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Effects of Koniag artificial cranial deformation on Eskimo population comparisons

Jamelon Emmick
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Effects of Koniag Artificial Cranial Deformation
on Eskimo Population Comparisons

by
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B.S. University of Idaho, Moscow, 1996

Presented in partial fulfillment of the requirements
for the degree of
Master of Arts

The University of Montana

May 2001

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Chairperson

[Signature]
Dean, Graduate School

5/11/01
Date
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Anthropology

Effects of Koniag Artificial Cranial Deformation on Eskimo Population Comparisons

Director: Randall R. Skelton

Physical anthropologists have relied heavily upon cranial measurements to decipher the relationships between Alaska's Eskimo and Aleut populations. For the late prehistoric Koniag of Kodiak, results of analyses based on craniometric data have contradicted results based on other types of data. This has led to disagreement over how the Koniag were related to neighboring groups and even whether they were descended from the previous inhabitants of Kodiak. The Koniag are unique among Eskimo populations for the presence of artificial cranial deformation. This study looks at the association between degree of deformation observed in a specimen and its deviation from average group morphology based on cranial measurements. Two subsets of measurements produced statistically significant negative correlations, indicating that cranial measurements may be affected by deformation, that visual determination of degree of deformation may be possible, and that a high percentage of deformed specimens in a sample may alter average group morphology.
ACKNOWLEDGEMENTS

I would like to acknowledge the advice and support offered by my thesis advisor, Dr. Randall Skelton, and the members of my thesis committee, Dr. Thomas Foor and Dr. Jeffrey Gritzner. I also thank Dr. Richard Sherwood for allowing me access to the collection of crania at the University of Wisconsin—Madison.
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CHAPTER 1
INTRODUCTION

The use of infant cradleboards by the prehistoric people of Kodiak has had ramifications for Alaska Native population studies. The Koniag are the only Eskimo group known to exhibit artificial cranial deformation, a fact that has complicated the study of biological relationships between the Koniag, their predecessors, and neighboring Eskimo and Aleut groups.

The interpretation of cultural and biological relationships between Alaska’s extant populations is done through comparison of culture, language, genes, and morphology (Hrdlička 1944a; Szathmary 1979; Townsend 1979; Dumond 1987). For extinct populations, however, data gathered from archaeological and physical anthropological research are the principal means of comparison. Studies designed to decipher the relationships between Alaska’s Eskimo and Aleut populations have been based on all types of data, but admixture during historic times has introduced error that affects analyses of data gathered from modern people (Heathcote 1986: 33; Scott 1992: 157). In order to avoid this complication, researchers have focused on late prehistoric cultures, presumed to be ancestral to modern populations in the different Eskimo and Aleut regions, and attempted to trace their ancestries using archaeological and physical anthropological evidence (Clark 1984; Heathcote 1986, 1994; Turner 1988a).

Physical anthropologists have relied heavily upon craniometric data to interpret the relationships among these prehistoric groups. In the case of the late prehistoric Koniag population of Kodiak, results of analyses based on craniometric data have often
contradicted results based on other types of data, perhaps because deformation has altered natural cranial morphology. This has led to disagreement over how the Koniag were related to neighboring Eskimo and Aleut populations and even whether they were descended from the Kachemak, the previous inhabitants of Kodiak.

Population Comparisons

To reconstruct the origins of Alaska's historic and prehistoric native populations, some researchers have used non-biological data, such as linguistic, cultural, and archaeological evidence. Physical anthropologists and others have made comparisons based on biological characteristics, such as gene frequencies, metric and nonmetric cranial traits, dental morphology, and postcranial remains. In population comparisons, the term *affinity* refers to the overall similarity of groups or organisms based on such observable characteristics without any implication as to their relationship by ancestry (Sokal and Sneath 1963: 3). Biological distance analysis involves estimation of the relative degrees of genetic relatedness between groups based on these affinities. Distance values are generated from pairwise comparisons of samples from three or more populations, and the resulting relationships are often depicted in the form of dendrograms. In these branching diagrams, groups with more characteristics in common are grouped together while those with fewer common characteristics are separated.

Although dendrograms reflect only affinities between groups (Sokal and Sneath 1963: 27), in biological distance analyses, they are interpreted as depicting genetic relationships as well. For this reason, traits used in a biological distance analysis should
be strongly heritable. Environment influences expression of these variables to some degree, but it is assumed that genes are the stronger factor in trait development. Results of biological distance analyses can be used to infer genetic relationships because observable characteristics reflect primarily the genetic make-up of a population and not its environmental history (Scott 1992: 151).

When comparisons using different types of data are made among samples from the same set of populations, distance values based on one set of biological variables should parallel distance values based on another set of variables (Scott 1992). This is based on the hypothesis of nonspecificity, which states that “there are no distinct large classes of genes affecting exclusively one class of characters…or affecting special regions of the organism…” (Sokal and Sneath 1963: 85). In other words, similar classifications should result from different kinds of data. Correspondence between hierarchical arrangements of groups resulting from distance analyses based on different types of data is referred to as taxonomic congruence (Zegura 1975: 271). The degree to which different data sets yield congruent results provides some indication of the reliability of using any one of the data sets alone in biological distance studies (Droessler 1981: 8). The hypothesis of nonspecificity can be extended to non-biological characteristics as well. According to Heathcote (1994: 103-104), studies show that for Arctic populations, culture, language, and biology have co-evolved so that there should be concordance between population histories based on the three types of data.
Koniag Relationships

The Eskimo population system extends across Siberia, Alaska, Canada and Greenland. Anthropologists have long used the term *Eskimo* to collectively refer to these arctic peoples and continue to do so today (Hrdlička 1944a; Clark 1998). They divide Alaskan Eskimos into the western Yuit, or speakers of the Yupik language, and eastern Inuit, or speakers of the Inupik language (Zegura 1978: 8). Researchers consider the Aleuts, who inhabit the Aleutian Islands of southwestern Alaska, to be more distantly related to these two groups (Dumond 1987: 35).

This paper is concerned with the inhabitants of the Kodiak Archipelago, which lies off the coast of southcentral Alaska. This study includes Chirikof Island as part of the Kodiak grouping, although it is considered separately in some analyses (Zegura 1971, 1975, 1978). The prehistoric inhabitants of the Kodiak Archipelago are generally considered to be Yuit Eskimos, but there is some disagreement over the relationships of the late prehistoric Koniag population. The sequence of known cultural traditions on Kodiak spans the past 7,000 years, although earlier occupation is likely (Clark 1998: 172). The Kachemak tradition developed out of an earlier tradition approximately 1800 BC (Clark 1998: 178). The subsequent Koniag phase began approximately AD 1100 (Clark 1984: 146). Whether or not the Koniag phase is an outgrowth of the Kachemak Tradition is a matter of debate.

The controversy surrounding the issue of Kachemak-Koniag continuity and external relationships of Kodiak’s inhabitants began with Hrdlička’s assessment of human skeletal and cultural remains from the Uyak site on Kodiak Island during the
1930s and 1940s (Hrdlička 1944a, 1944b). The collection of more than 500 skeletons he recovered was housed at the Smithsonian Institution until its repatriation, and most analyses of human remains from Kodiak have been performed on this collection or on data compiled by Hrdlička (Zegura 1971, 1975, 1978; Ossenberg 1976, 1977; Szathmary and Ossenberg 1978; Uttermohle 1984, 1988; Heathcote 1986, 1994; Turner 1988a; Scott 1991, 1994). Three different types of skeletal data have commonly been used to interpret the biological relationships of Kodiak Islanders: craniometric data, nonmetric cranial traits, and dental morphology (Scott 1992). Classifications based on linguistics (Ossenberg 1977; Zegura 1978; Heathcote 1986, 1994; Dumond 1987), and genetics (Szathmary and Ossenberg 1978; Scott 1991, 1992) have also been compared to those based on skeletal data.

**Craniometric Analysis**

Craniometric data are commonly used in biological distance analyses because they are considered by anthropologists to be strongly heritable and, therefore, reliable indicators of genetic ties between groups. They have even been used to refute findings based on other types of data (Droessler 1981; Scott 1992); however, there is evidence that environment affects cranial dimensions. Boas compared physical characteristics of American-born children with those of their immigrant parents and, in his 1911 *Report on Changes of the Bodily Form of Descendants of Immigrants*, reported that the children differed significantly from their parents in body size and form (Molnar 1998: 17). He found head shape to be one of the traits most changed in the new environment. Even if quantitative traits are only moderately heritable, "it is still possible to reach valid
conclusions concerning past population structure” (Buikstra et al. 1990: 6).

Another factor complicating craniometric comparisons is brachycephalization, or a trend toward increasing round-headedness, which has been observed in many parts of the world over the past 2,000 years (Weidenreich 1945: 48; Beals et al. 1983: 425). This phenomenon has also been observed in late prehistoric Eskimo and Aleut populations (Utermohle 1984: 123, 131; Heathcote 1986: 97; Scott 1992: 161). According to Scott (1992: 161), one major difference between the Kachemak and Koniag is the hyperbrachycrany shown by the Koniag.

Despite the influences of environment and brachycephalization, the cranial vault is an important interpopulation indicator for the Eskimos, who show substantial morphological differentiation (Zegura 1978: 14). Craniometric data generally do not provide evidence that the Koniag are descended from the Kachemak. They do suggest that the Koniag are most closely related to Aleuts while the Kachemak share their closest ties with the Yuit Eskimos.

Hrdlička (1944a) compared craniometric measurements of Koniag and Kachemak to each other and to other groups. For Kachemak and Koniag, he acknowledged some resemblance in what he calls “secondary features,” but he believed that skulls of the two groups differ in “many important respects” (Hrdlička 1944a: 411). He said the two skull types belong to substantially different anthropological strains and concluded that the Koniag were relative newcomers to the island who replaced the Kachemak with little admixture (Hrdlička 1944a: 394). While Hrdlička (1944a) described the Kachemak as having some Mongoloid, Eskimoid, and Indian affinities, although no physically close
relations, he acknowledged that the Koniag show some similarity to neighboring groups. He commented that based on measurements of the face alone, the Koniag and Aleuts are very similar. Although he believed the differences between vault measurements of the two groups make close relatedness impossible, he concluded that the two groups are more closely related to one another than either are to the Eskimos (Hrdlička 1944a: 380).

In a test of congruence between linguistic and craniometric data, Zegura (1978) compared twelve Eskimo populations. His dendrograms show Chirikof Islanders, Koniag, and Aleuts as outliers. The Koniag are most similar to Aleuts with only secondary ties to Chirikof Islanders. Zegura’s analysis involved attributing languages to skeletal samples, so he did not include samples of earlier prehistoric populations such as the Kachemak and, therefore, could not comment on the issue of continuity.

Utermohle (1984) calculated biological distances between earlier and later Eskimo samples to find which groups are most likely to be related by descent and compared these to the expected results based on known linguistic relationships. He hypothesized that the distance between an earlier group and another believed to be descended from it should be smaller than the distance between that group and others not believed to be descended from it. For instance, he believed that biological distances between the earlier and later Kodiak groups would be smaller than distances between the early Kodiak group and other groups. The comparison of early and late samples from one Kodiak Island site yielded the results that would be expected for closely related samples. The male samples show the closest affinity of Kachemak to be with Yuit samples, then almost equally to Koniag and the Inuit, and finally to the Aleutian sample from Kagamil. Females follow the same
sequence except that the separation between Koniag and the Inuit is greater. Utermohle (1984: 317) concluded that there is evidence for the divergence of the Koniag series from the morphological pattern of other Yuit samples. He also concluded that the Kachemak sample appears to be a better ancestor of the Yuit than of the Inuit or the Koniag (Utermohle 1984: 332). The geographically close Koniag were shown to be more biologically distant from the early Aleuts than the more geographically distant Yuit series, suggesting that biological influences from outside the Eskimo population system might be operating on the recent population of Kodiak (Utermohle 1984: 317).

Heathcote (1986) compared the results of distance analyses based on different subsets of variables in order to identify those that reflect population relationships consistent with linguistic and cultural data. Although most of the analyses show Yuit crania are more similar to those of Inuit groups than to those of the Koniag, he developed one subset that minimizes these intra-group distances relative to inter-group distances, producing results that most accurately reflect expected population relationships. This subset is the one that eliminates those variables that could be affected by environmental factors such as cranial deformation. This placed the Yuit closer to the Koniag than to any of the Inuit samples; however, it also showed that Koniag are slightly closer to the Aleut group than to one of the two Yuit groups in the analysis. Heathcote (1986: 174) interprets this as a correct reflection of population historical relationships.

Nonmetric Cranial Analysis

Analyses of nonmetric data, which are recorded as the presence or absence of discrete morphological traits, have not been as widely used, but animal studies indicate
they may be useful for human population studies (Ossenberg 1976: 701-702). They indicate that the Kachemak and Koniag were closely related and that, externally, both were most closely related to Yuit Eskimos (Scott 1992).

Ossenberg (1977) compared biological distances based on nonmetric cranial traits, cranial measurements, and linguistic-geographic attributes in four Yuit Eskimo populations and one Aleut population. She found a significant correlation between nonmetric and metric distances, but concluded that the nonmetric distances show stronger congruence than metric distances with a hierarchy based on linguistic and geographical affinities (Ossenberg 1977: 96). In a study of the taxonomic congruence between distances based on measurements, distances based on discrete traits, and linguistic relationships in 12 Eskimo populations, Zegura (1975) reached the opposite conclusion. He found that metric data are more concordant with linguistic relationships than are attribute data (Zegura 1975: 283).

In her investigation of the affinities of the native people of northwestern North America, Ossenberg (1992, 1994) derived dendrograms and pairwise distance values for groups, including early, middle, and late samples from Kodiak Island. An analysis that included only Aleut and Eskimo samples produced a dendrogram in which the three Kodiak samples are closely linked within the Yuit cluster (Ossenberg 1994: 91). The closest external similarity of the Kodiak grouping is with southern Alaska Yuit samples. When Ossenberg (1994: 95) included Indian and Asian samples in her analysis, early and late Kodiak samples continued to cluster closely together and to be most similar to Yuit Eskimos. She also found that pairwise distances between selected samples show
temporal differences that could not be depicted in the dendrograms. In general, Kodiak samples become less similar to Aleuts and Na-Dene Indians and more similar to both Yuit and Inuit Eskimos over time (Ossenberg 1994: 95).

**Dental Analysis**

According to Turner (1983: 147), dental crown and root traits have a high genetic component and are evolutionarily stable, making them useful for deciphering past human relationships. While researchers do not agree on the external relationships based on dental data, they do state there is no difference between the Kachemak and Koniag, supporting arguments for continuity.

Turner (1988a, 1988b) compared dental trait frequencies of Eskimo and Indian groups. In most of his biological distance analyses, the combined Kodiak samples group with Northwest Coast Na-Dene Indians. Even when the Kachemak and Koniag samples are included separately in the analyses, they cluster with Northwest Coast Indians, showing no fundamental difference between Kachemak and Koniag (Turner 1988a: 30). Turner found little evidence that the Kodiak samples are closely related to Eskimos and proposes that at least until late prehistory, Kodiak was peopled by Na-Dene Indians.

Scott (1991) examined two Kachemak (earlier and later) and one Koniag sample for crown and root traits and found, in a chi-square analysis, that only two of 27 traits showed a significant difference in frequency between the three samples. In general, he found no consistent pattern of dental variation in the samples that would suggest the two Kachemak samples were more similar to one another than either was to Koniag (Scott 1991: 33, 1992: 156). Using crown trait frequencies, Scott (1994) calculated biological
distances between two Kachemak samples, one Koniag sample, and several samples from other Native American groups. He found the earlier Kachemak sample to be most similar to Koniag, and also found this sample to be closer to Northwest Coast Indians than to Eskimos. He found the late Kachemak sample, however, to be most similar to Eskimos, and both late Kachemak and Koniag to be more similar to Eskimos than to Northwest Coast Indians (Scott 1994: 72). Scott concluded that biological continuity on Kodiak can be interpreted in a broad sense if Kachemak and Koniag are understood to be derived from Eskimo populations that migrated to Kodiak at different times.

Postcranial Analysis

While postcranial evidence has been used very little in Eskimo population studies, metric data do support Kachemak-Koniag continuity (Scott 1991: 43). Hrdlička (1944a) compared measurements of Kachemak and Koniag long bones. “Here in anthropological experience is a unique and probably very significant example of two groups with great cranial, but practically no skeletal differences—none, at least so far as the main bones of the extremities are concerned” (Hrdlička 1944a: 425). While he acknowledged the striking similarities in postcrania, he believed that craniometric evidence made a stronger argument against continuity. Hrdlička found few similarities when he compared Kachemak and Koniag long bones to those of the Yuit Eskimos. He did find Koniag to be more similar postcranially to Aleuts than to Eskimos (Hrdlička 1944a: 393).

Archaeological Analysis

According to Clark (1998), all archaeological traditions on Kodiak appear to be outgrowths of previous traditions, except for the Koniag. At the end of the Kachemak
tradition and during the Koniag phase, there is evidence for major changes in material, social, and possibly political culture. Many of the changes were compatible with the earlier lifeways and technology, but some changes would have had an impact on social institutions and regional interactions (Clark 1998: 179-180). Clark says the changes in the archaeological record indicate strong outside influences, which are most likely the result of contact with mainland Eskimos and Pacific coast cultures as well as small-scale population movements consisting of individuals and nuclear families. He does not believe the evidence supports displacement of the Kachemak by an outside group migrating to Kodiak (Clark 1998: 180). According to Clark (1984: 148):

"The Koniag phase...is neither an in situ development nor a direct result of a population and cultural replacement; rather it is an amalgamation of old and new elements and replacement or loss of numerous former traits during the course of several centuries, accompanied by population mobility."

Linguistic Analysis

Unlike the biological and archaeological evidence reviewed here, linguistic data were only gathered only from the historic inhabitants of Kodiak Island, so researchers did not directly address the issue of Kachemak-Koniag continuity. Linguistic comparisons have played a large role in analysis of Kodiak Islanders' relationships with outside groups, so one researcher's findings are included here. According to linguistic evidence, the people of Kodiak speak a language classified as Pacific Yupik, a variant of the language spoken by the western Yuit Eskimos, found in Southern Alaska (Dumond 1987: 33). Although the Aleuts speak a language so different that it is classified separately from Eskimos, the two are believed to be derived from a common language that existed between 3,000 and 6,000 years ago (Dumond 1987: 35).
Dumond (1987) compared language to the biology and culture of Eskimo and Aleut groups and then tried to reconcile the different types of evidence. He found that Eskimos and Aleuts are generally more similar linguistically than biologically and that their languages are more similar to one another than to surrounding languages, such as that of the Northwest Coast Indians (Dumond 1987: 43-45). Dumond attributes this to either long-term, diverse patterns of gene flow between non-Eskimo-Aleut areas and the different areas of Eskimo-Aleut speech, or the more recent implantation of Eskimo-Aleut speech in portions of those areas. Likewise, linguistic relationships do not reflect biological similarities between Kodiak Islanders and the Northwest Coast Indians, probably as the result of recent linguistic expansion. Biological evidence also suggests deeper ties between Aleuts and Kodiak Islanders than does linguistic evidence. Dumond (1987) found little concordance between biology and language, but he believes this is to be expected because of the nature of the two types of evidence.

Summary of Comparisons

Researchers who have assessed nonmetric cranial, dental, and postcranial traits agree there is no significant difference between the Kachemak and Koniag, suggesting biological continuity between the two; however, most craniometric analyses do not reach the same conclusion. Most researchers are confident of the close relationship of the Kachemak to Yuit Eskimos, but they are less certain of the affinities of the Koniag, some suggesting close relationships to the Aleuts and even the Northwest Coast Indians.

While biological evidence, with the exception of cranial measurements, tends to agree on the relationship between Kachemak and Koniag, and to a degree their
relationships to neighboring groups, the linguistic and archaeological evidence tend to differ. To explain conflicting results based different types of data, Turner (1988b: 111) pointed out that evolutionary rates differ between culture, language, and biology. Culture change is most rapid while biological adaptation is slowest. Using similar reasoning, Scott (1994: 73) created a model that explains the overall biological similarity between Kachemak and Koniag despite archaeological and linguistic dissimilarity. He hypothesized that the two groups represent different migrations of Eskimos from the mainland. The time span between migrations was long enough for linguistic and cultural divergence but not long enough for significant changes in biology. Dumond (1987: 32) also stated that although the patterns of relationship produced by physical anthropology, linguistics and archaeology cannot be expected to neatly coincide, they should be reconcilable.

**Statement of the Problem**

“The distinctive craniometric features of the Koniag may reflect admixture with neighboring non-Eskimo populations, but cranial deformation, present in the Koniag but essentially absent in the Pre-Koniag, may also contribute to the different opinions on the taxonomic placement of the prehistoric Koniag among northern populations” (Scott 1992: 150).

In the passage above, Scott formulates two hypotheses for the difference between Koniag and other populations. In support of his first hypothesis, there is both skeletal evidence, as discussed above, and archaeological evidence for admixture with other populations. Technological change throughout western Alaska during late prehistory can be interpreted as the result of increased contact between groups (Clark 1998: 180). Clark believes that
on Kodiak Island, the shift in material technology between the Kachemak and Koniag may be the result of contact with mainland Eskimos and Northwest Coast Indians as well as small-scale migration of families. Therefore, the Koniag samples used in population comparisons may have included hybrids and individuals from other populations (Scott 1992: 162). A sample should include individuals from a specific breeding population, since the presence of individuals from another population could change which biological characteristics are attributed to that group.

Scott’s second hypothesis refers to artificial cranial deformation observed in Koniag crania. The Koniag are unique among Alaska’s Eskimo populations for the presence of artificial cranial deformation, likely the unintentional result of cradleboarding infants (Hrdlička 1944a: 357; Clark 1966: 169). According to Hrdlička (1941: 2), the Koniag laid their infants on cradleboards, but did not bandage their heads, and this caused a “slight to moderate occipital compression that raised the parietal part of the vault, leaving the coronal region flat or even with a slight postcoronal depression.” Most researchers have classified the type of deformation seen in Koniag crania as slight to moderate lambdoidal deformation (Clark 1966: 169; Zegura 1971: 43; Scott 1991: 42, 1992: 161), which is defined as flattening of the rear of the skull centered at lambda (Buikstra and Ubelaker 1994: 160). Although all researchers who have examined Koniag samples have noted the presence of deformation, there is disagreement over what percentage of the crania are deformed. Estimates for the Smithsonian sample range from 15 percent (Hrdlička 1944b: 35-42) to 93 percent (Heathcote 1986: 97), and Scott (1991: 42) cautiously estimated the number of deformed specimens in that sample to be 46.
percent. Deformation similar to that in the Koniag, but more subtle, has been noted for late prehistoric Aleut crania (Heathcote 1986: 95).

In population comparisons based on craniometric data, it is assumed that differences in cranial morphology reflect inherited differences between groups. Artificial cranial deformation is a potential source of noninherited variation in cranial morphology (Droessler 1981: 7). Some researchers believe its presence in cranial samples affects the outcome of biological comparisons based on metric data (Ossenberg 1977: 96), and several researchers have even hypothesized that it may be to blame for the distinctive placement of Koniag crania among other Eskimos (Zegura 1978: 30; Heathcote 1986: 97-99; Scott 1992: 161). Others believe the effects of deformation are minimal and can therefore be ignored, particularly when flattening is slight to moderate, as it is in the Koniag (Hrdlička 1944a: 366-367).

The more flattening a cranium exhibits, the more it will be altered from its natural state, and the more it will deviate metrically from the group average, assuming most of the crania are not altered more than slightly from their natural state (Droessler 1981: 113). In her study of prehistoric Illinois crania, Droessler (1981) looked for correlations between degree of deformation and deviation from the average group morphology. She divided craniometric measurements into three subsets representing the vault, face, and mandible, then calculated the generalized distance from the group average for each cranium based on these subsets. Next, she compared the distance values to the deformation scores visually determined for each cranium. Her analyses showed that for some variable subsets there is a statistically significant correlation between distance.
values and degree of deformation.

Deformation alters vault morphology more than it does that of the face, especially in samples that exhibit flattening only at the posterior of the cranium. Droessler (1981; 116) concluded that the cranial vault is more susceptible than the face to the effects of deformation. Similarly, Heathcote (1986: 99) found that slight occipital flattening has an effect on dimensions “covering” the region of flattening, but that most other cranial measurements are not seriously affected by deformation.

Hypotheses

While there are several factors that might introduce error into population comparisons based on craniometric measurements, this study focuses on the one factor that is unique to the Koniag and may, therefore, be the cause of their peripheral placement. This study will address the association between artificial cranial deformation and craniometric measurements and the effect this may have had on population comparisons. The purpose of this study is to demonstrate that comparisons based on craniometric data are unreliable unless measures are taken to eliminate the bias of cultural modification.

The first hypothesis is: There is a statistically significant correlation between the degree of deformation of a specimen and its deviation from the average group morphology based on cranial measurements. The second hypothesis is: Deformation is more strongly associated with deviation in measurements of the cranial vault than with deviation in measurements of the face.
CHAPTER 2

MATERIALS AND METHODS

The Sample

The 17 crania included in this sample were recovered from three archaeological sites on three different Islands on the Kodiak Archipelago (Clark 1966: 168-169; Workman 1966: 185; University of Wisconsin 1996), which are shown in Figure 1. They represent a time span of no more than 400 years (University of Wisconsin 1996) and are separated by a geographical distance of approximately 115 miles (or 185 kilometers). They were investigated between 1960 and 1963 as part of the University of Wisconsin Aleut-Konyag Project (Clark 1966: 155; Workman 1966: 185). Site names, components from which the crania originated, and approximate dates are listed in Table 1.

Five crania come from the site of Kiavak 418, located on the southern shore of Kiavak Bay on the southeast side of Kodiak Island. This historic village site of the late Koniag phase dates to between 200 and 400 years ago (University of Wisconsin 1996).

Eleven miles across Sitkalidak Strait from Kiavak, the site of Rolling Bay is located on the southwestern corner of Rolling Bay on southwestern Sitkalidak Island. Three of the crania in the sample are from this historic Eskimo village site, which is attributed to the Koniag phase and dates to AD 1500 (University of Wisconsin 1996). Rolling Bay and Kiavak are contemporaneous; both were occupied into the first half of the Nineteenth Century. Both were also permanent winter villages (Clark 1966: 159).

One cranium was recovered from a site on the northwestern shore of the Southwest Anchorage on Chirikof Island and is identified as belonging to the Late
Prehistoric Koniag phase (University of Wisconsin 1996). The remaining eight crania probably date to the 19th century and were collected from beach blowouts that were the result of erosional destruction of cemeteries of the Russian historic period on Chirikof Island (Workman 1966: 185).

Although restrictions should be placed on the temporal and spatial composition of

FIGURE 1. Locations of Sites on the Kodiak Archipelago.
a sample in order to approximate a biological population, in the absence of an adequate number of individuals at a single site, a number of sites in close proximity may be pooled. Utermohle (1984: 50) used this technique to create four of the groupings in his analysis.

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<th>Site</th>
<th>Component</th>
<th>Approximate date</th>
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<tr>
<td>Kiavak</td>
<td>Late Koniag</td>
<td>AD 1600-1800</td>
</tr>
<tr>
<td>Rolling Bay</td>
<td>Koniag</td>
<td>AD 1500-1800</td>
</tr>
<tr>
<td>Chirikof</td>
<td>Late Koniag</td>
<td>AD 1800-1900</td>
</tr>
</tbody>
</table>

**TABLE 1**
The Skeletal Sample

**Sex and Age Determination**

Metric data from male and female crania were treated separately in the assessment to exclude within-group variation contributed by sexual dimorphism. Sex was determined on the basis of sexually dimorphic traits of the skull and mandible because associated postcranial remains were unavailable in most cases. The following features were assessed: prominence of the glabella and supraorbital torus, size of mastoid processes, rugosity of the nuchal crest, thickness of the supraorbital margin, and chin shape when the mandible was associated (Buikstra and Ubelaker 1994: 20).

Only adult crania were used in the analysis. Determination of age was based on cranial suture closure and dental eruption. Fusion of the basilar suture (White 2000: 81) and eruption of the third molars (Ubelaker 1978: 47) occur at approximately age 18, so crania were classified as adult if they were judged to be at least 18 years of age based on these lines of evidence.
Degree of Deformation

This study uses Droessler’s (1981) method for evaluating the degree of cranial deformation and for finding the correlation between deformation and craniometric measurements in cranial samples. While one of the goals of her study was to examine the effects of deformation on cranial morphology of several skeletal series from west-central Illinois, her methods for doing so can be applied to other samples in which some of the crania have been artificially flattened. Droessler’s method for coding information concerning deformation is recommended in *Standards for Data Collection from Human Skeletal Remains* (Buikstra and Ubelaker 1994) because it can be widely applied.

Individual crania in a sample are grouped based on the type of deformation exhibited, and each region of the skull is considered separately. For example, crania with evidence of flattening at the posterior of the skull, such as lambdoidal or occipital deformation, are grouped together and are further subdivided according to their relative degree of deformation, which is determined visually. This Kodiak sample exhibits only lambdoidal deformation, which is characterized by posterior flattening of the crania centered at lambda (Buikstra and Ubelaker 1994: 160). These specimens are scored: 0=no flattening, 1=slight flattening, 2=medium flattening, and 3=marked flattening as depicted in Figure 2.

Using Droessler’s method, the deformation score must then be compared with measurements for each cranium to determine whether there is a correlation between degree of deformation and the deviation from the average group morphology.
FIGURE 2. Range of Lambdoidal Flattening in the Koniag Sample. (A) No flattening, scored 0; 63CF Burial 1. (B) Slight lambdoidal flattening, scored 1, 62CF AC37.
Measurement Techniques

The original list of variables included 31 cranial measurements. Table 2 lists the measurements, abbreviations, and measuring points, and Table 3 defines those measuring points. All measurements were taken by the author using standard anthropometric instruments: sliding and spreading calipers. All measurements were rounded to the nearest millimeter and bilateral measurements were taken on the left side. When the left side was incomplete or was not measurable, the measurements were taken on the right side. In general, measurements were not estimated when a landmark was missing or when the skull showed evidence of postmortem distortion, although in a few cases, measurements were estimated when the resulting error would be minimal. Data were recorded by hand on separate forms for each specimen.

**TABLE 2**

*List of Cranial Measurements*

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Abbrev.</th>
<th>Measuring Points</th>
<th>Source of Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vault</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum cranial length</td>
<td>L</td>
<td>g-op</td>
<td>Buikstra and Ubelaker 1994 (74)</td>
</tr>
<tr>
<td>Maximum cranial breadth</td>
<td>B</td>
<td>eu-eu</td>
<td>Buikstra and Ubelaker 1994 (74)</td>
</tr>
<tr>
<td>Basion-bregma height</td>
<td>H</td>
<td>ba-b</td>
<td>Buikstra and Ubelaker 1994 (74)</td>
</tr>
<tr>
<td>Cranial base length</td>
<td>LB</td>
<td>ba-n</td>
<td>Buikstra and Ubelaker 1994 (74)</td>
</tr>
<tr>
<td>Bioauricular breadth</td>
<td>BAB</td>
<td>au-au</td>
<td>Buikstra and Ubelaker 1994 (75)</td>
</tr>
<tr>
<td>Biasterionic breadth</td>
<td>ASB</td>
<td>ast-ast</td>
<td>Droessler 1981 (68)</td>
</tr>
<tr>
<td>Minimum frontal breadth</td>
<td>MF</td>
<td>ft-ft</td>
<td>Buikstra and Ubelaker 1994 (75)</td>
</tr>
<tr>
<td>Frontal chord</td>
<td>FC</td>
<td>n-b</td>
<td>Buikstra and Ubelaker 1994 (76)</td>
</tr>
<tr>
<td>Parietal chord</td>
<td>PAC</td>
<td>b-l</td>
<td>Buikstra and Ubelaker 1994 (76)</td>
</tr>
<tr>
<td>Occipital chord</td>
<td>OCC</td>
<td>l-o</td>
<td>Buikstra and Ubelaker 1994 (76)</td>
</tr>
<tr>
<td>Mastoid length</td>
<td>MDL</td>
<td>projection of mastoid ⊥ to Frankfort plane</td>
<td>Buikstra and Ubelaker 1994 (77)</td>
</tr>
<tr>
<td><strong>Face</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bizygomatic diameter</td>
<td>TFB</td>
<td>zy-zy</td>
<td>Buikstra and Ubelaker 1994 (74)</td>
</tr>
<tr>
<td>Basion-prosthion length</td>
<td>FL</td>
<td>ba-pr</td>
<td>Buikstra and Ubelaker 1994 (74)</td>
</tr>
<tr>
<td>Upper facial height</td>
<td>UFH</td>
<td>n-pr</td>
<td>Buikstra and Ubelaker 1994 (75)</td>
</tr>
<tr>
<td>Upper facial breadth</td>
<td>UFB</td>
<td>fmt-fmt</td>
<td>Buikstra and Ubelaker 1994 (75)</td>
</tr>
<tr>
<td>Midfacial breadth</td>
<td>MFB</td>
<td>zmi-zmi</td>
<td>Droessler 1981 (68)</td>
</tr>
<tr>
<td>Measurement</td>
<td>Abbreviation</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>--------------</td>
<td>-------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Internal biorbital breadth</td>
<td>IOB</td>
<td>Droessler 1981 (68)</td>
<td></td>
</tr>
<tr>
<td>Biorbital breadth</td>
<td>BOB</td>
<td>Buikstra and Ubelaker 1994 (76)</td>
<td></td>
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<tr>
<td>Anterior interorbital breadth</td>
<td>AIB</td>
<td>Droessler 1981 (68)</td>
<td></td>
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<tr>
<td>Interorbital breadth</td>
<td>DC</td>
<td>Buikstra and Ubelaker 1994 (76)</td>
<td></td>
</tr>
<tr>
<td>Orbital breadth</td>
<td>LOB</td>
<td>Droessler 1981 (68)</td>
<td></td>
</tr>
<tr>
<td>Orbital height</td>
<td>LOH</td>
<td>Droessler 1981 (68)</td>
<td></td>
</tr>
<tr>
<td>Nasal height</td>
<td>NH</td>
<td>Buikstra and Ubelaker 1994 (75)</td>
<td></td>
</tr>
<tr>
<td>Nasal breadth</td>
<td>NB</td>
<td>Buikstra and Ubelaker 1994 (75)</td>
<td></td>
</tr>
<tr>
<td>Minimum breadth of nasals</td>
<td>MN</td>
<td>Droessler 1981 (68)</td>
<td></td>
</tr>
<tr>
<td>Breadth of nasal bridge</td>
<td>BNB</td>
<td>Droessler 1981 (68)</td>
<td></td>
</tr>
<tr>
<td>Malar length, inferior</td>
<td>IML</td>
<td>Droessler 1981 (68)</td>
<td></td>
</tr>
<tr>
<td>Malar length, maximum</td>
<td>XML</td>
<td>Droessler 1981 (68)</td>
<td></td>
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<tr>
<td>Cheek height</td>
<td>CH</td>
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<tr>
<td>Maxillo-alveolar breadth</td>
<td>MB</td>
<td>Buikstra and Ubelaker 1994 (75)</td>
<td></td>
</tr>
<tr>
<td>Maxillo-alveolar length</td>
<td>ML</td>
<td>Buikstra and Ubelaker 1994 (75)</td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 3

**Definitions of Cranial Measuring Points**

- **Alare** (al) Most lateral points on the nasal aperture.
- **Alveolon** (alv) Point on the palate where a line drawn through the most posterior points of the alveolar ridges crosses the midline.
- **Asterion** (ast) Common meeting points of the temporal, parietal and occipital bones.
- **Auriculare** (au) Point on the lateral aspect of the root of the zygomatic process at the deepest incurvature (Buikstra and Ubelaker 1994: 71).
- **Basion** (ba) Lowest point in the median sagittal plane on the anterior margin of the foramen magnum.
- **Bregma** (b) Point of intersection of the coronal and sagittal sutures.
- **Dacryon** (d) Point where the lacrimo-maxillary suture meets the frontal bone.
- **Ectoconchion** (ec) Point where the orbital length line from maxillofrontale, roughly parallel to the upper orbital margin, meets the outer rim.
- **Ectomolare** (ecm) Most lateral point on the outer surface of the upper alveolar process, usually opposite the middle of the second molar.
- **Euryon** (eu) Points opposite each other on the sides of the skull which form the termini of the line of greatest breadth.
- **Frontomalare orbitale** (fmo) Point on the orbital end of the fronto-zygomatic suture.
- **Frontomalare temporale** (fmt) Most lateral point on the fronto-zygomatic suture (Buikstra and Ubelaker 1994: 71).
- **Frontotemporale** (ft) Most medial point in the incurve of the temporal crest, just above the fronto-zygomatic suture.
- **Glabella** (g) Most forward projecting point in the median sagittal plane between the supraorbital ridges.
- **Lambda** (l) Meeting point of the sagittal and lambdoidal sutures.
- **Maxillofrontale** (mf) Point of intersection of the anterior lacrimal crest with the fronto-maxillary suture.
- **Nasion** (n) Upper end of the internasal suture where it meets the frontal bone.
- **Nasospinale** (ns) A point where a line drawn between the lowest points of the nasal aperture crosses the midsagittal plane (Buikstra and Ubelaker 1994: 71).
- **Opisthion** (o) Median point of the posterior margin of the foramen magnum.
- **Opisthocranion** (op) Posterior terminus of the maximum length of the braincase from glabella in the median sagittal plane.
Prosthion (pr) Most anterior point of the intermaxillary suture on the alveolar margin between the two medial incisors.
Zygomaticus inferior (zmi) Lowest point of the zygo-maxillary suture.
Zygomaticus superior (zms) Highest point of the zygo-maxillary suture at the edge of the orbit.
Zygion (zy) Most lateral point on the zygomatic arch.

* from Droessler (1981: 69-71) unless otherwise noted

Statistical Procedures

Following data collection, the effects of deformation on different subsets of measurement variables were examined by measuring the association between distance of cases from the group average based on those subsets and the degree of deformation determined by scoring the crania during data collection. Several statistical procedures were used in this analysis.

The first objective was to compute values of generalized distance from average group morphology for each cranium using discriminant analysis. This procedure requires that each case in the analysis have values for all measurement variables. In order to include as many cases as possible, missing values were replaced with those calculated from equations derived through multiple linear regression analysis as explained below. Next, those variables missing in several cases and those that shared most of their variation with another variable were eliminated. The remaining variables were divided into subsets representing the vault, face and a combination of the two. For each cranium, discriminant analyses were carried out using each of the three subsets in order to obtain Mahalanobis $D^2$ values, which are estimates of generalized distance between a particular case and the group average.
The second objective was to determine the correlation between generalized distance values and degree of cranial deformation. Degree of cranial deformation was determined at the time measurement data were collected. Each cranium was compared to others in the sample and given a score ranging from 0 (no flattening) to 3 (marked flattening). Coefficients of correlation between $D^2$ values and deformation scores were used to measure the association between deformation and deviation from average group morphology. Correlations were computed separately for distance values obtained from each of the three variable subsets. These correlations were then compared with one another to determine if deformation effects vary according to the data set used to compute the $D^2$ estimates.

Replacement of Missing Values

As explained above, discriminant analysis requires that each case have values for all variables, so to retain as many cases as possible, missing values had to be replaced. The SPSS subprogram Regression was used to perform multiple linear regression in order to derive equations by which a value for each of the 31 measurement variables could be predicted when values were missing. Linear regression estimates the coefficients of the linear equation, involving one or more independent variables that best predict the value of the dependent variable (SPSS 1997: 189).

Equations were derived separately for each of the 30 measurements that had missing values (only PAC had no missing values), so each of them was in turn treated as the dependent variable. The independent variables entered into each such analysis consisted of the 25 measurements that had the least number of missing data. The
program then selected the variable or variables which explained the greatest amount of variance in the dependent variable through a stepwise procedure, meaning that the variables were examined at each step for entry into (probability of $F < .05$) or removal from (probability of $F < .10$) the analysis. The program then provided the constant ($y$ intercept) and the regression coefficients for the independent variables with which the equation could be written. The equations used for the prediction of missing values were selected to include those independent variables having statistically significant ($F$ test, $p < .05$) regression coefficients. Separate equations were generated for males and females.

The general form of the regression equation is as follows:

$$Y' = A + B_1X_1 + B_2X_2 + \ldots + B_pX_p$$

where $Y'$ is the predicted value for the dependent variable $Y$, $A$ is the $y$ intercept, the $X$'s are the independent variables, and the $B$'s are the regression coefficients (Nie et al. 1975: 328).

Missing data were deleted listwise from the regression analyses, meaning that only cases with valid values for all variables were used to compute the correlation coefficients on which the regression analyses were based (SPSS 1997: 178). For both the male and female data sets, these complete cases were fairly representative of the range of cranial deformation. In the male data set, the three complete cases consisted of crania with no flattening, medium flattening, and marked flattening. In the female data set, the five complete cases consisted of crania with no flattening and medium flattening.

It was possible to estimate approximately 32 percent of the total number of missing values using these regression equations.
Variable and Case Selection

Next, variables were selected for discriminant analysis in a manner similar to that used for biological distance analyses. Variables that were missing in more than 20 percent (or more than four) of the cases were eliminated prior to the analysis in order to retain as many of the crania as possible for the discriminant analysis. The SPSS subprogram Correlations was used to calculate Pearson product-moment correlation coefficients ($r$), which were used to calculate the coefficients of determination ($r^2$), in order to eliminate those variables which shared more than 55 percent of their variance with other variables. In distance analyses, a more reliable assessment includes uncorrelated variables (Scott 1992: 152). This left eight measurement variables representing the vault area of the cranium and seven variables representing the face.

Three data subsets, representing the vault, face, and a combination of the two, were selected from the original 31 measurements:

1. **Vault**: L, B, H, ASB, MF, FC, PAC, OCC
2. **Face**: TFB, UFB, AIB, NB, MN, IML, CH
3. **Combination**: L, B, H, PAC, TFB, UFB, NB, IML

For the vault subset, there were seven female cases and six male cases with values for each of the variables; whereas, for the face and combination subsets, there were six female and five male cases with values for each. As many variables as possible were chosen to represent each subset because researchers believe that when many variables are used in distance analyses, a more reliable assessment of affinity and relatedness can be achieved (Sokal and Sneath 1963: 117; Scott 1992: 152).
**Distance from Group Centroid**

Using the SPSS subprogram Discriminant, discriminant analyses were carried out to distinguish between males and females of the sample using each of the three data sets. For each case, the program calculated Mahalanobis $D^2$ values, which are estimates of generalized distance between a particular case and its group centroid. These $D^2$ values were used as the measure of deviation from average group morphology for each cranium. The majority opinion is that Mahalanobis $D^2$ represents the best available distance statistic for use on craniometric data (Zegura 1978: 25; Droessler 1981: 74).

**Correlation between Distance and Deformation**

The relative susceptibility of each data set to deformation effects was examined by measuring the association between degree of deformation and distance of cases from group centroids derived from the different data sets. Using the SPSS subprogram Nonparametric Correlations, Kendall rank-order coefficients of correlation between deformation scores and $D^2$ values obtained from each of the three subsets were computed for males and females to measure the association between degree of deformation and deviation from average group morphology. A two-sided test for significance ($p<.05$) was used because, although a positive correlation between degree of deformation and deviation from average group morphology was expected, a negative correlation was also possible. These correlations were then compared with one another to determine if deformation effects vary according to the data set used to compute the $D^2$ estimates.
CHAPTER 3

RESULTS

Sex

Nine of the crania in the sample were determined to be male and eight were determined to be female based on the criteria described above. Discriminant analysis identified one case as being misclassified as female, but this only occurred when the vault variable subset was used to perform the analysis. The numbers of male and female crania from each site are similar and these figures are listed in Table 4.

<table>
<thead>
<tr>
<th>Sites</th>
<th>Males</th>
<th>Deformation</th>
<th>Females</th>
<th>Deformation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kiavak</td>
<td>3</td>
<td>no flattening &amp; slight flattening</td>
<td>2</td>
<td>slight flattening</td>
</tr>
<tr>
<td>Rolling Bay</td>
<td>2</td>
<td>slight flattening</td>
<td>1</td>
<td>slight flattening</td>
</tr>
<tr>
<td>Chirikof</td>
<td>4</td>
<td>slight, medium &amp; marked flattening</td>
<td>5</td>
<td>no flattening &amp; medium flattening</td>
</tr>
</tbody>
</table>

Degree of Deformation

While both male and female forms represent each site, there is disparity in the percentage of deformed crania and the range of deformation for each of the sites. Twelve of the total 17 crania in the Koniag sample, or 70 percent, were scored as being deformed. All Rolling Bay crania were deformed, 60 percent of Kiavak crania were deformed, and 66 percent of Chirikof crania were scored as being deformed. Except for two Kiavak crania that are undeformed, all crania from the Kiavak and Rolling Bay sites show slight
flattening. The Chirikof crania exhibit a greater range of forms, from no flattening to marked flattening, with medium flattening being the most common.

Deformation and Individual Measurements

When considered separately, several measurement variables show statistically significant correlations with deformation scores and these are presented in Table 5. For females, two vault measurements show statistically significant correlations with deformation scores: maximum cranial length is negatively correlated, while maximum cranial breadth is positively correlated. The same two vault measurements show a significant correlation with deformation scores in male crania as well, although both correlations are positive. Two other vault measurements, minimum frontal breadth and parietal chord, and two face measurements, upper facial breadth and nasal breadth, show a statistically significant positive correlation with deformation scores in males.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Abbreviation</th>
<th>Kendall rank-order coefficients of correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Female</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum cranial length</td>
<td>L</td>
<td>-.672</td>
</tr>
<tr>
<td>Maximum cranial breadth</td>
<td>B</td>
<td>.840</td>
</tr>
<tr>
<td><strong>Male</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum cranial length</td>
<td>L</td>
<td>.890</td>
</tr>
<tr>
<td>Maximum cranial breadth</td>
<td>B</td>
<td>.882</td>
</tr>
<tr>
<td>Minimum frontal breadth</td>
<td>MF</td>
<td>.868</td>
</tr>
<tr>
<td>Parietal chord</td>
<td>PAC</td>
<td>.655</td>
</tr>
<tr>
<td>Upper facial breadth</td>
<td>UFB</td>
<td>.788</td>
</tr>
<tr>
<td>Nasal breadth</td>
<td>NB</td>
<td>.770</td>
</tr>
</tbody>
</table>
Deformation and Distance Values

Table 6 presents coefficients of correlation between deformation scores and the $D^2$ values obtained from the three different variable subsets. For females, the association between deformation and $D^2$ is strongest when vault measurements are used to compute distance estimates. This correlation is negative and statistically significant. The associations between deformation and $D^2$ scores based on the face and combination subsets are not as strong as those based on the vault subset, and they are not statistically significant. The correlation between deformation and $D^2$ is weaker when $D^2$ values are derived from face measurements than when they are obtained from the combined measurement subset. For the male crania, however, the results are quite different. The association between deformation and $D^2$ scores based on the face subset is stronger than that based on the vault subset. Furthermore, there is a statistically significant negative correlation between deformation and $D^2$ values derived from the combination subset, which includes both vault and face measurements.

<table>
<thead>
<tr>
<th></th>
<th>Kendall rank-order coefficients of correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vault</strong></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>-.072</td>
</tr>
<tr>
<td>Females</td>
<td>-.764*</td>
</tr>
<tr>
<td><strong>Face</strong></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>.105</td>
</tr>
<tr>
<td>Females</td>
<td>.389</td>
</tr>
<tr>
<td><strong>Combination</strong></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>-.949*</td>
</tr>
<tr>
<td>Females</td>
<td>.545</td>
</tr>
</tbody>
</table>

* $p < .05$, two-sided test
As noted above, statistically significant correlations were found between deformation scores and distance values based on the female vault subset and the male combination subset. Both correlations are negative, meaning that the greater the degree of deformation in a specimen, the smaller the distance between that case and the average group morphology based on the subset of measurements. This relationship is shown in Table 7. For female cases, distance values based on the vault subset are smallest for the most deformed specimens and largest for the undeformed specimens. The same is true for male cases based on the combination subset. This indicates that in these cases, the most deformed specimens most closely represent the average group morphology. In fact, the only specimen in the sample scored as markedly deformed (a score of 3) was found to have a $D^2$ value of .000 from the average morphology of the males based on the combination subset of measurements.

<table>
<thead>
<tr>
<th></th>
<th>Females: Vault subset</th>
<th>Males: Combination subset</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$D^2$</td>
<td>Deformation score</td>
</tr>
<tr>
<td>62CF BC20</td>
<td>5.273</td>
<td>0</td>
</tr>
<tr>
<td>63CF B-1</td>
<td>1.673</td>
<td>0</td>
</tr>
<tr>
<td>Ki. 418 B-5</td>
<td>.660</td>
<td>1</td>
</tr>
<tr>
<td>62CF AC29</td>
<td>.327</td>
<td>2</td>
</tr>
<tr>
<td>Ki. 418 B-8</td>
<td>.236</td>
<td>1</td>
</tr>
<tr>
<td>62CF AC33</td>
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<td>62CF BC03</td>
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<td>2</td>
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<tr>
<td>Ki. 418 B-6</td>
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<td>2</td>
</tr>
<tr>
<td>62CF AC39</td>
<td>.000</td>
<td>3</td>
</tr>
</tbody>
</table>
The purpose of this study is to indirectly address the effects of artificial cranial deformation on biological distance analyses by more directly assessing its effect on individual crania and the samples that include those crania. If a significant correlation could be found between the degree of deformation and the distance of crania from the average group morphology, it could mean that metric attributes of those crania are affected by the deformation. It would also indicate that their presence in a sample might affect the outcome of biological distance analyses based on cranial measurements.

Researchers have used several techniques to assess the effects of deformed crania on their analyses. Zegura (1971: 90) first ran statistical analyses of Eskimo crania that included two series with deformed crania and then ran another that excluded them. He compared the importance of individual variables for distinguishing between Eskimo groups in both cases and found that the effects of deformation were slight. He also found that the results of discriminant function analysis for assigning specimens to their correct groups were nearly identical before and after removal of the two deformed series. A comparison of the effects of deformation on coefficients of canonical variates showed that deformation had some effect, but may not have accounted for all discrepancies between the two analyses.

Instead of eliminating series with deformed crania from his study altogether, Heathcote (1986, 1994) eliminated from his analyses of Eskimo crania those variables he believed were susceptible to deformation and other influences that do not reflect
phylogeny (Heathcote 1994: 106-108). The resulting subset of 18 craniometric variables was 100 percent accurate in the discriminant classification of individual crania into their correct skeletal series and it also produced the matrix of inter-group distance values that was most congruent with relationships based on linguistic, geographic and archaeological evidence. Heathcote (1986) indicated that his “optimal” set of variables has a better chance of producing data on group relationships that are consistent with expected relationships than alternative variable sets formulated by other or no trait selection criteria.

Heathcote (1986) also attempted to determine the effects of deformation on cranial measurements by comparing the means of measurements from deformed and undeformed crania. He compared 23 deformed specimens to only two undeformed specimens and found that the deformed crania were 5.2 mm shorter and 4.2 mm broader than undeformed crania (Heathcote 1986: 98). He was cautious to draw any conclusions because of the small size of the undeformed sample, but he found that cranial measurements were generally not seriously affected by deformation. Heathcote (1986: 99) said that an analysis of differences between deformed and undeformed crania from Kodiak would be most helpful in understanding the effects of the observed degree of deformation on cranial measurements.

Droessler (1981) focused on the effects of deformation within cranial series to extrapolate to the effects it may have had on her population comparisons involving prehistoric Illinois groups. Rather than identifying and eliminating from her analyses those variables that were affected by deformation, she chose to include those variables in
her population comparisons in order to maximize the data available from small samples (1981: 112). Following her analyses, she looked for correlations between the degree of deformation and the deviation from average group morphology for individual crania in the different study series and found that, in some cases, they were statistically significant (Droessler 1981: 114-116).

Zegura (1971) and Heathcote (1986, 1994) demonstrated deformation's effects, or lack thereof, by comparing the outcomes of biological distance analyses when particular variables or cranial series were and were not included. Heathcote (1986) also attempted to address the effects of deformation on individual crania, as did Droessler (1981). Likewise, the present study was designed to evaluate the effects of deformation on individual crania in order to draw informed conclusions about its effects on biological distance analyses.

For females, the results of the statistical analysis conform in part to expectations. It was expected that degree of deformation would be strongly associated with distance from group centroid based on vault measurements because lambdoidal deformation affects the rear of the cranial vault. This strong association was found in the female specimens; however, instead of becoming greater with increasing degree of deformation, the deviation from group average actually became less. The face subset produced the least association between distance values and deformation scores, and there was a somewhat stronger association between the two based on the combination subset of variables, which was also expected because that subset includes both vault and face measurements. The results for the male specimens do not conform to expectations.
Distance values based on the vault and face subsets for males have very little association with degree of deformation, but those based on the combination subset show a strong negative correlation with degree of deformation. Again, rather than the expected positive correlation between deviation from group average and degree of deformation, there is a negative association when the coefficient of correlation is statistically significant.

These results demonstrate that the association between degree of deformation and deviation from average morphology can vary by sex within a sample. Although the range of deformation, no flattening to medium flattening in females and no flattening to marked flattening in males, is represented in both sexes in this sample, the results of analyses differ between the two. Droessler (1981: 115) also found that for some subsets, one sex in a sample would show a correlation between generalized distance values and degree of deformation while the other sex would not. The present study also found differences between males and females when variation in individual measurements was compared to degree of deformation. Several more variables are significantly correlated with deformation scores when measurements are taken from the male specimens in the sample than when they are taken from the female specimens. Lack of similar correlations for both female and male crania indicate that the composition of the sample, particularly the sex of the individuals included, may affect the results of analyses.

The results of this statistical analysis also indicate that the subset of variables used to calculate generalized distance values can impact results. There is a significant correlation between degree of deformation and distance values based on the combination subset for males while there is very little association between deformation and distance
values based on the vault or face subsets. The combination subset is made up of selected variables from the other two subsets, so it seems that the choice of variables can drastically affect the outcome of the analysis. Also, when individual variables are compared to degree of deformation, only a small percentage is strongly associated. The inclusion or exclusion of certain variables could have an impact on statistical studies that are looking for association between deformation and deviation from group centroid, and could also affect the outcomes of biological distance analyses.

One of the fundamental problems with this study was the same difficulty Heathcote (1986) found when trying to determine the effects of deformation on individual crania—too few undeformed crania. The purpose of the above statistical analysis is to measure the association between degree of deformation and deviation from average group morphology under the assumption that average morphology is also normal, or undeformed, morphology. It is designed for cranial samples in which only a small percentage of the crania are deformed. In this Kodiak sample, only two of the eight female crania and two of the nine male crania were judged to be undeformed. That means that rather than constituting a small percentage of the sample, deformed crania make up over 70 percent of the series. Average group morphology was, therefore, not calculated from predominantly undeformed crania and, as a result, the measures of deviation from group centroid cannot be equated to deviation from undeformed morphology. This may explain the strong negative correlations found in the statistical analysis. In the instances where there is a significant correlation between degree of deformation and distance from average group morphology, the most deformed specimens
are associated with the least distance from the group centroid. The presence of medium to marked flattening, as well as the prevalence of deformation in general within this sample, has altered the average group morphology so that the most deformed specimens are most representative of the average morphology.

The small number of undeformed crania is not the only problem with this sample. The sample size is small and had to be further subdivided by sex for the statistical analyses. Had the sample size been larger, there may have been more undeformed crania for comparison. A larger sample is likely to be more representative of the population from which it originated. Also, the crania pooled into this sample may not represent one breeding population. They come from sites separated by approximately 115 miles (or 185 kilometers) of water and up to 400 years. Cultural differences may be reflected in the disparity in the degree of deformation between crania from Kodiak sites: the deformation in the crania from the geographically and temporally close Kodiak and Sitkalidak Island sites range from no flattening to only slight flattening; crania from Chirikof Island do include individuals with no flattening and slight flattening, but most show medium and marked flattening. Finally, the visual assessment that led to these designations of degree of deformation is subjective and presents a problem as well. Although deformation is continuous rather than discrete, it was divided into ranks for this study and in some cases it was difficult to categorize the crania.
CHAPTER 5

CONCLUSION

Results of the statistical analysis support the hypothesis that there is a statistically significant correlation between the degree of deformation of a specimen and its deviation from the average group morphology based on cranial measurements. According to Droessler (1981: 113), “the association between degree of cranial deformation and distance from group centroid can be used as an indirect indication of the overall effects of cranial deformation on the set of measurements used to perform the discriminant analysis.” The statistically significant correlations between degree of deformation and deviation from average group morphology based on the female vault and male combination subsets indicate that those sets of measurements may be affected by deformation and therefore may not reflect natural vault morphology. The strong association between degree of deformation and deviation from average group morphology also indicates that visual assessment of artificial cranial deformation is possible. Therefore, previous studies in which deformed specimens were visually identified and eliminated from the Koniag sample could be considered more reliable than those in which deformed specimens were included.

The strong association between deformation and distance values based on the vault subset of female specimens supports the hypothesis that deformation is more strongly associated with deviation in measurements of the cranial vault than with deviation in measurements of the face. Furthermore, distance values based on the face subset are least correlated with deformation, while those based on the combination subset...
show a somewhat stronger association. The results for male specimens do not support this hypothesis. The association between distance values and deformation is strong only when a combination of face and vault measurements is used to compute distance estimates. Researchers must consider that if crania in their samples exhibit deformation, measurements of the face, as well as those of the cranial vault, may be altered and may not reflect natural morphology. Previous studies in which measurements were selected to minimize the effects of deformation on analyses could be considered more reliable than those in which all cranial measurements were used. The discrepancies between the sexes in this study suggest researchers may need to consider males and females separately when determining which variables are most affected by deformation and this has generally not been done in the past.

Perhaps more importantly, this study has shown that the presence of deformation can alter the average group morphology of a sample. As stated above, researchers have estimated that 15 percent to 93 percent of Koniag crania in the Smithsonian sample were deformed. The percentage in this sample was estimated near the high end of that range, at 70 percent, and is likely to be the reason that the most deformed crania were found to be most representative of average group morphology. Even with a smaller percentage of deformed crania, the average group morphology could be altered considerably and affect the accuracy of biological distance analyses involving the sample. This may be the reason the Koniag are shown as outliers in analyses when they are compared to the Kachemak, mainland Eskimos, and other populations in which deformation is absent. Artificial cranial deformation has, however, been noted in some Aleut specimens, so its
presence in both the Koniag and contemporary Aleut populations could account for the close grouping of the two in biological distance analyses.

Craniometric studies of Kachemak-Koniag continuity may also be biased by the presence of deformation in the Koniag sample. These comparisons may be further complicated by environmental influence and by the trend toward round-headedness in late prehistory, suggesting that other biological traits should be weighed more heavily. Nonmetric cranial, postcranial, and dental evidence points to continuity between the Kachemak and Koniag, and according to the hypothesis of nonspecificity, study of metric cranial traits should produce similar results. Because they generally do not agree with the majority of biological evidence and because of the complicating factors, craniometric comparisons alone should not be the basis for conclusions regarding biological continuity on Kodiak.

Scott (1992) believes that even if cranial deformation were factored out, the Koniag would still be unique craniometrically and in other traits as well. "While they are technically a Yupik population, they are more closely related to the Aleuts than are other Yupik groups and nonmetric cranial and dental traits even suggest some ties to Na-Dene populations" (Scott 1992: 162). According to Droessler (1981: 110) there are three ways to factor out deformation: mathematically calculating its effects on individual crania, selecting those variables that are least affected to derive biological distance estimates, or deleting deformed crania from biological distance analyses altogether. Unless there is a large portion of undeformed crania representing normal morphology, it would be difficult to calculate the effects of deformation on individual crania. This is complicated by the
fact that the undeformed crania in a sample can include a range of forms, making it
difficult to accurately determine the natural state of an individual. This study has not
shown definitively that one subset of measurements is least affected by deformation,
leaving this matter to be dealt with independently for each analysis. Heathcote's (1986)
method for selecting an optimal subset of variables based partly on the outcome of
analyses may be one way around this problem, but this method could also eliminate
variables that reflect the uniqueness of the sample but aren't affected by deformation.
The results of this analysis suggest that visual identification of deformed specimens may
be possible, making deletion of deformed crania from samples prior to biological distance
analysis an option; however, problems arise when the undeformed portion of the sample
is not large enough for biological distance analysis.

Data previously collected from the large Smithsonian collection from the Uyak site, repatriated in 1991, could offer more insights into the effects of artificial cranial
deformation on biological distance analyses. The larger sample size and greater number
of undeformed specimens would likely provide more accurate results in an analysis of the
association between deformation and distance from average group morphology. With
more reliable conclusions regarding the effects of deformation on individual crania and
cranial samples, it would be possible to judge the value of particular studies of Kodiak
relationships and avoid the use of culturally biased data in the future.
**APPENDIX A**

*Craniometric Data*

|                | L | B | H | LB | BAB | ASB | MF | FC | PAC | OCC | MDL | TFB | FL | UFH | UFB | MFB | IOB | BOB | AIB | DC | LOB | LOH | NH | NB | MN | BNB | IML | XML | CH | MB | ML |
|----------------|---|---|---|----|-----|-----|----|----|----|-----|-----|-----|----|-----|-----|-----|-----|-----|----|-----|-----|----|----|----|-----|-----|-----|-----|-----|
| Ki. 418 B-2    | 165 | 139 | 134 | 98 | 129 | 116 | 92 | 106 | 100 | 94 | 22 | 140 | 96 | 61 | 100 | 99 | 90 | 90 | 15 | 17 | 43 | 35 | 51 | 23 | 6 | 58 | 37 | 54 | 25 | 60 | 52 |
| Ki. 418 B-3    | 179 | 144 | 132 | 102 | 130 | 114 | 93 | 109 | 108 | 89 | 31 | 145 | 104 | 61 | 10 | 101 | 101 | 92 | 93 | 17 | 145 | 104 | 61 | 10 | 101 | 101 | 92 | 93 | 17 | 145 | 104 | 61 | 10 |
| Ki. 418 B-5    | 174 | 145 | 131 | 100 | 125 | 112 | 100 | 109 | 101 | 95 | 22 | 133 | 101 | 61 | 100 | 96 | 92 | 93 | 17 | 46 | 37 | 43 | 26 | 9 | 56 | 30 | 53 | 23 | 61 | 51 |
| Ki. 418 B-6    | 168 | 132 | 123 | 101 | 124 | 106 | 90 | 106 | 85 | 96 | 31 | 140 | 102 | 101 | 96 | 96 | 91 | 16 | 18 | 44 | 10 | 101 | 101 | 92 | 93 | 17 | 145 | 104 | 61 | 10 |
| Ki. 418 B-7    | 166 | 142 | 122 | 92 | 122 | 110 | 84 | 105 | 101 | 97 | 89 | 140 | 102 | 101 | 98 | 94 | 93 | 21 | 7 | 37 | 28 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 |
| Ki. 418 B-8    | 177 | 143 | 132 | 111 | 96 | 111 | 103 | 93 | 27 | 148 | 148 | 116 | 102 | 101 | 18 | 21 | 49 | 40 | 54 | 22 | 101 | 101 | 98 | 93 | 17 | 18 | 21 | 49 | 40 | 54 | 22 | 101 | 101 | 98 |
| RB-7           | 177 | 143 | 132 | 111 | 96 | 111 | 103 | 93 | 27 | 148 | 148 | 116 | 102 | 101 | 18 | 21 | 49 | 40 | 54 | 22 | 101 | 101 | 98 | 93 | 17 | 18 | 21 | 49 | 40 | 54 | 22 | 101 | 101 | 98 |
| 62CF AC29      | 165 | 153 | 135 | 95 | 132 | 110 | 95 | 99 | 107 | 86 | 23 | 132 | 91 | 67 | 103 | 96 | 92 | 93 | 13 | 18 | 42 | 34 | 50 | 23 | 6 | 49 | 31 | 55 | 25 | 62 | 50 |
| 62CF AC33      | 166 | 148 | 130 | 95 | 125 | 113 | 90 | 107 | 97 | 90 | 29 | 129 | 92 | 69 | 100 | 100 | 92 | 93 | 12 | 17 | 43 | 37 | 53 | 23 | 5 | 52 | 29 | 54 | 24 | 61 | 51 |
| 62CF AC37      | 177 | 147 | 136 | 103 | 135 | 110 | 94 | 109 | 106 | 94 | 31 | 145 | 99 | 72 | 107 | 104 | 100 | 100 | 14 | 19 | 45 | 34 | 53 | 23 | 8 | 55 | 35 | 58 | 28 | 65 | 53 |
| 62CF AC39      | 180 | 159 | 140 | 101 | 138 | 130 | 100 | 109 | 109 | 94 | 29 | 145 | 102 | 69 | 111 | 111 | 100 | 102 | 18 | 22 | 45 | 36 | 52 | 28 | 10 | 71 | 28 | 53 | 28 | 65 | 57 |
| 62CF AC45      | 179 | 148 | 133 | 101 | 132 | 117 | 96 | 106 | 103 | 94 | 31 | 140 | 102 | 69 | 113 | 105 | 105 | 104 | 17 | 24 | 46 | 33 | 54 | 25 | 5 | 53 | 37 | 65 | 28 | 64 | 56 |
| 62CF BC03      | 162 | 150 | 126 | 98 | 124 | 117 | 89 | 102 | 96 | 83 | 23 | 126 | 98 | 74 | 103 | 94 | 96 | 86 | 15 | 17 | 43 | 36 | 52 | 22 | 3 | 55 | 26 | 52 | 24 | 58 | 49 |
| 62CF BC20      | 182 | 142 | 129 | 100 | 124 | 114 | 96 | 111 | 102 | 97 | 31 | 130 | 95 | 72 | 106 | 95 | 99 | 93 | 15 | 21 | 45 | 39 | 54 | 24 | 10 | 53 | 35 | 48 | 23 | 60 | 50 |
| 63CF B-1       | 167 | 140 | 114 | 90 | 125 | 111 | 93 | 99 | 99 | 87 | 21 | 128 | 98 | 66 | 103 | 97 | 96 | 100 | 15 | 21 | 43 | 31 | 45 | 26 | 4 | 53 | 31 | 56 | 27 | 61 | 50 |
| Chirikof       | 120 | 99 | 130 | 130 | 90 | 109 | 101 | 24 | 145 | 145 | 106 | 114 | 101 | 102 | 18 | 23 | 46 | 34 | 44 | 18 | 68 | 28 | 27 | 62 | 45 |

*Cranial measurements in italics were estimated by linear regression.*
### APPENDIX B

**Sex, Deformation Scores, and Distance Values**

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<th></th>
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