DENTAL MORPHOLOGY IN THE ESTIMATION OF BIOLOGICAL

DISTANCE: THE GRAY SITE

A Thesis

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by

Darrell Michael Zbeetnoff

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"DENTAL MORPHOLOGY IN THE ESTIMATION OF BIOLOGICAL
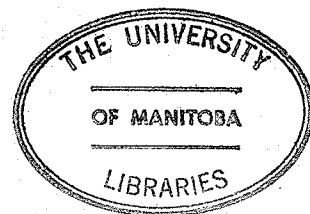DISTANCE: THE GRAY SITE"

by

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A dissertation submitted to the Faculty of Graduate Studies of
the University of Manitoba in partial fulfillment of the requirements
of the degree of

MASTER OF ARTS

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Chapter 1

INTRODUCTION

The use of non-metric, osteological traits as
indicators of biological distance has become popular in
recent years. Among the research (see Kellock and
Parsons,'70:409), studies on mice have been particularly
informative. These have resulted in the development of
statistical methods appropriate to non-metric, osteological
analyses and have contributed to an understanding of the
patterns of inheritance for non-metric variables.

Berry ('68) has used non-metric, cranial variation to
estimate genetic distances between mouse populations.
Gruneberg ('52) defined the quasi-continuous variable and
its correlation with penetrance and expressivity in studies
of skeletal variation of the mouse. This definition
established two main characteristics of the quasi-continuous
variable:

a) its underlying polygenic continuous nature, and

b) its discontinuous manifestation as a result of
developmental processes. Modification of the continuous and
additive character of the genotype in phenotypic expression
has also been examined in plants (Weber,'59). The term
"epigenetic" has been used by Berry and Berry ('67:362) to

indicate non-metric, osteological traits of multi-factorial determination.

In human populations, non-metric variation appears to exhibit similar morphological characteristics to mice. Berry ('68) has suggested that the morphological similarities imply similar modes of inheritance. Non-metric data have been applied to estimation of biological distance between native populations of India (Sanghvi,'53). This study demonstrated that estimates based upon morphological characteristics discriminated between populations complementary to estimates based upon blood groups, taste and color vision. Laughlin ('63) and Laughlin and Jorgensen ('56) have presented estimates of genetic distance based on cranial characteristics in Aleut and Greenland Eskimo populations, respectively. Berry and Berry ('67) have considered cranial non-metric variation in world poulations. Kellock and Parsons ('70) have analyzed patterns of non-metric cranial variation in aborigines and have gained insights into possible migrations in prehistoric Australia. Berry and Smith ('68) indicate that statistical analysis of non-metric variation may provide reliable estimates of genetic separation of populations than analyses based upon metric traits.

Studies of tooth morphology in the mouse suggest that dental traits are quasi-continuous variables under

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pleiotropic genetic control (Gruneberg,'65). Sofaer ('69) demonstrated polygenic inheritance of a supernumerary molar cusp in the mouse, as opposed to a monogenic mode. Gruneberg ('52) showed variable penetrance and expression in third molar agenesis, associated with more than two stable levels of the character, a indication of quasi-continuous variability. Recently, Sofaer et al.('72b) have differentiated between native populations of the Southwestern U.S. and world populations. Their conclusions suggest that comparative studies in dental morphology, although suffering from a lack of standards for trait expression, may provide useful information about relationships between populations.

Objectives

The objectives of this study are 1) to describe and present frequencies of non-metric dental characters of the Gray site population and 2) to interpret the biological relationship of the Gray site to selected Asian, Eskimoan and Amerind populations. The common rationale for the use of the dentition in the study of skeletal remains includes the post-mortem preservative qualities of the teeth, the reduced environmental effect on developing elements due to the complete development before eruption (Dahlberg,'62) and high genetic component (Greene,'67a; Turner,'67b;'69).

The second objective, the use of dental characters in the estimation of biological affinity of the Gray site to other Mongoloid populations, is an independent discriminator of North American aboriginal relationships. The Gray site represents occupants of a geographical region previously undefined as to physical type. An analysis of biological distance presents evidence and permits discussion of prehistoric interpopulational relationships and/or migrational influxes into the New World.

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Approach

The Gray site population is evaluated with respect to most dental traits commonly studied in the field (see Dahlberg,'51;'63) and other characters that have been referred to as "anomalies" of the dentition (Appendix:135). Frequencies of trait manifestation are based on numbers of teeth thus, no consideration is made for individual bilateral asymmetry. This decision is prompted by the incomplete nature of the skeletal material.

Although there is some indication by radiocarbon dating that the entire sample may represent more than one population, So and Wade ('75:2) believe that "(T)he use of the site may have been less discontinuous than would seem initially apparent on the basis of the relatively small number of dates." In the absence of any sound basis for possible division of the site temporally the material is assumed to represent a genetically homogeneous population over an extended period of time.

The statistical analysis in the third chapter is employed under the premise of the existence of quasi-continuous variation in dental traits. This assumes that the underlying range of continuous variation is related to the development of the character. The relationship between incidence and degree of expressivity of the

quasi-continuous variable is such that "...as the continuous distribution crosses the critical level, the first few normals will generally be only slightly affected; as the distribution is further shifted in the same direction, an increase in the percentage of abnormals will go together with the appearance of more severely affected individuals (Gruneberg,'52:108)." The critical characteristic of any variable is the position of its mean, as the mean is an approximation of the threshold position and this can be estimated from population frequencies of the affected class. Sofaer et al.('72b) indicate that further classification gives no information except for a test of equality of variance between populations (this is assumed to be equal). Therefore, all observations were distributed between two classes, "affected" or "non-affected", from which were calculated Chi-square estimates of divergence (Sanghvi,'53:393; Sofaer et al.,'72b:359). Chi square = sum (1...n)*sum (1...r)* ((P1-Q)*2/Q + (P2-Q)*2/Q)/ degrees of freedom, where:

P1 and P2 are percentage incidences of two populations of each of r classes in which a given character is scored.

Q = (P1+P2)/2

n = number of characters scored

Degrees of freedom = n(r-1)=n, as r=2 in every case.

A discussion and interpretation of results follows.

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Chapter 2

THE MORPHOLOGY OF THE GRAY SITE

Material

The present study is based upon examination of the
skeletal remains of the Gray site, near the town of Swift
Current in southwestern Saskatchewan and radiocarbon dated
at 5100-3485 B.P. (So and Wade,'75). A detailed account of
the site is to be found in Millar et al.('72). A summary of
possible cultural affinities is presented in Knutson ('75).

A total of 141 (complete and fragmentary) individuals
were examined ranging in age from 4 years to adult. The
individuals are represented by 100 maxillae and 116
mandibles.

Individual tooth counts reveal a high rate of
post-mortem loss. In the incisor region, an average of 50%
of the teeth are missing while molars are lost postmortem in
direct proportion to the tendency of their roots to fuse
(average postmortem loss of all molars, mandibular and
maxillary, is 25%). The degree of attrition is generally
pronounced.

X-rays aided in the determination of hypodontia,
impaction, hyperodontia and root fusion.

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Incisor Shovelling

Table 1 presents frequencies of the shovel character in incisors of the Gray site. Dahlberg ('51) has suggested that the use of pronounced and moderate forms is a more reliable method of comparing findings of different authors. Thus, the subjective scale of incisor shovelling of Hrdlicka ('20) was slightly modified as follows:

Hrdlicka's scale	Present study
- shovel	- pronounced
- semi-shovel	- moderate
- trace shovel,	- absent
no shovelling	

The metric technique of recording shovelling suggested by Dahlberg and Mikkelson ('47) and used by Goaz and Miller ('68) and Rothhammer et al.,('68), was not applied to the present data due to the prevalence of extreme attrition in the Gray site remains. Where wear is not below the enamel rim that defines the shovel character, the cross-sectional incisor shape is used to determine degree of shovelling.

Frequencies of shovelling in the Gray site material with respect to sex were not considered due to the greater number of individuals of indeterminable sex. Sexual differences in shovelling are not believed to be statistically significant (Greene,'67a). Rothhammer et al., ('68) found women with higher indexes of shovelling in a

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Chilean population but stated that the result may be accounted for by sampling error.

The Gray site exhibits the typically Amerindian frequency of maxillary incisor shovelling, characterized by a high percentage of observations in the pronounced and moderate categories of trait expression (Dahlberg,'63). This contrasts with Caucasians, who show a predominance of trace and moderate degrees, and Negroid populations who exhibit a frequent absence of shovelling (Carbonell,'63). Differences of shovelling among Oceanic populations suggest a dispersion of pro-Mongoloid groups from Indonesia to Polynesia (Riesenfeld,'56; Suzuki and Sakai,'64).

In mandibular incisors, the shovelling trait is not as pronounced or as frequent as among maxillary incisors, an observation also noted by Turner ('67b). Among Peruvian Indians, Goaz and Miller ('68) found mandibular incisors with less pronounced shovel forms than their maxillary counterparts, although both were characterized by 100% shovelling.

Table 1

Incisor Palatal Shovelling in the Gray Site

	Maxilla		Mandible	
	I1	I2	I1	I2
Pron.	85.7	77.3	0.0	0.0
Mod.	11.9	18.2	61.1	46.1
Pron. & Mod.	97.6	95.5	61.1	46.1
Trace & Abs.	2.4	4.5	38.9	53.9
N	42	44	36	39

Missing and Anomalous Lateral Incisors

The study of Bradlaw ('34) of a three generation pedigree established a genetic connection between the inheritance of dwarfed and absent maxillary lateral incisors. Later studies have shown that agenesis and peg-shaped maxillary lateral incisors are variations of the same genetic complex (e.g., Taylor,'69). In a study based on admixed Hawaiian schoolchildren, Chung et al.('72) conclude that peg laterals and missing laterals are variations of a trait of multifactorial inheritance. The frequency of the complex may be much higher than reported in earlier studies.

Whether peg-shaped and anomalous lateral incisors are variations of the same complex is open to question. Dahlberg ('51) includes malformations of the cingulum, principally the barrel shape and dens en dente, as manifestations of the anomalous form. In the present study all cases of reduced incisors were regarded as manifestations of the same genetic trait, although in instances of severely worn teeth it was often not possible to determine if the barrel shape had ever been present. Presumably, all forms are related to the reduced maxillary lateral incisor as this is the sole site of their occurrence (Dahlberg,'51).

The frequency of missing upper laterals (excluding peg laterals) is in the vicinity of 2.5% in world populations. No clear pattern of variability is evident from the

frequencies available for human populations, "...there being relatively low and high figures among the European, Mongoloid, and Negroid samples studied" (Brothwell et al.,'63:182). Frequencies of missing and anomalous lateral incisors in American Indian populations have been reported by Dahlberg ('51).

The Gray site population is seen to be within expected Mongoloid frequencies for congenital absence of upper laterals whereas the frequency of the anomalous forms is higher (Table 2). Different forms of the reduced incisor have probably not been considered as manifestations of the missing incisor complex and this may in large part explain the differences from frequencies reported by previous investigators. On the other hand, the presence of relatively high incidences of the reduced incisor form are found in Indian Knoll, Navaho and South American Indian dentitions (Dahlberg,'51; Dunkel,'65; Niswander,'67 and Goaz and Miller,'68, respectively).

The sex distribution of missing and anomalous laterals in the Gray site is presented in Table 3. Previous reports have indicated a tendency for anomalous forms to be more common in males and agenesis higher in females (Hrdlicka,'21; Schultz '32;'34; Montagu,'40). However, there are exceptions (Chung et al.,'72; Beiguelman,'62).

The barrel shaped lateral incisor is considered a

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Mongoloid dental trait (Chung et al.,'72; Niswander,'67).

Table 2

Distribution of Missing and Anomalous Maxillary

Lateral Incisors in the Gray Site

	N	Conq. Abs.	Anomalous	Both
Teeth	111	1.0	17.1	18.1
Individuals	59	1.7	20.3	20.3

Table 3

Sex Distributions of Missing and Anomalous Maxillary

Lateral Incisors in the Gray Site

	Male	Female	Indet. Sex
Anomalous (bilateral)	4	2	1
Anomalous (unilateral)	2	2	1
Agenesis (unilateral)	0	1	0
Totals	6	4#	2

- one female with anomalous and missing lateral incisor.

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Mesial-palatal Version

Winging of the maxillary central incisors is reported to vary between 22-38% among American Indians, with lower incidences in Japanese (10%) and Caucasians (3%) (Dahlberg,'63). Prehistoric Aleut (Turner,'67a) and some South American Indian populations (Campusano et al.,'72; Rothhammer et al.,'68; Wright,'42) exhibit high frequencies of the trait (41.0-82.5%). The causes of the mesial palatal version are not clear. Leigh ('37) reported the occurrence of the trait in cases where the torsion occurs with no indication of incisor crowding. The illustrations of Oschinsky ('61) of Eastern Canadian Eskimo palates show winging of the central incisors associated with "instanding laterals" which he attributes to crowding of the maxilla in relation to the size and number of teeth (Oschinsky and Smithurst,'60). Crowding in Eastern Canadian Eskimo palates varies from 22-40%.

Dahlberg ('63) found in a majority of cases that crowding was not necessary for the trait to occur. The very rare incidence of incisor rotation among Negroes and North American Caucasoids (Oschinsky,'61) argues for the status of winging as a Mongoloid trait (see Niswander,'67).

Winging of the central maxillary incisors is found to occur in 22.7% of Gray site inhabitants (N=22). Two cases are unilateral while the others are bilateral occurrences of

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winging. Obvious crowding is not present in the maxillae examined.

Crowding_in_the_Premolar_Region

Niswander ('67) has presented the only known population study on transposition of maxillary canine and first premolar. Among the Xavante, one bilateral and two unilateral cases were observed, with a frequency of 0.18%. Tables 4 and 5 show the distribution of the types of crowding observed in the present study. Instances of transposition, impaction of canines and canine crowding may all be the result of the same factors. Lasker ('45), in passing, has noticed cases of canine crowding among the Chinese.

In the mandibular premolar region a significant number of first and second premolars are either rotated or crowded. Crowding is predominantly in the area of the second premolar and is principally directed to the lingual aspect. Instances of rotation are not to be confused with 180 degree rotation reported by Greene ('67b) in ancient Sudanese. In the present study all cases of rotation involve no more than 30 to 45 degrees and generally appear to be associated with mandibular crowding. Moorrees and Reed ('54:87), however, note that mandibular crowding may occur in both large and

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small mandibles where lack of space is not evident and in cases where tooth size may be reduced. One case occurs where a first and second premolar are both found rotated on the same side of the same mandible.

Table 4

Crowding in Gray Site Maxillae

(N = 109 Maxillary Sides)

	Number Affected	Percent Affected
Unilateral impacted canine	3	2.9
Bilateral canine crowding	1	0.9
Unilateral canine crowding	2	1.8
Totals	6	5.6

Table 5

Crowding in Gray Site Mandibles

(N = 149 Mandibular Sides)

	Number Affected	Percent Affected
Unilateral canine crowding	1	0.66
Crowded First premolars (bilat.)	2	1.33
Crowded First premolars (unilat.)	4	2.67
Crowded second premolars (bilat.)	4	2.67
Crowded Second premolars (unilat.)	6	4.02
Totals	17	11.39

The Cusp of Carabelli

Carabelli's cusp is a tubercle present on the mesio-lingual surface of the permanent molars and the deciduous second molar of the maxilla. In the permanent dentition it is found predominantly on the first molar (Kraus,'51). It is usually found at the junction of the middle and occlusal thirds of the crown (Dietz,'44). All forms of pit, groove, and cusp are regarded as manifestations of the cusp trait (Kraus,'59; Dahlberg,'63; Snyder et al.,'69).

The classification employed in the present study is a condensation of the categories of Dahlberg ('63) and Snyder et al.('69). The following modification is conventional (see Bang and Hasund,'72).

Dahlberg ('63)	Snyder et al.('69)	Present Study
a	0	Absent
b,c	f	Moderate
d,e,f,g	c1,c2,c3	Pronounced

The expression of the Carabelli trait is reported to be almost always bilateral (Kraus,'59). However, there may be variable intensities of expression on each side (e.g. Dietz,'44; Meredith and Hixon,'54).

The trait is reported to be manifested similarly in both sexes (Garn et al.,'66; Meredith and Hixon,'54).

Relationships between Carabelli's cusp and other

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aspects of the dentition have been suggested. Keene ('65) found that size and frequency of the cusp on M1s are positively correlated with maxillary third molar agenesis (i.e., total frequency and degree of expression of cusps on M1 were reduced when unilateral or bilateral upper M3 agenesis or tricuspidity of maxillary M2 occurred). Keene ('68) reported that Carabelli's trait and the hypocone seem parallel in their variability and expression and that both are dependent to some extent upon factors related to structural and numerical reductions in the maxillary molars. On the other hand, Bang and Hasund ('72) indicate, in their study of Alaskan Eskimos, that the presence of Carabelli's cusp is found to be "genetically independent" of cusp number, groove morphology, or mesio-distal diameter of M1. Tsuji ('58:22) found no association between Carabelli's trait and blood groups or taste ability.

World frequency distributions of the Carabelli cusp generally range from high among Caucasians to low among Mongoloids. Africans show moderate incidences of the trait. The pronounced form of the character is found predominantly among Caucasians, while the moderate (pit and ridge) forms are the major degrees of expression to be found in Mongoloid populations. Amerind populations exhibit higher frequencies of absent and moderate expressions of the trait, and thus show general affinity to Mongoloids, although there are

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notable exceptions to this pattern (Pima, Papago and Zuni groups of the American Southwest). Eskimo groups range from complete absence of the character (e.g., East Greenland Eskimo) to a frequency of 42.7% (Alaskan Eskimo). Snyder et al. ('69) found a high frequency of expression of the cusp among the Tarahumara and Mestizos of Mexico and suggested that the incidence of Carabelli's cusp is probably higher in Mongoloid groups than previously believed. Instances of pit and groove expressions may have been overlooked in previous studies.

The Carabelli trait in the Gray site population falls into what is considered the Mongoloid region of the frequency spectrum. Predominant expressions of the cusp are of the moderate variety. All expressions of the pronounced cusp are characterized by an eminence without a defining groove (c1 of Snyder et al.,'69).

Table 6

Frequencies of Carabelli's Cusp in the Gray Site

Tooth	Pron.	Mod.	Abs.	N
M1	2.7	13.3	84.0	75
M2	0.0	4.3	95.7	70
M3	0.0	5.8	94.2	34

Maxillary Molar Patterns

Gray site cusp numbers on maxillary molars are presented in Table 7. General world distributions show Caucasians exhibiting a reduction in numbers of cusps, particularly in the M2 and M3 region with Mongoloids showing a retention of the 4-4-4 cuspal pattern. Australians and Bushmen almost always possess four cusps on the first two maxillary molars and on three-quarters of the M3s (Lasker and Lee,'57). Amerind populations are characterized by a high frequency of four cusps on M1 (approaching 100%) while showing variability in the M2 region and predominantly three-cusped M3s (Dahlberg,'51;'63).

The following classification is employed (after Dahlberg,'51:164): "Four well developed cusps on a tooth gives the tooth a classification 4. If the hypocone is reduced in size, the tooth is designated as 4-. Total absence of the hypocone is indicated by 3 and if the 3 type has a cuspule on the distal border it is called a 3+ tooth." Maxillary M3s are often highly crenulated and of irregular cuspal configuration.

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Table 7

Cusp Numbers on Maxillary Molars of the Gray Site

Tooth	4 Cusps	4-	3+	3 Cusps	2 Cusps	N
M1	99.0	1.0	0.0	0.0	0.0	119
M2	36.8	18.9	25.4	18.9	0.0	95
M3	36.2	0.0	10.4	50.0	3.5	58

Mandibular Molar Cusp and Fissure Patterns

The classification of Gregory and Hellman ('26) is widely used today. The Y5 type or "Dryopithecus pattern" is defined as when the hypoconid and metaconid form common border (Robinson and Allin,'66), i.e., cusp 2 and cusp 3 contact, after the numbering system of Gregory and Hellman ('26). The plus five pattern occurs when the protoconid and metaconid have a common border (1-4 contact).

The four cusped molar patterns involve loss of the hypoconulid along with the posterior fissure and fovea (Robinson and Allin,'66) and are considered to be evolutionarily advanced types due to the trend toward reduction in size and form of the lower molar teeth in hominid dentitions. The Y4 pattern exists when the hypoconid borders the metaconid (2-3 contact) while the +4 condition is found with the protoconid, entoconid, metaconid and hypoconid meeting at a common junction (i.e., it cannot be determined which diagonal pair has the most basal contact). A further classification called the X pattern has been proposed by Jorgensen ('55) where there is basal, linear contact between the protoconid and entoconid cusps. The number of cusps in the lower molars may involve the retention and disappearance of different cusps. While Jorgensen ('55) states that the X configuration represents the most advanced stage of the Y5 - +4 -X4 pattern series,

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Zoubov ('64) notes that the change from five cusps to three may or may not proceed through the four cusp stage and may involve any two of the entoconid, metaconid, hypoconid or hypoconulid.

The finding of Jorgenson ('55) that the 4- and 5- cusp types are not correlated with the plus and Y patterns, respectively,is an important result. "This is reason enough for treating the two structural elements separately instead of collectively..." (Jorgensen,'55:198). A study by Garn et al.('66) indicates that this assumption is probably valid, as chi square tests of independence show that cusp number and groove pattern in the mandibular molars are "...independent morphological and, presumably, genetic variables" (Greene,'67a).

A substantial range of variation in cusp number is found in world populations, with M3 appearing to be the most variable. Although previous studies have reported Caucasians to possess higher frequencies of the 4-cusped varieties, there are notable exceptions, e.g., Danish and Dutch populations (Jorgensen,'55). Among the Aleut and Alaskan Eskimo groups, high frequencies of 4-cusped mandibular molars have similarly been shown to be uncharacteristic (Pedersen,'49; Turner,'67a). Mongoloid and Caucasian frequencies have a sizeable overlap.

The Gray site material exhibits a sizeable proportion

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of six- cusped M1s. This character is reported to be high among Polynesian populations (Suzuki and Sakai,'73). Tratman ('50) reports the occurence of five- and six- cusped M1s with large crowns to be more common in Mongoloids than in Caucasoids. Six- and seven- cusped forms are found in relatively high incidence among Alaskan and East Greenland Eskimos on M2. The second molar pattern in the Gray site is consistent with what Dahlberg ('63) sees as a decided shift to the four cusped variety among all Amerindian groups. M3 is found with irregular cuspal formation resulting in a number of six- and seven-cusped teeth and also markedly reduced forms. This condition is also found among the Pima (Dahlberg,'51). The Gray site shows the 5-5 pattern predominant over the 5-4 pattern on mandibular M1 and M2 and thus exhibits affinities with the generalized Eskimo population which is believed to be the only human group with 5-5 prevalent over 5-4 (Goldstein,'31).

Table 8

Cusp Numbers on Mandibular Molars in the Gray Site

Tooth	7 Cusps	6 Cusps	5 Cusps	4 Cusps	3 Cusps	N
M1	1.0	22.9	76.1	0.0	0.0	104
M2	0.0	9.0	52.2	38.8	0.0	90
M3	1.6	7.8	50.0	36.9	3.7	65

Table 9

Mandibular Molar Fissure Patterns in the Gray Site

Pattern	M1	M2	M3
Y7	1.0		
Y6	19.8		
Y5	68.3	6.9	18.9
Y4		4.6	6.9
+7			1.7
+6	3.0	9.2	8.6
+5	7.9	45.9	36.2
+4		32.1	13.8
X4		1.2	13.8
N	101	87	58

Hypodontia

The possible aetiologies of hypodontic conditions have been grouped into four major categories (Brothwell et al.,'63):

1) Local influences to tooth germs, e.g., osteomyelitis, trauma, tumours, radiation, etc.

2) Constitutional diseases, e.g., tuberculosis, rickets, syphilis. Campbell ('34) believes syphilis plays a role in most cases of hypodontia.

3) Endocrine and nutritional disturbances (see Hutton,'36; Brekhus et al.,'44).

4) Heredity.

Of concern in this study are those instances in which the hypodontia is congenital (corroborated by X-ray). Agenesis of M3 is a singularly important genetic trait.

Agenesis of M3 is believed to be part of a complex associated with agenesis of teeth of other morphological classes, delayed M3 eruption, variability in formation timing, and tooth eruption sequence. (Davies,'68; Sofaer et al.,'72a; Garn et al.,'63; Keene,'65; Gruneberg,'52). These authors have noted that incidence of hypodontia increases within other morphological classes with an increase in the number of M3s congenitally missing.

Mongoloid populations generally have relatively high frequencies of M3 agenesis (Dahlberg,'63) although, apart

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from Eskimos (East Greenland Eskimos, Alaskan Eskimo), North American aboriginal populations show a substantial range of variation in incidence. Negroid and Oceanic groups exhibit a great range of variability (Lasker and Lee,'57), while M3 agenesis in Caucasians falls between 7 and 26% (Garn et al.,'63). In the Gray site material, the frequency of M3 agenesis is found to be comparatively low for a Mongoloid population.

The frequency of impacted third molars in the Gray site is 3.7% (N=81 mandibles). No cases of impacted maxillary third molars were encountered. A high rate of impaction may indicate developmental abnormalities as well as genetic factors. Garn et al.('63) note that delayed eruption is a particular manifestation of the tendency toward suppression of M3 and agenesis. In addition, delayed eruption is also related to nutritional factors, while impaction is fundamentally determined by angle of tooth eruption toward the back, growth rate in the length of the mandible, and direction of condylar growth (Bjork et al.,'56). Previous reports of impaction include 5.4% in Eskimos by Goldstein ('32) and 9% in Eskimos by Hellman ('28).

One instance of a mandibular right third molar, fully erupted but rotated 90 degrees, is noted. No previous mention of this condition is known.

The only other cases of hypodontia found in the Gray site are one instance of unilateral maxillary I2 agenesis and one instance of bilateral mandibular I1 agenesis. Both cases were independent of M3 agenesis and of each other.

Table 10

Missing and Reduced Forms of the Third Molar

in the Gray Site

	N	Percent		
		Agenesis of	One or More	Totals
		1 or More M3s	Dimin. M3s	
Maxilla	55 ind.	3.6	7.3	9.1
	117 teeth	1.7	4.2	5.9
Mandible	81 ind.	11.1	1.2	12.3
	148 teeth	6.7	1.3	8.0
Totals	94 ind.	10.6	5.3	14.9
	265 teeth	4.5	2.6	7.1

The Paramolar Cusp Formations

The paramolar tubercle is located on the buccal surface of molars and premolars of the upper and lower jaws (Dahlberg,51). The terminology adopted in the present study is that suggested by Dahlberg ('45) where cuspule formations on the mandibular molars are labelled protostylid and those on the maxillary molars are designated parastyle.

The protostylid is defined as a specialization of the cingulum limited to the anterior portion of the buccal surface of molars (Dahlberg,'50). It is manifested with greatest size and character in the deciduous second lower molars and decreasingly from this tooth through the sequence of first, second, and third molars (Dahlberg,'63). The trait behaves as a continuous variable, ranging from a pit to a pronounced cusp.

A modification of the classification of Dahlberg ('63) is used in assessment of the degree of manifestation of the parastyle and the protostylid.

Dahlberg's scale	Present study
0	Absent
P,1	Moderate
2,3,4,5	Pronounced

Occurrence of pit forms of the trait on M1 are commonly found in both Caucasian and Mongoloid populations, while Mongoloids may exhibit higher frequencies of the

pronounced forms. Pedersen ('49) reported only pit developments in East Greenland Eskimo dentitions and Moorrees ('57) noted no protostylids among the Aleuts. The character is found predominantly on M3 in the Gray site (Table 11). The Gray site population shows a strong similarity in frequencies of the protostylid to Pima and Papago groups (Sofaer et al.,'72b) for M1 but less resemblance to other Amerind populations.

The parastyle is found in the same location in the maxillary molars as is the protostylid in the mandible. North American Indian populations show a low frequency for the trait (Kustaloqu,'62), while Turner ('67b) records a relatively high incidence among his pan-Arctic series. The range of morphological variation and frequency of forms in Aleut and Eskimo crania is similar to that observed for the Carabelli's trait (Turner,'67b:913).

Table 11

Expression of the Protostylid in the Gray Site

Tooth	Pron.	Mod.	Abs.	N
M1	0.9	4.5	94.6	110
M2	2.3	23.2	74.7	86
M3	15.0	38.4	46.6	60

Table 12

Expression of the Parastyle in the Gray Site

Tooth	Pron.	Mod.	Abs.	N
M1	0.0	2.5	97.5	79
M2	0.0	0.0	100.0	74
M3	2.6	2.6	94.8	38

Root Variations

a) Normal, coalesced and fused root forms in the molars

The classification adopted in this study distinguishes between three degrees of root fusion. "Normal" indicates no tendency toward root fusion. The coalesced condition exists when a tendency toward fusion is evident (i.e., roots are interconnected by cementum) but root differentiation is complete as separate root pulp cavities still occur. The fused root term is applied to compressed roots or to roots interconnected by cementum with failure of root and pulp cavity differentiation. Assessments of degree of root involvement were based on root examination, root socket examination, and/or X-ray material.

A tendency toward fusion of roots is reported in Mongoloids (Lasker and Lee,'57; Tratman,'50). M2s have reduced roots in Mongoloid racial stock, while maxillary M3s show reduction of form accompanied by partial or complete fusion of roots into pyramidal root forms. The tendency toward root fusion of posterior molar teeth is reported to be associated with relatively small-sized roots in Pecos Pueblos Indians (Nelson,'38). Caucasians exhibit low frequencies of maxillary and mandibular molar root fusion (Visser,'48) while extremely high incidences of root fusion are found in South African Bushmen (Drennan,'29) and East

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Greenland Eskimo (Pedersen,'49). The Gray site and Pecos Pueblos Indians are intermediate between Caucasoids and the other populations mentioned above.

b) Root numbers:

In the usual situation, maxillary molars are characterized by three distinct roots and mandibular molars by two (Ackerman et al.,'73). Deviations from normal root numbers in the molar series are considered to be a Mongoloid trait (Tratman,'38,'50; Turner,'71). The additional distal-lingual root found on mandibular M1s and M3s is reported to be present in greater than 10% of Mongoloid cases (rare on M2) while scarcely present at all in Indo-European Caucasoids (Tratman,'50). The presence of the supernumerary root is associated with the retention of the hypoconulid on the lower molars (Leigh,'25; Tratman,'50).

Arctic populations show high incidences of the character while Amerinds are consistently less affected. Asiatic Mongoloid groups are intermediate in frequency of expression of the trait. Tratman ('38) reports that Asiatics have high frequencies of three-rootedness on both deciduous lower m2s and permanent lower M1s, with the trait occuring four to eight times more frequently on the latter tooth. Three-rooted mandibular molars were found on 5.9% of M1s (N=152) and 7.6% of M3s (N=92) in the Gray site population.

Supernumerary maxillary molar roots were found in the

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Gray site sample. Four-rooted forms were recorded in 3.4% of M2s, 5.7% of M3s, but were absent on M1s. Reduction in root numbers was also noted in the maxillary molars. Two rooted forms were observed in 0.8% of M2s, 4.6% of M3s. No cases were recorded for M1.

It has been reported in earlier studies that "...the occurrence of the two-rooted forms (of maxillary and mandibular premolars) is sufficiently rare in both groups (Mongoloids and Indo-Europeans) to be considered as an abnormality rather than one coming within the range of normal variation (Tratman, '50:63)." On the other hand, Leigh ('37) has noted that the premolars of pre-Spanish Peruvians were commonly three-rooted. Three-rooted maxillary first premolars are encountered in 6.8% of Gray site dentitions (N=88).

Table 13

Maxillary Molar Root Fusion in the Gray Site

Tooth	Normal	Coalesced	Fused	N
M1	95.9	4.1	0.0	147
M2	46.6	27.1	26.3	118
M3	17.2	23.0	59.8	87

Table 14

Mandibular Molar Root Fusion in the Gray Site

Tooth	Normal	Coalesced	Fused	N
M1	98.0	1.3	0.7	152
M2	73.0	10.9	16.1	137
M3	59.9	19.5	20.6	92

Enamel Extension on Maxillary and Mandibular Molars

This condition involves extension of the enamel between the buccal roots on the buccal aspect (Tratman,'50), in which "...the lower border of the enamel at the necks of the molars presents a point of enamel running towards the bifurcation of the roots (Chappel,'27:10)." The character is often associated with pearl (odontome) production on radicular portions of molars, and the two phenomena may be genetically related.

Enamel extension may take the form of (Watson and Woods,'26):

a) Extension with a spine.

b) Extension with a tongue between the roots:

- passing under and becoming invaginated in cementum.

- tongue terminating in an enamel nodule.

- isolated patches of enamel, often circular, lying between the roots.

Mongoloids are reported to exhibit high frequencies of expressions of the trait. Tratman ('50) records a 90% incidence in maxillary M1s (lower frequencies indicated for M2s and M3s). Chappel ('27) found Hawaiians with enamel extensions occurring almost exclusively on permanent molars. (93.53% of cases examined). Caucasians are reported to possess the trait in frequencies of 27% (Chappel,'27) and

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17% (Watson and Woods,'26). Amerind populations have frequent occurrences of the character (e.g., Fenstermaker,'36,'37, in historic Iroquois; Leigh,'28, in aboriginal Californians). Frequencies of enamel extension and pearl formation in the Gray site show predominance of the condition in both maxillae and mandibles.

Table 15

Enamel Extension in Gray Site Molars

	N	M1	N	M2	N	M3	Mean M1-M3
Maxilla	120	43.3	87	77.0	49	62.8	57.8
Mandible	156	44.9	117	59.8	65	67.7	54.4

Table 16

Odontome Production in Gray Site Molars

	N	M1	N	M2	N	M3	Mean M1-M3
Maxilla	120	2.5	87	6.9	49	10.2	5.4
Mandible	156	5.8	117	4.3	65	7.7	5.6

Enamel Pearling

Enamel pearl formation has been categorized as follows
(Cavanha, '65):

a) Extradental:

- coronal

- cervical

- radicular

b) Intradental:

- coronal

- cervical

- radicular

In addition, the crown, neck, and root may be the
sites of either a true enamel pearl, an enamel dentin
pearl, or an enamel dentin pulp pearl. Pindborg ('70) calls
the intradental condition dens invaginatus and labels the
extradental form dens evaginatus. The latter type, when
found on the occlusal surface of molars, premolars, or
canines, is known as an odontome of the axial core type.
When pearling is found on the radicular surface of teeth the
odontome associated with enamel extension results.

Occlusal pearl formations have been described in
various terms. Merrill ('64) states that the following
represent the same condition reported by a number of
authors: interstitial cusp, Leong's premolar, odontome of
the axial core type, tuberculated premolar, occlusal enamel

pearl, cone-shaped supernumerary cusp, evaginated odontome, and the simplest type of composite dilated odontome. Lau ('55), regarding the genesis of the tubercle, indicates that it is probably caused by "...an evagination or extrusion of a part of the inner enamel epithelium' to the stellate reticulum occurring in the early stages of tooth development (p.220)." The tubercle has an outer enamel covering and core of dentin around a central canal which is continuous with the pulp (Villa et al.,'59). This corresponds to the extradental coronal enamel-dentin-pulp pearl of the classification of Cavanha ('65), above.

The Leong premolar is found in one instance in the Gray site population (0.37%; N=269). It is a rare Mongoloid trait and non-existent in Indo-European Caucasians (Tratman,'50). Lau ('55) reports the condition to be rare in Europeans and Africans. The frequency of the trait in Japanese and Chinese is reported between one and two percent (Lau,'55; Kato,'37; Wu,'55). The expression of the Leong premolar may be slightly more frequent in Eskimo Aleut and Amerinds (Merrill,'64), although Moorrees ('57) finds only one instance of the character in living Aleuts.

The presence of the Leong premolar often leads to infection of the pulp and periapical region (pulpitis) because bacteria invade the pulp through the opened axial canal after the tubercle is broken off (Lau,'55; Villa et

al.,'59). Oehlers et al.('67) indicate that the odontome is liable to fracture after eruption, implying that the trait may be maladaptive. Knutson ('75) finds no evidence of increased susceptibility of premolars to ante mortem loss or decay in the Gray site material. Thus, the true incidence of Leong premolar in the Gray site population in probably close to that observed.

Hyperodontia

The frequencies of supernumerary maxillary incisors in populations of the Southwestern U.S. have been presented by Snyder ('60). Studies of various world populations indicate that the incidence of the trait is low. In the Gray site, 5.1% (3 of 59 maxillae) are found to possess mesiodens and in one case two supernumerary I1s are in the same maxilla. All cases were confirmed by X-ray.

One instance (0.6%) of a supernumerary fourth molar was encountered in the Gray site. The root socket was found in the right side of a mandible, distal to M3 and situated in alignment with other teeth of the molar series. Snyder ('60) finds fourth molars are rare in all populations, with greater frequencies being found in Bushmen and Negroes than in Whites or Mongoloids (Lasker and Lee,'57; Klatsky,'56). Amerind and Eskimo populations may possess lower incidences

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of the fourth molar. However, it is not known if the slightly variable incidences are indicative of actual racial differences.

Chapter 3

ESTIMATES OF BIOLOGICAL DISTANCE

Material

Source data for fourteen populations is considered, of which five are of Eskimo origin, seven are Amerind, one is Japanese, and the last is Chinese. The choice of populations was determined by the availability of appropriate studies in the literature.

A,B,and C) Zuni, Pima, Papago - Original data were presented on 610 Zunis, 327 Pimas, and 164 Papagos by Sofaer et al. ('72b). Trait frequencies were assessed by intra-oral examination and on the basis of dental casts on living individuals.

D) Pima - All data were presented in Dahlberg ('51). Percentages of incisor shovelling presented in Dahlberg and Mikkelson ('47) are also used in calculations.

F) Pecos Indian - All data are a result of excavations at Pecos Pueblo in north-central New Mexico (1915-24). 250 well preserved skeletons out of 1250 original were studied by Nelson ('38) at the Peabody Museum. This is the same material examined by Hooton ('30). Pecos Indians are pre-contact and believed to be slightly later than a

neighboring settlement dated by Douglass ('29, cited in Nelson, '38), to be approximately A.D. 1073-1272.

G) Texas Indian - Original data on 370 pre- and proto-historic skeletons from various parts of Texas was presented by Goldstein ('48). Most of the sample is believed to have had no contact with Europeans (Goldstein, '48:66).

K) East Greenland Eskimo - All original data was reported in Pedersen ('49). The sample consisted of pre - Danish East Greenland skulls, casts of present day East Greenland Eskimo dentitions, and dental records of present day East Greenland Eskimos. Weighted mean frequencies were calculated for the values used in this study.

L) Aleut Eskimo - The sample of eastern and western Aleuts is comprised of data collected on 75 individuals during the 1946 expeditions of the Peabody Museum and Harvard University to the Aleutian Islands, and reported in Moorrees ('57).

M) Alaskan Eskimo - This population is a composite sample consisting of data on incisor shovelling by Hrdlicka ('20) from an Eskimo sample at the U.S. National Museum; data on shovelling, Carabelli's cusp, upper molar cusp numbers (Bang and Hasund, '71, '72, '73), on Eskimos from Point Hope and Anaktuvuk Pass. Lower molar data were presented in Goldstein ('48) from the collection of the U.S. National Museum and has been pooled with material studied by Hellman

('28).

N)   Japanese - This material is a composite sample of
pooled data for incisor shovelling from Sakai ('54),Takehisa
('57), Kikuchi ('54), and Suzuki and Sakai ('65) (compiled
in Suzuki and Sakai,'66), and Hrdlicka ('20); data on the
Carabelli's cusp by Mori, Yamada, Ma, and Suzuki and Sakai
(presented in Suzuki and Sakai,'57); material on the upper
molars by Suzuki and Sakai ('56a) and on the lower molars by
Suzuki and Sakai ('56b). Frequency of the protostylid is
reported in Suzuki and Sakai ('54).

P)   Chinese - The data on incisor shovelling was
presented by Hrdlicka ('20) and Lasker ('45); data on
Carabelli's cusp from Oshima ('49) and Maruyama ('57); data
on upper molars by Suzuki and Sakai('56) and lower molars by
Hellman('28).

Q)   Paleo-Aleut - All data are presented in Turner
('67a), consisting cf a composite sample of 151 western,
central and eastern Aleut dentitions.

R) Paleo-Eskimo - Representatives of this group are
Eskimos from Kodiak Island, Arctic coast of Alaska,
Sadlermuit from Southampton Island and Western Greenland
coastal Eskimos. Data are found in Turner ('67a). The
inclusion of the above individuals into the same Eskimo
group by Turner is accepted in the present study. There is
no basis upon which to divide the material into breeding

isolates (Turner,'67a). On the other hand, the individuals of this group are not likely to overlap the other populations of this study, with the exception of the Alaskan Eskimo sample, and thus are suitable as a check on the frequencies observed in the latter population. The designation of this composite population as Paleo-Eskimo is not strictly true, as some of the skeletal remains are prehistoric while others are definitely historic (see Turner '67a).

Table 17

Scoring of Dental Characters in Biological Distance

Estimates (after Sofaer et al.,'72b)

Tooth	Character	Affected	Non-affected
UI1	Palatal shovelling	Marked, shovel, and semi-shovel	Absence and trace shovel
UI2	Barrel-shape	All forms of anomalous I2	Normal shovelled incisor
UM1	Cusp of Carabelli	All degrees of formation	No feature
UM2	Cusp number	4 cusps and 3 plus	3 cusps
LM1	Protostylid	All degrees of formation	No feature
LM1	Cusp number	6 cusps or more	5 cusps or less
LM1	Fissure pattern	Y or X pattern	Plus pattern
LM2	Cusp number	5 cusps or more	4 cusps or less
LM2	Fissure pattern	Y or X pattern	Plus pattern

Results

Individual Chi-square tests of significance have been calculated for nine dental characters for all population combinations for which the appropriate frequencies are available. The methodology involved in character assessment is indicated in Table 17.

In addition to individual Chi-square tests of significance, cumulative Chi-squares are calculated. Using the results of a concordance study undertaken two months after the initial scoring of morphological characters, dental traits are added to a cumulative Chi-square value beginning with traits with highest concordance and proceeding to those of lowest concordance. LM1 protostylid and UI2 barrel-shape are excluded from the cumulative Chi-square testing because of the reduced number of populations for which frequencies are available.

Concordance in the present study is generally higher than that observed by Sofaer et al.('72b), a consequence that may be attributable to a greater reliability in the examination of skeletal material as opposed to cast and intra-oral examination. For some characters, the range of expression varies from population to population, introducing more opportunity for misclassification in populations where the range of trait manifestation is greater. The overall sequence of traits from those with greatest to those with

the lowest concordance is similar to the finding of Sofaer et al. ('72b). Characters such as shovelling and barrel-shape in the Gray site are more affected by single instances of discordance due to the small sample sizes involved in the determination of the frequencies of these characters.

The following relationships are suggested:

1) Chi-square analysis of UI1 palatal shovelling indicates an overall closeness in statistical relationship between the Gray site and all Amerind groups with the exception of Pecos Pueblo (F). East Greenland Eskimo (K) and Living Aleut (L) are closely related to each other and to Amerind populations. Genetic relationships are suggested among a cluster of populations consisting of Alaskan Eskimo (M), Paleo-Aleut (Q), Paleo-Eskimo (R), Pecos Pueblo, and Chinese (P) populations, while the Japanese diverge from all groups considered. This observation is consistent with the theory of Japanese isolation from presumed pro-Mongoloid elements for some time. The overall lack of significant values less than 0.05 reflects the homogeneity of expression of shovelling among Amerinds. On the other hand, the statistical separation due to lower frequencies of the trait is characteristic of Asiatic Mongoloids.

2) On the basis of statistical analysis of UI2 barrel-shape, the Gray population exhibits separation from American Indian groups due to a higher frequency of the character.

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Estimates of relationship between Eskimo and Amerind groups are generally not significant due to the small range of variability in frequency of the trait in all populations. Two clusters are suggested: a) Alaskan Eskimo, Paleo-Aleut, Paleo-Eskimo and Pecos Pueblo and b) Papago, Pima, Japanese and Chinese.

3) Manifestation of Carabelli's cusp in UM1 is suggestive of strong affinity among Alaskan Eskimo, Papago, Pima (D), Zuni, and Paleo-Eskimo populations due to the strong development of this cusp in these groups. Lack of homogeneity between the Eskimo populations is evident. The Gray site, Pecos Pueblo, living Aleut, Chinese, and Japanese groups indicate intermediate distance relationships from East Greenland Eskimo on the one hand and Southwestern U.S. and other circumpolar groups on the other. The Japanese sample is particularly close to Paleo-Aleuts.

4) Significant variability is found among Amerind populations with respect to UM2 cusp number. Although Texas Indian (G) and Zuni(A) groups show close connection to each other, they similarly show diffuse relationships to living Aleuts, East Greenland Eskimo, Alaskan Eskimo and Paleo-Aleuts. Pecos Pueblo is singularly differentiated from all populations however, Paleo-Eskimos also possess a high frequency of UM2 4-cusped forms. Japanese and Chinese groups are statistically related to the Pima, Papago and Gray site

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populations.

5) The frequency of LM1 protostylid has not been reported for all populations considered. Although the character has been suggested to be a Mongoloid genetic marker, the frequency of manifestation is generally low in Amerind populations. Zuni, Papago, Gray, Living Aleut, and Pima (B) are noted as showing general relationships to each other on the basis of the virtual absence of the character in these samples. By contrast, Pima (D), Paleo-Aleut, and Paleo-Eskimo indicate affinity to each other in their substantial development of the protostylid. The Japanese population is closest to the Paleo-Eskimos.

6) In the analysis of LM1 cusp number close relationships indicated within the Paleo-Aleut, Paleo-Eskimo, and Gray group and the Zuni, Papago, Pecos Pueblo, Alaskan Eskimo and East Greenland group. The Japanese, Texas Indian and Pima (B) comprise another cluster of related populations with respect to this trait. The absence of 6-cusped forms of the LM1 in living Aleuts is probably not valid as an indicator of close relationship to Pima (D) and Chinese populations, Moorrees ('57) apparently not recording the frequency of the character in the former.

7) Analysis of LM1 fissure pattern shows close relationships among Chinese, Alaskan Eskimo, East Greenland Eskimo, Pima (B), and Pima (D) groups. A second cluster of

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populations consists of Texas Indian, Papago, and Zuni, which shows association with Paleo-Aleut, Paleo-Eskimo, and Japanese groups. The Pecos Pueblo and Gray populations appear closely related to each other and intermediate in distance between the two clusters indicated above. Distinct separation is evident between Paleo- and later Eskimo and Aleut populations.

8) The clustering of Eskimo populations when Chi-square analysis of LM2 cusp number is considered reflects the predominance of 5-cusped forms among circumpolar groups, although Paleo-Aleut and Paleo-Eskimo are statistically separated from the other Eskimos and Aleuts. Pima (D) and Gray suggest Eskimo genetic influence with respect to this character. The close relationship among Zuni, Papago, Pima (B), Pecos Pueblo, Texas Indian, and the Chinese population is suggestive of recent common ancestry for these groups characterized by advanced acquisition of the 4-cusped LM2.

9) Chi- square analysis of LM2 fissure pattern finds that a number of Amerind populations (Papago, Zuni, Pima (D), and Texas Indian) are closely related to the Chinese group. Japanese, Paleo-Aleut, and Paleo-Eskimo groups are found to be statistically close and separate from other populations. Less immediate connections are indicated between Pima (B), Gray, Pecos Pueblo, and living Aleut and

other Amerind populations referred to above. This situation is suggestive of mixture between what continually emerges as evidence for two fairly distinct ancestral lines in circumpolar prehistory. Finally, while East Greenland and Alaskan Eskimos both possess high frequencies of the Y pattern on LM2, there is a statistical separation between the two populations.

A summation of the numbers of significant interpopulation Chi-square values shows that close biological relationships are apparent between Texas Indian, Papago and Zuni populations. Pima (B) and the Gray groups are close together and suggest affinities to Eskimo populations. The Pecos Indian sample reflects possible common ancestry or admixture with circumpolar groups and the Chinese population although distinct from Gray and Pima (B).

Paleo-Aleut and Paleo-Eskimo populations are closely related to the Japanese group and distinct from virtually all others. Finally, the Chinese sample exhibits vaguely closer relationships to most Amerind groups than to Eskimos or the Japanese. The difficulty in determining relative biological distances between populations can be noted where groups show relatively low significance values for a number of characters and highly significant values for others.

On the basis of cumulative Chi-square analysis, it is possible to gain further insight into interpopulation

comparisons on two counts. First, with the exception of three closely related Southwestern groups (Papago, Zuni, Texas Indian), Chi-square values are significant for some dental characters between all populations. Thus, relative distance determined by absolute values of the Chi-square can be highly misleading because slight changes in observed frequency of a dental trait can cause paramount changes in estimates of distance where distance is actually fairly large to begin with. The cumulative Chi-square averages individual trait values on the assumption that they are genetically independent. This is not strictly true. Sofaer et al. ('72b) and Sanghvi ('53) have noted that this assumption of independence may lead to certain effects on the statistical test employed by exaggerating differences and similarities between distant and closely related populations, respectively. In lieu of knowing the mode of inheritance of dental traits one can increase the number of characters in the analysis and hope that spurious values will tend to equalize themselves.

Second, in addition to the magnitude of the statistic, the direction of change in the cumulative Chi-square value may be taken into consideration. Sofaer et al. ('72b) presumed that lack of concordance was a prime source of the noise that was introduced into estimates of biological distance with an increase in the number of dental traits

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utilized. This point is valid where low levels of repeatability of scoring dental characters are encountered (e.g. 79% concordance for Carabelli trait in their study). However, one may observe the type of effect that the addition of a single Chi-square has on the cumulative value. Examination of the "pattern" that emerges may help to clarify the analysis where large numbers of interpopulation comparisons are attempted (in this case there are 91 different comparisons). Similar patterns of cumulative Chi-square changes might also be presumed to indicate relative biological distances between populations.

On the basis of the analysis outlined several initially obscure relationships are brought into sharper focus.

1) The Texas Indian, Papago and Zuni samples exhibit the closest relationships among populations of the Southwestern U.S. The indication of pattern difference of Pima (B) and Pima (D) from the above mentioned cluster becomes evident when they are viewed in distances from the Chinese population. The relative positions of Pima (B) and Pima (D) point to influence by pro-Mongoloid elements (such as appear to be represented in the Gray population) by their closer distance estimate to East Greenland and Alaskan Eskimo groups. This view is reinforced by the closeness of Pima (B) to the Gray site.

2) The Pecos Pueblo population exhibits more distant relationships to groups of the Southwestern U.S. by showing a consistent decrease in probability of not belonging to the cluster with an increase in the number of characters in the cumulative Chi-square. The similar types of relationship between Pecos and all Amerind samples considered, including the Gray site, suggests that Pecos is substantially separate from most Amerind groups. This indication is augmented by the observation that the closest Pecos distance measure is to the Chinese sample. The general distance estimates among all Amerind populations considered suggests sizeable gene flow between them in prehistoric times. Evidence for extensive gene flow between Pima and surrounding populations has been presented in the blood group studies of Brown et al. ('58).

3) The position of the living Aleut population in relation to Southwestern U.S. groups again indicates a separation of the Papago, Zuni, Texas Indian and Pima (D) cluster from Pima (B) and Gray. The Chinese population exhibits a pattern change similar to Pima (D) with the addition of dental traits to the cumulative Chi-square, thus suggesting that the living Aleuts are more distantly related to Amerind groups than are the Chinese. The most interesting aspect of the relative distance of the living Aleuts is their estimated distance from the Paleo-Aleuts and Eskimo

populations. No relationship is evident to Paleo-Aleuts, Paleo-Eskimo, East Greenland Eskimo or Alaskan Eskimo samples. Japanese are similarly well separated from this population.

4) The Alaskan Eskimo distance estimates imply remote relationship with both Pima groups, Gray, and East Greenland Eskimo, which suggests their distant relationship to Pima (D) and Gray. The Paleo-Aleut population appears to have been the ancestral group to both the East Greenland and Alaskan Eskimos. Paleo-Eskimos are closely related to Paleo-Aleuts and Japanese but do not seem to have been ancestors of the Eskimos samples selected in this study. Paleo-Eskimos, Japanese, Paleo-Aleut, and Paleo-Eskimo are probably derived from the same ancestral stock.

Discussion

Evidence for close biological relationships between Pima, Papago, and Zuni groups has been presented by Niswander et al.('70) and Sofaer et al.('72b). To this cluster may be added the Texas Indians, who show consistently close distance values to the Papago and Zuni in particular. The high frequencies of Carabelli's cusp manifestation among the Pima, Papago, and Zuni is unique among Amerind populations. The condition may be attributable to genetic drift or admixture. The low frequency of the character in the Gray and Texas Indian samples and the close relationship shown between Gray and Pima (B) groups do not reveal whether microevolution or admixture is more probable (see Niswander et al.,'70).

All populations of the Southwestern U.S. and the Gray site exhibit affinity to the Chinese sample. The strongest association is manifested by Pecos Pueblos Indians, who may have been a late population to infiltrate the region in post-Pleistocene times. The Southwestern U.S. has absorbed the brunt of many intrusions. Wormington ('59) states that in Early Christian times the Cochise was superceded by Anasazi, Hohokam, and Mogollon desert cultures. The Anasazi remnants are found in contemporary Pueblos while living Pima and Papago are generally believed to be remnants of the Hohokam culture.

The Eskimo and Aleut populations considered appear to represent a heterogeneous mixture of circumpolar peoples. The close relationship between Paleo-Aleut and Paleo-Eskimo has previously been indicated by Turner ('67a). The most interesting situation, however, is that concerning the origin of the living Aleut population. Turner ('67a:189), after an analysis of Arctic and sub-Arctic dentitions, concluded: "In sum, Aleut dentitions are, and probably always have been, more like those of Eskimos than Indians, and both Aleuts and Eskimos are more like Asiatic Mongoloids than are Indians in most respects. Most of the geographical variation in living Aleut dentitions is the result of local prehistoric evolution, rather than due to differential historic (European) admixture."

While Alaskan Eskimo and East Greenland Eskimo populations show ancestral biological relationships to the Paleo-Aleut, the living Aleuts are singularly separated from them all. Closest distance estimates are to the Amerindians and the Chinese. In fact, the distance estimate between Paleo-Aleut and living Aleut is greater than most other interpopulation comparisons. If the Paleo-Aleuts are ancestors of modern Aleuts the implication would be that, due predominantly to accepted evolutionary principles such as genetic drift, dental differences are greater through time than over geographical distance.

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The separation of the composite Paleo-Eskimo sample also is a complicating factor in the reconstruction of Arctic prehistory, as this population shows no relationship to the presumed descendant Eskimo groups.

A possible explanation proposed by Hrdlicka, but not supported by Turner ('67a), is that the Paleo-Aleut population was replaced by a biologically distinct population. A possibility in this respect could be a proto-Chinese group. However, there is no supporting cultural evidence nor do cranial measurements as re-evaluated by Turner reflect sudden changes in physical type to support this explanation.

The Paleo-Aleut and Paleo-Eskimo probably represent an ancestral group from which East Greenland and Alaskan Eskimo originated. This has been termed as (one of) the Epi-Gravettian pro-Mongoloid migrations (Bandi,'69) to North America. Its people are presumed not to have dispersed to a great extent toward the south, possibly due to Arctic pre-adaptation (Bandi,'69:31).

The Paleo-Eskimo population holds the possibility of being ancestral to pre-Dorset populations that occupied the Canadian Arctic prior to the rapid dispersion of the Eskimo small tool culture. This would acount for the lack of biological relationship between Paleo-Eskimo and Alaskan and East Greenland Eskimo and would tend to support the theory

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of Collins ('51;'64) of a Southeastern Alaskan (Paleo-Aleut)
origin of present-day Eskimos.

Certain Amerind samples from the Southwestern U.S.
support the view (e.g., on the basis of transition to
4-cusped LM2s and loss of the Y pattern on lower molars),
that earlier Amerinds were probably less Mongoloid than
present day Eskimos. Muller-Beck ('66) believes that the
leaf-shaped points of the upper Paleolithic in Eurasia
(30-25,000 B.P.) are evidence of the ancestral groups which
are traceable in the early Llano complex of the Southwestern
U.S. and of which some Amerind groups are possible
descendants (i.e., Zuni, Papago, Pima). Sites in the Lake
Baikal region of Northeastern Asia are considered by Bandi
('69) to represent a group of semi- or proto-Mongoloid
stock, closely related to Amerindian ancestral populations.
Pro-Mongoloid elements as found in the Pecos Pueblo and Gray
groups may indicate subsequent migration of, or contact
with, populations sharing ancestry with Paleo-Aleut,
Paleo-Eskimo, and Japanese.

The Japanese affinities to Paleo-Aleut and
Paleo-Eskimo, on the one hand, and the indication of
relationship between living Chinese and Pecos Pueblo groups,
on the other, are suggestive of at least two late migrations
to the New World. Speculation concerning the nature of
biological relationships between living Aleut, Chinese, and

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Southwestern U.S. populations is weak. However, the relatively close distance of these groups to one another may be evidence of common ancestry or contact. On the basis of variable frequency of three-rooted LM1s and through the use of major linguistic divisions in North America (see Swadesh,'60), Turner ('71) hypothesized at least three major migrations to the New World. Although examination of skeletal remains cannot confirm linguistic affiliation, the present the present study gives physical evidence of diversity that supports the theory of multiple origins of North American aboriginal inhabitants.

Conclusions:

Certain factors make the results of this study highly tentative. Foremost is the lack of good comparative material between populations because of lack of standardization of measurement in the field, observer bias, and small population samples.

Second, one of the problems related to the use of dental non-metrics has been the lack of knowledge about their genetic basis. In most cases the effect of factors causing variation in penetrance and expressivity of the variable cannot be identified. Berry ('68) finds that, in a particular group, the accumulation of certain allelomorphs will be manifested regularly and appear to be inherited in a regular fashion, implying simple assumptions about the inheritance of the character. In other populations, however, the nature of the presumed inheritance changes, probably due to the different composition of the genotype.

Third, the prehistory of North America is complex, having neither concrete evidence of time of initial occupation or subsequent migrations (see Salzano,'62, for a discussion of genetic aspects). As the date of initial inhabitation is pushed back, evolutionary processes can be assumed to have had more and more chance to obscure initial biological relationships.

Stewart ('60) and Hulse ('63) support the view that

early migrants to the New World were a small homogeneous population and that the variability seen in Amerinds is a result of independent evolution according to accepted biological and genetic principles. Increasing evidence, however, supports the theories that the initial occupying population was heterogenous or that subsequent waves of migration have considerably altered the gene pool at different points in prehistory (see Newmann,'67; Genoves,'67). Early classifications of North and South Amerinds have continually sought to explain the diversity in physical type in terms of biological influence from Australia, Polynesia, different regions of Asia, Africa and Europe (see Comas,'60, for a review). In summation, Genoves ('67:303) states "...the heterogeneity found in modern Amerind populations is certainly due to such factors as differential selection in varied environments, genetic drift in isolates, morphological adaptation, gene flow from one area to another, etc., but these explanations though valid do not seem to suffice."

Studies on physical type also indicate the heterogeneity of Amerinds. The study of Neumann ('52), attempting to classify Indian crania into morphological types, has been examined by Long ('66) using multiple-discriminant analysis. Although their results differ, evidence for substantial differences between

proximal groups exists and suggests microevolution or the effects of migrational influx. Giles and Bleibtreau ('61) and Bass ('64) used facial and cranial metrics and morphology to evaluate the persistence of inherited characters through time in the Pecos population and relationships between protohistoric Pawnee and Arikara, respectively. Spuhler ('54) has revealed a biological hodgepodge in his analysis of Southwestern U.S. skeletal series.

An important problem in the present study is the biological position of the living Aleut relative to other Aleut and Eskimo populations. If genetic drift accounts for the genetic change between prehistoric and living Aleuts as measured by dental morphology, then the utility of dental characteristics may be lessened as estimators of biological distance. That such an outcome is unlikely is implied by the types of relationships suggested among Amerind populations. Analysis of dental morphology appears to be another reasonably good independent discriminator of biological distances between populations.

Summary

On the basis of a Chi-square analysis of nine dental characters, several relationships among selected North American populations are suggested.

1) Close biological relationship is apparent between Papago, Zuni, and Texas Indian. Slightly more distant are the two Pima populations and the Gray site.

2) Eskimo groups are heterogeneous in biological composition as measured by dental analysis. Paleo-Aleut and Paleo-Eskimo samples indicate common ancestry with the Japanese. The origin of Alaskan and East Greenland Eskimos is implied to be from the Paleo-Aleut. Living Aleuts are found to exhibit evidence of marked separation from all Eskimo and Aleut populations. Paleo-Eskimos are probably ancestral to pre-Dorset culture but not closely related to present day Eskimos.

3) Pecos Pueblos, Gray and Pima populations show pro-Mongoloid biological influence as reflected in affinities toward historic Eskimos and the Chinese.

4) At least two later migrations to the New World are supported in the present study. One is the pro-Mongoloid Japanese, Paleo-Aleut, Paleo-Eskimo group, ancestral to East Greenland and Alaskan Eskimo populations. The other migration is suggested by the Chinese and Pecos Pueblo

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groups, who show affinities to living Aleut and Amerind populations. The nature of the relationships between these populations is obscure. The proto-Mongoloid element seen in the Southwestern U.S. tends to support the theory of an even earlier proto-Mongoloid migration to North America.

Figure 1

Change in Relationship between Chinese and the Papago,
Zuni, Texas Indian Cluster with Increase in the Number
of Character in Cumulative Chi-square Analysis

Probability of belonging to the Chinese sample

Number Char.	95	90	80	70	50	30	20	10	5	0
2					C			A		G
3					C	A		G		
4					C	A		G		
5				C	A		G			
6						CA		G		
7								C	A	

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Figure 2

Change in Relationship between Chinese and the Pima D,
Pima B, Gray Cluster with Increase in the Number of
Characters in Cumulative Chi-square Analysis
Analysis

Probability of belonging to the Chinese sample

	95	90	80	70	50	30	20	10	5	0
Number Char.										
2				D	B	J				
3					D	BJ				
4			D					B	J	
5								DB		J
6						B	D			J
7								D	BJ	

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Figure 3

Change in Relationship between Living Aleut and the

Papago, Zuni, Texas Indian Cluster with Increase

in the Number of Characters in Cumulative

Chi-square Analysis

Probability of belonging to the L. Aleut sample

	95	90	80	70	50	30	20	10	5	0
Number										
Char.										
2							AC	G		
3					AC	G				
4					AC		G			
5					A		CG			
6							ACG			
7							AC			

Change in Relationship between Living Aleut and the
Pima B, Pima D, Gray Populations with Increase
in the Number of Characters in Cumulative
Chi-square Analysis

Probability of belonging to the L. Aleut sample

Number Char.	95	90	80	70	50	30	20	10	5	0
2								D	P	BJ
3					D		PBJ			
4			D		P				B	J
5				D		B	PJ			
6										DPBJ
7									J	DPB

Table 18

Percentages of Dental Observations in the Affected

Class for Selected Mongoloid Populations

	UI1	UI2	UM1	UM2	LM1 prot	LM1 cusp	LM1 fiss	LM2 cusp	LM2 fiss
Zuni A	94.4	3.0	36.2	66.7	0.1	4.0	84.5	34.9	5.6
Pima B	97.5	6.7	53.3	81.8	7.8	17.4	94.8	45.5	10.6
Papago	97.3	6.5	44.6	75.6	3.3	5.1	78.0	24.3	5.2
Pima D	97.4	8.0	35.0	81.0	31.0	---	99.4	71.0	3.0
Pecos F	89.5	0.4	8.8	98.2	---	3.9	89.0	34.3	12.0
Texas G	95.1	---	---	59.3	---	11.8	69.3	27.7	4.9
Gray J	97.6	17.1	16.0	81.1	5.4	23.9	89.1	61.2	12.8
G.Esk K	98.3	---	0.0	65.3	---	1.2	95.9	68.5	32.8
Aleut L	97.3	---	13.3	69.1	0.0	0.0	41.4	55.5	0.0
A.Esk M	81.5	1.5	42.7	70.9	---	6.2	92.7	72.2	18.5
Jap. N	77.4	4.7	19.4	84.6	18.5	12.5	77.3	53.7	55.8
Chi. P	90.1	7.7	6.1	84.8	---	0.0	99.9	23.0	5.0
P.Aleut	88.6	0.0	23.0	70.0	32.0	21.0	80.0	91.0	49.0
P.Esk R	90.5	1.5	36.0	91.2	20.0	22.0	79.0	99.0	43.0

Table 19

Concordance between Two Independent Scorings of Dental

Characters in the Gray Site

Character	Concordance
UM2 cusp number	0.99
LM1 protostylid	0.99
LM2 fissure pattern	0.97
UI1 shovelling	0.97
UI2 barrel-shape	0.95
LM1 cusp number	0.95
LM2 cusp number	0.94
UM1 cusp of Carabelli	0.93
LM1 fissure pattern	0.89

Table 20

Chi-square Values for UI1 Shovelling

	B	C	D	F	G	J	K
A	1.24	1.06	1.14	1.62	0.05	1.33	2.16
B		0.01	0.00	5.27**	0.81	0.00	0.16
C			0.00	4.93**	0.66	0.02	0.23
D				5.10**	0.73	0.01	0.19
F					2.21	5.44**	6.76**
G		* = 0.1>p>0.05				0.89	1.60
J		** = p<0.05					0.12

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Table 20 (continued)

	L	M	N	P	Q	R
A	1.06	7.85**	11.93**	1.29	2.16	1.09
B	0.01	13.62**	18.41**	4.71**	6.12**	4.34**
C	0.00	13.17**	17.92**	4.39**	5.78**	4.04**
D	0.00	13.39**	18.16**	4.55**	5.95**	4.19**
F	4.93**	2.58	5.30**	0.02	0.04	0.06
G	0.66	8.95**	13.21**	1.82	2.82*	1.58
J	0.02	13.85**	18.65**	4.87**	6.30**	4.50**
K	0.23	15.54**	20.46**	6.15**	7.69**	5.75**
L		13.17**	17.92**	4.39**	5.78**	4.04**
M			0.51	3.04*	1.98	3.36*
N				5.93**	4.45**	6.37**
P					0.12	0.01
O						0.19

Table 21

Chi-square Values for UI2 Barrel-shape

	B	C	D	F	G	J	K
A	1.48	1.35	2.41	2.02	---	11.00**	---
B		0.00	0.12	5.80**	---	5.16**	---
C			0.17	5.59**	---	5.40**	---
D				7.18**	---	3.77*	---
F					---	17.46**	---
G						---	---
J							---

Table 21 (continued)

	L	M	N	P	Q	R
A	---	0.51	0.39	2.18	2.76*	0.51
B	---	3.44*	0.37	0.07	6.63**	3.44*
C	---	3.26*	0.31	0.11	6.42**	3.26*
D	---	4.67**	0.92	0.01	8.03**	4.67**
F	---	0.64	3.72*	6.86**	0.18	0.64
G	---	---	---	---	---	---
J	---	14.43**	7.92**	4.07**	18.38**	14.43**
K	---	---	---	---	---	---
L	---	---	---	---	---	---
M			1.70	4.38**	1.23	0.00
N				0.77	4.52**	1.70
P					7.71**	4.38**
Q						1.23

Table 22

Chi-square Values for UM1 Cusp of Carabelli

	B	C	D	F	G	J	K
A	5.91**	1.47	0.03	21.53**	---	10.58**	43.86**
B		1.51	6.79**	46.25**	---	30.72**	72.31**
C			1.92	32.74**	---	19.37**	57.05**
D				20.07**	---	9.50**	42.09**
F					---	2.39	8.90**
G						---	---
J							17.08**

Table 22 (continued)

	L	M	N	P	Q	R
A	14.08**	0.88	7.03**	27.17**	4.18**	0.00
B	36.02**	2.25	24.84**	53.36**	19.45**	6.06**
C	23.81**	0.07	14.59**	39.17**	10.43**	1.54
D	12.85**	1.25	6.14**	25.58**	3.50*	0.02
F	1.03	30.05**	4.53**	0.53	7.54**	21.28**
G	---	---	---	---	---	---
J	0.29	17.19**	0.40	4.98**	1.56	10.40**
K	13.94**	53.95**	21.73**	6.29**	25.67**	43.56**
L		21.44**	1.36	2.96*	3.17*	13.87**
M			12.68**	36.31**	8.80**	0.94
N				7.95**	0.39	6.88**
P					11.48**	26.90**
Q						4.06**

Table 23

Chi-square Values for UM2 Cusp Number

	B	C	D	F	G	J	K
A	5.96**	1.93	5.29**	34.29**	1.17	5.38**	0.04
B		1.15	0.02	14.94**	12.18**	0.02	7.00**
C			0.86	22.43**	6.05**	0.89	2.55
D				15.87**	11.24**	0.00	6.27**
F					45.21**	15.76**	36.28**
G						11.36**	0.77
J							6.36**

Table 23 (continued)

	L	M	N	P	Q	R
A	0.13	0.41	8.70**	8.92**	0.25	18.06**
B	4.35**	3.29*	0.28	0.32	3.81*	3.78*
C	1.06	0.56	2.54	2.67	0.79	8.79**
D	3.78*	2.79	0.46	0.51	3.27*	4.35**
F	30.96**	28.53**	11.77**	11.54**	29.74**	4.88**
G	2.09	2.96*	15.86**	16.14**	2.50	27.32**
J	3.85**	2.85	0.43	0.48	3.34*	4.27**
K	0.33	0.72	9.92**	10.15**	0.50	19.71**
L		0.08	6.75**	6.95**	0.02	15.35**
M			5.42**	5.60**	0.02	13.42**
N				0.00	6.07**	2.05
P					6.25**	1.94
Q						14.37**

Table 24

Chi-square Values for LM1 Protostylid

	B	C	D	F	G	J	K
A	7.81**	3.06*	36.35**	---	---	5.25**	---
B		1.93	17.21**	---	---	0.47	---
C			27.00**	---	---	0.53	---
D				---	---	22.01**	---
F					---	---	---
G						---	---
J							---

Table 24 (continued)

	L	M	N	P	Q	R
A	0.00	18.14**	20.07**	---	37.76**	21.90**
B	7.81**	3.83*	5.01**	---	18.37**	6.22**
C	3.06*	10.19**	11.89**	---	28.34**	13.55**
D	36.35**	5.46**	4.19**	---	0.02	3.18*
F	---	---	---	---	---	---
G	---	---	---	---	---	---
J	5.25**	6.67**	8.15**	---	23.27**	9.61**
K	---	---	---	---	---	---
L		18.14**	20.07**	---	37.76**	21.90**
M			0.09	---	6.17**	0.32
N				---	4.83**	0.07
P					---	---
Q						3.74*

Table 25

Chi-square Values for LM1 Cusp Number

	B	C	D	F	G	J	K
A	9.40**	0.14	3.79*	0.00	4.18**	16.49**	1.55
B		7.58**	18.74**	9.58**	1.26	1.29	15.56**
C			4.94**	0.17	2.90*	14.25**	2.49
D				3.68*	12.23**	26.82**	0.94
F					4.31**	16.71**	1.47
G						4.99**	9.24**
J							23.48**

Table 25 (continued)

	L	M	N	P	Q	R
A	3.79*	0.50	4.77**	3.79*	13.21**	14.32**
B	18.74**	6.03**	0.94	18.74**	0.42	0.67
C	4.94**	0.11	3.41*	4.94**	11.14**	12.19**
D	0.00	6.10**	13.02**	0.00	23.14**	24.40**
F	3.68*	0.55	4.91**	3.68*	13.41**	14.53**
G	12.23**	1.91	0.02	12.23**	3.09*	3.70*
J	26.82**	12.25**	4.35**	26.82**	0.24	0.10
K	0.94	3.51*	10.00**	0.94	19.86**	21.10**
L		6.10**	13.02**	0.00	23.14**	24.40**
M			2.34	6.10**	9.32**	10.31**
N				13.02**	2.59	3.16*
P					23.14**	24.40**
Q						0.03

Table 26

Chi-square Values for LM1 Fissure Pattern

	B	C	D	F	G	J	K
A	5.72**	1.39	15.00**	0.88	6.50**	0.92	7.35**
B		12.01**	3.76*	2.26	22.08**	2.19	0.14
C			22.85**	4.39**	1.95	4.48**	14.12**
D				9.90**	34.32**	9.79**	2.67
F					11.76**	0.00	3.41*
G						11.90**	24.62**
J							3.33*

Table 26 (continued)

	L	M	N	P	Q	R
A	39.82**	3.33*	1.67	16.49**	0.69	1.01
B	65.63**	0.38	12.76**	5.04**	9.95**	10.96**
C	27.84**	8.64**	0.01	24.40**	0.12	0.03
D	80.72**	5.92**	23.72**	0.36	20.37**	21.60**
F	49.93**	0.82	4.90**	11.33**	3.09*	3.72*
G	15.75**	17.79**	1.64	35.94**	3.03*	2.45
J	50.17**	0.78	4.97**	11.22**	3.17*	3.80*
K	69.01**	0.95	14.91**	3.89**	11.93**	13.01**
L		59.56**	26.70**	82.52**	31.23**	29.50**:
M			9.30**	7.27**	6.84**	7.73**
N				25.28**	0.22	0.08
P					21.90**	23.14**
Q						0.04

Table 27

Chi-square Values for LM2 Cusp Number

	B	C	D	F	G	J	K
A	2.34	2.70	26.16**	0.01	1.21	13.85**	22.61**
B		9.89**	13.37**	2.62	6.83**	4.95**	10.79**
C			43.71**	2.41	0.30	27.82**	39.28**
D				27.01**	37.50**	2.14	0.15
F					1.02	14.50**	23.41**
G						22.72**	33.34**
J							1.17

Table 27 (continued)

	L	M	N	P	Q	R
A	8.57**	27.97**	7.16**	3.44*	67.47**	92.85**
B	2.00	14.72**	1.33	11.24**	47.77**	71.38**
C	20.30**	45.94**	18.17**	0.05	91.11**	118.01**
D	5.17**	0.04	6.37**	46.25**	13.00**	30.75**
F	9.08**	28.85**	7.63**	3.12*	68.69**	94.16**
G	15.91**	39.60**	13.99**	0.58	83.04**	109.48**
J	0.67	2.72	1.14	29.93**	24.41**	44.82**
K	3.59*	0.33	4.60**	41.70**	15.67**	34.18**
L		6.04**	0.06	22.15**	32.16**	53.84**
M			7.33**	48.52**	11.77**	29.13**
N				19.92**	34.77**	56.82**
P					94.33**	121.40**
Q						6.74**

Table 28

Chi-square Values for LM2 Fissure Pattern

	B	C	D	F	G	J	K
A	1.68	0.02	0.82	2.55	0.05	3.10*	23.84**
B		2.00	4.56**	0.10	2.27	0.23	14.50**
C			0.62	2.94*	0.01	3.53*	24.75**
D				5.84**	0.48	6.60**	30.21**
F					3.26*	0.03	12.44**
G						3.87**	25.44**
J							11.36**

Table 28 (continued)

	L	M	N	P	Q	R
A	5.46**	7.85**	59.22**	0.04	47.45**	38.02**
B	10.89**	2.51	46.06**	2.18	35.24**	26.76**
C	5.04**	8.47**	60.39**	0.00	48.55**	39.06**
D	2.76*	12.52**	67.16**	0.52	54.99**	45.17**
F	12.46**	1.63	42.81**	3.15*	32.29**	24.10**
G	4.73**	8.95**	61.28**	0.00	49.39**	39.85**
J	13.37**	1.23	41.02**	3.75*	30.69**	22.67**
K	38.90**	5.36**	10.72**	25.21**	5.43**	2.21
L		20.07**	77.03**	4.83**	64.55**	54.43**
M			29.80**	8.79**	20.80**	14.09**
N				60.98**	0.93	3.28*
P					49.11**	39.58**
Q						0.72

Table 29

Number of Characters for which Significant Values
were Recorded in Interpopulational Comparisons
(p<0.05)

	B	C	D	F	G	J	K	L	M	N	P	Q	R
A	5	0	4	2a	2c	6	4b	4a	4a	7	3a	5	5
B		3	5	5a	3c	3	5b	6a	3a	5	5a	7	6
C			4	5a	1c	5	4b	5a	5a	5	4a	7	6
D				7a	4c	5	3b	4a	6a	7	3a	6	7
F					3c	5a	5b	5b	3a	6a	3a	5a	5a
G						5c	4c	3c	4c	4c	3c	2c	3c
J							4b	4a	5a	6	6a	5	7
K								3b	3b	7b	6b	6b	7b
L									7b	6a	5b	5a	7a
M										5a	7a	6a	5a
N		a = based on 8 characters									5a	6	3
P		b = based on 7 characters										7a	6a
O		c = based on 6 characters											3

Table 30

Cumulative Chi-square Values for Two Characters:

UM2 Cusp Number and LM2 Fissure Pattern

	B	C	D	F	G	J	K
A	3.82	0.98	3.05	18.42**	0.61	4.24	11.94**
B		1.57	2.29	7.52**	7.22**	0.12	10.75**
C			0.74	12.68**	3.03	2.21	13.65**
D				10.85**	5.86*	3.30	18.24**
F					24.23**	7.89**	24.36**
G		* = 0.1>p>0.05				7.60**	13.10**
J		** = p<0.05					8.86**

Table 30 (continued)

	L	M	N	P	Q	R
A	2.79	4.13	33.96**	4.48	23.85**	28.04**
B	7.62**	2.90	23.17**	1.25	19.52**	15.27**
C	3.05	4.51	31.47**	1.33	24.67**	23.92**
D	3.27	7.65**	33.41**	0.51	29.13**	24.76**
F	21.71**	15.08**	27.29**	7.34**	31.01**	14.49**
G	3.41	5.95*	38.57**	8.07**	25.95**	33.58**
J	8.61**	2.04	20.73**	2.11	17.01**	13.47**
K	19.61**	3.04	10.32**	17.68**	2.97	10.96**
L		10.07**	41.89**	5.89*	32.28**	34.89**
M			17.61**	7.20**	10.41**	13.75**
N				30.49**	3.50	2.66
P					27.69**	20.76**
Q						7.55**

Table 31

Cumulative Chi-square Values for Three Characters:

UM2 Cusp Number, LM2 Fissure Pattern and UI1

Palatal Shovelling

	B	C	D	F	G	J	K
A	2.96	1.00	2.41	12.82**	0.42	3.27	8.68**
B		1.05	1.52	6.77*	5.08	0.08	7.22*
C			0.49	10.**	2.24	1.48	9.**
D				8.93**	4.15	2.20	12.22**
F					16.89**	7.07*	18.49**
G						5.37	9.27**
J							5.94

Table 31 (continued)

	L	M	N	P	Q	R
A	2.21	5.37	26.62**	3.41	16.62**	19.06**
B	5.08	6.47*	21.58**	2.40	15.06**	11.63**
C	2.03	7.40*	26.95**	2.35	18.37**	17.29**
D	2.18	9.57**	28.59**	1.86	21.40**	17.90**
F	16.11**	10.91**	19.96**	4.90	20.69**	9.68**
G	2.49	6.95*	30.12**	5.98	18.24**	22.92**
J	5.74	5.97	20.04**	3.03	13.44**	10.48**
K	13.15**	7.20*	13.70**	13.83**	4.54	9.22**
L		11.10**	33.90**	5.39	23.45**	24.61**
M			11.91**	5.81	7.60*	10.29**
N				22.30**	3.82	3.90
P					18.50**	13.84**
Q						5.10

Table 32

Cumulative Chi-square Values for Four Characters:

UM2 Cusp Number, LM2 Fissure Pattern, UI1 Palatal

Shovelling and LM1 Cusp Number

	B	C	D	F	G	J	K
A	4.57	0.78	2.76	9.62**	1.36	6.57	6.89
B		2.68	5.83	7.47	4.13	0.38	9.30*
C			2.14	7.61	2.40	4.67	7.50
D				7.62	6.17	8.35*	9.40*
F					13.74**	9.48*	14.23**
G						5.27	9.26*
J							10.33**

Table 32 (continued)

	L	M	N	P	Q	R
A	2.61	4.15	21.16**	3.51	15.77**	17.87**
B	8.49*	6.38	16.30**	6.48	11.39**	8.88*
C	2.76	5.57	21.07**	3.00	16.56**	16.02**
D	1.63	8.70*	24.70**	1.39	21.84**	19.53**
F	13.00**	8.32*	16.20**	4.59	18.87**	10.89**
G	4.92	5.69	22.59**	7.54	14.45**	18.11**
J	11.01**	7.54	16.12**	8.98*	10.14**	7.89*
K	10.10**	6.28	12.78**	10.61**	8.37*	12.19**
L		9.85**	28.68**	4.04	23.37**	24.55**
M			9.52**	5.88	8.03*	10.29**
N				19.98**	3.51	3.71
P					19.66**	16.48**
Q						3.83

Table 33

Cumulative Chi-square Values for Five Characters:
UM2 Cusp Number, LM2 Fissure Pattern, UI1 Palatal
Shovelling, LM1 Cusp Number and LM2 Cusp Number

	B	C	D	F	G	J	K
A	4.12	1.16	7.44	7.69	1.33	8.03	10.04*
B		4.12	7.33	6.50	4.67	1.29	9.60*
C			10.02*	6.57	1.98	9.30*	13.80**
D				11.50**	12.43**	7.11	7.55
F					11.20**	10.48*	16.07**
G						8.76	14.08**
J							8.49

Table 33 (continued)

	L	M	N	P	Q	R
A	3.80	8.91	18.36**	3.49	26.11**	32.87**
B	7.19	8.03	13.31**	7.43	18.67**	21.38**
C	6.26	13.65**	20.53**	2.41	31.47**	37.87**
D	2.34	6.97	21.03**	10.36*	20.07**	21.77**
F	12.22**	12.42**	14.48**	4.30	28.84**	27.55**
G	7.12	12.47**	20.87**	6.15	28.17**	36.39**
J	8.94	6.58	13.12**	13.17**	13.00**	15.27**
K	8.80	5.09	11.14**	16.83**	9.83*	16.59**
L		9.09	22.96**	7.66	25.13**	30.41**
M			9.08	14.41**	8.78	14.06**
N				19.97**	9.76*	14.34**
P					34.59**	37.47**
O						4.41

Table 34

Cumulative Chi-square Values for Six Characters:
UM2 Cusp Number, LM2 Fissure Pattern, UI1 Palatal
Shovelling, LM1 Cusp Number, LM2 Cusp Number
and LM1 Fissure Pattern

	B	C	D	F	G	J	K
A	4.39	1.19	8.70	6.56	2.19	6.84	9.59
B		5.44	6.74	5.79	7.57	1.44	8.02
C			12.16*	6.21	1.97	8.49	13.90**
D				11.23*	16.08**	7.56	6.73
F					11.29*	8.74	13.96**
G						9.28	15.83**
J							7.64

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Table 34 (continued)

	L	M	N	P	Q	R
A	9.80	7.98	15.58**	5.66	21.87**	27.56**
B	16.93**	6.75	13.22**	7.03	17.22**	19.65**
C	9.86	12.81**	17.11**	6.07	26.25**	31.57**
D	15.40**	6.79	21.48**	8.69	20.12**	21.74**
F	18.50**	10.49	12.88**	5.47	24.54**	23.58**
G	8.56	13.36**	17.66**	11.11*	23.98**	30.73**
J	15.81**	5.61	11.76*	12.84**	11.36*	13.36**
K	18.83**	4.40	11.77*	14.67**	10.18	15.99**
L		17.50**	23.58**	20.14**	26.15**	30.26**
M			9.11	13.22**	8.46	13.01**
N				20.86**	8.17	11.96*
P					32.48**	35.08**
Q						3.68

Table 35

Cumulative Chi-square Values for Seven Characters:
UM2 Cusp Number, LM2 Fissure Pattern, UI1 Palatal
Shovelling, LM1 Cusp Number, LM2 Cusp Number, LM1
Fissure Pattern and UM1 Cusp of Carabelli

	B	C	D	F	G	J	K
A	4.60	1.23	7.47	8.70	---	7.38	14.48**
B		4.88	6.74	11.57	---	5.63	17.21**
C			10.70	9.29	---	10.05	20.07**
D				12.49*	---	7.84	11.79
F					---	7.83	13.24*
G						---	---
J							8.99

Table 35(continued)

	L	M	N	P	Q	R
A	10.41	6.97	14.62**	8.73	19.35**	23.62**
B	19.66**	6.11	14.88**	13.65*	17.54**	17.71**
C	11.85	10.99	16.75**	10.80	23.99**	27.28**
D	15.04**	6.00	19.29**	11.10	17.74**	18.64**
C	16.01**	13.29*	11.69	4.76	22.12**	23.25**
G	---	---	---	---	---	---
J	13.59*	7.27	10.14	11.72	9.96	12.94*
K	18.13**	11.48	13.19*	13.47*	12.39*	19.93**
L		18.06**	20.41**	17.69**	22.86**	27.92**
M			9.62	16.52**	8.50	11.28
N				19.02**	7.06	11.23
P					29.48**	33.91**
O						3.74

DATA SOURCES:

1. Bang, G. and A. Hasund 1971 Morphologic characteristics of the Alaskan Eskimo dentition. I. Shovel-shape of incisors. Amer. J. Phys. Anthrop. 35:43-7.

2. 1972 Morphologic characteristics of the Alaskan Eskimo dentition. II. Carabelli's cusp. Amer. J. Phys. Anthrop. 37: 35-40.

3. 1973 Morphologic characteristics of the Alaskan Eskimo dentition. III. Number of cusps on the upper permanent molars. Amer. J. Phys. Anthrop. 38:721-5.

4. Dahlberg, A.A. and O. Mikkelsen 1947 The shovel-shaped character in the teeth of the Pima Indians. Amer. J. Phys. Anthrop. 5:234-5.

5. Dahlberg, A.A. 1951 Dentition of the American Indian. In Laughlin, W.S. (ed) Papers on the physical anthropology of the American Indian. Viking Fund, New York pp137-76.

6. Goldstein, M.S. 1948 The dentition of Indian crania from Texas. Amer. J. Phys. Anthrop. 6:63-84.

7. Hellmam, M. 1928 Racial characters in human dentition. Proc. Amer. Philos. Soc. 67:157-74.

8. Hrdlicka, A. 1920 Shovel shaped teeth. Amer. J. Phys. Anthrop. 3:429-65.

9. Kikuchi, 1954 In Suzuki, M. and T. Sakai 1966

Morphological analysis of the shovel-shaped teeth.
Jinrui-Gaku Zasshi 74(752): 202-17.

10. Lasker, G.W. 1945 Observations on the teeth of
Chinese born and reared in China and America
(including data on Peking prisoners collected by
Liang Ssu-Yung). Amer. J. Phys. Anthrop. 3:129-50.

11. Maruyama, 1957 In Suzuki, M. and T. Sakai 1957 The
living Sakhalin Ainu dentition. Anthrop. Rep.
18:303-46.

12. Moorrees, C.F. A. 1957 The Aleut dentition. Harvard
University Press, Cambridge.

13. Nelson, C.T. 1938 The teeth of the Indians of Pecos
Pueblo. Amer. J. Phys. Anthrop. 23:261-93.

14. Oshima, S. 1938 Dental anomalies of the Chinese. J.
Orient. Med. 26:no.6

15. Pedersen, P.O. 1949 The East Greenland Eskimo
dentition. Meddelelser om Gronland, Bd 142, Nr 3.

16. Sakai, T. 1954 In Suzuki, M. and T. Sakai 1966
Morphological analysis of the shovel-shaped teeth.
Jinrui-Gaku Zasshi 74(752): 202-17.

17. Sofaer, J.A., J.D. Niswander, C.J. Maclean and P.L.
Workman 1972b Population studies on southwestern
Indian tribes. V. Tooth morphology as an indicator
of biological distance. Amer. J. Phys. Anthrop.
37:357-66.

18. Suzuki, M. and T. Sakai 1954 On the protostylid of the Japanese. Jinrui-Gaku Zasshi 63:81-4.

19. 1956a On the occlusal surface patterns of cusps of maxillary molars in recent Japanese. Jinrui-Gaku Zasshi 65:54-61.

19. 1956b On the "Dryopithecine pattern" in recent Japanese. Jinrui-Gaku Zasshi 64:87-94.

21. 1957 The living Sakhalin Ainu dentition. Anthrop. Rep. 18:303-46.

22. 1965 In Suzuki, M. and T. Sakai 1966 Morphological analysis of the shovel-shaped teeth. Jinrui-Gaku Zasshi 74(752):207-17.

23. Takehisa, 1957 In Suzuki, M. and T. Sakai 1966 Morphological analysis of the shovel-shaped teeth. Jinrui-Gaku Zasshi 74(752): 207-17.

24. Tsuji, T. 1958 Incidence and inheritance of the Carabelli's cusp in a Japanese population. Jap. J. Hum. Genet. 3:21-31.

25. Turner, C.G.,II, 1967a The dentition of Arctic peoples. Phd Dissertation, University of Wisconsin.

REFERENCES CITED

Ackerman, J.L., A.L. Ackerman, and A.B. Ackerman 1973
Taurodont, pyramidal and fused molar roots
associated with other anomalies in a kindred. Amer.
J. Phys. Anthrop. 38:681-94.

Bandi, H.G. 1969 Eskimo prehistory. Translated by Ann E.
Keep. University of Alaska Press.

Bang, G. and A. Hasund 1972 Morphologic characteristics
of the Alaskan Eskimo Dentition. II. Carabelli's
cusp. Amer. J. Phys. Anthrop. 37:35-40.

Bass, W.M. III 1964 The variation in physical types of
prehistoric plains Indians. Plains Anthrop. Mem 1.
9(24):65-145.

Beiguelman, B. 1962 Incisor anomalies and dental
occlusion among Japanese in Brazil. Hum. Biol.
34:214-7.

Berry, R.J. 1968 The biology of non-metrical vvariation
in mice and men. In Brothwell, D.R.(ed) 1968 The
skeletal biology of earlier human populations.
Pergamon Press, Oxford. pp103-33.

Berry, A.C. and R.J. Berry 1967 Epigenetic variation in
the human cranium. J. Anat. 101:361-79.

Berry, R.J. and C.A.B. Smith 1968 The genetical
characterization of rat populations from skeletal
data. Cited in Berry, A.C. and R.J. Berry 1968

118

Epigenetic variation in the human cranium. J. Anat. 101:361-79.

Bjork, A., A.E. Jensen, and M. Palling 1956 Mandibular growth and third molar impaction. Acta Odont. Scand. 14:231-72.

Bradlaw, R. 1934 An inheritance of dwarfed or absent upper lateral incisors in three generations. Dent. Rec. 54:113-8.

Brekhus, P.J., C.P. Oliver, and G. Montelius 1944 Study of pattern and combination of congenitally missing teeth in man. J. Dent. Res. 23:117-31.

Brothwell, D.R., V.M. Carbonell, and D.H. Goose 1963 Congenital absence of teeth in human populations. In Brothwell, D.R.(ed) Dental anthropology. Pergamon Press, New York. pp179-90.

Brown, K.S., B.L. Hanna, A.A. Dahlberg, and H.H. Strandskov 1958 The distribution of blood group alleles among Indians of Southwest North America. Amer. J. Hum. Genet. 10:175-195.

Campbell, D.K. 1934 Congenitally missing upper lateral incisor teeth. Dent. Cos. 76:459-71.

Campusano, C., H. Figueroa, B. Lazo, J. Pinto-Cisternas and C. Salinas 1972 Some dental traits of Diaquitas Indian skulls. Amer. J. Phys. Anthrop. 36:139-42.

Carbonell, V. 1960 The tubercle of Carabelli in the Kish

dentition, Mesopotamia 3000 B.C. J. Dent. Res. 39:124-8.

1963 Variations in the frequency of shovel-shaped incisors in different populations. In Brothwell, D.R.(ed) Dental anthropology. Pergamon Press, New York. pp211-34.

Cavanha, A.O. 1965 Enamel pearls. Oral Surg. 19:373-82.

Chappel, H.G. 1927 Jaws and teeth of ancient Hawaiians. Mem. Bernice P. Bishop Mus. 9:249-68.

Chung, C.S., J.D. Niswander, D.W. Runck, S.E. Bilben, and M.C.W. Kau 1972 Genetic and epidemiological studies of oral characterisrics in Hawaii's school children: Dental anomalies. Amer. J. Phys. Anthrop. 36:427-33.

Collins, H.B.,Jr, 1951 The origin and the antiquity of the Eskimo. Yearbook of Physical Anthropology for 1951. Published 1953. 7:75-123.

1964 the Arctic and sub-Arctic. In Jennings, J.D. and E. Norbeck (eds) Prehistoric man in the New World. University of Chicago Press, Chicago. pp85-114.

Comas, J. 1960 Manual of physical anthropology (Revised edition). Charles C. Thomas, Springfield, Illinois.

Crispim, J., K.G. Trigueiro, F.R. de Sa e Benevides Filho, and F.M. Salzano 1972 Third molar agenesis in a trihybrid Brazillian population. Amer. J. Phys.

Anthrop. 37:289-92.

Dahlberg, A.A. 1945 The paramolar tubercle (Bolk). Amer. J. Phys. Anthrop. 3:97-103.

1950 The evolutionary significance of the protostylid. Amer. J. Phys. Anthrop. 8:15-25.

1951 Dentition of the American Indian. In Laughlin, W.S.(ed) Papers on the physical anthropology of the American Indians, 1949. Viking Fund, New York. pp137-76.

1962 Genetic aspects of evolution of the human dentition. In Witkop, C.(ed) Genetics and dental health. McGraw-Hill Book Co. Inc., New York.pp113-21.

1963 Analysis of American Indian dentition. In Brothwell, D.R.(ed) Dental anthropology. Pergamon Press, New York. pp149-77.

Dahlberg, A.A. and O. Mikkelsen 1947 The shovel-shaped character in the teeth of the Pima Indians. Amer. J. Phys. Anthrop. 5:234-5.

Davies, P.L. 1968 Relationship of cusp reduction in the permanent first molar to agenesis of teeth. J. Dent. Res. 47:499.

Dietz, V.H. 1944 A common dental morphotrophic factor: the Carabelli cusp. J. Amer. Dent. Assoc. 31:784-9.

Drennan, M.R. 1929 The dentition of a Bushman tribe.

Annals. S. Afric. Mus. 24:61-87.

Dunkel, I.C. 1965 The prevalence and significance of dental anomalies in the Navajo Indian. Unpublished manuscript. Cited in Niswander, J.D. 1967 The oral status of the Xavantes of Simoes Lopes. Amer. J. Hum. Genet. 19:543-53.

Fenstermaker, G.B. 1936 Unusual enamel formation on the teeth of Indians. Penn. Archaeol. 6:75.
1937 Enamel formation on teeth found on historic Iroquois site. Nat. Archaeol. News 1:7.

Fisher, R.A. and F. Yates 1963 Statistical tables for biological, agricultural and medical research. Hafner Publishing Co. Inc., New York.

Garn, S.M., A.B. Lewis, and J.H. Vicinus 1963 Third molar polymorphism and its significance to dental genetics. J. Dent. Res. 42:1344-63.

Garn, S.M., R.S. Kerewsky, and A.B. Lewis 1966 Extent of sex influence on Carabelli's polymorphism. J. Dent. Res. 45:1823.

Genoves T., S. 1967 Some problems in the physical anthropological study of the peopling of America. Curr. Anthrop. 8:297-312.

Giles, E. and H.K. Bleibtreau 1961 Canial evidence in archaeological reconstruction: A trial of multivariate techniques for the Southwest. Amer.

Anthrop. 63:48-61.

Goaz, P.W. and M.C. Miller 1966 A preliminary description of the dental morphology of the Peruvian Indian. J. Dent. Res. 45:106-19.

Goldstein, M.S. 1931 The cusps in the mandibular molar teeth of the Eskimo. Amer. J. Phys. Anthrop. 16:215-35.

1932 Congenital absence and impaction of the third molar in the Eskimo mandible. Amer. J. Phys. Anthrop. 16:381-8.

Greene, D.L. 1967a Genetics, dentition and taxonomy. University Wyoming Publications, Laramie. 33(12-13).

1967b Dentition of Meroitic, X-Group and Christain populations from Wadi Halfa, Sudan. University Utah Press, Anthrop. Papers.

Gregory, W.K. and M. Hellman 1926 The crown pattern of fossil and recent human molar teeth and their meaning. Nat. Hist. 26:300-9.

Gruneberg, H. 1952 Genetical studies on the skeleton of the mouse. IV. Quasi-continuous variations. J. Genet. 51:95-114.

1965 Genes and genotypes affecting the teeth of the mouse. J. Embryol. exp. Morph. 14:137-59.

Hellman, M. 1928 Racial characters in human dentition. Proc. Amer. Philos. Soc. 67:157-74.

Hooton, E.A. 1930 The Indians of Pecos Pueblo. A study of their skeletal remains. New Haven, Mass.

Hrdlicka, A. 1920 Shovel shaped teeth. Amer. J. Phys. Anthrop. 3:429-65.

1921 Further studies on tooth morphology. Amer. J. Phys. Anthrop. 4:141-76.

Hulse, F.S. 1963 The human species. Random House, New York.

Hutton, J.H. 1936 Relation of endocrine disorders to dental disease. J. Amer. Dent. Assoc. 23:226-36.

Jennings, J.D. 1974 Prehistory of North America. McGraw-Hill Book Co. (Second edition), New York.

Jorgensen, K.D. 1955 The Dryopithecus pattern in recent Danes and Dutchmen. J. Dent. Res. 34:195-208.

Kallay, J. 1966 Extra cusp formation in the human dentition. J. Dent. Res. 45:1381-94.

Kato, K. 1937 Contribution to the knowledge concerning the cone shaped supernumerary cusp in the center of the occlusal surface on remolars of Japanese. Nehon Shika Gakukai Zasshi 30:28-49.

Keene, H.J. 1965 The relationship between third molar agenesis and the morphologic variability of the molar teeth. Angle Orthodont. 35:289-98.

1968 The relationship between Carabelli's trait and the size, number and morphology of the maxillary

molars. Arch. Oral Biol. 13:1023-5.

Kellock, W.L. and P.A. Parsons 1970 Variation of minor non-metrical cranial variants in Australian aborigines. Amer. J. Phys. Anthrop. 32:409-22.

Klatsky, M. 1956 The evidence of six anomalies of the teeth and jaws. Hum. Biol. 28:420-8.

Knutson, I. 1975 Dental pathology of human remains from an Archaic site in Southwestern Saskatchewan. M.A. Thesis, University of Manitoba.

Kraus, B.S. 1951 Carabelli's anomaly of the maxillary molar teeth: Observations on Mexicans and Papago Indians and an interpretation of the inheritance. Amer. J. Hum. Genet. 3:348-55.
1959 Occurence of the Carabelli trait in Southwest ethnic groups. Amer. J. Phys. Anthrop. 17:117-23.

Kustalogu, O.A. 1962 Paramolar structures of the upper dentition. J. Dent. Res. 41:75-83.

Lasker, G.W. 1945 Observations on the teeth of Chinese born and reared in China and America (including data on Peking prisoners collected by Liang Ssu-Yung). Amer. J. Phys. Anthrop. 3:129-50.

Lasker, G.W. and M.M.C. Lee 1957 Racial traits in the human teeth. J. Forensic Sci. 2:401-19.

Lau, T.C. 1955 Odontomes of the axial core type. Brit. Dent. J. 99:219-25.

Laughlin, W.S. 1963 Eskimo and Aleuts: Their origins and evolution. Science 142:633-45.

Laughlin, W.S. and K.D. Jorgensen 1956 Isolate variation in Greenlandic Eskimo crania. Acta Genet. Stat. Med. 6:3-12.

Leigh, R.W. 1925 Dental pathology of the Eskimo. Dent. Cos. 67:884-98.

1928 Dental pathology of aboriginal California. University Calif. Publications Amer. Archaeol. Ethnol. 21:1099-114.

1937 Dental morphology and pathology of pre-Spanish Peru. Amer. J. Phys. Anthrop. 22:267-96.

Long, J.K. 1966 A test of multi-discriminant analysis as a means of determining evolutionary changes and intergroup relationships in physical anthropology. Amer. Anthrop. 68:444-64.

Meredith, H.V. and E.H. Hixon 1954 Frequency, size and bilateralism of Carabelli's tubercle. J. Dent. Res. 33:435-40.

Merrill, R.G. 1964 Occlusal anomalous tubercles on premolars of Alaskan Eskimos and Indians. Oral Surg. 17:484-96.

Millar, J.F.V., H. Epp, T.W. Foster, J.S. Wilson, and G. Adams 1972 The southwestern Saskatchewan archaeological project. Napao 3:1-39.

Montagu M.F.A. 1940 The significance of the variability of the upper lateral incisor teeth in man. Hum. Biol. 12:323-58.

Moorrees, C.F.A. 1957 The Aleut dentition. Harvard University Press, Cambridge.

Moorrees, C.F.A. and R.B. Reed 1954 Biometrics of crowding and spacing of the teeth in the mandible. Amer. J. Phys. Anthrop. 12:77-88.

Muller-Beck, H. 1966 Paleohunters in America: Origins and diffusion. Science 152:1191-210.

Nelson, C.T. 1938 The teeth of the Indians of Pecos Pueblo. Amer. J. Phys. Anthrop. 23:261-93.

Neumann, G.K. 1952 Archaeology and race in the American Indian. In Griffin, J.B. (ed) Archaeology of the eastern United States. University Chicago Press, Chicago.

Newman, M.T. 1967 Critique of Genoves ('67). Curr. Anthrop. 8:305.

Niswander, J.D. 1967 The oral status of the Xavantes of Simoes Lopes. Amer. J. Hum. Genet. 19:543:53.

Niswander, J.D., K.S. Brown, B.Y. Iba, and P.L. Workman 1970 Population studies on Southwestern Indian tribes. I. History, culture and genetics of the Papago. Amer. J. Hum. Genet. 22:7-23.

Oehlers, F.A.C., K.W. Lee, and E.C. Lee 1967 Dens

evaginatus (evaginated odontome). Its structure and responses to external stimuli. Dent. Practit. Dent. Rec. 17:239-44.

Oschinsky, L. 1961 A short note on upper lateral incisor tooth crowding among the Eskimo. Anthropologica 3:90-4.

Oschinsky, L. and R. Smithurst 1960 On certain dental characters of the Eskimo of the Eastern Canadian Arctic. Anthropologica 2:105-12.

Pedersen, P.O. 1949 The East Greenland Eskimo dentition. Meddeelelser om Gronland, Bd 142, Nr 3.

Pindborg, J.J. 1970 Pathology of the dental hard tissues. Munksgaard, Copenhagen.

Rao, C.R. 1952 Advanced statistical methods in biometric research. (Reprint, 1970). Hafner Publishing Co., Darien, Conn.

Riesenfeld, A. 1956 Shovel-shaped incisors and a few other dental features among native peoples of the Pacific. Amer. J. Phys. Anthrop. 14:505-21.

Robinson, J.T. and E.F. Allin 1966 On the Y of the Dryopithecus pattern of mandibular molar teeth. Amer. J. Phys. Anthrop. 25:323-4.

Rothhammer, F., E. Lasserre, R. Blanco, E. Covarrubias, and M. Dixon 1968 Microevolution in human Chilean populations: IV. Shovel-shape, mesial palatal

version and other dental traits in Pewenche Indians.
Zeit. Morph. Anthrop. 60:162-9.

Salzano, F.M. 1962 Some genetic aspects of the demography
of the American Indians. Entret. Monaco Sci. Hum.
1:23-39. Reprinted in Yearbook of Physical
Anthropology, 1963. 11:284-300.

Sanghvi, L.D. 1953 Comparison of genetical and
morphological methods for a study of biological
differences. Amer. J. Phys. Anthrop. 11:385-404.

Schultz, A.H. 1932 The tendency to eliminate the upper
lateral incisors. Hum. Biol. 4:34-40.
1934 Inherited reduction in the dentition of man.
Hum. Biol. 6:627-31.

Snyder, R.G. 1960 Hyperodontia in prehistoric southwest
Indians. Southwest. J. Anthrop. 16:492-502.

Snyder, R.G., A.A. Dahlberg, C.C. Snow, and T. Dahlberg
1969 Trait analysis of the dentition of the
Tarahumara Indians and Mestizos of the Sierra Madre
Occidental, Mexico. Amer. J. Phys. Anthrop.
31:65-76.

So, J.K. and W.D. Wade 1975 Preliminary paleodemographic
analysis of the Gray site population, Swift Current,
Saskatchewan. University Manitoba, Anthrop. Papers,
No. 13.

Sofaer, J.A. 1969 The genetics and expression of a dental

morphological variant in the mouse. Arch. Oral Biol.
14:1213-25.

Sofaer, J.A., H.L. Bailit, and C.J. Maclean 1972a
Heredity and morphological variation in early and
late developing teeth of the same morphological
class. Arch. Oral Biol. 17:811-6.

Sofaer, J.A., J.D. Niswander, C.J. Maclean, and P.L.
Workman 1972b Population studies on Southwestern
Indian tribes. V. Tooth morphology as an indicator
of biological distance. Amer. J. Phys. Anthrop.
37:357-66.

Spuhler, J.N. 1954 Some problems in the physical
anthropology of the American Southwest. Amer.
Anthrop. 56:604-25.

Stewart, T.D. 1960 A physical anthropologist's view of
the peopling of the New World. Southwest. J.
Anthrop. 16:259-73.

Suzuki, M. and T. Sakai 1964 Shovel-shaped incisors among
the living Polynesians. Amer. J. Phys. Anthrop.
22:65-71.

1973 Occlusal surface patterns of the lower molars
and the second deciduous mlar among living
Polynesians. Amer. J. Phys. Anthrop. 39:305-16.

Swadesh, M. 1960 On interhemisphere linguistic
connections. In Diamond, S. (ed) Culture in history.

Columbia University Press, New York. pp894-924.

Taylor, R.M.S. 1969 Variation in form of human teeth: I.
An anthropologic and forensic study of maxillary
incisors. J. Dent. Res. 48:5-16.

Tratman, E.K. 1938 Three rooted lower molars in man and
their racial distribution. Brit. Dent. J. 64:264-74.
1950 A comparison of the teeth of people.
Indo-European racial stock with the Mongoloid racial
stock. Dent. Rec. 70:31-53;63-88.

Tsuji, T. 1958 Incidence and inheritance of the
Carabelli's cusp in a Japanese population. Jinrui
Idengaka Zasshi 3:21-31.

Turner, C.G.,II, 1967a The dentition of Arctic peoples.
Phd. dissertation. University of Wisconsin.
1967b Dental genetics and microevolution in
prehistoric and living Koniag Eskimo. J. Dent. Res.
46:911-7.
1969 Microevolutionary interpretations from the
dentition. Amer. J. Phys. Anthrop. 30:421-26.
1971 Three-rooted mandibular first permanent molars
and the question of American Indian origins. Amer.
J. Phys. Anthrop. 34:229-42.

Villa, V.G., C.A. Bunag, and A.B. Ramos Jr. 1959 A
developmental anomaly in the form of an occlusal
tubercle with central canal which serves as the

pathway of infection to the pulp and periapical region. Oral Surg. 12:343-8.

Visser, J.B. 1948 Beitrag zur Kenntnis der menschlichen Zahnurzelformen. Medical dissertation, Zurich. Cited in Gorlin, R.J. and H.M. Goldman (eds) Thoma's oral pathology. Sixth Edition. C.V. Mosby Co., St. Louis.

Watson, A.E. and E.C. Woods 1926 Some irregularities of the enamel margin observed in human molars. Brit. Dent. J. 47:854-8

Weber, E. 1959 The genetical analysis of characters with continuous variability on a Mendelian basis. I. Monohybrid segregation. Genetics 44:1131-9.

Wormington, H.M. 1959 Prehistoric Indians of the Southwest. Denver Mus. Nat. Hist. Pop. Series No. 7.

Wright, H.B. 1942 A frequent variation of the maxillary central incisors, with some observations on dental caries among the Jivaro (Shuara) Indians of Ecuador. Proc. Eighth Amer. Sci. Congr., Washington, 1940 2:237-40.

Wu, K.L. 1955 Survey on mid-occlusal tubercles in bicuspids. China Stomatol. 3:294.

Zoubov, A.A. 1960 The cusp reduction order and the modification of the crown pattern in permanent lower molars of man transformed from the 5 cusp type into the 3 cusp type. In Yearbook of Physical

Anthropology 12:116-24.

APPENDIX

DENTAL TRAITS CONSIDERED IN THE GRAY SITE

<u>Maxilla</u>

Incisors

    Shovel Shape

    Mesial Palatal Version

    Mesiodens

    Missing and Anomalous I2s

Premolars

    Crowding

    Root number in PM3

Molars

    Cusp of Carabelli

    Parastyle

    Cusp Number

    Root Number

    Coalesced and Fused Roots

    Enamel Extension and Odontome Production

    Agenesis and Diminutive Third Molars

Mandible

Incisors

Shovel shape

Agenesis

Premolars

Crowding

Leong's premolar

Molars

Protostylid

Cusp Number

Fissure Pattern

Root Number

Coalesced and Fused Roots

Enamel Extension and Odontome Production

Agenesis and Diminutive Third Molars

Hyperodontia