3-1983

Multivariate Discriminant Function Analyses of the Mandible in American Caucasoid and American Negroid Populations

Dorn P. Kile
University of Tennessee, Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Dorn P. Kile entitled "Multivariate Discriminant Function Analyses of the Mandible in American Caucasoid and American Negroid 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.

William M. Bass, Major Professor

We have read this thesis and recommend its acceptance:

Pat Willey, Richard Jantz

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

MULTIVARIATE DISCRIMINANT FUNCTION ANALYSES OF THE MANDIBLE IN AMERCIAN CAUCASOID AND AMERICAN NEGROID POPULATIONS

A Thesis

Presented for the

Master of Arts

Degree

The University of Tennessee, Knoxville

Dorn P. Kile

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material and sending me the results as verification of my own system of analysis.

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ABSTRACT

The purpose of this thesis is to develop a statistical method whereby the race and sex of an unknown individual may be ascertained from measurements taken from the mandible alone. Twenty-five such measurements were obtained from 160 mandibles representing, equally, American male and female Negro and Caucasian individuals. The skeletal collection used was the Terry collection at the Smithsonian Institution in Washington, D.C.

The data obtained were analyzed by nine separate discriminate functions representing various aspects of the mandible, including one which discriminated the samples by race only.

To test the significance and reliability of using such a procedure for forensic purposes, 13 test specimens were obtained from the University of Tennessee Anthropology Department forensic cases. These were subjected to discriminant function analysis which correctly identified anywhere from 38.5% to 76.9% of them (as opposed to a classification range of 37.5% to 97.5% in the reference samples themselves).

Further, using the discriminant function which classified only race, a test was set-up to ascertain the reliability of using such skeletal collections as the Terry samples to obtain data for use in establishing discriminant functions which test mandibular specimens from groups which may be temporally or genetically removed from the reference samples.

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CHAPTER I

INTRODUCTION AND OBJECTIVES

Anthropologists, and other scientists as well, have for years been measuring, grouping, and cataloguing the human species, not to mention the individual human. The purpose for this has been not so much to assign individuals and groups to their particular taxonomic niche in the human hierarchical scheme, although this has been done periodically with much fervor and fanfare; but simply to learn more about the differences which exist among groups and individuals, mostly from a morphological point of view.

For many years there were few systematic attempts at analysis of the informational data which were being stockpiled on human populations, both extant and expired. Facts and figures were accumulated, with some attempts at scientific differentiation (Cobb, 1942; Hrdlicka, 1940b and c; Morant, 1936). However, all too often the studies undertaken were simply either of a descriptive or accumulative nature (Todd and Lindala, 1928; Todd and Tracy 1930), which at the time was considered acceptable scientific procedure.

Recently, however, the exactness of science and the fire of wrath propelled by those previously described as primitive populations have made it imperative that all studies of human differences and similarities be as objective and as scientific as possible. For not only is the validity of the study dependent on such exacting methods, but the

future tranquility between all parties involved is more likely assured if a rational scientific base can be established.

This particular study will focus on the forensic application of human metrical analysis. For some years now systematic analysis of human skeletal material has been used for the purpose of identification (Giles, 1964; Howell, 1970), as well as classification. The usefulness of such metrical analyses has met with some criticism (Kowalski, 1972; Lavelle, 1977), but the methods employed are not so unreliable as to be totally useless. Kowalski's (1972) claim that test statistics are complicated functions which have no intuitive value as summaries of the informational content of the data, is certainly too strong a statement to be taken either literally or seriously. However, even though some problems do exist in such testing methods, steps can be taken to minimize these through such means as using prior probability to lessen the number of misclassifications (Morrison, 1967) or simply by testing as much as possible within the analysis group itself (Giles, 1966).

The use of multivariate statistical methods to accommodate the identification of skeletal material for forensic purposes has been used quite extensively in recent years (Giles, and Elliot, 1962; Glassman, 1978; Howells, 1970). Since the possibilities for the use of human metrical data in taxonomic analysis was first suggested (Fisher, R. A., 1936) the anthropological approach to anthropometric studies has become more and more scientific. There are, of course, still problems which will be evidenced in this study.

Since the skeletal elements are among the most easily quantified physical aspects of human populations, they are often subjected to forensic testing for purposes of identification. Not to mention the fact that much of the time the skeleton is all that remains of an individual. And when comparing present populations, physically, to those of the past there is little choice but to do so from a skeletal standpoint.

For purposes of differentiation the two most obvious, and most often studied, criteria for identification are race and sex. Both of these possibilities have been utilized fully in the past, but usually only with respect to a certain number of skeletal elements: the cranium (Todd and Tracy, 1930), the pelvis (Douglass, 1979), and the mandible and teeth (Giles, 1964). Some have been utilized more than others but all have been shown to be fairly reliable sources for either sexual or racial differentiation. Even the mandible whose racial possibilities was once described by Krogman (1961) as 'a moot question', now (according to this study) seems to be a fairly reliable element upon which forensic identification may rely.

The mandible, the bone which supports the lower dentition and articulates with the cranium at the temporo-mandibular joint and the upper dentition, was in fact, chosen for this study because it had been rejected or ignored by modern anthropologists as apparently racially neutral. At least there was very little to be said for or about it on a racially quantitative basis since Morant's (1936) study. However, the mandible has been used extensively in metrical

analyses for determining sex (Giles, 1964; Kile, 1977; Thieme, and Schull, 1957) in recent years.

With the foregoing review in mind, the objective of this study may bestated: that is, to develop a reliable and consistent data source from which identification of both American Negroes or American Caucasians may be obtained solely through the use of the mandible. More specifically, for forensic purposes especially, a number of discriminant functions are supplied (discriminant functions being analyses which maximize differences among a set of populations and permit individual specimens to be classified along with information concerning their use. In addition, the procedures utilized in measuring the mandible in order to procure data which can be successfully used in the prescribed function are described. With this tool it is hoped that the problem of the identification of human skeletal material may be somewhat lessened, and the procedures for obtaining such information expanded.

CHAPTER II

MATERIALS AND METHODS

A major obstacle to determining race through the use of discriminant function analyses on the mandible, as with any such study, is obtaining a sample collection, upon which to base the study, which is as representative of the entire population as possible. Even though this is an extremely difficult task, there are a few documented skeletal collections in the United States upon which one might base such a study. The Terry Collection, housed at the Smithsonian Institution in Washington, D.C., was used in this particular analysis; and even though there are problems associated with this collection, for statistical and practical purposes, its advantages far outweigh the drawbacks. Giles (1964) noted that there are disadvantages to using a St. Louis dissecting room skeletal collection obtained in the 1930s. And from the documentation available at the Smithsonian Institute's Museum of Natural History on each sample individual, as well as the obvious condition of the skeletal material itself, it would appear that a typical cross section of the population is not evident here. The Caucasian specimens are fewer and older than the Negroid specimens and quite often exhibit more pathologies and anomalies (as opposed to cosmetic restructuring) than those evident in the Black sample. Whatever may be said of the socio-economic status of the contributing population is pure conjecture; however, it would appear that the sample Caucasoid population is probably not as indicative of the whole

population as the sample Negroid collection (with its wider range of ages and mandibular conditions). Still, the collection must suffice, and it has been used effectively in many studies heretofore (Giles and Elliot, 1962; Giles, 1964; Gilbert and McKern, 1973; Glassman, 1978).

The data collected for this study were taken from 160 mandibles in the Terry Collection. Forty each, male and female, White and Black specimens were used to keep the selection of individual mandibles as random as possible, however, some selectivity was, of necessity, used in obtaining the forty Caucasian female samples due to their scarcity, and oftentimes, poor physical condition.

Twenty-five measurements were then recorded from each mandible through the use of either a sliding caliper or a goniometer. Two or three discrete traits from each mandible were also noted.

When only one side of the mandible was being used to obtain a measurement, the left side was utilized unless the condition of the bone was such that an accurate measurement was unobtainable, then the right side was used. Interpolation was used sparingly when a particular point on an occasional mandible was missing.

The mandible was held in an anatomically correct position when sliding calipers were used for measurements and was placed flat with inferior corpus borders and posterior ramus borders touching the instrument plates when a goniometer was used. The descriptions of the measurements below include the instrument utilized, the abbreviations employed in this study, and the anatomical landmarks from which the measurements were taken (Figures 1, 2 and 3).

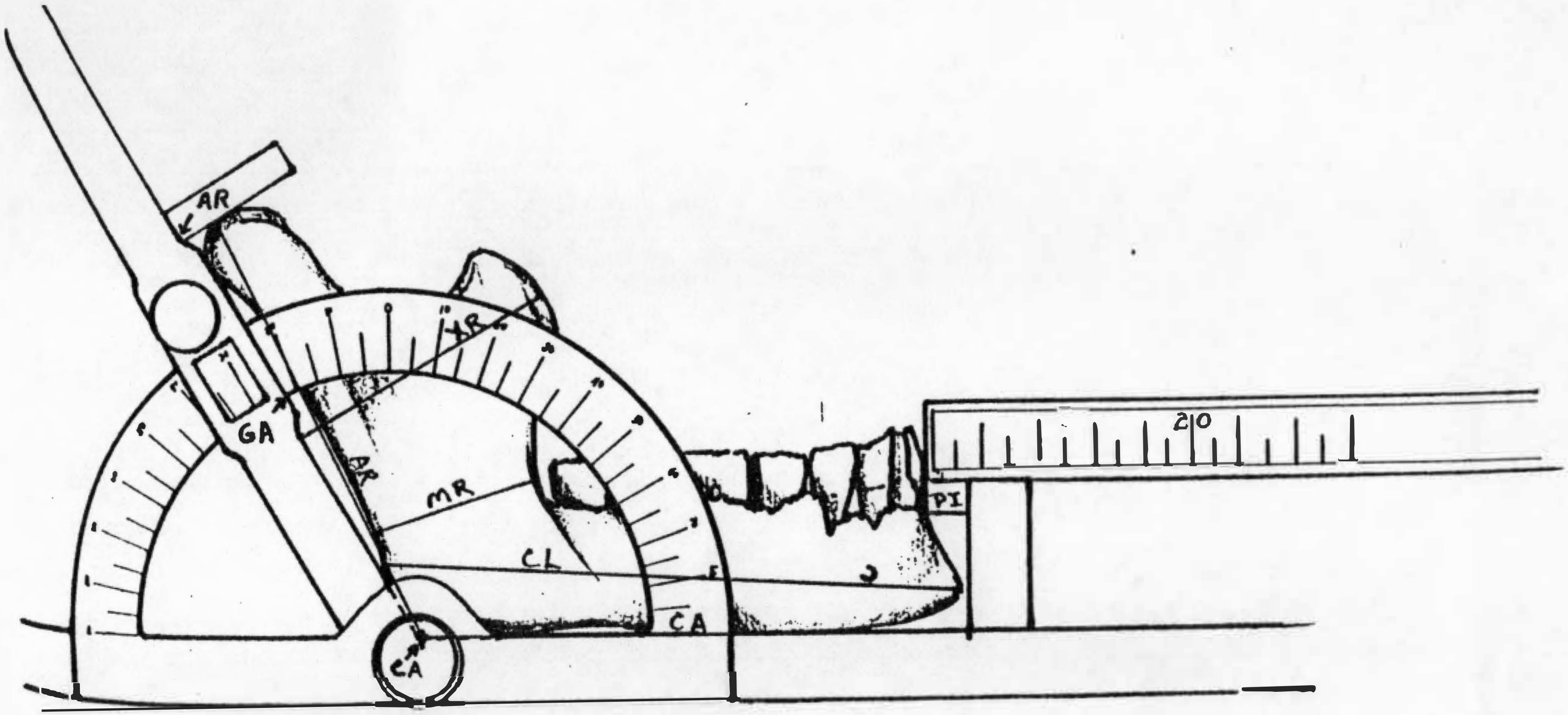

Figure 1. Goniometer and end of sliding caliper.
Mandible positioned for illustration of the following measurements:
GA, XR, MR, AR, CL, CA, and PI.

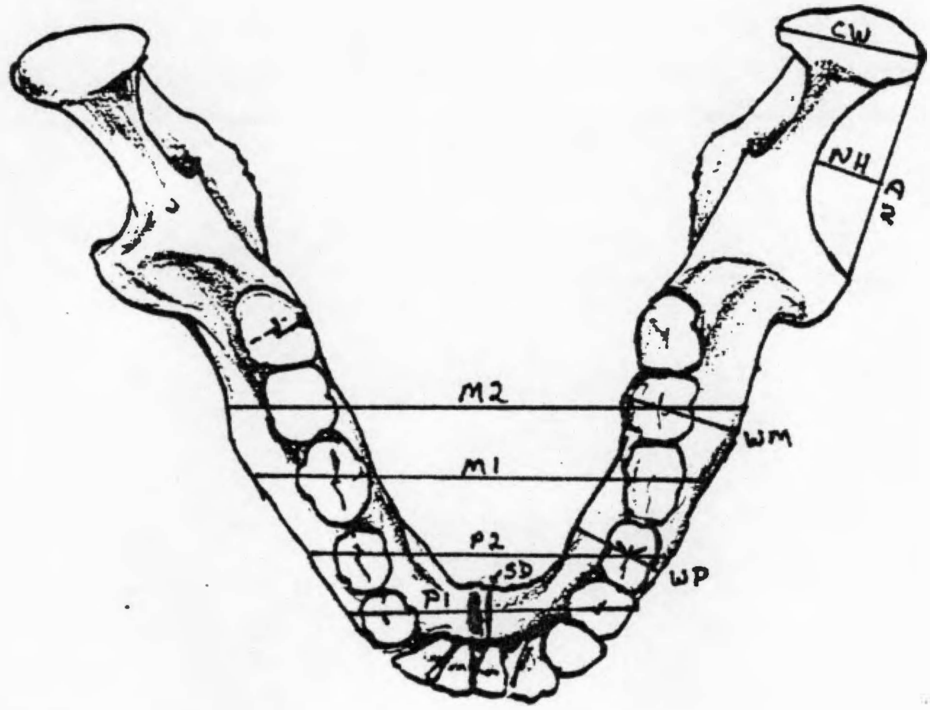

Figure 2. Occlusal view of mandible.
Includes measurements: M_2, M_1, P_2, P_1, SD, CW, NH, ND, WP, and WM.

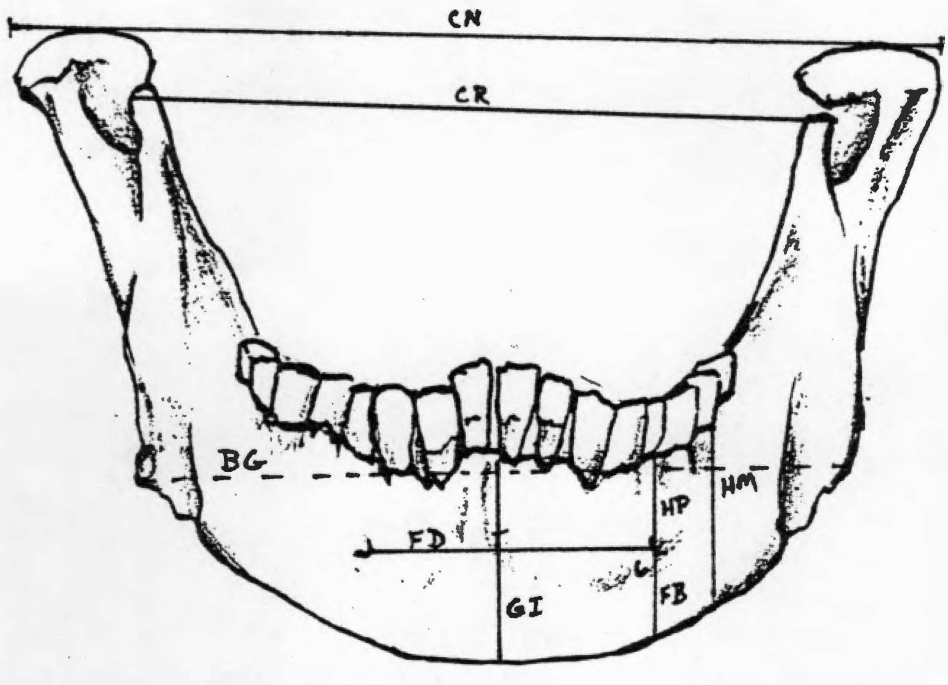

Figure 3. Frontal view of mandible.
Includes measurements: CN, CR, BG, FD, GI, HP, FB, HM.

1. Alveolar to eminence (PI). Antero-posterior distance from pogonion (mental eminence) to infradentale. Goniometer and sliding caliper used. (Figure 1).
2. Corpus length (CL). Distance from pogonion to the most posterior point on the margin of the ramus. Sliding caliper. (Figure 1).
3. Ascending ramus height (AR). Height from most superior point on mandibular condyle to most inferior point on base of corpus. Measured at an angle on the goniometer with all mandibular facets articulating with instrument plates. (Figure 1).
4. Corpus length with angle (CA). Distance from most anterior point on symphysis to point below gonion where perpendicular plate of goniometer sits when touching the most posterior points of ascending ramus and mandibular condyle. (Figure 1).
5. Symphyseal height (GI). Height of the symphyseal corpus from gnathion to infradentale. Sliding caliper. (Figure 3).
6. Intra mental foramen (FD). Distance between points of sliding caliper when they are inserted into both mental foramina. (Figure 3).
7. Maximum ramus depth (XR). Three points of the ascending ramus, the most anterior point of the coronoid process, the most posterior point of the mandibular condyle, and the

posterior ramus margin directly superior to gonion, are affixed to the surfaces of the sliding caliper. (Figure 1).

8. Minimum ramus depth (MR). Minimum distance from anterior to posterior borders of ascending ramus. Sliding caliper. (Figure 1).
9. Bicondylar breadth (CN). Distance between the lateral surfaces of the mandibular condyles. Sliding caliper. (Figure 3).
10. Bicoronoid breadth (CR). Distance between the lateral surfaces of the coronoid processes. Sliding caliper. (Figure 3).
11. Mandibular notch depth (ND). Distance from the posterior aspect of the superior margin of the coronoid process to the most anterior aspect of the condyle. Sliding caliper. (Figure 2).
12. Mandibular notch height (NH). Distance from the lowest point of the notch to an imaginary line formed by contact with the most superior aspects of the coronoid process and the mandibular condyle. Sliding caliper. (Figure 2).
13. Gonial angle (GA). Angle derived from positioning mandible on goniometer so that the two most inferior points of the corpus andthe two most posterior points of the ascending ramus articulate with the plates of the instrument. (Figure 1).

14. Bigonial breadth (BG). Distance between the lateral surfaces of the gonial angle (at point gonion). Sliding caliper. (Figure 3).
15. Symphyseal depth (SD). Distance from the most anterior point of the symphyses (pogonion) to the most posterior aspect of the lingual surface of the symphyseal corpus (genial eminence). Sliding caliper. (Figure 2).
16. Corpus width at P_2 (WP). Width of the corpus at P_2 measured parallel to the axis and at a point as near as possible to the center of the tooth socket on both the lingual and buccal surfaces of the corpus. Sliding caliper. (Figure 2).
17. Corpus width at M_2 (WM). Same measurement as #16, only at M_2. (Figure 2).
18. Corpus height at P_2 (HP). With mandible held in an anatomically correct position, the distance (parallel to the axis) along the midline of the tooth socket, and corpus, on the buccal side. Sliding caliper. (Figure 3).
19. Corpus height at M_2 (HM). Same technique as with #18, only at M_2. (Figure 3).
20. Transmandibular breadth at M_2 (M2). Distance between the lateral (buccal) surfaces of the corpus taken from two points on those surfaces which when connected by an imaginary line and viewed from above would transsect (diagonal cross-section) the tooth crowns or sockets on both the left and right M_2s. Sliding caliper. (Figure 2).

21. Transmandibular breadth at M_1 (M1). Same as #20. (Figure 2).

22. Transmandibular breadth at P_2 (P2). Same process as #20. (Figure 2).

23. Transmandibular breadth at P_1 (P1). Same technique as #20. (Figure 2).

24. Condylar width (CW). Distance from the most medial point to most lateral aspect of the left condyle. Sliding caliper. (Figure 2).

25. Mental Foramen to Torus Base (FB). Measurement obtained when one caliper point is inserted in the mental foramen and the other point is articulated, on a perpendicular line, with the most inferior aspect of the corpus. (Figure 3).

After the measurements were recorded and checked, the data was transferred to standard 80 column computer cards and statistically analyzed by the computer at the University of Tennessee Computer Center using the discriminant function subroutine in the SPSS package (Nie, Hull, Jenkins, Steinbrenner, and Bent, 1975).

First, summary statistics (means and standard deviations) were obtained on all twenty-five measured variables. Averages were derived from each measurement by grouping the specimen scores on the basis of race, as well as sex. Next, a stepwise analysis was obtained which separated and ordered those factors (variables) which, individually, contributed most heavily to the differentiation, and thus eventual identification, between the two races. Those factors which were highly correlated were either ignored or fed into the analysis at a

very low priority, while those with the highest individual discriminating scores were used later to set up partial discriminant functions.

Nine such discriminant functions analyses were obtained. One function included all twenty five measurements while a second function differentiated between Negroid and Caucasoid groups only, not attempting to break down the analysis by sex also. The other seven analyses obtained functions based on both race and sex and are intended to allow identification through use of from five to seven measurements each. These were based on specific variable lists using either partial mandibular sections or areas (ascending ramus, symphysis, corpus, etc.), or measurements which seemed to have a high racial correlation as identified either through original observation (i.e., prognathic difference seen in alveolar to eminence measurement) or as indicated in the original 25 measurement analysis. The group (White Male, WM; White Female, WF; Black Male, BM; and Black Female, BF) sectioning points (SP) were then derived from the group centroids (GC) which were included on the computer printout of each discriminant function analysis. This allows an unknown mandible to be classified according to the guidelines set up by this study, in order to test it's validity and reliability in identifying both the race and the sex of that particular mandible.

In order to confirm the validity of the results obtained when the individual sample cases were subjected to the discriminant function analysis derived from those same collective sample specimens (the Terry Collection), a test set of specimens was obtained. This was a

group of thirteen mandibles selected from the forensic cases of Dr. William Bass of the University of Tennessee Anthropology Department. All thirteen individuals had been positively identified; therefore, the mandibles were of known race and sex.

Finally, the 160 computer coded cards were recoded in order to test for racial variations only (racial recode), without sexual breakdown. These results were also tested against the forensic cases in an attempt to establish further credible means to differentiate unknown mandibles, at least on the basis of race.

In addition to the measurements obtained from the mandibles for racial discrimination, two or three discrete (non-metric) traits were also observed. Since such traits cannot be quantified they were not included in the discriminant function analysis. However, one of these observations, the position of the mental foramen in relation to the tooth sockets, seems to be of enough significance (observed also by Simonton, 1923) to mention and chart in this study.

CHAPTER III

RESULTS AND DISCUSSION

Most scientists are a little skeptical when the results of their testing coincides with their predictions. Especially so on the initial trial. And rightfully, they should be so, because there is always the possibility of unknown factors entering an experiment and providing misleading results. On the other hand there is always the chance that one might be accurate also. Assuming the second premise, this study continues.

The problem associated with using a dissecting room skeletal collection has already been discussed and dealt with. However, there are other factors related to using any skeletal assemblage which could give rise to problems. The main one, of course, is the location of and accuracy in acquiring measurements from a specific skeletal part, in this case the mandible. It is of utmost importance that any calculations dependent upon this study be done in an exact manner, duplicating the listed measurements whether one agrees with them or not. Many have been taken from previous studies (Giles and Elliot, 1962; Hrdlicka, 1940b and c; Murphy, 1957), others were employed simply from a desire for a particular measurement or because similar measurements from earlier studies were not deemed suitable.

Two or three of the more important variables and an explanation of their use follows. The pogonion to eminence distance is believed to be of great use because of its ability to measure alveolar

prognathism (quite common in blacks as noted by Scott, 1974), or the lack thereof. It used to be known as the symphyseal angle (Hrdlicka, 1940c) and was measured as such; but by determining this measurement as shown in Figure 1 (page 8) it is felt that a more reliable and accurate account of it can be established. Incidentally, the results (summary statistics) obtained in this study (Table 1) differ with respect to those of Walker and Kowalski (1972) concerning alveolar prognathism in that the PI index here shows females to be more prognathic, while their study attributes continued growth after puberty to be the factor in males being more prognathic.

The use of the goniometer is also quite essential in determining the length of the corpus (CA), another important variable. By aligning the posterior and anterior aspects of the mandible onto the plates of the goniometer (Figure 1), the guesswork of: 'at what angle should one position the caliper?', or 'where on the ramus is the most posterior point of the corpus?', or, 'should the mandible be held in an anatomically correct position?' is alleviated. It is obvious from the differences in the corpus means statistics between this study and the Giles and Elliot study (1962) that not all persons measure alike. Who is more exact is not as important as making sure that any measurements depending on a particular study should be taken with the definitions of that particular study in mind.

The gonial angle is a variable that certainly requires some discussion. It is the only variable which does not follow some kind of pattern when comparing the races and sexes and the means of each. Although the fact that the Caucasian angles, and especially the White

Table 1. Summary statistics of Terry samples.

	Caucasoid				Negroid			
	Male		Female		Male		Female	
Variable	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
PI	10.225	2.72206	9.475	2.84639	6.300	3.68782	5.575	3.04570
CL	84.675	5.04029	78.175	4.26006	91.175	4.80858	86.450	5.37778
AR	65.200	4.24989	55.700	3.72930	62.200	4.40978	55.500	3.79608
CA	76.950	5.08870	71.725	4.64089	82.225	5.02551	78.775	4.27568
SH	30.775	3.14999	28.400	3.08678	35.775	3.09248	32.250	2.81707
FD	44.975	2.51648	42.500	2.48069	45.150	2.38101	46.275	2.43887
XR	40.775	3.26196	37.325	3.16542	42.925	3.04991	39.600	2.86267
MR	30.600	2.61945	27.850	3.28595	34.000	3.28945	32.225	2.96551
CN	117.500	4.98716	110.975	6.31436	117.200	5.68038	111.375	5.07729
CR	96.725	5.07880	92.500	5.26722	101.000	7.48331	94.825	4.60149
ND	14.100	1.67638	12.450	1.88040	13.725	1.39574	11.975	1.57688
NH	26.000	3.73480	24.425	3.00331	25.600	3.88158	23.750	3.20056
GA	123.825	6.51187	127.600	7.23170	125.850	10.46251	125.100	6.68255
BG	99.750	4.63404	91.375	4.87636	96.025	5.94629	89.250	5.09273
SD	15.075	1.45686	13.875	1.58822	15.250	1.77951	13.850	1.64161
WP	12.025	1.45862	11.000	1.21950	13.150	1.45972	11.950	1.55167
WM	14.850	1.76214	14.125	1.20229	15.625	1.62808	14.975	1.68686
HP	29.700	2.36643	26.675	2.71168	31.775	2.75948	28.900	2.31827
HM	25.475	2.29813	22.600	2.53994	26.650	2.91372	24.700	2.39872
MZ	80.875	3.52418	77.225	3.10902	79.125	2.71923	76.775	4.23954
MI	71.250	4.35448	67.675	3.48173	68.825	3.50741	67.225	4.00952
PZ	58.975	4.15401	56.500	3.39683	56.725	3.53726	56.150	4.14822
PI	51.475	4.05088	47.875	2.75669	48.825	3.35037	48.700	4.23175
CW	20.850	1.67255	18.400	2.40512	20.750	1.72091	19.475	1.73925
FB	14.175	1.41217	13.025	1.40489	14.225	1.64063	12.975	1.29075

female angles, are larger than the Black gonial angles, as noted by Hrdlicka (1940b), the Black female mean angle is not more obtuse than the male as one would suspect. In other words, there is no symmetry of the gonial angle means distribution as with the other twenty-four variables. One might be inclined to blame this factor on age since the White female in the study averaged nearly fifty percent more (51.5 years) than the age of the Black females (35.9 years). That is if Robinson and Boling (1952) can be believed in their statement that "lack of function or loss of teeth" (involved often in old age) lead to an increase in the angle. In Gray's Anatomy (1977) it is also noted that the angle becomes more obtuse, as opposed to perpendicular, with loss of teeth and, thus, alveolar resorption. On the other hand, both Hrdlicka (1940b) and Israel (1973) maintain that there is no change in the angle as the result of aging. They do note, however, that there is often alveolar loss, and this could give the appearance of a more obtuse angle since it does actually make the internal angle larger, as noted by Enlow (1975).

Whatever causes this assymmetry in the gonial angle means seems to be of little consequence, for the stepwise discriminant function analysis (Table 2) chose the gonial angle as the seventh variable to enter in the analysis.

A few general observations, which reveal a definite pattern of variability, are noted when comparing the mean scores derived from the measurements of the Negroid and Caucasoid mandibles. The White males had the largest dimensions in 44% of the variables, while Black males were largest in 48% of the variables. The Caucasian measurements

Table 2. Stepwise analysis.

Step Number	Variable Entered	F* to Enter or Remove	Probability
1	AR	56.06120	0.00
2	CL	43.32207	0.00
3	PI	27.93359	0.00
4	SH	13.99265	0.00
5	BG	10.73298	0.00
6	FD	11.92222	0.00
7	GA	4.52300	0.00
8	CR	3.03777	0.00
9	P1	2.68212	0.00
10	ND	2.11452	0.00
11	WO	1.87962	0.00
12	SD	2.50018	0.00
13	WM	2.24058	0.00
14	CA	1.85236	0.00
15	P2	1.80435	0.00
16	FB	1.28180	0.00
17	CW	1.19404	0.00
18	CN	1.71785	0.00
19	NH	1.61240	0.00
20	XR	1.57298	0.00
21	M1	1.00845	0.00

*Variables with significance levels so low that they have nothing to add to analysis: MR, HP, HM, M2.

generally indicated a wider mandibular arch (bigonial breadth, arch width at P1, M1, etc.) whereas the Negroid dimensions indicated thicker and higher corpus and ramus sizes (SH, XR, WP, HP, etc.) and a greater breadth at the site of attachment to the skull (CR).

However, Howell (1969) and Granat (1975) both indicate that the arch is a measure of size and should not be retained as a distinguishing racial characteristic. This seems to be verified by the discriminant function utilizing the extra variables, four of which are arch size dimensions (Figure 4). The stepwise analysis also minimizes the significance of two of the these arch measurements, M_1 and M_2 (Table 2). If, on the other hand, size can be used as a discriminating factor in such an analysis, then its value should be recognized as such even though the trait, by itself, might be comparatively useless. Coincidentally, about 54% of the test cases were correctly identified from the aforementioned analysis, slightly better than one would expect from chance.

Generally, the means arrived at agree well with those from Giles' study (1964); and the few areas where there is disagreement seem to be the result of differing techniques in measurements. For the proportions are similar, only the dimensions differ.

Another interesting observation is that in 60% of the mean scores the distance between male and female Caucasian dimensions is greater than the distance between corresponding dimensions of Negroe mean scores of both sexes. Whether this denotes less sexual dimorphism within the Negroid race is unclear; however, an interesting development does occur in the racial recode discriminant function.

a.

Variable	Function 1	Function 2
CN	0.1063330	-.05930906
CR	.04902536	0.1686499
M2	0.1504517	-0.1049260
M1	.01153003	-.05500949
P2	-.08402389	.02909842
P1	.06235028	-.04577334
Constant	-27.74434	3.152139

b.

Group	Function 1		Function 2	
	Group Centroids (GC)	Sectioning Point (SP)	GP	SP
WM	0.73523	-0.018685	-0.54923	0.00638
WF	-0.77260		-0.20258	
BM	0.69549	0.018685	0.56219	-0.006375
BF	-0.60812		0.18983	

c.

Function	Eigenvalue	Percent of Variance	Cumulative Percent		After Removing Function	Wilkes' Lambda	Chi-Squared	Degree of Freedom	Probability Significance
				:	0	0.5323291	97.096	18	0.0000
1	0.49332	66.74	66.74	:	1	0.7949358	35.342	10	0.0001
2	0.17821	24.11	90.84	:	2	0.9365979	10.087	4	0.0390
3	0.06769	9.16	100.00	:					

Figure 4. Discriminant function derived from extra (unused) variables.
a. Functions 1 and 2
b. GC and SP of both functions
c. Statistical information pertinent to functions

One discrete trait which seemed to be significant enough to use in a racial analysis as a partial classificatory scheme, along with the discriminant functions, should be discussed. In Table 3, there is seen a definite dichotomy in the position of the mental foramen between the Negroid and Caucasoid races. Although the same landmarks were not used in the two studies (Simonton, 1923 and the present), they do show a definite tendency toward a more forward positioning of the foramen in Whites. Whether this is due to the more anterior placement of the corpus with relation to the teeth (a kind of reverse prognathism) in Caucasians, is not clear. Both Gray (1977) and Scott and Dixon (1966) assign the position of the mental foramen as inferior to the second premolar in at least 50% of all humans. There seems to be no clear or definitive pattern with respect to placement under certain tooth sockets, however. Whatever the main positioning factor

Table 3. Position of the mental foramen with reference to tooth sockets.

Position	P_1	P_1(post.)	P_1-P_2	P_2(ant.)	P_2	P_2(post.)	P_2-M_1	M_1
Simonton study								
Whites	2	13	26	29	46	14	7	4
Blacks	1	1	4	6	12		12	
Present study								
WM	3		23		11		3	
WF	1		25		11		3	
BM			10		26		4	2
BF			4		24		10	

is, whether it be corpus or teeth, it is clear that there is a distinct difference between the races in the location of the mental foramen.

The multiple discriminant function, like a simple discriminant function, is a multivariate statistical technique whereby the distance of a particular individual to the group centroid may be found. However, it is accomplished through the use of simultaneous discriminants (there is always at least one less function than the number of groups) which form coordinate axes at right angles through the use of sectioning points, derived from group coordinates which place each particular group (theoretically) in a separate quadrant when joined.

There is much controversy over just how accurate or reliable such a statistical method can be. Birkby (1966) claimed that when classifying Amerindian crania, through the use of a Negro-Caucasian discriminant function, a very high percentage of both normal and deformed skulls were classified as White. Likewise, Howells (1970) states that such methods do not recognize hybridization, and he questions their validity in use upon Europeans and Africans. Similarly, Lavelle (1977) suggests that although "men, apes, and monkies may be discriminated, the system does not work well within the species." However, most have suggested, as does Giles (1966) that within group testing offers by far the best results. The problem is, where does one population group stop and another start? Just because a method does not have all the answers on a universal basis is not sufficient cause to dismiss its validity or usefulness. Solving the puzzle a piece at a time is better than giving up because the parts will not assemble

themselves upon request. The best results may come from within group classification (that is, identification of mandibles which were used in the study), but a number of studies, and this one included, have shown that quite impressive results may also be obtained in dealing with populations from a related gene pool (of which the sample group may be considered a part).

In the following discussion of the nine multivariate discriminant function analyses used in this study, the third function of each analyses will be omitted. It was felt that its contribution to the identification of the mandible was not important enough to be included for practical purposes. The function was statistically significant in all cases (as can be seen in the figures); however, after the first two functions had discriminated for both race and sex there was so little variance left that the factors involved with the third function were not felt to be important enough to enter into the study.

Included in the following discriminant function figures will be the functions themselves, a second list containing the group centroids and sectioning points of each of the first two functions, and finally a cumulative arrangement of the appropriate statistical information on each discriminant analysis.

Of particular importance is the second list on each figure. Once an individual mandible has been assigned two discriminant scores (one for each function) this information may be used to determine the test mandible's classification. This is done through the use of a scatter-plot (Figure 5). Scatterplots may be constructed on regular graph paper. By joining the sectioning points (SP) of each function along a

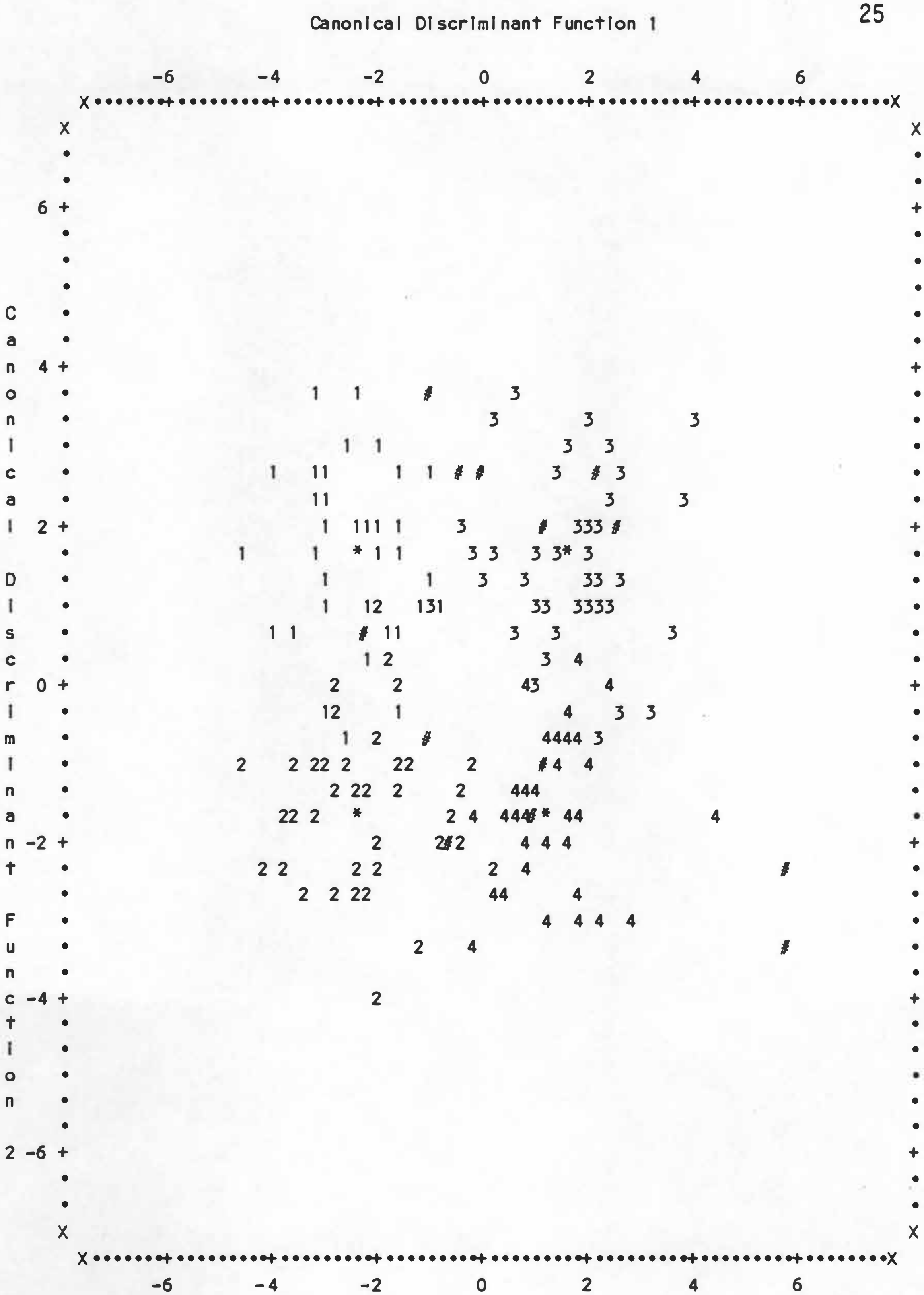

Figure 5. Scatterplot of twenty-five variable discriminant function. 1 denotes White Male, 2 denotes White Female, 3 denotes Black Male, 4 denotes Black Female, * denotes group centroid, # denotes forensic cases.

vertical axis and then a horizontal axis, the plot will be divided into four quadrants representing the field of scores to which an individual mandible can be assigned. For practical purposes the sectioning points for most of the analyses may be considered to be the vertical and horizontal zero axes on a piece of graph paper. However, if the sectioning point is above .100 on any of the functions there is a greater chance of misclassifying, in the 'grey area,' if the actual (exact) sectioning points are not plotted.

Then, by taking the discriminant scores obtained from the two functions, and plotting them to a single point, the mandible will be designated as either a Black male, a Black female, a White male, or a White female depending on which quadrant it falls in. Usually, the further the specimen is located from the sectioning lines the more chance there is that it will be classified correctly. Also, its distance from the group mean can be obtained by plotting the group centroid (GC) in each quadrant just as the individual case was plotted. The group centroid is designated as an asterisk (*) in the scatterplot. In the plot on Figure 5, the third set of figures (#) indicate the position of the test cases in this particular discriminant function. More of them, interestingly, were assigned to the correct quadrant in some of the other functions (Table 4), than in this particular scatterplot of the function using all twenty-five variables (Figure 6). Even though this function had the highest within group classification percentages (all were 90 or higher), it had the lowest percentage of correct classification of the thirteen forensic test cases (38.5%). Many of the White mandibles were classified as Black.

Table 4. Discriminant function analyses.

Description	Variables Used	Percent Correct Classification (within group) WM	WF	BM	BF	(test samples) (Forensic Cases)
1. High Individual Coefficients	1,2,3,5,6,14	82.5	90.0	82.5	92.5	76.9
2. Corpus with Ramus	3,4,7,8,13,15	75.0	82.5	75.0	75.0	76.9
3. High Individual Coefficients (including gonial angle)	1,2,3,5,6,13,14	85.0	90.0	87.5	92.5	76.9
4. Symphysis	1,5,6,15,25	67.5	72.5	65.0	67.5	69.2
5. Racial Recode (no sex breakdown)	All 25 variables	WM&F 95.0		BM&F 97.5		69.2
6. Possible Racial Traits (observed high correlation)	1,2,4,5,6,8	65.0	82.5	80.0	70.0	53.8
7. Remaining (non-used variables)	9,10,20,21,22,23	47.5	57.5	42.5	37.5	53.8
8. All Variables	1-25	95.0	90.0	90.0	95.0	38.5
9. Corpus	16,17,18,19,25	42.5	67.5	57.5	40.0	38.5

a.

Variable	Function 1	Function 2
PI	-0.2880121	-.02578450
CL	0.1045059	.03891679
AR	-.06481874	0.2195953
CA	.07543305	.04289244
SH	0.1626901	.03885288
FD	.007130295	-0.1363281
XR	0.1017633	-.001404119
MR	.01200470	-.009340822
CN	.03690318	-.04407672
CR	.008070017	.02159275
ND	-.04039787	0.1266290
NH	-.1323205	.04906951
GA	.08194644	.03384078
BG	-.05759905	.09438251
SD	-0.1059155	-0.1567877
WP	0.3033739	0.2254050
WM	-0.1986218	-0.1208572
HP	-.03701314	.01776528
HM	-.004145174	-0.1070198
M2	.02533732	-.02887642
M1	-.07306894	.09016963
P2	.03505678	-.05539913
P1	.06521992	-.3862616
CW	-0.1285544	0.1169555
FB	-0.1017299	0.1849524
Constant	-20.79364	-27.57461

b.

	Function 1		Function 2	
Group	GC	SP	GC	SP
WM	-1.91640	0.04584	1.61975	0.03868
WF	-1.79111		-1.54239	
BM	2.00808	-0.04584	1.53241	-0.03868
BF	1.69943		-1.60977	

c.

Function	Eigenvalue	Percent of Variance	Cumulative Percent
1	3.53874	54.77	54.77
2	2.54927	39.45	94.22
3	0.37354	5.78	100.00

After Removing Function	Wilks' Lambda	Chi-Squared	Degree of Freedom	Probability Significance
: 0	0.0451944	447.49	75	0.0000
: 1	0.2051256	228.91	48	0.0000
: 2	0.7280461	45.863	23	0.0031

:

Figure 6. Discriminant function using all variables.

a. Functions 1 and 2

b. GC and SP of both functions

c. Statistical information pertinent to functions

A possible explanation for this will be explored when the racial recode discriminant function (Figure 7) is discussed.

The variables used in Figure 8 were chosen because of the high individual scores they received for mean variability in the stepwise analyses (Table 2, p. 19). All of the sample groups achieved at least an 80% correct classification rate; but more impressively, this function correctly classified over three-quarters of the test cases. Both the function discriminating for race and the function discriminating for sex contributed relatively close percents of variance (54.6 and 41.7) to the classification. Therefore, this function should be fairly reliable in the future testing of mandibles of which neither the sex or race is known.

The next two functions, one derived from corpus and ramus measurements (Figure 9) and the other comprised of the exact same variables as used in the high individual coefficient function, with the inclusion of the gonial angle (Figure 10) are also quite reliable in classifying unknowns (both over 75%). They also assigned the within group cases correctly at least 70% of the time in every single group. In fact, as Table 4 (#3) indicates, this particular function classified the sample (reference) cases better than any other function except the complete (25 variable) one.

Although the analysis derived from the symphysis (Figure 11) has a within group classification of only 65 to 72.5% for all four groups, it does classify correctly nearly 70% of the forensic cases. This is most probably due to the high percent (75.25) of variance from the first function (based on race), which was derived from such high

a.

Variable	Function 1
PI	-0.2870461
CL	0.1055521
AR	-.06870879
CA	.07105299
SH	0.1603280
FD	.02999873
XR	0.1019404
MR	.01090563
CN	.03211484
CR	.004760779
ND	-.05068928
NH	-0.1335199
GA	.07826736
BG	-.05637103
SD	-0.1170337
WP	0.2922050
WM	-0.1899893
HP	-.03671566
HM	-.001871583
M2	.01631929
M1	-.06701838
P2	.02077635
P1	.08433714
CW	-0.1171116
FB	-0.1055517
Constant	-19.77032

b. Sectioning Point 0.0

Group Centroids

Group	Function 1
White	-1.85977
Black	1.85977

c.

Function	Eigenvalue	Percent of Variance	Cumulative Percent
1	3.50252	100.00	100.00

After Removing Function	Wilks' Lambda	Chi-Squared	Degree of Freedom	Probability Significance
0	0.2220978	218.92	25	0.0000

Figure 7. Discriminant function for racial recode.
a. Functions 1 and 2
b. SP and GC of both functions
c. Statistical information pertinent to functions

a. Variable	Function 1	Function 2
PI	0.2082145	-.08161837
CL	-0.1190733	.09723500
AR	0.1575604	0.1439427
SH	-0.1545055	.09593129
FD	-.08943675	-0.1530579
BG	.06229605	0.1030878
Constant	2.144576	-22.12409

	Function 1		Function 2	
b. Group	GC	SP	GP	SP
WM	1.90068	0.358615	1.01131	-0.314015
WF	1.08825		-1.63934	
BM	-1.18345	-0.358615	1.60073	0.314015
BF	-1.80548		-0.97271	

c. Function	Eigenvalue	Percent of Variance	Cumulative Percent		After Removing Function	Wilkes' Lambda	Chi-Squared	Degree of Freedom	Probability Significance
				:	0	0.0881634	374.00	18	0.0000
1	2.42492	54.65	54.65	:	1	0.3019525	184.41	10	0.0000
2	1.85095	41.71	96.36	:	2	0.8608506	23.074	4	0.0001
3	0.16164	3.64	100.00	:					

Figure 8. Discriminant function derived from variables with high individual coefficients.
a. Functions 1 and 2
b. GC and SP of both functions
c. Statistical information pertinent to functions

a. Variable	Function 1	Function 2
AR	0.2412647	-.09818896
CA	.04915023	0.1224821
XR	.06927464	-.03333724
MR	-.02741411	0.2534064
GA	.06412151	.05021462
FB	0.1445542	-.06671673
Constant	-30.14313	-15.58439

	Function 1		Function 2	
b. Group	GC	SP	GP	SP
WM	1.34414	0.025835	-0.89429	0.020165
WF	-1.29247		-0.91704	
BM	1.07242	-0.025835	0.93462	-0.020165
BF	-1.12409		0.87671	

c. Function	Eigenvalue	Percent of Variance	Cumulative Percent		After Removing Function	Wilkes' Lambda	Chi-Squared	Degree of Freedom	Probability Significance
				:	0	0.2106679	239.85	18	0.0000
1	1.51047	63.50	63.50	:	1	0.5288761	98.098	10	0.0000
2	0.84176	35.38	98.88	:	2	0.9740617	4.0472	4	0.3997
3	0.02663	1.12	100.00	:					

Figure 9. Discriminant function derived from variables of corpus and ascending ramus.
a. Functions 1 and 2
b. GC and SP of both functions
c. Statistical information pertinent to functions

a. Variable	Function 1	Function 2
PI	-0.2522841	-.06432163
CL	0.1480663	.07664900
AR	-.08781679	0.2121425
SH	0.1524468	.03357407
FD	.05712457	-0.1627395
GA	.03998760	.04496662
BG	-.04658200	0.1030786
Constant	-13.41501	-27.80718

	Function 1		Function 2	
b. Group	GC	SP	GP	SP
WM	-1.61712	0.00429	1.42119	0.00328
WF	-1.51844		-1.41463	
BM	1.62570	-0.00429	1.38192	-0.00328
BF	1.50986		-1.38848	

c. Function	Eigenvalue	Percent of Variance	Cumulative Percent		After Removing Function	Wilkes' Lambda	Chi-Squared	Degree of Freedom	Probability Significance
				:	0	0.0808781	386.02	21	0.0000
1	2.52393	53.67	53.67	:	1	0.2850087	192.68	12	0.0000
2	2.01501	42.85	96.52	:	2	0.8593051	23.275	5	0.0003
3	0.16373	3.48	100.00	:					

Figure 10. Discriminant function derived from variables with high individual coefficients including gonial angle.
a. Functions 1 and 2
b. GC and SP of both functions
c. Statistical information pertinent to functions

a.

Variable	Function 1	Function 2
PI	-0.1923544	.08329269
SH	0.2870592	.05919492
FD	.09854184	-0.1332974
SD	.04268394	0.3420142
FD	-0.1166885	0.3246115
Constant	-11.04986	-5.956363

b.

	Function 1		Function 2	
Group	GC	SP	GP	SP
WM	-0.76111	0.34347	0.47921	0.150775
WF	-1.45953		-0.17766	
BM	1.44805	-0.34347	0.50102	-0.150775
BF	0.77259		-0.80257	

c.

Function	Eigenvalue	Percent of Variance	Cumulative Percent		After Removing Function	Wilkes' Lambda	Chi-Squared	Degree of Freedom	Probability Significance
				:	0	0.2789286	197.27	15	0.0000
1	1.38546	75.25	75.25	:	1	0.6653726	62.945	8	0.0000
2	0.29650	16.10	91.35	:	2	0.8626556	22.826	3	0.0000
3	0.15921	8.65	100.00	:					

Figure 11. Discriminant function derived from variable associated with symphsis.
a. Functions 1 and 2
b. GC and SP of both functions
c. Statistical information pertinent to functions

individual-coefficient variables as the pogonion to infradentale indicator, which has shown to be a useful racial discriminator, and also, the symphyseal height. Similarly, the analysis based on probable racial traits (selected partially on the basis of notable distances between group means of certain variables) had an extremely high variance (86.46) in the racially selective first function (Figure 12). However, while discriminating well within the Terry collection groups (65 to 82.5%), this analysis performed little better than would be expected from chance when classifying the forensic test cases (53.8%). Still, the first function in both of the foregoing analyses would be helpful, at least, in determining race if nothing else were known.

The final two abbreviated discriminant function analyses, derived from the unused variables and from the corpus (Figure 4, p. 21 and Figure 13, respectively), do not seem to be very reliable for correctly classifying either the sample or the test cases. The analysis of unused variables, mentioned previously as those relating to the mandibular arch, apparently does not even do a good job of discriminating for size (more sex than racerelated) as I had earlier thought. On the other hand, although the corpus analyses does seem to differentiate the races well (first function percent of variance is 85.37), probably due to simple height and thickness differences, it does not do a good job of discriminating when all four groups are involved. Therefore, these two functions should probably not be used unless all else has failed or if there are no other parts of the mandible available.

a.

Variable	Function 1	Function 2
PI	-0.2281389	0.2437841
CL	0.1320763	0.1013279
CA	.03230633	-.08547400
SH	0.1900837	.06100647
FD	-0.2237869	-0.1797453
MR	-.05041101	0.1289710
Constant	-15.41495	-1.852743

b.

	Function 1		Function 2	
Group	GC	SP	GP	SP
WM	-0.77736	0.57237	0.38260	0.15782
WF	-1.89098		-0.06696	
BM	1.92210	-0.57237	0.34558	-0.157825
BF	0.74624		-0.66123	

c.

Function	Eigenvalue	Percent of Variance	Cumulative Percent		After Removing Function	Wilkes' Lambda	Chi-Squared	Degree of Freedom	Probability Significance
				:	0	0.2313583	225.42	18	0.0000
1	2.16191	86.46	86.46	:	1	0.7315351	48.142	10	0.0000
2	0.18142	7.26	93.72	:	2	0.8642478	22.468	4	0.0002
3	0.15708	6.28	100.00	:					

Figure 12. Discriminant function derived from variables with possible racial traits.
a. Functions 1 and 2
b. GC and SP of both functions
c. Statistical information pertinent to functions

a. Variable	Function 1	Function 2
WP	0.3992913	-0.1317931
WM	-.09355887	-0.21100865
HP	0.3240975	-0.1176877
HM	-.01640842	.05299983
FB	-.02497857	0.7393117
Constant	-12.14687	-3.213566

	Function 1		Function 2	
b. Group	GC	SP	GP	SP
WM	0.11887	-0.504095	0.41642	0.1884
WF	-1.12706		0.05725	
BM	1.14754	0.504095	-0.03962	-0.1884
BF	-0.13935		-0.43405	

c. Function	Eigenvalue	Percent of Variance	Cumulative Percent		After Removing Function	Wilkes' Lambda	Chi-Squared	Degree of Freedom	Probability Significance
				:	0	0.5353871	96.526	15	0.0000
1	0.67197	85.37	85.37	:	1	0.8951505	17.113	8	0.0290
2	0.09401	11.94	97.32	:	2	0.9793076	3.2305	3	0.3574
3	0.02113	2.68	100.00	:					

Figure 13. Discriminant function derived from corpus.
a. Functions 1 and 2
b. GC and SP of both functions
c. Statistical information pertinent to functions

The final discriminant function analysis, the racial recode (Figure 7, page 30) makes no attempt to differentiate between sexes. However, as seen in Table 4 (page 27), it does an excellent job of discriminating racially (95.0% White and 97.5% Black correct classification) within the Terry collection. This analysis also classified nearly 70% of the forensic cases correctly. Interestly though, when viewed in the stacked histogram (Figure 14), the forensic cases appeared to be skewed toward a Negroid classification. And, in fact, the four test cases which were incorrectly identified were all Whites classified as Blacks. Upon the advice of Dr. Richard Jantz, tests were then set up to attempt to determine the significance of and reasons for the skewed results.

First, the mean (x) discriminant scores, as well as the standard deviations (s) and variances (s^2), were determined for the following four groups: Terry Caucasians, Terry Negroes, Forensic caucasians, and Forensic Negroes. The results are listed below:

	x	s	s^2
Terry blacks	1.85977	.99315	.98636
Terry whites	-1.85977	1.05421	1.11137
Forensic blacks	3.91647	2.3255	5.4079
Forensic whites	.23603	1.3984	1.9557

A T-test was then set up to determine whether the differences in the populations shown in the skewed histogram results were the result of sampling error or whether there was another significant reason for the shifting of discriminant scores from the Terry collection to the forensic text cases. The formula used for deriving the T-test is

```
   16 +                                                                                +
      .                                                                                .
F     .                                                                                .
r     .                                                                                .
e 12  +                                                                                +
q     .                                                                                .
u     .                                              3                                 .
e     .                              2               3   #                             .
n  8  +                              2 # 2         3 3  33                             +
c     .                              2  2 22       3 3  33                             .
y     .                              22 2222      33#3 333                             .
      .                              2222222    #  33#3 3333#                          .
    4 +                          2  22222222    3  3333333333                          +
      .                          2 222222222 ##2##23  3333333333                       .
      .                     2 22 2 2222222222232232333333333333333   3                 .
      .                     2 22 22222222222222222323233333333333333  3 33 3    ##     .
        ........+.........+........+.........+.........+.........+........+.........
               -6        -4       -2         0         2         4        6
```

Figure 14. Stacked historgram of racial recode function.
2 denotes Caucasians, 3 denotes Negroes, # denotes forensic cases.

$$T = \frac{\left(\overline{x}_1 - \overline{x}_2\right)}{\sqrt{\left[\frac{(n_1 - 1)s_1^{\,2} + (n_2 - 1)s_2^{\,2}}{n_1 + n_2 - 2}\right]\left(\frac{n_1 + n_2}{n_1 n_2}\right)}} .$$

Both T values, 3.7463 when Terry Blacks were compared to Forensic Blacks, and 4.2357 when Terry Whites were tested with Forensic Whites, are considered significant at an alpha level of .001 at between 80 and 90 degress of freedom. This means that the difference exhibited by the shift in discriminant scores is almost assuredly not the result of sampling error.

What then would cause this shift? One possibility is that the change may be due to temporal factors. That is, an actual transition in the size or shape of the mandible might have occured from the time the individuals who would later comprise the Terry collection lived, and the present, a period of over fifty years. This secular change might be due to diet, growth increases over the past few decades, or a number of health or medically oriented reasons. It is known that people are now healthier and, in fact, larger than persons living fifty years ago, so this temporal, or secular, change could indeed be a factor in the shift.

Another possibility might simply be explained as being due to the presence of different genetic pools. This is certainly feasible when it is considered that the Terry collection is comprised of natives of the St. Louis, Missouri area, and the University of Tennessee forensic cases represent a Tennessee population, although there are a few cases

on individuals from Kansas. Not only would the geographical distance between the two groups be likely to be sufficient reason for dissimilar genetic pools (even though we are now considered a very mobile society), but the mere nature of the United States itself is adequate testimony to the existence of numerous genetic populations. America has been called both a "melting pot" as well as a "salad bowl"; whatever it is, whether the continuous flow of immigrants keeps its identity or assimilates into the whole population, it remains quite evident that in most societies, background, culture, and spatial proximity are major factors in the selection of breeding partners. With that in mind it can be maintained that differing genetic pools are present here.

Probably there are differing secular changes also. Whether they are distinct enough to invalidate such an explanation remains to be seen.

CHAPTER IV

SUMMARY AND CONCLUSION

The purpose of any scientific investigation, this one included, is to address a particular problem. A query is formed, a line of attack is formed, and a solution is sought. Whether the answer proves to be a negative or a positive confirmation depends on the material, the research, the researcher, and of course the original question and its intent. It is not so important that one prove or disprove, or obtain negative or positive results, but that through such research some of the alternative possibilities are disposed of, thus making an ideal situation one step closer. It is with that idea that the results obtained in this thesis should be viewed.

As previous investigations on similar topics have shown, it is possible through multivariate discriminant analysis to separate populations from one another on the basis of quantifiable variables, in this case, somatic measurements. Further, one may attempt to place single individuals into one of the designated (four, in this case) categories by deriving discriminant scores based on those same variables and assigning the test individual to a particular categorical population. This would be, of course, another step toward developing a more complete method of forensic identification of human skeletal material.

Even though the classification percentages are not as high in the test cases as they are from within the sample group, they are high

enough in many of the analyses to be used for identification purposes. Even single function variances and individual coefficients in a few cases, are sufficient to classify, at least by race. However, the original purpose of this study was to provide a means for determining both the sex and the race of an unknown mandible. Many studies have attempted to delineate groups on either a basis of race or sex, but few have tried both. The results here seem to be positive. Enough of the analyses work sufficiently well and provide encouraging enough results so that they should prove to be useful on a practical forensic level.

However, there are still areas which need further work. The percentage of misclassification needs to be reduced. The problem here lies not so much in the analysis itself but in the reference data. The skeletal populations are simply not large, modern, or diverse enough to make the system foolproof. As Howells (1970) said, any mandible could be subjected to a discriminant function analysis and be classified as a particular type even though its real identity may not even be close to its assigned classification. Here, one simply must be prudent, one would be unwise to use the discriminant functions offered above when working in the western territories of Australia.

The racial recode analysis, and associated histogram, have shown that even in the United States, time and geography can cause a shift in the population means. But still, anywhere that has a relatively homogenous genetic pool, or a stable heterogenous pool, should provide an adequate base for such a study.

Similarly, it would be advantageous to expand the number of possible groups an individual might be assigned to. In reference to this, certain Amerindian mandibular measurements (Kile, 1977) were superficially compared to the mean scores obtained here for the American Negroid and Caucasoid populations. The Amerindian means offered a contrast in the areas of the symphyseal height, corpus height, ramus depth, and bicondylar breadth, being much larger and more robust, as would be expected according to studies on muscle use (Jacobs, 1972). Futher studies would undoubtedly show that such mandibles are quite distinctive and could easily be discriminated from American Whites and Blacks. This would be most useful in almost all areas of the United States where the three populations are somewhat common.

As for other genetic populations, the only answer seems to be an ever expanding reference data bank. The difficulty will be in obtaining such a storehouse. Until then one must be content with using the current sources of data and to continue to explain the statistical anomalies as adequately as possible. This, along with an attempt to sort out known problems in such procedures (instead of merely criticizing them), may one day lead to a near ideal situation for the use of multivariate statistical discriminant analysis in the area of forensic application and skeletal identification.

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APPENDIX

Table 5. Twenty-five fariable univariate F-ratio.

Variable	Wilks' Lambda	F-Ratio 3 and 156 Degrees of Freedom	Significance
PI	0.70248	22.02	0.0000
CL	0.51761	48.46	0.0000
AR	0.47785	56.82	0.0000
CA	0.60637	33.76	0.0000
SH	0.55734	41.30	0.0000
FD	0.75573	16.81	0.0000
XR	0.69438	22.89	0.0000
MR	0.63970	29.29	0.0000
CN	0.75784	16.62	0.0000
CR	0.76624	15.86	0.0000
ND	0.77378	15.20	0.0000
NH	0.93559	3.580	0.0153
GA	0.97016	1.600	0.1917
BG	0.60943	33.33	0.0000
SD	0.85726	8.658	0.0000
WP	0.77396	15.19	0.0000
WM	0.89623	6.021	0.0007
HP	0.65486	27.41	0.0000
HM	0.74398	17.89	0.0000
M2	0.81314	11.95	0.0000
M1	0.85620	8.733	0.0000
P2	0.92064	4.483	0.0048
P1	0.87620	7.347	0.0001
CW	0.77806	14.83	0.0000
FB	0.84911	9.241	0.0000

Table 6. Pooled within-groups covariance matrix with 156 degrees of freedom.

	Var001	Var002	Var003	Var004	Var005	Var006	Var007	Var008	Var009	Var010	Var011	Var012	Var013	Var014	Var015	Var016	Var017	Var018	Var019	Var020	Var021	Var022	Var023	Var024	Var025
PI	9.596955																								
CL	3.847115	23.89888																							
AR	-1.198718	6.591667	16.45641																						
CA	3.263782	20.03045	6.094872	22.74247																					
SH	1.707532	3.470192	1.169231	2.334776	9.237500																				
FD	-0.9897436	4.129327	3.413462	4.426763	0.3870192	6.025962																			
XH	-0.4939103	4.734135	3.642949	4.751282	0.6929487	1.641827	9.539263																		
MR	-1.805929	7.864103	4.281410	8.817788	1.753526	2.834135	6.172756	9.318429																	
CN	-0.5516026	4.663622	7.283897	4.566026	3.730449	4.459455	2.521955	3.765865	30.69712																
CR	-4.153846	1.256891	5.318590	3.104968	0.9568910	3.459295	0.2129808	1.828045	13.97196	32.67788															
ND	-0.1511218	0.4520833	0.9891026	0.4897436	-0.7020833	0.5642628	1.428365	0.4777244	1.686058	1.089263	2.695192														
NH	-0.1092628	2.258494	0.3352564	0.6540064	0.2698718	0.1900641	6.847917	3.242308	.06650641	-4.559295	0.5429487	12.06971													
GA	9.600481	-9.950929	-16.96282	-15.50962	3.086378	-5.053686	-3.950160	-12.28269	-10.16154	-12.53990	-0.6516026	4.496154	62.20561												
BG	1.872276	0.1823718	0.9891026	-0.09198718	2.485814	3.271474	1.435577	0.1858974	13.09247	9.881410	1.004968	.06746795	6.842308	26.63686											
SD	0.9560897	2.928205	1.973718	2.206250	0.8681090	0.9405449	1.138782	1.133333	1.696314	0.3350962	0.2919872	.004006410	-1.310096	1.576122	2.626603										
MP	0.2828526	1.142147	1.215385	1.027244	0.8530449	0.7607372	0.8261218	1.031090	0.6735974	0.3520833	0.1442308	-0.5134615	-1.107212	0.6897436	1.487981	2.038301									
WH	-.07660256	1.706731	1.116667	1.937340	1.484135	0.8517628	0.4198718	1.644712	0.7211538	0.2415064	-0.1910256	-0.3549679	-1.116667	0.6875000	0.9786859	1.438141	2.511699								
HP	2.358173	4.190705	2.969672	3.409936	5.509455	1.408013	1.918269	1.904808	2.756250	.06089744	0.1440705	0.4418269	2.280449	1.712179	1.121314	0.9067308	1.047115	6.485577							
HM	0.5732372	5.280929	5.396718	4.474359	3.343109	2.415865	2.702724	3.371154	2.925641	0.8597756	0.4048077	0.4307692	-5.243429	0.2506410	1.662019	1.327083	1.187821	4.667628	6.494071						
M2	2.298237	1.666506	2.552564	2.083814	1.728526	2.718590	-0.1491987	-0.1706731	2.804487	3.977885	-0.2653846	-1.481250	2.848558	8.721154	1.095513	0.9738782	1.748558	2.491346	1.718109	11.86348					
M1	3.563141	2.196795	2.551282	2.075878	1.888622	2.588288	-0.6900641	-0.7562500	2.773718	1.639904	-0.1208333	-1.852724	3.080769	6.957051	1.421314	1.405449	1.876442	2.507051	2.046795	11.36587	14.86594				
P2	3.811378	2.303846	3.284615	1.162019	1.094872	2.172917	0.4092949	-0.9791667	1.980449	-0.4629808	-0.1972756	-0.4961538	2.458814	5.423237	1.379647	1.102404	1.143429	1.636699	1.611699	8.596795	11.86843	14.82853			
PI	4.795513	3.158173	3.244231	2.105449	1.196795	2.143109	0.7280449	-0.7016026	3.270994	-0.2011218	0.5084936	-0.3889423	3.131250	5.466667	1.614744	1.051122	0.7535256	2.098077	1.570032	7.651765	10.18013	11.91571	13.28542		
CW	-0.5524038	2.079808	1.573718	1.548878	0.7451923	1.186699	0.6237179	0.9405449	6.110737	2.235096	0.3661859	-0.6733974	-1.795192	2.371795	0.8897436	0.4461538	0.3193910	0.6926282	0.8554487	0.4370192	0.4530449	0.5785256	0.6076923	3.642147	
FB	0.8706731	0.9613782	0.4974359	0.5344551	1.765705	0.2923077	0.1508013	0.4241987	1.250641	-0.7035256	-.02371795	-0.2056090	0.6927885	0.6692308	0.6358974	0.5604167	0.5850962	1.495833	1.313622	0.9570513	0.8549679	0.8608974	1.013301	0.1370192	2.081410

VITA

Dorn Patrick Kile was born in Oak Ridge, Tennessee on May 15, 1950. He was raised near there on a cattle farm, and attended St. Mary's Elementary School and Webb High School before entering the University of Notre Dame where he obtained a B.A. in history in 1972.

He then taught school for six years, interrupting that period for one year to become a full time graduate student in Anthropology. After finishing his required courses he returned to Webb School of Knoxville where he taught social studies (mainly American History) and coached two sports, including the 1980 Class A State Championship Team in Track and Field.

During this time he also taught two courses in Anthropology (Human Cultures) in the University of Tennessee Evening School while a graduate student, and began more work, including this thesis, in the area of forensic identification.

In 1980, Dorn left teaching and began work in his family's business, raising inbred mice for science and polled Hereford cattle for breeding stock, at which he is still involved.