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To the Graduate Council:

I am submitting herewith a thesis written by David M. Glassman entitled "A Multivariate Analysis of Palatal Measurements in Four Populations." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

Richard L. Jantz, Major Professor

We have read this thesis and recommend its acceptance:

Fred H. Smith, William M. Bass

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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We have read this thesis
and recommend its acceptance:

Accepted for the Council:

Vice Chancellor
Graduate Studies and Research

A MULTIVARIATE ANALYSIS OF PALATAL MEASUREMENTS IN FOUR POPULATIONS

A Thesis

Presented for the

Master of Arts

Degree

The University of Tennessee, Knoxville

David M. Glassman

December 1978

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I was fortunate to have gained permission to study the Terry Skeletal Collection housed at the Smithsonian Museum of Natural History located in Washington, D.C. My thanks are extended to Dr. Douglas H. Ubelaker for granting this permission. While at the Smithsonian, conversations with Dr. J. Lawrence Angel and Dr. Lucille E. St. Hoyme proved to be a valuable source of ideas. I also wish to thank Mr. Dwight Schmidt, my friend and colleague for accompanying me to Washington, D.C., taking care of the living arrangements, recording data, and conforming to a unique work schedule.

The Larson and Mobridge Arikara material used in this project was excavated under the directorship of Dr. William M. Bass. Funds for excavation were generously provided by the following agencies: the National Science Foundation—GS837 in 1966; GS1635 in 1967; GS2717 in 1970, and the National Geographic Society—699,912 during 1968 and 1969. The skeletal material is housed at the Department of Anthropology, University of Tennessee.

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Finally, and most importantly, I wish to thank my parents for their continual support and encouragement in my academic career. It is to them that I dedicate this thesis.

ABSTRACT

This study presents a multivariate analysis based on sets of twenty-six palatal measurements from males and females of three racial groups. The analysis examines the occurrence and degree of inter- and intrapopulational relationships. Morphological interpretations are provided whenever possible for the multivariate functions and factors identified. Additionally, discriminant functions from which individuals may be classified into their proper racial and sexual group are calculated and their degree of accuracy discussed.

The data for this investigation were obtained from two skeletal collections. Representatives of Negro and White populations were provided from the Terry Collection housed at the Smithsonian Museum of Natural History, Washington, D.C. Data from two American Indian populations, the Mobridge and Larson, were obtained from the Bass Plains Skeletal Collection housed at the Department of Anthropology, University of Tennessee, Knoxville.

The total sample consists of palates from fifty White males and twenty-four females, fifty male and female American Negroes, and twenty-five males and females from each American Indian site. Measurements representing length, breadth, and height dimensions were taken on each palate. In addition, eight measurements were taken on each male cranium for correlation analysis.

All statistical analyses of the data were carried out utilizing the Statistical Package for the Social Sciences (SPSS) except in the

classification analysis for which discriminant functions were computed through procedures of the Biomedical Series (BMD). The data were subjected to univariate and multivariate statistical techniques including discriminant and factor analyses. The results were then examined in order to determine whether variability in palatal morphology could be identified within and between racial groups. Finally, tests of probability were used to evaluate the significance of the observed group differences.

The results indicate that significant differences in palatal morphology do occur between the samples. Evidence also suggests that interpopulational differences are greater than intrapopulational differences. For both sexes, the morphological pattern may be summarized as follows: long, moderately wide and moderately deep palates in the Negro samples; short, wide and deep palates in the American Indian samples; short, narrow and shallow palates in the White samples. The evolutionary causes for these differences in palatal dimensions are not discussed in this investigation.

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CHAPTER I

INTRODUCTION

Systematic, metrical analyses of the human facial skeleton and cranium were attempted by various anatomists and physical anthropologists during the early decades of the twentieth century. These studies of biometric craniology included the dedicated and detailed metrical descriptions recorded by Macdonnell (1906-1907), Morant (1923, 1924, 1925, 1926, 1927), Hooke (1926), and Pearson and Davin (1924). Their common goal was to accumulate the largest possible series of cranial data representing as many populations as possible. This data was to be used subsequently in the identification and analyses of racial relationships.

Among the numerous facial and cranial measurements taken in these early studies, the palatal observations showed considerable variability between populations (for example, see Morant 1923: 218). These palatal measurements generally consisted of maximum length and maximum breadth both taken either internally or externally of the alveolus depending upon the investigator (Flower 1881: 161-162). This variability in how measurements were taken caused some doubt as to the validity of making cross-population comparisons. It became imperative that the standardization of measures be established. Hrdlicka (1920) and Wilder (1920) provided guidelines for obtaining basic cranial measurements while

Parsons (1913), Pearson (1925) and Campbell (1925) defined additional landmarks for morphological studies of the palate.

Before continuing, the term palate must be defined. A palate is considered to include the adjoining palatine processes of the maxillae anteriorly, and the adjoining horizontal plates of the palatine bones posteriorly. This area is often referred to as the bony or hard palate (Jacob and Francone 1970; Goss 1973). In this study, the alveolar arch produced from the articulation of the alveolar processes of the maxillae is also included into the palatal complex.

The use of the palate as a discriminator of populations was soon recognized after standardization was introduced into anthropometry and became an important part of large comparative studies (MacCurdy 1923; Leigh 1925, 1937). A few investigators attempted detailed research projects involving the total morphology of the human palate. Campbell (1925) examined and measured the maxillae and mandibles of approximately 630 Australian Aboriginal crania. He dealt with the size, contour, form and height of the palate. The data were presented by the calculated average and range for all measurements recorded.

Taylor (1962) identified the form and orientation of the palate based on measurements from Chatham Island and Maori skulls. He utilized standard statistical procedures of mode, arithmetic mean, standard deviation and the coefficient of variation in the description of palatal areas, contours, height, breadth, and distances along the midline.

Although few other studies have concentrated on the identification of the total morphological pattern of the normal palate, the awareness of palatal variability persists. Most often the context surrounding

the discussions is based on qualitative or univariate statistical observations and relates to sex differences (Krogman 1962; Bass 1971; El-Najjar and McWilliams 1978), and general race differences (Howells 1959; De Villiers 1968; Oliver 1969). More interesting, perhaps, are the studies which use palatal dimensions in the examination of variability due to growth (Knott 1961; Moss and Chase 1967) or adaptation (Brace 1967; McCann et al. 1967; Hylander 1977a, 1977b). Because of their qualitative or limited statistical orientation, these studies give no indication as to the degree of variability or to the total pattern of population relationships.

The early studies by Campbell (1925) and Taylor (1962) were undertaken prior to the recognition and true appreciation of the implications for multivariate statistical techniques in the biological sciences. Although these "descriptive" studies were instrumental in the recognition of palatal morphology, population differences were limited to comparisons of one or two measurements at a time. Also, distinctions of shape could only be inferred through ratios and indices.

Multivariate analysis is generally considered to include those statistical procedures concerned with the analysis of multiple measurements that have been made on "N" individuals (Cooley and Lohnes 1962: 1). The techniques enable the investigators to account for correlation among the variates and to consider a multitude of variates at any one time. Additionally,

> . . . the multivariate procedures are able to reduce the original test space to the minimum number of dimensions needed to describe the relevant information contained in the original observations. (Cooley and Lohnes 1962: 2)

The mathematics involved in multivariate analysis will not be discussed in this study. They may be found in the numerous texts which deal with this subject (Kendall 1957; Anderson 1958; Cooley and Lohnes 1962; Morrison 1967).

The applications of multivariate analysis to the field of anthropology seem limitless and utilization is extremely common in recent publications. This is not to suggest that no criticisms have surfaced concerning their use. On the contrary, ever since the inception of using multivariate statistics in physical anthropological studies (Giles and Elliot 1962, 1963; Howells 1966; Crichton 1966), there has been debate over the types of problems to which they may be accurately applied (Birkby 1966; Giles 1967; Howells 1969; Kowalski 1972).

Discriminant analysis is a multivariate procedure to classify an individual with respect to known populations. This is accomplished through the utilization of a function which has weights for a number of variables and ultimately yields a single score for each individual. The discriminant function was first described by Fisher (1936) and is computed from

> . . . the measurements of two defined and distinct populations so that the difference between the mean scores of the populations is at a maximum, and the deviations of the individual scores from their respective means are at a minimum, among all possible combinations of weights which might be used. (Howells 1966: 2)

The affiliation of any individual, known or unknown, on the basis of the relevant variables, is then judged by the relationship of his discriminant score to the population mean scores.

By its nature, discriminant analysis is ideal for forensic and any other studies which depend upon the positioning of a single individual into one group or another. It has been applied to problems of sexing (Giles and Elliot 1963; Giles 1964, 1970; Flander 1978) and racial determination (Giles and Elliot 1963; Howells 1970; Flander 1978) from cranial and other skeletal element measurements. Discriminant analysis has relieved the investigator of total reliance on visual inspection and has become a valuable aid in classification decisions. Accuracy of the sex and race functions have been shown to exceed 85% for the individuals from which the functions were derived (Giles 1970; Howells 1970).

Multiple discriminant analyses have advantages over single discriminant functions. They provide a series of uncorrelated functions, centroids of the groups for each function, and scores of the individuals. The number of functions cannot exceed one less than the number of populations or the number of variables, whichever is smaller (Howells 1966). Tests of statistical significance are provided to evaluate the discrimination of the groups by each function. Cooley and Lohnes (1962) suggest that if only two or three discriminant functions are involved, the plotting of group centroids in the discriminant space may be extremely beneficial to the observation of group locations in the reduced space. The group centroids may also be used in the computation of the generalized distance statistic, D^2. These distances provide a means for estimating the amount of intergroup differences among the populations (Jantz 1972).

The utilization of multiple discriminates in physical anthropology generally involves the examination of population relationships between three or more groups. Studies of this nature have been successfully attempted using cranial (Jantz 1972; Howells 1973; Owsley and Jantz 1978) and dental data (Friedlaender 1975).

In spite of the number of specialized studies with primary reference to the palate, only the most relevant of which were cited earlier in this introduction, few attempts have been made to describe the structure of populational differences from a number of palatal measurements using a multiple discriminant analysis. Lavelle et al. (1970) used a canonical analysis to examine the differences in dental arch size and shape between different age groups. They found that dental arch morphology changed maximally between the ages of five to seven and eleven to thirteen. This was attributed to corresponding major phases of permanent tooth eruption (Lavelle et al. 1970).

More recently, Lavelle (1974) demonstrated that dental arch morphology may be used to discriminate between British samples representing different time periods from Anglo-Saxon to the present. Using similar procedures, Lavelle (1977) also showed that discrimination is possible between various ethnic groups. Both of these studies utilized canonical analyses based on multiple measurements of palatal arch breadth and interdental chords.

Smith and Bailit (1977) and Smith et al. (1978) have currently studied variation in dental occlusion and arches among Melanesians of Bougainville Island. Utilizing univariate statistics, they have

identified patterns of geographic microdifferentiation with arch length and width decreasing in size from north to south. Multiple discriminant analysis was also successful in identifying the structure of differences among the 14 Bougainville populations. In comparison to Friedlaender's (1975) study, Smith et al. suggest their results indicate palatal variables are superior to dermatoglyphic traits but less effective than anthropometry data, for discrimination among these populations.

Multiple discriminant analyses used in this investigation are similar to the method employed by Lavelle (1974, 1977) and Smith et al. (1978). That is, discriminates will hopefully provide an opportunity to examine within and between population relationships. In contrast to these other studies, measurement data will not be restricted to dental arch breadth, or as in the case of Smith et al. (1978), with the addition of a single length measurement, but will include various measurements of length, breadth and height. It is believed that additional information on palatal variability may be obtained from their inclusion.

Factor analysis is a multivariate procedure for ascertaining the structure of intercorrelations within a set of variables (Cooley and Lohnes 1962: 151). From the examination of the patterning of correlations, the variability which exists among the individuals within a population may be identified. The factors represent the correlated systems in reduced dimension and may be rotated to more meaningful positions. Jantz and Owsley (1977: 358), suggest that "rotated factors are superior to unrotated factors in picking out clusters of related variables."

Although several factor analyses have been carried out using craniofacial (Landauer 1962; Brown et al. 1965; Howells 1973, Nakata et al. 1974; Lombardi 1976) and dental (Potter et al. 1968; Lombardi 1975, 1976) data, no previous attempt has been made to examine the patterning of correlations based exclusively on palatal measurements. The present study will utilize a factor analysis to determine intersample variation between the factor structure of the male and female samples. It will also evaluate intrasample variation due to differences in racial morphology within the samples.

CHAPTER II

OBJECTIVES

The first and most important objective of this study is the identification of significant differences in palatal morphology among and between populations. This is accomplished by taking raw palatal measurements from males and females of four populations and examining the results derived from subjecting them to univariate and multivariate statistical procedures. It is the hope of the investigator that for any significant difference observed, a meaningful morphological interpretation may be determined.

The multivariate analyses used in this study include multiple discriminant analysis and factor analysis. The objectives of their utilization are to examine the structure of interpopulational differences as they relate to sex and race, and to examine the patterning of correlations within the respective populations. To determine whether the observed variability in population relationships is significant, tests of probability are applied.

An additional objective of this study is to determine the practicality of using two-group discriminant functions based on palatal measurements for classifying unknown individuals into their proper racial and sexual groups. It may be assumed that the greater the variability that exists in palatal morphology between samples, the more accurate the classification and vice versa.

The final objective is to examine the correlation between palatal and cranial dimensions. This is achieved by observation of the patterning of correlations produced by a factor analysis. That is, high loading on specific palatal and cranial measurements for individual factors will be accepted to suggest correlation. Due to the lack of complete female crania, only the male sample will be subjected to this statistical analysis.

CHAPTER III

MATERIALS AND METHODS

The adult cranial and palatal data collected for this investigation were drawn from four populations representing three racial groups. The first two groups were composed of samples from Whites and American Blacks belonging to the Terry Collection. This collection is housed at the Smithsonian Museum of Natural History located in Washington, D.C. The disadvantages of utilizing a sample population derived from a medical school dissecting room have been reported in the literature (Giles 1964: 129). In response, Giles (1964: 129), has added that, "The positive values of such a collection, however, outweigh the negative ones." He continues, "Without question, any serious study of sex differences in the skeleton can only be based on collections where the sex is positively known from written records." The Terry Collection does provide records of sex, race, and other demographic data which have been utilized in conjunction with various studies (Gilbert and McKern 1973; Giles 1964; Giles and Elliot 1963; Trotter and Gleser 1952, 1958).

The third and fourth populations for analysis originate from two Indian cemetery sites, the Mobridge and Larson, located along the Missouri River in South Dakota. These sites were excavated under the directorship of Dr. William M. Bass. All skeletal remains from these excavations are currently part of the Bass Plains Collection and are housed at the University of Tennessee.

The total sample was composed of fifty White males, twenty-four White females, fifty American Negro males and females, twenty-five Mobridge males and females, and twenty-five Larson males and females. The American Indian samples were sexed by the innominates. The entire sample was limited to crania from which complete sets of data were obtainable. In certain instances, however, when one or at the most two dental sockets were resorbed, the dental point landmark was carefully estimated. This was done sparingly and was tolerated most often when sample size was small, for example in the White female group. There also occurred four individual cases where both corresponding landmarks were missing. These missing observations were supplied utilizing the substitution of the group mean for the respective variable.

All cranial measurements were taken with standard spreading or sliding calipers. Palatal measurements, length and breadth, were taken with a Vernier sliding caliper with graduations to one-twentieth millimeter. The palatal height measurements were taken with a Palatometer graciously provided by Dr. William M. Bass. This instrument is comprised of a central housing which carries a coordinate arm and two lateral arms which may be extended to the breadth of the palate (see Figure 1).

Once all of the data were properly recorded, they were punched on standard 80 column computer cards. The information on the cards was checked against the original measurements to minimize error. All computer analysis was done on the IBM 360 computer at the University of Tennessee Computer Center.

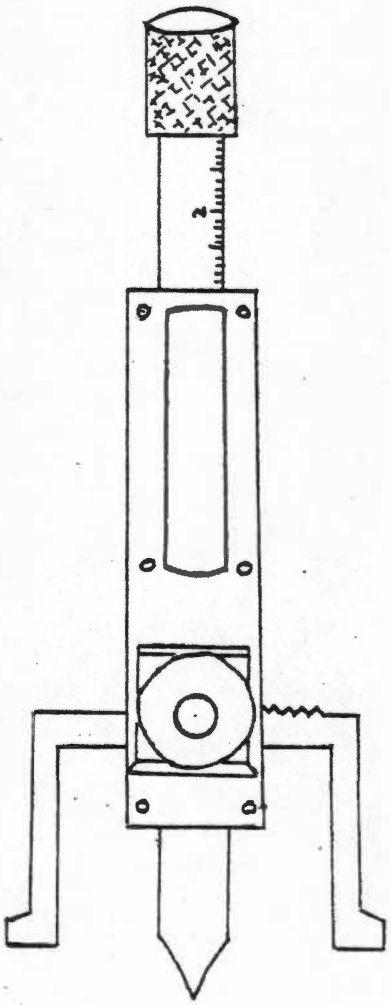

Figure 1. Palatometer used in taking palatal height measurements.

A total of twenty-six measurements were taken on each palate and an additional eight on each male skull. All palatal measurements, with the exceptions of external palatal length, exterior palatal breadth at P2, and exterior palatal breadth at M2, were restricted to the area internal to the dental arch of the maxilla.

The majority of length measurements were taken on the palatal midline. Palatal length measurements, their abbreviations as used in this study, instrument employed, and anatomical landmarks are as follows:

1. External palatal length (EXL). Vernier caliper. From prosthion to alveolon.

2. Orale-spinale length (OSP). Vernier caliper. From orale to spinale.

3. Orale-staphylion length (OST). Vernier caliper. From orale to staphylion.

4. Orale-alveolon length (ORT). Vernier caliper. From orale to alveolon.

5. Orale-basion length (OBA). Vernier caliper. From orale to basion.

6. Spinale-basion length (SBA). Vernier caliper. From spinale to basion.

7. Orale-suture point length (OSU). Vernier caliper. From orale to the intersection of the median palatine and transverse palatine sutures. (Note: In cases where the right and left sides of the transverse palatine suture did not evenly meet at the median palatine suture, measurement was taken at approximately one half the distance between them (see Figure 2).)

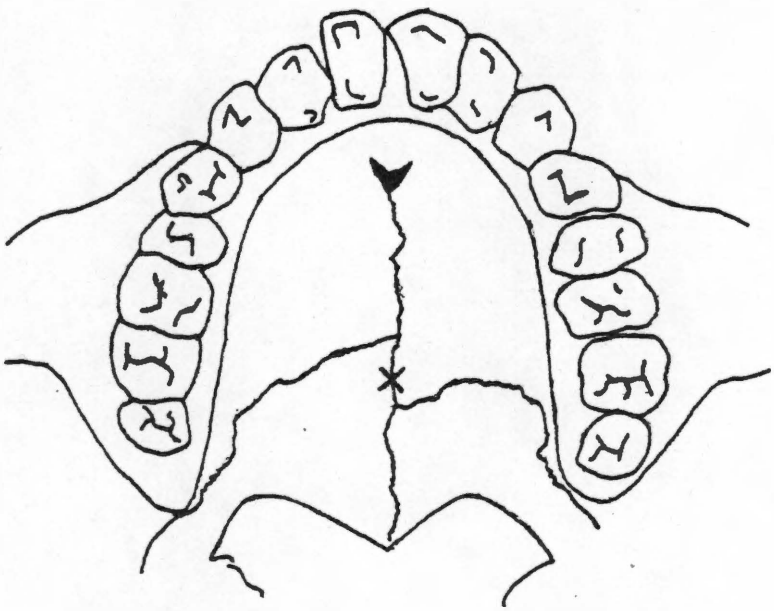

Figure 2. Cross indicates the suture point location when the transverse palatine suture does not evenly meet the median palatine suture.

8. Suture point-foramen point length (SFO). Vernier caliper. From suture point to the most posterior point on the incisive foramen.

9. Orale-canine points (OCC). Palatometer. From orale to the midpoint on a transverse line between the two canine points.

10. Orale-first premolar points (OP1). Palatometer. From orale to the midpoint on a transverse line between the two first premolar points.

11. Orale-second premolar points (OP2). Palatometer. From orale to the midpoint on a transverse line between the two second premolar points.

12. Orale-first molar points (OM1). Sliding caliper. From orale to the midpoint on a transverse line between the two first molar points.

13. Orale-second molar points (OM2). Sliding caliper. From orale to the midpoint on a transverse line between the two second molar points.

The EXL and OST lengths were measured after the method of Bass (1971: 70). All other landmarks and length measurements are of the method defined by Taylor (1962: 12-61, 58-60), with the following modifications:

1. Orale was used as the base point for palatal length measurements.

2. Measurements were made directly between landmarks and not on an imaginary horizontal plane.

3. Dental points were defined as the most internal point on the rim of the tooth socket.

Palatal length measurements are shown graphically in Figures 3 and 4.

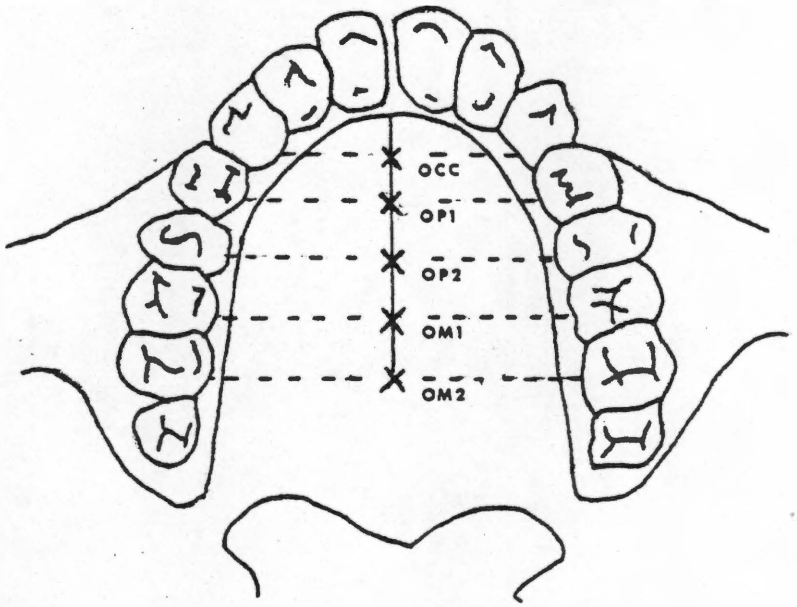

Figure 3. Crosses indicate points on the midline where measurement of orale to dental points were taken.

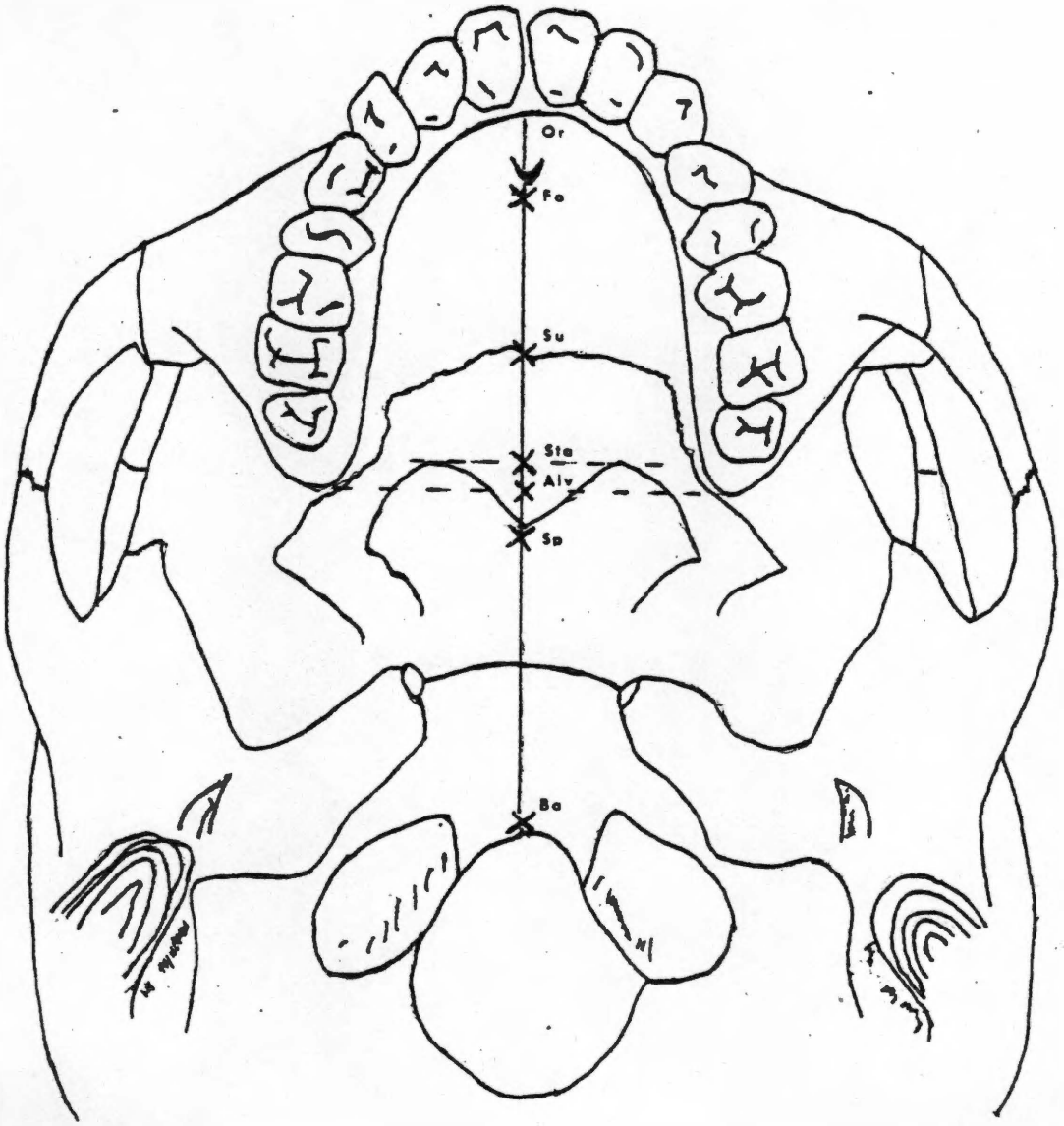

Figure 4. Crosses indicate points on the midline where nondental point length measurements were taken.

The majority of breadth measurements on the palate were taken as the distance between corresponding dental points. Two exterior breadth measurements were taken between the most external surfaces of the alveolar borders opposite the second premolars and second molars. The breadth measurements utilized in this investigation include:

1. Distance between canine points (CCB). Vernier caliper.
2. Distance between the first premolar points (P1B). Vernier caliper.
3. Distance between the exterior second premolar points (XP2). Vernier caliper.
4. Distance between the second premolar points (P2B). Vernier caliper.
5. Distance between the first molar points (M1B). Vernier caliper.
6. Distance between the exterior second molar points (XM2). Vernier caliper.
7. Distance between the second molar points (M2B). Vernier caliper.
8. Distance between the most posterior points on the post-dental alveolar process (TTB). Vernier caliper.

The posterior points of the post-dental alveolar process are described in Campbell (1925: 41-42). All other breadth measurements are defined by Taylor (1962: 58-59). Modification has previously been stated for the position of dental points. These measurements are shown graphically in Figure 5.

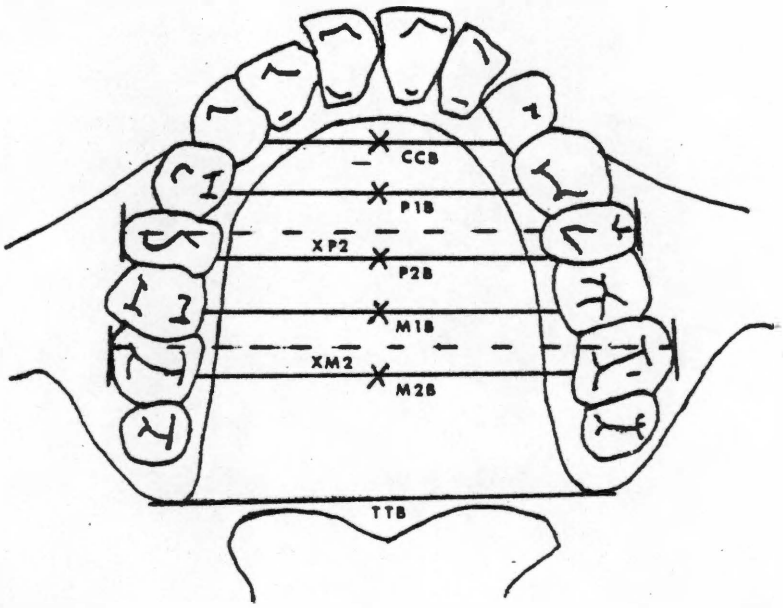

Figure 5. Transverse lines indicate palatal breadth measurements. Crosses show locations from which palatal height was recorded.

Measurements of height were taken from the midsection of the transverse lines connecting corresponding dental points to the bony palate. Thus, height measurements were recorded at the transverse lines for canines, both premolars, and first and second molars (see Figure 5). In instances where there occurred a "Torus palatinus" (Campbell 1925; Miller and Roth 1940; Woo 1950), the measurement was taken to the greatest palatal depth at either side of the bony elevation.

The cranial measurements utilized in this investigation, their abbreviations, anatomical landmarks, and instruments employed are as follows:

1. Maximum cranial length (MXL). Spreading caliper. From glabella to opisthocranion.

2. Maximum cranial breadth (MXB). Spreading caliper. From euryon to euryon.

3. Bizygomatic breadth (BIZ). Spreading caliper. From zygion to zygion.

4. Upper facial height (UPF). Sliding caliper. From nasion to alveolare.

5. Basion-bregma height (BAB). Spreading caliper. From basion to bregma.

6. Nasospinale-prosthion height (NSP). Sliding caliper. From nasospinale to prosthion.

7. Minimum frontal breadth (MNF). Spreading caliper. From frontotemporale to frontotemporale.

8. Nasal breadth (NOB). Vernier caliper. From alare to alare.

All cranial methods and landmarks are described by Bass (1971: 59-67).

The statistical analysis in this study is broken down into four sections. The first of these is simply the computation of summary statistics for all variables for each group (White males, Negro females, etc.). The summary statistics include means and standard deviations. These computations will hopefully reveal sexual and racial differences in size, shape and group variance.

The second section is the examination of the practical application of discriminant analysis based on palatal measurements in accurate sex and race identification. This is dependent upon the degree of intra-populational and interpopulational variation. The extent of sexual and racial group differences is observable through the calculation of a series of palatal classification functions using the procedures of the Biomedical series (BMD07M), a stepwise discriminant function program (Dixon 1976). The stepwise discriminant analysis is used in order to select an optimal set of discriminating variables from the total twenty-six palatal measurements.

To determine intrapopulational differences, two group classification functions were calculated between the sexes in each racial group: White, Negro and Indian (Mobridge and Larson groups were pooled for this analysis). Additionally, an all-race function was calculated for determining the sex of an individual without prior knowledge of racial affiliation. In determining the relationships between the racial groups, a function was calculated for Whites and Negroes, Whites and Indians, and Negroes and Indians. The sexes in this case were analyzed separately but in parallel.

In section three a multiple discriminant analysis is computed for all four populations based on the entire twenty-six palatal measurements. This analysis has been done separately for the two sexes. For each possible function, the relative percentage of the variance in discrimination and the level of significance are reported. To identify the differentiation of the populations by the functions, generalized distances were calculated and tested for significance. Plots of the populations on the first two discriminant functions are also provided.

The last procedure in this section attempts to interpret the individual degree of contribution of the original variables to the first two functions. This is approached by first utilizing a Fortran computer program worked out by Jantz (personal communication) which will calculate discriminant function scores for each individual. These scores are then collated with the original data sets and run through a discriminant function program. The pooled within correlation matrix computed by the program reveals the correlation of the two functions to each variable. The greater the correlation, the greater is the contribution of that variable to the respective function.

The final section in this study involves factor analysis of the palatal measurements. The first procedure of this section is the calculation of the factor structure for all males taken together and similarly for all females. Truncated component factor analysis was used, which leaves the diagonal of the correlation matrix unaltered. All factors with associated eigenvalues greater than one are rotated by the Varimax method and then subjected to morphological interpretation.

Individual factor scores are computed for each member of all four populations. They are derived from a Fortran program worked out by Jantz (personal communication) which utilizes the factor score coefficient matrix output from the original factor analysis program, the grand means and pooled within-group standard deviations of the variables, and the raw data. Once obtained, the mean factor scores are calculated for each group.

Pairs of mean factor scores are compared, tested for significance by means of t-test, and morphologically interpreted. A significance level of at least .05 is considered acceptable.

The last step of the factor analysis section is the examination of the Varimax rotated factor structure produced by the addition of cranial measurements to the original palatal data set. This is undertaken in order to identify patterns of positive and/or negative loadings. These patterns are suggestive of meaningful correlations between the cranial and palatal dimensions. Only the male data is subjected to this statistical manipulation.

All summary statistics and statistical analyses were done utilizing SPSS package programs (Nie et al. 1975), except where previously specified.

In the following chapter the results of the statistical techniques provide evidence of size and shape differences among and between the four populations. It demonstrates a working example of the usefulness of multivariate analysis in the study of populational variability of skeletal populations.

CHAPTER IV

RESULTS AND DISCUSSION

The following results and discussion were generated from the statistical procedures described in the previous chapter and will be presented in the same order. Each section will be characterized by appropriate statistical tables, examination of significant values, and morphological interpretations as to how these values reflect the pattern and degree of inter- and intrapopulational variability.

A. Summary Statistics

The summary statistics (Table 1 through Table 3) reflect a similar pattern to those seen in visual observations of the palate. For example, within a population, the palates of males tend to be longer and wider than the palates of females. Between populations, the palates of Negroes tend to be longer than the White and American Indian groups, while the American Indians have the broadest palates. The male means and standard deviations for cranial data (Table 2) will be discussed in conjunction with the factor analysis section.

The summary statistics may be divided into three measurement areas: measurements which reflect length (EXL-OM2), breadth (CCB-TTB), and height (CCH-M2H). Males will be examined first followed by females.

Table 1. Male means and standard deviations for palatal measurements (in millimeters).

	White		Negro		Mobridge		Larson	
Variable	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
EXL	52.85	3.06	56.30	4.46	53.43	2.21	54.29	2.98
OSP	49.57	3.19	53.26	3.76	52.59	1.75	52.52	2.70
OST	45.28	2.88	49.23	3.58	47.84	1.58	47.42	2.44
ORT	47.75	3.10	51.43	4.18	49.61	1.73	49.46	2.68
OBA	90.29	5.41	96.48	6.66	95.09	2.88	94.52	4.49
SBA	42.05	3.74	44.55	3.86	44.05	2.26	43.82	3.22
OSU	35.00	3.34	38.27	4.62	35.90	2.12	36.69	2.76
SFO	26.41	3.55	27.20	3.32	25.76	2.46	25.74	2.75
OCC	6.14	0.96	6.64	1.23	6.70	0.76	6.32	0.80
OP1	11.06	1.34	11.61	1.90	11.88	1.09	11.40	1.00
OP2	16.80	1.78	18.01	2.32	17.96	1.27	17.52	1.33
OM1	23.90	1.94	24.93	2.51	25.52	1.09	24.96	1.34
OM2	31.87	1.94	33.75	2.73	33.48	1.48	32.84	1.52
CCB	23.86	2.19	25.37	2.69	25.74	1.67	25.92	1.79
P1B	29.09	2.27	30.09	2.71	30.85	1.80	31.72	1.56
XP2	51.29	3.21	54.97	3.29	53.81	1.94	54.40	1.82
P2B	34.11	2.62	35.44	2.96	36.48	2.03	37.50	2.09
M1B	35.43	3.15	37.56	3.23	37.79	2.19	38.03	2.06
XM2	62.23	4.42	67.18	4.09	65.07	2.29	65.82	2.42
M2B	39.81	3.31	41.35	3.00	42.56	2.35	43.55	2.26
TTB	45.80	4.27	48.93	3.68	49.09	3.16	50.54	2.72
CCH	6.70	2.18	6.85	2.10	8.16	1.88	7.80	1.80
P1H	9.18	2.40	9.90	2.31	11.04	2.06	11.16	1.95
P2H	11.98	2.23	12.80	2.07	14.14	2.29	14.12	2.11
M1H	12.20	2.44	13.75	2.13	14.88	2.31	14.44	1.90
M2H	12.73	2.47	13.58	2.40	15.34	2.13	14.84	1.82

Table 2. Male means and standard deviations for cranial measurements (in millimeters).

	White		Negro		Mobridge		Larson	
Variable	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
MXL	184.96	8.10	185.28	7.33	178.16	6.52	182.48	5.13
MXB	142.28	5.54	136.80	5.30	138.48	4.68	140.00	3.61
BIZ	130.86	5.10	131.24	4.88	137.92	6.44	139.64	4.25
UPF	70.66	4.44	72.81	5.27	75.54	4.95	75.64	2.96
BAB	137.32	5.90	129.84	5.04	133.24	4.27	134.28	4.51
NSP	20.29	3.18	22.51	3.27	22.75	2.45	23.09	2.28
MNF	96.50	5.17	96.14	5.43	93.60	3.82	93.72	3.47
NOB	23.62	2.22	26.21	1.88	25.37	1.64	25.56	1.70

Table 3. Female means and standard deviations for palatal measurements (in millimeters).

	White		Negro		Mobridge		Larson	
Variable	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
EXL	49.98	2.54	54.52	3.06	51.56	3.33	51.30	3.24
OSP	46.63	2.36	50.92	3.32	50.52	3.05	50.15	3.13
OST	42.68	2.56	47.27	3.24	46.16	2.50	45.77	2.85
ORT	44.80	2.34	49.83	3.08	47.61	3,03	47.12	3.13
OBA	84.41	4.51	93.28	4.63	91.77	3.77	89.48	3.43
SBA	39.10	3.32	43.51	2.71	42.71	2.43	41.17	2.09
OSU	33.79	2.87	37.23	3.33	34.86	2.68	34.54	2.62
SFO	25.31	2.86	26.97	3.62	24.75	2.24	23.54	2.54
OCC	5.79	1.29	6.42	1.16	6.16	0.69	5.64	0.81
OP1	10.63	1.58	11.21	1.32	11.28	1.17	11.00	1.12
OP2	16.17	1.66	17.65	1.70	17.18	1.35	17.00	1.50
OM1	23.17	1.90	24.72	1.83	24.36	1.50	24.52	1.94
OM2	30.69	1.96	32.81	1.94	32.08	1.82	31.92	2.72
CCB	22.51	2.31	24.97	1.92	24.97	1.70	24.56	1.57
P1B	27.43	2.46	29.46	2.22	30.06	1.94	29.33	1.82
XP2	48.16	3.13	53.50	2.77	52.60	2.69	52.42	2.64
P2B	32.40	2.62	34.60	2.26	35.23	2.85	35.24	2.09
M1B	34.06	3.10	36.91	2.40	36.55	2.09	36.51	2.44
XM2	59.18	4.00	65.18	3.38	62.61	2.77	62.98	2.86
M2B	38.48	2.97	40.69	2.43	41.13	2.22	40.87	2.30
TTB	44.38	3.62	45.81	4.40	48.53	2.84	47.62	2.63
CCH	6.71	1.83	7.39	2.03	9.02	1.93	8.28	2.13
P1H	9.21	1.35	9.74	2.48	11.60	1.65	10.60	1.87
P2H	11.46	2.09	11.92	2.44	14.22	2.09	13.12	1.90
M1H	11.75	1.76	12.39	2.50	14.42	1.88	13.48	2.08
M2H	11.60	1.68	11.92	2.13	14.10	1.86	13.40	1.87

Negro males show the greatest values in the majority of length related measurements while the shortest palates are characteristic of the Whites. Negroes have the greatest variance for most of these measurements. Whites are consistently second highest in variance values with the Indian groups having the least.

The Mobridge and Larson male populations show the greatest values for breadth measurements except in the two exterior measures, XP2 and XM2, where the Negro population has the greatest value for these two measurements. This is the case in both sexes. Whites consistently reflect the narrowest palate in all breadth measurements. The Negro and White populations display the highest values of variance for breadth measurements similar to the condition described for palatal lengths.

The American Indian males are characterized by the deepest palates, and the White population the most shallow. Whites have the greatest variance in the majority of the palatal depth measurements. No other consistent trend of variance is observable for the remaining three populations.

Females (Table 3) show much the same pattern for length, breadth and height dimensions, as noted in the male populations. Negro females have the longest palates with greater values in most of the length measurements while the White females generally have the shortest palates. There is no consistent pattern of variance for length measurements in the four female populations, although generally, the Negro and White groups show higher values than the American Indian groups.

The Negro and American Indian females show similar mean values for palatal breadth measurements. These values are consistently larger than

those characteristic of the White population. For breadth measurements, the White sample has the greatest variance and the American Indian groups the least.

The Mobridge and Larson females display the greatest values for all depth measurements and the Whites consistently show the lowest values. Negro females have the largest degree of depth related variance followed by the two American Indian groups and finally the White population.

Comparison of the male summary statistics (Table 1, page 26) with the female statistics (Table 3, page 28) reveals that the mean values for males are consistently greater than those for females in length and breadth dimensions. Mean values for anterior depth measurements (CCH-P2H) are similar between the sexes. This is the only area in which females across all populations display at least one greater mean value for a measurement than the males. Males, in turn, show greater mean values for all posterior depth measurements (M1H-M2H). More interesting is the comparison of variance values. The variance for all measurements is generally greater in the males than the females of the Negro and White populations. In only 15% of the measurements for Whites and 19% for Negroes do the females show greater variance values. American Indian females display higher variance values for the majority of measurements over their respective males. Mobridge females show greater variance in 61% of the total measurements and Larson females in 57%.

B. Classification of Unknown Specimens

The results of the two-group discriminant function analysis for proper classification of unknown individuals appears in Tables 4, 5,

Table 4. Discriminant function coefficients by sex.

WHITES				NEGROES				AMERICAN INDIANS				ALL RACES (Whites, Negroes, Am. Indians)			
		Classification Coefficients				Classification Coefficients				Classification Coefficients				Classification Coefficients	
Variable	Cond'l. F	Males	Females	Variable	Cond'l. F	Males	Females	Variable	Cond'l. F	Males	Females	Variable	Cond'l. F	Males	Females
OBA	14.0908	4.49652	4.14269	OSP	8.8278	3.70495	3.30083	OSP	1.0474	-0.86951	-1.20227	EXL	1.4644	0.87288	0.79019
OSU	0.3056	0.73093	0.80452	OSU	1.3647	-1.46092	-1.32552	OST	4.1949	-2.16280	-1.39380	OBA	4.4693	1.80759	1.71967
OCC	0.6694	-7.05004	-6.72543	OCC	0.3112	-0.17955	-0.37310	OBA	6.0228	6.20582	5.90096	OSU	4.9275	-2.21351	-2.03746
OM1	4.5376	-10.12066	-9.40027	OP1	4.6394	-1.29601	-2.05097	SFO	4.5092	2.42757	2.12226	SFO	4.2976	2.79415	2.64118
OM2	4.5282	13.71180	13.05820	OM1	12.9165	1.19394	2.14549	OCC	11.7854	5.77262	4.19136	OCC	4.1466	-2.94709	-3.29478
CCB	0.6983	-4.39345	-4.13494	XP2	3.1858	3.21089	2.95046	P1B	2.1964	-0.28291	-0.66371	OM1	8.8134	-2.45479	-2.03197
P1B	2.3317	8.47253	7.95097	XM2	2.0649	1.27835	1.46102	XP2	3.6977	2.28228	2.70745	OM2	2.6236	5.80597	5.58401
XP2	1.4644	2.06522	1.82741	TTR	10.2009	1.45157	1.20479	XM2	12.4235	8.46010	7.83528	TTB	4.4908	2.19994	2.11561
M1B	1.6742	-0.83379	-0.60268	CCH	10.3810	-0.04469	0.60649	CCH	4.3486	1.46933	2.00039	CCH	21.1447	0.27367	0.71735
P1H	1.8244	8.82340	8.46420	P2H	3.4600	0.98008	0.37713	P1H	1.8686	-6.49009	-6.08957	P2H	8.1926	2.14569	1.76252
P2H	1.6886	4.02590	3.62959	M1H	1.0707	0.80333	1.16240	M1H	1.6886	-1.15326	-0.72973	M1H	9.4050	-3.11367	-2.63391
M1H	4.5171	-8.07235	-7.51926	M2H	4.5986	0.58544	0.10564	M2H	14.0824	6.73151	5.54558	M2H	20.7729	1.82317	1.29838
Constant		-416.08740	-372.29175	Constant		-259.80640	-239.64380	Constant		-616.20630	-558.19263	Constant		-220.29114	-204.96362
Percent Correctly Classified		84	79	Percent Correctly Classified		80	74	Percent Correctly Classified		88	88	Percent Correctly Classified		75	72

Table 5. Discriminant function coefficients by race for males.

WHITE X NEGROES				WHITES X AM. INDIANS				NEGROES X AM. INDIANS			
		Classification Coefficients				Classification Coefficients				Classification Coefficients	
Variable	Cond'l. F	Whites	Negroes	Variable	Cond'l. F	Whites	Am. Indns.	Variable	Cond'l. F	Negroes	Am. Indns.
UST	16.1040	2.38001	2.88040	EXL	7.7449	1.85387	1.42426	OP2	2.2184	0.21450	-0.34564
SFO	2.2565	0.55298	0.40602	OSP	4.0444	4.16846	5.07549	OM1	8.9340	5.24944	6.36848
OM1	7.1708	-4.27443	-4.94571	OBA	1.5107	-1.16343	-1.71879	CCB	6.0462	-4.63162	-5.38738
OM2	2.6291	5.02025	5.40818	SBA	2.8103	3.99811	4.75333	P1B	4.4914	8.05129	8.83266
P1B	9.0831	-0.61785	-1.16595	CCB	4.3982	-0.46262	0.03235	P2B	4.8575	-2.74909	-2.03457
XP2	3.3982	2.45113	2.77306	P2B	6.0359	2.00800	2.51784	M1B	6.6482	-2.23101	-2.93020
XM2	1.8464	0.36345	0.53555	XM2	1.5629	2.28154	2.11267	XM2	61.0343	4.38327	3.30900
T1B	5.7817	2.16612	2.37154	P1H	8.5653	3.66171	4.16142	M2B	19.7800	3.21837	4.37959
M2H	6.4962	-1.06603	-1.44172	M1H	3.0525	-1.99237	-1.68057	M2H	10.1747	1.60305	2.13765
Constant		-198.09485	-230.94946	Constant		-288.20068	-321.56079	Constant		-263.78735	-271.39795
Percent Correctly Classified		84	82	Percent Correctly Classified		84	86	Percent Correctly Classified		84	90

and 6. They have been divided into functions to determine both sexual and racial affiliation. The Conditional F statistic is provided for each variable. This statistic is a conditional F ratio with each variable conditional on the others in the set. It represents the unique contribution of that variable to the total distribution.

The classification functions for sex determination were based on twelve variables. Nine variables were utilized for the classification of race. The number of variables included in the functions was chosen on the basis of relative usefulness. This is the point at which the inclusion of additional variables does not produce any significant effect in proper classification. The variables themselves were selected by the computer program according to their discriminating power between the two groups involved.

Classification of an unknown specimen may be predicted by comparing the sums of the products provided by multiplication of the raw measurements with the two population columns of classification coefficients. After adding the respective constants, the population column that displays the greater value may be considered the group to which the unknown shows the closest relationship.

The computer program utilized the classification coefficients to test predicted group membership with actual group membership based on the original sample of individuals. This provides a measure of the usefulness of the analysis to accurate classification and is presented for each population as the percent correctly classified (Table 4 through Table 6).

Table 6. Discriminant function coefficients by race for females.

WHITES X NEGROES				WHITES X AM. INDIANS				NEGROES X AM. INDIANS			
		Classification Coefficients				Classification Coefficients				Classification Coefficients	
Variable	Cond'l. F	Whites	Negroes	Variable	Cond'l. F	Whites	Am. Indns.	Variable	Cond'l. F	Negroes	Am. Indns.
OSP	2.6889	-0.04806	-0.44695	EXL	8.5805	0.78469	0.04202	EXL	5.411	0.51193	0.06901
OBA	14.0920	3.39857	3.97668	OST	3.5555	-2.33406	-1.67603	OSP	6.3552	2.62099	3.06174
CCB	4.7289	1.16704	1.89404	OBA	7.8205	5.05269	5.55198	SFO	6.0758	0.78990	0.46204
XP2	5.1939	2.76529	3.32711	SFO	7.7893	1.52228	0.96751	OCC	2.3156	1.59116	0.99673
P2B	11.6681	-1.40652	-2.51435	OCC	3.9964	-3.79455	-4.85627	P2B	4.2531	0.01664	0.44426
XM2	5.1123	1.44487	1.93635	XP2	9.5900	2.47893	3.18842	XM2	28.2763	4.57344	3.54518
TTB	3.2863	0.70338	0.45417	XM2	5.8306	0.47573	-0.14152	M2B	4.1222	1.60286	2.18722
CCH	3.3237	2.61809	3.17748	TTB	8.0989	3.13293	3.71944	TTB	10.9752	0.29081	0.69884
P2H	1.3303	0.34975	0.05152	M2H	18.5573	1.45067	2.59155	M2H	25.2962	1.06593	1.91623
Constant		-268.40112	-328.78320	Constant		-343.04053	-397.96362	Constant		-291.40088	-281.28467
Percent Correctly Classified		87.5	94	Percent Correctly Classified		95.8	92	Percent Correctly Classified		88	88

In Table 4, the samples are divided into groups of Whites, Negroes, and American Indians to facilitate examination of sexual differences in each population. A pooled-race function is also included in this table for classification when racial affiliation is unknown. The percentage of correct classification averages 81.5% for Whites, 77% for Negroes, 88% for American Indians, and 73.5% for the pooled-race sample. It is assumed that the accuracy of correctly classifying individuals into their proper groups reflects the amount of existing variability between those groups. Thus, the American Indian group may be considered to possess the greatest degree of sexual dimorphism and the Negro population the least.

The accuracy of race determination is observable when the samples are divided into males (Table 5) and females (Table 6). Placement is tested for each sex between Whites and Negroes, Whites and American Indians, and Negroes and American Indians. For males, the average correct classification is 83%, 85%, and 87% respectively. Females exceed males in accurate racial classification averaging 91% between Whites and Negroes, 94% between Whites and American Indians, and 88% between Negroes and American Indians. It should be noted that these correct classification values are somewhat inflated since they are based upon the sample from which the functions were derived. Although the degree of inflation is unknown, it is not considered to invalidate the general observations of variability between and within the populations.

Comparison reveals that the accuracy for sex classifications with an overall average of 82% is not as good as the 87% achieved for race.

This means that within race sex differences are not as great as between race differences. Nevertheless, it is felt that both are sufficiently high to be utilized in practical application where unknown samples are involved.

A test sample of ten individuals not included in the original sample was subjected to the classification functions presented in this study. The sample is composed of a Negro male and female, a White male, and seven female American Indians. The sex of the individuals was determined on the basis of the all-race classification function. The two Negro individuals were classified correctly for both sex and race. The White male was misclassified for sex, but correctly placed into the White population. Of the seven female Indians, all were correctly classified according to race and two were misclassified according to sex. This produces test case results of 100% correct classification for race and 70% for sex. Although these results are quite good, the true classification value of the functions may only be ascertained through a sample of considerable size.

C. Interpopulation Relationships

The descriptive statistics of the four-group discriminant analysis for both males and females appear in Table 7 and Table 8 respectively. Both are based on the total twenty-six palatal measurements. Considering males first (Table 7), it is found that only the first two of the three possible discriminant functions yeild significant values. The first function accounts for 56.25% of the variance in the discriminating

Table 7. Descriptive statistics of the four group discriminant analysis for males.

Discriminant Function	Eigenvalue	Relative Percentage	Chi-square	Degrees of Freedom	Significance
1	1.39572	56.25	229.151	78	$p < .001$
2	0.81110	32.69	112.077	50	$p < .001$
3	0.27438	11.06	32.490	24	0.115

Table 8. Descriptive statistics of the four group discriminant analysis for females.

Discriminant Function	Eigenvalue	Relative Percentage	Chi-square	Degrees of Freedom	Significance
1	2.02895	56.51	236.872	78	$p < .001$
2	1.24126	34.57	117.185	50	$p < .001$
3	0.32050	8.93	30.025	24	0.184

variables and is interpretable as separating the Negro population from the American Indians and placing the White group at approximately equal distance to each. The second function explains an additional 32.69% of the variance and appears to discriminate between the White population and the remaining three populations.

The females (Table 8) show a similar pattern to that of the males. Once again, only the first two functions display significant discriminating values with $P < .001$. The first function accounts for 56.51% of the total variance and discriminates between the Negro and American Indian populations. The White group is placed in an intermediate position by this function. The second discriminant function accounts for an additional 34.57% of variance and separates the White population from the other three populations to a greater extent than is shown for males.

The relationships between the four populations based on the first two discriminant functions are graphically shown in Figure 6 for males and in Figure 7 for females. This provides a more comprehensible picture of the patterns produced from the discriminant values. For both sexes, the Negro and American Indian populations are separated by the first discriminant function and the White group from the others on the second. The two American Indian populations, Mobridge and Larson, cluster together on both functions for both sexes.

Raw generalized distance values (D^2) were obtained between each pair of populations and are presented in Table 9 for males and Table 10 for females. These values are based upon the group centroids for all

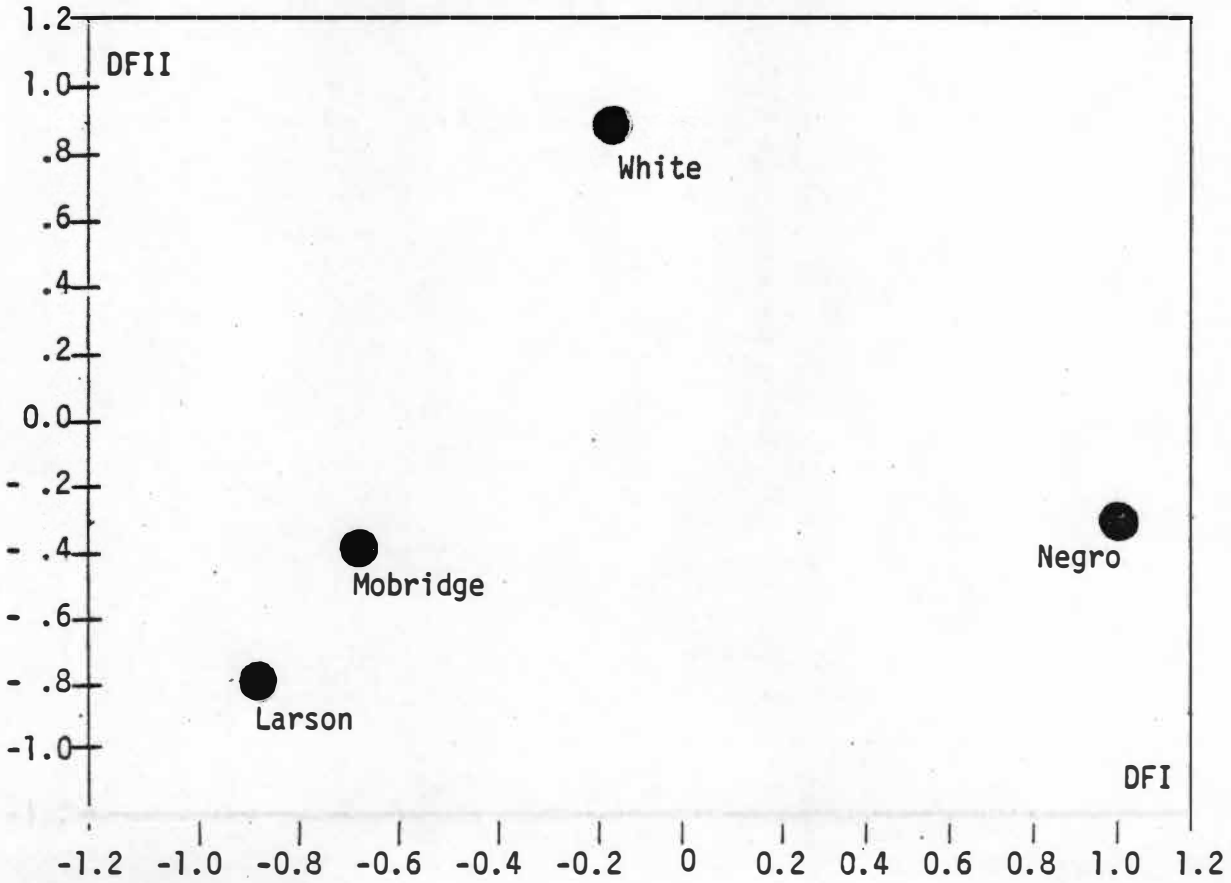

Figure 6. Relationship among the four male populations based on palatal measurements shown on the first two discriminant functions.

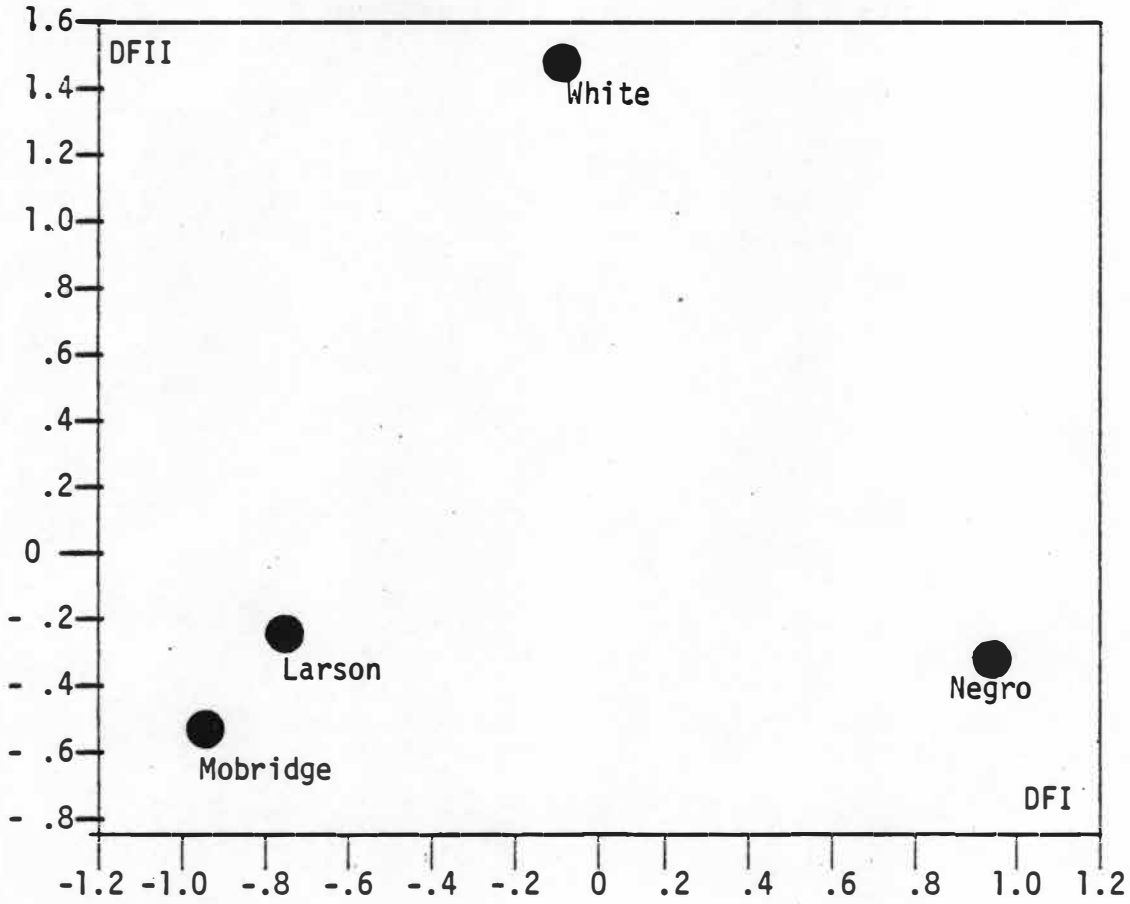

Figure 7. Relationships among the four female populations based on palatal measurements shown on the first two discriminant functions.

Table 9. D^2 values for males.

	White	Negro	Mobridge	Larson
White	———			
Negro	2.979**	———		
Mobridge	2.989**	3.839**	———	
Larson	2.714**	4.343**	2.664	———

*P < .05. ** P < .01.

Table 10. D^2 values for females.

	White	Negro	Mobridge	Larson
White	———			
Negro	4.338**	———		
Mobridge	5.297**	4.165**	———	
Larson	4.332**	3.615**	2.469	———

*P < .05. **P < .01

three discriminant functions. The D^2 values were then tested for significance by the equation $(N_a \cdot N_b / N_a + N_b) D^2_{ab}$, where N_a and N_b equal the sample sizes of populations a and b. The product represents X^2 with 26 degrees of freedom. The degrees of freedom being equal to the number of variables. A chi-square table is used to evaluate the significance level of probability.

Among the population pairs for males (Table 9), the greatest generalized distance occurs between the Negro and both American Indian groups. The White group is removed an equal distance from the Negro and Mobridge populations and still further from the Larson. The D^2 value for all population pairs except between Mobridge and Larson is significant at the .01 level of probability. The distance between the two American Indian samples is not significant at the lowest acceptable level of $P < .05$.

The D^2 values for pairs of female populations (Table 10) are generally greater than those for males. The populations most removed from each other are the Whites and American Indians followed by the White and Negro groups. The pattern of significance in D^2 values for the female sample is similar to the males. Again, only the generalized distance between Mobridge and Larson did not reach the .01 level of probability and it failed to reach .05.

The relative importance of each variable to the first two discriminant functions may be evaluated from the correlation values presented in Table 11. The first function discriminates most strongly between the Negro and American Indian populations. This pattern was noted to have occurred for both sexes.

Table 11. Correlation between the first two discriminant functions and individual palatal measurements.

Variable	Males		Females	
	DFI	DFII	DFI	DFII
EXL	0.2898	-0.2914	0.3406	-0.3307
OSP	0.1638	-0.5328	0.0883	-0.4679
OST	0.2782	-0.5098	0.1705	-0.4814
ORT	0.2667	-0.3849	0.2915	-0.4467
OBA	0.1873	-0.4791	0.2287	-0.6461
SBA	0.1115	-0.3109	0.2072	-0.4962
OSU	0.2362	-0.2989	0.2842	-0.2451
SFO	0.1581	0.0218	0.2922	-0.0243
OCC	0.0853	-0.1886	0.1574	-0.1348
OP1	0.0318	-0.1812	0.0265	-0.1594
OP2	0.1009	-0.2756	0.1283	-0.2694
OM1	-0.0002	-0.3125	0.0675	-0.2752
OM2	0.1602	-0.3500	0.1470	-0.3045
CCB	-0.0117	-0.4246	0.0560	-0.4513
P1B	-0.1321	-0.4330	-0.0217	-0.3782
XP2	0.1901	-0.5778	0.1489	-0.6139
P2B	-0.1482	-0.4989	-0.0604	-0.3784
M1B	0.0208	-0.4323	0.0710	-0.3791
XM2	0.2422	-0.5408	0.2629	-0.4985
M2B	-0.1396	-0.4986	-0.0203	-0.3532
TTB	-0.0111	-0.5461	-0.1867	-0.2806
CCH	-0.1588	-0.2149	-0.1935	-0.2671
P1H	-0.1361	-0.3475	-0.2084	-0.2528
P2H	-0.1516	-0.3947	-0.2467	-0.2601
M1H	-0.0640	-0.4832	-0.2210	-0.2725
M2H	-0.1659	-0.4022	-0.2908	-0.2682

For males, the correlations for the first function are generally low, but a trend is observable. The highest correlations are positive values for measurements EXL, OST, ORT, OSU, XP2, and XM2 and negative values for measurements CCH, P2H, and M2H. This reflects substantially the difference in the Negro and American Indian populations as observed from the group means (Table 1, page 26). Negroes display greater palatal length and exterior breadths and less palatal depth than the Mobridge and Larson samples.

Variable correlations to the first function for females are similar to the male pattern, but show greater values for additional length and height measurements. Their summary statistics (Table 3, page 28), also indicate these dimensions are the areas of greatest difference between the Negroes and American Indians.

The interpretation of significant variables to the second discriminant function is much more recognizable. This function was shown to discriminate the White population from the remaining three groups for both male and female samples. Because the larger correlations are directional, that is, all are negative, and represent dimensions of length, breadth, and height, the function reflects general size differences. The variable means for White males and females (Table 1 and Table 3, pages 26 and 28) agree with this pattern by showing lower values in all palatal dimensions than the remaining samples.

D. Factor Analysis

The eigenvalues and cumulative percentage of variance associated with the unrotated factors are presented for the all male sample in Table 12 and for the all female sample in Table 13. In both samples, six factors produced eigenvalues greater than 1.0. The total percentage variance for the six factors is similar for the males and females with 81.6% and 78.9% respectively. Similarity was also revealed in the general information content of the factor loadings for the two samples.

Rotated factor loadings are presented in Table 14 for the combined male sample and in Table 15 for the combined female sample. All six factors obtained for both sexes are interpretable from their variable loadings. Similar factors were found in both male and female samples, although there are differences in loading values.

For both the male and female samples, the types of factors which have emerged from the analysis are: (1) a breadth factor; (2) a full palatal length factor; (3) a segmented palatal length factor; (4) a height factor; (5) an OBA and SBA measurement factor; (6) a posterior breadth and height factor. The posterior breadth and height factor is expressed as a posterior breadth factor in the female sample. These factor types are listed in order of the rotated factors calculated for the combined male sample. The female order differs by the reversal of the full palatal length factor with the breadth factor and the OBA/SBA measurement factor with the posterior breadth factor.

The variance and percentage of variation explained by each of the six rotated factors are provided in Tables 16 and 17 for the male and

Table 12. Eigenvalues and cumulative percentage of variance associated with the first six principle factors of the all male sample.

Eigenvalue Number	I	II	III	IV	V	VI
Eigenvalue	8.93448	4.31616	3.10314	2.62959	1.23256	1.00758
Cumulative % of variance	34.4	51.0	62.9	73.0	77.8	81.6

Table 13. Eigenvalues and cumulative percentage of variance associated with the first six principle factors of the all female sample.

Eigenvalue Number	I	II	III	IV	V	VI
Eigenvalue	8.52111	4.05138	3.46824	2.12373	1.23242	1.10524
Cumulative % of variance	32.8	48.4	61.7	69.9	74.6	78.9

Table 14. Rotated factor loadings of all male sample using palatal measurement data.

Variable	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI
EXL	0.19458	0.70656	0.29101	0.14836	0.39796	-0.09097
OSP	0.20208	0.72155	0.30759	0.14514	0.34151	0.06625
OST	0.21961	0.76824	0.29918	0.15048	0.30226	0.04430
ORT	0.20756	0.73951	0.37460	0.14153	0.38664	-0.04191
OBA	0.21787	0.52763	0.21341	-0.00812	0.76745	0.06245
SBA	0.12239	0.16568	0.07227	-0.13966	0.87061	0.09022
OSU	0.03973	0.90996	0.06146	0.08275	0.02922	0.06353
SFO	0.07120	0.83014	-0.05841	-0.10916	-0.14048	-0.01648
OCC	0.02888	0.06719	0.78116	0.11135	0.02086	-0.04584
OP1	0.04518	0.05454	0.91468	0.03151	0.04011	-0.01204
OP2	0.10121	0.11651	0.92410	0.03185	0.09204	0.06702
OM1	0.25257	0.21978	0.84855	0.00287	0.10965	0.07693
OM2	0.18492	0.24084	0.81150	0.06813	0.10928	0.07640
CCB	0.74264	0.07321	0.24343	-0.11238	0.33158	-0.26966
P1B	0.84921	0.07484	0.12572	-0.14087	0.17096	-0.23727
XP2	0.76916	0.19991	0.21886	0.00006	0.18643	0.04759
P2B	0.93288	0.12838	0.03178	-0.03698	0.04498	-0.08019
M1B	0.87462	0.13665	0.07352	-0.09329	-0.07611	0.12516
XM2	0.75840	0.23166	0.17463	0.07944	0.09202	0.35775
M2B	0.84321	0.06022	-0.02967	0.04715	-0.04969	0.36430
TTB	0.49112	-0.16408	0.11067	0.01261	0.09669	0.56429
CCH	-0.01281	0.10425	0.00278	0.88924	-0.03841	-0.10225
P1H	-0.09389	0.02277	0.06661	0.91112	-0.07010	-0.04191
P2H	-0.06424	0.02634	0.14982	0.87734	-0.04938	0.26209
M1H	-0.02881	0.11533	0.06648	0.70311	0.03724	0.58372
M2H	-0.00320	0.14277	0.02091	0.57778	0.11135	0.62973

Table 15. Rotated factor loadings of all female sample using palatal measurement data.

Variable	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI
EXL	0.76357	0.19965	0.28728	0.17241	0.19248	-0.01982
OSP	0.78721	0.27804	0.34482	0.01905	0.02492	-0.08682
OST	0.83963	0.22657	0.35965	0.01426	0.07950	0.00956
ORT	0.80158	0.24436	0.33602	0.09308	0.14154	-0.00695
OBA	0.63726	0.25262	0.33003	-0.02731	0.07609	0.55024
SBA	0.10284	0.10764	0.08381	-0.00248	0.08748	0.96321
OSU	0.84896	-0.01189	0.13472	0.00779	-0.00156	0.16707
SFO	0.75759	-0.03314	-0.01269	-0.02491	-0.03952	0.08866
OCC	0.10654	0.07237	0.72378	0.10367	0.01711	-0.02354
OP1	0.17085	-0.04078	0.87180	0.08364	0.02923	-0.03484
OP2	0.19179	0.05676	0.89342	0.02663	0.06877	0.10705
OM1	0.28187	0.18330	0.81695	0.03956	-0.01445	0.07236
OM2	0.35450	0.12897	0.79528	0.06704	0.03420	0.12232
CCB	0.15708	0.86829	0.17864	-0.06784	-0.00986	-0.00982
P1B	0.18519	0.86003	0.08771	-0.02790	0.27460	0.07518
XP2	0.17592	0.64336	0.14766	0.04168	0.45175	-0.02441
P2B	0.12690	0.81143	0.04367	-0.03940	0.37768	0.14229
M1B	0.05856	0.59878	-0.06240	-0.02088	0.61830	0.22838
XM2	0.18674	0.36373	0.02098	0.17371	0.82092	0.07652
M2B	0.07575	0.38977	-0.05138	0.02658	0.80850	0.13560
TTB	-0.04380	0.05787	0.11712	0.01706	0.83088	-0.08813
CCH	-0.15551	-0.06358	0.23695	0.75212	0.08657	-0.13349
P1H	-0.07881	-0.06894	0.16379	0.83812	0.10481	-0.01900
P2H	-0.00608	0.01952	0.06647	0.92163	0.06661	0.02552
M1H	0.15187	0.00148	-0.02156	0.87008	-0.00630	0.08819
M2H	0.25391	0.01889	-0.09832	0.77269	-0.07726	0.00535

Table 16. Variance and percentage of variation explained by each of the six rotated factors of the all male sample.

Factor Number	I	II	III	IV	V	VI
Variance	5.39103	4.32336	4.35122	3.41319	2.14251	1.60191
Percentage of variation	20.7	16.6	16.7	13.1	8.2	6.2

Table 17. Variance and percentage of variation explained by each of the six rotated factors of the all female sample.

Factor Number	I	II	III	IV	V	VI
Variance	4.81399	3.58676	4.14144	3.57680	2.93767	1.44520
Percentage of variation	18.5	13.8	15.9	13.8	11.3	5.6

female samples respectively. Slight differences in the percentage of variation explained by specific factors are recognizable.

Factor scores were calculated on the six rotated factors for each individual in the male and female samples. While keeping the sexes separate, these scores were divided among their respective racial population. Group factor means and standard deviations were obtained and are presented in Table 18 for males and Table 19 for females.

Differences in the mean factor scores between population pairs were tested for significance by t-test procedures. The results are presented in Tables 20 and 21 for males and females respectively. The size of the values reflects the degree of difference between population pairs for a given function and their associated significance levels of probability are recorded. The sign, positive or negative, may be interpreted to suggest whether the palatal dimension represented by the factor is greater or lesser in the members of the first population of the population pair. For example, the Factor 1 value between the White and Negro male populations (Table 20) is -3.0458. This is accepted to show that the White palates are significantly less broad than those characteristic of the Negro population at a probability level of $P < .005$.

Further examination of the significant values in the male sample (Table 20) shows that for palatal breadth, Whites are more narrow than the other three populations and the Negro group is less broad than the Larson. For full palatal length, the Negro samples are longer than those for Whites and American Indians. The only significant difference in segmented length occurs between the White and Mobridge populations

Table 18. Male means and standard deviations for factor scores.

	White		Negro		Mobridge		Larson	
Factor	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1	-0.587	1.064	0.081	1.128	0.318	0.787	0.694	0.752
2	-0.246	0.969	0.501	1.239	-0.283	0.589	-0.227	0.832
3	-0.246	0.866	0.181	1.329	0.257	0.743	-0.129	0.623
4	-0.412	1.025	-0.155	1.049	0.586	0.919	0.548	0.921
5	-0.419	0.991	0.251	1.166	0.200	0.753	0.136	0.855
6	-0.392	1.039	0.209	1.078	0.208	0.965	0.160	0.760

Table 19. Female means and standard deviations for factor scores.

	White		Negro		Mobridge		Larson	
Factor	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1	-0.601	0.896	0.577	1.118	-0.239	0.917	-0.336	0.918
2	-0.841	1.186	0.065	1.003	0.384	1.046	0.293	0.712
3	-0.388	1.136	0.181	1.073	0.065	0.753	-0.055	0.919
4	-0.547	0.802	-0.315	1.108	0.825	0.996	0.330	0.940
5	-0.577	1.074	0.210	1.151	0.046	0.714	0.090	0.823
6	-0.775	1.243	0.403	1.008	0.227	0.910	-0.289	0.787

Table 20. T-test between mean factor scores of male population pairs. A generalized morphological interpretation shown in parentheses is provided for each factor.

Population Pair	Factor I (Breadth)	Factor II (Length)	Factor III (Segmented Length)	Factor IV (Height)	Factor V (OBA/SBA)	Factor VI (Posterior Breadth & Height)
White X Negro	-3.0458***	-3.3589***	9031	1.2397	-3.0958***	-2.8388**
White X Mobridge	-3.7623***	0.1751	-2.4813*	-4.1102***	-2.7482**	-2.4132*
White X Larson	-5.3761***	-0.0838	0.6013	-3.9517***	-2.3890*	-2.3572*
Negro X Mobridge	0.9408	2.9932***	0.2653	-3.0020***	0.1986	0.0039
Negro X Larson	-2.4545*	2.6507**	1.1042	-2.8466**	0.4372	0.2031
Mobridge X Larson	7270	-0.2748	1.9906	0.0077	0.2809	0.1954

*P $\leq$ .05. **P $\leq$ .01. ***P $\leq$ .005.

Table 21. T-test between mean factor scores of female population pairs. A generalized morphological interpretation shown in parentheses is provided for each factor.

Population Pair	Factor I (Length)	Factor II (Breadth)	Factor III (Segmented Length)	Factor IV (Height)	Factor V (Posterior Breadth & Height	Factor VI (OSB/SBA)
White X Negro	-4.5096***	-3.4264***	-2.0957*	-0.9155	-2.8118**	-4.3590***
White X Mobridge		-3.8384***	-1.6524	-5.2947***	-2.1943*	-3.2300***
White X Larson	-1.0219	-4.0789***	-1.1306	-3.5051***	-2.4455*	-1.6424
Negro X Mobridge	3.1550***	2799	0.4837	-4.3385***	0.6512	0.7359
Negro X Larson	3.5290***	-0.9286	0.9402	-2.4938*	0.4645	3.0033***
Mobridge X Larson	0.3737	0.3596	0.5053	1.8065	-0.2018	2.1455*

*P $\leq$ .05. **P $\leq$ .01. ***P $\leq$ .005.

where the Mobridge display greater lengths. The American Indian groups display greater palatal depth over the Negroes and Whites. There is no significant difference in palatal depth between the Negro and White populations. Negro, Mobridge and Larson samples display greater OBA-SBA lengths than the White group, but do not significantly differ among themselves. This pattern is also noted for the final factor representing posterior breadth and height.

The females (Table 21) differ only moderately from the pattern of variability noted within the male sample. In two cases, the factors for length and height, the populations with significant differences were the same as in the males. The female posterior breadth factor also shows the condition reported for the male posterior breadth and height factor.

For the breadth factor, the females vary from the males in that the Negro and Larson populations are not found to be significantly different at any level. The only female populations to be significantly different for the segmented length factor are the White and Negroes with larger length associated with the latter.

The OBA-SBA factor differed most greatly between the female and male samples. Unlike the males, the females show significant differences between the Negro and Larson and the Mobrigde and Larson populations and no significant difference between the White and Larson groups. The female OBA-SBA factor is the only one for both males and females to show any significant difference between the two American Indian populations.

The rotated factor loadings of the male sample using both palatal and cranial data are presented in Table 22. The first five factors have

Table 22. Rotated factor loadings of all male sample using palatal and cranial measurement data.

Variable	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI
EXL	0.17966	0.73838	0.30120	0.12298	0.35217	0.04535
OSP	0.19024	0.72907	0.31357	0.09243	0.29940	0.16107
OST	0.21016	0.77264	0.30623	0.09974	0.25762	0.15430
ORT	0.19811	0.76023	0.38265	0.11887	0.34553	0.06379
OBA	0.22080	0.56248	0.22692	-0.04486	0.71930	0.08292
SBA	0.14191	0.20163	0.08784	-0.16164	0.83778	0.03244
OSU	0.05085	0.87474	0.05972	0.06445	0.01644	5916
SFO	0.07995	0.78795	-0.06121	-0.08659	-0.13885	0.00213
OCC	0.01871	0.08505	0.78630	0.06745	-0.03173	0.04786
OP1	0.04298	0.06356	0.90960	0.02918	0.02591	0.00967
OP2	0.10999	0.10456	0.92010	0.04340	0.10039	0.03809
OM1	0.25729	0.21078	0.84700	0.00114	0.09874	0.04632
OM2	0.18659	0.23019	0.80904	0.07228	0.11004	0.06710
CCB	0.71653	0.14928	0.25686	-0.05225	0.27561	-0.31572
P1B	0.82216	0.13503	0.14316	-0.10653	0.10550	-0.25727
XP2	0.76868	0.21134	0.23720	-0.05544	0.13488	0.11836
P2B	0.91613	0.16356	0.03698	-0.01505	0.00434	-0.11527
M1B	0.88106	0.12304	0.07068	-0.08611	-0.07988	0.03836
XM2	0.77809	0.18723	0.17455	0.01229	0.10497	0.33086
M2B	0.85991	0.01747	-0.03928	0.01140	-0.02599	0.24749
TTB	0.54351	-0.24156	0.08289	0.05936	0.21160	0.24062
CCH	-0.03764	0.14648	0.00544	0.86198	-0.08140	0.13620
P1H	-0.10389	0.04923	0.06051	0.89953	-0.07715	0.16699
P2H	-0.05822	-0.01481	0.15356	0.81130	-0.02377	0.41410
M1H	0.00638	0.00383	0.08005	0.57114	0.09257	0.68200
M2H	0.03763	0.02499	0.03275	0.43220	0.18010	0.72394
MXL	0.13332	0.28862	0.04002	0.20004	0.28718	0.21192
MXB	0.06036	-0.11780	0.04033	-0.11657	-0.13202	-0.01465
BIZ	0.30602	0.10424	0.03623	-0.05871	0.02440	0.26209
UPF	0.11592	0.38465	0.07463	0.14670	-0.06388	0.62983

Table 22 (continued).

Variable	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI
BAB	0.06656	-0.13567	0.12843	0.03370	-0.04085	-0.00150
NSP	-0.00556	0.31406	0.07781	0.26843	-0.02260	0.64880
MNF	-0.01288	0.05853	-0.06662	0.17406	0.05005	-0.06513
NOB	0.42764	0.18533	-0.04453	0.07762	0.26329	-0.27141

similar interpretations and order to the male factor structure based only on palatal measurements. The sixth factor loads positively on posterior palatal height and posterior palatal breadth variables and negatively on measures of anterior palatal breadth.

Means and standard deviations for raw cranial measurements have been presented in Table 2, page 27.

The variance and the percentage of variation explained by each of the first six rotated factors are presented in Table 23. Additional factors yielded eigenvalues greater than 1.0 but were dismissed from the analysis because they represented only cranial variables.

Table 23. Variance and percentage of variation explained by each of the six rotated factors of the all male sample using palatal and cranial measurement data.

Factor Number	I	II	III	IV	V	VI
Variance	5.71419	4.77070	4.42176	3.04010	2.07274	2.73936
Percentage of variation	16.8	14.0	13.0	8.9	6.1	8.1

The attempt to identify intercorrelations between palatal and cranial variables through the examination of factor structures proved moderately successful. The greatest intercorrelations occur within the palatal breadth, length, and Factor VI factors.

The palatal breadth factor shows association with the cranial bizygomatic and nasal breadth variables. Somewhat surprisingly, the loading for maximum cranial breadth is almost negligible suggesting that the correlations are, in this case, restricted to the facial structures.

The palatal length factor is correlated with maximum cranial length, upper facial height, and nasospinale-prosthion length variables. Although it is understandable that maximum cranial length may be directly associated with palatal length, the other two variables must be considered further. If one accepts that NSP length and upper facial height reflect the degree of alveolar prognathism, this could account for the association. Not only would prognathism increase the distance from prosthion to other facial landmarks, it may be seen to lengthen the palate as well.

Nasospinale-prosthion length and upper facial height are also correlated with the previously described sixth factor. Unfortunately, no interpretation is provided for this occurrence.

CHAPTER V

CONCLUSION

This investigation has provided evidence that the morphology of the palate may be quantified by both univariate and multivariate procedures. From these analyses, the existence of variability has been identified among and between the four populations.

The discriminant function analyses allowed for the examination of the variability and provided a means, through generalized distance statistics, to distinguish the significance and relative degree of variability in population relationships. The existence of variability was also used in the two-group discriminant analyses to calculate functions based on palatal measurements from which unknown individuals may be classified into their proper racial and sexual groups. It was found that greater accuracy in classification occurs between racial groups than among males and females within a population.

The factor analyses and the correlations between the discriminant functions and individual variables exposed the palatal dimensions which significantly differed between and within the racial groups. It was shown that the morphological pattern for males and females reveals both similarities and differences, although the similarities greatly outweigh the differences.

This study did not attempt to explain the evolutionary causes of the reported variability. Instead, it presents the data as a model for

the identification of morphological variability in a skeletal structure within and between racial populations using statistical procedures whose results may be tested for their significant level of probability. The information about palatal morphology revealed from the study has direct implication to forensic anthropology and more generally it provides a data base for further investigations into the study of human variation.

BIBLIOGRAPHY

BIBLIOGRAPHY

Anderson, T. W.
1958 An Introduction to Multivariate Statistical Analyses. John Wiley and Sons, New York.

Bass, W. M.
1971 Human Osteology: A Laboratory and Field Manual of the Human Skeleton. Missouri Archeological Society, Incorporated, Columbia.

Birkby, W. H.
1966 An evaluation of race and sex identification from cranial measurements. American Journal of Physical Anthropology, 24: 21-28.

Brace, C. L.
1967 Environment, tooth form, and size in the Pleistocene. Journal of Dental Research, 46: 809-816.

Brown, T., M. J. Barrett and J. N. Darroch
1965 Craniofacial factors in two ethnic groups. Growth, 29: 109-123.

Campbell, T. D.
1925 Dentition and Palate of the Australian Aboriginal. The Hassell Press, Adelaide.

Cooley, W. W. and P. R. Lohnes
1962 Multivariate Procedures for the Behavioral Sciences. John Wiley and Sons, Incorporated, New York.

Crichton, J. M.
1966 Craniometry and Multivariate Analysis: A Multiple Discriminant Analyses of Egyptian and African Negro Crania. Papers of the Peabody Museum of Archaeology and Ethnology, Harvard University, Volume 57, Number 1, Cambridge.

De Villers, H.
1968 The Skull of the South African Negro: A Biometrical and Morphological Study. Witwatersrand University Press, Johannesburg.

Dixon, W. J.
1976 BMD Biomedical Computer Programs. University of California Publications in Automatic Computation Number 2. University of California Press, Berkeley.

EL-Najjar, M. Y. and K. R. McWilliams
1978 Forensic Anthropology: The Structure, Morphology, and Variation of Human Bone and Dentition. Charles C. Thomas, Springfield, Illinois.

Fisher, R. A.
1936 The use of multiple measurements in taxonomic problems. Annals of Eugenics, 7: 179-1-8.

Flander, L. B.
1978 Univariate and multivariate methods for sexing the sacrum. American Journal of Physical Anthropology, 49:103-110.

Flower, W. H.
1881 On the cranial characters of the natives of the Fiji Islands. Journal of the Royal Anthropological Institute of Great Britain and Ireland, 2: 153-174.

Friedlaender, J. S.
1975 Patterns of Human Variation: The Demography, Genetics, and Phenetics of Bougainville Islanders. Harvard University Press, Cambridge.

Gilbert, B. M. and T. W. McKern
1973 A method for aging the female Os pubis. American Journal of Physical Anthropology, 38: 31-38.

Giles, E.
1964 Sex determination by discriminant function analysis of the mandible. American Journal of Physical Anthropology, 22: 129-136.

1967 Statistical techniques for sex and race determination: Some comments in defense. American Journal of Physical Anthropology, 25: 85-86.

1970 Discriminant function sexing of the human skeleton. In Personal Identification in Mass Disasters. Edited by T. D. Stewart. National Museum of Natural History, Smithsonian Institution, Washington, pp. 99-109.

Giles, E. and O. Elliot
1962 Race identification from cranial measurements. Journal of Forensic Sciences, 7: 147-157.

1963 Sex determination by discriminant function analysis of crania. American Journal of Physical Anthropology, 21: 53-68.

Goss, C. M.
1973 Gray's Anatomy. Twenty-Ninth American Edition, Lea and Febiger, Philadelphia.

Hooke, B. G. E.
1926 A third study of the English skull with special reference to the Farringdon Street crania. Biometrika, 18: 1-55.

Howells,
1959 Mankind in the Making: The Story of Human Evolution. Doubleday and Company, Incorporated, Garden City, New York.

1966 Craniometry and Multivariate Analysis: The Jomon Population of Japan, A study by Discriminant Analysis of Japanese and Ainu Crania. Papers of the Peabody Museum of Archeology and Ethnology, Harvard University, Volume 57, Number 1, Cambridge.

1969 The use of multivariate techniques in the study of skeletal populations. American Journal of Physical Anthropology, 31: 311-314.

1970 Multivariate analysis for the identification of race from crania. In Personal Identification in Mass Disasters. Edited by T. D. Stewart. National Museum of Natural History, Smithsonian Institution, Washington, pp. 11-121.

1973 Cranial Variation in Man: A Study by Multivariate Analysis of Patterns of Difference among Recent Human Populations. Papers of the Peabody Museum of Archeology and Ethnology, Harvard University, Volume 67, Cambridge.

Hrdlicka, A.
1920 Practical Anthropometry. The Wistar Institute of Anatomy and Biology, Philadelphia.

Hylander, W. L.
1977a The adaptive significance of Eskimo craniofacial morphology. In Orofacial Growth and Development. Edited by A. A. Dahlberg and T. M. Graber. Mouton, The Hague, pp. 129-169.

1977b Morphological changes in human teeth and jaws in a high-attrition environment. In Orofacial Growth and Development. Edited by A. A. Dahlberg and T. M. Graber. Mouton, The Hague, pp. 301-330.

Jacob, S. W. and C. A. Francone
1970 Structure and Function in Man. W. B. Saunders Company, Philadelphia.

Jantz, R. L.
1972 Cranial variation and microevolution in Arikara skeletal populations. Plains Anthropologist, 17: 20-35.

Jantz, R. L. and D. W. Owsley
1977 Factor analysis of finger ridge-counts in Blacks and Whites. Annals of Human Biology, 4: 357-366.

Kendall, M. G.
1957 A Course in Multivariate Analysis. Hafner, New York.

Knott, V. B.
1961 Size and form of the dental arches in children with good occlusion studied longitudinally from age 9 years to late adolescence. American Journal of Physical Anthropology, 19: 263-284.

Kowalski, C. J.
1972 A commentary on the use of multivariate statistical methods in anthropometric research. American Journal of Physical Anthropology, 36: 119-132.

Krogman, W. M.
1962 The Human Skeleton in Forensic Medicine. Charles C. Thomas, Springfield, Illinois.

Landauer, C. A.
1962 A factor analysis of the facial skeleton. Human Biology, 34: 239-253.

Lavelle, C. L. B.
1974 The British dental arch. American Journal of Physical Anthropology, 41: 63-70.

1977 A study of the taxonomic significance of the dental arch. American Journal of Physical Anthropology, 46: 415-422.

Lavelle, C. L. B., R. M. Flinn, T. D. Foster, and M. C. Hamilton
1970 An analysis into the age changes of the human dental arch by a multivariate technique. American Journal of Physical Anthropology, 33: 403-412.

Leigh, R. W.
1925 Dental pathology of Indian tribes of varied environmental and food conditions. American Journal of Physical Anthropology, 8: 179-199.

1937 Dental morphology and pathology of pre-Spanish Peru. American Journal of Physical Anthropology, 22: 267-296.

Lombardi, A. V.
1975 A factor analysis of morphogenetic fields in the human dentition. American Journal of Physical Anthropology, 42: 99-104.

1976 Size integration of craniofacial and dental dimensions. In The Measures of Man: Methodologies in Biological Anthropology. Edited by E. Giles and J. S. Freidlaender. Peabody Museum Press, Cambridge, pp. 451-464.

MacCurdy, G. G.
1923 Human skeletal remains from the highlands of Peru. American Journal of Physical Anthropology, 6: 217-330.

Macdonnell, W. R.
1906-1907 A second study of the English skull with special reference to the Moorfield crania. Biometrika, 5: 86-104.

McCann, M., D. Torney, W. McCann, and T. Grant
1967 Occlusal attrition, transpalatal dimensions and the early New Zealand Moari. American Journal of Physical Anthropology, 25: 87-90.

Miller, S. C. and H. Roth
1940 Torus palatinus, a statistical study. Journal of American Dentistry Association, 27: 1950-1957.

Morant, G. M.
1923 A first study of the Tibetan skull. Biometrika, 14: 193-260.

1924 A study of certain oriental series of crania including the Nepalese and Tibetan series in the British Museum. Biometrika, 26: 1-105.

1925 A study of Egyptian craniology from prehistoric to Roman times. Biometrika, 17: 1-52.

1926 A first study of the craniology of England and Scotland from Neolithic to early Historic times, with special reference to the Anglo-Saxon skull in London museums. Biometrika, 18: 56-98.

1927 A study of the Australians and Tasmanian skulls, based on previously published measurements. Biometrika, 19: 417-440.

Morrison, D. F.
1967 Multivariate Statistical Methods. McGraw-Hill, New York.

Moss, M. L. and P. S. Chase
1967 Morphology of Liberian Negro deciduous teeth: Arch dimensions and occlusion. American Journal of Physical Anthropology, 25: 261-276.

Nakata, M., P. L. Yu, and W. E. Nance
1974 Multivariate analysis of craniofacial measurements in twin and family data. American Journal of Physical Anthropology, 41: 423-430.

Nie, N. H., C. H. Hull, J. Jenkins, K. Steinbrenner, and D. H. Bent
1975 Statistical Package for the Social Sciences. McGraw-Hill, New York.

Oliver, G.
1969 Practical Anthropology. Charles C. Thomas, Springfield, Illinois.

Owsley, D. W. and R. L. Jantz
1978 Intracemetery morphological variation in Arikara crania from the Sully site (39SL4), Sully County, South Dakota. Plains Anthropologist, 23: 139-147.

Parsons, F. G.
1913 On some Bronze Age and Jutish bones from Broadstairs, with type contours of all the Bronze Age skulls in the Royal College of Surgeons Museum. Journal of the Royal Anthropological Institute of Great Britain and Ireland, 43: 550-592.

Pearson, K.
1925 The definition of the alveolar point. Biometrika, 17: 53-56.

Pearson, K. and A. G. Davin
1924 On the biometric constants of the human skull. Biometrika, 26: 328-363.

Potter, R. H. Y., P. L. Yu, A. A. Dahlberg, A. F. Merritt, and P. M. Conneally
1968 Genetic studies of tooth size factors in Pima Indian families. American Journal of Human Genetics, 20: 89-100.

Smith, R. J. and H. L. Bailit
1977 Variation in dental occlusion and arches among Melanesians of Bougainville Island, Papua New Guinea: Methods, age changes, sex differences and population comparisons. American Journal of Physical Anthropology, 47: 195-208.

Smith, R. J., F. Kolakowski, and H. L. Bailit
1978 Variation in dental occlusion and arches among Melanesians of Bougainville Island, Papua New Guinea: Clinical variation, geographic microdifferentiation and synthesis. American Journal of Physical Anthropology, 48: 331-342.

Taylor, R. M. S.
1962 The human palate. Acta Anatomica, Supplement 43 to Volume 49: 1-138.

Trotter, M., and G. C. Gleser
1952 Estimation of stature from long bones of American Whites and Negroes. American Journal of Physical Anthropology, 10: 463-514.

1958 A re-evaluation of estimation of stature based on measurements of stature taken during life and of long bones after death. American Journal of Physical Anthropology, 16: 59-123.

Wilder, H. H.
1920 Laboratory Manual of Anthropometry. P. Blakiston's Son and Company, Philadelphia.

Woo, J. K.
1950 Torus palatinus. American Journal of Physical Anthropology, 8: 81-100.

APPENDIX

Table 24. Within group correlation matrix for male sample using palatal measurement data.

WITHIN GROUPS CORRELATION MATRIX

	EXL	OSP	OST	ORT	OBA	SBA	OSU	SFO	OCC	OPI
EXL	1.0000									
OSP	0.7730	1.0000								
OST	0.7803	0.9371	1.0000							
ORT	0.9068	0.8602	0.8694	1.0000						
OBA	0.7313	0.7739	0.7552	0.7817	1.0000					
SBA	0.4223	0.3162	0.3278	0.4235	0.8335	1.0000				
OSU	0.6027	0.6361	0.7008	0.6733	0.5348	0.2617	1.0000			
SFO	0.4669	0.3742	0.4476	0.4799	0.3519	0.1890	0.7808	1.0000		
OCC	0.2676	0.2546	0.2875	0.3500	0.2380	0.1505	0.1474	0.0841	1.0000	
OPI	0.3182	0.3297	0.3290	0.4049	0.2760	0.1535	0.1284	0.0158	0.7285	1.0000
OPS	0.3886	0.4299	0.4193	0.4709	0.3673	0.1991	0.1829	0.0535	0.6660	0.8653
OMI	0.4907	0.5110	0.5012	0.5558	0.4407	0.2307	0.2820	0.1383	0.5860	0.7348
OMS	0.5109	0.4925	0.4973	0.5700	0.4119	0.1970	0.2890	0.1253	0.5351	0.6880
CCH	0.3929	0.3225	0.3550	0.4115	0.4610	0.3769	0.1268	0.1202	0.2019	0.2438
PIH	0.2855	0.2811	0.2921	0.3369	0.3554	0.2595	0.1005	0.1488	0.1514	0.1620
XPS	0.4335	0.4099	0.4173	0.4677	0.4332	0.2858	0.2413	0.1552	0.2091	0.2307
PSH	0.2805	0.2958	0.3205	0.2996	0.3158	0.1950	0.1669	0.1649	0.0573	0.1049
MIH	0.2223	0.2874	0.3098	0.2440	0.2638	0.1289	0.1375	0.1726	0.0579	0.1283
XMS	0.4428	0.4248	0.4340	0.4608	0.4037	0.2354	0.2565	0.1614	0.2257	0.2206
MSH	0.1540	0.2169	0.2306	0.1634	0.2249	0.1433	0.1017	0.1155	0.0302	0.0335
TTH	-0.0101	0.1007	0.0752	0.0564	0.1599	0.1656	-0.0359	-0.0551	0.0431	0.0949
CCH	0.1751	0.1552	0.1764	0.1524	0.0289	-0.0946	0.1960	0.0557	0.1348	0.0674
PIH	0.1137	0.1031	0.1055	0.1195	-0.0368	-0.1461	0.1169	-0.0362	0.1439	0.0904
PSH	0.1251	0.1780	0.1748	0.1632	0.0098	-0.1312	0.1188	-0.0716	0.1683	0.1300
MIH	0.1502	0.2340	0.2412	0.1940	0.1105	-0.0069	0.1990	0.0004	0.1121	0.0692
MSH	0.1902	0.2503	0.2518	0.2012	0.1633	0.0728	0.2077	0.0274	0.0980	0.0658

Table 24 (continued).

	OP2	OM1	OM2	CCB	P1B	XP2	P2B	M1B	XM2	M2H
OP2	1.0000									
OM1	0.8478	1.0000								
OM2	0.7753	0.8374	1.0000							
CCB	0.3040	0.4520	0.3963	1.0000						
P1B	0.2113	0.3282	0.2506	0.8212	1.0000					
XP2	0.3169	0.4254	0.4093	0.6493	0.7144	1.0000				
P2B	0.1493	0.2822	0.2215	0.7167	0.8415	0.7289	1.0000			
M1B	0.1979	0.3131	0.2382	0.5879	0.6877	0.6311	0.8275	1.0000		
XM2	0.2718	0.3898	0.3513	0.4933	0.5591	0.7518	0.6796	0.6820	1.0000	
M2B	0.0864	0.2238	0.1566	0.4706	0.5513	0.5785	0.7454	0.8188	0.8003	1.0000
TTB	0.1761	0.2638	0.1893	0.2961	0.2945	0.3277	0.3722	0.4214	0.4917	0.5644
CCH	0.0475	0.0233	0.0516	-0.0987	-0.1536	-0.0363	-0.0390	-0.0808	0.0306	0.0423
P1H	0.0847	0.0391	0.0975	-0.1993	-0.2253	-0.1002	-0.1314	-0.1461	0.0152	-0.0168
P2H	0.1742	0.1555	0.2133	-0.1826	-0.2174	-0.0138	-0.0928	-0.0846	0.1206	0.0672
M1H	0.1432	0.1232	0.1717	-0.1730	-0.1826	0.0958	-0.0635	0.0019	0.2500	0.1710
M2H	0.0981	0.0812	0.1515	-0.1306	-0.1219	0.1171	-0.0317	0.0192	0.2940	0.2129

	TTB	CCH	P1H	P2H	M1H	M2H
TTB	1.0000					
CCH	0.0335	1.0000				
P1H	0.0156	0.7919	1.0000			
P2H	0.1310	0.6894	0.7848	1.0000		
M1H	0.2092	0.5054	0.5613	0.8119	1.0000	
M2H	0.2069	0.4389	0.4336	0.6050	0.8248	1.0000

Table 25. Within group correlation matrix for female sample using palatal measurement data.

WITHIN GROUPS CORRELATION MATRIX

	EXL	OSP	OST	ORT	OBA	SBA	OSU	SFO	OCC	OPI
EXL	1.0000									
OSP	0.7298	1.0000								
OST	0.7880	0.9297	1.0000							
ORT	0.8779	0.8312	0.8765	1.0000						
OBA	0.6482	0.7527	0.7845	0.7263	1.0000					
SBA	0.1647	0.0501	0.1649	0.1746	0.6707	1.0000				
OSU	0.5838	0.6102	0.7005	0.6333	0.5868	0.2321	1.0000			
SFO	0.4504	0.4327	0.5167	0.4743	0.3873	0.1296	0.7645	1.0000		
OCC	0.3103	0.3096	0.3478	0.3318	0.2686	0.0829	0.2519	0.1396	1.0000	
OPI	0.3465	0.4450	0.4545	0.4081	0.3546	0.0481	0.2920	0.1342	0.6822	1.0000
OP2	0.4038	0.4487	0.4751	0.4558	0.4627	0.1765	0.3276	0.1952	0.5700	0.7882
OM1	0.4822	0.4985	0.5370	0.5184	0.4924	0.1628	0.3599	0.2647	0.4983	0.6658
OM2	0.5460	0.5376	0.5857	0.5648	0.5477	0.2184	0.4300	0.2546	0.5342	0.6786
CCB	0.3176	0.3899	0.3678	0.3748	0.3714	0.1253	0.1863	0.1211	0.1778	0.1382
P1B	0.4020	0.3861	0.3960	0.3951	0.4118	0.2210	0.2020	0.1552	0.1766	0.0966
XP2	0.4049	0.3505	0.3658	0.4157	0.3359	0.1537	0.1526	0.0963	0.2013	0.0996
P2B	0.3060	0.3337	0.3308	0.3599	0.3897	0.2553	0.1604	0.1186	0.1250	0.0602
M1B	0.2317	0.2109	0.2112	0.2425	0.3077	0.2984	0.0814	0.0695	0.0147	-0.0123
XM2	0.4127	0.2633	0.3084	0.3893	0.3067	0.2082	0.1535	0.0706	0.0881	0.0740
M2B	0.2247	0.1564	0.2000	0.2342	0.2387	0.2082	0.1163	0.0576	0.0314	0.0053
TTH	0.1696	0.0383	0.0747	0.0966	0.0678	0.0259	-0.0328	-0.0831	0.0867	0.0829
CCH	0.1052	0.0004	-0.0095	0.0727	-0.0817	-0.1009	-0.1083	-0.1191	0.1967	0.2340
P1H	0.1570	0.0414	0.0287	0.1252	0.0088	0.0001	-0.0568	-0.0702	0.1296	0.1919
P2H	0.1858	0.0525	0.0518	0.1013	0.0354	0.0302	0.0098	-0.0171	0.1279	0.1000
M1H	0.2005	0.0925	0.1095	0.1357	0.0685	0.0628	0.1724	0.1062	0.1327	0.1105
M2H	0.2569	0.1154	0.1401	0.1792	0.0487	0.0063	0.2261	0.1538	0.0764	0.0608

Table 25 (continued).

	DP2	DM1	DM2	CCB	P1B	XP2	P2B	M1B	XM2	M2B
DP2	1.0000									
DM1	0.8315	1.0000								
DM2	0.7977	0.8478	1.0000							
CCB	0.2390	0.3716	0.3146	1.0000						
P1B	0.2037	0.2460	0.2412	0.7602	1.0000					
XP2	0.2026	0.2863	0.3274	0.5534	0.6690	1.0000				
P2B	0.1556	0.2213	0.1835	0.6683	0.8457	0.6435	1.0000			
M1B	0.0838	0.0773	0.0803	0.4730	0.6786	0.6016	0.7679	1.0000		
XM2	0.1563	0.1445	0.1846	0.3474	0.5466	0.6918	0.5943	0.7371	1.0000	
M2B	0.0838	0.0563	0.0814	0.3594	0.5629	0.5261	0.6689	0.8063	0.7984	1.0000
TTB	0.1195	0.1121	0.1385	0.1888	0.3159	0.3890	0.3300	0.3940	0.6236	0.5908
CCH	0.1774	0.1082	0.0950	-0.1284	-0.0594	0.0323	-0.0441	-0.0117	0.1042	0.0438
P1H	0.1559	0.1077	0.0673	-0.1085	-0.0469	0.0186	-0.0221	0.0016	0.1718	0.0387
P2H	0.0894	0.1140	0.1219	-0.0240	0.0232	0.1119	-0.0070	-0.0019	0.2238	0.0633
M1H	0.0506	0.0774	0.1854	-0.0116	0.0079	0.0424	-0.0228	0.0118	0.1851	0.0706
M2H	0.0020	0.0768	0.1241	0.0148	-0.0076	0.0315	-0.0232	-0.0380	0.1475	0.0114

	TTB	CCH	P1H	P2H	M1H	M2H
TTB	1.0000					
CCH	0.0266	1.0000				
P1H	0.0762	0.7944	1.0000			
P2H	0.1081	0.6536	0.7971	1.0000		
M1H	0.0535	0.4529	0.5565	0.7817	1.0000	
M2H	0.0022	0.3546	0.4209	0.6065	0.8240	1.0000

VITA

David Michael Glassman was born in St. Paul, Minnesota on November 16, 1953. He attended primary and secondary school in that city and graduated from Highland Park Senior High School in 1971. He entered Arizona State University the following fall and remained for one year. In the fall of 1973 he returned to Saint Paul and continued his undergraduate work at the University of Minnesota, receiving his B.A. in Anthropology in March 1976.

For the first three months following completion of his undergraduate work, David was involved in archaeological investigations in Morelos, Mexico. There he served as a supervisor of skeletal excavation and burial analysis. In September of 1976, he was invited back to Mexico to work as a physical anthropologist on the Proyecto Coatetelco in western Morelos.

David entered graduate school at the University of Tennessee, Knoxville in the Winter Quarter of 1977. Here he has been involved in the collection of dental and dermatoglyphic data for the Anthropology Department and most recently in the development of the Department's newly acquired marmoset skeletal collection.

David is a member of the American Association of Physical Anthropologists and the American Anthropological Association. He is planning to begin work on his doctorate in Anthropology at the University of Tennessee in January 1979.