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NON-METRIC ASSESSMENT OF SOUTHEAST AND
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NON-METRIC ASSESSMENT OF SOUTHEAST AND NORTHEAST ASIAN ANCESTRY IN THE FORENSIC CONTEXT

By

Amber Nichole Heard

A THESIS

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ABSTRACT

NON-METRIC ASSESSMENT OF SOUTHEAST AND NORTHEAST ASIAN ANCESTRY IN THE FORENSIC CONTEXT

By

Amber Nichole Heard

Use of non-metric traits for the assessment of ancestry in the forensic context has recently received renewed attention. In order for non-metric methods to be effectively employed, it is necessary for the forensic anthropologist to have an understanding of non-metric trait expression for a variety of populations. This thesis describes character state expression for a series of cranial and dental non-metric traits in a sample of individuals of Southeast and Northeast Asian ancestry. To date, the skeletal morphology of these populations has received limited attention in the forensic literature; however, the increase of East Asian populations living in the United States warrants an evaluation of their cranial and dental morphology. The sample for this study includes the remains of 49 individuals of Southeast Asian ancestry and 93 individuals of Northeast Asian ancestry. The cranial non-metric traits evaluated have been described by Hefner (2003) and the dental non-metric traits by Turner *et al*. (1991). Results show that the sample of Southeast Asian individuals can be distinguished from the sample of Northeast Asian individuals using a series of cranial and dental non-metric traits. Future analysis is necessary, however, to determine the strength of the ability to make this distinction. Additional research may possibly show that these regional populations are, in fact, best characterized as belonging to a broader East Asian group for the purpose of forensic ancestry assessment.

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PREFACE

Throughout the course of this thesis, *ancestry* should not be read as a euphemism for *race*. It is the author's contention that *race* is a social construct, and that biological race among human populations does not exist. This assertion is in agreement with that of a number of physical anthropologists (e.g. Brace 1964, 1982, 1996, 2005; Lieberman *et al.* 2003; Littlefield *et al.* 1982; Livingstone 1962; Montagu 1942; Sauer 1992), but continues to be ill received by others (e.g. Gill 1990).

Acceptance of the biological race concept in physical anthropology has declined over the past few decades (Lieberman *et al.* 2003) and one could argue that this trend will continue. Despite the fact that the majority of physical anthropologists do not accept the existence of biological racial groups within *Homo sapiens*, forensic anthropologists are faced with the task of identifying the *race* of an unidentified set of human remains. The ability of a forensic anthropologist to accomplish this was eloquently articulated by Sauer (1992) in his paper, "Forensic Anthropology and the Concept of Race: If Races Don't Exist, Why Are Forensic Anthropologists So Good At Identifying Them?" Sauer asserts that the assignment of *race* by a forensic anthropologist does not validate the existence of biological races. Instead, forensic anthropologists are attempting to determine what socially constructed group an unidentified individual may have belonged to. In order to effectively achieve a positive identification, the forensic anthropologist is forced to abandon their own understanding of the race concept, and oblige those of law enforcement and the larger society. As discussed by Cox and colleagues (2006:872), "people identify by 'race' or ancestry not only other people but also *themselves*."

Therefore, whether individuals of a society identify themselves as being *socially* or *biologically* distinct from others is irrelevant. What *is* relevant, however, is that forensic anthropologists recognize the means by which individuals may identify themselves so that they can more effectively identify the remains of the individual in question. The present study was undertaken in order to help strengthen the effectiveness of the forensic anthropologist in this endeavor.

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INTRODUCTION

One of the primary tasks of a forensic anthropologist when establishing the biological profile of an unidentified individual is the determination of ancestry. Ancestry is arguably the most difficult component of the profile to assess, as the forensic anthropologist is asked to determine with which social *race* the individual would have identified during life. When the ancestry of the unidentified individual is known, the list of potential identities from missing person reports can be greatly narrowed, increasing the likelihood that the remains will be positively identified.

As applied physical anthropologists, forensic anthropologists are trained to understand modern human phenotypic variation in both soft tissue and skeletal form. Variation in metric and non-metric trait expression of skeletal morphology has been documented for a number of populations, and the worldwide distribution of this variation is systematic. Having an understanding of this distribution is what enables the forensic anthropologist to estimate the ancestry of an unidentified set of human remains, meanwhile challenging them to place the individual into a discrete, socially determined category. In order to classify an individual as belonging to, or having identified as a member of, a particular social *race*, forensic anthropologists must oblige the population category schemes of both law enforcement and the society at large, which may conflict with their anthropological understanding of human variation (Sauer 1992). In other words, forensic anthropologists may be forced to temporarily abandon their awareness of the continuous nature of human variation in order to facilitate a positive identification.

Ancestry assessment in forensic anthropology can be accomplished through employment of metric or non-metric techniques, or a combination of both. Metric analysis involves taking a series of measurements between cranial landmarks, which can then be compared to a database of known ranges of the measurements for a variety of population groups. Based on these measurements, one can determine the likelihood that a particular individual belongs to a certain group using multivariate analyses (Howells 1970), such as discriminant function analysis (e.g. Giles & Elliot 1962; Snow *et al.* 1979) or calculation of indices (e.g. Gill *et al.* 1988). Some forensic anthropologists are, however, critical of metric methods for a number of reasons. Metric determination of ancestry is time consuming and requires that the entire cranium is present for preservation of the natural distance between landmarks. In addition, because the current database does not include data on every possible population group, an individual whose population group is not included in the data set would be misclassified (Birkby 1966). As a result, a number of practitioners of forensic anthropology prefer non-metric methods of ancestry assessment.

Non-metric analysis involves evaluating the presence, or degree of expression, of a series of traits that have been found to occur in differing frequencies among human populations. By assessing the nature of these traits, an estimate is made about the population affiliation of an unknown individual. Use of non-metric traits is currently the preferred method of ancestry determination by a large number of forensic anthropologists because the traits are easy to evaluate (Rhine 1990) and the method can be employed in cases of fragmentary remains (Buikstra & Ubelaker 1994). Despite their wide usage, non-metric methods are not without error. One criticism is that non-metric traits cannot be subject to the robust statistical analyses used to evaluate metric traits (Rhine 1990). Rather, assessment of the distribution of non-metric traits is performed by calculating the observed frequency of the trait within a defined population group. If a high frequency of a trait, or of a particular character state of trait expression, is observed in a population, that trait may be ascribed to the suite of traits characteristic of that population. Such methods have been employed to develop the series of cranial traits used by forensic anthropologists to distinguish between the skeletal remains of European, African, and Native American individuals (Brooks *et al.* 1990, Napoli & Birkby 1990, Rhine 1990).

Research into the distribution and expression of cranial non-metric traits has focused on documenting the variation exhibited by individuals of European (white), African (black), and Native American ancestry. These three groups represent the three "primary races" described by Hooton in 1946, though he referred to the groups as Whites, Negroids, and Mongoloids (Shanklin 1994). The reason that research has focused on documenting non-metric trait variation in these populations specifically is likely two-fold: 1) Because these three populations have historically comprised the majority of the population of the United States, it is highly likely that an unidentified set of remains will be an individual of European, African, or Native American ancestry; and 2) Reference populations available for study in American museums largely consist of individuals representing these three ancestral groups. The paucity of studies devoted to investigating non-metric trait expression in other populations is more likely related to the latter than to the former—reference populations for individuals of other ancestral backgrounds are lacking. As a result, there may be a tendency to lump a number of groups under one of the "primary" umbrella categories for which non-metric trait variation is understood. An inherent problem with this method is the assumption that certain groups will share a particular suite of non-metric traits. Assessment of non-metric trait distribution in other populations could demonstrate that they can be characterized as having their own unique suite of non-metric traits.

Of Hooton's primary races, the "Mongoloid" group has been used as an umbrella category that includes a number of populations. The term "Mongoloid" stems from writings of the eighteenth and nineteenth centuries where figures such as Johann Friedrich Blumenbach (1752-1849) and Georges Cuvier (1769-1832) created a scheme that divided the people of the world into four and three groups, respectively. "Mongoloid", meaning "Mongol-like", has since been used as a catch-all category that includes modern populations of East Asia, and their ancestors and descendents (including Native Americans and some Pacific Islanders). From an anthropological perspective, it seems inappropriate to use such a general term to refer to a group of populations that are clearly not biologically, linguistically, or culturally homogeneous. Further, the term "Mongoloid" carries negative connotations as it has historically been used to refer to the features of individuals with Down Syndrome—a flattened face, yellow pigmented skin, and inferior intelligence—all of which reminded Dr. Down of characteristics of East Asian populations (Brace 1996). In spite of the clear ambiguity and racial undertones associated with the term "Mongoloid", prominent texts in forensic anthropology continue to use the term to refer to individuals of East Asian and/or Native American ancestry (e.g. Bass 2005, Gill, 1998, Gill and Rhine 1990, Krogman 1955, Krogman & Iscan 1986). While the labeling system itself is problematic, so is the fact that one suite of traits is used to classify a variety of populations as being of "Mongoloid" ancestry.

Recently, physical anthropologists have noted that traits considered to be characteristic of the classic "Mongoloid" group were not derived from studies encompassing all of the populations that would be classified as "Mongoloid". While the term "Mongoloid" is used to refer to populations of East Asian ancestry, the reference population used for establishing the suite of traits characteristic of "Mongoloids" is primarily comprised of Southwest Native Americans (Rhine 1990). In other words, the current understanding of "Mongoloid" traits does not capture the true spectrum of diversity within the group, as little data has been collected on samples of individuals from mainland or insular East Asia. The call for the study of non-metric trait expression in a variety of East Asian populations for purposes of forensic identification began nearly twenty years ago, but has remained largely unanswered. Rhine (1990) noted that understanding the skeletal characteristics of Southeast Asian individuals was of increasing importance to forensic anthropologists due to the rise in refugee populations living in the United States. While it was astute of him to recognize this trend, Rhine (1990) cites the lack of an appropriate reference sample as his reason for not including a sample of Southeast Asian individuals in his study of cranial non-metric trait distribution. The rise in Southeast Asian refugee populations was also mentioned by Brooks and colleagues (1990), who suggested that the increasing presence of Southeast Asian individuals in the United States would make it difficult for forensic anthropologists to differentiate the facial skeletons of Asians from each other, and also with those of Native Americans.

Most recently, the issue of the lack of true Southeast and Northeast Asian data in the "Mongoloid" reference sample was addressed by Rankin and Moore (2004). As forensic anthropologists working at the Joint POW/MIA Accounting Command Center Central Identification Laboratory, Rankin and Moore were able to collect cranial non-metric data from samples of Southeast Asian individuals while on deployment missions in Southeast Asia. Cranial non-metric trait data were recorded for Thai individuals from the collections of the Chiang Mai University Medical School, Thailand; the Mahidol School of Medicine in Bangkok, Thailand; and from a collection of remains at the Memorial Museum at the former Choeung Ek Khmer Rouge prison in the Kingdom of Cambodia. These data were collected for a study comparing non-metric traits of Thai and Cambodian skeletal remains to those of the "Southwest Mongoloids" as described by Rhine (1990). The results were presented at the 2004 Annual Meetings of the American Academy of Forensic Sciences, but to date have not yet been published. As this study may possibly represent the largest that has been undertaken to document the expression of cranial non-metric traits for a modern sample of individuals of Southeast Asian ancestry, it is unfortunate that these results are not available for use by fellow forensic anthropologists.

The purpose of this thesis is to describe the expression of cranial and dental non-metric traits in a sample of Southeast and Northeast Asian individuals. Bioarchaeological studies of biological distance have demonstrated considerable differences in the expression of non-metric traits between these regional groups, but it is unclear if these differences are useful for the forensic anthropologist. In this thesis, the expression of cranial and dental non-metric traits commonly used in forensic anthropology will be described for a sample of Southeast and Northeast Asian individuals. Non-metric trait expression within Southeast Asians will be compared to trait expression in Northeast

Asians in order to determine if the two groups can be distinguished. The results of this study will contribute to the current understanding of non-metric trait expression in Asian populations, and may lend support to the deconstruction of the "Mongoloid" typology in forensic anthropology.

CHAPTER 1:

NON-METRIC ANCESTRY ASSESSMENT IN FORENSIC ANTHROPOLOGY

The use of cranial and dental non-metric traits to assess ancestry in a forensic context developed from early twentieth century efforts to document and understand the scale of modern human phenotypic variation. An understanding of the worldwide distribution of these traits, along with the genetic nature of their inheritance, is what enables forensic anthropologists to use a variety of non-metric traits to assess the probable ancestry of an unidentified set of human remains.

Roots of Non-Metric Trait Studies in Physical Anthropology

The study of modern human phenotypic variation has a long history in the field of physical anthropology, its application in the forensic context being, perhaps, the most recent. Researchers such as Russell (1900) and Wood-Jones (1930-31a,b,c; 1933-34) can be credited as some of the first to recognize that certain cranial traits can be used to distinguish populations, while a number of others have used non-metric traits to investigate population relatedness through biological distance analysis (e.g. Berry & Berry 1967). Interest in non-metric trait expression grew throughout the middle to latter half of the twentieth century for two primary reasons: first, non-metric traits are clearly definable and more easily scored than metric traits; and second, advancements in the field of genetics began to show that non-metric trait expression was the result of a complex pattern of inheritance, suggesting that traits should be predictably shared by members of a defined population. Traits of the cranium and dentition are considered to be best suited for population studies, as it has been suggested that their expression is more strongly buffered from environmental or functional influence than postcranial non-metric traits (Tyrrell 2000; but see Finnegan 1978).

Within the forensic literature, Earnest A. Hooton (1887 – 1954) is acknowledged as being the most influential contributor to the study of ancestry, or *race*, as well as one of the first to be interested in cataloguing non-metric trait expression for a variety of populations. Hooton's lineage of students includes prominent physical anthropologists that have devoted their studies to the issue of *race*, of whom many have contributed to the current standards for ancestry determination used by forensic anthropologists (Hefner *et al.* 2004). Hooton's interest in human phenotypic variation focused on the study of non-adaptive traits, which he predicted would offer the most reliable means for differentiating populations. During his tenure at Harvard, Hooton developed a list, known as the Harvard List, which served as a standard for data collection for a variety of cranial and post-cranial traits. The legacy of Hooton, as well as the impact of the Harvard List, has been discussed by Brues (1990) and more recently by Hefner and colleagues (2004). The publication by Brues (1990) includes examples of excerpt pages from the Harvard List, which highlights the extensive detail Hooton was interested in documenting from each set of human remains.

The Harvard List has since been adapted by forensic anthropologists as research has proved the utility of some non-metric traits over others for the purpose of ancestry assessment. While each practitioner in forensic anthropology may rely on their own set of non-metric traits to assign a probable ancestry to a set of remains, there is a consensus about the variation in expression of a handful of traits for individuals of European, African, and Native American ancestry. These traits, primarily of the mid-face and dentition, were described and illustrated by Rhine (1990) in his chapter *Non-Metric Skull Racing*, perhaps the most used and cited chapter of the entire Gill and Rhine (1990) volume, *Skeletal Attribution of Race.* Although the sample used to generate these descriptions was small, these traits have been, and are still considered by many to be, the standard for non-metric determination of ancestry.

Current Use of Non-Metric Traits in the Forensic Context

Shortly over a decade following the publication of Gill and Rhine's *Skeletal Attribution of Race*, a new era in the use of non-metric traits has begun to develop. This new research has been led by the work of Hefner and Ousley (e.g. Hefner 2002, 2003, 2003a; Ousley & Hefner 2005; Hefner & Ousley 2006), whose goal has essentially been three-fold: 1) Create standards for non-metric trait scoring by developing comprehensive definitions, descriptions, and illustrations of character states; 2) Document the frequency of occurrence of the various traits for a variety of populations; and 3) Develop a statistical means of ancestry assessment. Accomplishment of these goals, in particular the latter, would allow the forensic anthropologist to strengthen their ancestry estimation by providing posterior and/or typicality probabilities that an unidentified individual belongs to a defined ancestral group. The impetus for this renewed interest in non-metric ancestry determination stems from the fact that the current methods fail to uphold the forensic standards for expert witness testimony set by *Daubert*. While many forensic anthropologists feel confident using non-metric traits to estimate the probable ancestry of an unidentified set of human remains, current methods do not allow them to state the statistical likelihood that individual X was of ancestry Y. The most recent work by

Hefner and Ousley (Ousley & Hefner 2005, Hefner & Ousley 2006) has attempted to provide forensic anthropologists with the ability to do just that using discriminant function analysis and logistic regression.

An effort to apply more robust statistical support for non-metric ancestry assessments has also been undertaken for dental traits. Edgar (2005) has developed a method of predicting ancestry based on characteristics of dental morphology using traits of the Arizona State University dental morphology system (Turner *et al.* 1991). By examining dental casts of a large set of African and European Americans, Edgar was able to develop probability tables based on Bayesian prediction and logistic regression. These tables allow the forensic anthropologist to state the probability that an unknown individual is of either African American or European American ancestry. While Edgar's publication represents a constructive contribution to the task of ancestry assessment, her method can only be applied in cases where the probable ancestry of the unidentified individual is African or European American. In order to strengthen the method, it is necessary to document dental non-metric trait frequencies for a variety of other populations, notably Native Americans, Hispanics and Asians.

The last point is of particular importance and is also true of the methods currently under development for cranial traits. In order for non-metric methods of ancestry determination to be effective, an understanding of trait distribution for major populations living in the United States is essential. Historically, forensic anthropologists have focused on cataloguing trait distribution among three primary ancestral groups: Caucasoids, Negroids, and Mongoloids. By using such categories, the intention was to capture the distribution of non-metric traits for European Americans, African Americans, and Native Americans, which (at the time) represented the principal populations of the United States. Using Rhine (1990) as a standard, other populations have been anecdotally classified as falling within one of the three primary categories despite a lack of devotion to studying the true nature of their cranial and dental morphology. Only very recently have forensic anthropologists begun to call for the study of non-metric trait expression in populations outside of the three traditional ones (e.g. Slice & Ross 2004, Rankin & Moore 2004, Birkby *et al.* 2008), highlighting the fact that populations that have been grouped for forensic identification purposes are not, in fact, homogenous. Such has been the argument for the classification of Hispanics (Slice & Ross 2004) and Asians (Rankin & Moore 2004), two groups that have typically been included within the Caucasoid (Rhine 1990) and Mongoloid categories, respectively.

Efforts to better understand non-metric trait expression in Hispanic populations have been accelerated by those working along the US-Mexican border, who are increasingly tasked with identifying the remains of Mexican migrants who succumb to the environmental challenges of crossing the terrain into the United States (Anderson 2008, Hinkes 2008, Birkby *et al.* 2008). While it is necessary to identify these individuals from a medico-legal perspective at the border, the number of Hispanics living legally across the US has also grown. The increase in the US Hispanic population translates into a greater likelihood that an unidentified set of remains could belong to an individual of Hispanic ancestry, creating a sense of urgency among forensic anthropologists to understand their skeletal morphology. This notion has caught the attention of a number of forensic anthropologists, many of whom are beginning to outline the suite of traits that can be used to identify an individual as Hispanic (e.g. Birkby *et al.* 2008).

Though there has been an improved attempt to understand the skeletal morphology of Hispanic peoples, less effort has been devoted to understanding non-metric trait expression in Asian populations. Despite the fact that Asian populations began immigrating to the United States in the second half of the eighteenth century (Tokuyama 2003), and Asians now make up a very large component of the US population, few studies of non-metric traits include Asian individuals in their sample. Until the recent work by Hefner (2002, 2003, 2003a), few papers in the forensic literature comment on cranial and/or dental non-metric trait expression in East Asian samples. Like Hispanic groups, the people commonly referred to as "Asian Americans" do not constitute one homogenous population. Rather, the group is comprised of individuals from nations such as China, Japan, and Korea, as well as those from the region of Southeast Asia, including the countries of Vietnam, Laos, Cambodia, and Thailand. Nonetheless, it has long been presumed that East Asians exhibit cranial and dental non-metric traits similar to those of Native Americans, their New World descendents. While the groups have been shown to share some traits, such as a high frequency of incisor shoveling, bioarchaeological analyses have proved that there are clusters of regional groups that can be characterized by differing expression of non-metric traits (e.g. Hanihara *et al.* 2003, Matsumura 1995). This suggests that it is inappropriate for forensic anthropologists to assume that non-metric trait expression is equivalent for all of the traditionally termed "Mongoloid" populations.

As the following chapter will highlight, non-metric trait expression in East Asian populations is well documented in the bioarchaeological literature. One of the goals of this thesis is to supplement this literature with an understanding of non-metric trait expression for traits commonly used in the forensic assessment of ancestry.

CHAPTER 2:

NON-METRIC TRAIT EXPRESSION IN EAST ASIAN POPULATIONS

Though few studies in the forensic literature include samples of East Asian individuals, these populations have been extensively studied in other subfields of anthropology. Within physical anthropology, much research has been devoted to understanding the population history of mainland and insular East Asia, with specific interest in regional migration and microevolution. Since the late 1970s, a debate has emerged regarding the population history of Southeast Asia, a discussion that has fueled research on prehistoric populations within mainland and insular East Asia. The conventional view holds that the region commonly referred to as Southeast Asia was first occupied by Australo-Melanesians and was later influenced by a southward expansion of Asian populations (from the area of modern China) during the Neolithic. This hypothesis has been supported by both archaeological and linguistic evidence (see Matsumura & Hudson 2005 for a review). The implications of this view are that the populations of Southeast Asia would have received genetic contributions from northern Asian populations, leading to a modern population of Southeast Asians that exhibits traits common to northern Asian populations and those of prehistoric Australo-Melanesians. In contrast, it has more recently been proposed that the early populations of Southeast Asia did not receive genetic influence from the north and, instead, exhibit cranial and dental morphologies that are the result of local, microevolutionary forces (Hanihara 1993, Turner 1990).

While the objective of the present paper does not warrant a review of the evidence supporting either side of the aforementioned debate, it is important to highlight the heterogeneity of cranial and dental morphology between regional Asian populations. Much of the literature dedicated to supporting either side of the argument has potential for being of use to forensic anthropologists interested in developing a suite of non-metric traits characteristic of Asian ancestry. Further, the dichotomization of the Asian, or "Mongoloid" group by some researchers suggests that it may be possible to differentiate individuals of Northeast Asian and Southeast Asian ancestry through the use of non-metric traits, notably those of the dentition.

Cranial and Dental Non-Metric Traits in Asian Populations: A Bioarchaeological Perspective

The earliest studies of non-metric traits in Asian populations focused on variation of the dentition. Hanihara (1969) was the first to define a "Mongoloid Dental Complex" based on his observations of the dentition of Japanese, Native American, and Eskimo populations. These "Mongoloid" groups were characterized by a high frequency of incisor shoveling, as well as three features of the lower molars, including a sixth cusp, the protostylid and deflecting wrinkle. Presence of these traits had come to be accepted as characteristic of "Mongoloid" individuals until Christy Turner II proposed that this dental complex is not, in fact, shared by all "Mongoloid" populations (Turner 1983, 1990). Through the study of non-metric traits, Turner (1983, 1990) has demonstrated that two dental complexes are exhibited by the people of mainland and insular Asia, as well as their New World and Pacific descendents. The first pattern is known as Sundadonty, and those who exhibit it the Sundadonts. Sundadonts include prehistoric and modern populations living in the region of mainland and insular Southeast Asia, on the region that was once a land mass known as the Sunda Shelf. The second pattern is Sinodonty and is exhibited by the Sinodonts. Sinodonts include the prehistoric and modern populations of North and East Asia, including the Chinese, Japanese and Koreans, as well as their North and South American descendents. Through his analysis, Turner (1990) determined that eight traits have significant mean differences between Sundadonts and Sinodonts, suggesting that these traits may be useful for distinguishing individuals as belonging to a Sundadont or Sinodont population (Table 1). Sinodonts are characterized as having significantly higher frequencies of incisor shoveling and double shoveling; single rooted upper first premolars; upper first molar enamel extensions; congenitally absent, pegged, or reduced upper third molars; lower first molar deflecting wrinkles; three rooted lower first molars; and a low frequency of four cusped lower second molars. These findings have been further supported by Hanihara (1992) and Matsumura (1995), who agree that East Asians can be characterized by two regional dental complexes.

Table 1: Significant t test scores between Sinodont and Sundadont groups (Turner 1990, Table 9, pp. 304).

	Sundadont		Sinodont				
Trait	Mean	S.D.	Mean	S.D.	t	*p*	d.f.
UI1 shovel	30.8	15.8	71.1	11.5	9.08	<10(-6)	39
UI1 double-shovel	22.7	18.2	55.8	21.9	5.29	4.90509E-6	39
UP1 one root	70.6	11.8	78.8	11.4	2.25	0.0299	39
UM1 enamel extension	26.4	16.5	50.1	9.5	5.41	3.255488E-6	39
UM3 P/R/CA	16.3	10.0	32.4	10.3	4.97	1.448393E-5	38
LM1 deflecting wrinkle	25.5	18.3	44.1	19.7	3.04	4.316424E-3	37
LM1 three roots	8.8	5.8	24.7	7.7	7.55	<10(-6)	39
LM2 four cusps	30.7	14.1	15.5	6.9	4.05	2.337923E-4	39

In addition to dental analyses, numerous studies of cranial non-metric traits have been conducted on Asian populations to investigate population relationships. These studies have been within the realm of bioarchaeology and have focused on determining population relatedness through biological distance analysis. Japanese scholars have had a strong interest in non-metric traits for a number of years, having conducted copious studies on prehistoric Asian populations (Ossenberg *et al.* 2006). The traits that are typically used in such studies, however, are different than those commonly used by the forensic anthropologist when making an assessment of ancestry. A review of the trait lists commonly used by both Japanese and American scholars to document non-metric trait variation in Asian populations reveals that few of the traits match those frequently used by forensic anthropologists for ancestry determination (Table 2). In particular, only one trait was found in the bioarchaeological literature, *metopism* (or persistence of the metopic suture), that is on Hefner's (2002, 2003) list of non-metric traits, a list that is admittedly still growing, but is nonetheless on its way to becoming a standard for data collection within the field of forensic anthropology.

Table 2: Summary of cranial non-metric traits commonly used within the bioarchaeological literature to investigate population relationships in mainland and insular East Asia.

Cranial Non-Metric Traits	Publications of Descriptions and/or Use
Supernumerary Ossicles	
Occipito-mastoid bone	Ossenberg 1970; Dodo 1974; Ishida & Dodo 1993; Ishida 1995; Hanihara *et al.* 2003; Hanihara & Ishida 2001a; Fukumine *et al.* 2006; Ossenberg *et al.* 2006
Ossicle at lambda	Dodo 1974; Ishida & Dodo 1993; Ishida 1995; Hanihara & Ishida 2001a; Hanihara *et al.* 2003; Fukumine *et al.* 2006
Parietal notch bone	Dodo 1974; Ishida & Dodo 1993; Ishida 1995; Hanihara & Ishida 2001a; Hanihara *et al.* 2003; Fukumine *et al.* 2006

Table 2 (*continued*)

Asterionic bone	Ossenberg 1970; Ishida & Dodo 1993; Ishida 1995; Hanihara & Ishida 2001a; Hanihara *et al.* 2003; Fukumine *et al.* 2006
Hypoostotic Traits	
Transverso-zygomatic suture trace	Dodo 1974; Ishida & Dodo 1993; Ishida 1995; Hanihara & Ishida 2001b; Hanihara *et al.* 1998, 2003; Fukumine *et al.* 2006; Ossenberg *et al.* 2006
*Metopism**	Hauser & De Stefano 1989; Ishida & Dodo 1993; Ishida 1995; Hanihara & Ishida 2001b; Hanihara *et al.* 2003; Fukumine *et al.* 2006
Tympanic dehiscence	Dodo 1974; Ishida & Dodo 1993; Ishida 1995; Hanihara & Ishida 2001b; Hanihara *et al.* 2003; Fukumine *et al.* 2006; Ossenberg *et al.* 2006
Ovale-spinosum confluence	Dodo 1974; Ishida & Dodo 1993; Ishida 1995; Hanihara & Ishida 2001b; Hanihara *et al.* 2003; Fukumine *et al.* 2006
Biasterionic suture	Dodo 1974; Ishida & Dodo 1993; Ishida 1995; Hanihara & Ishida 2001b; Hanihara *et al.* 2003; Fukumine *et al.* 2006
Hyperostotic Traits	
Medial palatine canal	Dodo 1974; Hauser & De Stefano 1989; Ishida & Dodo 1993; Ishida 1995; Hanihara & Ishida 2001c; Hanihara *et al.* 2003; Fukumine *et al.* 2006
Hypoglossal canal bridging	Dodo 1974; Ishida & Dodo 1993; Ishida 1995; Hanihara & Ishida 2001c; Hanihara *et al.* 2003; Fukumine *et al.* 2006; Ossenberg *et al.* 2006
Jugular foramen bridging	Dodo 1986a,b; Ishida & Dodo 1993; Ishida 1995; Hanihara & Ishida 2001c; Hanihara *et al.* 2003; Fukumine *et al.* 2006
Mylohyoid bridge	Dodo 1974; Ishida & Dodo 1993; Ishida 1995; Jidoi *et al.* 2000; Hanihara & Ishida 2001c; Hanihara *et al.* 2003; Fukumine *et al.* 2006; Ossenberg *et al.* 2006
Precondylar tubercle	Ishida & Dodo 1993; Ishida 1995; Hanihara & Ishida 2001c; Hanihara *et al.* 2003; Fukumine *et al.* 2006
Paracondylar process	Ishida & Dodo 1993; Ishida 1995
Condylus tertius	Dodo 1974; Hanihara *et al.* 2003
Auditory exostosis	Dodo 1972; Hanihara & Ishida 2001c; Hanihara *et al.* 2003
Pterygobasal spur or bridge	Ossenberg *et al.* 2006
Clinoid bridge	Ishida & Dodo 1993; Ishida 1995; Ossenberg *et al.* 2006
Trochlear spur	Ossenberg *et al.* 2006

Table 2 (*continued*)

Vessel/Nerve-Related Traits	
Supraorbital foramen	Dodo 1974, 1987; Ishida & Dodo 1993; Ishida 1995; Hanihara & Ishida 2001d; Hanihara *et al.* 2003; Fukumine *et al.* 2006; Ossenberg *et al.* 2006
Spraorbital nerve groove	Ishida & Dodo 1993; Ishida 1995
Postcondylar canal absent	Ossenberg *et al.* 2006
Lateral condylar canal	Ossenberg *et al.* 2006
Condylar canal patent	Dodo 1974; Hauser & De Stefano 1986; Ishida & Dodo 1993; Ishida 1995; Hanihara & Ishida 2001d; Hanihara *et al.* 2003; Fukumine *et al.* 2006
Accessory infraorbital foramen	Berry & Berry 1967; Hanihara & Ishida 2001d; Hanihara *et al.* 2003
Accessory mental foramen	Hanihara & Ishida 2001d; Hanihara *et al.* 2003; Ossenberg *et al.* 2006
Accessory optic canal	Ossenberg *et al.* 2006
Marginal foramen of tympanic plate	Ossenberg *et al.* 2006
Other	
Sagittal sinus groove flexes left	Ishida & Dodo 1993; Ishida 1995
Orbital suture variant	Ossenberg *et al.* 2006
Infraorbital suture variant	Ossenberg *et al.* 2006
Pharyngeal fossa	Ossenberg *et al.* 2006
Frontal grooves	Ossenberg *et al.* 2006

*Commonly used by forensic anthropologists.

It is clear from the bioarchaeological literature that Asian populations have received a wealth of attention with regards to the expression of non-metric traits, however the traits of interest differ than those commonly used by the forensic anthropologist. While the goal of biological distance analysis as performed by the bioarchaeologists is to study the degree of relatedness between two populations, forensic anthropologists are interested in determining the social *race* with which an unidentified individual most likely identified with during life. To this end, the suite of traits used by the bioarchaeologist includes traits with known heritability rates and those that show regional variation in expression (e.g. Cheverud 1981, 1982). In contrast, the traits preferred by the forensic anthropologist are ones that have differences in expression with a more global pattern, reflecting the traditional major geographic *races* of humans. It is unclear at this point whether or not select non-metric traits may be of use in both endeavors.

Due to the current lack of agreement in trait batteries used by bioarchaeologists and forensic anthropologists, the bioarchaeological literature on non-metric trait expression in Asian populations is of limited use in describing the suite of non-metric traits characteristic of Asian ancestry for use in the forensic context. For the forensic anthropologist, the bioarchaeological discussion of dental non-metric traits will likely prove to be more informative than that of the cranial non-metric traits, with the exception of metopism. In order to gain a better understanding of non-metric trait expression in Asian populations for use in the forensic context, this study will describe the expression of traits commonly used for the forensic assessment of ancestry.

CHAPTER 3:

EAST ASIAN POPULATIONS LIVING IN THE UNITED STATES

East Asian peoples first came to the Americas in the middle of the eighteenth century as merchants, prompted by economic ventures and missionary sponsored education programs (Bankston & Hidalgo 2007). The earliest settlers were from the islands of the Philippines, who started a small community in present day Louisiana (Tokuyama 2003, Gold & Rumbaut 2007). The initial settlement of Filipino populations in Louisiana was followed a century later by the Chinese in California, and the Japanese in Hawai'i.

During the Gold Rush of the late 1840s, a number of Chinese merchants came to the United States to work in the mining fields of California, Idaho, Wyoming, and Colorado. With the end of the Gold Rush in the mid 1850s, Chinese workers were hired to work for the railroads. In 1865, the Transcontinental Railroad Project began, with aspirations of building a railroad system that would connect California and Nebraska. It is estimated that approximately 12,000 of the workers of the Transcontinental Railroad Project were Chinese (Gold & Rumbaut 2007). The next group of East Asians to immigrate was the Japanese. Japanese workers settled in the islands of Hawai'i in the late nineteenth century to work in agricultural jobs (Gold & Rumbaut 2007), and eventually moved to the continental US once trade began with the islands of the Pacific. It is estimated that less than 150 Japanese lived in the United States in 1880, but by 1900 there were approximately 24,330 (Tokuyama 2003). Such a drastic influx of Chinese and Japanese workers was unsettling to the European population living in America, and discrimination against these East Asian populations escalated. With the implementation of the Chinese Exclusion Act of 1882, Asian immigration halted at the turn of the twentieth century (Zhou & Gatewood 2007).

In spite of the discrimination efforts directed against Chinese and Japanese migrants, groups of individuals from Southeast Asia began immigrating to the United States after Congress repealed the Chinese Exclusion Act in 1943. It is estimated that approximately 130,000 Filipinos were living in the U.S. by the 1930s, and around 7,000 Koreans were working in the sugar plantations of Hawai'i by 1950 (Gold & Rumbaut 2007). The largest resettlement of Southeast Asians in the United States followed the end of the Vietnam War. United States military involvement in Vietnam opened the gate for movement between the US and Southeast Asia. As Vietnamese civilians began seeking refuge in Thailand, the US government took action to assist Southeast Asian refugees, as evidenced by the Refugee Act of 1980. In 1975, around 135,000 Vietnamese refugees entered the United States, followed by a second wave of nearly 400,000 Vietnamese refugees from 1977 to 1982 (Gold & Rumbaut 2007). Refugee groups comprised of Cambodians, Laotians, and Hmong settled in America by the tens of thousands, making Southeast Asians the largest refugee population to ever enter the United States (Tokuyama 2003).

The current US population of "Asian Americans" is a heterogeneous group comprised of individuals whose cultural, linguistic, religious, and political backgrounds are at times in stark contrast (Philip 2007). The Census Bureau defines "Asian" as those individuals with origins in areas of the Far East, Southeast Asia, or the Indian subcontinent. This includes individuals from countries such as Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam. According to the US Census Bureau, the population of Asian and Pacific Islanders living in the United States increased by 108% between 1980 and 1990, and totaled 12.5 million in March of 2002. Between 1990 and 2000, the Asian population increased faster than the total population, increasing by some 50%, while the total US population only grew by 13%. The enormous increase in the migration of Asian populations to America was the direct result of changes in US immigration law during the 1960s, and also the influx of Southeast Asian refugees following the fall of Saigon in April of 1975 (Barringer *et al.* 1993). These refugees are primarily from the countries of Vietnam, the Philippine Islands, Laos, Cambodia, and Thailand, and currently make up one third of the Asian American population (Bankston & Hidalgo 2007). Asian families living in America are most concentrated in the West (51%), followed by the South (19%), Northeast (19%), and Midwest (12%) (Reeves & Bennett 2003). Approximately 51% of Asian Americans live in one of three states: California (4.2 million), New York (1.2 million), and Hawai'i (0.7 million) (Barnes and Bennett 2002). The census data also show that 95% of all Asian and Pacific Islanders live in metropolitan areas such as New York, Los Angeles, San Diego, San Francisco, Chicago, Houston, and Honolulu.

Change in the composition of America's population can affect a variety of facets of society. As forensic anthropologists, we are impacted by this change as we are forced to understand the skeletal variation of an increasing number of populations. A change in society's population structure could mean a change in the possible ancestral identities of individuals in a missing persons report. Rhine (1990), Brooks and colleagues (1990), and Rankin and Moore (2004) have called attention to the lack of understanding among forensic anthropologists of the skeletal traits of East Asian populations, particularly Southeast Asian peoples. Having an understanding of the skeletal morphology of these populations is essential if forensic anthropologists wish to accurately identify East Asian ancestry in a forensic context.

CHAPTER 4:

RESEARCH OBJECTIVES, HYPOTHESES, AND PREDICTIONS

This section outlines the hypotheses and predictions for the present thesis. The hypotheses and related predictions have been generated from a synthesis of both the forensic and bioarchaeological literature on non-metric trait expression in East Asian, Native American, and Pacific populations. Because these populations qualify as members of the traditional "Mongoloid" ancestral group, it is hypothesized that the sample of Southeast and Northeast Asian individuals included in the current analysis will exhibit similar expression of non-metric traits.

RESEARCH OBJECTIVES AND HYPOTHESES

Research Objective 1a

As little has been written in the forensic literature about the expression of cranial and dental non-metric traits in contemporary Southeast Asian populations, the first objective of this study is to describe non-metric trait expression within the Southeast Asian sample. This will be accomplished by determining the frequency of expression of the various trait forms for the cranial and dental non-metric traits under consideration.

Research Objective 1b

One criticism of non-metric trait usage in forensic anthropology is the subjectivity of trait expression interpretation. As a result, it is important to establish both intra- and inter-observer repeatability in trait scoring. The second goal of Research Objective 1 is to establish intra-observer repeatability in scoring. A goal for future research will be to also establish the level of inter-observer repeatability in scoring.

During the data collection period at the Joint POW/MIA Accounting Command Central Identification Laboratory, the cranial non-metric traits of each individual of the Southeast Asian sample was scored on two separate occasions by the author. In order to establish repeatability, the score assigned during the first scoring period will be compared to those assigned during the second scoring period using Cohen's Kappa Coefficient.

- *$H1_0$:* Scores assigned during the second trial will show no relationship to scores assigned during the first trial.
- *$H1_1$:* Scores assigned during the second trial will show consistency with scores assigned during the first trial.

If the null hypothesis of Research Objective 1b is accepted, there is poor to no congruence in scoring between the scores assigned during the first and second scoring period. If the null hypothesis is rejected based on the analysis of the sample, this demonstrates a strong level of intra-observer consistency in scoring. Rejection of the null hypothesis would further suggest that the traits can be easily interpreted using the available published descriptions.

Research Objective 2

While the expression of cranial non-metric traits has already been studied for a portion of this particular sample of Northeast Asian individuals (Hefner 2003), the expression of dental non-metric traits has yet to be evaluated. The goal of the second research object is to determine the frequency of expression of the various dental non-metric trait forms in the sample of Northeast Asian individuals. Cranial non-metric traits will also be evaluated in this sample, as the uncertainty of the level of inter-observer error in scoring precludes the use of trait frequencies collected by other observers (e.g. Hefner 2003).

Research Objective 3

In order to determine whether or not the two East Asian populations can be recognized by different suites of non-metric traits, the frequency of individuals expressing the different trait forms for the Southeast Asian sample will be compared to the expression of traits within the Northeast Asian sample. A chi-square goodness-of-fit test will be used to assess the degree of statistical significance of this relationship.

- $H3_0$: Ancestry does not have an effect on the distribution of character state forms for the various non-metric traits.
- $H3_1$: Ancestry has an effect on the distribution of character state forms for the various non-metric traits.

In other words, if the null hypothesis is true in the population, a character state of a given non-metric trait is equally as likely to be exhibited by an individual of Southeast Asian ancestry as it is by an individual of Northeast Asian ancestry. If the alternative hypothesis is true, certain trait forms will be exhibited in higher frequency for individuals of Southeast Asian ancestry compared to individuals of Northeast Asian ancestry, and vice versa. By rejecting the null hypothesis, it can be argued that certain trait forms of the various cranial and dental non-metric traits may be characteristic of individuals of Southeast Asian ancestry, and others may be characteristic of individuals of Northeast Asian ancestry based on the analysis of the sample. This would lend support to the hypothesis that Southeast Asian and Northeast Asian populations can be characterized by different suites of non-metric traits.

PREDICTIONS

The first two research objectives of this thesis can be generalized to entail describing the expression of cranial and dental non-metric traits in the Southeast and Northeast Asian sample. Because of the migratory history of East Asians into North America and the Pacific Islands, it is predicted that the East Asian populations analyzed in this study will share trait expression with these groups on some level. More specifically, the sample of Southeast Asian individuals is expected to share trait expression with Pacific Islanders, while the sample of Northeast Asian individuals is expected to share trait expression with Native Americans. These expectations follow the history of population movement out of East Asia and the subsequent directional pattern of gene flow.

Biological distance analyses of East Asian archaeological populations have shown that regional Southeast and Northeast Asian populations cluster into discrete groups. When populations outside of continental East Asia are included, Southeast Asian groups form a cluster with Pacific Island populations, and Northeast Asian groups form a cluster with Alaskan Eskimos and Native American populations (Matsumura 1995). While bioarchaeologists study a battery of traits that differs from those of forensic anthropologists to establish these population clusters, it is hypothesized that a number of the non-metric traits examined in the present thesis will show a difference in expression between the Southeast Asian and Northeast Asian sample.

Traits Expected to Characterize Southeast and Northeast Asian Ancestry

Though there is a dearth of studies discussing non-metric trait expression of East Asian populations in the forensic literature, Gill (1998) provides a very general description of trait expression. According to his observations, East Asians have small nasal bones with a medium nasal form. In profile, the nasal area is concave with a medium-projected nasal spine. The nasal sill is described as medium, which contributes to moderate alveolar prognathism. Malar tubercles are projecting from the maxillae, which meet the zygomatics at an "angled" suture. The palate is parabolic or elliptical in shape and the palatine suture is straight or jagged.

The use of vague descriptors in non-metric trait analyses was addressed by Hefner (2003), who included a sample of East Asian individuals in his study. One of Hefner's (2003) primary goals was to establish a higher level of standardization in scoring by creating drawings and descriptions of the various character states of each non-metric trait. The observations of Hefner (2003) are, therefore, much more detailed than those offered by Gill (1998). In his analysis, Hefner (2003) found that East Asians were characterized by a straight inferior nasal aperture (i.e. absence of a nasal sill and guttering); a nasal aperture width that was widest at the base; the absence of a post-bregmatic depression;

minimal projection of the nasal spine; an S-shaped zygomaticomaxillary suture; variable expression in shape of the transverse palatine suture; moderate expression of both the posterior zygomatic and malar tubercles; a low incidence of nasal overgrowth; near absence of the metopic suture; and a high incidence of supra-nasal suture obliteration. While the results of Hefner's (2003) analysis are more detailed than the summary of traits given by Gill (1998), the sample only included individuals representing Northeast Asian populations. In order to learn something about non-metric trait expression in Southeast Asian populations, one must reference the bioarchaeological literature.

Bioarchaeological studies of non-metric trait expression in East Asian populations are much more extensive than the few accounts from the forensic literature. However, the traits commonly assessed for biological distance analysis differ from those used by the forensic anthropologist to assess ancestry. For this reason, we can rely on only a few select trait frequencies from the bioarchaeological literature to make predictions about what we should expect to see in the current samples. One trait that has received attention from both bioarchaeologists and forensic anthropologists is the persistence of the metopic suture into adulthood. This trait, which is sometimes referred to as *metopism*, has been observed in low frequency among Northern Chinese archaeological samples (Ishida 1995, Ishida & Dodo 1993), Hawaiian (Ishida & Dodo 1993, Kellock & Parsons 1970), Modern Japanease (Ishida & Dodo 1993), and Alaskan Eskimos (Ishida & Dodo 1993). These observations suggest that the persistence of the metopic suture should also occur in low frequency among the two East Asian samples in this study.

Another trait that has received attention by bioarchaeologists and forensic anthropologists alike is the presence of incisor shoveling of the maxillary central and lateral incisors of populations of East Asian ancestry. While the trait has been observed in both Southeast and Northeast regional populations, it has a higher frequency, or a more marked expression, among Northeast Asians and their New World descendents. Suzuki and Sakai (1964) observed a high frequency of shoveling among Chinese, Japanese, and Native American groups, but a low frequency of marked incisor shoveling among Polynesians. A similar pattern was found by Matsumura and Hudson (2005), who observed a lower incidence of shoveling in Southeast Asian populations compared to more northern East Asian groups. These observations suggest that the degree of incisor shoveling (in constellation with other characters) may be a reliable trait that can be used to distinguish individuals of Southeast and Northeast Asian ancestry.

Finally, it is expected that the differences in dental non-metric traits that distinguish Sundadonts from Sinodonts (Turner 1983, 1990; Table 1) (or in the present study, Southeast Asians from Northeast Asians, respectively) will be observed. With specific reference to the use of such features in the forensic context, Scott and Turner (1997) suggest that dental remains exhibiting incisor shoveling, bilateral winging of the first incisors, upper first molar enamel extensions, and the absence of a molar fifth cusp are more likely to represent an individual of Sinodont (Northeast Asian) descent compared to any other population. However, the authors warn that the traits should be used "as constellations of characters rather than as isolated traits" in order to facilitate an ancestry estimation (Scott & Turner 1997: 315).

CHAPTER 5: MATERIALS AND METHODS

This study documents the expression of cranial and dental non-metric traits in a sample of individuals of Southeast and Northeast Asian ancestry. The sample includes cranial and dental remains of 49 individuals of Southeast Asian ancestry and 93 individuals of Northeast Asian ancestry (Table 3). The remains of the individuals of Southeast Asian ancestry were recovered between 1974 and spring of 2007 by teams of the Joint POW/MIA Accounting Command Center Central Identification Laboratory (JPAC—CIL) during recovery missions in Southeast Asia, including the countries of Laos, Vietnam, and Cambodia. All of the individuals in this sample are casualties of the Vietnam Conflict and are currently housed in the collections of the JPAC—CIL. The Northeast Asian sample includes the remains of individuals acquired by a variety of means. The collection of 74 Chinese individuals is comprised of salmon cannery workers recovered from Kodiak Island by Hrdlicka during the early twentieth century. Fifteen of the Japanese individuals are former anatomical specimens from the Tokyo Medical School, and the other is a WWII casualty recovered by teams of the JPAC—CIL from the island of Okinawa. Finally, the Korean sample is comprised of two individuals recovered by teams of the JPAC—CIL during recovery missions in the Republic of Korea, while the other was collected by Hrdlicka during a visit to Northeast Asia. The three individuals recovered by teams of the JPAC—CIL are currently housed in the collections at the JPAC—CIL. The remains of the other Northeast Asian individuals are currently housed in the collections at the National Museum of Natural History, Smithsonian Institution, Washington D.C.

Table 3: Summary of the sample used in the present study.

Location of Recovery	**Ancestry**	**Number of Individuals**
Laos	Southeast Asian	3
Cambodia	Southeast Asian	4
Vietnam	Southeast Asian	42
Kodiak Island	Northeast Asian (Chinese)	74
Tokyo Medical School	Northeast Asian (Japanese)	15
Okinawa	Northeast Asian (Japanese)	1
Republic of Korea	Northeast Asian (Korean)	3

Cranial Non-Metric Traits

While researchers have used numerous non-metric traits to investigate population relatedness and document human variation, only a selection of these are used in the forensic assessment of ancestry. Recently, Hefner (2002, 2003, 2003a) has proposed a move towards the standardization of scoring methods for cranial non-metric traits in the forensic context by developing discrete categories that can be scored using a categorical scale for 13 cranial non-metric traits. In order to further support these efforts, the present study evaluates these 13 traits on each cranium according to Hefner (2003). Both the descriptions and illustrations (Hefner 2003) of the various trait forms were used to assign a score to each non-metric trait. Table 4 provides an abbreviated description of the cranial non-metric traits and their forms of expression.

Table 4: Summary of the cranial non-metric traits evaluated in the present study. The thirteen traits are described and illustrated by Hefner (2003).

Cranial Non-Metric Trait	Trait Abbreviation	Possible Score
Inferior nasal morphology	INA	0 – guttered 1 – incipient gutter 2 – straight 3 – partial sill 4 – sill
Nasal bone structure	NBS	0 – Quonset-hut (round) 1 – hut (oval) 2 – tented (plateau) 3 – vaulted (semi-triangular) 4 – steepled (triangular)
Nasal aperture width	NAW	1 – long (narrow) 2 – rounded 3 – wide
Interorbital breadth	IOB	1 – narrow 2 – intermediate 3 – broad
Post-bregmatic depression	PBD	0 – absent 1 – present
Anterior nasal spine	ANS	0 – short, rounded 1 – dull 2 – medium 3 – long
Zygomaticomaxillary suture shape	ZS	1 – angled 2 – smooth 3 – S-shaped
Transverse palatine suture	TP	0 – straight, symmetrical 1 – anterior bulging at midline, symmetrical 2 – anterior bulging right side, posterior bulging left side 3 – posterior bulging at midline, symmetrical
Posterior zygomatic tubercle	ZT	0 – absent 1 – weak 2 – medium 3 – strong
Malar tubercle	MT	0 – absent 1 – incipient 2 – trace 3 – present
Nasal overgrowth	NO	0 – absent 1 – present 2 – unobservable
Metopic suture	MS	0 – absent 1 – present
Supranasal suture	SPS	1 – open 2 – closed, but visible 3 – closed, barely visible 4 – obliterated

Dental Non-Metric Traits

Non-metric traits of the dentition have received extensive attention in the bioarchaeological literature, and less so in the forensic (but see Edgar 2005). Regardless of the context, however, most researchers interested in non-metric dental variation focus on evaluating the crown and/or root traits described in the Arizona State University Dental Anthropology System. For the present study, each tooth was scored for the appropriate non-metric traits according to the guidelines outlined in the ASU system. In order to assign a score to each trait, both the descriptions (Turner *et al.* 1991, Scott & Turner 1997) and casts of the various trait forms were used. Table 5 provides an abbreviated description of the dental non-metric traits and their forms of expression.

Table 5: Summary of dental non-metric traits evaluated in the present study. A full description of the various trait forms is provided by Turner *et al.* (1991) and Scott and Turner (1997).

Dental Non-Metric Trait	Teeth Scored	Possible Score
Winging	UI1	1 – bilateral winging 2 – unilateral winging 3 – straight 4 – counter-winging
Shoveling	UI1, UI2, UC, LI1, LI2	0 – absent 1 – faint 2 – trace 3 – semishovel 4 – semishovel, stronger than grade 3 5 – shovel 6 – marked shovel 7 – barrel (UI2 only)
Labial convexity	UI1	0 – flat 1 – trace convexity 2 – weak convexity 3 – moderate convexity 4 – pronounced convexity

Table 5 (*continued*)

Double shoveling	UI1, UI2	0 – absent 1 – faint 2 – trace 3 – semi-double shovel 4 – double shovel 5 – pronounced double shovel 6 – extreme double shovel
Interruption groove	UI1, UI2	0 – none M – mesiolingual border D – distolingual border MD – both lingual borders Med. – medial are of cingulum
Tuberculum dentale	UI1, UI2, UC	0 – no expression 1 – faint ridging 2 – trace ridging 3 – strong ridging 4 – pronounced ridging 5 – small cuspule with free apex 6 – strong cusp with free apex
Canine mesial ridge	UC	0 – M and D ridges are the same size 1 – mesiolingual ridge larger than distolingual; is weakly attached to the tuberculum dentale 2 – mesiolingual ridge larger than distolingual; is moderately attached to the tuberculum dentale 3 – mesiolingual ridge is much larger than distolingual; fully incorporated into the tuberculum dentale
Canine distal accessory ridge	UC, LC	0 – absent 1 – faint 2 – weakly developed 3 – moderately developed 4 – strongly developed 5 – very pronounced
Premolar mesial and distal accessory cusps	UP	0 – absent 1 – present
Tricusped premolars	UP	0 – extra distal cusp (hypocone) absent 1 – hypocone present
Distosagittal ridge	UP3	0 – normal premolar form 1 – distosagiggal ridge present

Table 5 *(continued)*

Metacone	UM1, UM2, UM3	0 – absent 1 – attached ridge at metacone site 2 – fait cuspule with free apex present 3 – weak cusp present 4 – metacone large 5 – metacone very large
Hypocone	UM1, UM2, UM3	0 – absent 1 – faint ridging present at site 2 – faint cuspule present 3 – small cusp present 3.5 – moderate-sized cusp present 4 – large cusp present 5 – very large cusp present
Cusp 5 (Metaconule)	UM1, UM2, UM3	0 – site of cusp 5 is smooth 1 – faint cuspule present 2 – trace cuspule present 3 – small cuspule present 4 – small cusp present 5 – medium-sized cusp present
Carabelli's trait	UM1, UM2, UM3	0 – mesiolingual aspect of cusp 1 is smooth 1 – groove is present 2 – pit is present 3 – small Y-shaped depression present 4 – large Y-shaped depression present 5 – small cusp without a free apex 6 – medium cusp with an attached apex 7 – large free cusp present
Parastyle	UM1, UM2, UM3	0 – buccal surfaces of cusps 2 and 3 are smooth 1 – pit present near buccal groove between cusps 2 and 3 2 – small cusp with an attached apex is present 3 – medium cusp with a free apex is present 4 – large cusp with a free apex is present 5 – very large cusp with a free apex is present 6 – free peg-shaped crown attached to the root of UM3

Table 5 *(continued)*

Enamel extensions	UP, UM1, UM2, UM3	0 – enamel border is straight 1 – faint, approximately 1.0 mm- long extension toward the root present 2 – medium, approximately 2.0 mm-long extension toward the root present 3 – extension > 4.0 mm-long
Premolar lingual cusp variation	LP3, LP4	A – no lingual cusp 0 – one lingual cusp 1 – one or two lingual cusps 2 – two lingual cusps; mesial is much larger than distal 3 – two lingual cusps; mesial is larger than distal 4 – two lingual cusps; mesial and distal are equal in size 5 – two lingual cusps; distal is larger than mesial 6 – two lingual cusps; distal is much larger than mesial 7 – two lingual cusps; distal is very much larger than mesial 8 – three lingual cusps; equal in size 9 – three lingual cusps; mesial is much larger than medial and/or distal
Anterior fovea	LM1	0 – absent 1 – weak ridge connects mesial aspects of cusps 1 and 2 2 – connecting ridge is larger than in grade 1 3 – groove is longer than in grade 2 4 – groove is very long and mesial ridge is robust
Groove pattern	LM1, LM2, LM3	Y – cusps 2 and 3 are in contact + – cusps 1 – 4 are in contact X – cusps 1 and 4 are in contact
Cusp number	LM1, LM2, LM3	4 – cusps 1 – 4 are present 5 – cusp 5 (hypoconulid) is also present 6 – cusp 6 (entoconulid) is also present

Table 5 (*continued*)

Deflecting wrinkle	LM1	0 – absent 1 – cusp 2 medial ridge is stright, but has a midpoint constriction 2 – medial ridge is deflected distally, but does not contact cusp 4 3 – medial ridge is deflected distally, contacting cusp 4
Distal trigonid crest	LM1, LM2, LM3	0 – absent 1 – present
Protostylid	LM1, LM2, LM3	0 – buccal surface is smooth 1 – pit occurs in the buccal groove 2 – buccal groove is curved distally 3 – faint secondary groove extends mesially from the buccal groove 4 – secondary groove more pronounced 5 – secondary groove stronger 6 – secondary groove extends across most of the buccal surface of cusp 1 7 – cusp with a free apex present
Cusp 5 (hypoconulid)	LM1, LM2, LM3	0 – absent 1 – present, but very small 2 – small 3 – medium-sized 4 – large 5 – very large
Cusp 6 (entoconulid)	LM1, LM2, LM3	0 – absent 1 – much smaller than cusp 5 2 – smaller than cusp 5 3 – equal in size to cusp 5 4 – larger than cusp 5 5 – much larger than cusp 5
Cusp 7 (metaconulid)	LM1, LM2, LM3	0 – absent 1 – faint cusp present 1A – bulge on the lingual surface of cusp 2 2 – small 3 – medium-sized 4 – large

U = maxillary, L = mandibular, I = incisor, C = canine, P = premolar, M = molar

Scoring, Recording, and Analysis of the Non-Metric Traits

Cranial and dental non-metric traits were scored for each individual by the author. Each set of remains was examined individually, and all scores were recorded on separate scoring sheets (cranial and dental) before moving on to the next individual. Crania of the Southeast Asian sample were scored twice to establish the degree of intra-observer error. Scoring sessions were separated by four weeks and no reference was made to the scores assigned during the first scoring session. Intra-observer agreement in scoring was established using Cohen's Kappa statistic.

It is important to note that sample size for each trait does not reflect the true sample size of the study. It was the intention of the author to score all traits when possible; however, due to the fragmentary nature of some remains, it was not possible to score all of the traits for each individual. For traits that are bilaterally occurring, a score was given for both the right and left side, though only the score from the side with the greatest expression of a trait was used in the final analysis. Such a method uses the individual, rather than the side, as the unit of analysis, and has been advocated by Korey (1980) and McGrath and colleagues (1984) (but see Green *et al.* 1979 and Ossenberg 1981 for an alternative position).

The frequency of each character state for all non-metric traits was determined for both the Southeast and Northeast Asian samples. Contingency tables were created using the Statistical Package for Social Sciences (SPSS) version 16.0 in order to compare the frequency of expression of the various character states for each of the cranial and dental non-metric traits. The statistical significance of the observed differences was evaluated using a chi-square goodness-of-fit test.

CHAPTER 6: RESULTS

The expression of cranial and dental non-metric traits in a sample of individuals of Southeast and Northeast Asian ancestry is assessed in order to determine if there is a suite of traits characteristic of each group. In order to determine whether or not traits were being consistently scored by the observer, the cranial traits were scored on two separate occasions for the sample of Southeast Asian individuals. Cohen's kappa statistic, which evaluates the level of agreement between two sets of scores assigned to mutually exclusive categories, was used to evaluate the level of intra-observer agreement. A kappa value of 1 indicates perfect agreement, and a value of 0 indicates a level of agreement that is no greater than what would be expected by chance. The results of the current analysis show a high level of intra-observer agreement in scoring for the non-metric cranial traits (Table 6). This suggests that Hefner's (2003) trait descriptions and illustrations are comprehensible to those other than the original author. The level of inter-observer agreement in scoring, however, remains to be established.

Summary of Non-Metric Trait Expression in the Southeast Asian Sample

Due to the circumstances surrounding the deposition of the remains, the sample of individuals of Southeast Asian ancestry was highly fragmentary in nature. Fragmentation of the cranial remains precludes the observer from examining the *gestalt* of the crania in order to make an ancestral assessment. However, the few crania that were complete can be qualitatively characterized as being spherical in shape with flat facial features and laterally flaring zygomatic arches.

Table 6: Summary of Cohen's Kappa results for the test of intra-observer reliability in scoring of the cranial non-metric traits for the Southeast Asian sample using the scoring methods outlined by Hefner (2003).

Trait	Kappa value	Approx. Sig.
Inferior nasal aperture	0.614	0.000
Nasal bone structure	0.590	0.000
Nasal aperture width	0.596	0.000
Inter-orbital breadth	0.422	0.001
Anterior nasal spine	0.625	0.000
Zygomaticomaxillary suture shape	0.655	0.000
Transverse palatine suture shape	0.644	0.000
Zygomatic tubercle	0.532	0.000
Malar tubercle	0.730	0.000
Nasal overgrowth	0.627	0.000
Metopic suture	0.839	0.000
Supranasal suture	0.700	0.000

Non-metric trait expression in the Southeast Asian sample was variable. The fragmentary nature of the remains often led to a reduction in sample size, but inherently offers support for the need of further research into non-metric trait expression as a means of assessing ancestry in a forensic context. The Southeast Asian sample is characterized as having a nasal aperture that is widest at the base with only slight expression of a nasal sill inferiorly. The inferior nasal margin has moderate expression of the anterior nasal spine. The overall shape of the aperture is most often exhibited as hut (oval), but may also appear as Quonset-hut (round) or steepled (triangular); the valuted (semi-triangular) form was absent in the Southeast Asian sample. The middle-grade of nasal aperture width is accompanied by a middle-grade of inter-orbital breadth, which qualitatively adds to the flatness of the face. Below the orbits, the maxillae exhibit variable expression of the malar tubercle, the majority of cases having a process of bone that project inferiorly to an imaginary horizontal line placed bilaterally below the zygomaticomaxillary suture. The expresson of the zygomaticomaxillary suture is S-shaped, and there is a low incidence of a tubercle on the posterior zygomatic. The transverse palatine suture shape appears to be variable, as no single type was found to be characteristic of the group. There is a very low persistence of the metopic suture, but a moderate persistence of the supranasal suture.

Analysis of dental non-metric trait expression in the Southeast Asian sample was also plagued by small sample sizes due to the fragmentary nature of the remains. The sample of single-rooted teeth was small, as these teeth may often be lost during decomposition, especially in cases of secondary burials. The central maxillary incisors that were present in the sample exhibited a moderate degree of shoveling (ASU grades 2-4), as did the lateral incisors. Double-shoveling was minimal on the maxillary incisors and absent on the maxillary canines and premolars. Maxillary canines were lacking a mesial ridge, and few exhibited a distal accessory ridge. An accessory distal cusp was lacking on the maxillary premolars, as were enamel extensions. The first maxillary molars (UM1) are characterized as having pronounced metacones and hypocones, with no expression of a fifth cusp. A pronounced metacone was also present on the second maxillary molar (UM2), however the hypocone was not as pronounced as on UM1; UM2 also lacked a fifth cusp. Accessory cusps of UM1, the parastyle and Carabelli's trait, were absent in the

Southeast Asian sample. Enamel extensions were occasionally exhibited on UM1 and UM2, but with projection rarely exceeding 2.0 mm.

The sample of mandibular dentition for the Southeast Asian individuals was also dominated by teeth of the distal arcade. The first mandibular molars (LM1) all exhibited 5 cusps, and each lacked an anterior fovea, distal trigonid crest, and protostylid. The groove pattern of LM1 was variable, with the majority exhibiting the "X" pattern (contact between the protoconid and entoconid). Few LM1 teeth showed the projection of a sixth cusp, and one displayed a developed seventh cusp. The second mandibular molar (LM2) was often lacking a pronounced hypoconulid, and exhibited both the "Y" (contact between the metaconid and hypoconid) and "+" (equal contact between the protoconid, metaconid, hypoconid, and entoconid) groove patterns in equal frequencies. Cusp 6 and 7 were not exhibited on the LM2 in this sample, while enamel extensions for LM1 and LM2 were exhibited by approximately half of the teeth observed.

Summary of Non-Metric Trait Expression in the Northeast Asian Sample

The majority of crania in the Northeast Asian sample were complete, except for those of the few individuals that were recovered by teams of the JPAC—CIL. Overall, the crania of the Northeast Asian individuals can qualitatively be described as spherical with wide, flattened facial features. The zygomatic arches flared laterally, and the shape of the palate was elliptical.

The completeness of the crania in this sample created a much larger Northeast Asian sample compared to the Southeast Asians. For nearly all individuals in this sample, it was possible to evaluate all of the 13 cranial non-metric traits. The nasal aperture of Northeast Asian individuals is widest at the horizontal midline, with more than half of the individuals exhibiting some level of expression of a nasal sill at the inferior margin. The overall shape of the nasal aperture is best described as Quonset-hut (round) or hut (oval), though all shapes were present in the sample. The inter-orbital breadth was of a medium or wide grade, which presumably adds to the appearance of the flattened facial morphology. The area inferior to the orbits was moderately marked by the presence of a malar tubercle, and nearly always exhibited an S-shaped zygomaticomaxillary suture. The posterior margin of the zygomatic bone was frequently marked by the projection of a posterior zygomatic tubercle. The shape of the transverse palatine suture was variable, with all types being exhibited in near equal frequencies. Finally, there was a low incidence in the persistence of the metopic suture, but the supranasal suture was visible in half of the crania surveyed.

Tooth preservation was also better in the Northeast Asian sample, which translates to more data on the anterior dentition than was possible with the Southeast Asian sample. However, the retention of the teeth in the alveolus, combined with the museum collection curation, meant that root traits were not able to be examined for this sample. As a result, root traits could not be compared between the two populations.

The maxillary central incisors were most often straight in-line with the upper dental arcade, and did not exhibit significant "winging". Shoveling of both the central and lateral maxillary incisors was pronounced, with double-shoveling also common. The maxillary canines lacked double-shoveling, but did exhibit a slight expression (grade 1) of the tuberculum dentale. The canine mesial and distal accessory ridge was nearly absent in the sample, as was the presence of accessory cusps on the maxillary premolars. The first maxillary molar (UM1) was marked by pronounced expression of the metacone and hypocone, but only minimal expression of a fifth cusp. Accessory cusps such as the parastyle and Carabelli's trait were also absent on UM1. The second maxillary molar (UM2) expressed the metacone to its full potential, but has hypocones that are smaller than seen on UM1. The fifth cusp, parastyle, and Carabelli's trait were all absent on UM2 in the Northeast Asian sample. Enamel extensions for the maxillary dentition were absent from the premolars, but present on UM1 and UM2, with both teeth frequently exhibiting projections beyond 2.0 mm.

The mandibular teeth of the Northeast Asian sample were well secured within the alveolus and did not permit scoring of the root traits; crown traits, however, were easily observable and scored. The first mandibular molar (LM1) exhibited frequent expression of the hypoconulid, though it was only moderately developed. The groove pattern of LM1 was most always "Y" (contact between the metaconid and hypoconid), with minimal expression of the deflecting wrinkle, and a sixth cusp. The second mandibular molar (LM2) was also characterized by a frequent expression of the hypoconulid in moderate form, but most often exhibited the "X" (contact between the protoconid and entoconid) groove pattern. The sixth and seventh cusps were seldom observed on the LM2. Finally, enamel extensions of the mandibular dentition were absent on the premolars, but were frequent and far projecting on the LM1 and LM2.

Comparison of Cranial Non-Metric Traits in the Southeast and Northeast Asian Samples

Results of the cranial analysis show that a distinction between individuals of Southeast Asian and Northeast Asian ancestry is not easily achieved using the discrete categories developed by Hefner (2003). When sample size is relatively small, an increase in the number of categories per trait correspondingly increases the likelihood that cells will have expected counts less than 5. Violation of this statistical assumption means that the data cannot be subjected to a variety of statistical analyses, as was found with the present data set for 11 of the 13 traits, the exceptions being the transverse palatine suture shape and the posterior zygomatic tubercle.

In order to allow further statistical analysis, the discrete categories developed by Hefner (2003) were modified (when possible) to a two-category, present-or-absent system. Traits that lend themselves to such a scoring system include those that are scored on a graded scale, but not those for which each category represents a discrete shape. For example, instead of scoring the inferior nasal aperture on a graded scale from 0 to 4, where 0 = guttering, 1 = incipient guttering, 2 = straight, 3 = partial sill, and 4 = sill, the trait was changed to examine the presence or absence of the nasal sill. In this new scale, absence of the sill corresponds to Hefner's (2003) 0 – 2 categories, and presence is defined by Hefner's (2003) 3 – 4 categories. In other words, if any evidence of a sill is present the individual is scored as a 1, or presence of the nasal sill, regardless of how far the sill projects from the mid-face. Table 7 summarizes the traits whose scale was modified to enable further analysis.

Table 7: Summary of modifications to cranial non-metric trait scoring system developed by Hefner (2003).

Hefner (2003) Scoring System	Changed?	Modified Scoring System
Inferior nasal morphology	Yes	**Presence of nasal sill**
0 – guttered 1 – incipient gutter 2 – straight 3 – partial sill 4 – sill		0 (Hefner 0 – 2) = absent 1 (Hefner 3 -4) = present
Nasal bone structure	No	
Nasal aperture width	No	
Interorbital breadth	No	
Post-bregmatic depression	NA	
Anterior nasal spine 0 – short, rounded 1 – dull 2 – medium 3 – long	Yes	**Presence of nasal spine** 0 (Hefner 0 – 1) = absent 1 (Hefner 2 – 3) = present
Zygomaticomaxillary suture shape	Yes	**Presence of smooth suture shape**
1 – angled 2 – smooth 3 – S-shaped		0 (Hefner 1, 3) = absent 1 (Hefner 2) = present
Transverse palatine suture	No	
Posterior zygomatic tubercle	Yes	**Presence of zygomatic tubercle**
0 – absent 1 – weak 2 – medium 3 – strong		0 (Hefner 0) = absent 1 (Hefner 1 – 3) = present
Malar tubercle 0 – absent 1 – incipient 2 – trace 3 – present	Yes	**Presence of malar tubercle** 0 (Hefner 0 – 1) = absent 1 (Hefner 2 – 3) = present
Nasal overgrowth 0 – absent 1 – present 2 – unobservable*	Yes	**Presence of nasal overgrowth** 0 (Hefner 0) = absent 1 (Hefner 1) = present
Metopic suture	NA	

Table 7 *(continued)*

Supranasal suture	Yes	**Presence of supranasal suture**
1 – open 2 – closed, but visible 3 – closed, barely visible 4 – obliterated		0 (Hefner 4) = absent 1 (Hefner 1 – 3) = present

*Character state was eliminated as a category during scoring modification.

Modifications to the scoring system allowed 9 of the 13 traits to be scored on a present-or-absent basis, which enabled the data to be compared between populations using the Chi-Square goodness-of-fit test. Such a test permitted investigation of the statistical significance of any observed differences in the distribution of frequency of expression of various trait forms between the Southeast and Northeast Asian samples.

Table 8 summarizes the observed frequency of expression of the various character states for each of the cranial non-metric traits as scored using the modified system[1]. The table also shows which of those characters were exhibited in frequencies found to be statistically significant between the two populations. Cranial non-metric traits that were found to differ significantly between the Southeast and Northeast Asian population include the presence of the nasal sill (inferior nasal aperture), nasal aperture width, inter-orbital width, posterior zygomatic tubercle, and nasal overgrowth.

[1] Tables summarizing the results using the scoring method outlined by Hefner (2003) can be found in Appendix A.

Table 8: Summary of cranial non-metric trait comparison between the Southeast and Northeast Asian samples.

Trait	SE Asian sample	NE Asian sample	*p*-value*
Inferior nasal aperture			
Presence of nasal sill	13/35	57/88	0.005
	More likely to have guttered or incipient gutter	More likely to have partial sill or sill	
Nasal bone structure			
Quonset-hut (round)	3/26	24/78	0.124
Hut (oval)	15/26	32/78	
Tented (plateau)	0/26	1/78	
Vaulted (semi-triangular)	3/26	13/78	
Steepled (triangular)	5/26	8/78	
Nasal aperture width			
Long (narrow)	2/29	0/89	0.000**
Rounded	20/29	33/89	
Wide	7/29	56/89	
	More likely to have nasal aperture that is widest at the base with a superior constriction	More likely to have nasal aperture that is widest at the horizontal midline	
Inter-orbital breadth			
Narrow	6/32	7/90	0.002**
Intermediate	18/32	28/90	
Broad	8/32	55/90	
	More likely to have intermediate inter-orbital breadth	More likely to have wide inter-orbital breadth	
Post-bregmatic depression			
Presence of depression	0/28	11/89	0.051
Anterior nasal spine			
Presence of nasal spine	5/35	24/84	0.098
Zygomaticomaxillary suture shape			
Presence of smooth suture shape	30/35	79/87	0.410
Transverse palatine suture shape			
Straight, symmetrical	9/29	13/82	0.186
Anterior bulging at midline, symmetrical	3/29	21/82	
Asymmetrical bulging at midline	10/29	29/82	

Table 8 (*continued*)

Posterior bulging at midline, symmetrical	7/29	19/82	
Posterior zygomatic tubercle			
Presence of zygomatic tubercle	19/36 Less likely to have projection of bone known as posterior zygomatic tubercle	76/90 More likely to have projection of bone at site of zygomatico-frontal suture	0.000
Malar tubercle			
Presence of malar tubercle	22/34	43/90	0.092
Nasal overgrowth			
Presence of nasal overgrowth	6/22	3/67	0.002**
	More likely to have nasal bones that project beyond the maxillae	Less likely to have nasal bones that project beyond the maxillae	
Metopic suture			
Presence of metopic suture	4/33	6/89	0.336
Supranasal suture			
Presence of supranasal suture	24/32	56/89	0.178

*significance is at the p=0.05 level.
**significance possibly a result of cells with expected counts < 5.

Results of this analysis reveal that Southeast Asian individuals are characterized as being more likely to display guttering or incipient guttering of the inferior nasal aperture; exhibit nasal aperture widths that are widest at the base; have a narrow inter-orbital breadth compared to Northeast Asian individuals; are not likely to display a posterior zygomatic tubercle; and are more likely to have nasal bones that project anteriorly beyond the maxillae. Northeast Asian individuals are characterized as being more likely to have a partial or full nasal sill; display a nasal aperture that is widest at the horizontal midline; have a wide inter-orbital breadth; exhibit some degree of bone projection on the posterior zygomatic; and are less likely than

Southeast Asian individuals to have nasal bones that project anteriorly beyond the maxillae. Both populations were found to exhibit variation in nasal bone structure, although the tented (plateau) form was found in low frequency among both groups (0.0% among Southeast Asians and 1.3% among Northeast Asians). Few individuals from either population had a presence of post-bregmatic depression or metopic suture, while individuals from both populations exhibited the smooth zygomaticomaxillary suture shape in high frequency (85.7% among Southeast Asians and 90.8% among Northeast Asians).

Comparison of Dental Non-Metric Traits in the Southeast and Northeast Asian Samples

Results of the dental analysis show there are few traits that differ significantly between the Southeast and Northeast Asian samples. Sample size presented the same problem as was encountered during the cranial analysis, in fact more notably so because the number of discrete categories describing the expression of each dental trait was greater than for the cranial traits. As a result, only one of the 72 generated cross tabulations, the protostylid of the first mandibular molar, produced a valid chi-square statistic, where no cells had expected counts less than 5. In order to facilitate further analysis, modifications were made to the ASU dental scoring system procedures in accordance with those previously published in the literature. A number of researchers have modified the scoring of these traits from the graded to a presence or absence scale, and their scoring criteria were used if available. Table 9 summarizes the traits whose scoring system has been previously modified.

Table 9: Summary of modifications to ASU dental non-metric trait scoring system procedures.

ASU Scoring System (Turner *et al.* 1991)	Changed?	Modified Scoring System
Winging	No	
Shoveling	No	
Labial convexity	No	
Double shoveling	No	
Interruption groove	No	
Tuberculum dentale	Yes	Turner *et al.* 1991
0 – no expression 1 – faint ridging 2 – trace ridging 3 – strong ridging 4 – pronounced ridging 5 – small cuspule with free apex 6 – strong cusp with free apex		0 (ASU 0 – 2) = absent 1 (ASU 3 – 6) = present
Canine mesial ridge	Yes	0 = absent
0 – M and D ridges are the same size 1 – mesiolingual ridge larger than distolingual; is weakly attached to the tuberculum dentale 2 – mesiolingual ridge larger than distolingual; is moderately attached to the tuberculum dentale 3 – mesiolingual ridge is much larger than distolingual; fully incorporated into the tuberculum dentale		1 (ASU 1 – 3) = present
Canine distal accessory ridge	No	
Premolar mesial and distal accessory cusps	NA	
Distosagittal ridge	No	
Metacone	Yes	0 (ASU 0 – 3) = absent
0 – absent 1 – attached ridge at metacone site 2 – fait cuspule with free apex present 3 – weak cusp present 4 – metacone large 5 – metacone very large		1 (ASU 4 – 5) = present
Hypocone 0 – absent 1 – faint ridging present at site 2 – faint cuspule present	Yes	0 (ASU 0 – 2) = absent 1 (ASU 3 – 5) = present

Table 9 (*continued*)

3 – small cusp present 3.5 – moderate-sized cusp present 4 – large cusp present 5 – very large cusp present		
Cusp 5 (Metaconule) 0 – site of cusp 5 is smooth 1 – faint cuspule present 2 – trace cuspule present 3 – small cuspule present 4 – small cusp present 5 – medium-sized cusp present	Yes	0 (ASU 0 – 3) = absent 1 (ASU 4 – 5) = present
Carabelli's trait 0 – mesiolingual aspect of cusp 1 is smooth 1 – groove is present 2 – pit is present 3 – small Y-shaped depression present 4 – large Y-shaped depression present 5 – small cusp without a free apex 6 – medium cusp with an attached apex 7 – large free cusp present	Yes	0 (ASU 0 – 4) = absent 1 (ASU 5 – 7) = present
Parastyle 0 – buccal surfaces of cusps 2 and 3 are smooth 1 – pit present near buccal groove between cusps 2 and 3 2 – small cusp with an attached apex is present 3 – medium cusp with a free apex is present 4 – large cusp with a free apex is present 5 – very large cusp with a free apex is present 6 – free peg-shaped crown attached to the root of UM3	Yes	0 (ASU 0 – 2) = absent 1 (ASU 3 – 6) = present
Enamel extensions 0 – enamel border is straight 1 – faint, approximately 1.0 mm-long extension toward the root present 2 – medium, approximately 2.0 mm-long extension toward the root present 3 – extension > 4.0 mm-long	Yes	0 (ASU 0 – 1) = absent 1 (ASU 2 – 3) = present
Premolar lingual cusp variation	No	
Anterior fovea	No	

Table 9 *(continued)*

Groove pattern 1 – X, cusps 1 and 4 are in contact 2 – Y, cusps 2 and 3 are in contact 3 – +, cusps 1 – 4 are in contact	Yes	**Presence of Y pattern** Jørgensen 1955 0 (1, 3) = absent 1 (2) = present **Presence of X pattern** Jørgensen 1955 0 (2, 3) = absent 1 (1) = present
Molar cusp number 4 – cusps 1 – 4 are present 5 – cusp 5 (hypoconulid) is also present 6 – cusp 6 (entoconulid) is also present	Yes	**Hypoconulid reduction** Turner *et al.* 1991 0 (ASU 5 – 6) = absent 1 (ASU 4) = present
Deflecting wrinkle 0 – absent 1 – cusp 2 medial ridge is stright, but has a midpoint constriction 2 – medial ridge is deflected distally, but does not contact cusp 4 3 – medial ridge is deflected distally, contacting cusp 4	Yes	Turner *et al.* 1991 0 (ASU 0 – 1) = absent 1 (ASU 2 – 3) = present
Distal trigonid crest	NA	
Protostylid 0 – buccal surface is smooth 1 – pit occurs in the buccal groove 2 – buccal groove is curved distally 3 – faint secondary groove extends mesially from the buccal groove 4 – secondary groove more pronounced 5 – secondary groove stronger 6 – secondary groove extends across most of the buccal surface of cusp 1 7 – cusp with a free apex present	Yes	0 (ASU 0 – 6) = absent 1 (ASU 7) = present
Cusp 5 (hypoconulid) 0 – absent 1 – present, but very small 2 – small 3 – medium-sized 4 – large 5 – very large	Yes	0 (ASU 0 – 2) = absent 1 (ASU 3 – 5) = present

Table 9 *(continued)*

Cusp 6 (entoconulid)	Yes	Turner *et al.* 1991
0 – absent 1 – much smaller than cusp 5 2 – smaller than cusp 5 3 – equal in size to cusp 5 4 – larger than cusp 5 5 – much larger than cusp 5		0 = absent 1 (ASU 1 – 5) = present
Cusp 7 (metaconulid)	Yes	Turner *et al.* 1991
0 – absent 1 – faint cusp present 1A – bulge on the lingual surface of cusp 2 2 – small 3 – medium-sized 4 – large		0 (ASU 0 – 1) = absent 1 (ASU 2 – 4) = present

U = maxillary, L = mandibular, I = incisor, C = canine, P = premolar, M = molar

Table 10 summarizes the observed frequency of expression of the various character states for each of the dental non-metric traits as scored using the modified system[2]. The table also shows which of those characters were exhibited in frequencies found to be statistically significant between the two populations. Root traits were eliminated from the analysis as they were unable to be examined in the Northeast Asian sample. In addition, assessment of the character state for a variety of other traits was not undertaken after preliminary analysis proved these traits to be too variable within each sample (e.g. anterior fovea), and/or there were too few teeth in one or both of the samples (e.g. maxillary incisors). These traits have therefore been omitted from the summary table (Table 10).

[2] Tables summarizing the results using the scoring method outlined by Turner *et al.* 1991 can be found in Appendix B.

Table 10: Summary of dental non-metric trait comparison between the Southeast and Northeast Asian samples.

Trait	Tooth	SE Asian sample	NE Asian sample	p-value
Tuberculum dentale				
Presence of tuberculum dentale	UI1	0/6	0/24	---
	UI2	0/11	0/12	---
Canine mesial ridge				
Presence of canine mesial ridge	UC	2/9	2/34	0.133
Premolar accessory cusps				
Presence of accessory cusp	UP3	0/15	0/56	---
	UP4	0/18	0/62	---
Metacone				
Presence of metacone	UM1	25/25	63/63	---
	UM2	19/22	53/56	0.217
	UM3	0/13	26/41	0.000
		Absence of metacone on third mandibular molar	More likely to have metacone on third mandibular molar	
Hypocone				
Presence of hypocone	UM1	26/26	63/64	0.522
	UM2	18/23	45/56	0.833
	UM3	3/13	16/40	0.269
Cusp 5 (Metaconule)				
Presence of metaconule	UM1	0/29	1/63	0.495
	UM2	0/22	0/57	---
	UM3	0/14	0/42	---
Carabelli's trait				
Presence of Carabelli's cusp	UM1	1/28	0/66	0.123
Parastyle				
Presence of Parastyle	LM1	1/27	0/65	0.119
	LM2	0/22	1/57	0.532
	LM3	0/14	0/41	---

Enamel Extensions				
Presence of Enamel Extension	UM1	2/28	20/54	0.004
	UM2	4/23	23/48	0.013
	UM3	2/13	10/35	0.348
		Less likely to have enamel extensions on maxillary 1st and 2nd molars	More likely to have enamel extensions on maxillary 1st and 2nd molars	
	LM1	0/18	30/57	0.000
	LM2	3/23	32/58	0.001
	LM3	3/20	15/41	0.083
		Less likely to have enamel extensions on mand. 1st and 2nd molars	More likely to have enamel extensions on mand. 1st and 2nd molars	
Groove pattern Y				
Presence of "Y" groove pattern	LM1	1/18	22/34	0.000
Groove pattern X				
Presenc of "X" groove pattern	LM2	30/37	35/54	0.000
		Less likely to have "X" groove pattern on second mandibular molars	More likely to have "X" groove pattern on second mandibular molars	
Molar Cusp Number				
Hypoconulid Reduction	LM1	0/18	1/52	0.553
	LM2	13/22	20/53	0.090
	LM3	12/17	21/42	0.149
Deflecting wrinkle				
Presence of deflecting wrinkle	LM1	2/15	2/32	0.417
Protostylid				
Presence of protostylid	LM1	0/20	0/58	---
	LM2	0/23	0/56	---
	LM3	0/19	0/48	---
Cusp 5 (Hypoconulid)				
Presence of hypoconulid	LM1	17/18	45/48	0.916
	LM2	6/20	29/48	0.022
	LM3	4/17	21/41	0.053
		Less likely to have presence of hypoconulid on 2nd and 3rd molars	More likely to have presence of hypoconulid on 2nd and 3rd molars	
Lower molar cusp 6				
Presence of cusp 6	LM1	7/19	8/47	0.082

Table 10 (*continued)*

Lower molar cusp 7				
Presence of cusp 7	LM1	1/19	3/55	0.975

*significance is at the 0.50 level.
**significance possibly a result of cells with expected counts < 5.

Dental non-metric traits that were found to differ significantly between the Southeast and Northeast Asian population include the presence of the metacone on the third mandibular molar; the presence of enamel extensions on the first and second maxillary and mandibular molars; the presence of the "X" groove pattern on the second mandibular molar; and the presence of the hypoconulid on the second and third mandibular molar. All of these traits were exhibited in higher frequency within individuals of Northeast Asian ancestry. Individuals of both the Southeast and Northeast Asian populations can be characterized by an absence of the tuberculum dentale of the maxillary incisors; absence of maxillary premolar accessory cusps; a high prevalence of the metacone and hypocone on the maxillary first and second molars; a low prevalence of Carabelli's cusp, the parastyle, and protostylid; moderate expression of the "Y" groove pattern on the first mandibular molar; a low prevalence of the deflecting wrinkle; and low prevalence of the deflecting wrinkle, and sixth and seventh cusps of the first mandibular molar.

CHAPTER 7: DISCUSSION

The ability of the forensic anthropologist to make an accurate assessment of the ancestry of an unidentified set of human remains is permitted through an extensive understanding of human skeletal variation. Most methods of ancestry assessment require careful measurement or classification of traits of the cranium and/or dentition. Due to their ease of scoring and utility in cases of fragmentary remains, evaluation of non-metric traits is a preferred method for a large number of forensic anthropologists. Recent research into the expression of cranial and dental non-metric traits has aimed to improve the statistical support of such methods, and continues to be a valuable contribution to the field. Improvements to non-metric methods also involve the continued collection of data on non-metric trait expression for a variety of population groups, as exemplified by the recent work that has been devoted to describing trait expression in Hispanic peoples (Anderson 2008; Hinkes 2008; Birkby *et al.* 2008). The purpose of the present thesis is to continue in this endeavor by describing the expression of cranial and dental non-metric traits in a sample of Southeast and Northeast Asian individuals.

Non-Metric Assessment of Southeast and Northeast Asian Ancestry

Comparison of the relative trait frequencies between the Southeast and Northeast Asian samples shows that a number of the examined traits differ significantly in form between individuals of Southeast and Northeast Asian ancestry. These results suggest that the traits commonly used by forensic anthropologists to assess ancestry in a forensic context may have the ability to distinguish Southeast and Northeast Asian individuals if a particular constellation of characters were observed. Table 11 summarizes the traits that may be of use for distinguishing Southeast and Northeast Asian ancestry.

Table 11: Summary of cranial and dental non-metric traits that differ in frequency between the sample of individuals of Southeast Asian and Northeast Asian ancestry. "High" refers to a high observed frequency within the population; "moderate" refers to a moderate observed frequency within the population; "low" refers to a low observed frequency within the population.

Trait		Southeast Asian	Northeast Asian
Cranial Non-Metric Traits			
Presence of nasal sill		Low	High
Round nasal aperture		High*	Low*
Wide nasal aperture		Low*	High*
Wide inter-orbital breadth		Low*	High*
Presence of zygomatic tubercle		Moderate	High
Presence of nasal overgrowth		Moderate*	Low*
Dental Non-Metric Traits	**Tooth**		
Presence of metacone	UM3	Low	High
Enamel extensions	UM1	Low	High
	UM2	Low	High
	LM1	Low	High
	LM2	Low	High
Presence of "X" groove pattern	LM2	Low	High
Presence of hypoconulid	LM2	Low	High
	LM3	Moderate*	High*

*Difference is only marginally significant

Cranial Non-Metric Traits

Cranial non-metric traits have received the most attention in the forensic literature as an anthroposcopic means of assessing ancestry. For this study, however, it was expected that the series of cranial non-metric traits would be poorer at distinguishing Southeast Asian individuals from Northeast Asian individuals than the dental non-metric traits. This hypothesis was based on the fact that Turner (1983, 1990) has extensively documented differences in dental morphology between these groups. Of the 13 cranial non-metric traits examined, five show potential for discriminating between these groups. Presence of a partial or full nasal sill is characteristic of individuals of Northeast Asian ancestry, while guttering or incipient guttering of the inferior nasal aperture is characteristic of Southeast Asian ancestry. Presence of a posterior zygomatic tubercle is consistent with Northeast Asian ancestry, and its absence with Southeast Asian ancestry. The three other traits that were found to distinguish the groups did so at only a marginal level. These traits include the presence of nasal overgrowth, nasal aperture width, and inter-orbital breadth. While Southeast Asian individuals were more likely to exhibit nasal overgrowth, the trait was exhibited in low frequency within the sample. Nasal aperture width appears to be a more reliable trait, as Northeast Asian individuals most often exhibited an aperture that was widest at the horizontal midline, while Southeast Asian individuals most often exhibited an aperture that was widest at the base, or inferior margin.

The results of this analysis are similar to those obtained by Hefner (2003) for the Northeast Asian sample, but differ for a selection of traits (Table 12). Both the study by Hefner (2003) and the present study found an absence of a post-bregmatic depression; a high incidence of a smooth, or S-shaped, zygomaticomaxillary suture; variable expression of the transverse palatine suture shape; and near absence of metopism. The low incidence of metopism confirms the observations of other researchers who have found a near absence of the trait among individuals of East

Table 12: Frequencies of the various character states of the cranial non-metric traits for the Northeast Asian sample as scored by Heard (2008) and Hefner (2003).

	Heard (2008)		Hefner (2003)	
Trait	**n**	**%**	**n**	**%**
Inferior nasal aperture				
0	5	5.7	9	12.0
1	15	17.0	13	17.3
2	11	12.5	48	64.0
3	36	40.9	3	4.0
4	21	23.9	2	2.7
Nasal bone structure				
0	24	30.8	17	22.0
1	32	41.0	18	24.0
2	1	1.3	30	40.0
3	13	16.7	9	12.0
4	8	10.3	1	1.3
Nasal aperture width				
1	0	0.00	1	1.3
2	33	37.1	66	88.0
3	56	62.9	8	10.7
Inter-orbital breadth				
1	7	7.8	31	41.3
2	28	31.1	39	62.0
3	55	61.1	5	6.7
Post-bregmatic depression				
0	28	100.0	63	84.0
1	0	0.00	8	10.7
2	--	--	4	5.3
Anterior nasal spine				
0	8	9.5	26	34.0
1	52	61.9	34	45.3
2	24	28.6	10	13.3
3	0	0.00	5	6.7
4	--	--	0	0.00
Zygomaticomaxillary suture shape				
0	--	--	4	5.3
1	8	9.2	21	28.0
2	79	90.8	38	50.7
3	0	0.00	12	16.0
Transverse palatine suture shape				
0	13	15.9	34	45.3
1	21	25.6	25	33.3
2	29	35.4	11	14.7
3	19	23.2	5	6.7

Table 12 (*continued*)

Posterior zygomatic tubercle				
0	14	15.6	18	24.0
1	38	42.2	30	40.0
2	19	21.1	17	22.7
3	19	21.1	10	13.3
Malar tubercle				
0	15	16.7	32	42.7
1	32	35.6	25	33.3
2	40	44.4	10	13.3
3	3	3.3	8	10.7
Nasal overgrowth				
0	64	71.1	51	68.0
1	3	3.3	19	25.3
2	23	25.6	5	6.7
Metopic suture				
0	83	93.3	68	90.7
1	6	6.7	7	9.3
Supranasal suture				
1	1	1.1	1	1.3
2	1	1.1	5	6.7
3	54	60.7	24	32.0
4	33	37.1	45	60.0

Asian ancestry (Ishida & Dodo 1993; Ishida 1995; Kellock & Parsons 1970). Despite this relative agreement of expression for some of the cranial non-metric traits, the observed frequency of others was not in congruence with the findings of Hefner (2003). While Hefner observed a high incidence of a straight inferior nasal aperture, results of this study show that a partial or full nasal sill is common among individuals of Northeast Asian ancestry. The shape of the nasal aperture also differs, as Hefner's documentation of a nasal aperture that is widest at the base was observed in the current sample of Southeast Asian individuals, but not within the Northeast Asian group.

These results emphasize the need for further research into cranial non-metric trait expression and the level of inter-observer repeatability in scoring. A study investigating the level of inter-observer agreement in scoring using the cranial non-metric traits outlined by Hefner (2003) is currently underway (Heard & Malone, *in press*). The preliminary results suggest that the level of inter-observer agreement in scoring is lower than the level of intra-observer agreement for the 13 traits described by Hefner (2003). It is unclear at this time if these differences are due to different levels of observer experience in evaluating non-metric traits, and/or different interpretations of Hefner's descriptions. It will be important to confirm that a high degree of inter-observer agreement in scoring is possible before methods utilizing these traits (and their descriptions for scoring) can be effectively employed within forensic anthropology.

Dental Non-Metric Traits

The work by Turner (1983, 1990) has extensively documented dental variation in archaeological samples from both mainland and insular East Asia. His dichotomization of Hanihara's "Mongoloid Dental Complex" into the Sundadont and Sinodont patterns (Turner 1983, 1990) suggests that distinguishing populations of Northeast and Southeast Asian ancestry is possible through examination of dental remains. The results of this study reveal that distinguishing these two regional population groups based on dental non-metric traits may be possible if a particular constellation of characters were observed; however, the traits used by Turner (1983, 1990) to distinguish these regional groups did not prove as useful. Turner (1990) found that Sinodonts (Northeast Asians) could be distinguished from Sundadonts (Southeast Asians) based on differing expression of eight dental non-metric traits (Table 1). Of Turner's eight traits, three were not able to be evaluated in this study. Turner (1990) found that Sinodonts exhibited a higher frequency of single rooted maxillary first premolars and three rooted mandibular first molars than Sundadonts, but root traits were unable to be examined in the present study for the Northeast Asian sample. He also noted differences of the maxillary third molars, but third molars were often excluded from analysis in this thesis due to limited sample size. Of the remaining five traits (UI1 shovel, UI1 double-shovel, UM1 enamel extensions, LM1 deflecting wrinkle, and LM2 four cusps), those of the maxillary incisors were eliminated from comparison due to a limited sample of Southeast Asian incisors (n = 5 UI1; n = 11 UI2). While shoveling could not be quantitatively compared between the two samples, it can be qualitatively noted that extensive shoveling was observed on both the central and lateral maxillary incisors of the Northeast Asian sample, and double-shoveling was marginally expressed in this group. These observations are in agreement with the findings of others that Northeast Asian populations have a high incidence of incisor shoveling (e.g. Matsumura & Hudson 2005; Scott & Turner 1997; Suzuki & Sakai 1964; Turner 1983, 1990).

It was expected that the sample of Southeast Asian individuals could be distinguished from the individuals of Northeast Asian ancestry using the eight dental non-metric traits described by Turner (1983, 1990). As a number of these traits were not suitable for inclusion in the present analysis, the results of this thesis cannot confirm whether or not these traits can continue to be used to distinguish the regional populations from one another. While further analysis may confirm the utility of this particular suite of traits for use by the forensic anthropologist, it should be noted that other non-metric traits of the dentition may also prove useful. These traits include the metacone of the third maxillary mandibular molar; first and second maxillary and mandibular molar enamel extensions; the presence of the "X" groove pattern on the second mandibular molar; and the presence of the hypoconulid on the second and third mandibular molars. All of these traits were observed in statistically significant higher frequency among the sample of Northeast Asian individuals than the sample of Southeast Asian individuals. As these forms of trait expression demonstrate an exaggeration of trait expression, they seem to coincide with Turner's (1983, 1990) suggestion that the dentition of Sinodonts represents a more derived and complex morphology than that seen among Sundadont populations.

Implications for Forensic Anthropology

In summarizing the results of this thesis, it is important to note the implications for the field of forensic anthropology. As discussed in the introductory chapters, Asian families living in the US are most concentrated in the West, followed by the South, Northeast, and Midwest, and approximately 51% of Asian Americans live in the states of California, New York, and Hawai'i. The census data also show that 95% of all Asian and Pacific Islanders live in metropolitan areas such as New York, Los Angeles, San Diego, San Francisco, Chicago, Houston, and Honolulu. The concentration of East Asian populations in particular areas of the US means that the pool of potential ancestral identities for unidentified remains found in these areas will include East Asian. It is therefore necessary for forensic anthropologists, especially those working in these areas, to have an understanding of the expression of non-metric traits of these East Asian populations.

An understanding of non-metric trait expression in East Asian populations is also needed by those working at JPAC-CIL. Through personal communication with forensic anthropologists at this facility, it has been brought to my attention that these scientists are interested in the results of research such as that of the present study, as well as future ones. The majority of recovery missions conducted by teams of the JPAC-CIL take place in countries within the region of Southeast Asia, and teams are often confronted with the task of distinguishing the remains of American soldiers with those of Vietnamese and/or Japanese forces. Given the current methods available, these anthropologists are unable to provide equivocal evidence that a set of recovered remains are those of an individual of East Asian ancestry.

Non-metric methods of ancestry assessment are especially important to forensic anthropologists working at JPAC-CIL. Because the objective of these scientists is to positively identify the remains of individuals who were victim to military conflict, the remains are often fragmentary in nature. In such cases, ancestry assessment by metric means is eliminated as an option, and an understanding of non-metric trait distribution among populations is needed.

Future Research Considerations

The surge of renewed interest in non-metric methods of ancestry assessment creates a number of areas for continued research. Such areas include gathering more information about the expression of non-metric traits for a variety of populations, as well as continued comparison of the expression of those traits across populations. In addition, it is equally as necessary for researchers to continue to standardize trait classification and methods of scoring.

As discussed in the opening of this thesis, documentation of non-metric trait expression has historically focused on understanding trait expression across three primary ancestral groups: European Americans (Whites), African Americans (Blacks), and Native Americans. In order to effectively employ non-metric methods of ancestry assessment in a forensic context, it is necessary for the forensic anthropologist to understand the anthroposcopic variation of these populations as well as others. The recent research devoted to documenting non-metric trait expression in Hispanic peoples (Anderson 2008, Hinkes 2008, Birkby *et al.* 2008) is a move in the right direction, as is the focus of the present thesis with regard to East Asian populations. Continued research devoted to understanding non-metric trait expression in both Hispanic and East Asian populations will be essential as forensic anthropologists work to develop a suite of traits that can be considered characteristic of these groups.

While understanding non-metric trait expression in Hispanic and East Asian populations will greatly enhance our understanding of population morphological diversity, there still remains a number of broad population groups for which forensic anthropologists have limited understanding of their skeletal morphology. An example of such a group includes populations of Middle Eastern descent. Gaining an understanding of non-metric trait expression in populations from this area of the world may become crucial if military conflict continues in this region. The current and future placement of forensic anthropologists in this region for the purpose of both US soldier and civilian identification necessitates a need to understand the scope of skeletal variation within these peoples. When the magnitude of weapon force and increased use of explosive devices in the current conflicts is considered, it is clear that methods of positive identification will rely on techniques that can extract the most amount of information from the smallest of skeletal elements. Non-metric methods, therefore, will be preferred to metric techniques when ancestry is assessed.

As forensic anthropologists continue to document the expression of non-metric traits for a variety of populations, it is critical that comparisons are made across populations. As evidenced by the results of this thesis, it is possible that regional population groups may permit distinction using a particular constellation of non-metric traits. It is important for the forensic anthropologist to understand which populations can and cannot be distinguished using a particular suite of traits, so as to not limit the possibilities of ancestral identity for a set of unidentified remains. To this end, there is potential for additional research to supplement the work that was undertaken for this thesis. Not only should more individuals of both Southeast and Northeast Asian ancestry be examined, but the expression of non-metric traits for these groups should be compared to other populations, notably Native Americans and Hispanics. As Native Americans represent the New World descendents of East Asian populations, and Hispanic phenotypes represent an interaction of Native American and European American gene flow, it is worth determining which traits will be consistent and which will differ across these populations.

In addition to furthering our understanding of non-metric trait expression within and across a variety of population groups, it is equally as important for forensic anthropologists to continue to establish standards for the application of non-metric methods. This was the goal of the recent work by Hefner (2003), but there remains room for improvement. Notably, further testing of intra- and inter-observer reliability in scoring is necessary to determine whether or not the trait descriptions and illustrations outlined by Hefner (2003) are comprehensive to forensic anthropologists of varying levels of experience. The modifications made in this study to Hefner's (2003) scoring procedures were performed to facilitate further statistical testing, but it is also hypothesized that a present-absent scoring system of non-metric traits may be more comprehensible across observers (Heard & Malone, *in prep*). Scoring traits on a graded scale is thought to capture more subtleties in variation between populations (Tyrrell 2000), but there is also a greater chance of intra- and inter-observer scoring error. This is because using a graded scale of expression for a particular trait essentially divides a trait with a continuous form of expression into discrete categories. Grades of expression at the extreme ends (e.g. grade 1 versus grade 5 of incisor shoveling) are more likely to be classified correctly; but those that are close, for example a grade 3 versus a grade 4 of incisor shoveling, may be scored as a 3 or a 4 within and between observers. This was the criticism of Nichol and Turner (1986) in their analysis of discrete categories for a variety of dental non-metric traits, having found it difficult to reach a high level of inter-observer agreement in scoring traits with multi-category character states. Establishment of intra- and inter-observer scoring reliability for non-metric cranial traits was investigated by Gualdi-Russo and colleagues (1999), who found that establishment of scoring repeatability was possible within observers, but was more difficult between observers. The results of these earlier efforts support the notion that a high level of inter-observer reliability in scoring is difficult to establish, reinforcing the need to test inter-observer repeatability in scoring for the traits recently described by Hefner (2003).

An additional methodological concern has to do with choosing the appropriate traits to examine. It has not yet been established that the traits outlined by Hefner (2003) are the best to document non-metric trait variation across multiple populations. In fact, Hefner (2002, 2003a) has shown that some of the traits for which he has chosen to document variation in trait expression may not differ in a predictable manner across populations. In order for the traits to be reliable indicators of ancestry, there must be a high correlation of a particular character state of expression within a given population. As we attempt to establish which traits will best correlate with a particular population group, it is likely best to not limit the traits for which data is collected. In other words, approaching a project with a pre-determined list may preclude the observer from collecting data on traits that may prove to be important for distinguishing that population, but which may not show variation in others (Tyrrell 2000). It is for this reason that bridging the gap between forensic anthropology and the field of bioarchaeology is important. As evidenced by this thesis, populations of Southeast Asian ancestry and those of Northeast Asian ancestry have consistently been distinguished using traits commonly used for biological distance analysis, and this may also be possible using those traits more commonly used by forensic anthropologists. It remains to be determined, however, if traits of the bioarchaeologist's repertoire should be added to those commonly examined by the forensic anthropologist when assessing ancestry.

CONCLUSIONS

This thesis marks one of the few attempts in the forensic literature to understand cranial and dental non-metric trait expression in contemporary samples of individuals of East Asian ancestry. Prior studies of non-metric variation have focused on documenting trait expression in individuals of European, African, and Native American ancestry, as there are large skeletal collections of individuals of these ancestral backgrounds. While it has historically, and may still be, the case that forensic anthropologists will most frequently encounter the remains of individuals of European, African, or Native American ancestry, the composition of the population in the United States is changing. This change affects our job as forensic anthropologists, as we must be prepared to identify an increasing number of ancestral identities. To address this concern, research into the expression of non-metric traits among Hispanic populations in the American Southwest has escalated, as it has been recognized that they do not share the presumed traits with Southwest Native American populations. And though it has been duly noted that populations of East Asian ancestry also may not share the same suite of non-metric traits as Southwest Native Americans, little effort has been put forth to investigate this possibility.

The primary objective of this thesis was to describe non-metric trait expression for a series of commonly used non-metric traits in a contemporary sample of individuals of Southeast and Northeast Asian ancestry. Further, this study tested whether or not there were certain traits that were exhibited differently between the two population samples, as such a distinction between regional East Asian populations has been extensively noted in the bioarchaeological literature.

The results of this study suggest that the Southeast and Northeast Asian samples share the expression of a series of non-metric traits, but show differences in the expression of others. Cranial non-metric trait expression shared by the two samples includes the presence of a smooth zygomaticomaxillary stuture shape, and near absence of both post-bregmatic depression and a persisting metopic suture. Dental non-metric trait expression shared by the two samples includes a low incidence of the tuberculum dentale of the maxillary incisors, maxillary premolar accessory cusps, Carabelli's cusp, parastyle, protostylid, deflecting wrinkle, and sixth and seventh cusps of the first mandibular molar. Both samples were characterized by a "Y" groove pattern on their first mandibular molar, and the presence of a large metacone and hypocone on the first and second maxillary molars.

Of the various non-metric traits examined, relatively few were found to differ significantly in expression between the Southeast and Northeast Asian samples. However, if a particular constellation of these characters were observed, it may be possible to assert that an individual was of either Southeast or Northeast Asian ancestry. Cranial non-metric trait expression that was found to characterize Southeast Asian ancestry includes a lack of a nasal sill; a nasal aperture width that is widest at the base; an intermediate inter-orbital breadth; lack of a posterior zygomatic tubercle; and the presence of nasal overgrowth. Traits that were found to be characteristic of Northeast Asian ancestry include the presence of a nasal sill; a nasal aperture width that is widest at the horizontal midline; a wide inter-orbital breadth; the presence of a posterior zygomatic tubercle; and the lack of nasal overgrowth.

In addition to the cranial non-metric traits, a series of dental non-metric traits were also found to differ significantly in expression between the two East Asian samples. These traits include the presence of the metacone on the third maxillary molar; the presence of enamel extensions of the first and second maxillary and mandibular molars; the presence of the "X" groove pattern on the second mandibular molar; and the presence of a large hypoconulid on the second and third mandibular molars. All of these features were observed in the sample of Northeast Asian individuals and were absent or occurred in low frequency within the Southeast Asian sample. The inability to statistically assess traits of the anterior maxillary dentition (e.g. shoveling) is regrettable, and it is hoped that future investigations with increased samples sizes will enable such analyses, in addition to those of the root traits.

Future research will be necessary to determine the strength of the ability to distinguish these groups using non-metric traits. Studies of East Asian skeletal morphology should be encouraged, especially by forensic anthropologists working in areas of the country where East Asian individuals comprise a large portion of the population. These regions include large metropolitan areas such as New York, Chicago, Houston, Honolulu, San Diego, and San Francisco. In particular, East Asian families living in the United States are especially concentrated along the Pacific Coast, making it especially important for forensic anthropologists in this portion of the country to be familiar with the traits that characterize Southeast and Northeast Asian populations. Forensic anthropologists who regularly encounter remains of individuals of Southeast and/or Northeast Asian ancestry, such as those working at JPAC—CIL, will be crucial to furthering our understanding of East Asian skeletal morphology. These scientists may have access to international collections that are difficult for American forensic anthropologists or graduate students to visit, so it is important for them to document trait expression or other useful information when possible. The long term presence of the JPAC—CIL in Southeast Asian countries and their continued activity in this region additionally highlights the need to better our understanding of non-metric trait expression in East Asian populations.

The results of this thesis offer a first look at non-metric trait expression in East Asian populations. In order to enhance these results, future research into non-metric trait expression in additional samples will be necessary, as will the comparison of non-metric trait expression in East Asian population samples to that of Native American samples. Non-metric trait expression has been studied in a series of Native American samples, and these traits have historically been used to characterize "Mongoloid" populations. Continued use of the term "Mongoloid", as well as use of a single suite of traits to characterize the many populations that would fall beneath the "Mongoloid" umbrella, is problematic. The results of this study highlight the heterogeneity in non-metric trait expression within the traditional "Mongoloid" ancestral group, suggesting that an all-inclusive "Mongoloid" category does not accurately capture the spectrum of non-metric variation of these diverse populations, including Southeast and Northeast Asians, Native Americans, and Hispanic Americans. Confirmation that each of these population groups is characterized by its own suite of non-metric traits lends support to discontinuing the use of the "Mongoloid" typology in forensic anthropology.

APPENDIX A

Table A1: Frequencies of the various character states of the inferior nasal aperture for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Inferior nasal aperture				
0	9	25.7	5	5.7
1	11	31.4	15	17.0
2	2	5.7	11	12.5
3	8	22.9	36	40.9
4	5	14.3	21	23.9
Total	35	100.0	88	100.0

Table A2: Frequencies of the various character states of the nasal bone structure for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Nasal bone structure				
0	3	11.5	24	30.8
1	15	57.7	32	41.0
2	0	0.00	1	1.3
3	3	11.5	13	16.7
4	5	19.2	8	10.3
Total	26	100.0	78	100.0

Table A3: Frequencies of the various character states of the nasal aperture width for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Nasal aperture width				
1	2	6.9	0	0.00
2	20	69.0	33	37.1
3	7	24.1	56	62.9
Total	29	100.0	89	100.0

Table A4: Frequencies of the various character states of the inter-orbital breadth for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Inter-orbital breadth				
1	6	18.8	7	7.8
2	18	56.3	28	31.1
3	8	25.0	55	61.1
Total	32	100.0	90	100.0

Table A5: Frequencies of the various character states of the post-bregmatic depression for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Post-bregmatic depression				
0	28	100.0	78	87.6
1	0	0.00	11	12.4
Total	28	100.0	89	100.0

Table A6: Frequencies of the various character states of the anterior nasal spine for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Anterior nasal spine				
0	8	22.9	8	9.5
1	22	62.9	52	61.9
2	5	14.3	24	28.6
Total	35	100.0	84	100.0

Table A7: Frequencies of the various character states of the zygomaticomaxillary suture shape for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Zygomaticomaxillary suture shape				
1	4	11.4	8	9.2
2	30	85.7	79	90.8
3	1	2.9	0	0.00
Total	35	100.0	87	100.0

Table A8: Frequencies of the various character states of the transverse palatine suture shape for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Transverse palatine suture shape				
0	9	31.0	13	15.9
1	3	10.3	21	25.6
2	10	34.5	29	35.4
3	7	24.1	19	23.2
Total	29	100.0	82	100.0

Table A9: Frequencies of the various character states of the posterior zygomatic tubercle for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Posterior zygomatic tubercle				
0	17	47.2	14	15.6
1	8	22.2	38	42.2
2	9	25.0	19	21.1
3	2	5.6	19	21.1
Total	36	100.0	90	100.0

Table A10: Frequencies of the various character states of the malar tubercle for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Malar tubercle				
0	6	17.6	15	16.7
1	6	17.6	32	35.6
2	13	38.2	40	44.4
3	9	26.5	3	3.3
Total	34	100.0	90	100.0

Table A11: Frequencies of the various character states of the nasal overgrowth for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Nasal overgrowth				
0	16	44.4	64	71.1
1	6	16.7	3	3.3
2	14	38.9	23	25.6
Total	36	100.0	90	100.0

Table A12: Frequencies of the various character states of the metopic suture for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Metopic suture				
0	29	87.9	83	93.3
1	4	12.1	6	6.7
Total	33	100.0	89	100.0

Table A13: Frequencies of the various character states of the supranasal suture for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Supranasal suture				
1	1	3.1	1	1.1
2	6	18.8	1	1.1
3	17	53.1	54	60.7
4	8	25.0	33	37.1
Total	32	100.0	89	100.0

APPENDIX B

Table B1: Frequencies of the various character states of maxillary incisor winging for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Winging				
1	1	25.0	0	0.00
1B	0	0.00	6	13.6
3	3	75.0	38	86.4
Total	4	100.0	44	100.0

Table B2: Frequencies of the various character states of maxillary incisor labial convexity for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Labial convexity				
1	3	60.0	34	89.5
2	1	20.0	2	5.3
3	1	20.0	2	5.3
Total	5	100.0	38	100.0

Table B3: Frequencies of the various character states of incisor shoveling for the Southeast and Northeast Asian samples.

Trait	Southeast Asian n	%	Northeast Asian n	%
Maxillary central incisor				
1	0	0.00	9	24.3
2	2	40.0	12	32.4
3	2	40.0	10	27.0
4	1	20.0	5	13.5
5	0	0.00	1	2.7
Total	5	100.0	37	100.0
Maxillary lateral incisor				
0	2	18.2	1	2.7
1	1	9.1	5	13.5
2	1	9.1	6	16.2
3	2	18.2	7	18.9
4	4	36.4	11	29.7
5	0	0.00	4	10.8
6	1	9.1	3	8.1
Total	11	100.0	37	100.0
Mandibular incisors				
1	5	100.0	32	82.1
2	0	0.00	7	17.9
Total	5	100.0	39	100.0

Table B4: Frequencies of the various character states of maxillary double-shoveling for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Central incisor double-shoveling				
0	3	60.0	25	69.4
1	1	20.0	0	0.00
2	0	0.00	3	8.3
3	1	20.0	6	16.7
4	0	0.00	1	2.8
5	0	0.00	0	0.00
6	0	0.00	1	2.8
Total	5	100.0	36	100.0
Lateral incisor double-shoveling				
0	6	54.5	33	82.5
1	3	27.3	1	2.5
2	2	18.2	2	5.0
3	0	0.00	3	7.5
4	0	0.00	1	2.5
Total	11	100.0	40	100.0
Canine double-shoveling				
0	8	88.9	47	95.9
1	1	11.1	1	2.0
2	0	0.00	1	2.0
Total	9	100.0	49	100.0
P3 double-shoveling				
0	14	100.0	55	98.2
1	0	0.00	1	1.8
Total	14	100.0	56	100.0

Table B5: Frequencies of the various character states of the maxillary tuberculum dentale for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Central incisor tuberculum dentale				
0	1	16.7	2	8.3
1	5	83.3	20	83.3
2	0	0.00	2	8.3
Total	6	100.0	24	100.0
Lateral incisor tuberculum dentale				
0	1	9.1	6	50.0
1	10	90.9	6	50.0
Total	11	100.0	12	100.0
Canine tuberculum dentale				
0	1	10.0	0	0.00
1	8	80.0	26	96.3
2	1	10.0	1	3.7
Total	10	100.0	27	100.0

Table B6: Frequencies of the various character states of the maxillary canine mesial ridge for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Canine mesial ridge				
0	7	77.8	32	94.1
1	2	22.2	1	2.9
2	0	0.00	1	2.9
Total	9	100.0	34	100.0

Table B7: Frequencies of the various character states of the canine distal accessory ridge for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Maxillary canine distal accessory ridge				
0	7	77.8	34	100.0
1	0	0.00	0	0.00
2	2	22.2	0	0.00
Total	9	100.0	34	100.0
Mandibular canine distal accessory ridge				
0	4	100.0	44	100.0
Total	4	100.0	44	100.0

Table B8: Frequencies of the various character states of the maxillary premolar distal cusp for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
P3 distal cusp				
0	15	100.0	56	100.0
Total	15	100.0	56	100.0
P4 distal cusp				
0	18	100.0	62	100.0
Total	18	100.0	62	100.0

Table B9: Frequencies of the various character states of the metacone for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
M1 metacone				
0	0	0.00	0	0.00
1	0	0.00	0	0.00
2	0	0.00	0	0.00
3	0	0.00	0	0.00
4	4	16.0	1	1.6
5	21	84.0	62	98.4
Total	25	100.0	63	100.0
M2 metacone				
0	0	0.00	0	0.00
1	0	0.00	0	0.00
2	1	4.5	1	1.8
3	2	9.1	2	3.6
4	11	50.0	16	28.6
5	8	36.4	37	66.1
Total	22	100.0	56	100.0
M3 metacone				
0	2	15.4	0	0.00
1	4	30.8	3	7.3
2	1	7.7	0	0.00
3	6	46.2	12	29.3
4	0	0.00	19	46.3
5	0	0.00	7	17.1
Total	13	100.0	41	100.0

Table B10: Frequencies of the various character states of the hypocone for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
M1 hypocone				
0	0	0.00	1	1.6
1	0	0.00	0	0.00
2	0	0.00	0	0.00
3	0	0.00	0	0.00
4	10	38.5	5	7.8
5	16	61.5	58	90.6
Total	26	100.0	64	100.0
M2 hypocone				
0	0	0.00	2	3.6
1	3	13.0	5	8.9
2	2	8.7	4	7.1
3	4	17.4	19	33.9
4	14	60.9	13	23.2
5	0	0.00	13	23.2
Total	23	100.0	56	100.0
M3 hypocone				
0	4	30.8	10	25.0
1	4	30.8	12	30.0
2	2	15.4	2	5.0
3	3	23.1	12	30.0
4	0	0.00	3	7.5
5	0	0.00	1	2.5
Total	13	100.0	40	100.0

Table B11: Frequencies of the various character states of cusp 5 for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Maxillary M1 cusp 5				
0	29	100.0	47	74.6
1	0	0.00	11	17.5
2	0	0.00	3	4.8
3	0	0.00	1	1.6
4	0	0.00	1	1.6
Total	29	100.0	63	100.0
Maxillary M2 cusp 5				
0	22	100.0	56	98.2
1	0	0.00	0	0.00
2	0	0.00	0	0.00
3	0	0.00	1	1.8
Total	22	100.0	57	1.00
Maxillary M3 cusp 5				
0	14	100.0	40	95.2
1	0	0.00	1	2.4
2	0	0.00	0	0.00
3	0	0.00	1	2.4
Total	14	100.0	42	100.0
Mandibular M1 cusp 5				
0	1	5.6	1	2.1
1	0	0.00	1	2.1
2	0	0.00	1	2.1
3	1	5.6	2	4.2
4	3	16.7	3	6.3
5	13	72.2	40	83.3
Total	18	100.0	48	100.0
Mandibular M2 cusp 5				
0	9	45.0	9	18.8
1	3	15.0	3	6.3
2	2	10.0	7	14.6
3	2	10.0	7	14.6
4	3	15.0	10	20.8
5	1	5.0	12	25.0
Total	20	100.0	48	100.0

Table B11 (*continued*)

Mandibular M3 cusp 5				
0	10	58.8	16	39.0
1	2	11.8	1	2.4
2	1	5.9	3	7.3
3	1	5.9	3	7.3
4	1	5.9	8	19.5
5	2	11.5	10	24.4
Total	17	100.0	41	100.0

Table B12: Frequencies of the various character states of the parastyle of the maxillary molars for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
M1 parastyle				
0	26	96.3	65	100.0
1	0	0.00	0	0.00
2	0	0.00	0	0.00
3	0	0.00	0	0.00
4	0	0.00	0	0.00
5	0	0.00	0	0.00
6	0	0.00	0	0.00
7	1	3.7	0	0.00
Total	27	100.0	65	100.0
M2 parastyle				
0	22	100.0	56	98.2
1	0	0.00	0	0.00
2	0	0.00	0	0.00
3	0	0.00	0	0.00
4	0	0.00	1	1.8
Total	22	100.0	57	100.0
M3 parastyle				
0	14	100.0	41	100.0
Total	14	100.0	41	100.0

Table B13: Frequencies of the various character states of the Carabelli's trait for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
M1 Carabelli's trait				
0	25	89.3	52	78.8
1	2	7.1	13	19.7
2	0	0.00	0	0.00
3	0	0.00	1	1.5
4	0	0.00	0	0.00
5	0	0.00	0	0.00
6	1	3.6	0	0.00
Total	28	100.0	66	100.0
M2 Carabelli's trait				
0	21	95.5	56	98.2
1	0	0.00	1	1.8
2	0	0.00	0	0.00
3	0	0.00	0	0.00
4	0	0.00	0	0.00
5	0	0.00	0	0.00
6	1	4.5	0	0.00
Total	22	100.0	57	100.0
M3 Carabelli's trait				
0	14	100.0	40	100.0
Total	14	100.0	40	100.0

Table B14: Frequencies of the various character states of enamel extensions for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Maxillary P3 enamel extension				
0	15	88.2	61	100.0
1	2	11.8	0	0.00
Total	17	100.0	61	100.0
Maxillary P4 enamel extension				
0	19	100.0	68	100.0
Total	19	100.0	68	100.0
Maxillary M1 enamel extension				
0	20	71.4	22	40.7
1	6	21.4	12	22.2
2	1	3.6	13	24.1
3	1	3.6	7	13.0
Total	28	100.0	54	100.0
Maxillary M2 enamel extension				
0	12	52.2	13	27.1
1	7	30.4	12	25.0
2	3	13.0	16	33.3
3	1	4.3	7	14.6
Total	23	100.0	48	100.0
Maxillary M3 enamel extension				
0	8	61.5	14	40.0
1	3	23.1	11	31.4
2	2	15.4	8	22.9
3	0	0.00	2	5.7
Total	13	100.0	35	100.0
Mandibular P3 enamel extension				
0	13	100.0	65	98.5
1	0	0.00	1	1.5
Total	13	100.0	66	100.0
Mandibular P4 enamel extension				
0	14	100.0	61	100.0
Total	14	100.0	61	100.0

Table B14 (*continued*)

Mandibular M1 enamel extension				
0	11	61.1	20	35.1
1	7	38.9	7	12.3
2	0	0.00	19	33.3
3	0	0.00	11	19.3
Total	18	100.0	57	100.0
Mandibular M2 enamel extension				
0	12	52.2	12	20.7
1	8	34.8	14	24.1
2	2	8.7	25	43.1
3	1	4.3	7	12.1
Total	23	100.0	58	100.0
Mandibular M3 enamel extension				
0	10	50.0	13	31.7
1	7	35.0	13	31.7
2	2	10.0	13	31.7
3	1	5.0	2	4.9
Total	20	100.0	41	100.0

Table B15: Frequencies of the various character states of premolar odontomes for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Maxillary P3 odontome				
0	14	100.0	59	100.0
Total	14	100.0	59	100.0
Maxillary P4 odontome				
0	18	100.0	64	100.0
Total	18	100.0	64	100.0
Mandibular P3 odontome				
0	14	100.0	53	100.0
Total	14	100.0	53	100.0
Mandibular P4 odontome				
0	15	100.0	54	100.0
Total	15	100.0	54	100.0

Table B16: Frequencies of the various character states of the mandibular premolar lingual cusp for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
P3 lingual cusp				
0	1	6.3	3	5.7
1	1	6.3	0	0.00
2	0	0.00	0	0.00
3	8	50.0	8	15.1
4	2	12.5	1	1.9
5	0	0.00	1	1.9
6	0	0.00	0	0.00
7	1	6.3	1	1.9
8	0	0.00	1	1.9
9	3	18.8	38	71.1
Total	16	100.0	53	100.0
P4 lingual cusp				
0	7	43.8	30	65.2
1	0	0.00	0	0.00
2	2	12.5	7	15.2
3	0	0.00	2	4.3
4	0	0.00	0	0.00
5	0	0.00	0	0.00
6	0	0.00	0	0.00
7	4	25.0	6	13.0
8	2	12.5	1	2.2
9	1	6.3	0	0.00
Total	16	100.0	46	100.0

Table B17: Frequencies for the various character states of the anterior fovea of the first mandibular molar for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
Anterior fovea				
0	5	100.0	1	6.7
1	0	0.00	8	53.3
2	0	0.00	1	6.7
3	0	0.00	5	33.3
Total	5	100.0	15	100.0

Table B18: Frequencies for the various character states of the mandibular molar groove pattern for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
M1 groove pattern				
X	10	58.8	6	16.2
Y	5	29.4	31	83.8
+	2	11.8	0	0.00
Total	17	100.0	37	100.0
M2 groove pattern				
X	1	5.6	22	64.7
Y	8	44.4	8	23.5
+	9	50.0	4	11.8
Total	18	100.0	34	100.0
M3 groove pattern				
X	5	31.3	30	81.1
Y	3	18.8	5	13.5
+	8	50.0	2	5.4
Total	16	100.0	37	100.0

Table B19: Frequencies of the various character states of the mandibular molar cusp number for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
M1 cusp number				
4	0	0.00	1	1.9
5	18	100.0	46	88.5
6	0	0.00	5	9.6
Total	18	100.0	52	100.0
M2 cusp number				
4	13	59.1	20	37.7
5	9	40.9	32	60.4
6	0	0.00	1	1.9
Total	22	100.0	53	100.0
M3 cusp number				
3	2	11.8	1	2.4
4	10	58.8	20	47.6
5	5	29.4	19	45.2
6	0	0.00	2	4.8
Total	17	100.0	42	100.0

Table B20: Frequencies of the various character states of the mandibular deflecting wrinkle for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
M1 deflecting wrinkle				
0	13	86.7	29	90.6
1	0	0.00	1	3.1
2	1	6.7	1	3.1
3	1	6.7	1	3.1
Total	15	100.0	32	100.0
M2 deflecting wrinkle				
0	14	93.3	43	93.5
1	0	0.00	1	2.2
2	0	0.00	0	0.00
3	1	6.7	2	4.3
Total	15	100.0	46	100.0
M3 deflecting wrinkle				
0	12	92.3	38	95.0
1	0	0.00	0	0.00
2	1	7.7	0	0.00
3	0	0.00	2	5.0
Total	13	100.0	40	100.0

Table B21: Frequencies of the various character states of the mandibular distal trigonid crest for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
M1 distal trigonid crest				
0	16	100.0	33	100.0
Total	16	100.0	33	100.0
M2 distal trigonid crest				
0	18	100.0	47	100.0
Total	18	100.0	47	100.0
M3 distal trigonid crest				
0	14	100.0	38	100.0
Total	14	100.0	38	100.0

Table B22: Frequencies of the various character states of the protostylid for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
M1 protostylid				
0	20	100.0	58	100.0
Total	20	100.0	58	100.0
M2 protostylid				
0	23	100.0	56	100.0
Total	23	100.0	56	100.0
M3 protostylid				
0	19	100.0	48	100.0
Total	19	100.0	48	100.0

Table B23: Frequencies of the various character states of the mandibular molar sixth cusp for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
M1 cusp 6				
0	12	63.2	39	83.0
1	3	15.8	1	2.1
2	3	15.8	2	4.3
3	0	0.00	3	6.4
4	1	5.3	1	2.1
5	0	0.00	1	2.1
Total	19	100.0	47	100.0
M2 cusp 6				
0	22	95.7	50	94.3
1	1	4.3	1	1.9
2	0	0.00	1	1.9
3	0	0.00	0	0.00
4	0	0.00	0	0.00
5	0	0.00	1	1.9
Total	23	100.0	53	100.0

Table B23 (*continued*)

M3 cusp 6				
0	17	94.4	39	88.6
1	0	0.00	1	2.3
2	1	5.6	1	2.3
3	0	0.00	0	0.00
4	0	0.00	0	0.00
5	0	0.00	3	6.8
Total	18	100.0	44	100.0

Table B24: Frequencies of the various character states of the mandibular seventh cusp for the Southeast and Northeast Asian samples.

	Southeast Asian		Northeast Asian	
Trait	n	%	n	%
M1 cusp 7				
0	18	94.7	52	94.5
1	0	0.00	2	3.6
2	0	0.00	0	0.00
3	1	5.3	0	0.00
4	0	0.00	1	1.8
Total	19	100.0	55	100.0
M2 cusp 7				
0	22	100.0	54	96.4
1	0	0.00	0	0.00
2	0	0.00	1	1.8
3	0	0.00	1	1.8
Total	22	100.0	56	100.0
M3 cusp 7				
0	18	100.0	44	97.8
1	0	0.00	0	0.00
2	0	0.00	1	2.2
Total	18	100.0	45	100.0

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