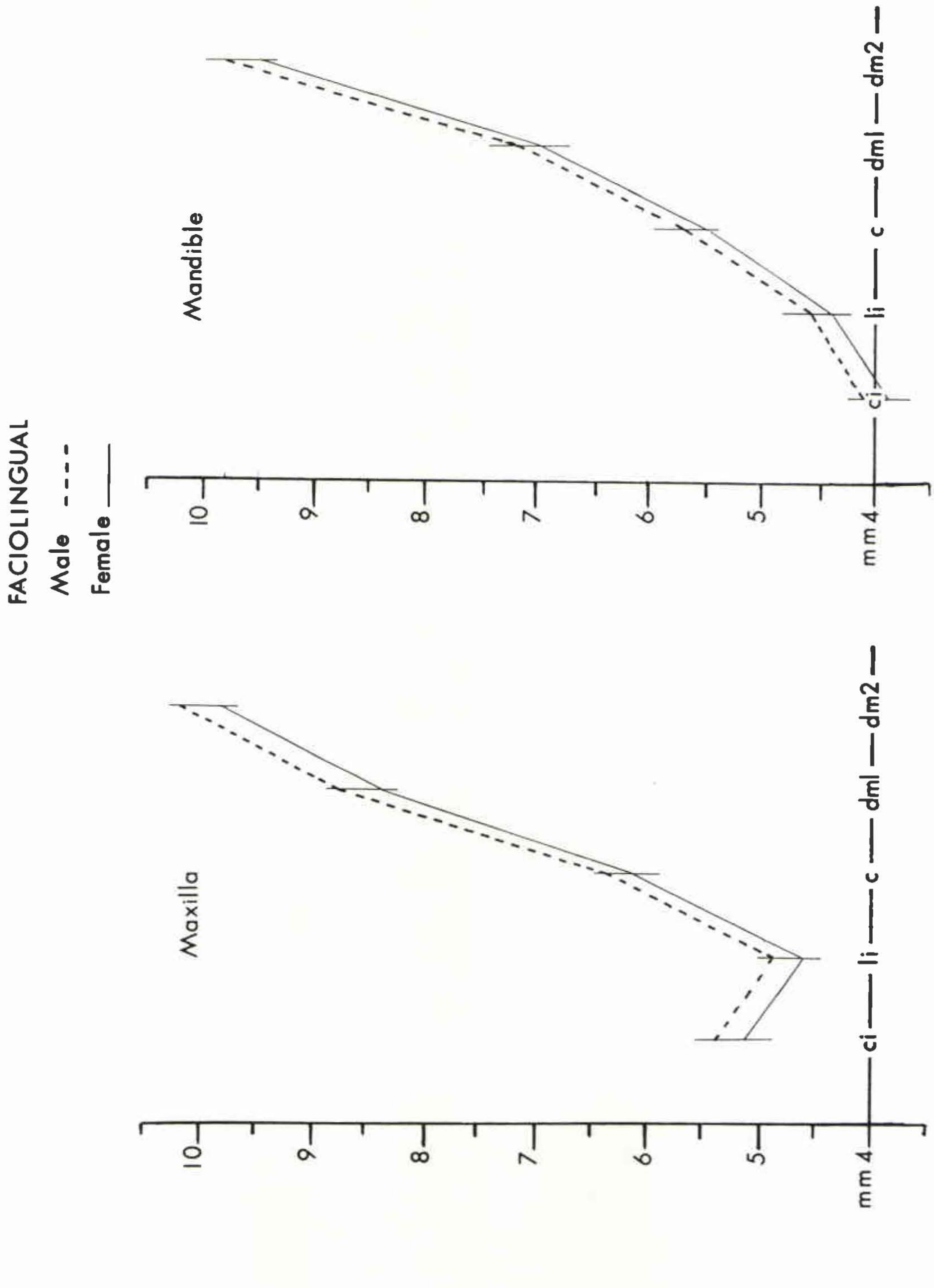


TABLE 4.1: MESIODISTAL DECIDUOUS CROWN DIAMETERS DISPLAYING SIGNIFICANT DIFFERENCES BETWEEN MALES & FEMALES MALES N=82, FEMALES N=80)

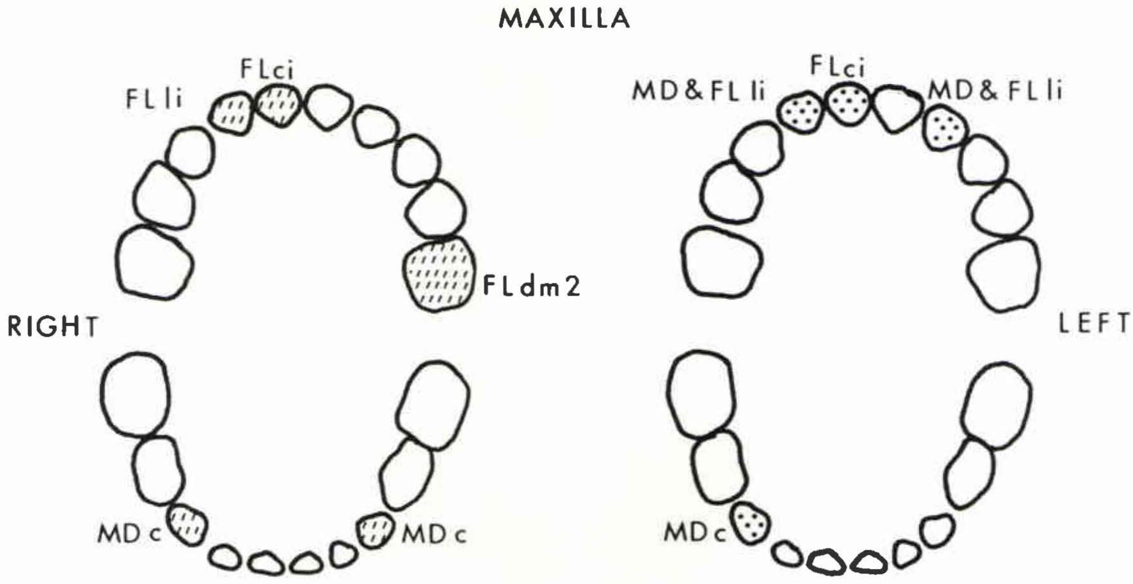
TOOTH	SIDE	T-SCORE	SIGNIFICANT AT: $p \leq 0.05$	$p \leq 0.01$	$p \leq 0.001$
Maxilla					
ci	R	3.06	x	x	
	L	3.70	x	x	x
li	R	4.18	x	x	x
		4.31	x	x	x
c	R	3.92	x	x	x
	L	4.28	x	x	x
dm1	R	3.44	x	x	x
	L	3.32	x	x	x
dm2	R	2.04	x		
	L	2.34	x		
Mandible					
ci	R	3.17	x	x	
	L	3.15	x	x	
li	R	2.70	x	x	
	L	2.47	x		
c	R	5.52	x	x	x
	L	5.06	x	x	x
dm1	R	3.36	x	x	x
	L	4.20	x	x	x
dm2	R	2.80	x	x	
	L	2.75	x	x	

TABLE 4.2: FACIOLINGUAL DECIDUOUS CROWN DIAMETERS DISPLAYING SIGNIFICANT DIFFERENCES BETWEEN MALES & FEMALES (MALES N=82 FEMALES N=80)

TOOTH	SIDE	T-SCORE	SIGNIFICANT AT:		
			$p \leq 0.05$	$p \leq 0.01$	$p \leq 0.001$
Maxilla					
ci	R	5.34	x	x	x
	L	3.99	x	x	x
li	R	4.84	x	x	x
	L	3.82	x	x	x
c	R	3.79	x	x	x
	L	3.27	x	x	x
dm1	R	4.67	x	x	x
	L	4.28	x	x	x
dm2	R	4.43	x	x	x
	L	4.93	x	x	x
Mandible					
ci	R	3.02	x	x	
	L	3.32	x	x	x
li	R	3.12	x	x	
	L	3.14	x	x	
c	R	2.64	x	x	
	L	3.40	x	x	x
dm1	R	3.11	x	x	
	L	4.03	x	x	x
dm2	R	3.28	x	x	x
	L	3.03	x	x	

FIGURE 4.3: DECIDUOUS CROWN DIAMETERS DISPLAYING THE GREATEST SIGNIFICANT DIFFERENCES & HIGHEST PERCENTAGE SEXUAL DIMORPHISM

DECIDUOUS DENTITION



A. Diameters with greatest significant differences ($p<0.001$)

B. Diameters with highest percentage sexual dimorphism

MANDIBLE

TABLE 4.3: PERMANENT FIRST MOLAR CROWN DIAMETERS DISPLAYING SIGNIFICANT DIFFERENCES BETWEEN MALES & FEMALES (MALES N=42 FEMALES N=39)

SIDE	T-SCORE	SIGNIFICANT AT: $p \leq 0.05$	$p \leq 0.01$	$p \leq 0.001$
Maxilla				
		MESIODISTAL		
R	3.72	x	x	x
L	3.41	x	x	x
		FACIOLINGUAL		
R	5.65	x	x	x
L	5.53	x	x	x
Mandible				
		MESIODISTAL		
R	4.38	x	x	x
L	4.70	x	x	x
		FACIOLINGUAL		
R	2.60	x	x	x
L	2.80	x	x	x

The coefficients of variation for the deciduous dentition for each tooth type showed females to be generally more variable than males except in the canines (Table 4.4, page 54). In both sexes together the lateral incisors were more variable than the central incisors in the maxilla, while the central incisors were more variable than the laterals in the mandible. For both sexes the second molars were less variable than the first molars in both the maxilla and mandible. In general, the second molar was the least variable tooth for either sex in either jaw, although in the female maxilla the mesiodistal diameter of the canine varies less than does the second molar. In the maxilla the lateral incisor is the most variable tooth while in the mandible the central incisor is most variable. Calculation of the mean coefficients of variation (Table 4.5, page 55) shows that, overall, the females display slightly more variability than do the males, and for both sexes, the faciolingual mandible is the most variable dimension.

The calculation of the percentage sexual dimorphism in the deciduous teeth did not reveal any systematic pattern when the diameters were ranked (Table 4.6, page 56). The percentage dimorphism ranged from 1.91% to 6.44%. The individual diameters with the highest percentage dimorphism were the mesiodistal and faciolingual diameters of the maxillary lateral incisors, the faciolingual diameter of the maxillary right central incisor, and the mesiodistal diameter of the mandibular right canine (Figure 4.3, page 51). When right and left sides were averaged (Table 4.7, page 57; Figure 4.4, page 58), dimorphism was greater in the maxillary deciduous dentition than in the mandibular and greater faciolingually than mesiodistally.

TABLE 4.4: COEFFICIENTS OF VARIATION FOR THE DECIDUOUS DENTITION (MALES N=82 FEMALES N=80)

TOOTH	SEX	MESIODISTAL		FACIOLINGUAL	
		RIGHT	LEFT	RIGHT	LEFT
<u>Maxilla</u>					
ci	M	6.14	6.45	6.16	6.73
	F	7.18	6.63	6.32	6.49
	M+F	6.83	6.80	6.76	6.92
li	M	7.05	6.57	7.67	8.77
	F	7.27	7.04	8.77	7.76
	M+F	7.51	7.15	8.76	8.66
c	M	5.53	5.44	7.62	8.26
	F	4.86	5.16	6.41	6.25
	M+F	5.44	5.60	7.36	7.61
dm1	M	5.63	6.01	5.76	5.58
	F	6.85	6.76	6.19	5.84
	M+F	6.46	6.58	6.34	6.01
dm2	M	5.22	5.17	5.17	5.39
	F	6.54	6.28	5.40	5.11
	M+F	5.96	5.81	5.57	5.63
<u>Mandible</u>					
ci	M	7.37	7.05	7.95	8.50
	F	7.16	7.48	8.41	7.86
	M+F	7.48	7.46	8.37	8.45
li	M	7.09	7.10	6.89	7.30
	F	7.46	7.11	6.67	6.54
	M+F	7.42	7.22	6.98	7.13
c	M	5.33	5.09	8.00	7.74
	F	5.30	5.06	7.15	6.28
	M+F	5.78	5.45	7.75	7.31
dm1	M	5.87	5.17	5.76	5.20
	F	5.41	5.03	6.21	6.69
	M+F	5.83	5.37	6.14	6.23
dm2	M	4.16	4.10	4.92	4.85
	F	4.86	4.60	5.69	5.77
	M+F	4.61	4.44	5.45	5.44

TABLE 4.5: MEAN COEFFICIENTS OF VARIATION FOR THE DECIDUOUS DENTITION (MALES N=82 FEMALES N=80)

	MESIODISTAL		FACIOLINGUAL	
	RIGHT	LEFT	RIGHT	LEFT
Maxilla				
Males	5.91	5.93	6.48	6.95
Females	6.54	6.37	6.62	6.29
Total Maxillary Mean:				
Males	5.92		6.72	
Females	6.46		6.46	
Mandible				
Males	5.96	5.70	6.70	6.72
Females	6.04	5.86	6.83	6.63
Total Mandibular Mean:				
Males	5.83		6.71	
Females	5.95		6.73	
Overall Total Mean				
Males	6.30			
Females	6.40			

TABLE 4.6: **PERCENTAGE SEXUAL DIMORPHISM IN THE DECIDUOUS DENTITION INCLUDING TOTAL RANK POSITION IN THE MAXILLA & MANDIBLE**

	MESIODISTAL				FACIOLINGUAL			
TOOTH	RIGHT	TOTAL RANK	LEFT	TOTAL RANK	RIGHT	TOTAL RANK	LEFT	TOTAL RANK
Maxilla								
ci	3.28	28	3.87	15	5.38	2	4.24	10
li	4.81	4	4.71	5	6.44	1	5.12	3
c	3.26	29	3.64	22	4.31	9	3.87	15
dm1	3.44	24	3.40	26	4.48	7	3.92	14
dm2	1.91	39	2.13	37	3.74	19	4.17	11
Mandible								
ci	3.70	20	3.66	21	3.96	13	4.37	8
li	3.15	31	2.80	34	3.40	26	3.49	23
c	4.71	5	4.12	12	3.21	30	3.85	17
dm1	3.03	32	3.43	25	2.96	33	3.85	17
dm2	2.01	38	1.90	40	2.77	35	2.56	36

TABLE 4.7: THE AVERAGED PERCENTAGE SEXUAL DIMORPHISM IN THE DECIDUOUS DENTITION FOR THE MESIODISTAL AND THE FACIOLINGUAL DIAMETERS*

TOOTH	MESIODISTAL	FACIOLINGUAL
Maxilla		
ci	3.56	4.81
li	4.76	5.78
c	3.45	4.09
dm1	3.42	4.20
dm2	2.02	3.96
Mandible		
ci	3.68	4.17
li	3.00	3.45
c	4.42	3.53
dm1	3.23	3.41
dm2	1.96	2.67

*Right and left sides averaged

PERCENTAGE SEXUAL DIMORPHISM

(Right and Left Sides Averaged)

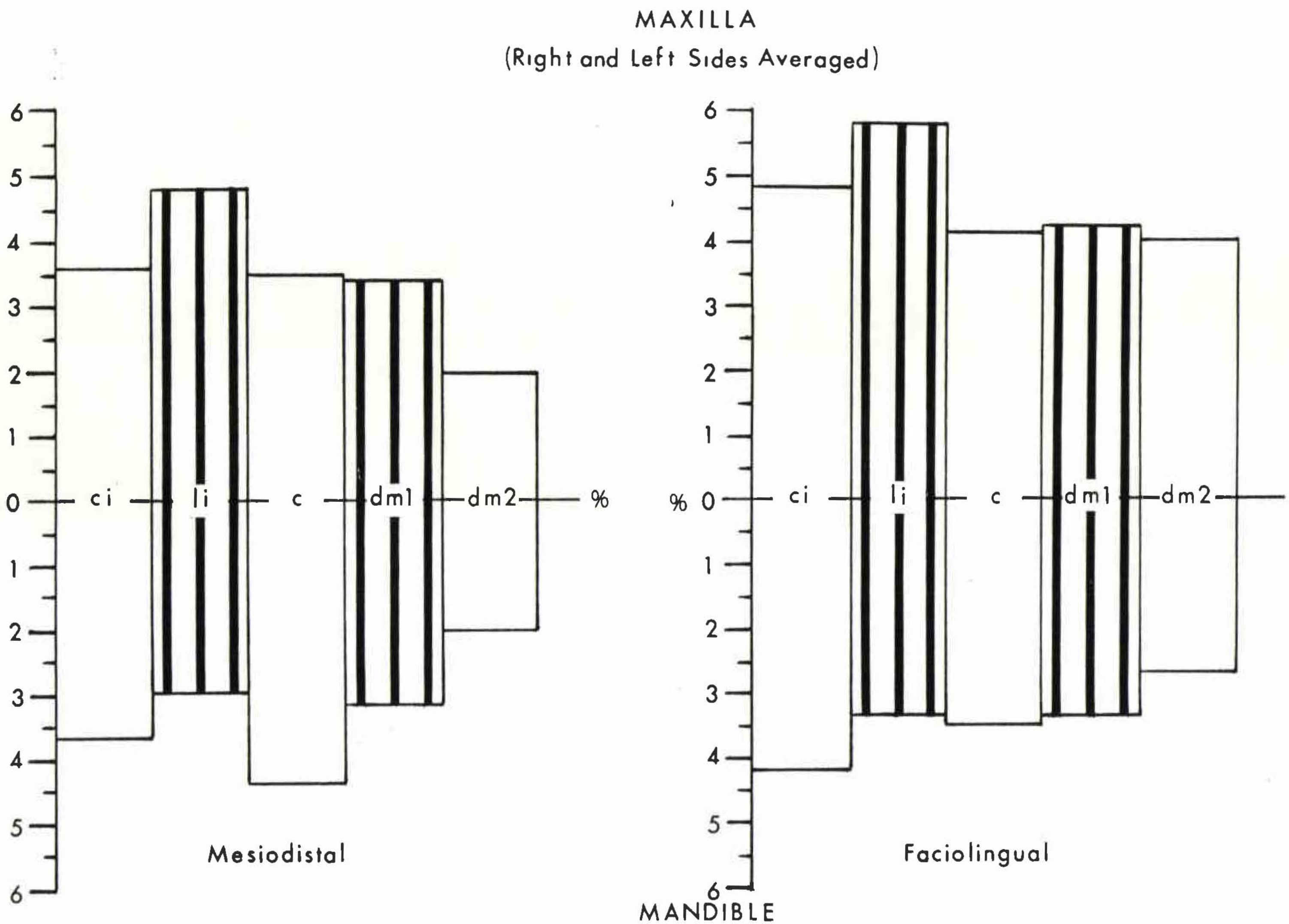


FIGURE 4.4: PERCENTAGE SEXUAL DIMORPHISM IN THE DECIDUOUS DENTITION

Multivariate Analysis

A. The Deciduous Variables

In the preliminary stepwise analysis, in which no holdout sample was specified, 157 cases (80 males and 77 females) of the 162 deciduous dentition cases were used as the analysis sample and were classified with the resulting discriminant function. The cases used were those having measurements for the 40 deciduous diameter variables. The analysis reduced the deciduous variables to a classificatory group of 16 variables which involved 14 deciduous teeth (Table 4.8, page 60). The classification of the analysis sample, using those 16 variables in a discriminant function equation, resulted in an accuracy level of 79.62%, with 125 cases being correctly classified. Sixty-six of the 80 males (82.5%) and 59 of the 77 females (76.6%) were accurately grouped.

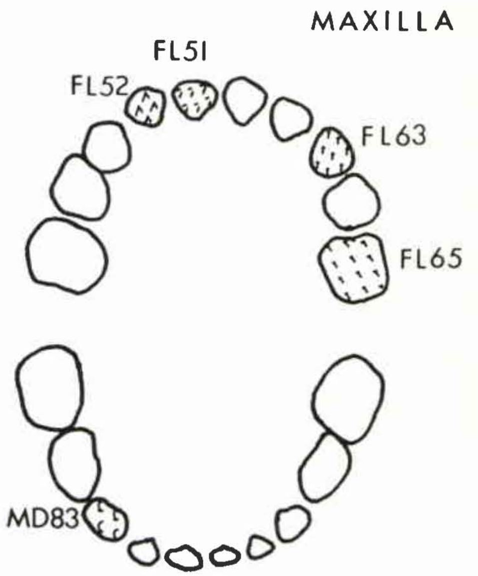
Direct discriminant analysis was then run, using the first 5 of the 16 variables which had been originally selected: in the maxilla the faciolingual diameters of the right central and lateral incisors and the left canine and second molar, and in the mandible, the mesiodistal diameter of the right canine (Figure 4.5, page 61). Of the 162 cases, 160 formed the analysis sample and the entire 162 cases were then classified with the derived discriminant function (Table 4.8, page 60). A classification accuracy of 77.16% was achieved, 125 cases of the total 162 being correctly classified, 65 of the 82 males (79.3%) and 60 of the 80 females (75.0%).

The next stepwise analysis involved Group A (Table 4.9, page 63). Keeping the holdout sample of 21 cases separate, the 136

TABLE 4.8: DISCRIMINANT ANALYSIS OF THE DECIDUOUS DENTITION (N = 162)

ANALYSIS SAMPLE		DISCRIMINANT FUNCTION STRUCTURE		PERCENT CORRECTLY CLASSIFIED ($p < 0.05$)		
SEX	N CASES	N VARIABLES USED	N TEETH USED	CLASSIFICATION SAMPLE N	CORRECTLY CLASSIFIED N	%
Stepwise Analysis:						
M	80			80	66	82.50
F	77			77	59	76.60
M+F	157	16	14	157	125	79.62
Direct Analysis:						
M	81			82	65	79.30
F	79			80	60	75.00
M+F	160	5	5	162	125	77.16

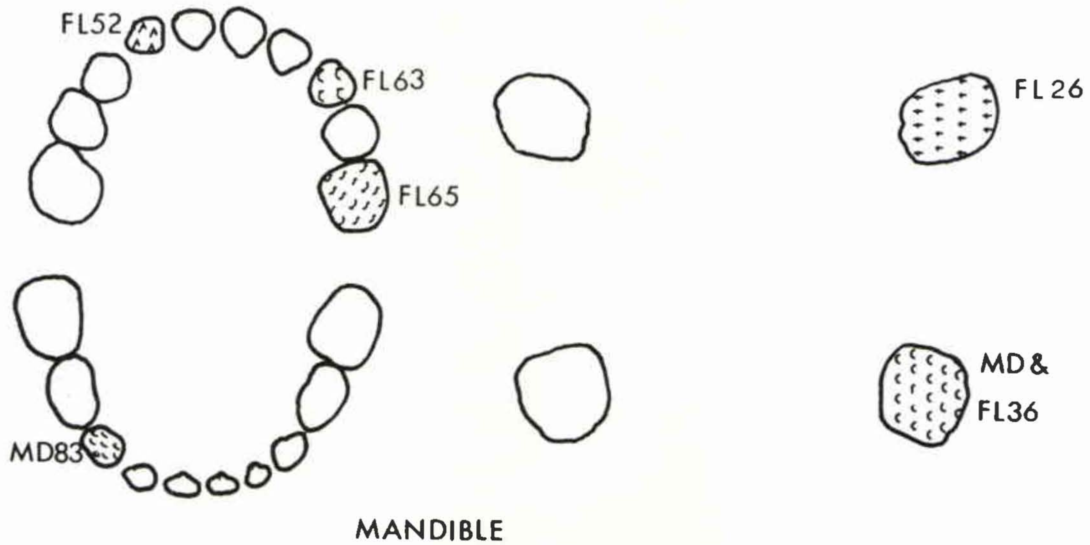
FIGURE 4.5: THE CLASSIFICATORY VARIABLES USED IN THE DIRECT DISCRIMINANT ANALYSIS



I. The 5 deciduous variables used to classify Groups A & B.

Deciduous dentition Permanent dentition

II. The 4 deciduous & 3 permanent variables used to classify Groups C & D.



remaining cases which had measurements for all 40 of the deciduous variables were used in the calculations. The analysis yielded 14 classificatory variables, and the discriminant function derived correctly grouped 138 (77.5%) of the cases which had measurements for those 14 variables. Fifty-eight (80.6%) of the 72 males and 49 (74.2%) of the 66 females in the analysis sample were accurately classified.

For the classification of the holdout group of 21 cases, 12 females and 9 males, the independent variables were reduced to the first 5 of the 16 variables selected as being the most effective discriminators. A direct analysis was then run with the 5 variables, in the maxilla, the faciolingual diameters of the right central and lateral incisors and the left canine and second molar, and in the mandible, the mesiodistal diameter of the right canine (Table 4.10, page 64; Figure 4.6, page 65). With the resulting discriminant function a classificatory accuracy of 90.48% was achieved, 19 of the 21 cases being correctly classified. Of the 9 males, 100% were correctly grouped as male, and of the 12 females, 83.3% were correctly grouped as female. The variables were then subdivided into a maxillary and a mandibular set and the holdout sample was again classified (Table 4.10, page 64; Figure 4.6, page 65). With the 4 maxillary variables, 16 (76.19%) of the 21 cases were correctly classified, 9 (75.0%) of the 12 females and 7 (77.8%) of the 9 males. With the single mandibular variable 15 cases (71.43%) were correctly grouped. Box's M test results were all non-significant.

For the stepwise discriminant analysis run with Group B, the 40 deciduous diameters were termed the independent variables. The holdout

TABLE 4.9: STEPWISE DISCRIMINANT ANALYSIS OF GROUP A USING THE 40 DECIDUOUS DIAMETER VARIABLES

	ANALYSIS SAMPLE	VARIABLES SELECTED	ANALYSIS SAMPLE CLASSIFIED	CORRECTLY CLASSIFIED		INCORRECTLY CLASSIFIED	
SEX	N	N	N	%	N	%	N
M	71		72	80.6	58	19.4	14
F	65		66	74.2	49	25.8	17
M+F	136	14	138	77.54	107	22.46	31

TABLE 4.10: DIRECT DISCRIMINANT ANALYSIS OF GROUP A USING 5 DECIDUOUS DIAMETER VARIABLES

ANALYSIS SAMPLE		VARIABLES SELECTED	HOLDOUT SAMPLE CLASSIFIED	CORRECTLY CLASSIFIED		INCORRECTLY CLASSIFIED		BOX'S M TEST ($p \leq 0.05$) SIGNIFICANCE
SEX	N	N	N	%	N	%	N	($p \leq$)
1. 4 Maxillary and 1 Mandibular Variable:								
M	73		9	100.0	9	-	0	
F	68		12	83.3	10	16.7	2	
M+F	141	5	21	90.48	19	9.52	2	0.22

Discriminant Function Equation:

- 20.342 + 1.500 (FL R max li) + 1.091 (FL R max ci) + 0.654 (FL L max dm2) - 1.489 (FL L max c) + 1.640 (MD R mand c)

SEX	N	N	N	%	N	%	N	($p \leq$)
2. 4 Maxillary Variables:								
M	73		9	77.8	7	22.2	2	
F	68		12	75.0	9	25.0	3	
M+F	141	4	21	76.19	16	23.81	5	0.16

Discriminant Function Equation:

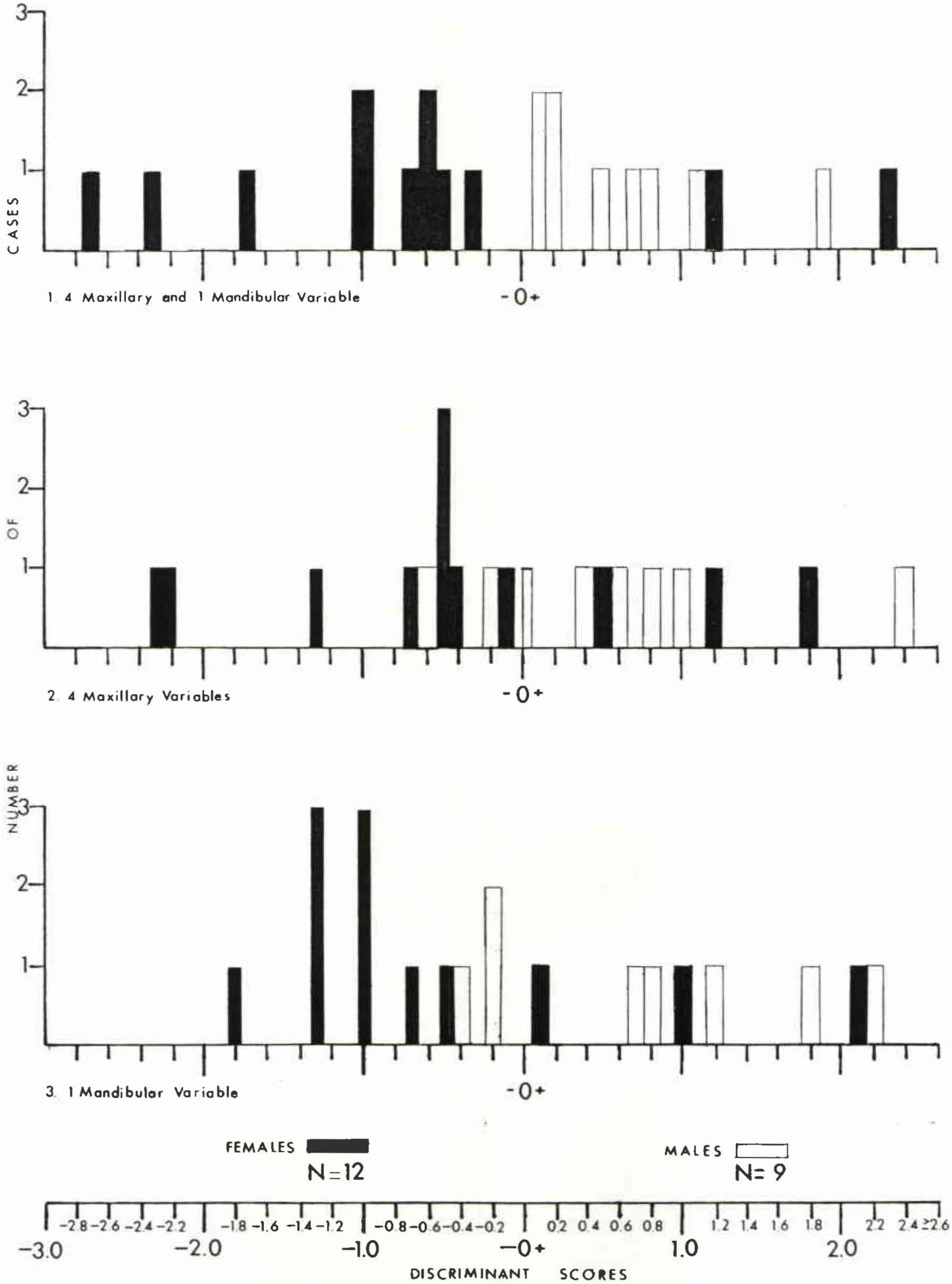
- 18.564 + 1.625 (FL R max li) + 1.239 (FL R max ci) + 1.135 (FL L max dm2) - 1.141 (FL L max c)

SEX	N	N	N	%	N	%	N	($p \leq$)
3. 1 Mandibular Variable:								
M	73		9	66.7	6	33.3	3	
F	68		12	75.0	9	25.0	3	
M+F	141	1	21	71.43	15	28.57	6	0.49

Discriminant Function Equation:

- 18.861 + 3.079 (MD R mand c)

FIGURE 4.6: GROUP A DISCRIMINANT SCORES - DECIDUOUS VARIABLES



sample (the 40 Error Study cases which were entered as 'sex unknown') was excluded from the calculation of the discriminant function. Of the remaining cases, the 119 which had measurements for all 40 diameters were used for the analysis. In that analysis 17 diameters or variables were selected as being the most effective discriminators between females and males (Table 4.11, page 67). The discriminant function derived from those 17 variables correctly classified 110 (82.64%) of the 121 cases in the analysis sample which had measurements for those variables. Of the 62 males, 56 cases (90.3%) were classified as male and of the 59 females, 44 cases (74.6%) were classified as female.

In order to test the accuracy of the discriminant function the holdout sample was then classified through direct analysis, using the same 5 deciduous diameter variables as had been used for Group A. For the 40 Error Study cases a classification accuracy of 80.0% was achieved, with 32 cases being correctly grouped (Table 4.12, page 68; Figure 4.7, page 69) when the entire 5 variables were used to derive the discriminant function. Sixteen (80.0%) of the 20 females and 16 (80.0%) of the 20 males were correctly classified by sex. Using the 4 maxillary variables, 72.5% (29 cases) of the holdout sample were correctly grouped by sex, 14 (70.0%) of the females and 15 (75.0%) of the males. With the single mandibular variable 26 cases (65.0%) of the holdout sample were correctly grouped, 13 (65.0%) of the females and 13 (65.0%) of the males. Box's M test results were all non-significant.

The stepwise analysis of Group C used a holdout sample of 21 cases and an analysis sample of 138 cases with measurements for the 40 deciduous variables and yielded 15 classificatory variables (Table

TABLE 4.11: STEPWISE DISCRIMINANT ANALYSIS OF GROUP B USING THE 40 DECIDUOUS DIAMETER VARIABLES

	ANALYSIS SAMPLE	VARIABLES SELECTED	ANALYSIS SAMPLE CLASSIFIED	CORRECTLY CLASSIFIED		INCORRECTLY CLASSIFIED	
SEX	N	N	N	%	N	%	N
M	61		62	90.3	56	9.7	6
F	58		59	74.6	44	25.4	15
M+F	119	17	121	82.64	110	17.36	21

TABLE 4.12: DIRECT DISCRIMINANT ANALYSIS OF GROUP B USING 5 DECIDUOUS DIAMETER VARIABLES

ANALYSIS SAMPLE SEX	N	VARIABLES SELECTED N	HOLDOUT SAMPLE CLASSIFIED N	CORRECTLY CLASSIFIED %	N	INCORRECTLY CLASSIFIED %	N	BOX'S M TEST ($p \leq 0.05$) SIGNIFICANCE ($p \leq$)
1. **4 Maxillary and 1 Mandibular Variable**:								
M	62		20	80.0	16	20.0	4	
F	60		20	80.0	16	20.0	4	
M+F	122	5	40	80.0	32	20.00	8	0.26

Discriminant Function Equation:

- 19.736 + 1.380 (FL R max li) + 0.896 (FL R max ci) + 0.357 (FL L max dm2) - 1.474 (FL L max c) + 2.266 (MD R mand c)

ANALYSIS SAMPLE SEX	N	VARIABLES SELECTED N	HOLDOUT SAMPLE CLASSIFIED N	CORRECTLY CLASSIFIED %	N	INCORRECTLY CLASSIFIED %	N	BOX'S M TEST ($p \leq 0.05$) SIGNIFICANCE ($p \leq$)
2. **4 Maxillary Variables**:								
M	62		20	75.0	15	25.0	5	
F	60		20	70.0	14	30.0	6	
M+F	122	4	40	72.5	29	27.5	11	0.32

Discriminant Function Equation:

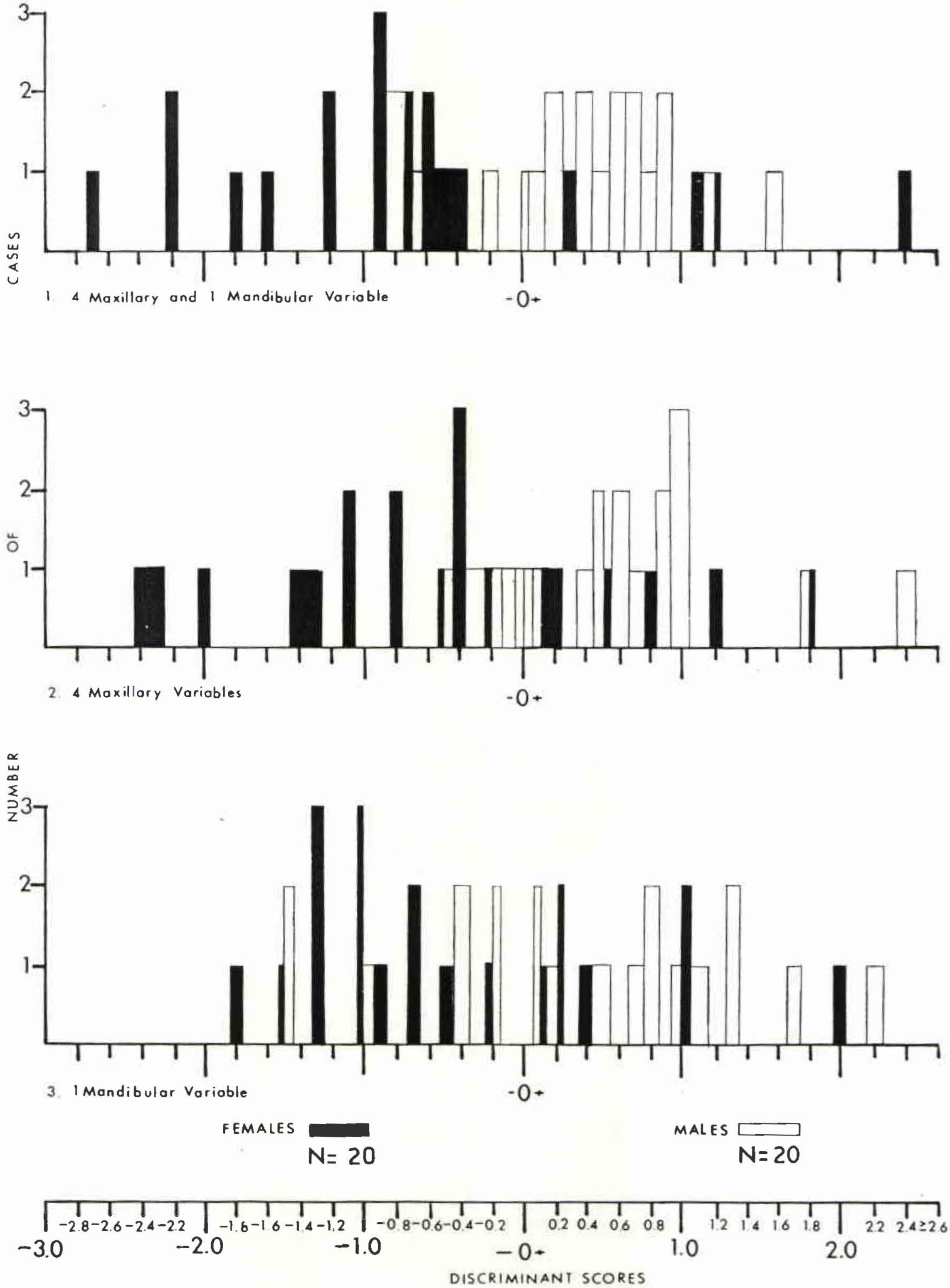
- 18.192 + 1.690 (FL R max li) + 0.967 (FL R max ci) + 1.184 (FL L max dm2) - 1.097 (FL L max c)

ANALYSIS SAMPLE SEX	N	VARIABLES SELECTED N	HOLDOUT SAMPLE CLASSIFIED N	CORRECTLY CLASSIFIED %	N	INCORRECTLY CLASSIFIED %	N	BOX'S M TEST ($p \leq 0.05$) SIGNIFICANCE ($p \leq$)
3. **1 Mandibular Variable**:								
M	62		20	65.0	13	35.0	7	
F	60		20	65.0	13	35.0	7	
M+F	122	1	40	65.0	26	35.0	14	0.64

Discriminant Function Equation:

- 18.699 + 3.051 (MD R mand c)

FIGURE 4.7: GROUP B DISCRIMINANT SCORES—DECIDUOUS VARIABLES



4.13, page 71). With those variables 109 (77.86%) of 140 cases were correctly classified. To classify the holdout sample the 15 variables were then reduced to the first 4 of the selected variables: the facio-lingual diameters of the maxillary right lateral incisor, left first molar, and left canine, and the mesiodistal diameter of the mandibular right canine. Those variables were also the first 4 of the 5 variables selected for the classification of Groups A and B (Figure 4.5, page 61).

The classification of the Group C holdout sample, using the 4 variables, resulted in an accuracy of 66.7%, with only 14 of 21 cases being correctly grouped by sex, 6 (54.5%) of the 11 females and 8 (80.0%) of the 10 males (Table 4.14,page 72; Figure 4.8, page 73). Using the 3 maxillary variables, 71.43% (15 cases) of the holdout sample were correctly grouped by sex, 7 (63.6%) of the 11 females and 8 (80.0%) of the 10 males, but the Box's M test was significant at $p \leq 0.05$. With the single mandibular variable 15 cases (71.43%) of the holdout sample were correctly grouped, 8 (72.7%) of the 11 females and 7 (70.0%) of the 10 males.

Holdout Group D consisted of 42 cases in the holdout sample and 120 remaining cases, of which 117 cases were used in the stepwise analysis to derive a discriminant function (Table 4.15, page 74). The 12 classificatory variables selected correctly grouped 93 (79.5%) of the 117 analysis sample cases by sex, 49 (80.3%) of the 61 males and 44 (78.6%) of the 56 females.

The first 4 variables selected in the Group D stepwise analysis were the same 4 variables selected in the Group C stepwise analysis and were, therefore, used in the direct analysis of the Group D holdout

TABLE 4.13: STEPWISE DISCRIMINANT ANALYSIS OF GROUP C USING THE 40 DECIDUOUS DIAMETER VARIABLES

	ANALYSIS SAMPLE	VARIABLES SELECTED	ANALYSIS SAMPLE CLASSIFIED	CORRECTLY CLASSIFIED		INCORRECTLY CLASSIFIED	
SEX	N	N	N	%	N	%	N
M	70		71	81.7	58	18.3	13
F	68		69	73.9	51	26.1	18
M+F	138	15	140	77.86	109	22.14	31

TABLE 4.14: DIRECT DISCRIMINANT ANALYSIS OF GROUP C USING 4 DECIDUOUS DIAMETER VARIABLES

ANALYSIS SAMPLE SEX	N	VARIABLES SELECTED N	HOLDOUT SAMPLE CLASSIFIED N	CORRECTLY CLASSIFIED %	N	INCORRECTLY CLASSIFIED %	N	BOX'S M TEST ($p \leq 0.05$) SIGNIFICANCE ($p \leq$)
1. 3 Maxillary and 1 Mandibular Variable:								
M	72		10	80.0	8	20.0	2	
F	69		11	54.5	6	45.5	5	
M+F	141	4	21	66.67	14	33.33	7	0.08

Discriminant Function Equation:

- 20.306 + 1.598 (FL R max li) + 1.178 (FL L max dm2) - 1.721 (FL L max c) + 1.882 (MD R mand c)

ANALYSIS SAMPLE SEX	N	VARIABLES SELECTED N	HOLDOUT SAMPLE CLASSIFIED N	CORRECTLY CLASSIFIED %	N	INCORRECTLY CLASSIFIED %	N	BOX'S M TEST ($p \leq 0.05$) SIGNIFICANCE ($p \leq$)
2. 3 Maxillary Variables:								
M	72		10	80.0	8	20.0	2	
F	69		11	63.6	7	36.4	4	
M+F	141	3	21	71.43	15	28.57	6	0.04

Discriminant Function Equation:

- 18.719 + 1.857 (FL R max li) + 1.808 (FL L max dm2) - 1.324 (FL L max c)

ANALYSIS SAMPLE SEX	N	VARIABLES SELECTED N	HOLDOUT SAMPLE CLASSIFIED N	CORRECTLY CLASSIFIED %	N	INCORRECTLY CLASSIFIED %	N	BOX'S M TEST ($p \leq 0.05$) SIGNIFICANCE ($p \leq$)
3. 1 Mandibular Variable:								
M	72		10	70.0	7	30.0	3	
F	69		11	72.7	8	27.3	3	
M+F	141	1	21	71.43	15	28.57	6	0.42

Discriminant Function Equation:

- 18.425 + 3.004 (MD R mand c)

FIGURE 4.8 : GROUP C DISCRIMINANT SCORES – DECIDUOUS VARIABLES

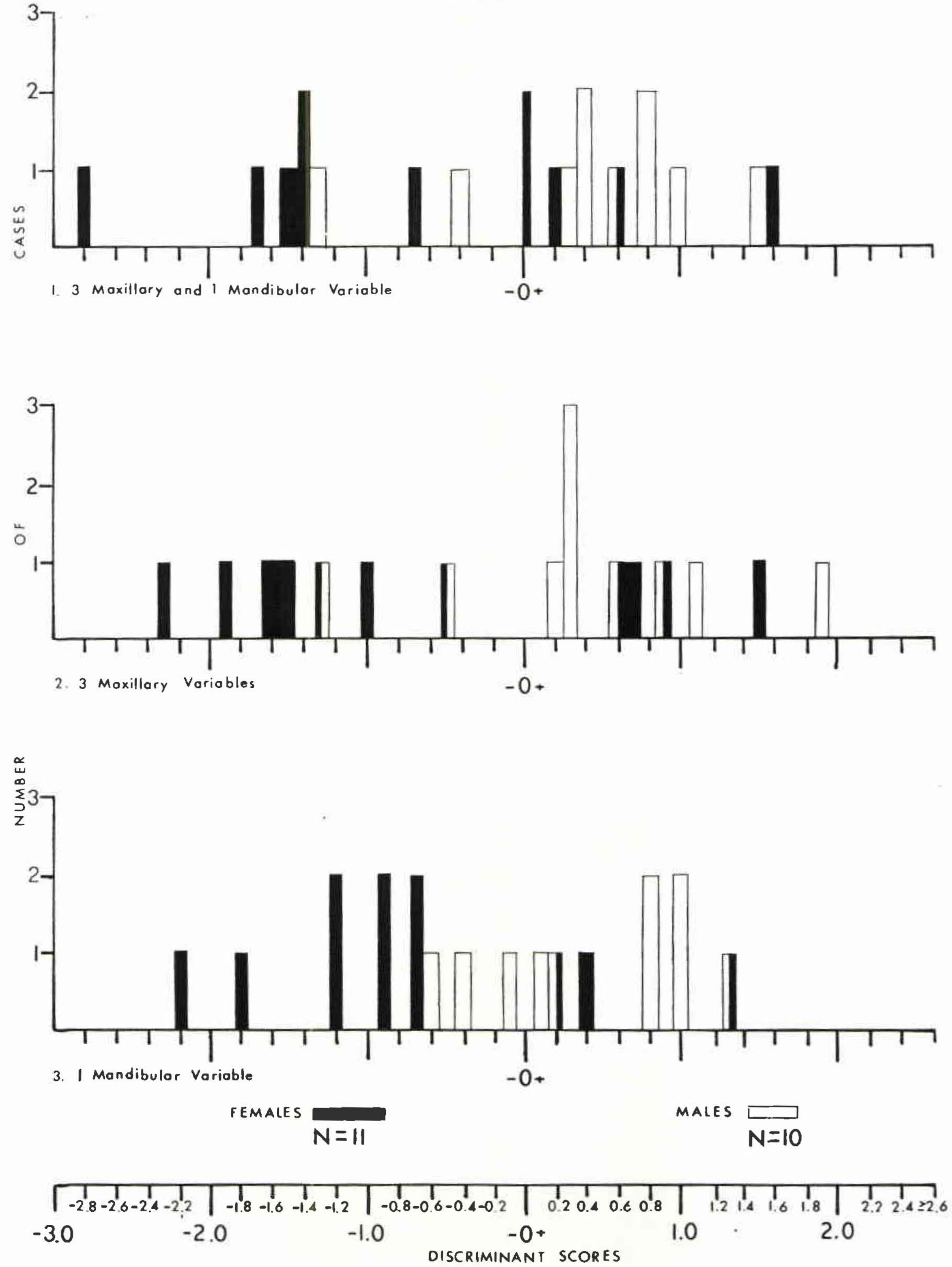


TABLE 4.15: STEPWISE DISCRIMINANT ANALYSIS OF GROUP D USING THE 40 DECIDUOUS DIAMETER VARIABLES

	ANALYSIS SAMPLE	VARIABLES SELECTED	ANALYSIS SAMPLE CLASSIFIED	CORRECTLY CLASSIFIED		INCORRECTLY CLASSIFIED	
SEX	N	N	N	%	N	%	N
M	61		61	80.3	49	19.7	12
F	56		56	78.6	44	21.4	12
M+F	117	12	117	79.49	93	20.51	24

sample (Table 4.16, page 76; Figure 4.9, page 77). The combination of all 4 variables resulted in the correct classification of 31 (73.8%) of the 42 cases, with 17 (73.9%) of the 23 females and 14 (73.7%) of the 19 males being accurately grouped by sex. With 3 maxillary variables 32 (76.19%) of the holdout sample were accurately grouped, 16 (69.57%) of the females and 16 (84.21%) of the males. With only the mandibular canine 30 (71.43%) of the 42 cases were correctly classified, 17 (73.91%) of the females and 13 (68.42%) of the males. Box's M test results were non-significant at $p \leq 0.05$.

B. The Deciduous and Permanent Variables Combined

In order to determine the effect that the addition of the permanent diameter measurements to the discriminant analysis might have upon classificatory accuracy, the Group D holdout sample, which had cases with both deciduous and permanent measurements, were each analyzed. For Group D the analysis sample contained 42 cases.

A preliminary stepwise analysis using the entire 84 permanent dentition cases as the analysis sample had shown 3 permanent diameters, the faciolingual diameter of the right maxillary permanent first molar and both diameters of the left mandibular permanent first molar, to be the most effective classificatory variables (Figure 4.5, page 61). With those three variables 64 (76.19%) of the 84 cases were correctly classified, 35 (77.8%) of the 45 females and 29 (74.4%) of the 39 males (Table 4.17, page 78).

The stepwise analysis of Group D, using 42 cases in the

TABLE 4.16: DIRECT DISCRIMINANT ANALYSIS OF GROUP D USING 4 DECIDUOUS DIAMETER VARIABLES

ANALYSIS SAMPLE SEX	N	VARIABLES SELECTED N	HOLDOUT SAMPLE CLASSIFIED N	CORRECTLY CLASSIFIED %	N	INCORRECTLY CLASSIFIED %	N	BOX'S M TEST ($p \leq 0.05$) SIGNIFICANCE ($p \leq$)
1. 3 Maxillary and 1 Mandibular Variable:								
M	63		19	73.7	14	26.3	5	
F	57		23	73.9	17	26.1	6	
M+F	120	4	42	73.8	31	26.2	11	0.18
2. 3 Maxillary Variables:								
M	63		19	84.21	16	15.79	3	
F	57		23	69.57	16	30.43	7	
M+F	120	3	42	76.19	32	23.81	10	0.10
3. 1 Mandibular Variable:								
M	63		19	68.42	13	31.58	6	
F	57		23	73.91	17	26.09	6	
M+F	120	1	42	71.43	30	28.57	12	0.28

Discriminant Function Equations:

1. 3 Maxillary and 1 Mandibular Variable:

- 20.138 + 1.899 (FL R max li) + 1.174 (FL L max dm2) - 1.750 (FL L max c) + 1.653 (MD R mand c)

2. 3 Maxillary Variables:

- 18.425 + 2.084 (FL R max li) + 1.688 (FL L dm2) - 1.353 (FL L max c)

3. 1 Mandibular Variable:

- 18.407 + 3.000 (MD R mand c)

FIGURE 4.9: GROUP D DISCRIMINANT SCORES – DECIDUOUS VARIABLES

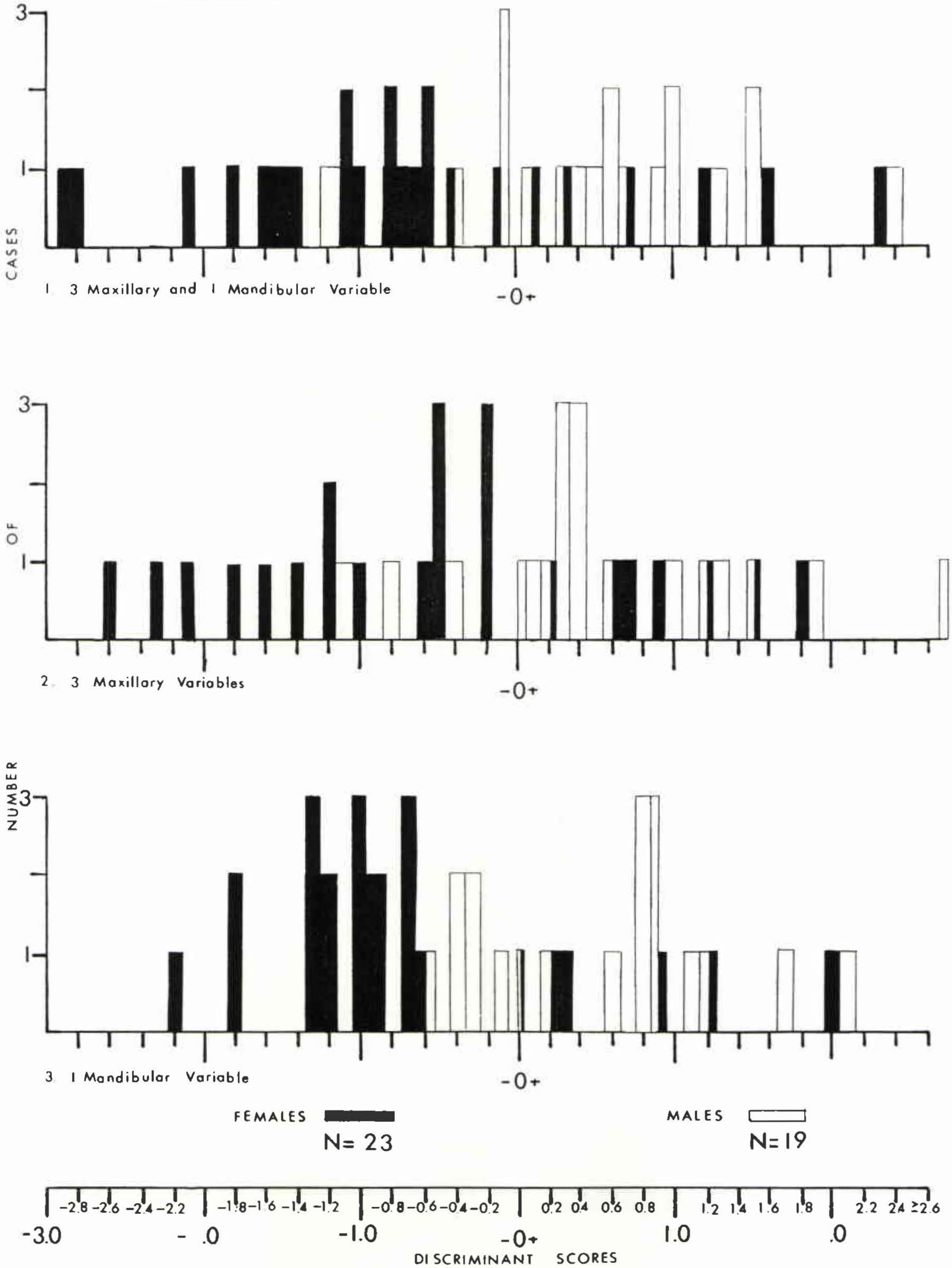


TABLE 4.17: STEPWISE DISCRIMINANT ANALYSIS OF THE PERMANENT DENTITION USING THE 8 PERMANENT DIAMETER VARIABLES

ANALYSIS SAMPLE		DISCRIMINANT FUNCTION STRUCTURE		PERCENT CORRECTLY CLASSIFIED ($p < 0.05$)		
SEX	N CASES	N VARIABLES USED	N TEETH USED	CLASSIFICATION SAMPLE N	CORRECTLY CLASSIFIED N	%
M	39			39	29	74.4
F	45			45	35	77.8
M+F	84	3	2	84	64	76.19

analysis sample, resulted in 3 permanent diameters being the most effective classificatory variables: the faciolingual diameter of the left maxillary permanent first molar and both diameters of the left mandibular permanent first molar (Figure 4.5, page 61). With those 3 variables, 31 (73.81%) of the 42 cases were correctly classified, 15 (75.0%) of the 20 males and 16 (72.7%) of the 22 females (Table 4.18, page 80).

To classify the Group D holdout sample, various combinations of the 4 deciduous and 3 permanent variables were used (Table 4.19, page 81; Figure 4.10, page 82). All 7 variables produced a classification accuracy of 83.3%, correctly grouping 35 of the 42 cases, 21 (91.3%) of the 23 females and 14 (73.68%) of the 19 males. The 4 maxillary variables produced a classification accuracy of 78.57%, correctly grouping 33 of 42 cases, 19 (82.61%) of the females and 14 (73.68%) of the males. With the 3 mandibular variables 83.3% (35 cases) were correctly classified, 20 (86.96%) of the females and 15 (78.95%) of the males.

However, Box's M test results were significant for the last 2 of the 3 subsections of the Group D direct discriminant analysis. Therefore, an analysis was run with Group C to see if similar results would be obtained. The use of the same 3 combinations of the deciduous and permanent variables, a larger analysis sample (63 cases), and a smaller holdout sample (21 cases), produced an overall classification accuracy of 85.7% for each combination of the variables and non-significant Box's M test results (Table 4.20, page 83; Figure 4.11, page 84).

TABLE 4.18: STEPWISE DISCRIMINANT ANALYSIS OF GROUP D USING THE 8 PERMANENT DIAMETER VARIABLES

ANALYSIS SAMPLE		DISCRIMINANT FUNCTION STRUCTURE		PERCENT CORRECTLY CLASSIFIED ($p < 0.05$)		
SEX	N CASES	N VARIABLES USED	N TEETH USED	CLASSIFICATION SAMPLE N	CORRECTLY CLASSIFIED N	%
M	20			20	15	75.0
F	22			22	16	72.7
M+F	42	3	2	42	31	73.81

TABLE 4.19: DIRECT DISCRIMINANT ANALYSIS OF GROUP D USING 4 DECIDUOUS AND 3 PERMANENT VARIABLES

ANALYSIS SAMPLE SEX	ANALYSIS SAMPLE N	VARIABLES SELECTED N	HOLDOUT SAMPLE CLASSIFIED N	CORRECTLY CLASSIFIED %	CORRECTLY CLASSIFIED N	INCORRECTLY CLASSIFIED %	INCORRECTLY CLASSIFIED N	BOX'S M TEST ($p \leq 0.05$) SIGNIFICANCE ($p \leq$)
1. 4 Deciduous and 3 Permanent Variables:								
M	20		19	73.68	14	26.32	5	
F	22		23	91.3	21	8.7	2	
M+F	42	7	42	83.3	35	16.7	7	0.09

Discriminant Function Equation:

- 16.413 + 0.162 (FL R max li) - 0.577 (FL L max dm2) - 0.315 (FL L max c) + 0.473 (MD R mand c) + 2.324 (FL L max M1) + 0.836 (MD L mand M1) - 1.496 (FL L mand M1)

ANALYSIS SAMPLE SEX	ANALYSIS SAMPLE N	VARIABLES SELECTED N	HOLDOUT SAMPLE CLASSIFIED N	CORRECTLY CLASSIFIED %	CORRECTLY CLASSIFIED N	INCORRECTLY CLASSIFIED %	INCORRECTLY CLASSIFIED N	BOX'S M TEST ($p \leq 0.05$) SIGNIFICANCE ($p \leq$)
2. 3 Deciduous and 1 Permanent Maxillary Variable:								
M	20		19	73.68	14	26.32	5	
F	22		23	82.61	19	17.39	4	
M+F	42	4	42	78.57	33	21.43	9	0.05

Discriminant Function Equation:

- 20.547 - 0.061 (FL R max li) - 0.482 (FL L max dm2) + 0.181 (FL L max c) + 2.029 (FL L max M1)

ANALYSIS SAMPLE SEX	ANALYSIS SAMPLE N	VARIABLES SELECTED N	HOLDOUT SAMPLE CLASSIFIED N	CORRECTLY CLASSIFIED %	CORRECTLY CLASSIFIED N	INCORRECTLY CLASSIFIED %	INCORRECTLY CLASSIFIED N	BOX'S M TEST ($p \leq 0.05$) SIGNIFICANCE ($p \leq$)
3. 1 Deciduous and 2 Permanent Mandibular Variables:								
M	20		19	78.95	15	21.05	4	
F	22		23	86.96	20	13.04	3	
M+F	42	3	42	83.3	35	16.7	7	0.03

Discriminant Function Equation:

- 17.866 + 1.809 (MD R mand c) + 0.842 (MD L mand M1) - 0.251 (FL L mand M1)

FIGURE 4.10: GROUP D DISCRIMINANT SCORES — DECIDUOUS AND PERMANENT VARIABLES COMBINED

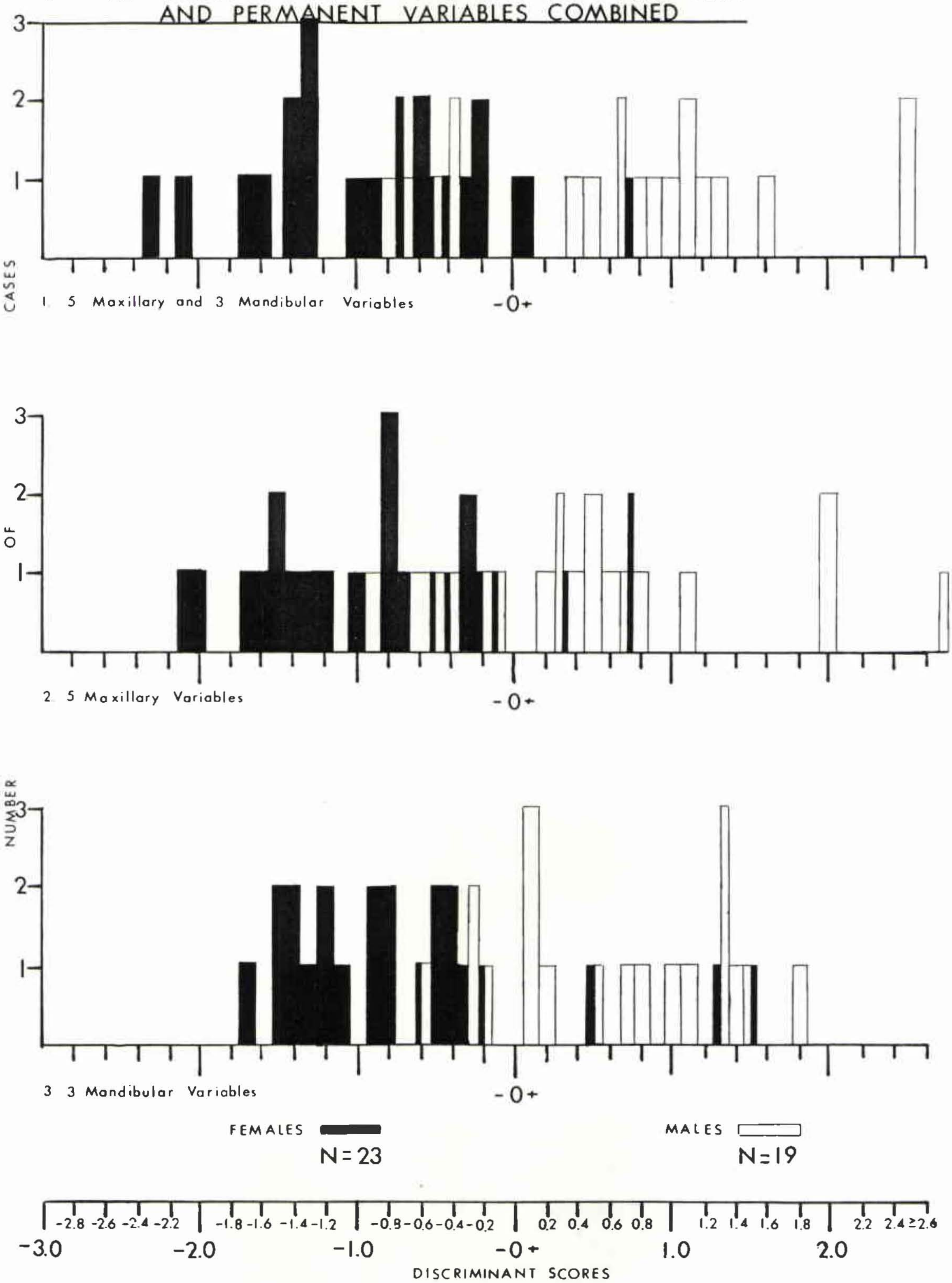


TABLE 4.20: DIRECT DISCRIMINANT ANALYSIS OF GROUP C USING 4 DECIDUOUS AND 3 PERMANENT VARIABLES

ANALYSIS SAMPLE SEX	ANALYSIS SAMPLE N	VARIABLES SELECTED N	HOLDOUT SAMPLE CLASSIFIED N	CORRECTLY CLASSIFIED %	CORRECTLY CLASSIFIED N	INCORRECTLY CLASSIFIED %	INCORRECTLY CLASSIFIED N	BOX'S M TEST ($p \leq 0.05$) SIGNIFICANCE ($p \leq$)
1. 4 Deciduous and 3 Permanent Variables:								
M	29		10	80.0	8	20.0	2	
F	34		11	90.9	10	9.1	1	
M+F	63	7	21	85.7	18	14.3	3	0.33

Discriminant Function Equation:

- 17.423 + 0.542 (FL R max li) + 0.279 (FL L max dm2) - 0.723 (FL L max c) + 1.058 (MD R mand c) + 1.837 (FL L max M1) + 0.628 (MD L mand M1) - 1.692 (FL L mand M1)

ANALYSIS SAMPLE SEX	ANALYSIS SAMPLE N	VARIABLES SELECTED N	HOLDOUT SAMPLE CLASSIFIED N	CORRECTLY CLASSIFIED %	CORRECTLY CLASSIFIED N	INCORRECTLY CLASSIFIED %	INCORRECTLY CLASSIFIED N	BOX'S M TEST SIGNIFICANCE ($p \leq$)
2. 3 Deciduous and 1 Permanent Maxillary Variable:								
M	29		10	80.0	8	20.0	2	
F	34		11	90.9	10	9.1	1	
M+F	63	4	21	85.7	18	14.3	3	0.07

Discriminant Function Equation:

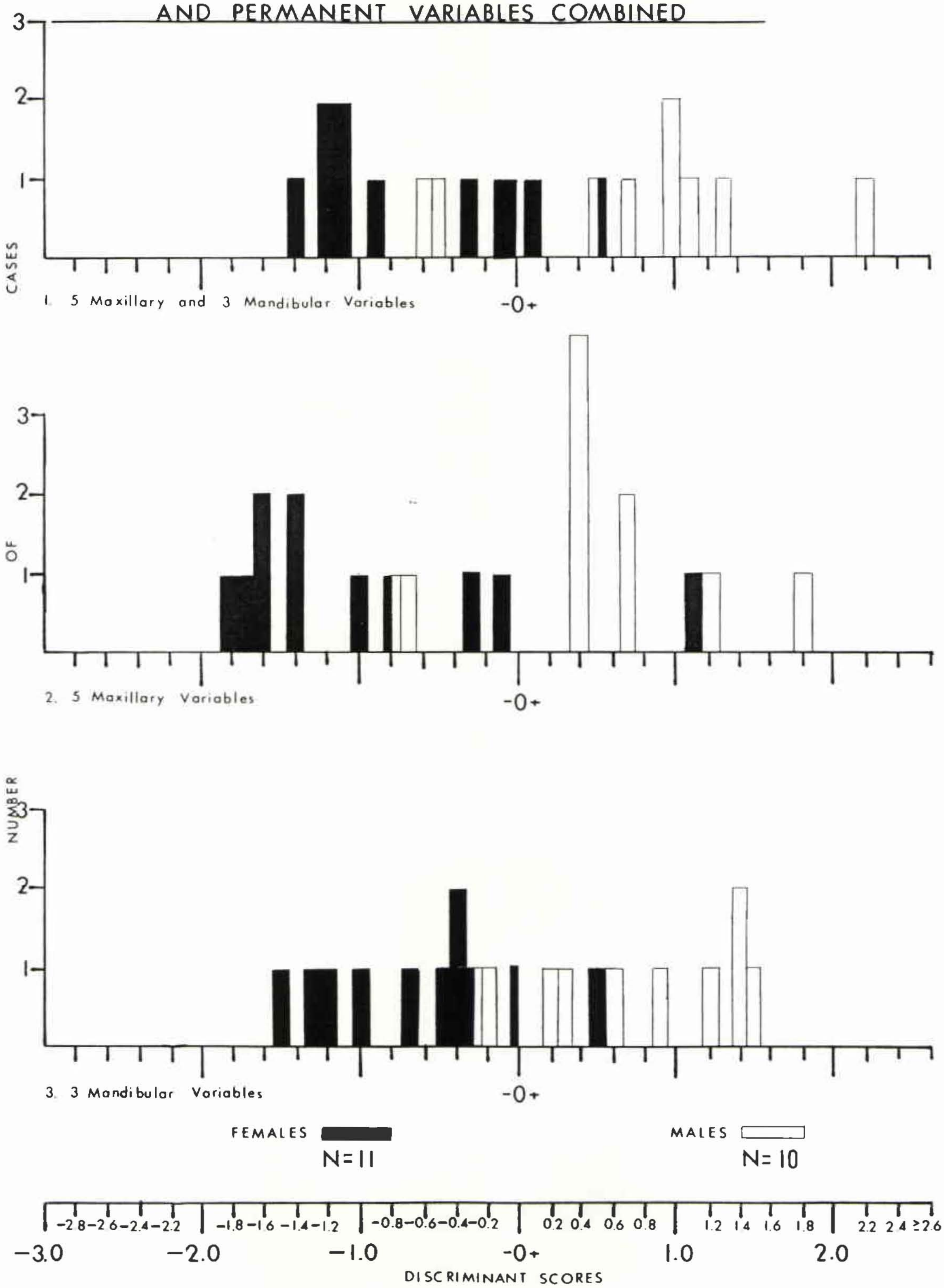
- 21.314 + 0.574 (FL R max li) + 0.393 (FL L max dm2) - 0.371 (FL L max c) + 1.521 (FL L max M1)

ANALYSIS SAMPLE SEX	ANALYSIS SAMPLE N	VARIABLES SELECTED N	HOLDOUT SAMPLE CLASSIFIED N	CORRECTLY CLASSIFIED %	CORRECTLY CLASSIFIED N	INCORRECTLY CLASSIFIED %	INCORRECTLY CLASSIFIED N	BOX'S M TEST SIGNIFICANCE ($p \leq$)
3. 1 Deciduous and 2 Permanent Mandibular Variables:								
M	29		10	80.0	8	20.0	2	
F	34		11	90.9	10	9.1	1	
M+F	63	3	21	85.7	18	14.3	3	0.31

Discriminant Function Equation:

- 16.872 + 2.049 (MD R mand c) + 0.887 (MD L mand M1) - 0.516 (FL L mand M1)

FIGURE 4.11: GROUP C DISCRIMINANT SCORES – DECIDUOUS AND PERMANENT VARIABLES COMBINED



CHAPTER FIVE

DISCUSSION

Univariate Statistical Analysis

A. Univariate Statistical Results

The Burlington data proved to be normally distributed for males and for females and displayed significant sexual dimorphism for all tooth types, with all male means being greater than female means. The percentage sexual dimorphism expressed in the Burlington data approximates the results determined for the permanent teeth of various populations by Garn et al. (1967), Potter et al. (1981), and by Axelsson & Kirveskari (1983).

The females were more variable than the males for all the teeth except the canines, and the faciolingual mandible was most variable in both sexes. Percentage sexual dimorphism ranged from 1.91% to 6.44% and was greatest in the faciolingual maxilla. The teeth displaying the greatest sexual dimorphism were the maxillary lateral incisors, the faciolingual right maxillary central incisor, and the mesiodistal right mandibular canine.

B. Intergroup Comparisons: Deciduous Teeth

1. Factors Affecting Such Comparisons

Although the main goal of this study was to determine the classificatory effectiveness of a discriminant function, an additional objective was to compare the univariate statistical results to those published by other researchers. Studies of the deciduous dentition (and permanent also) base their conclusions about population differences and similarities upon such intergroup comparisons.

However, several factors must be considered before assuming that such comparisons will be valid. These include deciding whether a sample used in a study is truly representative of the population and whether the methods used to obtain the raw data are actually equivalent. Axelsson and Kirveskari (1984), for example, maintain that Icelanders have a larger deciduous dentition than do "...modern whites...of mainly Northwest European origin..." (Axelsson & Kirveskari 1984: 342), but make comparisons only with Black's (1978) study of American children. The question is whether that study population is really representative of modern white children of Northwest European origin. Sawyer et al. (1982) in a comparison of Pre-Columbian Peruvian deciduous dentition with Black's (1978) study describe that sample more narrowly as "...modern, Ohio whites..." (Sawyer et al. 1982: 375), as does Lukacs (1981: 265, Table 3), but Lukacs then concludes that the deciduous crown diameters of his East Indian sample exceed those of "American children of European descent..." (Lukacs 1981: 262), a group again represented only by that Ohio sample.

Attention must be paid to the methods of obtaining the raw data in these studies. Variation in sample sizes can affect the reliability of the individual variables being used for comparison. Differing measurement methods and treatments of the raw measurement data can produce nonequivalent variables. Therefore, when samples and/or measurement methods vary among studies, only very general conclusions should be made about any intergroup similarities and differences.

2. Groups Included in the Comparisons

Initially, the results of 6 studies involving modern (20th Century) populations were chosen to compare to the present study. These included Moorrees (1959), Black (1978), Margetts and Brown (1978), Lysell and Myrberg (1982), Lukacs, Joshi, and Makhija (1983), and Axelsson and Kirveskari (1984). The studies conducted by Moorrees (1959) and Black (1978) involved American white children of European origin. Moorrees' (1959) 184 children, 91 males and 93 females, were from the Northeastern U.S.A. Black's (1978) 133 children, 69 males and 64 females, were from Ohio and were part of the University School Growth Study of the University of Michigan. Margetts and Brown (1978) examined 197 Australian Aboriginal children, 119 males and 78 females, from the Northern Territory, but the actual number of individuals measured varied for each diameter, from a low of 8 cases to a high of 115 cases. Lysell and Myrberg (1982) used 1,110 Swedish children, 530 males and 580 females and although varying numbers of children were used in obtaining each diameter, the actual number was always greater than 300 cases. Lukacs, Joshi, and Makhija (1983) measured 100 Gujarti Hindu children from Western India, 50 males and 50 females. Axelsson and Kirveskari (1984) studied a total of 540 Icelandic children, 286 males and 254 females, but for each diameter measured, the sample size varied from as few as 6 to as many as 245 cases.

3. Measurement Methods Used in the Study of each Group

A comparison of measurement methods reveals that several of the studies differ in method from the present study (Table 5.1, page 89). For example, Moorrees (1959) used dental casts and measured between contact points, but he measured only the mesiodistal diameter, used sliding calipers reading to 0.10mm, and averaged the measurements made on the right and left sides. Margetts and Brown (1978) used dental casts, measured between contact points, measured both the faciolingual and the mesiodistal diameters, and used a Helios dial caliper, but readings were taken to 0.10mm and the measurements made on the right and left side of each dental cast were then averaged (Margetts & Brown 1978: 494). Black (1978) also measured between contact points and measured both the faciolingual and mesiodistal diameters, but he used the OPTOCOM, an optical digitizing instrument which reads to 0.10mm (Moyers et al. 1976; van der Linden et al. 1972), obtained measurements only from the right side of the dental arch, and then averaged the measurements made on multiple casts of each individual. Lysell and Myrberg (1982) used sliding calipers reading to 0.10mm and measured only the maximum mesiodistal diameter of both the right and the left sides of dental casts. Luckacs, Joshi, and Makhija (1983) made multiple measurements on a single cast for each individual until the readings were consistent, using Helios dial calipers reading to 0.05mm. However, only left-side data was used and the final measurement was

TABLE 5.1: THE STRUCTURE OF THE MODERN STUDIES USED IN THE DATA COMPARISONS

Study	EQUIPMENT: HELIOS DIAL CALIPER YES	NO	CALIPER MM: 0.10	0.05	DENTAL ARCH: R	L	DIAMETERS: MD	FL	MD DIAMETER MEASURED: BETWEEN CONTACT POINTS	MAXIMUM	TREATMENT OF DATA
1. Moorrees (1959):		x	x		x	x	x		x		Averaged R & L sides
2. Black (1978)		x	x		x		x	x	x		Averaged measurements from multiple casts.
3. Margetts and Brown (1978)	x		x		x	x	x	x	x		Averaged R & L sides
4. Lysell and Myrberg (1982)	x		x		x	x	x			x	
5. Lukacs, Joshi, and Makhija (1983)	x			x		x	x	x	x		Measurements rounded off to 0.10mm. Repeated measurements made until readings consistent.
6. Axelsson and Kirveskari (1984)	x			x	x		x	x		x	
7. De Vito (1988)	x			x	x	x	x	x	x		

rounded off to the nearest 0.10mm. Axelsson and Kirveskari (1984) measured the faciolingual and the mesiodistal diameters with calipers reading to 0.05mm, but measured the maximum mesiodistal diameter (which would affect the determination of the measuring reference points and the results for the faciolingual diameter, as discussed on page 10), and used measurements obtained only from the right side of the dental cast.

In making comparisons among the seven studies the means ($\bar{X}$), the coefficients of variation (CV), and the percentage sexual dimorphism results were all examined. For the Burlington group, only the results for the right side of the dental arches were used.

4. Comparison of the Means ($\bar{X}$)

Comparisons of the sample means ($\bar{X}$) are summarized in Tables 5.2-5.3 (pages 91-92) and Figures 5.1-5.4 (pages 93-96). Though the differences among the groups are greater for the male means than for the females, the Australian group has the largest means for crown dimensions in both males and females, particularly for the mesiodistal maxillary central and lateral incisors. The Aboriginal group means converge closely with those for the other groups only in the facio-lingual maxilla. The distinctly large means for the deciduous tooth crown diameters of the Australian Aborigines in comparison to the means for other populations has been noted by other researchers (including Lukacs 1981; Margetts & Brown 1978; Axelsson & Kirveskari 1984; Sawyer et al. 1982).

For the six groups remaining mesiodistally, the Burlington, Icelandic, and Indian groups display the largest means. The means for

TABLE 5.2: MESIODISTAL DECIDUOUS CROWN DIAMETERS
- COMPARATIVE DATA FOR THE MEANS (X)

		MOORREES (1959)		MARGETTS & BROWN (1978)		LYSELL & MYRBERG (1982)		AXELSSON & KIRVESKARI (1984)		LUKACS JOSHI & MAKHIJA (1983)	BLACK (1978)	DE VITO (1988)
(SIDE:		R+L		R+L		R		R		L	R	R)
										M N=50	M N=69	M N=82
										F N=50	F N=64	F N=80
TOOTH	SEX	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	$\bar{X}$	$\bar{X}$	$\bar{X}$
<u>Maxilla</u>												
ci	M	64	6.55	29	7.35	369	6.41	20	6.49	6.73	6.40	*6.69
	F	69	6.44	18	7.20	394	6.31	18	6.43	6.52	6.52	*6.48
li	M	64	5.32	54	6.00	443	5.23	71	5.35	5.50	5.24	5.52
	F	69	5.23	36	5.93	460	5.15	50	5.28	5.31	5.33	5.27
c	M	65	6.88	113	7.41	510	6.86	236	6.98	6.82	6.78	7.27
	F	69	6.67	77	7.21	559	6.70	193	6.90	6.53	6.66	7.04
dm1	M	64	7.12	112	7.55	428	6.94	116	7.17	7.44	6.69	7.35
	F	68	6.95	74	7.28	478	6.75	118	7.04	7.12	6.59	7.11
dm2	M	63	9.08	113	9.65	459	8.60	168	9.00	9.21	8.84	9.21
	F	68	8.84	76	9.42	525	8.38	158	8.97	9.08	8.79	9.04
<u>Mandible</u>												
ci	M	64	4.08	18	4.51	342	4.06	10	4.27	4.18	4.03	*4.29
	F	68	3.98	8	4.34	350	4.00	6	3.90	4.05	4.10	4.14
li	M	65	4.74	34	5.01	443	4.65	36	4.70	4.76	4.58	4.94
	F	69	4.63	19	4.91	460	4.57	26	4.57	4.66	4.72	*4.78
c	M	65	5.92	109	6.31	498	5.86	187	5.94	5.91	5.83	6.27
	F	68	5.74	62	6.16	548	5.74	132	5.82	5.77	5.81	5.98
dm1	M	65	7.80	109	8.25	346	7.64	80	7.98	8.15	7.85	8.05
	F	69	7.65	70	8.12	414	7.41	80	7.81	7.78	7.74	7.82
dm2	M	63	9.83	115	10.89	514	9.50	96	10.11	10.24	9.88	9.94
	F	69	9.64	69	10.64	427	9.31	93	9.95	9.91	9.69	9.75

* M N=81 and/or F N=79

TABLE 5.3: FACIOLINGUAL DECIDUOUS CROWN DIAMETERS - COMPARATIVE DATA FOR THE MEANS (X)

		MARGETTS & BROWN (1978)		AXELSSON & KIRVESKARI (1984)		LUKACS JOSHI & MAKHIJA (1983)	BLACK (1978)	DE VITO (1988)
(SIDE:		R+L		R		L	R	R)
						M N=50	M N=69	M N=82
						F N=50	F N=64	F N=80
TOOTH	SEX	N	$\overline{X}$	N	$\overline{X}$	$\overline{X}$	$\overline{X}$	$\overline{X}$
Maxilla								
ci	M	29	5.47	29	5.08	5.25	5.13	5.41
	F	18	5.30	20	5.01	5.04	5.19	5.13
li	M	56	5.24	70	5.01	4.94	4.71	4.93
	F	36	5.01	54	4.93	4.71	4.64	4.64
c	M	113	6.61	238	6.37	6.19	6.11	6.36
	F	77	6.34	196	6.27	5.96	5.97	6.10
dm1	M	114	9.07	212	8.87	9.07	8.83	8.77
	F	76	8.77	174	8.69	8.76	8.56	8.39
dm2	M	114	10.65	245	10.10	10.15	9.54	10.18
	F	76	10.27	200	9.88	9.75	9.36	9.81
Mandible								
ci	M	18	4.33	11	3.91	3.88	3.86	4.09
	F	8	4.19	6	3.78	3.87	3.84	3.93
li	M	33	4.75	35	4.45	4.35	4.37	4.56
	F	18	4.65	26	4.29	4.21	4.35	4.41
c	M	102	6.05	188	5.71	5.64	5.60	5.66
	F	60	5.84	133	5.61	5.38	5.55	5.48
dm1	M	112	7.92	162	7.35	7.51	7.37	7.24
	F	73	7.49	136	7.29	7.27	7.31	7.03
dm2	M	115	9.87	133	9.09	9.32	8.90	9.25
	F	75	9.57	107	9.02	8.87	8.70	9.01

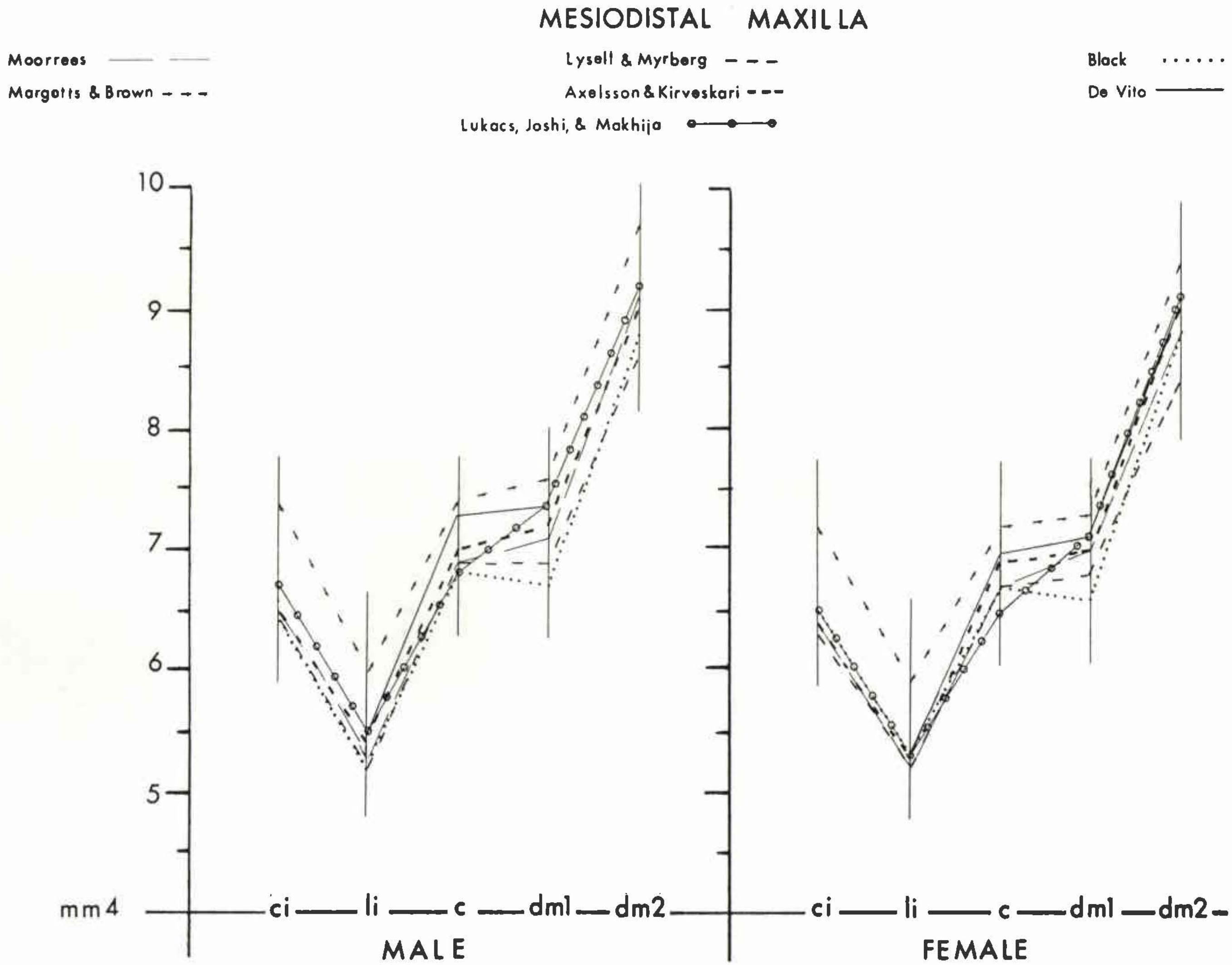


FIGURE 5.1: MESIODISTAL MAXILLA— COMPARATIVE DATA FOR THE MEAN ($\bar{X}$)

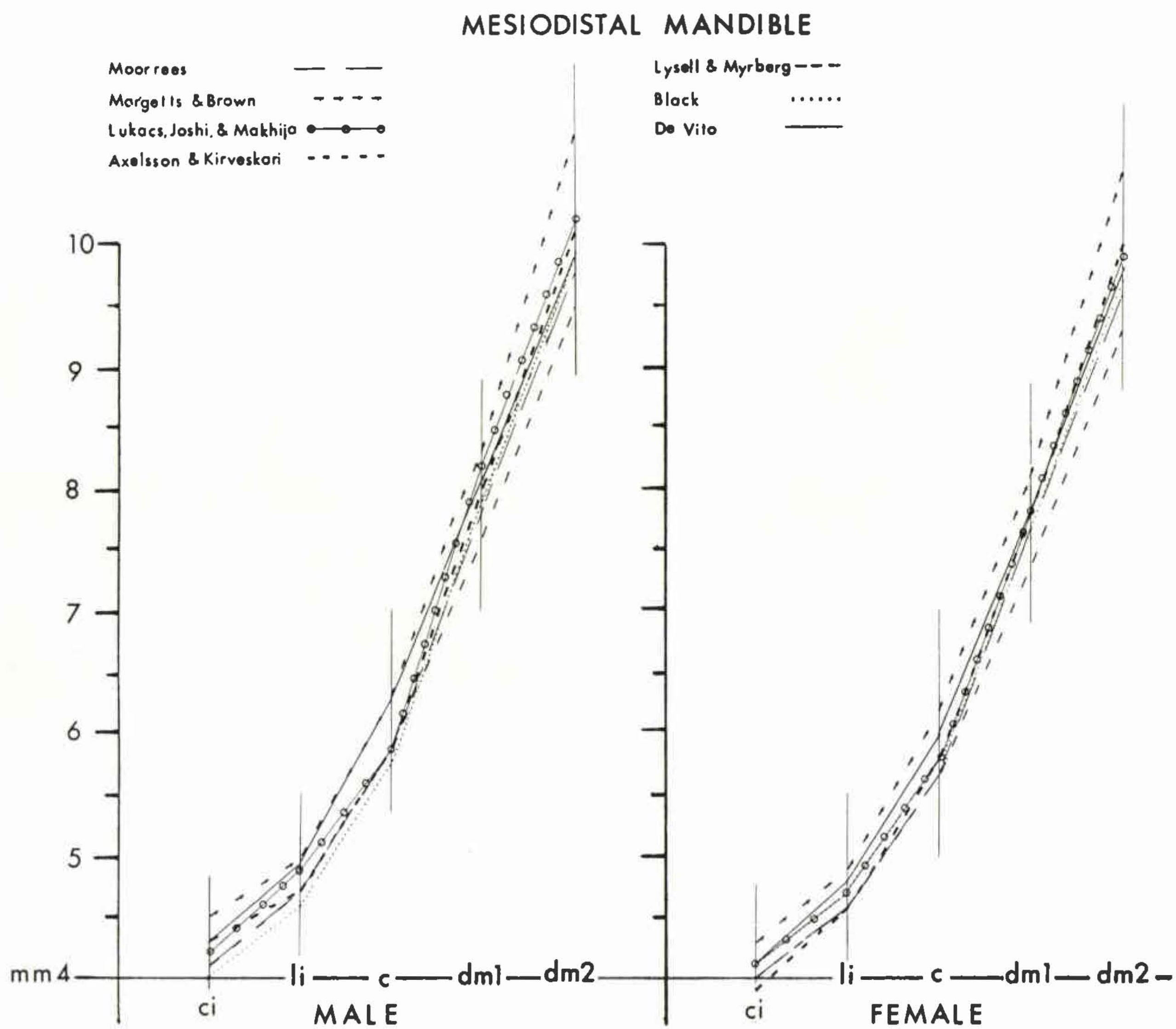


FIGURE 5.2: MESIODISTAL MANDIBLE—COMPARATIVE DATA FOR THE MEAN ($\bar{X}$)

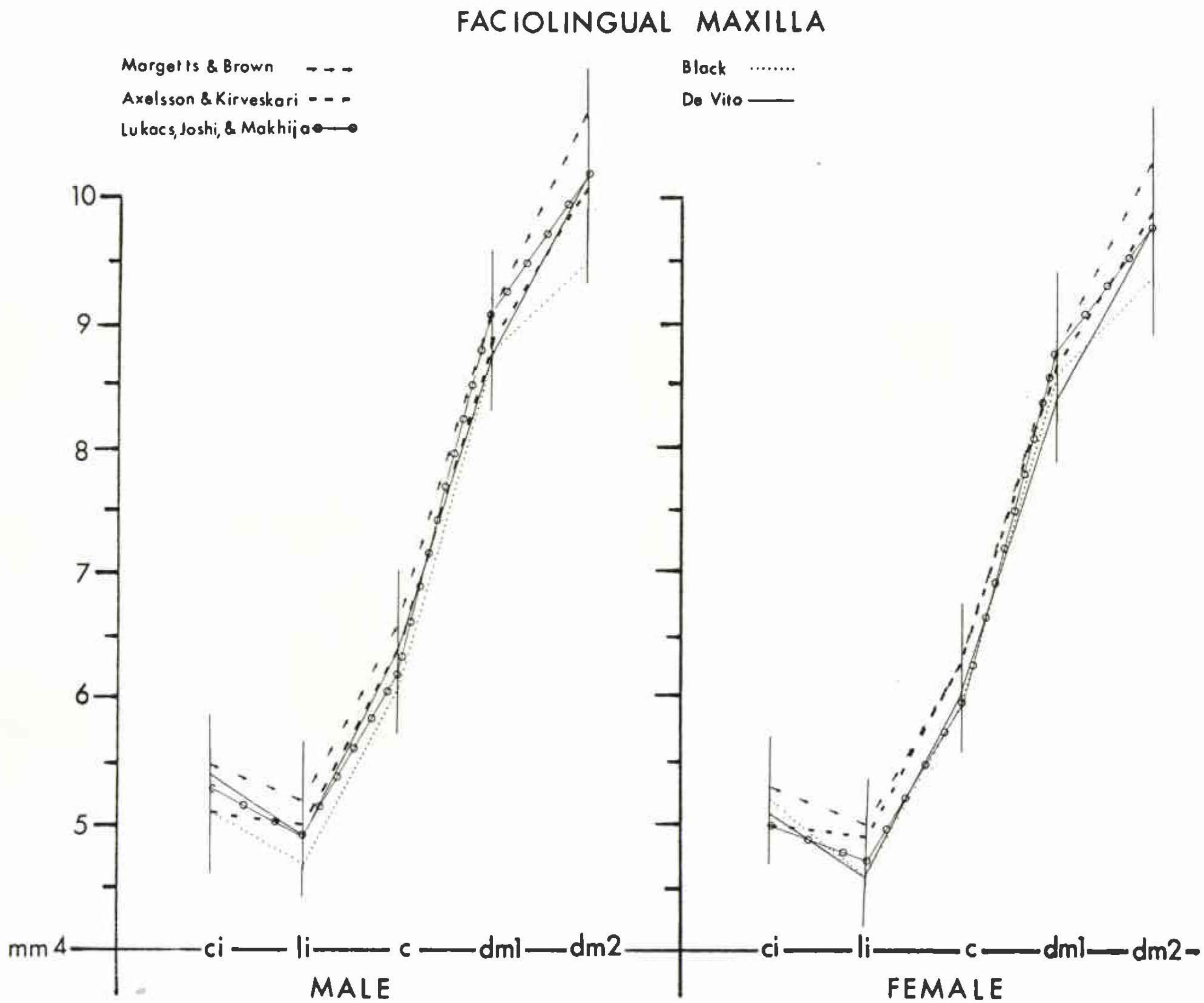


FIGURE 5.3: FACIOLINGUAL MAXILLA—COMPARATIVE DATA FOR THE MEAN ($\bar{x}$)

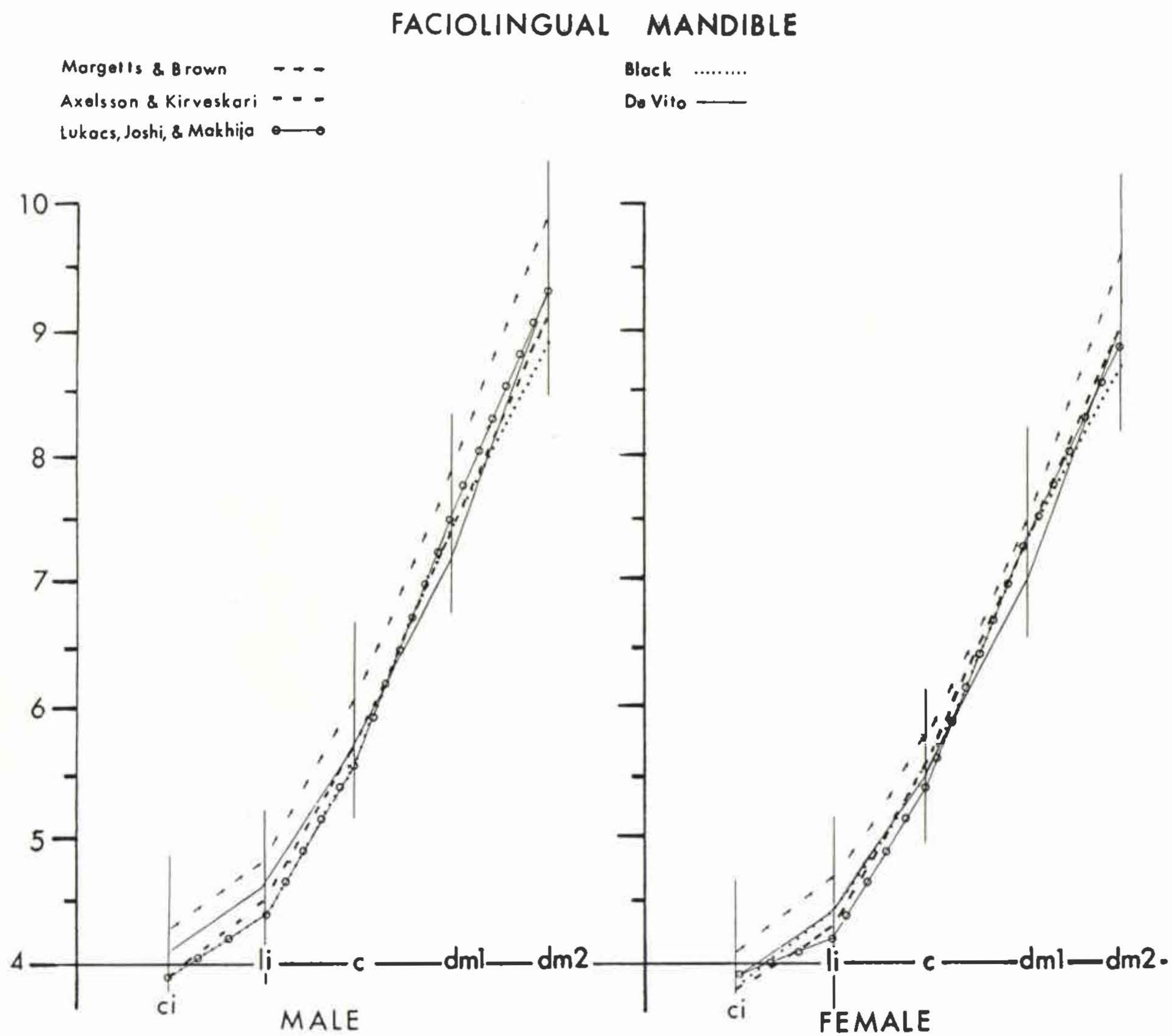


FIGURE 5.4: FACIOLINGUAL MANDIBLE—COMPARATIVE DATA FOR THE MEAN ($\bar{X}$)

the Burlington females alone are actually as large as or larger than those for the males of the Swedish and Ohio groups (except for the mandibular second molar of the Ohio group). The mesiodistal canine means for the Burlington group are larger than the means for either the other European or the East Indian groups, especially in the maxilla. In addition, when the means for the mesiodistal maxillary central incisor are examined, canine length exceeds central incisor length in the mesiodistal maxillary dentition of all the European groups, while in the East Indian and the Australian Aboriginal groups, the two lengths are almost equivalent. Hanihara (1967: 925) maintains that a value of 105 or greater for the canine breadth (or length) index:

$$\frac{\text{Mesiodistal maxillary canine diameter}}{\text{Mesiodistal maxillary central incisor diameter}} \times 100$$

is a characteristic of the Caucasoid dentition, while a value of approximately 100 is a feature of the non-Caucasoid dentition. The five groups of European origin have canine breadth index values of approximately 105 or greater, while the East Indian and Australian Aboriginal values equal approximately 100. Faciolingually, the Burlington group displays the smallest first molar diameter of any group for both males and females, particularly in the mandible.

5. Comparison of the Coefficients of Variation

The variability in the measurements for the seven groups mesiodistally and five groups faciolingually was examined using the coefficients of variation (Tables 5.4-5.5, pages 98-99). In accordance

TABLE 5.4: MESIODISTAL DECIDUOUS CROWN DIAMETERS
- COMPARATIVE DATA FOR THE COEFFICIENT OF VARIATION (CV)

		MOORREES (1959)		MARGETTS & BROWN (1978)		LYSELL & MYRBERG (1982)		AXELSSON & KIRVESKARI (1984)		LUKACS JOSHI & MAKHIJA (1983)	BLACK (1978)	DE VITO (1988)
(SIDE:		R+L		R+L		R		R		L	R	R)
										M N=50	M N=69	M N=82
										F N=50	F N=64	F N=80
TOOTH	SEX	N	CV	N	CV	N	CV	N	CV	CV	CV	CV
Maxilla												
ci	M	64	6.55	29	6.15	369	6.86	20	6.92	5.20	6.92	*6.14
	F	69	6.44	18	6.79	394	6.34	18	7.01	6.44	5.52	*7.18
li	M	64	5.32	54	7.35	443	7.27	71	7.11	6.36	7.10	7.05
	F	69	5.23	36	7.27	460	6.80	50	6.68	6.78	7.35	7.27
c	M	65	6.88	113	5.74	510	5.54	236	5.18	4.69	5.53	5.53
	F	69	6.67	77	6.36	559	5.67	193	5.10	6.13	5.33	4.86
dm1	M	64	7.12	112	6.93	428	6.20	116	6.75	5.78	7.09	5.63
	F	68	6.95	74	5.99	478	6.07	118	5.69	5.62	7.06	6.85
dm2	M	63	9.08	113	5.87	459	5.47	168	4.97	5.97	6.97	5.22
	F	68	8.84	76	4.87	525	5.13	158	4.97	6.39	5.32	6.54
Mandible												
ci	M	64	4.08	18	8.27	342	7.64	10	6.96	8.13	8.31	*7.37
	F	68	3.98	8	9.11	350	7.25	6	8.47	5.43	7.54	7.16
li	M	65	4.74	34	8.97	443	7.31	36	8.17	6.51	9.41	7.09
	F	69	4.63	19	8.60	460	7.44	26	7.68	7.08	8.18	*7.46
c	M	65	5.92	109	5.84	498	5.80	187	5.58	5.41	5.78	5.33
	F	68	5.74	62	6.71	548	5.75	132	5.26	4.85	4.51	5.30
dm1	M	65	7.80	109	6.99	346	6.41	80	5.57	4.66	5.64	5.87
	F	69	7.65	70	5.55	414	6.75	80	5.80	5.14	5.21	5.41
dm2	M	63	9.83	115	5.62	514	5.37	96	4.32	5.96	4.88	4.16
	F	69	9.64	69	4.59	427	5.26	93	4.83	4.54	5.66	4.86

* M N=81 and/or F N=79

TABLE 5.5: FACIOLINGUAL DECIDUOUS CROWN DIAMETERS - COMPARATIVE DATA FOR THE COEFFICIENT OF VARIATION (CV)

		MARGETTS & BROWN (1978)		AXELSSON & KIRVESKARI (1984)		LUKACS JOSHI & MAKHIJA (1983)	BLACK (1978)	DE VITO (1988)
(SIDE:		R+L		R		L	R	R)
						M N=50 F N=50	M N=69 F N=64	M N=82 F N=80
TOOTH	SEX	N	CV	N	CV	CV	CV	CV
Maxilla								
ci	M	29	7.71	29	5.19	5.90	8.38	6.16
	F	18	6.25	20	6.07	5.95	9.29	6.32
li	M	56	7.66	70	6.88	6.88	8.41	7.67
	F	36	7.85	54	7.67	7.01	8.36	8.77
c	M	113	6.77	238	6.10	7.59	6.48	7.62
	F	77	6.25	196	5.67	8.39	6.93	6.41
dm1	M	114	6.51	212	5.16	6.28	5.63	5.76
	F	76	5.38	174	4.57	6.16	6.43	6.19
dm2	M	114	5.14	245	4.38	5.81	5.16	5.17
	F	76	4.31	200	4.11	5.13	4.81	5.40
Mandible								
ci	M	18	6.74	11	5.63	6.44	9.90	7.95
	F	8	10.56	6	8.86	6.46	9.06	8.41
li	M	33	7.39	35	6.80	6.67	8.60	6.89
	F	18	7.95	26	5.42	8.08	6.44	6.67
c	M	102	6.94	188	5.91	6.91	5.48	8.00
	F	60	7.18	133	5.66	7.43	7.23	7.15
dm1	M	112	6.46	162	5.46	7.59	6.57	5.76
	F	73	6.79	136	5.14	5.97	6.06	6.21
dm2	M	115	4.96	133	4.12	6.55	4.45	4.92
	F	75	5.11	107	4.25	5.41	4.97	5.69

with the field model of tooth development (Rowe, Johns, & Osborn 1981: 257-60), Axelsson and Kirveskari (1984: 343) state that in the Icelandic deciduous dentition (sexes combined) the maxillary lateral incisors vary more than do the centrals, the mandibular central incisors vary more than do the laterals, and the first molars vary more than do the second molars.

Of the seven groups with mesiodistal measurements, only the Icelandic group and Moorrees' (1959) American group do not display the maxillary pattern in both males and females. In the mandible no group displays the mandibular pattern in both males and females. The Moorrees' (1959) American sample shows the opposite pattern to that expected according to the field model. Of the five groups with faciolingual measurements, only the Australian Aboriginal and the Ohio group do not display the maxillary pattern in both males and females. In the mandible only the Ohio and Burlington groups display the mandibular pattern in both males and females.

For the molars, the pattern of greater first molar than second molar variability is more consistent, particularly faciolingually. Mesiodistally, Moorrees' (1984) American sample and the East Indian group (except in the female mandible) display the reverse pattern. In the Ohio group the second molar in the female mandible varies more than the first.

6. <u>Comparison of the Percent Sexual Dimorphism</u>

Group comparisons of percent sexual dimorphism (Tables 5.6-5.7, pages 101-102; Figure 5.5, page 103) show the Burlington group as most dimorphic, ranging from 1.91-4.81% mesiodistally and from 2.77-

TABLE 5.6: MESIODISTAL DECIDUOUS CROWN DIAMETERS
- COMPARATIVE DATA FOR THE PERCENTAGE SEXUAL DIMORPHISM (%)

	MOORREES (1959)	MARGETTS & BROWN (1978)	LYSELL & MYRBERG (1982)	AXELSSON & KIRVESKARI (1984)	LUKACS JOSHI & MAKHIJA (1983)	BLACK (1978)	DE VITO (1988)
(SIDE:	R+L	R+L	R+L	R	L	R	R)
TOOTH	%	%	%	%	%	%	%
Maxilla							
ci	1.71	1.97	1.6	0.93	3.22	-1.84	3.28
li	1.72	1.11	1.6	1.33	3.58	-1.69	4.81
c	3.15	2.75	2.2	1.16	4.44	1.80	3.26
dm1	2.45	3.71	3.1	1.85	4.94	1.52	3.44
dm2	2.71	2.44	2.4	0.33	1.43	0.57	1.91
Average	2.35	2.40	2.2	1.12	3.52	±1.48	3.34
Mandible							
ci	2.51	3.94	1.8	9.49*	3.21	-1.71	3.70
li	2.38	2.01	2.0	2.84	2.15	-2.97	3.15
c	3.14	2.53	2.1	2.06	2.43	0.34	4.71
dm1	1.96	1.55	3.5	2.81	4.76	1.42	3.03
dm2	1.97	2.37	2.5	1.61	3.33	1.96	2.01
Average	2.39	2.48	2.4	3.76* 2.33**	3.18	±1.68	3.32
Overall Average	2.37	2.44	2.3	2.44* 1.73**	3.35	1.58	3.33

* Result possibly due to extremely small sample size (N=16)
** Average without including mandibular central incisor

TABLE 5.7: FACIOLINGUAL DECIDUOUS CROWN DIAMETERS - COMPARATIVE DATA FOR THE PERCENTAGE SEXUAL DIMORPHISM (%)

	MARGETTS & BROWN (1978)	AXELSSON & KIRVESKARI (1984)	LUKACS JOSHI & MAKHIJA (1983)	BLACK (1978)	DE VITO (1988)
(SIDE:	R+L	R	L	R	R)
TOOTH	%	%	%	%	%
Maxilla					
ci	3.34	1.40	4.17	-1.16	5.38
li	4.59	1.62	4.88	1.51	6.44
c	4.23	1.59	3.86	2.34	4.31
dm1	3.37	2.07	3.54	3.15	4.48
dm2	3.74	2.23	4.10	1.92	3.74
Average	3.85	1.78	4.11	2.02	4.87
Mandible					
ci	3.20	3.44	0.26	0.52	3.96
li	2.04	3.73	3.33	0.46	3.40
c	3.74	1.78	4.83	0.90	3.21
dm1	5.81	0.82	3.30	0.82	2.96
dm2	3.05	0.78	5.07	2.30	2.77
Average	3.57	2.11	3.36	1.00	3.26
Overall Average	3.71	1.95	3.74	1.51	4.07

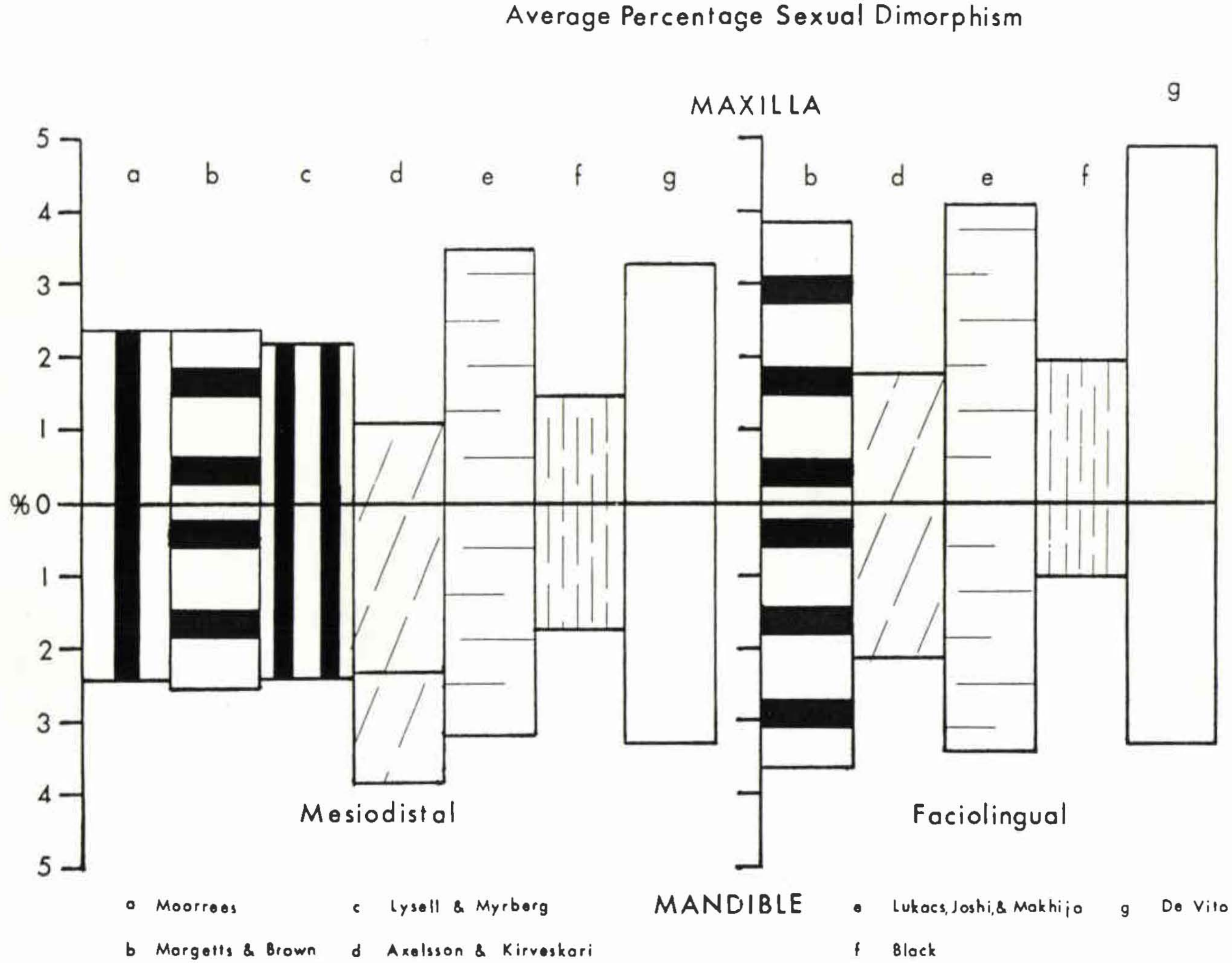


FIGURE 5.5 : COMPARATIVE DATA FOR THE AVERAGE PERCENTAGE SEXUAL DIMORPHISM

6.44% faciolingually. Next most dimorphic is the East Indian group, from 1.43-4.94% mesiodistally and from 0.26-5.07% faciolingually. The Australian Aboriginal group is third most dimorphic, ranging from 1.11-3.94% mesiodistally and from 2.04-5.81% faciolingually. Of the remaining groups having mesiodistal and faciolingual measurements, the Icelandic and Ohio groups display very little sexual dimorphism. The Icelandic group varies from 0.33-2.84% mesiodistally and from 0.78-3.73% faciolingually, the Ohio group from 0.34-(-)2.97% mesiodistally and from 0.46-3.15% faciolingually (with negative percentages indicating instances where the female mean for a crown diameter--the mesiodistal central and lateral incisors and the faciolingual maxillary central incisors--actually exceeds the male). The two groups which have only mesiodistal measurements, Moorrees' (1959) American group and the Swedish group, express a similar percentage sexual dimorphism to that seen in the Australian Aboriginal group, ranging from 1.71-3.15% for the American group and from 1.6-3.5% for the Swedish group.

Mesiodistally, only the Icelandic group displays a noticeable difference between the maxilla and the mandible in the expression of sexual dimorphism, with the mandible displaying the greater percentage dimorphism. Faciolingually, greater percentage dimorphism is expressed in the maxilla than in the mandible of the Ohio group.

Several studies of the permanent teeth of various populations have shown sexual dimorphism to be most strongly expressed in the mesiodistal diameter of the mandibular canines (Garn et al. 1967; Moss 1978; Potter et al. 1981; Axelsson & Kirveskari 1983). In this comparative analysis of deciduous teeth, the greatest percent sexual dimorphism expressed in individual teeth is seen, mesiodistally, in the canines for the American group, in the maxillary first molar and mandibular central incisor for the Australian Aborigines, in the first molars for the Swedish and East Indian groups, in the maxillary first molar and mandibular lateral incisor for the Icelandic group, in the maxillary central incisor and mandibular lateral incisor for the Ohio group, and in the maxillary lateral incisor and mandibular canine for the Burlington group. Faciolingually, percent dimorphism is greatest in the maxillary lateral incisor and mandibular first molar for the Australian Aborigine group, in the maxillary second molar and mandibular lateral incisor for the Icelandic group,in the maxillary lateral incisor and mandibular second molar for the East Indian group, in the maxillary first molar and mandibular second molar for the Ohio group, and in the maxillary lateral incisor and mandibular first molar for the Burlington group.

I examined whether the same teeth are most dimorphic and/or least dimorphic in the two diameters, mesiodistal and faciolingual. In the maxilla of the Australian Aboriginal and Icelandic groups the teeth which are the most dimorphic faciolingually are the least dimorphic mesiodistally whereas for the East Indian and Ohio groups the least dimorphic tooth faciolingually is the most dimorphic mesiodistally. In contrast, in the maxilla of the Burlington group, the most dimorphic tooth faciolingually is the most dimorphic mesiodistally. In both the maxilla and the mandible, the least dimorphic tooth faciolingually is also the least dimorphic mesiodistally.

In the mandible the most dimorphic tooth faciolingually in the

Australian group is the least dimorphic mesiodistally, while for the Ohio group the least dimorphic tooth faciolingually is the most dimorphic tooth mesiodistally. In contrast, for the Icelandic group the most dimorphic tooth faciolingually is among the most dimorphic mesiodistally (given that an extremely small sample size makes the results for the central incisor questionable). As with the Burlington group, the least dimorphic tooth faciolingually is the least dimorphic mesiodistally.

7. Summary of the Intergroup Comparisons

In summary, the Australian Aborigines exhibit the largest means for males and females. The East Indian group, except for the mesiodistal maxillary canines, is very similar in mean size to the five European and Euro-North American groups. Of the two European groups of Scandinavian origin, the Icelandic group displays much larger means than does the Swedish group, particularly in the posterior dentition. Among the three North American groups of European origin, the Burlington group exhibits the largest means, the Ohio group the smallest, and Moorree's (1959) American group is for the most part midway between the two. Because of the differences among these three groups, no one sample can be termed to be truly representative of all modern North American populations of European origin.

Osborn (Rowe, Johns, & Osborn 1981: 259-260) maintains that the field model remains unproved as a valid description or explanation of certain patterns seen in tooth development. My comparisons, using the coefficient of variation, demonstrate that a general pattern similar to the field model can be detected in all the groups but Moorrees' (1959), and most especially in the molars. Overall, the second molars were generally, though not consistently, the least variable teeth.

There is no single pattern in the expression of percent sexual dimorphism that is specific to any population group. The North American groups, for example, include the most dimorphic group, Burlington, and the least dimorphic group, Ohio. As well, the European populations cannot be said to be either more dimorphic or less dimorphic than the non-European populations. When looking at the expression of sexual dimorphism by tooth type, it is usually either the incisors or the molars which display the most, or the least, dimorphism, but again there is no pattern which is characteristic of all groups.

8. Comparison with a Study of the Evolution of the Deciduous Dentition

In 1978, Smith published an analysis of the evolution of the deciduous dentition. She states that in European populations:

> [D]eciduous teeth were decreasing in size throughout the Middle and Upper Pleistocene, with the rate of molar reduction slowing down towards the end of this period, while incisor reduction has continued to the recent past (Smith 1978: 402),

and that "...anterior teeth show more reduction than the posterior teeth, the second deciduous molar showing little change in size" (Smith 1978: 408). The dental measurements for Smith's (1978) study were made with vernier calipers reading to 0.05mm but the maximum mesiodistal diameter was measured and the sample sizes used in the study do not exceed 10 cases until the Neolithic period (Smith 1978: 402-406).

When the means for the Burlington group (N=162) are compared to those published for the European samples used in Smith's study, the Burlington group seems closest in size to the post-Neolithic results shown for the Roman and Recent European samples, which seems to confirm Smith's (1978) conclusions. However, because the pre-Neolithic sample sizes are extremely small, four cases having relatively large dentitions, 2 females and 2 males, were selected from the Burlington sample to compare to Smith's pre-Neolithic samples. The Burlington subsample measurements, individually and as a 'mean' of the four cases, were compared to the pre-Neolithic means for the European samples.

The reanalysis of Smith's (1978) study, using the Burlington material, shows that a reduction in the size of the mesiodistal (and possibly faciolingual) maxillary incisors occurred between the Middle Palaeolithic sample and the Wurm I-II sample but that no further reduction has actually occurred in the post-Middle Palaeolithic period. As well, there has been a decrease in the size of the maxillary canine diameters between the Lower Palaeolithic and the Middle Palaeolithic samples. There has also been a reduction in the crown diameters of the maxillary first molar between the Lower Palaeolithic and the Middle Palaeolithic samples and between the Wurm I-II and the Upper Palaeolithic samples and a reduction of the mesiodistal mandibular first molar diameter between the Lower Palaeolithic and the Middle Palaeolithic, with a further reduction between the Middle Palaeolithic and Wurm I-II samples.

However, any conclusions about evolutionary trends in the deciduous dentition must take into account the fact that the samples for the periods from the Lower Palaeolithic to the Mesolithic are not sufficiently large enough to constitute statistically representative samples of the populations of Europe in those time periods and cannot, therefore, be used in a comparative analysis with the much larger-numbered samples for the periods from the Mesolithic to the Recent period in Europe. When the means for the 4 Burlington subsample cases were compared to the overall (N-162) means for the Burlington group, the extremely small sample size yielded a distorted statistical picture of the group from within which the sample was drawn. The small sample sizes for the pre-Neolithic period in Smith's (1978) study obscure the extent to which the minimum to maximum range in crown size for a population can affect the overall mean for that population. In addition, to see the decrease in crown diameter size in the post-Mesolithic samples as being part of a greater evolutionary trend toward a decrease in the size of the deciduous dentition does not acknowledge the existence of actual interpopulation differences during each time period. The results of the comparative analysis of the 20th Century groups of European origin have shown that no one sample can be seen as being representative of all European or Euro-North American populations. Therefore, measurements made on a single sample cannot be said to show the average size of the deciduous tooth crown diameters for any particular time period in Europe.

Multivariate Statistical Analysis

Having determined that the Burlington study sample displays significant sexual dimorphism in the deciduous dentition, the level of classificatory accuracy was then tested using discriminant function analysis. The diameter variables included in the functions were the faciolingual diameters of the right maxillary central and lateral incisors and the left maxillary canine and second molar and the mesiodistal diameter of the mandibular right canine. In comparison, in the univariate analyses the diameters showing the greatest significant differences ($p<0.001$) between males and females were the faciolingual diameters of the maxillary right central and lateral incisors and the maxillary left second molar and the mesiodistal diameter of the mandibular right and left canines (Figure 4.3, page 50). The 5 most dimorphic diameters were the faciolingual diameters of the maxillary right central and lateral incisors and left lateral incisor and the mesiodistal diameters of the maxillary right and left lateral incisors and the mandibular right canine (Figure 4.3, page 50).

Depending upon the combination of diameter variables used in the derivation of the discriminant functions from an analysis sample, varying levels of accuracy were achieved in the classification by sex of several holdout samples selected from within the study sample. The original criterion of acceptability for classification accuracy had arbitrarily been set at 75% or better (at the 5% level of significance with Box's M test results being nonsignificant).

Using from 3 to 5 deciduous diameter variables for the discriminant analysis, four discriminant functions were derived which yielded a classification accuracy greater than 75%. A combination of the 4 maxillary variables and 1 mandibular variable was needed to achieve an accuracy level of 80% with the Group B holdout sample (N=40), and of

90% with the Group A holdout sample (N=21). The 4 maxillary variables alone, with the Group A holdout sample, and the 3 maxillary variables alone, with the Group D holdout sample (N=42), both produced a classification accuracy of 76%. The remaining deciduous analyses meeting the criteria correctly classified from 65% to less than 75% of the cases in the holdout samples. When the 3 permanent variables (from the permanent first molars) were included with the 4 deciduous maxillary and mandibular variables, the three combinations of variables (5 maxillary plus 3 mandibular, 5 maxillary alone, and 3 mandibular alone) each produced a classification accuracy of 85%, using the Group C holdout sample (N=21). The combined 5 maxillary and 3 mandibular variables achieved an accuracy of 83%, using the Group D holdout sample (N=42).

In contrast, Black (1978) had produced discriminant functions which consisted of 2 to 4 deciduous variables, but which correctly classified less than 70% (63%-68%) of his original analysis sample, at the 5% level of significance (and 75% of that sample if the 5% level were ignored). Black (1978) had derived his functions from a sample which expressed significant sexual dimorphism in only 5 of the 20 diameters measured and in which female means exceeded male means in another 5 of the 20 diameters. Frank, Massy, and Morrison (1965) state a fact basic to discriminant analysis:

> If the true means of all the variables
> are the same for each of the populations,
> it is clear that these variables cannot
> form the basis for classifying any cases
> by group membership (Frank, Massy, &
> Morrison 1965: 252)

In addition, the means "...may lie so close together that their distributions overlap so much that discrimination is not very effective

(Frank, Massy, & Morrison 1965: 252).

Buikstra and Mielke (1985) cite Black's (1978) study when stating that "...the deciduous dentition...may also be sufficiently dimorphic for sex estimates of reasonable reliability, although less accurate than those developed from the permanent teeth" (Buikstra & Mielke 1985: 384; underlining mine). However, previously in the same section they caution that a validation procedure, such as the use of a holdout sample, is necessary in any discriminant analysis to minimize the low estimate of misclassification inherent when the analysis sample used for discriminant function derivation is also used for classification by sex (Buikstra & Mielke 1985: 381-382), the method chosen by Black (1978) and also by Anderson and Thompson (1973) and by Sciulli, Williams, and Gugelchuk (1977), using the permanent teeth.

Using only mesiodistal permanent mandibular canines, Anderson and Thompson (1973) achieved a 74% accuracy level when classifying an analysis sample drawn from the Serial Experimental Group of the Burlington Growth Study (as was this present study sample). They concluded that the mesiodistal "...canine width alone...could be used for sex determination in forensic dentistry" (Anderson & Thompson 1973: 437). Sciulli, Williams and Gugelchuk (1977) used the faciolingual diameter of the permanent maxillary and mandibular canines in the discriminant analyis and classification of a combination of prehistoric Amerindian groups. Sex had initially been determined by skeletal features and the subsequent dental discriminant function matched that classification with an accuracy of 79%. In the present study a classification accuracy of 71% was achieved with the mesiodistal deciduous right mandibular canine, using holdout Groups A (N=21), C (N=21), and D (N=42).

Using the permanent teeth of a modern sample population, Owsley and Webb (1983) tested the accuracy of three discriminant analysis validation methods, the sample resubstitution, jackknife, and holdout sample methods. They produced an average correct classification of 70%, with a range of 60.9%-79.5% accuracy achieved with the holdout method, using 2-3 permanent variables. They demonstrated that sample resubstitution, where the analysis sample is also the classification sample, can bias the level of accuracy, increasing it by as much as 10% in comparison to the other two validation methods (Owsley & Webb 1983: 182). Using the holdout method in the discriminant analysis of the deciduous teeth of the Burlington group has produced classification accuracy results which are within the range obtained in other studies using the permanent teeth.

Further Discussion

The intergroup comparisons raise the question of why the Burlington sample seems larger and more dimorphic than the samples from the other European groups, the Ohio and Icelandic groups. In the Introduction the theory was presented that continued amelogenesis in the male possibly explained the greater tooth crown size seen in males postnatally (Coughlin 1967; Moss 1978). For the most part, male means do exceed female means in each group except Black's (1978) Ohio sample, where female means actually exceed male means for 5 of 20 deciduous crown diameters. The question might better be why Black's (1978) group, rather than the Burlington group, seems so different from the others. But are the differences among the three European groups really as pronounced as initially demonstrated? What impact has chance had upon the selection of the cases in each study and the magnitude of sexual dimorphism subsequently determined for each group? If Black had selected another combination of cases would the degree or pattern of sexual dimorphism prove more significant? Would the choice of a different group of children from the Burlington Growth Study have produced less significant results? Have the differences in the measurement methods and/or the data manipulation in each study actually had a greater effect upon the comparison results?

The differences seen among the three European groups might reflect an actual pattern of variation. It would be interesting to apply the discriminant functions from this study to some of the individual cases in either the Ohio or the Icelandic study to see what level of classification accuracy would be achieved testing an unrelated sample having a similar population background. It might also prove worthwhile to compare deciduous dentition measurements for other subgroups within other major populations to see if a pattern of variation emerges as has in the Northwest European groups (for example, a comparison of Japanese deciduous tooth measurements with those of sample groups from mainland China or Korea, or a comparison of various Amerindian groups) and to obtain more information about the range of human variation within and among populations.

For Stini (1985) the expression of sexual dimorphism in humans is an outcome of a survival strategy, a consequence of the balance between the necessity for a high degree of biological variation within the species and the need for a narrow range of variation in the female, physically structured for the support of an infant both pre- and postnatally. Males exhibit more of the extremes in variation than do females, but in turn are more affected by the extremes in the environment, such as nutritional inadequacies and certain disease processes (Stini 1985), an important consideration particularly during growth and development. Theoretically, in a population which is well-nourished and healthy throughout growth and development, the attainment of increased or even maximum body size, including increased tooth size, might be expected (within the limits of a population's actual potential). A consequence would then be the expression of a high level of sexual dimorphism, with males for the most part exceeding females in size. Therefore, a high percent sexual dimorphism would be expected in both the deciduous and permanent dentitions. The Burlington sample <u>cannot</u> be shown to include children who are better nourished or more healthy overall than the children of the Ohio or the Icelandic sample.

In addition, if sexual dimorphism was partly a function of size, one would assume that the greatest sexual dimorphism would be seen in the sample of Australian Aboriginal children, rather than in the Burlington sample. As well, although the Icelandic and the Burlington samples both display large means (along with the East Indian group), the Icelandic group displays a lower percentage sexual dimorphism. Studies of the permanent dentition of various populations conducted by Garn et al. (1967) and by Hanihara (1978) demonstrate that a positive correlation between tooth size and percentage sexual dimorphism does not exist in humans. Garn, Lewis, and Kerewsky (1967) found that the expression of sexual dimorphism in the dentition and in body size has only a low significant correlation. Frayer and Wolpoff (1985) maintain that, from an evolutionary perspective, body size has actually had little impact upon human sexual dimorphism. Therefore, the actual large tooth size seen in the Burlington group may not be a major factor contributing to the high percent sexual dimorphism.

CHAPTER SIX

CONCLUSIONS

Univariate analysis of the Burlington data (162 cases, 82 male and 80 female) revealed significant sexual dimorphism in the 40 deciduous diameters as great as or even greater than that seen in the permanent teeth of several sample populations. All male means are significantly larger than female means. In a comparison with several other published studies of deciduous teeth (Australian Aboriginal: Margetts & Brown 1978; Northern European: Axelsson & Kirveskari 1984, Lysell & Myrberg 1982; East Indian: Lukacs, Joshi, & Makhija 1983; Euro-North American: Black 1978, Moorrees 1959), the Burlington group proved to be the largest in mean size after the Australian Aboriginal group, and the most dimorphic. The comparative analysis emphasized the extent to which the pattern and degree of sexual dimorphism expressed in the deciduous tooth crown diameters varied both among and within populations. More importantly, the differences in mean size and dimorphism among just the three Euro-North American groups showed that no single sample group can be seen as being truly representative of a specific population. A positive correlation does not exist between tooth size and sexual dimorphism in the deciduous dentition. Both the Australian sample, which is largest in tooth size, and the Icelandic sample, which is almost as large in tooth size as the Burlington sample, display less sexual dimorphism than does Burlington sample.

Discriminant analysis of the Burlington data involved the division of the data into analysis groups to derive the discriminant functions and holdout groups to test the classification accuracy of those functions. The level of accuracy for correct classification by sex was set at 75% or better, at the 5% probability level. Depending upon the cluster of deciduous diameters or variables selected for inclusion in each function, and using from 3 to 5 deciduous teeth, accuracy levels of 75% to 90% were achieved in the classification of the holdout sample by sex, levels similar to those seen in discriminant analyses of the permanent teeth. The inclusion of permanent diameter variables (1 to 2 teeth) in the functions with the deciduous variables yielded accuracy levels of 83% to 85%.

Determination of the sex of adult remains is based more frequently, and with more accuracy, on skeletal morphology and measurement, rather than on multivariate analysis of the permanent dentition. Sex classification standards based on skeletal features comparable to those for adults do not exist for subadults. The discriminant functions derived through this analysis of the deciduous crown diameters of a sample of modern, white children provide standards for classifying subadult skeletal material by sex. Because the pattern and degree of sexual dimorphism differs among and within populations, the application of the discriminant functions produced in this study to an unrelated group would increase the probability of misclassification of individuals within that group. However, the levels of classification accuracy achieved in this study are within the range of accuracy achieved with the permanent dentition. Therefore, the discriminant functions could be used with care to determine the sex of children's skeletons in both forensic and archaeological studies.

FOOTNOTES

2.1 The ages of the children used in this study are based on chronological age. The casts made at 3 years of age include a child born in January 1951 with a child born in December 1951, (meaning that 11 months difference in growth and development is subsumed in that one age group). Chronological age is a method of organizing the casts and is actually not as important to this study as are the completion of dental eruption and the condition of the individual teeth in each cast. The goal of this study is to establish a possible method of determining sex and not chronological age.

2.2 Studies which have involved as few as 65 cases from the Serial Experimental Group (such as Sinclair & Little 1983) have been conducted to derive information about the normal and abnormal growth and development of the dentition of modern white <u>Ontario</u> children and about the effects of orthodontic intervention upon the individual.

APPENDIX

TABLE 4.A: RESULTS OF THE KOLMOGOROV-SMIRNOV TEST FOR NORMAL DISTRIBUTION BY SEX OF THE CROWN DIAMETERS FOR FEMALES (DECIDUOUS N = 80 PERMANENT N = 45)

TOOTH	KOLMOGOROV - SMIRNOV Z-SCORE	PROBABILITY $p \leq$	KOLMOGOROV - SMIRNOV Z-SCORE	PROBABILITY $p \leq$
	Right		Left	
		MESIODISTAL		
Maxilla				
ci	0.94*	0.34	0.87	0.43
li	0.82	0.52	0.62	0.85
c	2.34	0.20	2.09	0.19
dm1	0.69	0.74	0.69*	0.73
dm2	0.54	0.93	0.69	0.74
M1	0.64	0.81	0.67	0.76
Mandible				
ci	1.03	0.24	0.88	0.42
li	0.82*	0.51	1.01	0.27
c	1.04	0.23	0.90	0.40
dm1	1.05	0.22	0.91	0.38
dm2	0.91	0.38	0.58	0.89
M1	0.90	0.40	0.89	0.41
		FACIOLINGUAL		
Maxilla				
ci	0.98	0.29	0.60	0.87
li	0.79	0.57	0.62	0.84
c	0.63	0.82	0.68	0.75
dm1	0.71	0.69	0.70	0.71
dm2	0.58	0.89	0.63	0.71
M1	0.68	0.74	0.66	0.78
Mandible				
ci	0.97	0.30	0.61	0.85
li	0.55*	0.92	0.65	0.79
c	0.49	0.97	0.88	0.42
dm1	1.12	0.17	0.54	0.92
dm2	0.62	0.84	0.56	0.92
M2	0.83	0.50	0.95	0.33

* N = 79

TABLE 4.B: RESULTS OF THE KOLMOGOROV-SMIRNOV TEST FOR NORMAL DISTRIBUTION BY SEX OF THE CROWN DIAMETERS FOR MALES (DECIDUOUS N = 82, PERMANENT N = 39)

TOOTH	KOLMOGOROV - SMIRNOV Z-SCORE	PROBABILITY p ≤	KOLMOGOROV - SMIRNOV Z-SCORE	PROBABILITY p ≤
	Right		Left	
		MESIODISTAL		
<u>Maxilla</u>				
ci	0.66*	0.79	0.59	0.88
li	0.60	0.87	0.61	0.85
c	0.87	0.43	0.93	0.36
dm1	0.77	0.59	0.65	0.80
dm2	0.85	0.47	0.80	0.54
M1	0.60	0.87	0.51	0.96
<u>Mandible</u>				
ci	0.60*	0.87	0.73	0.67
li	0.60	0.87	0.91	0.39
c	0.58	0.89	0.78	0.58
dm1	1.23	0.10	1.07	0.20
dm2	0.61	0.85	0.72	0.67
M1	0.57	0.91	0.71	0.70
		FACIOLINGUAL		
<u>Maxilla</u>				
ci	0.73	0.65	0.69	0.72
li	0.71	0.69	0.78	0.57
c	0.83	0.50	0.82	0.51
dm1	0.48	0.97	0.51	0.96
dm2	0.92	0.37	0.93	0.35
M1	0.99	0.28	0.88	0.42
<u>Mandible</u>				
ci	0.87	0.43	0.67	0.77
li	0.70	0.71	0.83	0.50
c	0.91	0.38	0.77	0.60
dm1	0.91	0.38	0.70	0.71
dm2	0.57	0.90	0.59	0.88
M1	0.76	0.62	0.71	0.70

* N = 81

TABLE 4.C: MEAN ($\bar{X}$), STANDARD DEVIATION (SD), STANDARD ERROR ($S_{\bar{x}}$), RANGE (R), AND MINIMUM-MAXIMUM IN MM FOR THE MESIODISTAL MAXILLARY DECIDUOUS CROWN DIAMETERS (MALE N=82 FEMALE N=80)

TOOTH	SEX	$\bar{X}$	SD	$S_{\bar{x}}$	R	MINIMUM-MAXIMUM
Right						
ci (N=81)	M	6.692	.411	.046	2.00	5.55 - 7.55
(N=79)	F	6.480	.465	.052	2.35	5.60 - 7.95
	M+F	6.587	.450	.036	2.40	5.55 - 7.95
li	M	5.519	.389	.043	1.90	4.50 - 6.40
	F	5.266	.383	.043	1.85	4.50 - 6.35
	M+F	5.394	.405	.032	1.90	4.50 - 6.40
c	M	7.265	.402	.044	2.15	6.05 - 8.20
	F	7.036	.342	.038	1.55	6.40 - 7.95
	M+F	7.152	.389	.031	2.15	6.05 - 8.20
dm1	M	7.352	.414	.046	2.15	6.35 - 8.50
	F	7.108	.487	.054	1.95	6.10 - 8.05
	M+F	7.232	.467	.037	2.40	6.10 - 8.50
dm2	M	9.214	.481	.053	2.30	8.15 -10.45
	F	9.041	.591	.066	2.60	7.75 -10.35
	M+F	9.129	.544	.043	2.70	7.75 -10.45
Left						
ci	M	6.685	.431	.048	2.25	5.65 - 7.90
	F	6.436	.427	.048	2.00	5.50 - 7.50
	M+F	6.562	.446	.035	2.40	5.50 - 7.90
li	M	5.491	.361	.040	1.65	4.65 - 6.30
	F	5.244	.369	.041	1.90	4.25 - 6.15
	M+F	5.369	.384	.030	2.05	4.25 - 6.30
c	M	7.275	.396	.044	2.15	6.00 - 8.15
	F	7.019	.362	.041	1.75	6.25 - 8.00
	M+F	7.149	.400	.031	2.15	6.00 - 8.15
dm1	M	7.339	.441	.049	2.50	6.25 - 8.75
(N=79)	F	7.098	.480	.054	1.95	6.10 - 8.05
	M+F	7.220	.475	.037	2.65	6.10 - 8.75
dm2	M	9.154	.472	.052	2.05	8.10 -10.15
	F	8.963	.563	.063	2.40	7.90 -10.30
	M+F	9.060	.526	.041	2.40	7.90 -10.30

TABLE 4.D: MEAN ($\bar{X}$), STANDARD DEVIATION (SD), STANDARD ERROR ($S_{\bar{x}}$), RANGE (R), AND MINIMUM-MAXIMUM IN MM FOR THE FACIOLINGUAL MAXILLARY DECIDUOUS CROWN DIAMETERS (MALE N=82 FEMALE N=80)

TOOTH	SEX	$\bar{X}$	SD	$S_{\bar{x}}$	R	MINIMUM-MAXIMUM
<u>Right</u>						
ci	M	5.407	.333	.037	1.95	4.55 - 6.50
	F	5.131	.324	.036	1.45	4.45 - 5.90
	M+F	5.270	.356	.028	2.05	4.45 - 6.50
li	M	4.942	.379	.042	1.95	3.75 - 5.70
	F	4.643	.407	.045	2.10	3.45 - 5.55
	M+F	4.794	.420	.033	2.25	3.45 - 5.70
c	M	6.363	.485	.054	2.75	4.80 - 7.55
	F	6.100	.391	.044	1.85	5.15 - 7.00
	M+F	6.233	.459	.036	2.75	4.80 - 7.55
dm1	M	8.765	.505	.056	2.65	7.60 -10.25
	F	8.389	.519	.058	2.40	7.40 - 9.80
	M+F	8.579	.544	.043	2.85	7.40 -10.25
dm2	M	10.181	.526	.058	2.80	9.05 -11.85
	F	9.814	.530	.059	2.60	8.65 -11.25
	M+F	10.000	.557	.044	3.20	8.65 -11.85
<u>Left</u>						
ci	M	5.337	.359	.040	1.90	4.55 - 6.45
	F	5.119	.332	.037	1.55	4.35 - 5.90
	M+F	5.229	.362	.028	2.10	4.35 - 6.45
li	M	4.849	.425	.047	2.35	3.65 - 6.00
	F	4.613	.358	.040	1.65	3.70 - 5.35
	M+F	4.732	.410	.032	2.35	3.65 - 6.00
c	M	6.268	.518	.057	2.85	4.65 - 7.50
	F	6.035	.377	.042	1.85	5.15 - 7.00
	M+F	6.153	.468	.037	2.85	4.65 - 7.50
dm1	M	8.643	.482	.053	2.20	7.65 - 9.85
	F	8.318	.486	.054	2.30	7.20 - 9.50
	M+F	8.482	.510	.040	2.65	7.20 - 9.85
dm2	M	10.124	.546	.060	2.90	9.10 -12.00
	F	9.719	.497	.056	2.05	8.70 -10.75
	M+F	9.924	.559	.044	3.30	8.70 -12.00

TABLE 4.E: MEAN ($\bar{X}$), STANDARD DEVIATION (SD), STANDARD ERROR ($S_{\bar{x}}$), RANGE (R), AND MINIMUM-MAXIMUM IN MM FOR THE MESIODISTAL MANDIBULAR DECIDUOUS CROWN DIAMETERS (MALE N=82 FEMALE N=80)

TOOTH	SEX	$\bar{X}$	SD	$S_{\bar{x}}$	R	MINIMUM-MAXIMUM
Right						
ci (N=81)	M	4.290	.316	.035	1.75	3.50 - 5.25
	F	4.137	.296	.033	1.45	3.50 - 4.95
	M+F	4.214	.315	.025	1.75	3.50 - 5.25
li	M	4.925	.349	.039	1.65	4.25 - 5.90
(N=79)	F	4.775	.356	.040	1.40	4.15 - 5.55
	M+F	4.851	.360	.028	1.75	4.15 - 5.90
c	M	6.265	.334	.037	1.90	5.35 - 7.25
	F	5.983	.317	.035	1.40	5.40 - 6.80
	M+F	6.126	.354	.028	1.90	5.35 - 7.25
dm1	M	8.052	.473	.052	3.20	7.40 - 9.10
	F	7.815	.423	.047	2.00	6.95 - 8.95
	M+F	7.935	.463	.036	3.20	6.95 - 9.10
dm2	M	9.943	.414	.046	2.15	8.70 -10.85
	F	9.747	.474	.053	2.30	8.95 -11.25
	M+F	9.846	.454	.036	2.55	8.70 -11.25
Left						
ci	M	4.268	.301	.033	1.50	3.50 - 5.00
	F	4.118	.308	.034	1.60	3.50 - 5.10
	M+F	4.194	.313	.025	1.60	3.50 - 5.10
li	M	4.942	.351	.039	1.60	4.30 - 5.90
	F	4.807	.342	.038	1.45	4.20 - 5.65
	M+F	4.875	.352	.028	1.70	4.20 - 5.90
c	M	6.230	.317	.035	1.85	5.45 - 7.30
	F	5.983	.303	.034	1.35	5.45 - 6.80
	M+F	6.108	.333	.026	1.85	5.45 - 7.30
dm1	M	8.118	.420	.046	2.00	7.30 - 9.30
	F	7.849	.395	.044	1.95	7.00 - 8.95
	M+F	7.985	.429	.034	2.30	7.00 - 9.30
dm2	M	9.959	.408	.045	1.90	8.95 -10.85
	F	9.773	.450	.050	2.25	8.75 -11.00
	M+F	9.867	.438	.034	2.25	8.75 -11.00

TABLE 4.F: MEAN ($\overline{X}$), STANDARD DEVIATION (SD), STANDARD ERROR ($S_{\overline{x}}$), RANGE (R), AND MINIMUM-MAXIMUM IN MM FOR THE FACIOLINGUAL MANDIBULAR DECIDUOUS CROWN DIAMETERS (MALE N=82 FEMALE N=80)

TOOTH	SEX	$\overline{X}$	SD	$S_{\overline{x}}$	R	MINIMUM-MAXIMUM
Right						
ci	M	4.090	.325	.036	1.75	3.40 - 5.15
	F	3.934	.331	.037	1.55	3.25 - 4.80
	M+F	4.013	.336	.026	1.90	3.25 - 5.15
li	M	4.557	.314	.035	1.75	3.85 - 5.60
	F	4.407	.294	.033	1.30	3.80 - 5.10
	M+F	4.483	.313	.025	1.80	3.80 - 5.60
c	M	5.659	.453	.050	2.55	4.40 - 6.95
	F	5.483	.392	.044	2.10	4.25 - 6.35
	M+F	5.572	.432	.034	2.70	4.25 - 6.95
dm1	M	7.241	.417	.046	2.20	6.40 - 8.60
	F	7.033	.437	.049	2.10	6.05 - 8.15
	M+F	7.138	.438	.034	2.55	6.05 - 8.60
dm2	M	9.254	.455	.050	2.35	8.15 -10.50
	F	9.005	.512	.057	2.45	7.85 -10.30
	M+F	9.131	.498	.039	2.65	7.85 -10.50
Left						
ci	M	4.131	.351	.039	1.90	3.35 - 5.25
	F	3.958	.311	.035	1.40	3.25 - 4.65
	M+F	4.046	.342	.027	2.00	3.25 - 5.25
li	M	4.576	.334	.037	2.05	3.60 - 5.65
	F	4.421	.289	.032	1.35	3.75 - 5.10
	M+F	4.499	.321	.025	2.05	3.60 - 5.65
c	M	5.738	.444	.049	2.40	4.60 - 7.00
	F	5.526	.347	.039	1.45	4.85 - 6.30
	M+F	5.633	.412	.032	2.40	4.60 - 7.00
dm1	M	7.360	.383	.042	1.90	6.45 - 8.35
	F	7.088	.474	.053	2.30	6.15 - 8.45
	M+F	7.226	.450	.035	2.30	6.15 - 8.45
dm2	M	9.267	.449	.050	2.15	8.25 -10.40
	F	9.036	.521	.058	2.30	7.90 -10.20
	M+F	9.153	.498	.039	2.50	7.90 -10.40

TABLE 4.G: MEAN ($\bar{X}$), STANDARD DEVIATION (SD), STANDARD ERROR ($S_{\bar{x}}$), RANGE (R), AND MINIMUM-MAXIMUM IN MM FOR THE PERMANENT CROWN DIAMETERS (MALE N=39 FEMALE N=45)

TOOTH	SEX	$\bar{X}$	SD	$S_{\bar{x}}$	R	MINIMUM-MAXIMUM
				MESIODISTAL		
Maxilla						
Right M1	M	11.177	.591	.095	2.25	10.15 -12.40
	F	10.236	.496	.074	2.20	9.95 -12.15
	M+F	10.940	.583	.064	2.45	9.95 -12.40
Left M1	M	11.092	.653	.105	2.50	10.15 -12.40
	F	10.654	.523	.078	2.20	9.80 -12.00
	M+F	10.858	.624	.068	2.60	9.80 -12.40
Mandible						
Right M1	M	11.747	.672	.108	3.50	9.75 -13.25
	F	11.098	.683	.102	2.90	9.85 -12.75
	M+F	11.399	.748	.082	3.50	9.75 -13.25
Left M1	M	11.731	.608	.097	2.55	10.00 -12.55
	F	11.080	.653	.097	2.85	9.95 -12.80
	M+F	11.382	.708	.077	2.85	9.95 -12.80
				FACIOLINGUAL		
Maxilla						
Right M1	M	12.136	.492	.079	2.25	11.30 -13.55
	F	11.483	.557	.083	2.55	10.60 -13.15
	M+F	11.786	.619	.067	2.95	10.60 -13.55
Left M1	M	12.082	.496	.079	2.30	11.35 -13.65
	F	11.447	.549	.082	2.50	10.45 -12.95
	M+F	11.742	.611	.067	3.20	10.45 -13.65
Mandible						
Right M1	M	11.180	.434	.070	2.15	10.40 -12.55
	F	10.894	.558	.083	2.55	9.70 -12.25
	M+F	11.027	.521	.057	2.85	9.70 -12.55
Left M1	M	11.197	.448	.072	2.25	10.45 -12.70
	F	10.876	.583	.087	2.60	9.80 -12.40
	M+F	11.025	.546	.060	2.90	9.80 -12.70

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