# Evaluating standard non-metric cranial traits used to determine ancestry on a South African sample

By

Carla van Rooyen

Submitted in fulfilment of the requirements for the degree:

**M.Sc. (Anatomy)**

In the school of Medicine, Faculty of Health Sciences, University of Pretoria, South Africa

January- 2010

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

# DECLARATION

I, Carla van Rooyen, declare that this thesis is my own work. It is being submitted for the degree of Masters for Science in Anatomy at the University of Pretoria. It has not been submitted before any other degree or examination at this or any other University.

Sign______________

This_______Day of ________________, 2010

# ABSTRACT

Research on the estimation of age at death, sex and stature from skeletal remains has received more attention than methods used to evaluate ancestry. While this may be due to the stigma attached to classifying people into groups, the application, interpretation and precision of non-metric methods used to predict ancestry need to be examined; as these variables are routinely applied to forensic case work in South Africa. The aim of this study was to score fifteen non-metric cranial traits, namely nasal bone structure, nasal breadth, nasal overgrowth, anterior nasal spine, inferior nasal margin, interorbital breadth, zygomaxillary suture shape, malar tubercle, alveolar prognathism, mandibular and palatine tori, shovel-shaped incisors, Carabelli's cusps and the transverse palatine suture shape on a South African sample, with the intent to assess the influence of sex, ancestry and age at death on these facial features. A total of 520 crania were obtained from the Pretoria Bone, Raymond A. Dart and Kirsten Collections in South Africa and included 237 (135 males, 102 females) Africans, 158 (94 males, 63 females) Europeans and 125 (87 males, 38 females) persons of Coloured origin. Data were analyzed using SPSS v.11.5 for Windows. Ordinal regression was used to evaluate the effect the independent variables (age, sex and ancestry) had on the dependent variable (non-metric traits). Results showed that all the variables were associated with ancestral differences among and within groups. Interorbital breadth, nasal bone structure, nasal breadth and shovel-shaped incisors exhibited statistically significant interactions with sex and ancestry, whereas the appearance of the anterior nasal spine, alveolar prognathism, incisor shovelling of the upper incisors, and Carabelli's cusp morphology were correlated with age at death. If traditional classification methods are used, then these non-metric traits are not a valid prediction of ancestry in South African populations. Future research is to focus on several statistical approaches, including multi-variate analysis, for the classification of non-metric traits.

# ABSTRAK

Navorsing oor die bepaling van ouderdom, geslag en die lengte vanaf skeletale reste het altyd meer aandag geniet as metodes vir die bepaling van afkoms. Alhoewel daar ‘n stigma kleef aan die gedagte om mense in groepe te verdeel, word hierdie veranderlikes roetine gewys in Suid-Afrika gebruik in forensiese gevalle en moet die aanwending, interpretasie en presisie van nie-metriese metodes wat gebruik word vir afkomsbepaling, ondersoek word. Die doel van hierdie studie was om vyftien nie-metriese kenmerke, naamlik nasale been struktuur, nasale breedte, nasale oorgroei, die anterior nasale spina, die inferior nasale grens, interorbitale breedte, zigomaksillêre naatvorm, die malare tuberkel, alveolêre prognatisme, mandibulêre en palatine tori, graafvormige snytande, Carabelli se kuspe en die transvers palatiene naatvorm van ‘n Suid Afrikaanse steekproef, te oordeel met die doel om die verband met geslag, afkoms en ouderdom op hierdie kenmerke te bepaal. 520 Skedels uit die Raymond A. Dart, Kirsten en Pretoria Been versameling is ondersoek en sluit in 237 Negroïede (135 mans en 38 vrouens), 158 Europeërs (94 mans en 63 vrouens) en 125 Kleurlinge (87 mans en 102 vrouens). Data is ontleed met SPSS v.11.5 vir Windows. Ordinale regressie is gebruik om die effek van onafhanglike veranderlikes (ouderdom, geslag en afkoms) op afhangklike veranderlikes (nie-metriese kenmerke) te bepaal. Resultate toon dat alle veranderlikes ‘n verband het met oorspring tussen en binne groepe. Interorbitale breedte, nasale been struktuur, nasale breedte en graafvormige snytande toon statistiese betekenisvolle interaksie met geslag en afkoms, terwyl die voorkoms vn die anterior nasale spina, alveolêre prognatisme, graafvormige boonste snytande en Carabelli se kuspe morfologie ‘n verband toon met ouderdom. Indien klassieke klassifikasie metodes gebruik word, is hierdie nie-metriese kenmerke nie geldige aaduiers van afkoms in Suid-Afrikaanse bevolkings nie. Toekomstige navorsing sal fokus op verskeie statistiese benaderings, ingesluit veelvuldige verandering ontleding, vir die klassifikasie van nie-metriese kenmerke.

# ACKNOWLEDGEMENTS

I would like to express my appreciation for the advice, encouragement, time and effort of my supervisor Dr EN L'Abbé throughout this project. I also wish to thank Professor Stephen P. Nawrocki of the University of Indianapolis for the statistical contribution to the project and without whom I would have really struggled with the data analysis. Special thanks go to Professor Piet Becker for assisting me in the data processing and interpretation of the reliability analysis in which we frequently encountered difficulties. I would like to thank Professor Benjamin Page and Dr Elsa de Wit for permission to study the student bone collections of the Stellenbosch and Bloemfontein Universities. Also to Ms Nalini Pather for allowing me the opportunity to study the Raymond A Dart research Collection, at the Department of Anatomy, University of the Witwatersrand. I am also grateful to the Department of Anatomy at the University of Pretoria for allowing me the opportunity to use the Pretoria Bone Collection. I would also like to extend my appreciation to the NRF and Navkom for the funding that I received for this project.

Finally I would like to thank my family for their empathy and with keeping up me and my studies the last few years. I sincerely appreciate each and every one of you.

# TABLE OF CONTENTS

# LIST OF FIGURES

*Figure 3.1 to 3.9 were redrawn from Hefner, 2003.

# LIST OF TABLES

# Chapter 1: Introduction

Rich and diverse are only two words to describe the heritage of South Africa. Today, the Republic of South Africa is home to over 49 million people of diverse origins, cultures, languages and beliefs. According to estimates from Statistics South Africa (http: //www.statssa.gov.za/), Africans (blacks) are in the majority at just over 38 million, making up 79.6% of the total population. The white population is estimated at 4.3 million (9.1%), the coloured population at 4.2 million (8.9%) and the Indian/Asian population just short of 1.2 million (2.5%). Of the 11 official languages in South Africa, ten are African, reflecting a variety of ethnic groupings which nonetheless have a great deal in common in terms of background, culture and descent. Black Africans include the Nguni people, comprising the Zulu, Xhosa, Ndebele, and Swazi. The Sotho-Tswana people are comprised of the Southern, Northern and Western Sotho (Tswana), the Tsonga and the Venda. The white population in South Africa descended largely from the colonial immigrants of the late 17th, 18th and 19th centuries. These include the Dutch, German, French Huguenot and British. Linguistically, white South Africans are divided into Afrikaans and English-speaking groups. The label "coloured" is used with caution as it represents racial prejudice at large, but it is still used for people of mixed ancestry who descended from slaves brought in from East and Central Africa, the indigenous Khoisan who lived in the Cape at the time of colonization as well as admixture of modern indigenous blacks and whites. Over centuries, the most southern point of the continent of Africa gave birth to a mixture of people, diverse cultures and languages that is called South Africa. One way in which to explain human variation in South Africa, and the world, is to evaluate its origin and history of populations, and the way in which people perceive others, as well as themselves.

For more than two centuries the origin and nature of human variation sparked the interest of scientists, and laymen alike. As part of this interest, scientists have studied the fossil record in attempts to explain the nature of human diversity. In the process, they identified certain patterns, and have since used these snapshots in time as baseline knowledge for interpreting morphological differences among and between populations. In recent decades, scholars of human evolution have formulated two theories that attempt to explain the origin and diversification of people. A monophyletic model of human diversification postulates a single, more recent origin of humans (Gill, 1990; Morris, 2005). Proponents of the opposing theory, referred to as the polyphyletic view, suggests that humans emerged through largely parallel evolutionary processes in widely separated, well isolated parts of the world. Although the concept of a single, more recent origin of humans became more widely acknowledged, there is still no consensus as to which theory better describes the processes involved in human evolutionary pathways (Lahr, 1996). In fact, it was from attempts to explain human diversity that scientists of the 18th and 19th centuries began to generate the field of physical anthropology (Gill, 1990). However, the classification of people into one of only a few physical types, as seen among monophyletic and polyphyletic views, were not at first based on the superiority, or inferiority of these groups. Scholars suggest that it was the onset slavery, during the 15th and 16th centuries, that introduced the concept of biological human races. Previously, people were discriminated against based on almost any aspect of their being, except on their biological make-up (Montagu, 1964).

An example of how biology became a tool with which certain groups ascertained their rights as superior human beings, and fit to rule over others, can be traced throughout the early history of South Africa. When the European settlers infiltrated the Cape during the 17th century, they were frequently involved in hostilities with native groups from the continent. As a consequence, these groups were steadily eradicated, and those who had survived were enslaved for the purposes of the settlers (Katzen, 1969). In later years, the Dutch began to participate in large scale sea trading, and as a result imported slaves for work labour from various parts of the world including East, and West Africa, India, and Madagascar (Schoeman, 2007). Despite the fact that the indigenous and slave populations of South Africa played an integral part in the development of the Cape as a colony, they were often greatly suppressed by their rulers, the Dutch. On every level of society, distinctions were drawn between the white population who owned certain rights, and those who served them, who had none. The result of this type of discrimination was human exploitation (Schoeman, 2007). Today, the consequences of these actions are resident in the complexity of socio-political systems on a global scale.

At the time, European scientists began to express ideas on human evolution that strongly proposed a typological approach to classifying human populations. Scientists, who laid the foundation for the future development of the field of physical anthropology, include Carl Linnaeus (1707-1778) and Frederick Blumenbach (1752-1840). The main focus of both Linnaeus and Blumenbach was to catalogue the differences they encountered among diverse populations (Caspari, 2009). The eventual establishment of physical anthropology as an official discipline is imputed in the continual application of the type theory. Like any evolving discipline its development was continually altered and challenged by those who in their own right shaped the discipline as we know it today. For many, the early 20th century marked a period in which the study of human races became the major theoretical foundation of anthropology (Caspari, 2009). In South Africa, the development of the field of physical anthropology followed a similar route, in that the study of ethnological observation and collection by Europeans continued throughout the 19th and 20th centuries. In fact, the British colonial government encouraged research on native populations, in fear of their extinction in the near future (Morris, 2005). Although the study of human races gained some attention in South Africa, the main research on the subject was pursued in the United States.

During the early stages of physical anthropology in the United States, there were some anthropologists who fulfilled vital positions in the subsequent development of the field. Scholars such as Aleš Hrdlička, Franz Boas and Earnest Hooton were some of the most influential role players of the time on anthropology and race. The first publication of the American Journal of Physical Anthropology in 1906 portrayed the already existing conflicting views of these forerunners on research and race, as it was understood at the time (Caspari, 2009). During the 1920's and 1930's, Hooton showed a special interest in the variability of the human crania (Brues, 1990). From this research, he recognized a number of morphological features that he thought to be valuable to determine race. These traits later became known as the "Harvard List". The list eventually filtered through lineages of anthropologists, and what was an oral tradition became widely accepted as scientific knowledge and published in textbooks and research papers (Brues, 1990).

While more scholars modified these variables, it became evident that its use was plagued by difficulties. Many investigators felt that qualitative data was an unscientific way in which to ascertain information and the need to quantify these traits began to surface. During the 1960's renewed interest was shown in the application of discrete trait analyses. This was the result of the work of geneticists Berry and Berry (1967) who devised a quantitative method of data reduction from inbred strains of mice for the analysis of discrete variables in humans. From their statistically based research the authors suggested that variables were not influenced by environmental factors, sex or age-related changes (Berry and Berry, 1967). In accordance, numerous research designs were based on these assumptions and in return caused even more suspicion as to the validity and efficacy of these features as markers of ancestry (Corrucini, 1974).

In response to these reactions, North American anthropologists began to address the validity and reliability of traits used to determine ancestry. They addressed the subjective nature of these features by standardizing them with more rigorous definitions and comparing them among groups with basic frequency distributions. In recent years the typological experience-based approach to human variation in physical and forensic anthropology has been severely undermined (Ousley et al., 2009). Presently, there is an increasing force of new research which has set out to disprove the biological concept of race inherent in early traditional physical anthropology (Long and Healy, 2009). The greatest amount of overall agreement amongst scholars currently is that a substantial body of evidence points to strong geographic patterning of human variation despite overlap in their distributions (Long and Healy, 2009; Ousley et al., 2009). Although the ultimate goal would be to accurately identify individuals based on skeletal morphology, the current methodology at hand, which includes the application of North-American derived discrete traits to diverse populations, does not perform satisfactory on many levels of analyses (Long and Healy, 2009).

Forensic anthropology has been considered a subdiscipline of physical anthropology that focuses on methodology that assists law enforcement with the personal identification of human skeletal remains from forensic contexts (Ousley et al., 2009). Sex, age at death, ancestry and stature are the major estimates that form part of the biological profile from which law enforcement attempts to narrow the list of missing persons. Estimates of sex, age, stature, trauma and pathology have enjoyed far more attention than that of ancestry. The history of race has caused much ambiguity and controversy and is suggested as the reason why anthropologists ignore the topic or avoid it altogether (Hefner, 2003; İşcan and Steyn, 1999). Although perceptions on human variation continue to change, a demand should be placed on the development of terminology that could accurately explain the concept (Ousley et al., 2009). In the past, the term “race” has been substituted by terms such as “ethnic” group, “ancestry” and most recently “human variation” (Gill, 1998; Rhine, 1990; Ousley et al., 2009). However, it should be noted that in this study, the term “race” is used to refer to historical studies and to explain past research, not to interpret it.

While South Africa may not be unique in its rate of violent crimes or in its seemingly large number of unidentified persons, the heterogeneous nature of the population is certainly unusual when compared to other groups such as Europeans. Within the last 500 years various groups of people, namely Dutch, French, Malaysian, and Indian, to name but a few, migrated, both willingly and forcefully to the country. Over time, this amalgamation of genes and culture produced the South African identity as well as contributed to skeletal features associated with sexual dimorphism, ancestry and stature which differ from other groups, such as North Americans. The theory regarding skeletal differences between population groups is known as population specificity, and is often used to explain differences in sexual dimorphism, stature, and rates of aging between groups. While it has yet to be adequately examined, the notion of population specificity may also apply to non-metric traits used to determine ancestral groups; the primary aim of this project is to evaluate the efficacy of several non-metric traits developed on North American groups to those of white, black and coloured South Africans.

# Chapter 2: Literature review

The aim of the present study is to evaluate the significance of non-metric cranial traits in a South African context as it is used to estimate the ancestry of an unknown individual. A clear understanding of non-metric trait analysis partially depends on the origin of the concept of human variation, racial differences addressed through human evolutionary pathways, the origin and concepts of race, and the progress of the intellectual field of physical and forensic anthropology.

## 2.1. Human diversity: origin of anatomically modern humans

The events leading up to modern human diversification cannot be completely constructed because the fossil record only provides broad patterns (morphological, spatial and temporal) that can be extrapolated into theories and interpretations (Lahr, 1996). However, these patterns form a foundation for morphological differences found among worldwide population groups. According to Gill (1990), the concept of race (in the biological sense) remains an important issue in modern anthropology and it stresses the importance in understanding the evolutionary process, itself. In the introduction of Rhine's *Skeletal Attribution of Race* (1990), Gill explains that the survival of a species is dependent on an increase in both its numbers and radiation into different ecological niches that over time produce genetic responses in that species. Thus, an increase in physical variation prevents extinction of a species and can serve as a platform for the birth of a new species (Gill, 1990). Morphological variation, or ancestral differences among population groups, can therefore be considered an important aspect of the evolutionary processes (Gill, 1990).

In recent years, research has centred on two opposing hypotheses to explain the origin and diversification of modern humanity, namely the monophyletic and polyphyletic views. During the early 20th century, most physical anthropologists were convinced that human races emerged through largely parallel evolutionary processes in widely separated, well isolated parts of the Old World. The proponents of this polyphyletic view (e.g., Weidenreich, 1946) often showed reluctance towards the importance of migration even though they clearly acknowledged some effects of gene flow between groups (Gill, 1990). The polyphyletic theory was an early version (Smith et al., 1989) of the *multiregional evolution model* (MRE) (Gill, 1990). By the mid 20th century, this theory was largely obsolete, but some isolated supporters remained such as Carleton Coon, who suggested that *Homo sapiens sapiens* arose five different times from *Homo erectus* in five different places and at different rates (Caspari, 2003). Coon (1962) suggested that each racial lineage entered the *sapiens* "state" at different times in pre-history and he implied that the length of time each group had been in the *sapien*s state was correlated with the level of cultural achievement of that group (Caspari, 2003; Gill, 1990). Coon also contended that Caucasoids and Mongoloids entered into the *Homo sapiens* lineage considerably earlier than Africans (Negroids and Capoids) and Australians (Australoids) (Caspari, 2003; Gill, 1990). The multiregional model holds that the evolution of all humans from the beginning of the Pleistocene 1.8 million years ago to the present developed from regional archaic populations in several parts of the world. The core idea of this hypothesis implies that modern cranial form was superimposed on existing regional variation and that differences between recent populations would be as old as the establishment of the archaic regional patterns (Lahr, 1996).

The opposing theory advocates a single and recent origin for modern humans and suggests that the origin of species and groups within a species was a result of different processes occurring at different times during evolution (Gill, 1990; Morris, 2005). The *recent African origin of modern humans* theory originated in the 19th century with Darwin's *Descent of Man* but this theory remained speculative until the 1980's, when it enjoyed wide spread acceptance in the scientific community based on studies in mitochondrial DNA (Lahr, 1996). Monophyletic scholars interpret the origin of modern human populations as a radiation or a spread from some recent source or a common ancestor that underwent early differentiation (Lahr, 1996). This view suggests that early modern people expanded rapidly and remained isolated for long periods of time with subsequent replacement of the earlier populations. There are two modern versions of the monophyletic theory, the *Afro-European sapiens hypothesis* (AES), and the *Recent African evolution* model (RAE) (Gill, 1990). Both versions propose that the continent of Africa was the origin of modern humans (Gill, 1990). The AES model appears to be largely the work of Bräuer who is less extreme in his characterization of extinction/replacement of earlier archaic populations than some of the other monophyletic thinkers (Gill, 1990). He shares with the multi-regional (MRE) supporters an acknowledgement of some continuity of traits from archaic Eurasian populations to modern ones, but he views the phenomenon as largely one of replacement. He explained the disappearance of archaic human populations in Europe and Asia as the result of the replacement and hybridization, and characterizes the process as certainly having been a complex one (Gill, 1990). The implication is that it would be impossible to address the issue of diversification of humans without initially considering the process of modern human origins (Gill, 1990).

In many ways the RAE model is similar to the AES model. Both have been influenced by the mitochondrial DNA work of Cann and associates (1987) which has been interpreted to suggest that all modern human mitochondrial DNA had a common ancestry in Africa approximately 200,000 years ago (Gill, 1990). Both modern monophyletic theories suggest a single more recent origin of modern humans appearing in Africa earlier than in other continents. One crucial difference between these theories is that scholars who argue the RAE position, views the origin of modern humans as a biological speciation event. Therefore no significant admixture would have been possible in their view between the emerging modern African *sapiens* and the archaic Europeans or Asians that they would have supposedly encountered (Gill, 1990).

In contrast, Wolpoff and others believed that monophyleticists were overlooking important skeletal evidence that could have suggested gradual regional transitions from archaic populations to modern ones (Wolpoff and Caspari, 1997). They also suggested that monophyletitists could have also mistaken the effects of a common selective force and gene flow for evidence of sweeping mass migrations followed by total replacement of earlier indigenous populations. The same holds true for the polyphyletic theorists who tend to propose that cladogenesis (the branching of the family-tree) has occurred frequently in our phylogenetic past, when in fact it appears much more likely that most changes have been anagenetic (change within the evolving species line). The very fact of "branching off" infers speciation, at which time gene flow ceases and subspecies relationships disappear (Gill, 1990).

While the *Multiregional* and the *Out of Africa* models both emphasize and minimize the differences between races, they take the race concept as a conceptual reality. The result is that the proponents who prefer to view races as a reality are encouraged to do so and that students of human variation would be better off avoiding the term and instead describe genetic differences in terms of populations and clinal gradations (Lieberman and Jackson, 1995).

## 2.2. Human diversity: racial discrimination

Our modern understanding of human diversity originated from several fields of study, and represents an accumulation of knowledge spanning over centuries and even millennia within western civilization (Gill, 1990). Originally, the separation of people into distinct groups, as seen among the monophyletic and polyphyletic views of modern human origins, was not linked to value judgments of superiority or inferiority for these groups. To speculate as to the exact time in which racial discrimination had its origin would be unrealistic, but given visually complex social relationships of humans, they have always observed and commented on the physical differences among individuals and groups (Wolpoff and Caspari, 1997).

Discrimination against people based on the colour of their skin or on other physical features has been recorded throughout history. Although many views of discrimination against people in ancient societies never became official doctrine, several civilizations contributed markedly to written and verbal discrimination. Classical civilizations, spanning from Egypt to Greece, developed methods in which to separate themselves from other population groups. For example, ancient Egyptians referred to foreigners as "rustic" and "uninitiated", and considered themselves to be more human than others (Montagu, 1964). The foundation for these differences was based on class. In the ancient Egyptian sacred text, called the *Book of Gates,* people were categorized as "Libyans", "Asiatics", "Africans" and "Numbians". However, a foreigner with widely varying physical appearances could obtain full citizenship in Egypt and be promoted to the status of a god king once he mastered the native language and became acculturated to Egyptian style. In ancient Greece, an attempt was made to find a biological foundation for differences between people, but this notion never became part of mainstream society (Montagu, 1964). Once the institution of slavery in Greece faced opposition, its existence began to rely upon the theoretical justification of racial differences formulated by philosophers such as Aristotle and others (Montagu, 1974). These philosophers attempted to explain and categorize visible biological differences among people known to them. For example, a slave was to be considered only "partial human", "lacking the natural abilities of a soul", and needed to be ruled over by those possessing the "element of governance". Even before Aristotle, Plato proposed in his writings that because of the differences existing between people, some were better qualified to rule than others. Plato's theories were based on the idea that the natural world was made up of distinct ideal types, and that variation was the result of deviations from the ideal form. This type thinking, often referred to as essentialism, inferred that all unchanging forms that made up the physical world were fixed and that the only source of change could be an independent, origin of new forms (Wolpoff and Caspari, 1997). The slave did not embody the distinct type, which was the Caucasian male, and the variation he exhibited was regarded as imperfections of the ideal type. Many of the ideas of Plato governed the foundations of the biological arena and according to scholars had a limiting affect to its progress (Wolpoff and Caspari, 1997). While people in ancient times were discriminated against from others based on religious, cultural, political and class differences, they were never discriminated solely on biological grounds (Montagu, 1974). For example, in Europe during the Middle Ages and also during the Renaissance the Jews were discriminated against because they were thought to have killed Christ and to have partaken in religious ceremonies in which the blood of Christian children were sacrificed. They were accused of mostly anything, but what was held against them was never purely contributed to their biological affinity (Montagu, 1974). Another medieval model for explaining human diversity emerged as the idea that humanity as a whole descended from Shem, Ham and Japheth, the three sons of Noah which produced distinct Semitic (Asiatic), Hamitic (African), and Japhetic (Indo-European) peoples. This theory dates back to the Abrahamic tradition described in the Babylonian Talmud and states that the descendents from Ham are cursed by being black, and also depicts Ham as a sinful man (Hamel, 2002).

The 15th and 16th centuries brought the spirit of exploration and the eventual discovery of every corner of the globe (Wolpoff and Caspari, 1974). The age of exploration sparked the desire for knowledge, riches and curiosity about different nations around the world. When explorers such as Columbus, Cook, Da Gama and others returned from their voyages to the New World, they brought with them tales and treasures of other continents such as fruits, vegetables, gold and exotic people (Montagu, 1974). Many of their captives were brought to Europe where they were examined, pictured and exhibited to the amusement of the royal (Wolpoff and Caspari, 1997).

The goal of these European merchants was to explore continents, find new lands, and secure the riches for themselves and their kings. Their eagerness to expand was driven by prospects of endless riches and advancements in technology. At that point ships were designed to sail faster and improvements in compasses and chronometers marked progress in the field of metallurgy. Yet, the discovery of magnificent places and bountiful treasures produced as a consequence, concomitant slavery, murder, and colonialism (Wolfpoff and Caspari, 1997). The Europeans soon found other lands to be inhabited with people different from themselves and the only way they could claim what they had found was to justify their own superiority to the subordination of these people (Wolpoff and Caspari, 1997). Literature (Montagu, 1974, Wolpoff and Caspari, 1997) suggests that the whole concept of race developed as a direct result of the slave trade controlled by European merchants. According to Montagu (1974), the "objection to any people on racial or biological grounds is a purely modern innovation" (Montagu, 1974:21). Therefore, discriminating against people based on biological affinity was the manner in which race as a biological concept was born (Montagu, 1974, Wolpoff and Caspari, 1997).

Although trade with foreign people was considered to be general conduct and increased on a global scale, widespread approval was given to the suppression of infidels in the fifteenth century (Montagu, 1974). The result of this decree was the official sanction of the enslavement of Africans, or people of black skin colour. Wolpoff and Caspari (1997) discuss that as long as trading with slaves was granted and treated without any questions, slaves were considered human in every aspect but that of social status. Some English and American slave traders believed that while their captives were social inferiors, many of their prisoners were often considered mental equals and superior to many of them with regard to abilities and intelligence. The only thing they lacked was education and instruction (Montagu, 1974).

As part of the European imperialist tradition, beliefs developed in which physical, social, cultural, intellectual, behavioural and mental differences between groups were emphasized. Racial prejudice was often practiced as a means to justify their actions with regard to slavery. Kidnapped victims were often described as being without the "clearness and the light of the holy faith" living like "beasts" without any custom of "reasonable beings," having "no knowledge, and no understanding of good," and were without clothes" (Montagu, 1974:19). The Europeans often mentioned the black man's skin as "ugly", a symbol of mortal taint and ultimately designed "to be of service to his master, the white man" (Montagu, 1974:19).

In 1740, David Hume, the Scottish philosopher, claimed that as far as he was concerned "all Negroes, and in general all other species of men, were naturally inferior to whites" (Montagu, 1974:20). He even went as far as to disregard and belittle their intellectual capabilities and cultural behaviour. Hume described the black man as having "no ingenious manufactures amongst them, no arts, and no sciences" (Montagu, 1974:20). Word labels such as subordinates, beasts, and beings with no innate abilities were frequently used by European groups. Those who had begun to query the system did so without much effect. Slaves were permitted to be set free but the system of keeping people enslaved required a slave to be returned to his master, since he simply lacked the abilities of his superior and could not survive on his own. One's culture could afford itself all the rights and privileges pertaining to its own people and to view foreign cultures with varying degrees of hostility and inferiority (Montagu, 1974).

From the onset of human slavery in the 15th and 16th centuries, men have shown their discontentment towards the views and ideas of its advocators. By the end of the eighteenth century, the institution of slavery faced increased opposition and people started to ask questions on the status and relation of the various nations of the world. The 19th century marked the period in which acrimonious debates followed between anti- and proslavery advocates (Montagu, 1974). However, the damage had already been done and any discussion on the variation among humans was to forever be attributed to racial affiliations. These views affected the manner in which human variation was to be studied and taught among physical anthropologists in the United States and elsewhere (Wolpoff and Caspari, 1997).

### 2.3.1 Human diversity: typological concept of race

During the mid-18th century, physical anthropology was born from the studies and reports of voyagers, naturalists and social philosophers that centred on the writings of Charles Darwin and others (Montagu, 1974). An important focus of these early scientists was not only to study human evolutionary origins and the position of humans in the Systema Naturae from a scientific point of view, but also the origins and relationships of the diverse and contemporary populations of the world (Montagu, 1974; Gill, 1990). Much of the interest in human origin and variation in the early stages of physical anthropology has been retained and is of special interest in the present day (Brues, 1990).

Following the ideal types postulated by Plato and others, the scholars of the 18th and 19th centuries concerned themselves with dividing humans into discrete typological units. In Darwin's most controversial book, *The Descent of Man* (1871), he stated that humans have been studied more extensively than any other animal; yet there exists great speculation amongst scientists as to whether man is classified as a single species or race, or as two (Virey), as three (Jacquinot), as four (Kant), five (Blumenbach, six (Buffon), seven (Hunter), eight (Agassiz), eleven (Pickering), fifteen (Bory St. Vincent), sixteen (Desmoulins), twenty-two (Morton), sixty (Crawford), or as sixty-three, (Darwin, 1871). Darwin suggested that the range of morphological variation within and among population groups did not terminate abruptly but gradually became transformed from one group to the next (Darwin, 1871).

Two anatomists of the 18th and 19th centuries who opposed slavery and advocated racial equality were Carl Linnaeus (1707-1778), and Johann Frederick Blumenbach (1752-1840). Carl Linnaeus, a Swedish physician of the 18th century and also known as the father of taxonomy, classified plants and animals before their genetic relationship with each other was clearly understood. He developed a system for cataloguing and describing organisms, listing for each type both the morphological and behavioural characteristics which, despite several changes, remain in use today (Caspari, 2003). Linnaeus included *Homo sapiens* in his Systema Naturae and applied the principles of taxonomy of plants and animals to that of humans. He originally classified all humans together, but in 1758 defined four human races, namely Europeaus, Americanus, Asiaticus, and Africans (Montagu, 1974). Linnaeus insisted that his typological approach for describing humans was based on geographic patterning; however, it only acted to reinforce the typical racial view of that era that both embodied essentialism and biological determinism (Hefner, 2003).

Johann F. Blumenbach of the University of Göttingen has been described as the founder of scientific anthropology and the father of the study of race. Blumenbach, a monogenist, published *De Generis Humani Varietate Nativa (1775)*, in which he developed a modern racial classification. He was a typologist, who believed in a single and recent origin of man, but he also suggested that humans fell into one variable type or another. This left little room for the interpretation of intermediate forms. He had the notion that human races had a single origin and that some populations came to differ from the original ideal type as they moved into different environments (Hefner, 2003). He paid special attention to the differences between man and animal and attacked all political and social abuses of anthropological ideas. Blumenbach was convinced that there was an original template within the genetic make-up of humans, from which all variation could extend from. According to Blumenbach, Caucasians were the ideal original race, and "the most beautiful of the races of man" (Wolpoff and Caspari, 1997:62). In 1775, he classified humans into four race groups based on combinations of head shape, skin colour, and hair form. In 1781, he used the term race as a means to explain and to expand his classification of humans into five categories: the original Caucasoids; and the two races that differed most from Caucasoids were Asians and Africans (called Ethiopians). Two transitional races found between the ideal types (Caucasoids) and the extremes were Aboriginal Americans, or the Asians, and Malays (Hefner, 2003). An important key in understanding Blumenbach's reasoning lies within the Malay's classification. The Malays did not appear in Blumenbach's original formulation of race classification or in the writings of Linnaeus that preceded it. Linnaeus and Blumenbach originally defined races by geography. Later, Blumenbach turned them into taxonomically ranked entities, with "major" races being linked with more specific "minor" race groups. These extended in two directions from the ideal races to those farthest removed from the ideal types. The Malays were critical in his scheme because without them Blumenbach had no way to link Europeans and Africans. Thus, he viewed minor races as forms or gradations.

In other words, minor races were proof that major races were not discrete types but that all humans were members of the same species. For scientists like Blumenbach and Linnaeus, race was considered a minor human variant and not a fixed part of creation (Wolpoff and Caspari, 1974). The sorting of people into major and minor race groups was the first attempt to explain variation that did not correspond to the ideal form.

After Linnaeus and Blumenbach, various scientists had set out to prove that by dividing humans into discrete typological units, they could demonstrate differences in overall value; naturally, Europeans were placed at the top of the evolutionary tree (Hefner, 2003). The scientists of this period re-introduced the recapitulation theory of Ernst Haeckel. This theory implied that non-European groups, women included, represented earlier more primitive stages of evolution, and were, therefore, sub-ordinates to European males (Hefner, 2003). An example of how a measurement of worth was used to validate one group's superiority over another group's inferiority based on biological criterion was that of Morton and his use of mustard seeds to measure cranial capacity (Hefner, 2003). Morton unwaveringly believed that cranial capacity shared an increased proportional relationship with intellectual capability. From this study Morton demonstrated that European crania held the greatest number of mustard seeds, which he used to infer that they had the largest cranial capacity and were thus the most intelligent (Hefner, 2003). Later, Gould (1996) proved Morton's data to be biased as he allegedly knew the race of each specimen and had forced more seeds into European crania and less into African crania (Hefner, 2003).

During the early stages of the 20th century, race was the major theoretical foundation of anthropology and held immense importance within the field of physical anthropology in the United States (Caspari, 2003). During this period physical anthropology was practically synonymous with the study of race and by 1902, most anthropologists considered the concept as the way in which humans were internally subdivided (Caspari, 2009).

The establishment of physical anthropology as a distinct discipline in the United States was a crucial objective of the Czech born anthropologist, Aleš Hrdlička (1869-1943). More than ninety years ago, Hrdlička founded the American Journal of Physical Anthropology (AJPA) (Caspari, 2009). The journal's original committee consisted of members strongly advocating for applied racial anthropology, similar to what was practiced in Europe at the time (Caspari, 2009). On the other hand, Franz Boas (1858-1942), who represented the American Anthropological Association (AAA) and Columbia University, had challenged the race concept since the 19th century and was opposed to groups who perceived racial differences within humans (Caspari, 2009).

These two groups had an interconnected history, and although the AJPA were founded by Washingtonians, the emerging field it represented was quite different from much of European physical anthropology because of its position within the broader and more progressive American anthropological community (Caspari, 2003; Caspari, 2009). For example, in 1966, Margaret Mead and Theodosius Dobzhansky delivered a clear voice against a popular racism based on "misinformation" and "evil myths" about race (Caspari, 2003). In subsequent years most anthropologists gradually became opposed to the traditional claims about race and intelligence, and by the mid 1960's many scholars were now sceptical of the race concept, itself (Caspari, 2003). Moreover, and perhaps most importantly, physical anthropology developed within the context of a uniquely American four-field tradition, and therefore the Boasian influence on the development of biological anthropology within anthropology was profound (Caspari, 2003). The first volume of the AJPA therefore presented a picture of the main role players who shaped modern physical anthropology and the conflicting racial views they advocated.

As mentioned above, the first major contributor to the field of physical anthropology was Aleš Hrdlička. In 1881, he moved to New York where he filled the first position in the then newly formed division of physical anthropology at the Natural Museum of History. He aimed to form an institute of physical anthropology similar to those that were already established in France. Hrdlička was educated in Paris, under the pre-eminent French anthropologist, Paul Topinard, whose views were primarily founded on polygenist principles. Topinard mainly focused on the identification and categorization of racial groups (Caspari, 2009). Hrdlička understood racial anthropology as an applied science to be beneficial to the movement of eugenics and the war efforts, which at the time represented a difficult problem in physical anthropological thought. The problem centred on the use of anthropology as a means to validate biological determinism implicit in racial thinking (Caspari, 2009). Thus, applied physical anthropology in the early 1920's was based on the assumption of biological determinism and the link between biological and social conceptions of race.

The second influential role player in the early stages of physical anthropology was Franz Boas. The contribution of Boas to the first volume of the AJPA was based on human variation and racial affinities, but he had approached it in a non-racial manner while testing the concordance of racial features and other assumptions of the type concept. His strongest contributions to the field were statistical, which he applied to studies of osteometric variation in humans. For instance, he examined the variation found among European types and evaluated the anthropometric features of Swedish men, published earlier by Retzius and Furst

(1902) (Caspari, 2003). He paid attention to the distribution of these features in a population and he mapped the distribution of hair colour, eye colour, head length and breadth, stature, and the coefficient of correlation between head length and breadth. Boas noted the averages in values of these traits and their mathematical variation by geographical region. He was particularly interested in the relative homogeneity for the above-mentioned features. Throughout his career, Boas challenged the notion of biological determinism and the usefulness of typology as indicators of race in physical anthropology (Caspari, 2009). Much like the researchers today, he focused on the notion that there was more within group than between group variation. In contrast, Hrdlička focused on distinct typological groups and kinds within these groups.

The third prominent figure was Earnest Hooton (1887-1954). Hooton's influence on the field is of highest value since he was single handedly responsible for educating an entire academic field and shaping the discipline of physical anthropology as we know it today (Caspari, 2009; Hefner, 2003). Hooton, an evolutionary polygenist, supported the polyphyletic model of race forming processes that rejected the origin of race from separate species, but recognized a transformation of various races as they evolved from *Homo erectus* to *Homo sapiens sapiens* in various regions of the world (Hefner, 2003; Wolpoff and Caspari, 1997). Hooton held that non-adaptive morphological features were responsible for differentiating the various races, a belief grounded in the existence of once pure races that had separate evolutionary histories (Caspari, 2003; Hefner, 2003). Given that Hooton firmly believed in races, his views can appear paradoxal. His research had all the attributes of the race concept, but he was actively involved in many anti-racist campaigns (Caspari, 2003). In 1936, he published a statement on race in *Science*, which opposed racism underlying the racism of Germany (Caspari, 2003).

In the first volume of the AJPA, Hooton, like Boaz, reported on detailed studies involving biological variation and racial affinities. In his study, he demonstrated the taxonomic assumptions of race which imply that humans can be divided into relatively small discrete groups. The focus of his study was on four non-metric features in Icelandic crania and included the mandibular and palatine tori, thickened tympanic plate, and the scaphoid skull vault shape, which was considered typical of Eskimos. Moreover, Hooton argued that the features from his study were not racial but rather functional. He interpreted his analysis based on the fact that different races adapted to similar sub-Arctic environments and did not share these features with comparative samples of the same "racial stock". Hooton concluded that while admixture of the two races did occur, it was more likely that the similarities were caused by shared physiological responses mainly due to the composition of their diets (Caspari, 2009). The morphological skeletal indicators that he used to differentiate geographic races of human groups remain the principal indicators that are in use today, and constitute most of the traits applied in this study.

While few of Hooton's students rejected his ideas on race, many continued his focus on the subject and on human variation. Stanley Garn and, Carleton Coon paid attention to the problems of the race definition, the number of different races, and the problems on race formation (Caspari, 2003). Many papers focussing on these aspects were published, some of which included that of Coon (1950) who suggested that micro-areas could be defined by larger number of traits while they represented subdivisions of broad major races whose components shared a smaller amount of traits (Caspari, 2003). Shapiro (1939) and Hulse (1962) focused on the stability of racial traits, and demonstrated morphological changes in first generation Japanese immigrants from Hawaii (Caspari, 2003).

By evaluating the views and opinions of those who made valuable efforts in establishing the field of physical anthropology in the United States, it becomes clear that the concept of race remains a topic of discourse in modern day physical anthropology. The following paragraphs focus on information obtained from various research fields that serve, and continue to serve, as mechanisms to explore the nature of human variation.

### 2.3.2 Clines, populations, genetics and anti- and pro advocators of race

Racial variation in the skeleton has been described by numerous scholars, namely Bass (1995), Brues (1990), Hooton (1931), and Klepinger, (2006). There has been a recent emphasis in forensic anthropology to disprove the biological race concept of classic physical anthropology when discussing human variation (Ousley et al., 2009). The classic race concept of earlier physical anthropologists suggests that all humans belong to one of only a few biological types or races namely Caucasoid, African, and Mongoloid; additionally these groups are considered to have evolved in isolation from one another (Guido, 2005; Ousley et al., 2009). Many modern day studies have started to challenge the racial view and have failed to associate racial labels with recognizable genetic clusters (Guido, 2005). Recent studies have also failed to establish clearcut genetic boundaries between groups, which would be a requirement to recognize these groups as relatively isolated mating units (Guido, 2005). In contrary, allele frequencies of genetic variation seem to be distributed in gradients over the globe, which points to gene flow, rather than to gene isolation (Guido, 2005).

A misrepresentation of science during the 1960's resulted in fostered alliances between those who had opposed the notion of race for an already extensive period of time and those who had not. In 1966, the Mead-Dobzhansky symposium represented such an alliance and subsequently produced several volumes on the study of race that brought together work from a variety of disciplines (Caspari, 2003). One of the focal points of this alliance was to attack the inadequacy of the race concept for explaining human variation. This introduced the study of clines, the geographic distribution of individual morphological and genetic traits, where population replaced race as a focus point. However in 1964, Brace argued that races and even populations were inadequate for the study of human variation and suggested that the study of the distribution and selection of traits needed to be re-examined.

The study of clines became the main objective for many researchers such as Frank Livingstone, one of the first anthropologists to advocate anti-race theories in the study of human variation. Livingstone (1962) contended that while all humans could be divided into races based on the frequency of a single genetic character, it seemed as though different characters produced different and contradictory results with regard to the race group to which one was associated. Livingstone concluded that once a few characters were considered, there would be no grouping larger than a population (Long and Healy, 2009). Although some authors (Brues, 1990) embraced the significance of clines, they also acknowledged the possibility that the biology of groups could prove equally valuable in explaining human variation. The result, as described by Mayr (1969), marked the end of the concept of race, while a population, as a unit of study, replaced the traditional concept of race. Nevertheless, many 20th century anthropologists, whether studying genes or morphology considered *population* as a term synonymous with *race* (Caspari, 2003). For example, Garn (1962) understood that the contemporary approach to race was derived from population genetics and that a race was simply a breeding population isolated from other groups. Consequently, Garn considered the Bushmen of South Africa as an isolated breeding group (Caspari, 2003). A population was also regarded as a closed system, and therefore implicitly included the existence of types, even though the scientific focus was on their adaptations to the environment. According to Van Gerven (1982), studies in both skeletal biology and genetics continued to employ typological methods in the recognition and delineation of population groups (Caspari, 2003). The eventual result was that many studies of populations were just as typological as previous studies of racial groups. Apart from many typological genetic studies, genetics unequivocally influenced the changing race concept and throughout the years provided compelling evidence for the notion that humans were a single species (Caspari, 2003).

In 1972, Richard Lewontin rejected the use of race and made famous the assumptions that suggested that more variation exists within than between human groups (Caspari, 2003; Long and Healy, 2009). Lewontin examined 16 blood group frequencies and allele frequencies and found that relative to the total diversity for all humans, the within group component is 85.4%, the component for populations within races is 8.3%, and between race groups is only 6.3%. Based on these results, Lewontin confronted the race concept by showing that classical race groupings account for too little of the total diversity among humans (Lewontin, 1972). The effect of his research had an impact for more than 30 years and many studies of this kind followed and produced similar results (Long and Healy, 2009). Advances in genome technology have allowed geneticists of the current day to further their understanding of variability within and between groups. Several of these advances allow geneticists to reveal exact DNA sequence changes, analyze large volumes of data, and permit researchers to compare different species with each other (Long and Healy, 2009).

Subsequent studies of neutral genetic variation including that of Nei and Roychoudhury, (1982), Barbujani and colleagues (1997), and Rosenberg and associates (2002) have replicated the results of Lewontin (Long and Healy, 2009). In the study of Rosenberg and co-workers (2002), they found that most alleles are distributed worldwide, while alleles restricted to one group are very rare. Additionally, when the alleles were clustered into five groups, the resulting groups corresponded to the major geographic regions of the world: Africa, Eurasia (Europe and West, Central, and South Asia), East Asia, Oceania and the Americas. Also, the results suggested excellent agreement between individuals' membership in the clusters and their self-reported regions of ancestry (Klepinger, 2006). These and other studies have been used to discard the race concept in anthropology (Hunley et al., 2009; Klepinger, 2006). Conversely an interesting finding of Healy and colleagues (2009), which was based on the studies of the above mentioned scientists, was that portions of the variation between groups was statistically significant. However, this study was used to promote the Lewontinian theory, which suggested that the percentage was too low for taxonomic significance (Hunley et al., 2009).

According to Healy and associates (2009), Montagu (1964, 1974) is the most outspoken race critic of the 20th century. In many of his works (Montagu, 1964, 1974), he has argued that the concept of race held by physical anthropologists is false, and leads to confusion (Montagu, 1974). Healy and colleagues, (2009), regarded his research on race as being more emotional than rational. According to Gill (1998), Montagu's work has only produced a continuation of an already misunderstood concept of race and has placed a social restriction on a subject that is in need of clear, rational and dispassionate examination. Montagu (1964) suggested that race be substituted by *ethnic* group, but all this new term generated was more confusion and ambiguity. Subsequent researchers including Stewart (1979), Krogman and İşcan (1986), Bass (1987) and Brues (1990) have attempted to re-introduce the word race but with explicit definition of the racial categories and the trait complexes involved (Hunley et al., 2009). Unfortunately there have been misunderstandings about race, its abstract and arbitrary nature as well as serious political abuse of the concept (Hunley et al., 2009).

## 2.4. Current views across disciplines

Current debates exist over the exact meaning and validity of the concept of race across disciplines which assess human variation. Many scholars are of opinion that the concept of race lacks agreement. However within some fields, such as biology, there is strong consensus. Some points of agreement reflect a shared evolutionary perspective that focuses on describing and interpreting the distribution of biological variation contained by and between groups (Edgar and Hunley, 2009). From a recent symposium of the American Journal of Physical Anthropology in 2009, scholars of these views were in agreement that substantial variation among individuals within populations exists and that some biological variation is apportioned between individuals in different populations and among larger population groupings. Also, patterns of within and among group variation have been substantially influenced by culture, language, ecology and geography. The delegates of the symposium concluded that race, or ancestry, is not a precise or dynamic way to describe human biological variation; however, human variation research is to continue to fulfill important social, biomedical and forensic implications (Edgar and Hunley, 2009).

## 2.5. The use of non-metric trait analysis to explain human diversity

Traditionally, discrete traits have been studied via metric (craniometry) or non-metric (morphologic) techniques (Rhine, 1990). The focus of this study is on non-metric trait analyses.

Non-metric skeletal traits vary from one individual to another, are visually determined, and cannot be measured easily (Saunders, 1989; Parr, 2002; Ousley et al., 2009). In fact, these traits are considered normal skeletal variants that are generally not expressed externally on the human body and are not pathological or traumatic in nature (Parr, 2002). Non-metric analyses are simple to perform and have been more thoroughly applied in recent years (Wood-Jones, 1930a). Berry and Berry (1967), Corruccini (1974), and Hauser and De Stefano (1989) amongst others have conducted in-depth studies on the variation of discrete traits in the human skull. In these studies, variables are illustrated by line drawings and depicted in great detail to represent the traits which they are used to describe. Researchers have attempted to standardize the use of discrete trait analysis and made the descriptions available for scholars employing these traits in their own studies. As these variables become better understood and described, the more valuable they became. Due to increased standardization and ease of use, analysts are applying non-metric features in global population studies at an increasing rate (see Table 2.1) (Hauser and De Stefano, 1989; Hefner, 2003).

Most discrete traits fall into a number of different categories (Mays, 1998) and include the variation in the number of bones or teeth (example), anomalies of bone fusion, variation in bony foramina, articular facet variations, hyperostosis (traits characterized by a localized excess of bone formation), hypostosis (traits characterized by a localized deficiency of bone), and the variation in the form of the tooth crowns (Parr, 2002). Despite disagreement amongst many scholars, the scoring procedure of these variables is traditionally performed in two ways. Traits that are categorical in nature and associated with intermediate stages are scored through a ranking system, e.g., the contours of the nasal bone ranges from flat, to slightly projecting, culminating in vaulted and steepled appearances (Saunders, 1989). Some discrete traits are scored as being either present or absent. This includes the presence or absence of a particular bone or foramen, for example the lamboid ossicle or the foramen of Huschke. Bilateral traits are scored either in assessing the presence of the trait in skeletal material regardless of whether it appears on one or both sides of that individual or by scoring the variable separately as it appear on each side. Scoring non-metric traits by individuals may result in underestimating the occurrence of a particular trait within a population, while the scoring of sides tends to overestimate the occurrence of a trait, resulting in artificially inflated sample sizes (Suchey, 1975).

The frequent use of non-metric trait analysis in population studies over the last century has accumulated in a set of advantageous as well as disadvantageous opinions from various anthropologists. From a positive perspective, these traits do not require expensive, delicate or complex equipment (Rhine, 1990, Brues, 1990) and therefore allow analyses to be conducted fairly rapidly. Some authors (Rhine, 1990) are of opinion that this method can be applied to incomplete skeletal material, which in contrast to metric analysis requires a relative complete skull for an adequate evaluation. One of the major critiques in the use of non-metric analysis is the subjectivity of the anthropologist's characterization of the traits in question, which may account for the high degree of interobserver error (Parr, 2002). Another commonly encountered problem (specifically pertaining to some non-metric variables) is the lack of clear and detailed descriptions and illustrations in the literature (Rösing, 1984). Non-metric traits that have been continually tested should have greater reliability and be less prone to interobserver error. However, there are still some traits that have not been adequately described and tested and may therefore prove to be less valuable (Wood-Jones, 1930-31a).

For more than two centuries, researchers have considered non-metric features as phenotypic anomalies, which are expressed as minor skeletal variants in the human skull. According to Hanihara and colleagues (2001b) these traits have been used in earlier studies in comparative anatomy and phylogeny for advocating differences between two or more groups (Chambellan, 1883; Hauser and De Stefano, 1989; Le Double, 1903; Frasetto, 1904; Outes, 1911; Akabori, 1911; Wood-Jones, 1931; Hooton, 1930). An early study in descriptive morphology of the skull includes that of Stewart (1979), who classified crania into distinct u- and m-types. He studied morphological traits of 398 adult American black skulls, 64 white Anglo-Saxon skulls, and 277 African black skulls (Stewart, 1979). The skulls were evaluated on the basis of two contrasting variants of each trait. The author described five morphological traits and found that typical blacks had undulating supra-orbital ridges, sharp upper orbital margins, rounded glabellas, plain fronto-nasal junctions, and wide interorbital distances, while whites had mesa-like supra-orbital ridges, blunt upper orbital margins, depressed glabellas, beetling of the upper frontonasal junctions, and narrow interorbital distances (Stewart, 1979).

Studies in cranial base form and its relevance to race were also investigated. Ecker (1870) studied the flexure of the cranial base and found it to be greater in blacks, while Kramp (1936) studied racial differences in the position of the condyles and mastoid processes

(Krogman and Işcan, 1986). Post (1969) carried out a study in which he noted possible race differences in the incidence of dacryocystitis (Krogman and Işcan, 1986). He noted that dacryocystitis was less frequently found in blacks than in whites, and contributed it to possible differences in skull morphology. Results of the study indicated that American blacks had significantly larger apertures in the external opening of the nasolacrimal duct canal than American white males (Rhine, 1990).

From 1931 to 1934, Wood-Jones recognized the use of discrete traits in population studies based on their adaptiveness and non-adaptiveness (Hauser and De Stefano, 1989). Later, Laughlin and Jørgensen (1956), and Laughlin (1963) made efforts to quantify subjective comparative studies to show genetic separation between different groups (Corruccini, 1974; Finnegan and McGuire, 1979). Brothwell (1958) repeated the study of Laughlin and Jørgensen but applied it to larger groups and found that, while not as conclusive as the former authors' results, discrete traits offered an alternative method for differentiating populations (De Villiers, 1968). Vanguard studies have further explored a wide range of variants in calculating distance statistics. Kellock and Parson (1970) studied Australian Aborigines, Berry and Berry (1967) and Knip (1970-71) assessed Egyptian material, De Villiers (1968) examined a South African sample, Rightmire (1972) focused on "African Negro" material, and Berry (1974b) and Sjøvold (1974) focused on Northwest European material (Ossenberg, 1969).

Finnegan and Rubison (1984) described three different contexts in which non-metric traits have proven valuable for distinguishing between population groups. The first was in classifying one cranium or postcranial skeleton in an archaeological setting, while the second was in classifying a single cranium or postcranial skeleton in recent forensic case work to aid in personal identification, and the third was in the specific or sub-specific classification of animals in a given geographical region (Parr, 2002). The first and second methods are the most common applications of non-metric variants in the field of anthropology (Parr, 2002).

Renewed interest during the 1970's was shown in studies employing non-metric traits (also called epigenetic, discontinuous, discrete, morphoscopic) (Brasili et al., 1999; Trinkhaus, 1978; Corruccini, 1974; Berry and Berry, 1967) and was largely owed to geneticists Grüneberg (1963), and Berry and Searle (1963) working with experimental animals (Corruccini, 1974; Trinkhaus, 1978; Brasili et al., 1999; Hanihara and Ishida, 2001e). They studied non-metric features within crosses of inbred strains of mice and found that each variant was determined by a number of genes acting together, and that a developmental threshold in the genotype distribution led to the manifestation of phenotypic alternatives, rather than to a continuously distributed character. Their research concluded that most non-metric traits in mice are genetically determined (Berry, 1975), also these traits vary in frequency even between closely related groups, shows constancy under environmental change, do not vary with age, exhibit no sex differences, show no correlation with one another, and are easily defined and standardized (Corruccini, 1974). The work of Grüneberg and his colleagues was extended to humans by Berry and Berry (1967). In the classic paper *The epigenetic variation in the human cranium*, Berry and Berry (1967) formalized discrete trait analytical procedures for physical anthropologists. The authors created a framework for data reduction and population comparison based on the statistical work done by Grewal and Smith (Corruccini, 1974; Hefner, 2003). Following the advances in the field of genetics, the literature (Corruccini, 1974; Berry 1975) highlights the fact that many investigators constructed research designs based on the very assumption that non-metric characters (either directly or indirectly) are governed by the genetic make-up of an individual. Authors like Berry (1963), and Howe and Parsons (1967) supported the notion that morphological features are predominantly under genetic control, while others (Corruccini, 1974; Berry 1975) rejected the idea and suggested that factors including sex, age, and environmental changes could be related to the incidence of discontinuous traits. Furthermore, studies by Angel and Kelley (1990), Jantz (1970), Finnegan (1972), Sublette (1966), and Humphreys (1971) found significant inter-sex variation, while others such as Berry and Berry (1967), and Sawyer and colleagues (1998) failed to identify statistically significant sex differences associated with these traits (Corruccini, 1974). Some researchers (Finnegan, 1972; Jantz, 1970) excluded features that are influenced by the sex of an individual; however, this approach decreased the number of traits assessed and compromised analysis since traits affected by sex were usually the most variable between populations (Parr, 2002). Berry (1975) and Brasili et al., (1989) suggested that researchers should divide samples into male and female groups, while analyzing each group separately for the manifestation of these features.

Ossenberg (1970) detected age related changes when using discontinuous traits to assess differences in population groups. However, the differences encountered varied mostly in sub-adult individuals and were contributed to normal developmental growth patterns. Various discrete trait studies in adults (Corruccini, 1974; Molto, 1983) did show significant differences in the expression of these traits between population groups. Age at death was also found to be a factor such that hyperostotic features were more commonly found in older individuals while hypostatic conditions were associated with younger individuals (Hanihara and Ishida, 2001e). Studies that failed to associate statistically significant differences with age at death related changes pertaining to discrete features include those of Berry (1975) and Brasili et al (1999). Nevertheless, it has been noted that an assessment of discontinuous features should include a thorough assessment of age at death related phenomena (Parr, 2002).

The laterality of non-metric traits is an aspect, like age at death and sex. that has been widely debated amongst anthropologists. While several studies (Brasili et al., 1999; Sawyer et al., 1998) have shown that non-metric traits are symmetrical, others (Finnegan and Marcsik, 1989) reveal statistically significant differences between sides. Researchers who did find significant differences between the sides of a trait contend that previous results were possibly erroneous in the type of statistical analysis applied and have suggested the use of Chi-squared analysis (Green et al., 1979).

A landmark in the history of non-metric features in physical anthropology was the data recording forms developed Dr. Earnest Hooton (Rhine, 1990). These forms comprised of several pages of measurements and observations for the cranial as well as for the post cranial skeleton. The so-called "Harvard list" consisted of 102 observations divided into three categories. In Hooton's study of the *Indians of Pecos* (1930), he stated that he was able to observe and describe morphological features and suggested that they were more likely of greater anthropological value in certain groups than metric techniques (Brues, 1990). Hooton considered some morphological variables to be valuable in determining race (see Table 2.1) (Hefner, 2003). Many of the non-metric variables that are widely and frequently in use by physical and forensic anthropologists today have filtered through academic circles starting with Hooton, his students and eventually to subsequent lineages of his students, who over the decades modified and applied these traits in studies of their own. From a recent morphological study (Hefner, 2003) in ancestry estimation, it became clear that many morphological variables similar to those appointed by Hooton in the early 1920's are still in use and are referenced in current studies. However, these variables were not referenced by Hooton to a particular study but by other researchers (Hefner, 2003). Hefner (2003) made an important observation in that Hooton manufactured his own discrete variables from his research that subsequently became part of his students' work and who had passed on the tradition of his research (see Table 2.2). Thus, many researchers have failed to assess the actual frequencies or accuracy of these traits in modern population groups (Hefner, 2003).

The applicability of these non-metric traits in South Africa is largely dependent on the physical and social make-up of the country in comparison to that of North America, from which these traits are derived. For this reason, a brief history on the population of South Africa is provided.

## 2.6. Colonization of Southern Africa

### 2.6.2.1. Indigenous populations of South Africa

Before colonialism, the Cape had a local indigenous population in its southwestern regions that was predominantly occupied by the Ouena or Khoi, and the San. In the literature, the Khoi (pastoralists) and San (hunters) are referred to as "Bushmen" and "Hottentots," because in early accounts of these groups no systematic distinction was made between pastoralists with large herds of cattle and sheep and small groups of hunters and collectors who did not have stock (Katzen, 1969). The first contact with the Cape from beyond Africa was made by the Portuguese in 1487. The Portuguese seafarers encountered yellow-skinned natives along the coast. These people, referred to as the Khoi, lived on the land near the coast from the Swakop River on the Atlantic shore to the Buffalo on the Indian Ocean shore. They were nomadic and moved onto areas suitable for grazing for their stock. Today, the Khoi language is still spoken by hunter and gatherers living in the dry inland parts of the Kalahari. In 1652, the Dutch settlers came in contact with the Khoi herdsmen and valuable relations were established between these two groups.

In the mountain areas of the Western Cape and throughout the mountain areas of southern Africa, there were other yellow-skinned hunters who also spoke languages characterized by clicks but distinct from that of the Khoi people. They have been referred to as the Bushmen by white people, Twa by the Xhosa, Roa by the Sotho, and San (Saan) by the Khoi people (Katzen, 1969). San hunters inhabited the Drakenstein and Cedarberg ranges, the Outeniqua, Camdeboo, Sneeuberg, Winterberg, Stormberg, and Drakansberg. They were also found along the Orange River, valleys of the Vaal, Kei, Tsomo, Mzimvubu, and Tukela. Areas in which these people resided the longest periods were stony or arid country, and mountain sour veld. They still occupy dry parts of Botswana, South West Africa, and Angola (Schoeman, 2007). They are traditional hunters and gatherers, but like the Khoi herders, have regular temporary settlement areas.

As colonization increased in the Cape, the Dutch did not have sufficient labour to be successful as agricultural producers and realized the need for a substantial work force. With the crash of their delicate social system, the Khoisan was forced to become hired labourers on the lands of the Dutch. However, the native populations were far from helpless victims in their initial encounters with the settlers (Schoeman, 2007). For example, Khoi traded their sheep and cattle in exchange for goods from the settlers, while the settlers occupied their grazing lands. For their part, the natives saw many benefits to be had from maintaining relations with Europeans, and for a considerable period of time they engaged with Europeans voluntarily and on their own terms (Katzen, 1969). The Khoi in particular were an unwilling labour force because they were a pastoral people, and as long as they had their lands, flocks of sheep and herds of cattle, they could not be pressed into service for the Dutch settlers. The settlers also practiced a form of settled agriculture that came into direct conflict with the pastoral economy of the Khoi, and involved regular and structured seasonal migrations (Katzen, 1969). Therefore as the Dutch colony rapidly grew, independent Khoi communities were placed under unbearable pressure. Within 50 years of the establishment of the Dutch settlement, the indigenous communities near Table Bay had lost their lands and their independent way of existence had come to an end.

Individual Khoi men and women became integrated into the local colonial society as servants. Beyond the mountains of Table Valley, communities of Khoisan (as the Khoikhoi and the indigenous hunter-gatherer San are collectively called) survived until the end of the 18th century, but there can be little doubt that for the indigenous populations of the Cape the arrival of the Dutch settlers proved to be a major turning point in the destruction of their way of life (Katzen, 1969; Schoeman, 2007).

#### 2.6.2.2. The birth of slave trade in the East

By the time that Portuguese seafarers had rounded the Cape of Good Hope in 1488, they became involved in large-scale seaborne trading with the East. During 1595, Dutch trading expeditions began visiting Asia, while the *Verenigde Oostindische Compagnie* (VOC) officially received the monopoly in trade east of the Cape of Good Hope in 1602. In the process the VOC realised the benefits of slave labour (Schoeman, 2007).

In Indonesia, the Dutch enslaved entire populations, ruling them by force and coercing them to produce crops. In 1619 the VOC established the city of Batavia (the modern day Jakarta) on the island of Java in the Indonesian archipelago as a capital in the East and as its centre of trade. After this development had taken place, the need for labour became so great that small population of free whites (Free burghers) who had developed under the Company were encouraged to take part in slave trading (Katzen, 1969).

Initially slaves were obtained from Bengal in the north-east of India and Aracan (the present day Bangladesh) where they were taken captive in the delta of the Ganges. According to the literature (Schoeman, 2007) between 1626 and 1662, the Dutch regularly exported 150-400 slaves from the Arakan-Bengal coast. During the first 30 years of Batavia's existence, Indian and Arakanese slaves provided the main labour force of the company's Asian headquarters. The earliest slaves at the Cape would also be predominantly from Bengal, but after the area had been incorporated in the Mughal Empire in 1666, the supply of slaves was cut off. Another source of slaves was of Coromandel or the East Coast of India, where the VOC had established the trading posts at an early stage with a view to purchasing the cotton goods it required for its intra-Asian trade (Schoeman, 2007).

Schoeman (2007) describes the VOC settlements such as the one at the Batavia as "true slave societies" in which the slaves began to play a vital role in the luxury, productive capacities, empowering of elite, and influencing cultural developments while forming a large part of the total population. Due to a shortage of European women, it was not an uncommon practise for European men to have had children by local women, who were in some cases acknowledged and legitimised by their fathers. The offspring of such unions often inherited the status of the mother and were slaves themselves, and therefore it became possible for a white man to sell off his own family. Therefore, knowledge of the conditions in the East under regulation of the VOC serves as valuable information for the understanding of the developments of the population groups at the Cape.

#### 2.6.2.3. Early colonization and slave trade at the Cape of Good Hope (1652-1717)

In 1651, the VOC, then the world's largest trading company, decided to establish a halfway station at the Cape of Good Hope (Table Bay) for the benefit of bypassing ships between the Netherlands and the East. During the early stages of 1652, a small company under Jan van Riebeeck landed at the Cape and began building a fort and planted gardens on the banks of the mountain streams where passing ships could obtain their drinking water (Schoeman, 2007). What was originally intended to be a refreshment station grew into a thriving independent town. In order to maintain the growth of the colony, the VOC imported thousands of slaves to work on the farm lands and on the docks. By the end of the first year the pioneer company consisted of 110 men, 15 woman and children, all of them predominantly white and from the Netherlands, the north-western portion of the German speaking area and Scandinavia (Schoeman, 2007).

The presence of European settlers determined the composition of the new society at the Cape. Not long after Jan van Riebeeck's arrival on 21 April, 1652, he suggested that the soil of the Table Mountain Kloof needed to be cultivated. In 1654, after two years of struggling with an inadequate work force, the idea of slave labour had taken root with the

Dutch. Van Riebeeck suggested that it would be much cheaper to have the agricultural work, the seal catching and all the other necessary work done by slaves in return for food (Schoeman, 2007).

The multiracial nature of the VOC's trading empire became apparent with the arrival of the first slaves at the Cape. On the 15th of March, 1656 when Jasper van den Boogaerde, former Governer of the Moluccas (Melaku in Indonesia), arrived at the Cape as commander of the return fleet to the Netherlands, he brought with him at least two female slaves. One of them was to accompany him back to the Netherlands, while the second slave, Catharina van Bengalen, was left behind at the Cape to be returned to Batavia. However, before Catharina was sent back her owner Sarcerius arrived at the Cape after resigning from the Company service, and had set her free and allowed her to remain at the Cape. On the 26 April, 1656 Catharina from Bengalen received official permission to marry the Assistant Dutchman Jan Woutersz. Marriages between white men and white women on passing ships were not uncommon since there was a scarcity of marriage partners during the early years at the colony; however, this was the first incident of a racially mixed marriage at the Cape. Two years later, another racially mixed marriage took place at the Cape, the bride in this case was Maria van Bengalen, a slave resident at the Cape. She previously belonged to the chief gardener Hendrick Boom and subsequently to the sick comforter Pieter van der Stael after which she was bought by and married to the free burgher Jan Sacharias from Amsterdam. Apart from this handful of slaves, there was by 1657 still no slave labour at the Cape to assist in the work undertaken by the Company, and the need increased when freeburghership was introduced early in 1657 (Schoeman, 2007).

In 1658, a year after the first free burghers had been granted their plots of land, the first large groups of slaves were imported into South Africa, specifically for agricultural work. These slaves arrived at the Cape on 28 March 1658 on board the Amersfoort and had been captured by the Dutch from a Portuguese vessel en route to Brazil. Of the 250 seized slaves, only 180 survived the journey to the Cape and were mainly children. On 6 May 1658, 228 slaves from another group of slaves arrived at the Cape on board the Hassalt, from Ghana. From 1710 onwards, the adult slave population outnumbered the adult colonial population by as much as three to one (Schoeman, 2007). During the early part of the 18th century the Indian subcontinent was the main source of slaves for South Africa. In 1721, a slaving station was erected in Delagoa Bay (present-day Mosambique) but was abandoned in 1731. Between 1731 and 1765 more and more slaves were brought from Madagascar (Schoeman, 2007).

### 2.6.2.4 The British colonial era

In 1795, the Cape Colony became occupied by British rule before it was returned to the Dutch in 1802. In 1806, the British reclaimed the Cape as a colony after it had been taken by the Dutch during the Napoleonic wars. During their control of the Cape, the VOC sent slavers to Mozambique and Madagascar. The main purpose of these expeditions was to trade slaves. In those days, travelling by sea was very uncomfortable and unhygienic for ordinary people; however for slaves the journey was often unbearably cruel and fatal (Katzen, 1969).

Between 1720 and 1790, slave numbers increased from 2,500 to 14,500. At the time of the final ending of slavery in 1838, the slave population stood at around 38,000. However, unlike the European population, which doubled in number with each generation through natural increase, the harsh living conditions of the Cape's slave population meant that their numbers could only be sustained through continued importation. Between 1652 and the ending of the slave trade in 1807, about 60 000 slaves were imported into the Colony. This new era introduced a new element of evangelism which was believed to end slavery in South Africa. British evangelicals believed that the indigenous people could adopt the European Christian culture once the chains of oppression had been removed. Even though anti-slavery movements were introduced during the 1820’s and slaves were emancipated in 1838, the reality of freedom for these slaves was very different from what was promised. The Cape became not just a society in which some people were slaves, but a fully-fledged slave society. In slave societies, the institution of slavery touched all aspects of life, as slavery was central to the social, economic and legal institutions. As the boundaries of the Cape Colony expanded beyond the immediate vicinity of Table Bay, slaves were put to work on the wine and wheat farms of the south-western Cape. Quite simply, the colonial economy could not function without the use of slave labour, and therefore slave-ownership was widespread. Although most of the European settlers of the south-western Cape owned fewer than ten slaves, almost all of them owned at least some slaves (Schoeman, 2007).

The most important social feature of slave societies is that it was polarized between people who were slaves and those who were not. Slaves were also defined by their race, and although the VOC did not institute a codified form of racial classification, the fact is that all slaves were non-white. There were a few slaves who had been freed, who were called “free blacks”. These “free blacks” had managed to acquire slaves of their own, but these slave owners were a tiny minority of the slave-owning population. The ex-slaves as well as the Khoisan servants became labelled as the “coloured” people, a group which included the descendants of unions between indigenous and European people, and a substantial Muslim minority who became known as the "Cape Malays" who actually came from the Indonesian archipelago. The coloured people were strongly discriminated against based on their social status and ancestral roots. Among the less privileged, especially in and around Cape Town, intermarriage and racial mixing was not uncommon and continued throughout the 18th century. Thus, colonial South Africa was from the very start a society structured along racial lines, in which black and coloured people occupied a subordinate positions (Schoeman, 2007).

Slavery was fully supported by the Roman-Dutch legal system that the VOC brought to the Cape. In terms of Roman-Dutch law, slaves were defined, first and foremost, as property. This form of slavery, known as chattel slavery, meant that one human being was the legal belonging of another human being. Slaves could be bought and sold, bequeathed or used as security for loans. Since slaves were kept in a state of slavery against their will, the slave owners and the VOC needed a system of laws to ensure that slaves were kept in their subordinate position (Schoeman, 2007).

Therefore, slaves in the Cape were strictly controlled, and according to law, slaves could be severely punished for acts such as running away or failing to obey their owners' orders (Schoeman, 2007). The growing influence of the concept of human rights at the beginning of the 19th century, and the effects of a changing economic system in Western Europe during the same period both contributed to the questioning of the practice of slavery.

Therefore from 1806, the British introduced laws (Amelioration laws) aimed at improving the welfare of slaves in the Cape. The slave guardian appointed by the British government was responsible for enforcing these laws. As a result, the lives of some slaves improved after 1807 (Schoeman, 2007). The end of slavery at the Cape was not due to internal pressure, but from a decision from outside governments. In 1807, the British government banned the slave trade to all her colonies, including the Cape. This meant that no more slaves (from any destination) could be sent to work in the Cape colony. However, those who were already in the Cape continued to work as slaves until 1834 when all slaves in the British Empire were emancipated. Many of the slaves chose to remain on with their owners, while some started a new life in and around the Cape colonies as tradesmen, and gradually came to form the "coloured" community of the Cape (Katzen, 1969).

## 2.7. Physical anthropology in South Africa

The emergence of physical anthropology in South Africa has in many ways followed a similar route to that of the global setting in which the discipline had its origins. However, South Africa has had a turbulent physical, social and cultural history that is to guarantee that the country is to be long remembered as the place where social engineering on a racial basis became the law of the land (Morris, 2005).

The close of the 18th century marked a period of intense interest in the diverse inhabitants of the southern point of Africa. According to records (Morris, 2005), a British supervisor, William Somerville, was one of the first to have described "the structure of Hottentot women", a subject of much discourse amongst early travellers at the time. The tradition of ethnological observation and collection by European scientists continued throughout the 19th and 20th century colonial periods and the approach was not different from that of European zoological and botanical scientists who spent their time collecting type specimens of new species. The British colonial government strongly encouraged this type of approach and frequently emphasized the need to study native groups before they became extinct (Morris, 2005). The lack of proper local academic networks meant that research primarily remained in the hands of those whose approach was the purely descriptive cataloguing of human variation rather than its underlying causes (Morris, 2005). The first two universities (Cape Town and Stellenbosch) in South Africa developed into established institutions during the early part of the 20th century and became well acquainted with the housing of human remains and interests in physical anthropology.

By the 1950's, physical anthropology entered a new direction of research with special focus on racial studies. The majority of scientific papers published during these years were mainly concerned with whether or not the indigenous people had originated in South Africa or had migrated from elsewhere. An interest in anthropology and the origin of the people of the South spurred the research efforts of the anatomist Matthew Drennan. Drennan (1929) widely published on this subject and also produced the first text book on physical anthropology in South Africa (Morris, 2005). During the 1920's and 1930's, the University of the Witwatersrand developed into a prominent institution on the high veldt and appointed Raymond A. Dart as Chair in Anatomy of the school of medicine, at department of Anatomical Sciences. Dart's lineage of research orientated students included Alexander Galloway from Aberdeen, Laurie Wells and Phillip V. Tobias (Morris, 2005). Dart's academic beliefs by his own admission were strongly influenced by the work of Grafton Elliot Smith. Smith's views were primarily that of an extreme diffusionist who supported the concept that the fundamental nature of human evolutionary origins had only one occurrence, in Egypt. Dart published extensively on this topic and emphasized connections between South Africa, Egypt, Europe and Asia. In addition to his views on human evolutionary pathways, Dart also argued that KhoiSan people were both physically and culturally primitive and enthusiastically promoted the idea that the Bushmen were "living fossils" (Morris, 2005).

By the mid-19th century the Linnaean vision of typological classification was firmly established in the field of South African anthropology. The "type" concept, as was practised in Europe at the time, was by definition an individual who portrayed all the important physical characteristics of a particular group. Researchers of that period mostly focused on features that were able to differentiate between groups and regarded the ideal type as a standard to which other individuals could be compared. During the early stages of the 20th century, the study of types became evident after the discovery of the "Boskop" skull. The "Boskop" skull, a mineralized partial cranium, enjoyed wide spread attention due to its large size that was supposedly associated with features commonly observed in the San people (Morris, 2005). Dart invented the label of the "Boskop type" in order to represent a new race that could be compared to other living groups of South Africa. He saw different physical features as cultural artifacts resulting from ancestral lineages. The continued practice of typological classification during the 1940's and 1950's resulted in the in-depth studies on the origin of KhoiSan people. Amongst others, Dreyer and Meiring (1937) suggested that the living Khoikhoi were descendents from Hamitic migrants from the North. From a series of excavations along the banks of the Orange River near the town of Kakamas, they collected five skulls which they classified as the "Kakamas type". Dreyer and Meiring used these specimens to explain what they thought the North African Hamitic ancestors would have looked like. During the 1950's, Tobias attempted to clarify some of the myths and confusion that prevailed around the concept of the physical types. He identified eight genetic lineages that would have given rise to the living KhoiSan and Bantu-speaking people of southern Africa. Tobias did not reject the various types listed by previous workers; however, his future papers on the subject would strongly discard the typological model of classification (Morris, 2005).

The study of skeletal remains, in particular the skull and its relation to human evolutionary origins has gained a central position in physical anthropology in the country (De Villiers, 1968). In South Africa, there are only few modern studies related to race (ancestry) in the human skeleton (Ihunwo and Phukubye, 2006).

The majority of this research has focused on the similarities and differences between various indigenous groups, which include the Bushmen, Hottentot, Griqua and black South Africans (De Villiers, 1968). The history of racial studies, whether metric or non-metric, largely developed from typological studies often performed by visiting European scientists. Metric analysis on black South African crania include that of Shruball (1899) and Rightmire's (1970) who focussed on the crania of Bushman, Hottentot, and the South African Negro (De Villiers, 1968). Keen (1951) performed a craniometric study on 200 Cape Coloured individuals and could not find any significant differences in the dimensions of the skull between sexes. A recent study in the craniometric determination of population affinity in South Africans (İşcan and Steyn, 1999) indicated significant craniometric differences between South African blacks and whites.

Non-metric analysis include that of Gear (1929) who focused on the description of black cranial form and Galloway's (1937) description of the Sotho cranium (De Villiers, 1968). Studies in skeletal facial profile analysis were conducted by Meyer (1939) and Keen (1949). Tobias (1958; 1959) studied the curvature of the occipital bone of blacks, while De Villiers (1954a,b) described the incidence of metopic sutures, inca bones and variations in the clinoid processes of black South Africans (De Villiers, 1968). Shaw (1931), Galloway (1931) and Sperber (1958) drew their attention towards racial differences in the mandible, teeth, and palate (De Villiers, 1968). Kieser and Groenewald (1989) used discriminant function statistics to analyze dental dimensions in black and white South Africans and Lengua Indians of Paraguay. In a seminal study, De Villiers (1968) evaluated the osteometirc and morphological features of black South Africans in the Raymond Dart collection. De Villiers's findings suggested that both the 75 metric and 65 non-metric variables were in accordance with historical, archaeological, and geographical data, and that inter and intra group differences resulted from hybridization with the earlier Bushman and Hottentot inhabitants of South Africa (De Villiers, 1968). She also suggested that the African tribal groups were homogenous in nature, and should therefore be considered to belong to one group.

In recent years there has been an increase in the number of studies involved with the osteometric evaluation of ancestry from cranial and postcranial South African skeletal remains (Patriquin and Steyn, 2002; Oettlé 2009). However, studies in non-metric traits have been sparse and are often limited to single traits (Ihunwo and Phukubye, 2006);

**Table 2.1** Population Studies Utilizing Non-Metric Traits. Taken from Parr (2002).

| Population analyzed | Researcher |
|---|---|
| English | Berry, 1975 |
| Iceland | Hooton, 1918 |
| African | Rightmire 1972 |
| Italian | Gualdi-Russo et al., 1999 |
| Greenland | Laughlin & Jørgensen, 1956 |
| Australian | Kellock & Parsons, 1970 |
| South African | Berry & Berry, 1967; De Villiers, 1968 |
| Egyptian, Indian, Nigerian | Berry & Berry, 1967 |
| North American | Corrucini, 1974; Finnegan, 1972; Hefner, 2003; Ossenberg, 1976; Rhine, 1990 |
| Arikara, Chines, Dutch, East African, German, Japanese, West African | Hefner, 2003 |

**Table 2.2** Morphological variables used by Earnest Hooton. Taken from Hefner (2003).

| **Variable** | **Whites** | **Negroids** | **Mongoloids** |
|---|---|---|---|
| Interorbital space | Narrowest | Broad | Broad |
| Upper Nasalia | Arched, high | Broad, flat | Flat, often narrow |
| Bridge (space) | Narrowest | Broadest | Lowest |
| Bridge (height) | Highest | Intermediate | Lowest |
| Nasal aperture | Narrowest | Broadest | Intermediate |
| Nasal sills | Sharpest | Infantile | Least developed |
| Nasal spine | Most developed | Usually infantile | Variable |

# Chapter 3: Materials and Methods

## 3.1. Materials

### 3.1.1 South African skeletal collections

The sample was sourced from four modern osteological collections in South Africa, namely the Pretoria Bone Collection (PBC), housed at the Department of Anatomy, University of Pretoria (Gauteng Province); the Kirsten Collection lodged at the Tygerberg Medical campus, University of Stellenbosch (Cape Province); the Student Bone Collection, in the Department of Anatomy, Free State University (Free State Province), and the Raymond A. Dart Skeletal Collection, Department of Anatomy, School of Medicine, at the University of the Witwatersrand (Gauteng Province) (see Table 3.1). In South Africa, medical schools are the primary institutions that are involved in the development and maintenance of human skeletal collections for both education and research purposes (L'Abbé et al., 2005; Tal and Tau, 1983). From these four collections, only two (the Pretoria Bone Collection and Raymond A. Dart Collection) are suitable for research, while the Kirsten Collection (University of Stellenbosch), and the Student Bone Collection (University of the Free State) are mainly used as teaching aids for students. The lack of ancestral variation and poor availability of complete skeletal material within a collection are the main reasons for amalgamating these four collections into a single study sample. Ancestral variation within a collection is highly dependent upon the geographic distribution of the population groups; for this reason, multiple collections were used from distinct geographical regions of the country, namely Gauteng, the Free State and the Western Cape.

The manner in which an individual enters a skeletal collection is important, since it may have an affect on the interpretation of the results of the study. The majority of the skeletons in these collections are from cadavers of donors and unclaimed persons that were used in the dissection halls of the various medical schools (L'Abbé et al., 2005; Tal and Tau, 1983). The National Health Act, 2003 (ACT No. 61 of 2003) states that any person may donate his/her body for tissue transplants, medical training and research to an anatomically institution. The act also stipulates that the state may donate the remains of a destitute individual. For example, in the case where a person dies in a public health care facility without being removed for burial by a family member or a friend within 24 hours, the body may be entrusted to an institution, such as the University, for medical purposes (L'Abbé et al., 2005). Additionally, archaeological remains, mine disasters and accidents in which the remains are not claimed may also be accessioned into a collection (Tal and Tau, 1983).

More than half (53%; n=423) of the 704 complete crania in the Pretoria Bone Collection comprise of black males; similar statistics can also be found in the Raymond A Dart Collection and the student bone collection at the University of the Free State (Dayal et al., 2009). Researchers explain this trend as a consequence of a large migrant-labour work force in the country. Since the early 1900's, there has been a dramatic shift in people from the relatively remote, or rural towns, to urbanised areas in South Africa. This migration reflects the poor socio-economic circumstances of people in rural areas; a major issue is the lack of work-related opportunities in rural localities which forces the head of the household, usually a male, to seek work in large, metropolitan cities such as Pretoria, Cape Town, Johannesburg and Bloemfontein. Once in these cities, this person often experiences difficulty in contacting their families back home. When such an individual dies, the authorities either struggle to reach the immediate family of the diseased or the family is contacted but cannot afford a burial. In this case, the unclaimed body is often donated from the hospital to an official at an Anatomy Department. The opposite is true for black females, who tend to stay within their families and community. The Pretoria Bone Collection house only 7% (n=75) black females. White South Africans comprises the next largest portion of the collection and include 122 females and 150 males (L'Abbé et al., 2005). Needless to say, the use of additional collections from Johannesburg, Bloemfontein and the Cape was necessary to supplement the small number of coloured and white persons in the Pretoria Bone Collection. A brief description of the inception, history and distribution of material in each of the four skeletal collections is provided.

#### 3.1.1.2. The Pretoria Bone Collection (PBC)

The PBC began in the Department of Anatomy at the University of Pretoria in late 1942 (L'Abbé et al., 2005). The collection initially served as a practical teaching aid for students and staff in health care programs, but it has since grown into a valuable research tool that is used in various fields of study, both local and internationally (L'Abbé et al., 2005). During 2000, the research collection was re-organised into three categories which are skulls, complete and incomplete postcranial remains. For research purposes, the collection was further divided into five functional categories, which are complete skeletons, complete skulls, incomplete skulls, complete postcranials and incomplete postcranials. At present a total number of 704 complete skulls, 290 complete skeletons and 541 complete postcranial remains are available for research (L'Abbé et al., 2005); these numbers increase annually by approximately 50 individuals. The large amount of skeletal material in the collection provides researchers with unique study opportunities in fields such as anthropology, pathology, molecular biology, and forensic science. To be included in the collection, age at death, date of birth, sex and ancestry need to be known (L'Abbé. et al., 2005). As mentioned previously, the collection is dominated by black males, followed by white males, white females and black females. The age at death distribution, when separated by sex and ancestry, indicates that white South Africans (both male and female) are poorly represented between the age ranges of 30-39 and 40-49 years, but their numbers increase after the age of 50 with the majority of people being over 60 years of age. Black South Africans are represented in all age at death categories.

#### 3.1.1.3 The Raymond A. Dart Collection

During the early 1920's, Professor Raymond A. Dart started an anthropological collection in the Department of Anatomy at the Medical School of the Witwatersrand University in Johannesburg, South Africa. During the last eight decades, this collection has matured into one of largest documented cadaver-derived human skeletal assemblages in the world (Dayal et al., 2009). The collection contains 2605 skeletons representing individuals from regional South African black (76%), white (15%), coloured (4%) and Indian (0.3%) populations (Dayal et al., 2009). Information on age, sex, ancestry, as well the source and year in which an individual was added to the collection was recorded. Similar to the Pretoria Bone Collection, there is a predominance of middle to older aged black males (48%, n=1051) when compared to individuals from other ancestral backgrounds. White South Africans comprise approximately 40% (n=268 males; n=210 females) of the sample, followed by 10% (n=74 males, n=42 females) of individuals of mixed origins and at least 5% (n=48 males, n=24 females) from other African population groups (Dayal et al., 2009). The most predominant South African ethnic groups in this sample include Zulu (n=336 male, n=83 female), Sotho (n=260 male, n=96 female), and Xhosa (n=163 male, n=44 female), while the least represented are Venda (n=45 male, n=3 female), Tsonga (n=14 male, n=14 female) and Pedi (n=16 male, n=3 female) (Dayal et al., 2009). As can be seen, the number of males per ancestry group is at least 50% greater than that of females.

#### 3.1.1.4. The Student Bone (Free State University) and Kirsten Collections (Stellenbosch University)

The skeletons in the collection are obtained from cadaver material of unclaimed and donated individuals. The process of how an individual enters into the collection is similar to that of the Pretoria Bone and Raymond A. Dart skeletal collections. However, information on the inception and history of the collection is not known, but it currently functions as an aid for students in health care programs.

### 3.1.2. The South African skeletal sample

A total of 520 crania of known sex, age at death, and ancestry were assessed. As can be seen in Table 3.1, males outnumbered females in all of these collections. Persons who had been designated as "coloured" were present in the Kirsten (n=83) and Raymond A. Dart Collections (n=42); whereas none was available in the Pretoria Bone Collection or Student Bone Collection from the Medical School at the University of the Free State. The average age at death of the sample was 51 years, with an age range from 18 to 90 years. Table 3.2 presents the age distribution of the sample.

In order to more clearly interpret results obtained from 20th century skeletal sample, the possible effect of a secular trend within and between populations needs to be discussed. A secular trend can be loosely defined as a change, which is often recorded as a change in mean stature, from one generation to the next within a single population (Henneberg and Van Den Berg, 1990). In the 20th century, a statistically significant increase in stature over successive generations has been attributed to improved sanitation, nutrition, medication and general lifestyle (Tobias, 1975). In South Africa, a minimal to absent secular trend has been observed in stature among white, black and coloured South Africans (Smith and Steyn, 2007). This trend, or in this case the lack of a trend, has been suggested to be weak or absent in South African groups (Price and Tobias, 1987; Tobias, 1975; Henneberg and van den Berg 1990). Yet among the San Bushman, Tobias (1975) noted an increase in stature during the 20th century and attributed it to better nutrition and dietary supplements (Hausman and Wilmsen, 1985). Based on the available literature, it is unlikely that an increase in growth over time is to have a large effect on the interpretation of the results from our sample; however, it is important to record and assess the date of birth for the specimens under study should future analysis be necessary.

In Table 3.3, the date of birth is shown for persons in the Pretoria Bone and Raymond A. Dart Collections. As can be seen, the majority of the sample was born in the early to middle part of the 20th century, with only 36 born prior to 1900 and four after 1970. Within the last ten years, an increase has been observed in the number of people with late 20th century date of births (1970 and 1980). This can be partially attributed to the dramatic reduction in life expectancy in the country, on account of the HIV/AIDS pandemic (L'Abbé et al., 2008). This change in demographic structure is to have an effect on the type of cadaver material received at the medical schools and overtime is to change the demographic structure and profile of the skeletal collection.

## 3.2. Methods

### 3.2.1 Non-metric traits associated with ancestry

Fifteen non-metric cranial traits were documented (Table 3.4). The sample was selected on a random basis, but it represents the inclusion of virtually every available skull. Thirteen well-defined and frequently used discrete traits were chosen from the mid-facial region and two from the dental area; these include nasal bone structure, nasal breadth, nasal overgrowth, anterior nasal spine, inferior nasal margin, alveolar prognathism, inter-orbital breadth, zygomaxillary suture shape, zygomatic projection, malar tubercle, mandibular torus, palatine torus, incisor shovelling, Carabelli's cups, and transverse palatine suture shape. Bass (1995), Brues (1990), Berry and Berry (1967), Gill (1990), Hauser and De Stephano (1989), Hefner (2003), Hooton (1920), Hrdlička (1920), Spencer and Rogers (1984), and Rhine (1990) were responsible for the development and refinement of these traits. A summary of the 15 variables as well as a reference for each are presented in Table 3.4.

A scoring sheet, complete with condensed definitions and descriptive illustrations, was compiled and can be found in Appendix 1 (133-139). Each variable was compiled from either the original or a modified version of that specific discrete trait. Each scoring sheet had to be completed with the necessary information on the skull and mandible, and included a reference number, the location of the specimen, as well as the known sex and age of the individual. While scoring, the observer did not know the true ancestry of the person. The definitions, illustrations, scoring procedure and treatment of statistical analysis are described and explained in the following sections.

### 3.2.2. Scoring procedures for non-metric traits and their associated ancestral groups.

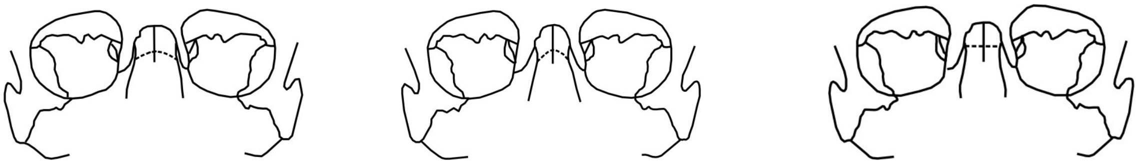
A scoring system was compiled to link the various characters states of each variable with a corresponding ancestral label. The ancestral label is derived from North American anthropologists who originally divided people into categories of European (white), African (black) and Mongoloid (Asian). The aim is therefore to evaluate how well our own sample population of white, black and coloured individuals compared to these non-metric standards developed from foreign groups. Prior to mentioning the traits that were used, it is important to discuss the manner in which these traits were scored and associated with generally accepted ancestral groups.

A score of 0 was assigned to indicate a "European" label, whereas a score of 1 and 2 respectively corresponded to an "African" and "Mongoloid" label. Due to the nature of categorical ordinal data (grading between character states), no two variables can or will have the same score assigned to its ancestral label. For the first variable, nasal bone structure (Nbs), there is four character states that define the nature of the contours of the nose. As explained and indicated by other researchers, each of these states has been suggested to belong to a specific ancestral group. In this instance, a character state score of 0 (quonset-hut shape) was synonymous with an ancestral label score of 1 (African). A character state score of 1 (oval-hut shape) equates to an ancestral label score of 2 (Mongoloid). The remainder of the character state scores of 2, 3, and 4 was assigned to the ancestral label score of 0, which is a European trait.

### 3.2.3. Standard discrete traits from the face and mandible.

#### 3.2.3.1. Nasal bone structure (Nbs).

For this study the *nasal bone structure* was defined as a combination of definitions described by Brues (1990) and Hefner (2003). Quonset-hut (round), oval, tented (plateau), semi-triangular and steepled (triangular) were used to describe the external surface contour of the nasal bones. The *quonset-hut* contour exhibits a low and rounded form which lies flat in profile. The *oval* contour is also rounded, but tends to be elongated superio-inferiorly projecting anteriorly from the mid-face. A *tented* nasal contour is steep with a broad and flat anterior-superior surface plateau. The *semi-triangular* nasal bone is steep-sided, but with a narrower anterior-superior surface plateau. A *steepled* nasal contour is triangular in profile, superior-inferiorly elongated with steep walls and no anterior-superior surface plateau (Hefner, 2003).



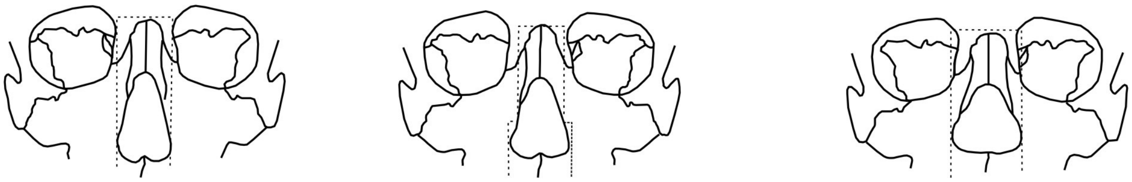
0-Quonset-hut (round) 1-Hut (oval) 2-Tented (plateau)

3-Vaulted (semi-triangular) 4-Steepled (triangular)

Figure 3.1 Character states of nasal bone structure (Redrawn from Hefner, 2003).

3.2.3.2. Nasal breadth (Nb).

Authors such as Gill (1990), Rhine (1990), and Bass (1995) have described this trait and its characteristic variants which include: narrow, medium, and wide (Rhine, 1990; Bass, 1995). The *narrow* morphology, as the word implies, is narrow and has a characteristic teardrop shape when viewed in an anterior position. The *medium* morphology is described as the greatest lateral projection of the nasal aperture at the inferior margin, coupled with a superior constriction that results in a bell shaped nasal aperture when viewed anteriorly. The *wide* nasal aperture is easily recognized and in modal form constitutes a large portion of the face, with the greatest lateral projection near the horizontal midline (Hefner, 2003).

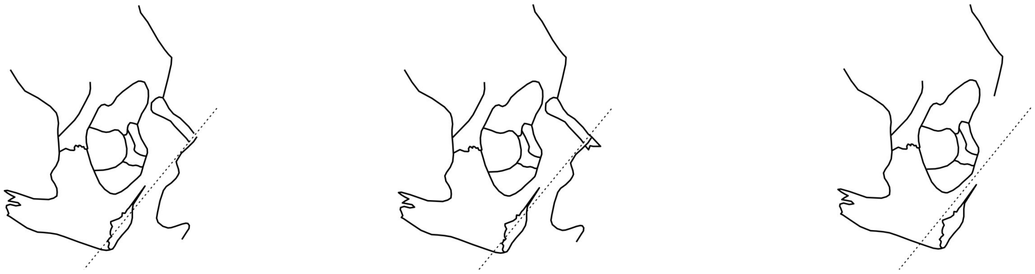


1-Narrow (long) 2-Medium (rounded) 3-Wide

Figure 3.2 Character states of nasal breadth (Redrawn from Hefner, 2003).

3.2.3.3. Nasal overgrowth (No).

Authors such as Rhine (1990) and Bass (1995) described *nasal overgrowth* as a projection of the nasal bones beyond their junction with the frontal portion of the maxilla. Hefner (2003:41) defines it as the "projection of the lateral border of the nasal bones beyond the maxilla". Individuals with projections beyond the maxilla are scored as *present*, and those without any projection as *absent*.

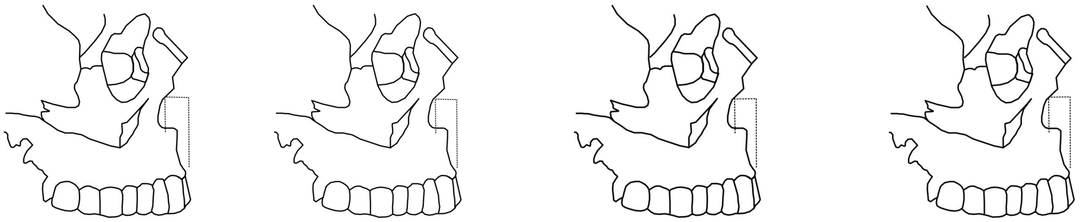


0-Absent 1-Present 5- Unobservable

Figure 3.3 Character states of nasal overgrowth (Redrawn from Hefner, 2003).

3.2.3.4. Anterior nasal spine (Ans).

This trait has been defined as being “absent”, “small”, “medium”, and “large”, and definitions such as “medium/tilted”, “large/long”, and “little” or “none”, are also found in the literature (Brues, 1990; Rhine, 1990; Berry and Berry, 1967). Hefner (2003) scored the anterior nasal spine progressively in a series ranging from short (rounded), dull, medium, and long (sharp). The *short (rounded)* anterior nasal spine is defined as minimal-to-no-projection of the anterior nasal spine. An imaginary line starting at the prosthion, which runs parallel to the face, is drawn. A *dull* anterior nasal spine is considered not to cross this imaginary line. A *medium* projection is one in which the anterior nasal spine projects to the prosthion, but neither reaches it, or terminates in a sharp anterior point. The *long (sharp)* projection terminates beyond the prosthion, and is usually characterized by a sharp anterior point.

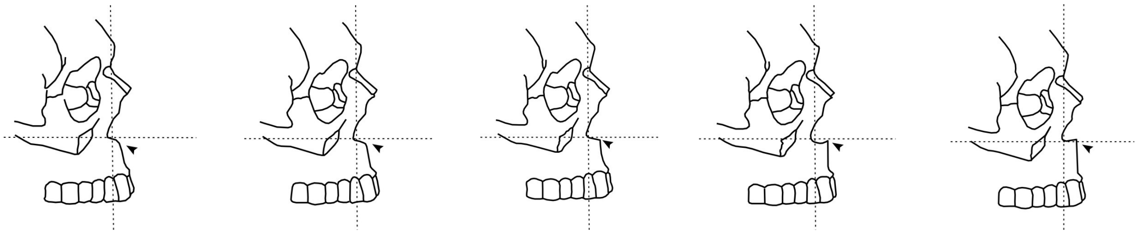


Short (rounded) Dull Medium Long (sharp)

Figure 3.4 Character states of anterior nasal spine (Redrawn from Hefner, 2003).

### 3.2.3.5. Inferior nasal margin (Inm).

This trait is defined as the most inferior part of the nasal aperture, which, when combined with the lateral alae, constitutes the transition from the nasal floor to the vertical portion of the maxilla, superior to the dentition. A series of variants accompanying this trait include a guttered appearance, incipient guttering, straight, transitioning to a partial sill, and finally, a complete sill. *Guttering* can be described as a gradual sloping of the nasal floor from a posterior to anterior position, originating where the vomer inserts into the maxillary bone and terminates at the vertical surface of the maxilla. The *incipient guttering* variant differs from the guttered appearance in that its sloping commences more anteriorly. It then proceeds in a manner similar to that of the guttered morphology, but the sloping from the nasal aperture to the maxilla is less. A *straight* inferior nasal appearance is characterized by an immediate transition from the nasal floor to the vertical maxilla, as well as the absence of an intervening projection of bone (i.e., a nasal sill). A *partial sill* constitutes a weak but present vertical ridge of bone, stretching between the two alae. When the ridge becomes pronounced, it prevents smooth transition from the nasal floor to the vertical portion of the maxilla, and is then considered to be a *sill* (Hefner, 2003; Bass, 1995; Krogman and İşcan, 1986; Rhine, 1990).

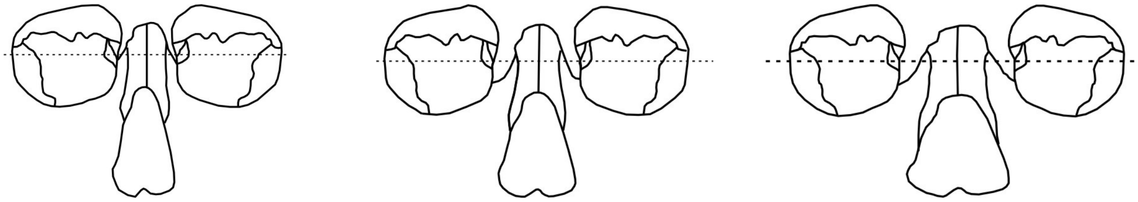


0-Guttered 1-Incipient guttering 2-Straight 3-Partial sill 4-Sill

Figure 3.5 Character states of inferior nasal margin (Redrawn from Hefner, 2003).

### 3.2.3.6. Interorbital breadth (Ib).

The interorbital breadth can be assessed by using the defined measurement dacryon to dacryon; however, in this study the interorbital breadth was assessed in the forms of narrow, intermediate, and broad (Hefner, 2003; Spencer and Rogers, 1984).

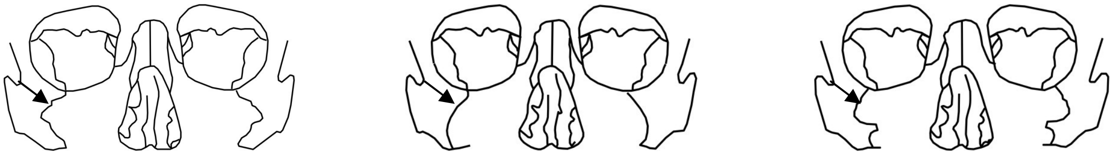


1-Narrow 2-Intermediate 3-Broad

Figure 3.6 Character states for interorbital breadth (Redrawn from Hefner, 2003).

### 3.2.3.7. Zygomaxillary suture shape (Zs).

The *zygomaticomaxillary* suture is a relatively new morphological trait used by forensic anthropologists. Several authors have described this trait by using two to three variants and it includes descriptions such as "angled", "curved", and "jagged" or "s-shaped". The use of various different terms to describe the morphological features used in nonmetric analysis contributes greatly to the confusion encountered when attempting to define these traits. The variants used in this study are classified as *angled, smooth,* and *s-shaped.* An *angled* zygomaticomaxillary suture has the greatest lateral projection of the suture at or near the midline. The zygomaticomaxillary suture is *smooth*, when the lateral projection of the suture is at the inferior terminus. An *s-shaped* suture is characterized by a zig-zag appearance (Hefner, 2003; Rhine, 1990; Berry and Berry, 1967).



1-Angled 2-Smooth S-Shaped

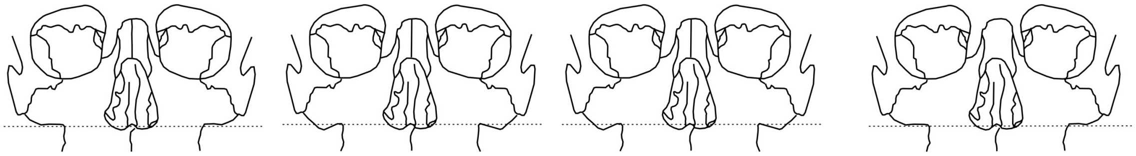
Figure 3.7 Character states of the zygomaticomaxillary shapes (Redrawn from Hefner, 2003).

### 3.2.3.8. Zygomatic projection (Zp).

Bass described *zygomatic projection* while holding the skull at the occipital region in one hand, and placing a pencil across the nasal aperture. A non-projecting face is when the observer is able to insert an index finger between the zygomatic bones and the pencil. *Retreating zygomatic bones* is therefore characterized by a face that comes to a point along the midline and cheek bones that do not extend forward. *Projecting zygomatic bones* is when the observer is unable to insert a pencil between the zygomatic bones and the pencil across the nasal aperture. The face is also much flatter with the cheek bones extending much more forward (Bass, 1995).

### 3.2.3.9. Malar tubercle (Mt).

The *malar tubercle* has been described as the tendency of the zygomatic and maxillary bones to form an inferior projection at the zygomaticomaxillary suture. For the purpose of this study, the malar tubercle was scored, according to methods developed by Hauser and De Stefano (1989), as absent, incipient, trace, and present. The nasospinale will be used as a plane of reference when scoring the malar tubercle. It is the lowest point on the inferior margin of the nasal aperture as projected in the mid sagittal plane. The amount of projection is made with reference to this plane and a score of *absent* is assigned when there is no projection near the zygomaticomaxillary suture. If a projection is noted, it is judged on whether the tubercle projects past the nasospinale plane or not. If not, the individual is assigned a score of *incipient,* but if the plane is crossed in the slightest way a score of *trace* is awarded. A specimen capable of extending beyond this plane to a great extent was scored as *present* (Hefner, 2003).



0-Absent 1-Incipient 2-Trace 3-Present

Figure 3.8 Character states of the malar tubercle (Redrawn from Hefner, 2003).

### 3.2.3.10. Alveolar prognathism (Ap).

The test for prognathism is also explained by Bass (1995), instructing the observer to place the end of a pencil “on or near the anterior nasal spine (on the midline of the skull) at the base of the nasal aperture”. The pencil should then be lowered “towards the face so that the pencil will touch the chin”. By doing this the observer will either see a *flat* (orthognathic) face in the dental area along the midline, or a face which exhibits *protrusion* (beyond the plane of the nasals) of the mouth region, known as prognathism (Bass, 1995).

### 3.2.3.11. Mandibular torus (Mdt).

In 1908, Fürst coined the term torus mandibularis and described it as a lingually directed bony protuberance on the lingual surface of the mandible, with its approximate center over the root of the mandibular second molar (Hauser and De Stephano, 1989). The mandibular torus usually appears bilaterally in the form of a swelling or a series of swellings of varying size and consists entirely of compact bone (Hauser and De Stephano, 1989; Suzuki and Sakai, 1960).

### 3.2.3.12. Palatine torus (Pt).

This trait is described by Spencer and Rogers (1984), Dorrance (1929) and Suzuki and Sakai (1960) as a bony cigar-shaped ridge of varying size, form and extent in the midline of the hard palate (Hauser and De Stephano, 1989). In some cases it may extend anteriorly to the incisive foramen and posteriorly to the posterior border of the palatine bones. It may appear short, uniform, symmetrical and smoothly elevated, but may also occur unilaterally, or less elevated at one side.

### 3.2.3.13. Incisor shovelling (Is).

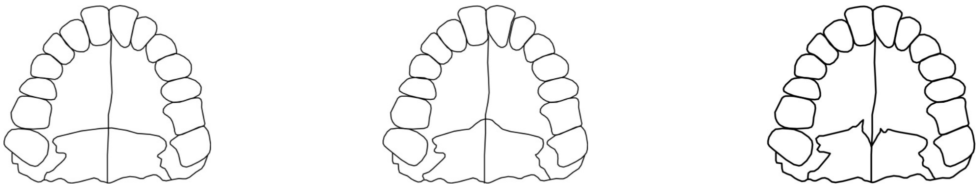
According to Hinkes (1990), *incisor shoveling* is a reliable skeletal indicator to distinguish modern Mongoloids from other groups, although no trait is completely population-specific. In order to compare different populations, it is important to have some consistency in terminology among investigators. In the 1920, Hrdlička developed a subjective scale for defining incisor shoveling. He classified incisors as *shoveled* (lingual surface shows enamel rim with enclosed fossa being well developed), *semi-shoveled* (distinct enamel ring, enclosed fossa is shallow), *trace* of shoveling (distinct traces of a rim), and *no shoveling* (no perceptible trace of rim or fossa). Since then, various authors have adopted his classification method, but have modified it with terms such as markedly shoveled, pronounced, faint, or moderate shoveling. This study used Hrdlička's method of scoring incisor shoveling, so that it is comparable to other studies (Hinkes, 1990).

### 3.2.3.14. Carabelli's cusp (Cc).

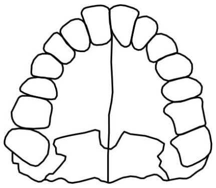
This trait was first named in 1842 by Von Carabelli and it may be the most studied of all the dental morphological variables. A cusp may be located on the mesiolingual side of the maxillary permanent molars (Edgar, 2005). The current study scored the trait as being either absent or present.

### 3.2.3.15. Transverse palatine suture shape (Tp).

As in the case of the zygomaticomaxillary suture, various authors have developed different terms to describe the shape of this particular suture. A wealth of terms such as “transverse”, “anterior”, “posterior”, “curved”, “straight”, and “jagged”, together with terms such as “bulging”, “z-shaped”, and “arched” have been used to describe this trait. From other sources in the literature, it was noted that symmetry and orientation were considered to be two important factors in describing the *transverse palatine suture*. The variants that are used in this study incorporate both these factors and include straight, symmetrical; anterior bulging, symmetrical; anterior/posterior bulging, (scalaris). A *straight symmetrical* suture intersects the palate perpendicular to the median palatine suture, but without deviating from the midline. The *anterior symmetrical* suture also crosses the median palatine, but deviates anteriorly near the juncture, but remains symmetrical. In the case where the suture deviates anteriorly as well as posteriorly (asymmetrically), the suture is described as *anterior/posterior bulging, scalaris*. *Posterior bulging* is symmetrical and is described as the transverse palatine suture that crosses the median palatine suture perpendicularly, but deviates posteriorly at the midline, on both the left and the right halve (Hefner, 2003).



0-Straight, symmetrical 1-Anterior bulging at midline 2-scalaris



Posterior bulging at midline (Symmetrical)

Figure 3.9 Character states of transverse palatine suture shape (Redrawn from Hefner, 2003).

## 3.3. Statistical analysis: Ordinal regression and Kappa statistics

### 3.3.1. Ordinal regression

Ordinal, or logistic, regression is a statistical technique that is used to predict behaviour of dependent variables with a set of independent variables (McCullagh, 1980). In ordinal regression the dependent variable is the order response category variable and the independent variable may be categorical, interval or a scale ratio variable (Stevens, 1951, 1958, 1968). Statistical analysis was performed using SPSS version 11.5 for Windows.

Key concepts in ordinal regression analysis include the dependent variable, factors (or independent variables), covariates and interactions. In ordinal regression the dependent variable is categorical such as the various character states in this study. In SPSS, the logit function is used to predict the dependent variable category. There is a k-1 prediction where k is the number of category in a dependent variable. The dependent variable can be coded in numeric or string terms, but coding is assumed to be ascending, with the first category corresponding to the lowest value. For example, the structure of the nasal bones are evaluated based on five ranked categories that range from flat or rounded (1), to slightly projecting (2), to tented (3), vaulted (4) and steepled (5) appearances. Sex and ancestry are also factors that can be defined as categorical independent variables. Covariates are the independent continuous variables, such as age at death, which are used to predict the dependent variable category. Ordinal regression may also contain interactions that can influence the dependent variable. The sex and ancestry denote such an interaction that may influence the variation observed in the dependent variable. Ordinal regression also contains an error component that allows for changes in the variance of nasal bone structure, for example that are not explaining the main factors such as sex, ancestry, interactions or covariates (age). For nasal bone structure, the ordinal regression model produces significant values for each of these independent variables. The following null hypotheses were tested in the current study: (Hn0): There are no differences in the trait expression among black, white and coloured South Africans. (Hn1) Sex does not affect the expression of the trait in blacks, whites, and coloureds. (Hn2) The age at death of an individual does not affect the expression of a trait. (Hn3) There are no interactions between sex and ancestry among black, white and coloured groups.

Ordinal regression is a popular method amongst researchers because it overcomes many of the restrictive assumptions of ordinal least squares regression. However, there are still other criteria that need to be fulfilled, such as the assumption that only one dependent variable is used. This type of analysis does not permit the use of multiple dependent variables. Ordinal regression requires assuming that there is one regression equation for each category except the last category. The last category probability can be predicted as 1- the second last probability category. The “test of parallel line assumptions” tests this critical assumption and should not be taken for granted (Benerjee et al., 1999).

Wald statistics is used to test the significance of the independent variable with degrees of freedom and standard error. A Goodness of fit test (Pearson's chi-square) provides information as to how many predicted cell frequencies differ from the observed frequencies (Benerjee et al., 1999).

### 3.3.2 The ordinal regression equation

Ordinal regression predicts the log odds of the dependent variable. What is predicted is not the raw value of the dependent but a transformation of it. The application of maximum likelihood estimation transforms the dependent variable into a logit variable and in this way the ordinal regression can estimate the odds of a certain event occurring (McCullagh, 1980). Thus, the ln(odds(event))=ln(prob(event)/prob(non-event):

$$z = b_0 + b_1 x_1 + b_2 x_2 + \ldots\ldots + b_k x_k$$

Where z is the log odds of the dependent variable, $b_0$ is the constant and there are $k$ independent (x) variables, some of which may be interaction terms. Thus for one-independent model, z would equal the constant, plus the b coefficient times the value of $x_1$ when predicting odds (event) for individuals with a particular value of $x_{1.}$ If $x_1$ is a binary (0; 1) variable, then $z = x_0$ (that is, the constant) for the "0" group on $x_1$, and equals the constant plus the b coefficient for the "1" group.

### 3.3.3. Kappa statistics

An inter-rater reliability analysis using the kappa statistic was performed to determine consistency among raters (Banerjee et al., 1999). For categorical data, consensus is measured as number of agreements divided by total number of observations. In the current study two observers independently rated a set of ranked categorical non-metric variables. The first observer initially scored a set of 15 non-metric traits from a sample of 520 individuals that was obtained from the Pretoria Bone Collection over a period of three months. For the purpose of intra-rater agreement the scoring procedure was repeated for 30 skulls after two months had elapsed from the original data analysis. Similarly, a second observer was asked to perform the scoring procedure of the 15 traits on the same 30 individuals. The main focus of this classification procedure between the two observers was to assess the precision in which the observers classified the given material. High measures of agreement would indicate consensus in the diagnosis and interchangeability of the observations (Banerjee et al., 1999). Rater agreement measures were recorded on a continuous scale, but the focus of the current study is on agreement measures that arise when ratings are given on a nominal or ordinal categorical scale.

According to Benejee and associates (1999), many studies use the test to measure agreement between raters. Yet, this statistic does not allow for the fact that a certain amount of agreement can be expected on the basis of chance alone and can occur even if there was no systematic tendency for the raters to classify the same subjects similarly (Banerjee et al., 1999). Benerjee and co-workers (1999) proposed that Cohen introduced the kappa as a chance-corrected measure of agreement. The Kappa measure would reduce the observed proportion of agreement by the expected level of agreement, given the observed marginal distributions of the rater's responses and the assumption that the rater reports are statistically independent (Banerjee et al., 1999).

Cohen's kappa measures the agreement between two raters who each classify *N* items into *C* mutually exclusive categories.

The equation for κ is:

$$\kappa = \frac{\Pr(a) - \Pr(e)}{1 - \Pr(e)},$$

where Pr(*a*) is the relative observed agreement among raters, and Pr(*e*) is the hypothetical probability of chance agreement, using the observed data to calculate the probabilities of each observer randomly saying each category. If the raters are in complete agreement then $\kappa=1$. If there is no agreement to be found among the raters (other than what would be expected by chance) then $\kappa \leq 0$.

Benerjee and colleagues (1999) indicated that Landis and Koch characterized different ranges of values for the kappa measure with respect to the degree of agreement they suggested. These original ranges of values were admitted to have been arbitrary, but nevertheless became incorporated into the literature as standards for the interpretation of Kappa values (Banerjee et al., 1999). Values less than 0.40 may be taken to represent poor agreement beyond chance, values between 0.40 and 0.75 indicate medium or good association, while values greater than 0.75 may be taken as excellent agreement between observers (Banerjee et al., 1999).

The Kappa analysis/inter-rater reliability was performed by SAS PROCFREQ and used to produce 3 × 3 contingency tables from the data. From these data the following output was created. The (Bowker's) Test of Symmetry tests the hypothesis that that $p_{ij} = p_{ji}$ (marginal homogeneity). If this test is non-significant, it indicates that two raters have the same tendency to select categories. If it is significant, then it means that the raters are selecting the categories in differing proportions. The simple kappa coefficient measures the level of agreement between two raters. When kappa is large, it indicates a strong level of agreement.

### 3.3.3.1. Interpretation of the Kappa statistics

When assessing the ability of non-metric variables to assist anthropologists in separating population groups, it is important that its interpretation is not a product of guesswork. This concept is often referred to as *precision* (though some incorrectly use the term *accuracy*). Precision, as it pertains to agreement between observers (interobserver agreement), is reported as the kappa-statistic. Kappa is intended to give the observer a quantitative measure of the magnitude of agreement between observers. Assessing whether the observers agree on the categories of a particular trait is an important aspect of the process, regardless of the validity of these traits.

For example, in the current study, two observers evaluated the usefulness of nasal bone structure as a non-metric trait (see Table 3.5). Observer 1 and observer 2 agree that nasal bone structure is assigned to the African category of groups in 50% (15/30), to the European category in 20% (6/30), to the Asian category in 3% (1/30), and unobservable in 10% (3/30) of the time. If the two observers randomly assigned their ratings, they would sometimes agree by chance, alone. Therefore, kappa gives a numerical value of the degree in which this occurs. The calculation is based on the difference between how much agreement is actually present ("observed agreement") compared to how much agreement would be expected to be present by chance alone ("expected" agreement). The observed agreement is the percentage of all the ancestral groups for which the two observers' evaluation agree, which is the sum of 15 + 6 + 1 + 3 divided by the total 30 which equals 83% or 0.83. We may also want to calculate how much different the observer agreement (0.83) is from the expected agreement (0.35). This value is automatically calculated from the SAS PROCFREQ. Kappa is a measure of this difference, standardized to lie on a -1 scale, where 1 is perfect agreement, 0 is exactly what would be expected by chance, and negative values indicate agreement less than chance, i.e., potential systematic disagreement between observers. In this example, the kappa is 0.7436. According to the scale presented in Table 3.6, a kappa of 0.7436 is in the "substantial" agreement range between the two observers, which would indicate good reliability of the trait. A kappa value less than 0.40 would indicate the variable to be less reliable.

**Table 3.1** Summary of the South African sample by sex and ancestry (n = 520).

| **Skeletal Collection** | **White** | | **Black** | | **Coloured** | |
|---|---|---|---|---|---|---|
| | **M** | **F** | **M** | **F** | **M** | **F** |
| PBC | 32 | 15 | 100 | 41 | 0 | 0 |
| Kirsten Collection | 1 | 1 | 12 | 2 | 61 | 22 |
| Student Bone Collection | 0 | 0 | 23 | 9 | 0 | 0 |
| Raymond Dart Collection | 61 | 48 | 0 | 50 | 26 | 16 |
| Total | 94 | 63 | 135 | 102 | 87 | 38 |
| Grand Total | 158 | | 237 | | 125 | |

**Table 3.2** Age at death distribution of South African sample.

| **Individuals** | **Age range (years)** | **Total N** | **Mean age (years)** | **Male n** | **Female n** |
|---|---|---|---|---|---|
| Young | 10-20 | 9 | 19 | 5 | 4 |
| | 21-30 | 52 | 26.5 | 19 | 33 |
| Middle-aged | 31-40 | 80 | 36.1 | 47 | 33 |
| | 41-50 | 102 | 45.9 | 66 | 36 |
| Older | 51-60 | 100 | 56.6 | 62 | 38 |
| | 61-70 | 74 | 65.5 | 54 | 20 |
| | 71-80 | 52 | 75.6 | 39 | 13 |
| | 81-90 | 18 | 85.1 | 6 | 12 |
| | 91-100 | | | 0 | 0 |
| Unknown | | 33 | | 14 | 19 |
| Total | | 520 | | 312 | 208 |

**Table 3.3** Date of birth in the Raymond A. Dart and Pretoria Bone (PBC) Collections.

| **Date of birth** | **Black** | | **White** | | **Coloured** | |
|---|---|---|---|---|---|---|
| **R. Dart** | **M** | **F** | **M** | **F** | **M** | **F** |
| 1850-1900 | 1 | 7 | 10 | 6 | 8 | 4 |
| 1901-1910 | 0 | 8 | 8 | 12 | 3 | 1 |
| 1911-1920 | 0 | 12 | 6 | 8 | 4 | 3 |
| 1921-1930 | 0 | 9 | 8 | 10 | 3 | 0 |
| 1931-1940 | 0 | 1 | 8 | 6 | 1 | 0 |
| 1941-1950 | 0 | 0 | 8 | 4 | 2 | 1 |
| 1951-1960 | 0 | 1 | 1 | 0 | 2 | 4 |
| 1961-1970 | 1 | 0 | 0 | 0 | 0 | 1 |
| 1971-1980 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1981-1990 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 2 | 38 | 48 | 46 | 23 | 14 |
| **Date of birth** | **Black** | | **White** | | **Coloured** | |
| **PBC** | **M** | **F** | **M** | **F** | **M** | **F** |
| 1850-1900 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1901-1910 | 7 | 0 | 1 | 1 | 0 | 0 |
| 1911-1920 | 14 | 0 | 6 | 4 | 0 | 0 |
| 1921-1930 | 18 | 4 | 10 | 2 | 0 | 0 |
| 1931-1940 | 24 | 3 | 6 | 5 | 0 | 0 |
| 1941-1950 | 10 | 12 | 3 | 0 | 0 | 0 |
| 1951-1960 | 10 | 4 | 0 | 0 | 0 | 0 |
| 1961-1970 | 11 | 3 | 0 | 0 | 0 | 0 |
| 1971-1980 | 2 | 2 | 0 | 0 | 0 | 0 |
| 1981-1990 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 96 | 28 | 26 | 12 | 0 | 0 |

**Table 3.4** Standard non-metric cranial traits.

| **Standard non-metric traits** | **Reference** |
|---|---|
| Nasal bone Structure (Nbs) | Brues (1990); Hefner (2003) |
| Nasal breadth (Nb) | Gill (1990); Rhine (1990); Stewart (1979) |
| Nasal overgrowth (Nov) | Rhine (1990); Bass (1995); Hefner (2003) |
| Anterior nasal spine (Ans) | Brues (1995); Rhine (1990); Berry &Berry (1967) |
| Inferior nasal margin (Inm) | Hefner (2003); Bass (1995); Krogman & İşcan (1986); Rhine (1990) |
| Interorbital breadth (Iob) | Hefner (2003); Spencer & Rogers (1984) |
| Zygomaxillary suture shape (Zss) | Hauser &De Stephano (1986); Rhine (1990) |
| Zygomatic projection (Zp) | Bass (1995) |
| Malar tubercle (Mt) | Hauser & De Stephano (1989); Hefner, (2003); Rhine (1990) |
| Alveolar prognathism (Ap) | Bass (1995) |
| Mandibular torus (Mdt | Hauser and De Stephano (1989); Suzuki and Sakai (1960) |
| Palatine torus (Plt) | Hauser and De Stephano (1986); Spencer & Rogers (1984); |
| Incisor shovelling (Is) | Hrdlička (1920) |
| Carabelli's cusp (Cc) | Edgar (2005) |
| Transverse palatine suture shape(Tps) | Hauser & De Stephano (1989); Rhine (1990) |

**Table 3.5** An example of interobserver error variation.

| Nasal Bone Structure | | | | | | |
|---|---|---|---|---|---|---|
| | **Observer 2** | | | | | |
| **Observer 1** | Score | 0 African | 1 European | 2 Asian | 5 Unobservable | Total |
| | 0 African | 15 | 0 | 0 | 0 | 15 |
| | 1 European | 0 | 6 | 0 | 0 | 6 |
| | 2 Asian | 0 | 0 | 1 | 0 | 1 |
| | 5 Unobservable | 1 | 2 | 2 | 3 | 8 |
| | Total | 16 | 8 | 3 | 3 | 30 |

**Table 3.6** Kappa values for the measure of intra and interobserver agreement.

| Kappa | Agreement |
|---|---|
| < 0 | Less than chance agreement |
| 0.001-0.20 | Slight agreement |
| 0.21-0.40 | Fair agreement |
| 0.41-0.60 | Moderate agreement |
| 0.61-0.80 | Substantial agreement |
| 0.81-0.99 | Almost perfect |

# Chapter 4: Results

In order to reliably use the previously mentioned 15 standard non-metric facial traits to estimate ancestry from South African remains, three criteria need to be examined as a means to determine the general efficacy of these traits for distinguishing one population group from another. First, the frequency distributions of these features among the major South Africans groups in this case white, black and coloured were compared with the traditional North American ancestral groups, which are Caucasoid (European), Mongoloid (Asian) and Negroid (African). Second, ordinal regression statistics were used to assess the contribution of sex, age at death and ancestry on the morphological appearance of these traits in the human cranium within a South African population. Third, the repeatability of the non-metric traits was evaluated.

## 4.1. Descriptive statistics

Frequency distributions of non-metric trait scores for white, black and coloured South Africans were tabulated for the 15 variables, namely nasal bone structure, nasal breadth, nasal overgrowth, anterior nasal spine, inferior nasal margin, inter-orbital breadth, zygomatic projection and alveolar prognathism (Table 4.1), as well as zygomatic suture shape and transverse palatine suture shape (Table 4.2), malar tubercle (Table 4.3), palatine and mandibular tori (Table 4.4), as well as the presence or absence of incisor shovelling and Carabelli's cusps (Table 4.5). From these tables, comparisons between South African groups and the three traditional ancestral categories can be made. The value, or usefulness, of a non-metric trait for estimating ancestry is dependent on whether that trait is useful in distinguishing one population group from another; this simple point needs to be considered fundamental for when these traits are used to estimate ancestry.

The non-metric traits associated with the appearance and shape of the nose and face are presented in Table 4.1. As can be seen for nasal bone structure, the majority of white South Africans exhibited tented, vaulted or steepled shapes (92%), which is consistent with previously defined standards for this group. Less than half of the black South Africans (44%) fell into the typical quonset or round nasal bone structure categories of known African groups, the majority (49%) displaying either oval shapes, which is often found in Asians, or tented shapes, which is noted in Europeans. Similar to black South Africans, the coloured group also had the greatest distribution in the quonset (African) and hut (Asian) categories

(75%). A score of 2, or tented/plateau shaped nasal bones, exhibited the greatest overlap among the three South African groups, whereas scores 3 and 4, indicative of vaulted and steepled shapes, had the least overlap. Therefore, it may be possible to exclude a South African of European descent, with a score of 3 or 4 from black and coloured South Africans; however, it is not possible to exclude a black or coloured person based on the visual features of the nasal bone structure.

Nasal breadth is considered one of the hallmark features for distinguishing African and European groups. However, only 12% of black South Africans and 43% of white South Africans fell into the traditional range of variation for nasal width (see Table 4.1). The three major groups overlapped in the intermediate shape, or score 2, which is suggested to occur most often among Asians. The overlap of the intermediate score guarantees a certain amount of difficulty in separating the three groups from each other.

A feature associated with Asian groups is nasal overgrowth (see Table 4.1). The absence of the trait in blacks (65%) and whites (87%) is consistent with previous published reports of Africans and Europeans distributions; however, the coloured group (50%) was more likely to have had some form of nasal overgrowth than either blacks or whites.

The shape and size of the nasal spine as well as the appearance of the inferior nasal margin are commonly used to distinguish Africans and Europeans. Among South Africans, the majority of black (76%) and coloured (81%) persons demonstrated a short or dull nasal spine, which did not project past the prosthion. In contrast, 87% of white South Africans were shown to have either a medium projecting spine, which terminated at the prosthion, or a long (sharp) spine that extended beyond prosthion. Overlap among the three groups tended to be the greatest for the medium projecting spine, with approximately 15% of coloured, 20% of black, and 26% of white South Africans. This trait may be useful in distinguishing black South Africans who have short and dull spines from white South Africans who have long projecting spines.

When assessing the inferior nasal margin (see Table 4.1), the results demonstrated that black and coloured groups were equally divided between the traditional Africans scores of guttered to incipient guttering, or scores 0 and 1, and the traditional European characteristics in which the nasal margin has either a partial or a complete nasal sill, or scores 3 and 4. While the appearance of a partial to complete nasal sill is almost exclusively observed in white South Africans (87%), it cannot be used as a criteria for separating whites from the other two groups as approximately 40% of the black and 51% of the coloured sample were found to exhibit this feature. Few of the South Africans groups fell into the Asian category, or a straight sill for this trait.

Similar patterns of variation can be observed when the frequency distribution of intra-orbital breadth and nasal breadth. Inter-orbital breadth has three scoring criteria, namely narrow (score 1), intermediate (score 2), and wide (score 3). The results for inter-orbital breadth are similar to those of nasal breadth (see Table 4.1) in that the intermediate shape, or score 2, exhibited the greatest overlap between the blacks (55%), whites (51%) and coloureds (66%). From these two traits it can be seen that black and coloured samples demonstrated a higher degree of variability within the intermediate state of the trait. As with many of the traits discussed in this chapter, separation of one group from another based on the distance between the orbits would prove to be fairly difficult among South Africans.

Assessing the non-metric features of the face in profile (see Table 4.1), coloured persons (27%) had a greater prevalence of forward projecting zygomatic bones than either their black (14%) or white (9%) counterparts. The degree in which the maxillary bone projects beyond the most anterior portion of the nasal bones is described as alveolar prognathism and is most often associated with Africans. As can be expected, the greatest percentage (87%) of whites and coloureds (62%) did not exhibit this feature; however, 43% of blacks also failed to display it.

In Tables 4.2 to 4.5, the frequency distribution of non-metric features including zygomatic suture shape, malar tubercle, the palatine and mandibular tori, as well as the presence or absence of shovel-shaped incisors and Carabelli's cusps are presented. South African groups had zygomatic suture shapes which were either angled (score 1) in 22% of blacks and 24% of coloureds or smooth (score 2) in 76% of blacks and 73% in coloureds; these features have been traditionally associated with African or Asian groups. Less than 2% of the white sample had the zig-zag S-shaped suture pattern that is characteristic of this group. Based on the frequency distribution for this trait, there are no marked differences in the pattern of variation in the South African sample that would aid in separating them from each other.

The malar tubercle has been described as the tendency of the zygomatic and maxillary bones to form an inferior projection at the zygomaticomaxillary suture. In North American groups, these tubercles are more likely to be observed on skeletal remains of European origin. However, an opposite tendency is noted for the South African white sample (80%), who were primarily classified as having no tubercle (score 0). Black and coloured groups were most likely to have either an absent (37% of blacks, and 35% of coloureds) or incipient score (56%

of blacks, and 55% of coloureds), which has been traditionally labelled as belonging to African or Asian groups. The greatest overlap among the three South African groups was therefore observed in both the absence and incipient variations, which have been described for the malar tubercle.

The palatine and mandibular tori are characterized by the presence of a bony ridge in either the midline of the hard palate or on the lingual surface of the mandible. These traits are anomalies of the oral cavity and have been described as occurring more frequently in Asian groups. However, the prevalence of these traits also appears to be highly variable in different populations. In the case of the palatine torus, the majority of the South African groups (blacks, 74%, whites, 58%, and coloureds, 69%) tend to not exhibit the trait, or score 0. However, almost half of the white population (42%) did exhibit this feature. The mandibular torus was found mainly to be absent in all three South African groups.

Shovel-shaped incisors have been considered to be a reliable skeletal indicator to distinguish Asians from other population groups. In Tables 4.5, the frequency distribution of incisor shovelling in the maxilla and mandible are shown. The coloured group exhibited the greatest frequency of shovel-shaped incisors, with 62 to 69% in the maxilla and 10 to 19% in the mandible. The presence of this trait was also relatively common among black South Africans (46 to 49% in the maxilla; 11 to 13% in the mandible) and least common in white South Africans (22 to 32% in the maxilla and 2% in the mandible). The prevalence of shovel-shaped incisors was assessed through individual teeth (four maxillary central and lateral incisors and four mandibular central and lateral incisors for a total of eight teeth) for each person. Poor dental conditions of some individuals as well as post-mortem damage severely reduced the amount of material available for testing. The prevalence of shovelling was therefore assessed by tooth type and not by the individual per se.

Carabelli's cusp is primarily regarded as a European feature and ranges from a small protuberance to an extra cusp on the mesiolingual surface of the first maxillary molar. From Table 4.7, it can be seen that the upper first molars presented with Carabelli's cusp in 26% of the individuals of the white sample. However, the trait also appeared in both black (15%) and coloured (17%) South African groups.

The occurrence of 15 non-metric traits in three South African population groups reveals distribution patterns similar to classic reports of typological research. However, the results obtained here also showed trait frequency patterns that were in contrast to the pre-conceived notions of type classification. For example, nasal breadth has long been regarded as one of the hallmark features for distinguishing African groups from other populations;

however, results from the current study indicate that this may not be the case among highly diverse South African groups. In general, the results display overlap of trait frequencies that may be attributed to the heterogenous nature of South African groups, or it may indicate a high amount of variability within a group. Also, taking into account the history and development of non-metric research it may be suggested that these traits do not necessarily demonstrate true ancestral differences.

## 4.2 Ordinal Regression

In Table 4.6, the statistically significant influence ($p<0.05$) of aspects such as sex, age at death, ancestry and the interaction between sex and ancestry on these 15 non-metric traits is shown. Only the variables that were significantly influenced by these aspects are presented, and include the nasal bone structure, nasal breadth, nasal overgrowth, anterior nasal spine, inferior nasal margin, interorbital breadth, zygomatic projection, and alveolar prognathism.

Ordinal regression is a technique that is used to predict the behavior of independent variables (such as sex, age and ancestry) with dependent variables (such as non-metric traits) and provide information about whether there is a statistically significant difference in the trait in question between at least two ancestral groups. This type of analysis can be counter-intuitive in that the white sample is revealed to be "redundant" in every trait analyzed. This is caused by the arbitrariness of the procedure in that it can only indicate that ancestry affects the dependent variable, but is unable to specify which ancestral group is actually different from the other groups. For example, the results for nasal bone structure in the ordinal regression (Table 4.7) indicate two statistically significant entries for ancestry ($p=0.000$ for blacks and $p=0.000$ for coloureds). However, the method is not able to predict the exact amount or direction in which the groups differ from one another. Therefore, in order to interpret the significant entries for ancestry in the ordinal regression, the frequency distribution of each trait needs to be taken into account (see Table 4.1). Thus, in the case of nasal bone structure, the frequency distribution indicated that black and coloured groups were assigned scores of 0 and 1 (indicative of African and Asian groups respectively), whereas whites were distributed throughout scores of 2, 3, and 4 (indicative of European groups). Moreover, although there is substantial overlap among the three groups, the trait in general matches the traditional classification scheme of North American ancestral categories. This suggests that in future, these traits may be amendable to multi-variate statistical analysis.

The interpretation of aspects that influence non-metric variation such as sex, age, and the interaction between sex and ancestry in the regression model requires an assessment of cross-tabulations, which are tables that are generated from the ordinal data. For example, from the cross tabulation of nasal bone structure (Table 4.8), it can be seen that black and coloured females differed from their male counterparts with respect to the frequencies of tented nasal shapes (score 2). Only five black females registered a score of 2 (tented sill), compared to the 23 black males who exhibited this form of the trait. There was also a difference noted in the number of coloured females (n=5) and males (n=10) for this form of the trait. Furthermore, black (n=48 females; n=32 males) and coloured females (n=21) and males (n=16) varied in the frequency of hut nasals shapes (score 1). Therefore the variation (different forms of the trait) in nasal bone structure is influenced by the sex male or in combination with the ancestry of an individual. Table 4.7 is an example of a complete ordinal regression output with a corresponding cross tabulation (Table 4.8).

However, no trait can be deemed population specific, such that it would only occur in one population, and therefore one cannot assume complete separation of groups based on the distribution of a single trait or even multiple traits. However if a trait is influenced by an aspect such as ancestry, the distribution of that trait may indicate an affiliation towards one particular ancestral group over another. This is the manner in which all of the significant entries for ancestry in the ordinal regression are to be interpreted.

In principle, the interpretation of the statistically significant entry in “ancestry” (p=0.000 for blacks; p=0.000 for coloureds) for nasal breadth in the ordinal regression (see Table 4.6) is similar to that which was described above for nasal bone structure. The frequency data displayed overlap among the three South African groups (see Table 4.1). Even though the three groups displayed an intermediate form of the trait, the trait, itself, followed a general trend in that blacks did not exhibit the characteristic European form and whites did not display the traditional African form. This explains the significance for “ancestry” in the ordinal regression

The ordinal regression results indicated two statistically significant entries in nasal breadth for the interaction between the sex and ancestral group of a person. These values included black (p=0.049) and coloured (p=0.042) females (see Table 4.6). From the cross-tabulation (Table 4.9) a difference in frequencies distributions were noted for the prevalence of intermediate scores for both black females (n=80) and their male (n=120) counterparts. The same type of separation was noted for coloured females (n=34) and males (males=78). Therefore, the subtle differences between the number of males and females in a particular ancestral group (black, white and coloured) influenced the variation observed in nasal breadth. Thus, the sex of a person as well as the ancestry has an effect on the shape of this trait.

Another trait in the series of non-metric characteristics that is associated with the appearance of the nose and face and that is influenced by ancestry (p=0.000 for blacks and p=0.01 for coloureds) and the interaction between the sex and ancestry (p=0.003 for black females; p=0.009 for coloured females) is inter-orbital breadth (see Table 4.6). Again, the frequency data revealed overlap among black, white and coloured groups in the intermediate form of the trait (see Table 4.1). However, the black South African group (42%) did exhibit variation typically associated with African populations. The frequency distribution therefore explains the entry for a statistical significance in "ancestry" as in the above described features. At this point it might be noteworthy to mention that the distance between the orbits is related to the width of the aperture of the nose. Previous discrete trait studies have shown wider distances between the orbits and between the alae of the nose. These results seems to be in contrast to the current results in which an intermediate distances was recognized among both of these traits.

There are two statistically significant entries for the interaction between sex and ancestry and included values for black (p=0.003) and coloured (p=0.009) females. From the cross tabulation (Table 4.10) the frequencies of blacks (females=52, males=79) and coloureds (females=22, males=60) displayed the intermediate (score 2) form of the trait. Whites (females=33, males=48) also differed in their frequencies for this form but to a lesser extent. Therefore as previously described the variation in the trait, denoted in non-metric terms as narrow, intermediate and wide, is influenced by sex and ancestry. In addition, another cross-tabulation (see Table 4.11) demonstrated the influence of sex on the variation in inter-orbital breadth. Differences were noted in the number of males (n=187) and females (n=107) in the intermediate (score 2) and wide (n=88 males, n=64 females) categories of the trait. The variation in inter-orbital breadth is therefore not only subjected to the ancestry of a person, but is also accordingly influenced by the sex, and the interaction of sex and ancestry.

The ordinal regression (Table 4.6) indicated two statistically significant entries (p=0.004 for blacks and p=0.01 for coloureds) in ancestry for nasal overgrowth. An evaluation of the frequency data for nasal overgrowth among the South African sample is another example of a discrete variable which generally followed the typological classification of classic physical anthropology. Despite the fact that nasal overgrowth has been regarded as a purely Native American or Asian characteristic, the distribution (Table 4.1) of the trait among the local groups (black=35%; white=13%) revealed not to be entirely absent, although the majority of the sample (blacks=65%; whites=87%) did not exhibit the trait. Approximately half of the coloured group displayed nasal overgrowth.

According to the results from the ordinal regression (Table 4.6), the anterior nasal spine is influenced by "ancestry" (p=0.000 for blacks and p=0.000 for coloureds) and age (p=0.035). A statistically significant entry in ancestry suggested a difference in the trait for two of the ancestral groups. Again, the statistical difference is explained by interpreting the results from the frequency data in order to establish which two groups were different. The frequency distribution (Table 4.1) indicated some overlap among blacks (76%) and coloureds (81%) as opposed to whites (87%), which showed the least amount of overlap with regard to the length of the anterior nasal spine.

Apart from the influence of ancestry, the anterior nasal spine was also significantly affected by the age (p=0.035) of a person. From the cross tabulation (Table 4.12), it appears that the length of the spine increased with an increase in the age of an individual. This might possibly be due to the fact that older individuals in the sample were often edentulous. When the upper teeth are lost, the maxillary bone resorbs and the spine appears to increase in length.

Significant entries for the inferior nasal margin in ancestry for blacks (p=0.003) and coloureds (p=0.009) were obtained from the ordinal regression (Table 4.6). The pattern of variability in the trait indicated that white (87%) South Africans appeared to be widely separated from blacks and coloureds based on the high prevalence of partial (score 3) and complete (score 4) sills in this group. However, black (55%) and coloured (51%) groups also displayed the characteristic European form of the trait as well as typical guttered (blacks 40%; coloureds 28%) and incipient guttered (blacks 15%; coloureds 17%) forms. Based on the distribution of the trait, it might be possible to exclude a white South African from a black and coloured person, but it would be much more difficult to separate a black person from a coloured person.

The results for zygomatic projection indicated a difference in ancestry (p=0.021) for coloureds (see Table 4.6). On closer examination the distribution of the trait (Table 4.1) among the local sample indicated that coloureds (27%) were much more likely to have projecting zygomatic bones (score 2) than either blacks (14%) or whites (9%). However, the coloured sample also demonstrated the higher frequency values for the appearance of non-projecting bones (score 1).

Alveolar prognathism presented two statistically significant entries in "ancestry" for blacks (p=0.000) and coloureds (p=0.003) in the ordinal regression (Table 4.6). This influence is explained by 57% of black South Africans presenting with prognathism (score 2), while 87% of whites and 62% of coloureds were orthognathic (score 1) (see Table 4.1).

The variables below include the zygomatic suture shape, malar tubercle, and the mandibular and palatine torus, which are influenced by the effect of ancestry as well as by age at death in the case of the palatine torus.

Statistically significant values for blacks (p=0.000) and coloureds (p=0.000) were observed for the zygomatic suture shape. The distribution of this trait (Table 4.1) indicated that blacks presented with angled (22 %) (score 1) or smooth (75%) (score 2) shapes for sutures, while coloureds (73%) mainly presented with smooth (score 2) shapes. Very few whites (2%) were classified as having the traditional zig-zag (score 3) appearance. The remainder of the ordinal regression outcomes for this variable revealed no influence by sex, age or the interaction between sex and ancestry.

Two statistically significant entries in ancestry (p=0.000) for the malar tubercle in blacks and (p=0.000) and coloureds were listed from the ordinal model. The direction of the significance is related to the raw frequency data. The malar tubercle can be considered a trait more commonly observed in European groups; yet, its frequency distribution (see Table 4.1) amongst black (56%), white (18%) and coloured (55%) South Africans shows the trait to be better associated with the Asian characteristic (score 1). The white sample (80%) were classified as having no malar tubercle (score 0).

The statistical significance of both the palatine (p=0.007 for blacks and p=0.033 for coloureds) and mandibular (p=0.000 for blacks and p=0.003 for coloureds) tori were obtained from the ordinal regression model. Traditionally these tori have been associated with Asian descent. The frequency distribution (Table 4.1) for both of these traits in the three South African groups resulted in it being classified as a European and African feature (score 0), contrary to the expected traditional ancestral classification. Additionally the palatine torus was significantly influenced by age (see Table 4.6).

For the upper central incisors, the regression results (see Table 4.15) produced only one statistically significant entry (p=0.0020) for coloureds in ancestry. The distribution (Table 4.1) in shovelling of the upper incisors indicated that the trait was found more frequently in coloured groups (54 to 59%) than in blacks (46 to 48%) or whites (11 to 13%). A similar trend amongst the three groups was noted in the lower incisors but to a lesser extent. Therefore, as pointed out earlier, if the coloured population of South Africa is considered to have higher proportions of Indian/Asian mixture than either the black or white groups, they should display higher incidences of incisor shovelling. However, the results of incisor shovelling in the ordinal regression should only be viewed as tentative. As mentioned previously, the prevalence of shovel-shaped incisors was assessed by the individual teeth for each person. Conditions such as poor dental health as well as post-mortem damage, which include tooth loss, severely reduced the amount of available material for viable testing. These and other factors could have had a possible influence on fitting the data into the ordinal model. For example in order to run the test it required an adequate cell count (sufficient entries of a score of 0 (shovelling) and 3 (no shovelling) that would give an account of the trait (see Table 4.1). As a rule of thumb, 80 % of the cells must have more than 5 counts and no cell should register a count of 0. This rule was slightly difficult to apply in this study because of the poor dentition of the skulls and thus resulted in compromised cell counts. The above mentioned factors therefore may have contributed to the fact that the test could not be properly run due to a lack of sufficient data. However, significant age-related results (p=0.019, p=0.004; p=0.001; p=0.011) were observed for all the upper incisor teeth examined. Fewer cases of shovelling are observed with advanced age which could be related to an increase in dental wear such that the tooth becomes worn over time and eventually looses its shovelled appearance.

The results from the ordinal regression of Carabelli's cusp should also be viewed as tentative, because the complete test could not be performed due to the same reasons mentioned above for the shovel shaped incisors. Factors such as antemortem and postmortem tooth loss would have affected these results. Statistically significant values for the upper right (p=0.002 for blacks; p=0.025 for coloureds) and upper left molars (p=0.000 for blacks; p = 0.017 for coloureds) were obtained. If the frequency distribution is examined (see Table 4.1), it becomes evident that the trait somewhat conforms to traditional standards in that more whites (36%) display the cusp than either blacks (15%) or coloureds (17%).

Two age-related statistically significant entries (p=0.013) for the first upper right molar and (p=0.015) for the first upper left molar are obtained. From the cross tabulations, it can be seen that for both the left and the right upper molars the absence of the trait (score 0) is associated with an increase in mean age (see Table 4.16 and Table 4.17), while the presence of the trait (score 1) is consistent with younger individuals. Thus, increased dental wear with age may possibly explain the absence of Carabelli's cusp in older individuals.

In summary, the application of ordinal regression provided valuable information as to the effects of ancestry, sex, age and the interaction between sex and ancestry on the 15 discrete cranial and facial traits. The majority of the traits including those associated with the face and nose as well as several others such as the zygomatic suture shape, malar tubercle and palatine and mandibular tori revealed to have been statistically significant for ancestry and sex. The direction of the significance was explained by evaluating the frequency data of each trait in order to establish how the groups differed from each other (see Table 4.1). In addition, several traits displayed interaction between sex and ancestry, and included the nasal bone structure, nasal breadth and inter-orbital breadth (see Table 4.6). The only traits to have been influenced by sex, alone, were inter-orbital breadth and incisor shovelling. Traits that were influenced by both ancestry and age were the anterior nasal spine and alveolar prognathism (see Table 4.6). The results from the ordinal regression strongly suggest that not only ancestry but also additional factors (sex, age and the interaction between sex and ancestry) influenced the traits in question.

### 4.3. Intra and Interobserver correlation

In many research fields, analysis of observer or inter-rater agreement data often provides a useful means of assessing the reliability of a rating system. In the current study, agreement coefficients were used to assess the extent to which 15 standard non-metric variables could reliably be classified into one of several demographic groups. The function of this test was to determine the precision of the classification process. A detailed description of the kappa method can be found in the materials and methods section (chapter 3:51-53). The results for inter-rater reliability are presented in Table 4.17.

An important aspect of the reliability analysis was to not only interpret the kappa (κ) value but also to consider the agreement value that accompanied it. For example, in some cases the results indicated high values for observer agreement, but low values for kappa. These apparent paradoxal difficulties occurred because kappa not only measures agreement, but is also affected by the presence of bias between observers and by the distributions of data across the categories that were used, which is often referred to as prevalence. When comparisons are made between agreement studies, it can be misleading to report kappa values alone, and it is thus recommended that researchers also include other measures such as p-values and confidence intervals. From the hypothesis test, a p-value was calculated and represents the probability of rejecting the null hypothesis, which states that the agreement between the variables is no better than chance when in fact the opposite is true. If this test is non-significant, it indicates that the two observers have the same tendency to select categories. A significant ρ-value implies that the agreement between the variables is not just chance but that the observers are selecting categories in differing proportions.

From Table 4.17, it can be seen that for nasal bone structure the intra-rater reliability was found to be substantial with an agreement of 83% ($\kappa = 0.7436$; $p = 0.1718$), while the inter-rater reliability was moderate with an agreement of 70% ($\kappa = 0.5369$; $p = 0.0611$). These values for the two independent observers indicated that nasal bone structure is a reliable trait for indicating ancestral differences and that the scores can be consistently recorded.

Intra-rater reliability for nasal breadth was found to be substantial (agreement 83%; $\kappa=0.6835$; $p=0.3679$), while an agreement of 70% ($\kappa=0.5603$; $p=0.0111$) was observed for the inter-rater. The p-value is significant and suggests that the agreement between the variables is not just due to chance but that the observers are selecting ancestral categories in differing proportions. Thus, although there is a considerable amount of agreement among them, they did not tend to select the same categories.

The reliability for nasal overgrowth (83%, $k=07409$; $p=0.3114$; 80%, $k=0.6809$; $p=0.2615$) was substantial for both the intra- and inter-rater agreement. Moderate to very high levels of agreement were also observed for the anterior nasal spine (86%, $k=0.8086$; $p=0.2615$; 70%, $k=0.5500$; $p=0.0293$). These variables can be scored consistently among observers. However, the significant p-value is problematic in that it implied that the observers failed to score each of the variables in the same manner.

The intra-rater agreement for the inferior nasal margin was moderate (76%) ($\kappa=0.5808$; $p=0.0302$). A statistical significant p-value indicated that the observer selected the categories differently during the second round of classification. For example, from the contingency table (see appendix 2:140-153) of the intra-rater agreement of the inferior nasal margin it can be seen that during the first round of classification the observer scored the trait as European (score 0, which equates into a partial or complete nasal sill) for a total of 15 individuals. However, during the second round of classification, the observer scored the trait as European for 15 individuals, but also as African (score 1, or guttered and incipient guttered appearances) for a total of 5 individuals (total of 20 individuals). From this kappa analysis, there seems to be a discrepancy of the manner in which the observer classified the trait during the two separate events. What seems to be unusual is the fact that there should be recognizable differences between guttered and partial or complete nasal sills. However, stemming from the p-value the observer seems not to have made this distinction. This might suggest that the trait descriptions are in need of more rigorous refinement.

The agreement for inter-orbital breadth was moderate for both the intra- 70% (κ=0.5337; p=0.0302) and interobservers 63% (κ=0.4388; p=0.0821). Again, a statistical significant p-value for the intraobserver agreement was noted. From the contingency table (see appendix 2:140-153) for inter-orbital breadth, it can be seen that the observer classified the trait in different proportions during the two separate scoring events. This means that the way in which the observers perceived the various states of the trait could have caused the scores to differ, and subsequently, resulted in different patterns for each of the variants observed. Overall, the agreement between the two independent observers proved to be a valuable indicator of the ability of this trait to be scored consistently

The results for the intraobserver reliability for incisor shovelling displayed a moderate (60%) agreement (κ=0.6023; p=0.0719), while the interobserver agreement (66%) was also found to be moderate (κ=0.4783; p=0.0752). If both the kappa and p- values are taken into account it appears that the trait can be scored consistency among the observers.

From the group of 15 non-metric variables, a total of six were shown to have much less agreement between the observers during the two classification events. These variables include the zygomatic suture shape, zygomatic projection, alveolar prognathism, the mandibular and palatine tori, and the transverse palatine suture shape.

For the zygomatic suture shape the intraobserver agreement was 63% with a kappa value that would classify the agreement as fair (κ=0.3855) (see table 4.16). The kappa analysis among two independent observers performed even worse with an agreement of only 50 % and a very low kappa value of 0.1071 (p=0.0203) which according to the kappa scale equates to slight agreement (see Table 4.16:92). The test for symmetry produced a statistically significant value and indicated that the observers scoring the trait selected the various categories much differently from one another. Zygomatic suture shape is scored less consistently among observers, and should therefore be applied with caution. Additionally, this trait was also shown to not be a valid indicator of ancestral differences among groups.

Zygomatic projection is a classic example in which there are high levels of agreement among observers but low kappa values. The intraobserver reliability was found to be moderate with an 86 % agreement and a kappa value of 0.5522 (p=0.1253). However, the interobserver reliability was fair (κ=0.2500; p=0.0821) with a high level of agreement, (83%). These results indicate that despite the high level of unadjusted agreement among the observers, the precision in which the trait was being scored was poor.

The mandibular torus also demonstrates the paradox of a high level of intra-rater agreement (80%) opposed to a kappa of 0.1628 that indicates poor agreement when accounting for chance. From the distribution (see Table 4.4) it can be seen that the trait is infrequently displayed among the three South African groups; 6% (n =14/223) in blacks, 12% in whites (n=19/156), 6% in coloureds. The reasons as suggested may be related to the incidence of the torus in the sample, as kappa is affected by the prevalence of the trait under consideration. The results for the interobserver reliability test have shown a similar pattern in that a high level of agreement was noted (76%) accompanied by a very low kappa value (-0.0769). A negative value of kappa would mean negative agreement; that is, the tendency of one rater to avoid assignments made by another rater. This may indicate a genuine disagreement, or it may reflect a problem in the application of the trait in question.

For alveolar prognathism, intra-rater reliability was fair with a 50% agreement between the first and second series of observations and with an even lower kappa value ($\kappa=0.2475$; $p=0.0090$). The symmetry test was used to determine the variance of kappa and was shown to be statistically significant and suggests that the observer selected different forms of the trait during the two rating procedures. For the interobserver reliability agreement was moderate (66%) with a kappa value of 0.5106 ($p=0.0186$). The significant p-value demonstrates the inability of the observer to have scored the trait consistently and suggests agreement as predicted by chance. Resorption of the maxillary bone as observed in older individuals could have a definite effect on how the observers interpreted the actual degree of prognathism which was present or absent. When the amount of agreement, kappa and p-values are taken into account alveolar prognathism may not be as reliable as once predicted.

The palatine torus (see Table 4.17) has shown very poor scoring consistency for both the intra- and interobserver agreement with 36 % ($\kappa=0.0625$; $p=0.0001$) and 43% ($\kappa=0.1146$; $p=0.0002$) respectively. The low kappa values indicated slight agreement between observes, while the p- values are quite small and thereby rejecting the null-hypothesis ($p<0.05$). The results are therefore only 5% likely and suggest that the agreement between observers is due purely to chance.

For the transverse palatine suture shape the intraobserver agreement was fair 63 % ($\kappa=0.3762$; $p=0.3916$). The scoring consistency of the trait during the first and second rounds of classification can therefore not be considered reliable. For the interobserver agreement, the situation is similar in that there was a fair 60% agreement ($\kappa=0.3782$; $p=0.0533$) between the observers. The extent to which the two independent observers agreed in the labeling of this trait into a particular category can not be considered reliable when taking the kappa and p-values into account.

The agreement among the intraobserver ratings for Carabelli's cusp has shown to be fair (60 %) (κ= 0.2123; p = 0.0356), while the inter-rater agreement was substantial (80%) (κ=0.6995; p=0.2615). The agreement among the ratings of the same observer is fair with a statistical significant p-value which indicates that the agreement is as predicted by chance (null-hypothesis rejected) and would therefore prove as a less reliable feature for indicating ancestral variation.

In summary, the results from this analysis have shown that the only trait that displayed substantial agreement among both intra- and interobserver classifications was nasal overgrowth. Variables that have shown moderate agreement for both the intra and interobserver tests include inter-orbital breadth, malar tubercle, and incisor shovelling. Several traits seemed to have a better correlation among the intraobserver agreement and include the nasal bone structure, nasal breadth, and anterior nasal spine opposed to interobserver ratings. Some variables displayed a better correlation among the interobserver classification errors and include the inferior nasal margin, alveolar prognathism and Carabelli's cup. The remainder of the variables displayed either moderate agreement or agreement that strongly indicated poor reliability for these traits. Although there was good reliability for some traits, their significant p-values suggested a compromised reliability in that traits were not scored in the same manner.

**Table 4.1** Frequency distribution of non-metric traits associated with the nose and face in three South African groups.

| Non-metric trait | | | Ancestry groups | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Nasal bone structure | | Black | | White | | Coloured | |
| | | | n =183 | % | n=129 | % | n=95 | % |
| 0 | Quonset-hut | African | **80** | **44** | 5 | 5 | **37** | **39** |
| 1 | Hut | Asian | **63** | **34** | 4 | 3 | **34** | **36** |
| 2 | Tented | European | **28** | **15** | **25** | **19** | **15** | **16** |
| 3 | Vaulted | | 7 | 4 | **47** | **36** | 5 | 5 |
| 4 | Steepled | | 5 | 3 | **48** | **37** | 4 | 4 |
| | Nasal breadth | | Black | | White | | Coloured | |
| | | | n=229 | % | n=148 | % | n=122 | % |
| 1 | Long | European | 1 | 0.4 | **63** | **43** | 5 | 4 |
| 2 | Rounded | Asian | **200** | **87** | **84** | **56** | **112** | **92** |
| 3 | Wide | African | **28** | **12** | 1 | 1 | 5 | 4 |
| | Nasal overgrowth | | Black | | White | | Coloured | |
| | | | n=171 | % | n=122 | % | n=78 | % |
| 0 | Absent | Eur/Afr | 111 | 65 | 106 | 87 | 39 | 50 |
| 1 | Present | Asian | 60 | 35 | 16 | 13 | 39 | 50 |
| | Anterior nasal spine | | Black | | White | | Coloured | |
| | | | n=233 | % | n=149 | % | n=118 | % |
| 0 | Short | African | **97** | **42** | 11 | 7 | **50** | **43** |
| 1 | Dull | Asian | **79** | **34** | 8 | 5 | **45** | **38** |
| 2 | Medium | European | 47 | 20 | **39** | **26** | 17 | 14 |
| 3 | Long | | 10 | 4 | **91** | **61** | 6 | 5 |
| | Inferior nasal margin | | Black | | White | | Coloured | |
| | | | n=234 | % | n=157 | % | n=122 | % |
| 0 | Guttered | African | **93** | **40** | 12 | 8 | **34** | **28** |
| 1 | Incipient guttering | | **34** | **15** | 3 | 2 | **21** | **17** |
| 2 | Straight | Asian | 12 | 5 | 5 | 3 | 5 | 4 |
| 3 | Partial sill | European | 52 | 22 | 11 | 7 | 39 | 32 |
| 4 | Sill | | 43 | 18 | 126 | 80 | 23 | 19 |

**Table 4.1** continued.

| Interorbital breadth | | | Black | | White | | Coloured | |
|---|---|---|---|---|---|---|---|---|
| | | | n=237 | % | n=158 | % | n=125 | % |
| 1 | Narrow | European | 7 | 3 | **58** | **37** | 9 | 7 |
| 2 | Intermediate | Asian | **131** | **55** | **81** | **51** | **82** | **66** |
| 3 | Wide | African | **99** | **42** | 19 | 12 | **34** | **27** |
| Zygomatic projection | | | Black | | White | | Coloured | |
| | | | n = 219 | % | n=149 | % | n=119 | % |
| 1 | Retreating | Eur/African | **189** | **86** | **135** | **91** | **87** | **73** |
| 2 | Projection | Asian | 31 | 14 | 14 | 9 | **32** | **27** |
| Alveolar prognathism | | | Black | | White | | Coloured | |
| | | | n=187 | % | n=113 | % | n=86 | % |
| 1 | Orthognathic | Eur/Asian | 81 | 43 | 98 | 87 | 53 | 62 |
| 2 | Prognathic | African | **106** | **57** | 15 | 13 | 33 | 38 |

*Numbers in bold are mentioned in the text.

**Table 4.2** Frequency distribution of zygomatic suture shape palatine suture shape in three South African groups.

| **Non-metric Trait** | | | **Ancestry groups** | | | | | |
|---|---|---|---|---|---|---|---|---|
| Zygomatic suture shape | | | Black | | White | | Coloured | |
| | | | n=188 | % | n=131 | % | n=99 | % |
| 1 | Angled | African | **41** | **22** | **65** | **49** | **24** | **24** |
| 2 | Smooth | Asian | **143** | **76** | **65** | **49** | **72** | **73** |
| 3 | S-shaped | European | 4 | 2 | 1 | 2 | 3 | 3 |
| Transverse palatine suture shape | | | Black | | Whites | | Coloured | |
| | | | n=196 | % | n=130 | % | n=93 | % |
| 0 | Straight | | 32 | 16 | 23 | 18 | 17 | 18 |
| 1 | Ant bulging | | 15 | 8 | 9 | 7 | 9 | 10 |
| 2 | Scalaris | | 99 | 50 | 66 | 50 | 45 | 48 |
| 3 | Posterior symmetrical | | 50 | 26 | 32 | 25 | 22 | 24 |

*Numbers in bold are mentioned in the text.

**Table 4.3** Frequency distribution of the malar tubercle in three South African groups.

| **Non-metric trait** | | | **Ancestry groups** | | | | | |
|---|---|---|---|---|---|---|---|---|
| Malar tubercle | | | Black | | White | | Coloured | |
| | | | n=214 | % | n=139 | % | n=111 | % |
| 0 | Absent | African | 80 | 37 | **111** | **80** | 39 | 35 |
| 1 | Incipient | Asian | **119** | **56** | **25** | **18** | **61** | **55** |
| 2 | Trace | European | 5 | 2 | 0 | 0 | 7 | 6 |
| 3 | Present | | 10 | 5 | 3 | 2 | 4 | 4 |

*Numbers in bold are mentioned in the text.

**Table 4.4** Frequency distribution of the palatine, and mandibular tori in three South African groups.

| **Non-metric trait** | | | **Ancestry groups** | | | | | |
|---|---|---|---|---|---|---|---|---|
| Palatine torus | | | Black | | White | | Coloured | |
| | | | n=230 | % | n=158 | % | n=122 | % |
| 0 | Absent | Eur/Afr | **170** | **74** | **91** | **58** | **84** | **69** |
| 1 | Present | Asian | **60** | **26** | **67** | **42** | **37** | **30** |
| Mandibular torus | | | Black | | White | | Coloured | |
| | | | n=223 | % | n=156 | % | n=107 | % |
| 0 | Absent | Eur/Afr | **209** | **94** | **137** | **88** | **101** | **94** |
| 1 | Present | Asian | 14 | 6% | 19 | 12% | 6 | 6% |

*Numbers in bold are mentioned in the text.

**Table 4.5** The frequency distribution of incisor shovelling (maxilla) and the presence of Carabelli's cusp in the maxillary first molars of three South African groups.

| **Non-metric trait** | **Ancestry groups** | | | | | |
|---|---|---|---|---|---|---|
| Incisor shovelling | Black | | White | | Coloured | |
| | n | % | n | % | n | % |
| Right upper incisor 1 | 24 | 46 | 9 | 22 | 26 | 62 |
| Left upper incisor 1 | **23** | **46** | **11** | **29** | **24** | **63** |
| Right upper incisor 2 | **31** | **47** | **13** | **32** | **33** | **69** |
| Left upper incisor 2 | **34** | **48** | **12** | **28** | **30** | **54** |
| Incisor shovelling | Black | | White | | Coloured | |
| | n | % | n | % | n | % |
| Right lower incisor 1 | 11 | 11 | 2 | 2 | 4 | 10 |
| Left lower incisor 1 | **12** | **13** | **2** | **2** | **4** | **10** |
| Right lower incisor 2 | **12** | **11** | **2** | **2** | **8** | **15** |
| Left lower incisor 2 | **13** | **11** | **2** | **2** | **10** | **19** |
| Carabelli's cusp | Black | | White | | Coloured | |
| | n | % | n | % | n | % |
| Upper right molar 1 | 14 | 8 | 11 | 16 | 5 | 6 |
| Upper left molar 1 | **12** | **7** | **15** | **25** | **8** | **11** |

*Numbers in bold are mentioned in the text.

**Table 4.6** Summary of ordinal regression results for eight non-metric traits associated with ancestry in three South African groups.

| **Trait analyzed** | **Ancestry** | **Sig.** | **Sex** | **Age** | **Sex*Ancestry** | **Sig.** |
|---|---|---|---|---|---|---|
| Nasal bone structure | Black<br>Coloured | **0.000**<br>**0.000** | n.s. | n.s. | Female*Black<br>Female*Coloured | **0.043**<br>**0.039** |
| Nasal breadth | Black<br>Coloured | **0.000**<br>**0.000** | n.s. | n.s. | Female*Black<br>Female*Coloured | **0.049**<br>**0.042** |
| Nasal overgrowth | Black<br>Coloured | **0.004**<br>**0.001** | n.s. | n.s. | n.s. | n.s. |
| Anterior nasal spine | Black<br>Coloured | **0.000**<br>**0.000** | n.s. | **0.035** | n.s. | n.s. |
| Inferior nasal margin | Black<br>Coloured | **0.000**<br>**0.000** | n.s | n.s. | n.s. | n.s. |
| Interorbital breadth | Black<br>Coloured | **0.000**<br>**0.001** | **0.005** F | n.s. | Female*Black<br>Female*Coloured | **0.003**<br>**0.009** |
| Zygomatic projection | Coloured | **0.021** | n.s. | n.s | n.s. | n.s |
| Alveolar prognathism | Black<br>Coloured | **0.000**<br>**0.003** | n.s. | **0.000** | n.s | n.s. |

Statistically significant p-values indicated in bold (p<0.05).

Sig. = Significance

F = Female

n.s. = Not Significant

**Table 4.7** Ordinal regression parameter estimates for nasal bone structure.

| Independent variables | Estimate | Std.Error | Wald | df | Sig | 95% Lower bound | 95% Upper bound |
|---|---|---|---|---|---|---|---|
| Sex=F | -0.149 | 0.334 | 0.201 | 1 | 0.654 | -0.803 | 0.505 |
| Sex=M | $0^a$ | . | . | 0 | . | . | . |
| Ancestry=Black | -3.395 | 0.356 | 91.125 | 1 | **0.000** | -4.092 | -2.698 |
| Ancestry=Coloured | -1.114 | 0.390 | 69.156 | 1 | **0.000** | -4.008 | -2.479 |
| Ancestry=White | $0^a$ | . | . | 0 | **.** | . | . |
| Sex=F*ancestry=Black | -0.925 | 0.456 | 4.108 | 1 | **0.043** | -1.819 | -0.030 |
| Sex=F* ancestry=Coloured | -1.114 | 0.539 | 4.278 | 1 | **0.039** | -2.170 | -0.058 |
| Sex=F*ancestry=White | $0^a$ | . | . | 0 | . | . | . |
| Sex=M*ancestry=Black | $0^a$ | . | . | 0 | . | . | . |
| Sex=M* ancestry=Coloured | $0^a$ | . | . | 0 | . | . | . |
| Sex=M*ancestry=White | $0^a$ | . | . | 0 | . | . | . |
| Age | 0.001 | 0.006 | 0.044 | 1 | 0.834 | -0.011 | 0.014 |

[a.] This parameter is set to zero because it is redundant. Numbers in bold are statistically significant ($p<0.05$).

**Table 4.8** Cross tabulation for the interaction between sex and ancestry for nasal bone structure.

| **Nasal bone structure** | **Sex** | **Ancestry** | | | **Total** |
|---|---|---|---|---|---|
| | | Black | Coloured | White | |
| 0-Quonset-hut | F | **48** | **21** | 3 | 72 |
| | M | 32 | 16 | 2 | 50 |
| | Total | 80 | 37 | 5 | 122 |
| 1-Oval | F | **21** | **7** | 1 | 29 |
| | M | **42** | **27** | 3 | 72 |
| | Total | 63 | 34 | 4 | 101 |
| 2-Tented | F | **5** | **5** | 15 | 25 |
| | M | **23** | **10** | 10 | 43 |
| | Total | 28 | 15 | 25 | 68 |
| 3-Vaulted | F | 4 | 1 | 18 | 23 |
| | M | 3 | 4 | 29 | 36 |
| | Total | 7 | 5 | 47 | 59 |
| 4-Steepled | F | 2 | 0 | 23 | 25 |
| | M | 3 | 4 | 25 | 32 |
| | Total | 5 | 4 | 48 | 57 |

*Numbers in bold are mentioned in the text.

**Table 4.9** Cross tabulation for the interaction between sex and ancestry for nasal breadth.

| **Nasal breadth** | **Sex** | **Ancestry** | | | **Total** |
|---|---|---|---|---|---|
| | | Black | White | Coloured | |
| 1-Narrow | F | 1 | 1 | 34 | 36 |
| | M | 0 | 4 | 29 | 33 |
| | Total | 1 | 5 | 63 | 69 |
| 2-Intermediate | F | **80** | **34** | **35** | 149 |
| | M | **120** | **78** | **49** | 247 |
| | Total | 200 | 112 | 84 | 396 |
| 3-Wide | F | 14 | 3 | 0 | 17 |
| | M | 14 | 2 | 1 | 17 |
| | Total | 28 | 5 | 1 | 34 |

*Numbers in bold are mentioned in the text.

**Table 4.10** Cross tabulation for the interaction between sex and ancestry in interorbital breadth.

| **Interorbital breadth** | **Sex** | **Ancestry** | | | **Total** |
|---|---|---|---|---|---|
| | | Black | White | Coloured | |
| 1-Narrow | F | 2 | 32 | 3 | 37 |
| | M | 5 | 26 | 6 | 37 |
| | Total | 7 | 58 | 9 | 74 |
| 2-Intermediate | F | 52 | 33 | 22 | 107 |
| | M | 79 | 48 | 60 | 187 |
| | Total | 131 | 81 | 82 | 294 |
| 3-Wide | F | 46 | 4 | 14 | 64 |
| | M | 53 | 15 | 20 | 88 |
| | Total | 99 | 19 | 34 | 152 |

**Table 4.11** Cross tabulation for the effect of sex on interorbital breadth.

| **Interorbital breadth** | **Sex** | | **Total** |
|---|---|---|---|
| | F | M | |
| 1-Narrow | 37 | 37 | 74 |
| 2-Intermediate | 107 | 187 | 294 |
| 3-Wide | 64 | 88 | 152 |
| Total | 208 | 312 | 520 |

**Table 4.12** Cross tabulation for the effect of age on the anterior nasal spine.

| **Anterior nasal spine** | **Mean age in years** | **N** | **Standard deviation** |
|---|---|---|---|
| 0-Short | 50.37 | 143 | 14.781 |
| 1-Dull | 47.16 | 121 | 16.731 |
| 2-Medium | 48.40 | 101 | 17.942 |
| 3-Long | 60.97 | 105 | 15.170 |
| Total | 51.49 | 470 | 16.878 |

**Table 4.13** Summary of ordinal regression results for zygomatic suture shape, malar tubercle, mandibular and palatine tori.

| Trait | Ancestry | Sig. | Sex | Age | Sex*Ancestry |
|---|---|---|---|---|---|
| Zygomatic suture shape | Black | **0.000** | n.s | n.s | n.s. |
| | Coloured | **0.000** | | | |
| Malar tubercle | Black | **0.000** | **n.s.** | n.s. | n.s. |
| | Coloured | **0.000** | | | |
| Mandibular torus | Black | **0.007** | n.s. | n.s. | n.s. |
| | Coloured | **0.033** | | | |
| Palatine torus | Black | **0.000** | n.s. | **0.060** | n.s. |
| | Coloured | **0.003** | | | |

Statistically significant p-values indicated in bold.

**Table 4.14** Summary of ordinal regression results for dental features associated with ancestry.

| Incisor shovelling | Ancestry | Sig. | Sex | Age | Sex*Ancestry |
|---|---|---|---|---|---|
| Right upper incisor 1 | coloured | **0.020** | 0.025 f | 0.019 | n.s. |
| Left upper incisor 1 | n.s. | | 0.017 f | 0.004 | n.s. |
| Right upper incisor 2 | n.s. | | 0.049 f | 0.001 | n.s. |
| Left upper incisor 2 | n.s. | | 0.070 f | 0.011 | n.s. |

Statistically significant p-values indicated in bold.

**Table 4.15** Summary of ordinal regression results for dental features associated with ancestry.

| Carabelli's cusp | Ancestry | Sig. | Sex | Age | Sex*Ancestry |
|---|---|---|---|---|---|
| Upper right molar 1 | Black | **0.002** | n.s. | **0.013** | n.s. |
| | Coloured | **0.025** | n.s. | n.s. | n.s. |
| Upper left molar 1 | Black | **0.000** | n.s. | **0.015** | n.s. |
| | Coloured | **0.017** | n.s. | n.s. | n.s. |

Statistically significant p-values indicated in bold.

**Table 4.16** Cross tabulation for the effect of age at death on Carabelli's cusp.

| Carabelli's cusp | Mean age (years) | N | Std. Deviation |
|---|---|---|---|
| Upper right molar 1 | | | |
| 0-Absent | 47.83 | 271 | 16.076 |
| 1-Present | 41.73 | 26 | 17.458 |
| 4-Unobservable | 31.00 | 1 | - |
| Total | 47.24 | 298 | 16.262 |

**Table 4.17** Cross tabulation for the effect of age at death on Carabelli's cusp.

| Carabelli's cusp | Mean age (years) | N | Std. Deviation |
|---|---|---|---|
| Upper left molar 1 | | | |
| 0-Absent | 47.68 | 255 | 15.933 |
| 1-Present | 43.87 | 31 | 17.046 |
| 4-Unobservable | 31.00 | 1 | - |
| Total | 47.24 | 298 | 16.262 |

**Table 4.18** Summary of the kappa statistic results from 15 non-metric traits.

| **Trait** | **Observer agreement** | **Symmetry p-value** | **Agreement %** | **Kappa** | **Agreement** |
|---|---|---|---|---|---|
| Nasal bone structure | Intra | 0.1718 | 83.00 | 0.7436 | Substantial |
| | Inter- | 0.0611 | 70.00 | 0.5369 | Moderate |
| Nasal breadth | Intra | 0.3679 | 83.00 | 0.6835 | Substantial |
| | Inter | **0.0111** | 70.00 | 0.5603 | Moderate |
| Nasal overgrowth | Intra | 0.3114 | 83.00 | 0.7409 | Substantial |
| | Inter | 0.2615 | 80.00 | 0.6809 | Substantial |
| Anterior nasal spine | Intra | 0.2615 | 87.00 | 0.8086 | Substantial |
| | Inter | **0.0293** | 70.00 | 0.5500 | Moderate |
| Inferior nasal margin | Intra | **0.0302** | 77.00 | 0.5808 | Moderate |
| | Inter | 0.1116 | 79.31 | 0.6525 | Substantial |
| Interorbital breadth | Intra | **0.0302** | 70.00 | 0.5337 | Moderate |
| | Inter | 0.0821 | 63.33 | 0.4388 | Moderate |
| Zygomatic suture shape | Intra | 0.4615 | 63.00 | 0.3855 | Fair |
| | Inter | **0.0203** | 50.00 | 0.1071 | Slight |
| Zygomatic projection | Intra | 0.1353 | 86.00 | 0.5522 | Moderate |
| | Inter | 0.0821 | 83.00 | 0.2500 | Fair |
| Malar tubercle | Intra | 0.2636 | 73.00 | 0.5294 | Moderate |
| | Inter | **0.0404** | 67.00 | 0.4361 | Moderate |
| Alveolar prognathism | Intra | **0.0090** | 50.00 | 0.2475 | Fair |
| | Inter | **0.0186** | 66.00 | 0.5106 | Moderate |
| Mandibular torus | Intra | 0.2466 | 80.00 | 0.1628 | Slight |
| | Inter | 0.1599 | 76.00 | -0.0769 | Less than chance |
| Palatine torus | Intra | **0.0001** | 36.00 | 0.0625 | Slight |
| | Inter | **0.0002** | 43.00 | 0.1146 | Slight |
| Transverse palatine suture shape | Intra | 0.3916 | 63.00 | 0.3762 | Fair |
| | Inter | **0.0533** | 60.00 | 0.3782 | Fair |

**Table 4.18** continued.

| | | | | | |
|---|---|---|---|---|---|
| Incisor shovelling | Intra | 0.0719 | 76.00 | 0.6023 | Moderate |
| | Inter | 0.0752 | 66.00 | 0.4783 | Moderate |
| Carabelli's cusp | Intra | **0.0356** | 60.00 | 0.2123 | Fair |
| | Inter | 0.2615 | 80.00 | 0.6995 | Substantial |

Statistically significant p-values indicated in bold.

# Chapter 5: Discussion

The expertise of a forensic anthropologist is to assist in the identification of unknown skeletal remains from forensic related situations, such as crime scenes or mass disasters (Gill, 1998; Kennedy, 1995; Klepinger, 2006; Ousley et al., 2009; Rhine, 1990). The process involves the construction of a biological profile of the unidentified person in which existing peer-reviewed standards on estimating sex, age at death, ancestry, and stature from the cranial and postcranial skeleton are applied and the results compared to possible missing individuals (İşcan and Steyn, 1999; Klepinger, 2006; Krogman and İşcan, 1986; Ousley et al., 2009). The estimation of ancestry is accomplished through observing morphological variation of the skull and mandible or through measurements of the cranial and post cranial skeleton. However, early studies of morphological variables often encouraged the use of these features because they do not require expensive laboratory equipment and can easily applied (Gill, 1998). In recent years, researchers realized that predicting ancestry using non-metric traits is not straightforward and in that its successes rely upon experience and an exceptional understanding of human variation (Hefner, 2009). New perspectives in the field suggest that there is no longer a place for intuitive, untestable, an unempirical research (Hefner, 2009). In the United States of America and Canada, the Daubert and Mohan criteria regarding expert testimony demand that scientists ensure their methodology is accurate, precise, testable and peer reviewed (Dirkmaat et al., 2008). While these laws do not apply to South Africa, they serve as a valuable guideline for the testing of previous North American methodology and its applicability in African courts of law.

For more than a century, anthropologists have explained the origin and diversification of humans with a typological system of classification (Gill, 1998; Hefner, 2009; Rhine, 1990). One result of this limited view of human diversity, which enjoyed great popularity and acceptance throughout many parts of the world, was slavery, human exploitation, and an era of science that had strongly opposed the notion of race, or biological race (Caspari, 2009). The application of non-metric variables as a tool for explaining ancestral variation in human populations has always had its roots in typology and therefore has often been criticised (Klepinger, 2006). For this reason, many scholars staunchly support the view that to predict ancestry from these traits is merely an excuse to practise racism, while others have avoided the topic altogether (Ĭşcan and Steyn, 1999; Klepinger 2006). A predicament forensic anthropologists often face is when law enforcement expects them to provide a racial classification of an individual, such as black, white, or coloured, for the purpose of identification; yet law enforcement and the public at large present with little understanding of both the scope of human variation within and between populations and the difficulty, if not impossibility, in differentiating an ethic identity, such as a black South African (Gill, 1998; Klepinger, 2006).

The outcome of this study has implications for the practical application of these non-metric variables used to estimate ancestry among South African forensic anthropologists. In order to assess the variation of these traits found in South African groups and the relationship of these traits with ancestry, frequency distributions were calculated and ordinal regression was employed. Reliability testing was also performed in an attempt to assess the precision in the scoring of these character states within and between observers.

Several issues warrant attention before interpreting the results of this study. The main objective of this project was to assess the general efficacy of non-metric variables on South African groups. One way of accomplishing this was to test the methods at hand but by using a South African documented sample. As would be expected the present study has resulted in lower accuracy rates than previous investigations. One of the most common explanations for this type of disagreement is population variability which would automatically prompt the development of regionally specific standards (Komar and Grivas, 2008). Other sources of variation have also been suggested and include intra- and interobserver reliability errors, bias in sampling methods whilst founding documented collections, bone remodelling due to aging and secular change, and the fact that these traits may not be strongly associated with ancestry (Komar and Grivas, 2008).

Standard discrete trait analyses have been developed on skeletal remains from North America and were not expected to perform well on other population groups (Rhine, 1990). Although these traits have been tested on various groups, including East and West Africans, Japanese, Chinese, and North Americans amongst others, it has not been tested on South African skeletal remains. Yet, in South Africa anthropologists frequently use these traits to estimate the ancestry of unknown remains. Although it may be interpreted that the populations in the United States are different from the descended population in South Africa, the effect of other influencing factors such as secular trends has not been considered.

As a means to place the aim of this study and the results within a contextual framework, the problems associated with the anthropological methodology on ancestry estimation and the skeletal samples from which the techniques are derived are discussed. Non-metric analysis of cranial variables has a complex and controversial history embedded in the field of physical anthropology. The history and development of these traits as well as the controversy which surrounded their use were reviewed in Chapter 2 (p.21-27). The major advocators who used and misused these variables in anthropological research need to be highlighted.

During the 1990's Stanley Rhine produced an infamous paper on the estimation of ancestry from skeletal remains entitled "Non-metric Skull Racing". Most articles, textbooks, or publications dealing with discrete trait analysis or ancestry determination include reference to the suite of character states which Rhine considered useful for differentiating "American Caucasoid", South Western Mongoloid", and "American blacks" (Hefner, 2003; Rhine 1990). However, the list of the variables that Rhine discussed would be problematic in that the distribution of the traits only represented a fraction of the variability seen among all humans. This was because his sample was derived from material only encountered in the South Western United States (Hefner, 2003). Unfortunately many scholars subsequently produced research based on the same set of variables used by Rhine and in which they did not consider the provenience of the material which unequivocally would have affected a broader population sample. In addition to this problem, not limited solely to Rhine's study, are the relatively small sample sizes in the research. Rhine suggested that his sample of "Caucasoids" (n=68), "Africans" (n=7) and "Mongoloids" (n=12) reflect(ed) the demography of New Mexico, and only represented a very small fragment of the continuum of variability for any given population (Hefner, 2003; Rhine 1990). The sample sizes that are used to study human variability play an important role in developing discriminating criteria and should therefore be of sufficient size. Bearing this criterion in mind it does not suggest that Rhine's (1990) study is of no value. In fact, to the contrary, Rhine's study should be regarded as a template for future research. However, researchers who pursue and replicate his findings should include the aforementioned limitations of his study in their own study designs. Many scholars are of the opinion that these traits, and the population groups to which they are associated, cannot be simply exported and applied to other populations, or continents without considerable testing as to their efficacy (Hefner, 2003).

The character states, which Rhine used in his analyses, are indistinguishable from those created by Hooton (Hefner, 2009). Like many academics, Hooton established an "oral tradition" with his students. Oral traditions can cause significant challenges when they become widely accepted, and subsequently passed down academic generations without scientifically validating and quantifying them with new, and larger, samples (Hefner, 2003). In addition to accepting the accuracy and precision of these traits without empirical testing, these early researchers did not perceive the three groups, African, European or Asian, to overlap in their frequency distributions (Ousley et al., 2009). Any overlap was automatically seen as admixture between the groups, and was not considered a normal variant of variation within that population. High levels of variation in the frequency distribution of these traits within a population have been seen as a reason for abandoning their use altogether (Kennedy, 1995). However, this has not been well accepted amongst forensic anthropologists who are requested to compile a profile of the missing individual. Within this profile, a reliable estimation of ancestry, particularly in a heterogeneous group such as South Africa, can be useful in making a presumptive identification; likewise, an incorrect evaluation of ancestry can lead to a delay in criminal procedures.

In the mid-twentieth century, researchers (Hanihara and Ishida, 2001e; Komar and Grivas, 2008) began to propose that differences in trait frequency distributions may be attributed to the variability found within the population. For example, many methods for estimating sex, age at death, ancestry and stature have been developed from skeletal remains in the United States and have not performed particularly well on skeletal series from other countries (Komar and Grivas, 2008). In a study on American blacks Stewart (1979) revealed that these individuals tended to portray skeletal features more similar to the stereotypic white than black Americans. He suggested that the forensic anthropologist must rely on his experience in deciding which ancestral background a particular skeleton is likely to have belonged. Therefore, the idea of variability within a population was known, but the manner in which to deal with it was not approached until recently.

Brace (1990) in his discussion on the use of race terminology in anthropological research, was the first to mentioned that the traits used to evaluate ancestry were manufactured in America and could thus not be exported to other countries. He also emphasized that these types of inquiries in ancestry have a practical use in forensics, but that scientists should focus on assessing broad geographic, or ancestral groups, and not socially defined populations. The problem with this is that the social and biological views of race are often intertwined, such that an analysis of one has implications for the other. The question then arises as to whether these traits are associated with ancestry, and if they are, can these traits be repeated with precision, or in other words, are they reliable. To elaborate on this question, the data obtained from this study were subjected to ordinal regression and kappa statistics.

Ordinal regression analysis revealed that all the variables with the exception of three of the upper incisor teeth (see Table 4.14, Chapter 4:90) were influenced by ancestry. The primary function of this statistical analysis was to permit the researcher to identify whether the variable was influenced by ancestry, sex or age at death. However, this type of analysis does not explain the extent to which the independent variables influenced the trait. Ordinal regression has been shown to be more useful in conjunction with other methods such as frequency data and reliability analysis in estimating ancestry (Hefner, 2009). Three traits (nasal bone structure, nasal breadth and inter-orbital breadth) were influenced by the interactions between sex and ancestry. Additionally, these also happen to be the traits most commonly used to exclude one population group from another (Rhine, 1990; Stewart, 1979). In South Africa, the observation of a “narrow” or “intermediate” nasal breadth is often used to exclude an individual from African ancestry. However, the interaction between sex and ancestry for nasal breadth has shown that an “intermediate” nasal aperture was more likely to be expressed among black and coloured males, than in black and coloured females. De Villiers (1968) found nasal breadth to be statistically significantly influenced by sex, where males, in general, had greater apertures than females (t=4.724). Therefore, this trait is clearly affected by more than ancestral variation alone, and thus the person’s sex needs to be considered before this trait can be reliably applied in future multi-variate statistical analyses.

Similarly, black and coloured males also had a greater prevalence of “intermediate” and “wide” inter-orbital breadth more frequently than the females of these groups. With regard to nasal bone structure, black and coloured males were more likely to display “oval” and “tented” nasal shapes, which are traditionally associated with Asian and European groups, whereas black and coloured females often exhibited the traditional “hut” shapes of African groups. With a statistically significant influence of sex on these traits, they may be less reliable to use on unknown material unless the sex of the person is known, or reliably estimated from other areas of the skeletons such as the pelvis, humeral or femoral head (Krogman and Ĭşcan, 1986). In essence, using these three variables, one cannot discuss the possibilities of ancestry without having knowledge, or presumed knowledge of sex.

The length of the anterior nasal spine, the absence/presence of alveolar prognathism and Carabelli’s cusp were shown to be associated with age at death. If the mean age of the individuals in each scoring division is considered, it can be seen that an increase in spine length is correlated with an increase in age. The characteristic short spines of Africans have a mean age of 50.37 years, while the long spines of Europeans have a mean age of 60.97 years. The same discrepancies were found in that orthognathic profiles were most often found at 54.6 years, while that of prognathic faces was 43.6 years. For Carabelli’s cusp it appears that the presence of the trait is associated with a lower mean age (47 years) while its absence is correlated with a higher mean age (41.73 years for the right upper first molar and 43.87 years for the left upper first molar). Many studies in the literature have focussed on different factors affecting the frequency distributions of discrete traits (Berry, 1975; Corruccini, 1974) and one of the influential factors described is that of mechanical deformation. One possible explanation for the differential length in the nasal spine is age at death. An aged person is more likely to be edentulous, in which the spine of the nose appears to have increased in length. This is to be expected such that with an increase in age, the alveolar bone undergoes resorption and remodelling of the bone takes place. Poor dental care and dental loss and wear can also be associated with an increase in age, and can therefore cause reduced forms of Carabelli's cusps.

In previous decades, many scholars often assumed that non-metric traits were easy to replicate (Corruccini, 1974), but in later years, it was found that poor definitions were more likely the norm than the exception (Hefner, 2009). The use of reliability testing, such as kappa statistics as used in this study, permits the researcher to identify those traits that have shown consistency among observers. Nevertheless, these results should be integrated and viewed together with the results from the frequency distributions as well as the ordinal regression analysis. Despite previous claims of poor interpretation of character states (Page, 1976), some of the traits assessed in this study demonstrated moderate to substantial within and between observer reliability and include nasal bone structure, nasal breadth, nasal overgrowth, anterior nasal spine, inferior nasal margin, interorbital breadth, malar tubercle, and incisor shovelling (Chapter 4:94). Several variables including alveolar prognathism, zygomatic suture shape, mandibular and palatine tori, transverse palatine suture shape and Carabelli's cusp were statistically lower in agreement than the other traits. Possible explanations for disagreement among researchers include difficulty in scoring traits in older individuals and/or and difficulty in assessing those traits with a present or absent classification system. While Brues (1990) suggested that a "present"/ "absent" system to discrete analysis can reduce observer error rates, it does not seem to have been the case in this study. Perhaps a large amount of information is lost in the "present"/ "absent" scale and could in fact misrepresent the actual variation in different groups.

Interobserver analysis demonstrated moderate reliability when the kappa values for the majority of the traits were taken into consideration, again indicating that these traits could be reliably scored. However, zygomatic projection (k=2500), mandibular (k=-0.0769) and palatine (k=1146) tori and the transverse palatine suture shape (k=0.3782) were significantly lower than the other traits.

Viera and Garrett, (2005) have suggested that a more accurate way of interpreting the reliability would be to include the p-value for each trait. The current study has shown that several traits (nasal breadth, anterior nasal spine, inferior nasal margin and inter-orbital breadth) demonstrated moderate to high levels of agreement but also revealed statistically significant p-values. The variables that demonstrated lower levels of agreement with statistical significant p-values included zygomatic suture shape, mandibular and palatine tori, and Carabelli's cusp. The p-value is an indication that although the observers could reliably score the trait, they were more likely to select the categories differently. This point is important because it would seem as if the majority of the traits show scoring consistency within and among observers. However, if the observers do not have the same tendency to select the same categories irrespective of their agreement the trait may not be as reliable. The most likely explanation for this type of discrepancy amongst observers is that the trait definitions are not clearly understood and interpreted.

## 5.2. Comparison of frequency distributions with North American studies.

The frequency distributions within this study were compared with two North American groups, Hefner (2003) and Rhine (1990), so as to better explain the pattern of variation within South Africans. These distributions can be found in Table 5.1. Much research has focused on the heritability of polygenic traits as indicators of ancestry; however the exact mechanisms involved in this process remain uncertain (Hauser and De Stefano, 1989). This has contributed to the mistrust of many scholars who feel that to quantify data is to conduct science while to evaluate it is merely experimental and produces unreliable results (Rhine, 1990). In addition to simply evaluating and comparing the prevalence of these traits among different groups the current study has also fitted an ordinal regression model to the data. The results from these tests were incorporated into the discussion tables and are indicated in bold (see Table 5.1). The ordinal regression has demonstrated that the majority of the traits were in fact influenced by the ancestry of a person but also by other factors such as sex, age at death, and the interaction between the sex and ancestry.

One of the most challenging aspects when comparing a set of discrete traits between studies is the extent to which these traits have been standardized. The definition of the trait is always a difficult matter. For example, it is an arduous task to decide at what point along a continuum of variation the shape of the nasal bone structure, for instance, becomes "tented" rather than "oval" or "rounded". Although the literature (Hefner, 2003) suggests that many of the difficulties have been overcome with clear and well defined definitions and illustrations, there exist areas of uncertainty. One of the advantages of comparing the results of this study to that of Hefner's (2003) is the fact that both studies made use of the same definitions and thus allowed for a better evaluation of the reliability of these traits.

Several traits from the South African sample, including nasal bone structure, nasal breadth, nasal overgrowth, anterior nasal spine, inferior nasal margin, inter-orbital breadth, zygomatic projection and alveolar prognathism, showed considerable overlap among the three main ancestral groups and, in most instances, were most similar to the frequency patterns of Hefner's (2003) and most dissimilar to those of Rhine (1990). Since it is unlikely that the population groups presented within the South African sample have a genetic relationship with those of Hefner (2003), it is perhaps prudent to say that these character states, while they have been shown to have an association with ancestry, are far more variable in their distribution across socially defined population groups, such as white, black and coloured, in South Africa. Furthermore, the institution of Apartheid in 1948 led to the social and physical division of these groups that would have caused limited gene flow amongst these populations. Thus, the variation observed within these modern groups is more likely due to variation within the populations, themselves, and less likely to be affected by direct mixture between groups in the last 50 years (Hefner, 2009). In essence, this study deviates from the traditional typological opinion of ancestral classification in which a person has traits which are only found within their group.

### 5.2.1. Black South Africans

In Table 5.1, the black South African sample expressed the highest frequencies of the quonset-hut (round) contour 44% (n=80/183); yet this trait was found in appreciable frequencies among coloureds, 39% (n=37/95), and whites 4% (5/129). The result for nasal bone structure can be compared to that of Hefner (2003) who found that individuals of African (East and West Africa) descent exhibited the characteristic African nasal bone contour in 59% of his sample (Hefner, 2003). Even though this trait did not obtain extremely high frequencies within the expected ancestral category it may prove valuable in distinguishing between local groups. This is particularly true when compared with white South Africans, who were most similar to their traditional prescribed groups for nasal bone structure such that 92% of them classified with European categories for tented (n=26/129; 20%), vaulted (n=47/129; 36%) and steepled (n=48/129; 37%) trait forms.

Similar patterns in trait frequencies were observed for nasal and interorbital breadth among South Africans and are in contrast to distribution patterns found among North

American groups. The majority of the South African sample was classified with nasal apertures (12% for blacks; 56% for whites, and 92% for coloureds) and inter-orbital distances (n=55% for blacks; 51% for whites and 66% for coloureds) of “intermediate” shape, which is slightly different to Hefner’s sample of American blacks in which the nasal aperture widths and interorbital distances seemed to have had a better association with the traditional African ancestry (see Table 5.1). A possible explanation for these differences, apart from arguing that South Africans are highly heterogenous and would not necessarily exhibit the extreme typical characteristics in the three main ancestral groups, would be to suggest that the trait unjustly represents the variation present within the population. For example if an observer is to classify an individual based on their nasal aperture width and is allowed to select a shape from a choice of an extremely “narrow” aperture, an “intermediate” distance and an extremely “wide” aperture, there is a likelihood that the individual may not portray the extreme forms (“narrow” or “wide”) of the trait. Thus, from a range of only three adjectives used to describe the most anticipated forms of variation in nasal aperture width, the “intermediate” shape of the variable would seem the most suitable.

The results for nasal breadth in itself and in comparison to those of De Villiers (1968) and Hefner (2003) suggest that the application of this variable is not as effective among South African groups in that it shows a great amount of overlap, whilst kappa analysis propose it to be less reliable than once presumed. A possible rectification of this problem would be omit this non-metric trait and substitute it with metric analysis.

Black South Africans portrayed higher incidences (65%) for the absence of nasal overgrowth, a feature typically associated with European and African groups. The result from the present study is similar to that of Hefner (2003) who found this form of the trait to be absent (n=117/180) 65% in individuals from East and West Africa. De Villiers (1968) described and assessed the growth of the anterior nasal bones in a series of black South Africans including the Natal Nguni, Cape Nguni, Sotho, and the Shangaan-Tsonga. Frequency distributions were recorded for normal growth, undergrowth, overgrowth as well as lateral overgrowth. Normal growth of the nasal bones occurred most commonly in black South Africans (65% of males and 67% in females), followed by undergrowth (25% of males, and 25% of females). Both forms of the overgrowth were uncommon, lateral overgrowth occurring slightly more frequently (7% for males and 5% for females) than anterior growth (3% for males, and 3% for females) (De Villiers, 1968). Therefore, the comparison of the current result for the presence or absence of nasal overgrowth is consistent with other results obtained from individuals of South Africa (De Villiers, 1968), as well as East and West

Africa (Hefner, 2003). The higher frequencies in the absence of nasal overgrowth in black South Africans may prove to be an accurate method for distinguishing black individuals from white and coloured South Africans.

For the varying lengths of the anterior nasal spine the frequency distributions were similar to the pattern observed for Hefner's sample (2003). In addition the results of the anterior nasal spine were also compared to De Villiers' morphologic study (1968) on the trait in which she found a similar distribution pattern among various black South African groups. Black South Africans present with the highest incidence (42%) of short anterior nasal spines, but there is an overlap of its frequencies with dull typical Asian (34%) and moderately and well-developed spines (24%) previously associated persons from the continent of Europe. The results from a morphological study on South African blacks (De Villiers, 1968) revealed that the anterior nasal spine may be absent (short), slight (dull) or moderate (medium) in development. In 58% of males and 55% of the females, the nasal spine showed a slight degree of development, while 28% of males and 30% of females presented with no spine. Moderate development of the spine was uncommon and occurred only in 13.5% of the males and 14.5% of female crania, while marked development which characterizes European spines did not occur. The results from De Villiers's study are consistent with the degrees of development of the spine observed in the present study. De Villiers (1968) also noted that an absent (short) or slightly developed (dull) spine is usually associated with a broad (platyrrhine) nasal aperture, while a moderate spine with a relatively narrow (meso- or leptorrhine apertures) aperture. This relationship between the degree of development of the spine and the relative breadth of the nose has been suggested as traits that are associated during the developmental stages. According to De Villiers, the higher incidence of absent or slight anterior spines should be consistent in South African blacks, since they are characteristically platyrrhine. However, this is not the case in the present study since the nasal breadth of black South Africans lends itself towards an "intermediate" shape distance and not to the "wide" characteristic apertures. From the same study De Villiers (1968) metrically assessed nasal breadth frequencies of various black South Africans. The study found that South African blacks not only presented with very broad nasal apertures but also with very narrow apertures and that males in general had greater apertures than females. This variation forms evidence in favour of the theory that there is more within group than between group variation.

Black individuals in the South African sample show higher frequencies of the characteristic guttered (n=93/234; 40%) and incipient guttered (n=34/234; 15%) margins of the inferior portion of the nose. This result is analogous to that of Hefner (2003) who found similar trait frequencies (68%) in black individuals from his sample of East and West Africans. This group also portrayed higher frequencies for retreating zygomatic bones (n=189/219; 86%) which is consistent with traditional associations with African decent (Gill, 1998). However, retreating zygomatic bones are also a characteristic feature of European groups. Thus, it is possible that this trait can either indicate African or European origin and because of this duality may not function as a suitable tool for indicating divergence between the aforementioned groups.

The anticipated outcome for alveolar prognathism was met with the vast majority of black and coloured South Africans who exhibited this feature, while whites were mainly orthognathic. Although Rhine (1990) compared frequencies of alveolar prognathism among the traditional ancestral groups, the sample size was too small to make any valuable comparisons. Instead, a visual study on the contour of alveolar prognathism of Brooks and France (1990) can be used to assess prognathism. From their sample of 113 Indian and Asian individuals, 71 American blacks and Sudanese Numbians, and 49 American whites, the authors found varying forms of prognathism in all the groups, except for the American whites. However, Brooks and France (1990) found a significant number (20%) of American black maxilla that were more similar to the American white profile with little or no prognathism. Again, this demonstrated a large amount of within group variation.

Black individuals in the South African sample expressed high frequencies, (n=143/188; 76%) for the prevalence of the characteristic Asian zygomatic suture shape, while there were only 22% (n=41) of individuals that were classified as having the typical African suture shape. In contrast to this result, it could be seen that from the distribution of the East and West African blacks (Hefner, 2003), the individuals expressed a form of variation usually found in Europeans. Based on the discordance in the distribution patterns in the black African groups from both studies, it seem as if the suture is less effective, and compromised in that neither the first nor the second samples expressed the anticipated angled form of the suture.

The prevalence of the palatine and mandibular tori appears to be highly variable in material of various origins (Barbujani et al., 1986). Comparing the range of variation between groups is compromised in the sense that many studies provide percentages for the incidence of the trait in a population group but not necessarily the number of individuals that were used to calculate that percentage. However, there are numerous studies on the occurrence of these variables among groups. Published results for the palatine torus range from 0.19% in Queckchi Indians from Guatemala, 10% in British skulls, 19% (n=43/227) for African skulls, 20% in American blacks, 29% in American whites, 56% (n=128/229) in Peruvian skulls, to 66% in Eskimos (Barbujani et al., 1986; Berry and Berry, 1967; Woo, 1950). As far as African studies are concerned the range of variation for the palatine torus is similar to that of Rightmire (1972) who found this feature to be less frequently occurring (3 to 10%) among East African (Rwanda, and Rundi) and South African (Zulu, Xhosa, Sotho, and Venda) individuals. Previous studies on the mandibular torus in black South Africans include the work of Shaw (1931), De Villiers (1968) and Rightmire (1972) who found its distribution variably different from global studies which indicated the trait in almost all populations studied (Ihunwo and Phukubye, 2006). A recent study of Ihunwo and Phukubye (2006) found the torus to be present in 24% of a well defined black South African sample. The present study indicated that black individuals from South Africa exhibit extremely low frequencies (6%) of the mandibular torus.

The incidence of incisor shovelling has been recorded primarily among Asian populations; however, black South Africans have expressed patterns of shovelling in both the upper, (46 to 46%) and lower (11 to 13%) incisor teeth. Trait frequency studies on the distribution of shovelling among different groups are scarce, and it is therefore difficult to comparatively analyze the outcome of this trait in the present study. However, a reference can be made to the study of Hinkes (1990) in which it was concluded that 44% to 45% (n=281/618; n=442/618) of American black males and females respectively, were found to have some form of shovelling of their incisor teeth. There are an increasing number of studies which have shown that the incidence of shovelling is not exclusively associated with groups from Asia (Hefner, 2003).

### 5.2.2. White South Africans

The results for the trait frequency distributions of white South Africans are difficult to interpret, mainly because the samples to which these results were compared to was either small or separated in time and space.

Persons of European ancestry had high frequencies (n=106/122; 87%) for the absence of nasal overgrowth, a trait formerly associated with Europeans and Africans. The results for nasal overgrowth were similar to those frequencies obtained from the morphological study of Hefner (2003) in which he found that (n=98/167; 59%) of Europeans failed to show any form of overgrowth of the nasal bones. The distribution of nasal overgrowth among individuals of European origin from both the aforementioned studies expressed an overlap of frequencies. The fact that white individuals portrayed variation normally associated with Europeans does not qualify the trait as an effective tool for distinguishing between groups, in that Africans and Asians also displayed the same type of distribution.

In Europeans, the inferior margin of the nose is characterized by a sharp edge. A large percentage (87%) of white South Africans have demonstrated partial (n=11/157; 7%) and complete nasal sills (n=126/157; 80%). A similar outcome has been observed for American whites who displayed these two forms of the nasal margin in 74% of a sampled population (Hefner, 2003). Black and coloured South Africans demonstrated the European form of the trait infrequently, which resulted in less overlap among the three main ancestral groups. If the amount of overlap in trait frequencies is reduced among the three main ancestral groups, it might be possible to attribute a particular form of the trait, such as a sharper nasal sill, more effectively to the white population (Hefner, 2009).

Ninety one percent (n=135/149) of white South Africans presented with non-projecting zygomatic bones (Gill, 1998). Retreating zygomatics, like many other non-metric traits shares this form not only with Europeans but also with Africans (Gill, 1998). Although the frequency distribution is a good indication of the trait's association with a specific ancestral group, a black (86%) and coloured (73%) individual may also present with this form of the trait which therefore downplays its effectiveness as a distinguishing factor between groups.

The frequency distribution of alveolar prognathism among the three main ancestral groups has shown that white South Africans are not prognathic, but express flat facial profiles (n=98/113; 87%) in a large majority of the group's members. Based on the results from this trait we can infer that an unidentified individual presenting with an orthognathic profile is more likely to be of European decent, although the possibility of African and Asian origins may not be excluded.

Many scholars have described the incidence and shape of the palatine torus in different population groups (Gill, 1998). Gill, (1998), has explained the trait as an exostosis, while Woo, (1950) has regarded it as an anatomical variation or defect. Axelsson and Hedegaard, (1985) have examined the effect of environmental, sex and age influences on the prevalence of the trait, and found it to be affected by age and population group, but not by sex. From the analysis of the ordinal regression results it became evident that the palatine torus was statistically significantly influenced by age at death. Because the torus is associated with age at death, it is unlikely to be a good ancestry trait.

The local white population has shown the palatine torus to be absent in more than half (n=91/158; 59%) of the individuals, yet it appears in (n=67/158; 42%) of the same sample. Regardless of whether the majority of the white sample infrequently displayed the palatine torus, there is still a considerable amount of overlap of frequencies, especially among individuals of African origin, and this overlap therefore reduces the trait's effectiveness as an ancestral marker for a particular group.

The mandibular torus has been frequently noted in the Eskimos, Lapps, Ostiaks and Icelanders, whereas it only occurred sporadically in Europeans and American Indians (Drennan, 1929). The mandibles of Africans, Australians and Melanesian were found not to exhibit the torus (Drennan, 1929). In the present study, the expected outcome for the mandibular torus was met, in that whites expressed the presence of the trait 12% (n=19/156) irregularly. Based on the frequency distribution of skeletal variants in the mandibular torus, the trait proved to be a valuable indicator of ancestral affinity. However, it should be kept in mind that the absence of the trait is also associated with individuals of African origin, and it will therefore be less efficient when confronted with unidentified skeletal material.

Apart from black South Africans that portrayed varying degrees of shovel-shaped incisors, white South Africans also presented with patterns of shovelling in the maxilla (22 to 28%), and 2% the mandible. Hinkes, (1990) found that the spade-like appearance of the distal surface of the incisor teeth was more often observed in the maxillary incisors than in the mandibular teeth. Hinkes (1990) also noted that whites rarely revealed pronounced or semi-shovelled incisors, but most often showed a trace of shovelling or complete absence of the trait. The results from the current study are consistent with what previous scholars have found with regard to the frequency to which shovelling occurred in European groups. However, this should be viewed as tentatively due to the small number of upper and lateral incisors available for analysis in this group.

### 5.2.3. Coloured South Africans

The frequency distributions among the set of traits observed from the current study in coloured individuals are of particular interest. The skeletal profile of black and white South Africans is to some extent expected to imitate the features that are associated with the traditional African, Asian, and European ancestral categories. Some character states that traditionally associated with Asian descent are more commonly found in coloureds than in black and white South Africans. This is because the group originated as a mixture between the Asian slave populations and the Dutch settlers from Europe, who arrived in the Cape during the 17th to 18th centuries. The term "coloured" was created during the early Cape colonial period, and was employed as a social construct by the public, and the government as a means to identify this group of "admixed" people. Despite the controversy that surrounds meaning and implication of the term, it remains in use in the present day.

Problems arose with the coloured group in that they presented with the greatest variability in character states, such that they expressed the highest frequencies of the quonset-hut nasal bone contour (n=37/95; 39%), as well as typical Asian (n=34/95; 36%) and to a lesser extent European (n=24/95; 25%) nasal bone characteristics. These results are distinct from those seen in North American samples, and may reflect the social emphasis of this group, which unlike white and black, is associated with a restriction of gene flow based on social parameters. However, it can be inferred that the variance in the nasal bone contours of coloured individuals exhibits characteristics of African, Asian as well as European groups, and is therefore disqualified as a valuable tool in forensic identification.

Coloured individuals displayed a high prevalence of rounded (n=112/122; 92%) or intermediate nasal aperture widths. Rhine (1990) and Klepinger (2006) have described this form of the trait as typical for populations from an Asian background. The higher incidence of this trait in the coloured sample is a good indication of its relative effectiveness as a measure of its association with Asian population groups. However, higher frequency distributions for the width of the nasal aperture are also found in South African blacks and whites. Therefore, when the forensic anthropologist examines the nasal aperture width of a skull of an unidentified deceased person and finds the aperture to be rounded or intermediate in breadth, the diagnostic power of this trait becomes diminished, based on its poor separation from the other groups. As mentioned previously, it may be best to measure this trait metrically, and to apply multi-variate statistics (Hefner, 2003).

From the distribution of nasal overgrowth, the coloured group has demonstrated a higher incidence (n=39/78; 50%) of the variable than either blacks (n=60/171; 35%), whites (n=16/122; 13%) or any of the ancestry groups from both the studies of Rhine (1990) and Hefner (2003) (see Table 5.1). In fact, the Indian (0%) and Asian (n=19/70; 27%) groups were assumed to more accurately represent characteristics inherent of Asian descent, but have failed to portray the feature in both of the North American studies. Instead, the trait was found more frequently among the European groups. The results obtained from non-metric traits such as nasal overgrowth show that while no clear separation is evident between the groups in question, some inferences can still be made with respect to the general direction these traits seem to follow (see Table 5.1). These differences my imply that these non-metric traits are amenable to multi-variate analyses.

The situation for interorbital breadth is similar to that of the inferior nasal margin and nasal aperture, in that the amount of overlap among the three South African groups is substantial. Coloured persons presented with elevated frequencies (n=82/125; 66%) for the intermediate distance between the two orbital spaces of the skull. While the intermediate trait form was more prominent among Asians, the wide African character state was encountered in (n=34/125; 27%) of the sample. Thus, although higher frequencies were obtained for the more common intermediate shape distance, the coloured group expressed considerable overlap of its frequencies among the three main ancestral groups, and therefore this trait might not be as useful in indicating ancestral affinity in a forensic context.

Individuals of colour were categorized as having nasal spines correlated with African (n=50/118; 43%), Asian (n=45/118; 38%), as well as European (n=23/118; 19%) origins. The result for the short spine in coloureds is similar to the blacks (n=97/233; 42%) from the same study.

Non-projecting zygomatic bones are more commonly observed in coloureds (n=32/119; 27%). This type of trait manifestation is usually encountered in persons of African or European origin, while Asians portray the more projecting form of the trait. This trait is rather difficult to interpret because the frequencies for protrusion and the lack thereof are distributed among the coloureds as well as among the blacks 86% (189/219) and whites 91% (135/149). The most general conclusive element of this trait is only that South African black, white and coloured persons do not exhibit zygomatic projection in a convincing fashion and should therefore not be considered as a tool for distinguishing between South African groups.

From the frequency distributions of the set of traits evaluated from the present study, it became evident that coloureds were more likely to display flat (orthognathic) European (n=53/86; 62%) facial profiles, and typical African zygomatic suture shapes (n=72/99; 72%). Additionally, coloured individuals exhibited almost 50% (n=45/93) for the typical European scalaris form of the zygomatic suture trait. The remaining frequencies are distributed among posterior symmetrical shape (n=22/93; 24%), the straight suture (n=17/93; 18%) and the African anteriorly bulging shape (n=9/93; 10%). The greatest overlap of frequencies for the transverse palatine suture shape is found in the European form of the trait, followed by a trait manifestation not associated with any ancestral group. Also, coloured persons also exhibited higher frequencies (n=61/111) 55% for the traditional incipient (Asian) form of the malar tubercle. However, as seen with many of the variables, blacks 56% (n=119/214) were also classified with the typical Asian form of the malar tubercle. In contrast to what would be expected, the coloured group did not perform particularly well in portraying both the palatine (n=30/122; 30%) and mandibular (n=6/107; 6%) tori, and revealed increased incidences for the absence of both these features. The incidence for Carabelli's cusp was poorly represented by the coloured group, such that the trait could only be found in 6% of the upper right molar, and in 11% of the upper left molar. Coloured individuals have provided evidence for the presence of shovel-shaped incisors in 54% and 69% for the upper teeth, and between 10% and 19% for the lower teeth. These figures are greater in coloureds than in both blacks, and whites, and are in agreement with the classical Asian form with which this trait is normally associated.

In summary, the examination of a larger cranial sample size permits the researcher to appreciate a more comprehensive view on the distribution of variance among a particular population group. From the results it became evident that morphological variability was more prominent from within the framework of a population than it was between groups (Ousley et al., 2009). This study was in strong agreement with that of Hefner (2003, 2009) who made similar conclusions from his studies, in that there was greater morphological variability within a particular group of people. For this reason, further application of morphological prediction of ancestry is strongly opposed. Future research should subject this methodology to more rigorous statistical evaluation, including multi-variate, ordinal and Baysesian analysis (Hefner, 2009). These steps are imperative in order to more accurately determine whether a person that presents with certain presumed morphological characteristics belongs to a specific group. Analysis of ordinal regression statistics has shown that the some variables were associated with the sex, and the interaction between sex and presumed ancestry of a person. Interobserver reliability indicated that some traits could be scored consistently among observers, while other traits were not reliable on this level analysis.

**Table 5.1** Comparison of frequency distributions of non-metric traits using North American and South African cranial sample.

| Trait | Nasal bone structure | | | | | | | | | | | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ancestral group | | African | | Asian | | European | | | | | | |
| Trait form | | Quonset | | Oval | | Tented | | Vaulted | | Steepled | | |
| | N | n | % | n | % | n | % | n | % | n | % | |
| **Black* (African)** | 183 | 80 | **44** | 63 | **34** | 28 | **15** | 7 | **4** | 5 | **3** | Current study |
| White (European) | 129 | 5 | **5** | 4 | **3** | 25 | **19** | 47 | **36** | 48 | **37** | |
| **Coloured*** | 95 | 37 | **39** | 34 | **36** | 15 | **16** | 5 | **5** | 4 | **4** | |
| African | 75 | 106 | **59** | 29 | **16** | 18 | **10** | 18 | **10** | 9 | **5** | Hefner (2003) |
| European | 184 | 8 | **4** | 28 | **15** | 33 | **18** | 52 | **28** | 63 | **34** | |
| Asian | 180 | 17 | **23** | 18 | **24** | 30 | **40** | 9 | **12** | 1 | **1** | |
| African | 3 | 1 | **33** | | | 2 | **67** | | | 2 | **67** | Rhine (1990) |
| European | 68 | 3 | **17** | | | 24 | **35** | | | 31 | **46** | |
| Indian | 3 | 1 | **33** | | | 2 | **66** | | | 0 | **0** | |

| Trait | Nasal breadth | | | | | | | Reference |
|---|---|---|---|---|---|---|---|---|
| Ancestral group | | African | | Asian | | European | | |
| Trait form | | Wide | | Intermediate (rounded) | | Narrow(long) | | |
| | N | n | % | n | % | n | % | |
| **Black *(African)** | 229 | 28 | **12** | 200 | **87** | 1 | **0.4** | Current study |
| White (European) | 148 | 1 | **1** | 84 | **56** | 63 | **43** | |
| **Coloured*** | 122 | 5 | **4** | 112 | **92** | 5 | **4** | |
| African | 180 | 107 | **59** | 66 | **37** | 7 | **4** | Hefner (2003) |
| European | 184 | 15 | **8** | 66 | **36** | 103 | **56** | |
| Asian | 75 | 8 | **11** | 66 | **88** | 1 | **1.3** | |
| African | 7 | 2 | **67** | 2 | **67** | 4 | **6** | Rhine (1990) |
| European | 68 | 0 | **0** | 0 | **0** | 26 | **38** | |
| Indian | 12 | 1 | **33** | 1 | **33** | 31 | **46** | |

**Table 5.1** continued.

| Trait | | Nasal overgrowth | | | | Reference |
|---|---|---|---|---|---|---|
| Ancestral group | | African/European | | Asian | | |
| Trait form | | Absent | | Present | | |
| | N | n | % | n | % | |
| **Black *(African)** | 171 | 111 | **65** | 60 | **35** | Current study |
| White (European) | 122 | 106 | **87** | 16 | **13** | |
| **Coloured*** | 78 | 39 | **50** | 39 | **50** | |
| African | 168 | 117 | **70** | 51 | **30** | Hefner (2003) |
| European | 167 | 98 | **59** | 69 | **41** | |
| Asian | 70 | 51 | **73** | 19 | **27** | |
| African | 7 | 7 | **100** | 0 | **0** | Rhine (1990) |
| European | 68 | 58 | **85** | 10 | **15** | |
| Indian | 12 | 12 | **100** | 0 | **0** | |

| Trait | | Anterior nasal spine | | | | | | | | Reference |
|---|---|---|---|---|---|---|---|---|---|---|
| Ancestral group | | African | | Asian | | European | | | | |
| Trait form | | Short (small) | | Dull | | Medium (Moderate) | | Long (large) | | |
| | N | n | % | n | % | n | % | n | % | |
| **Black *(African)** | 233 | 97 | **42** | 79 | **34** | 47 | **20** | 10 | **4** | Current study |
| White (European) | 149 | 11 | **7** | 8 | **5** | 39 | **26** | 91 | **61** | |
| **Coloured*** | 118 | 50 | **43** | **45** | **38** | 17 | **14** | 6 | **5** | |
| African | 176 | 43 | **24** | 98 | **56** | 23 | **13** | 12 | **7** | Hefner (2003) |
| European | 168 | 14 | **8** | 58 | **35** | 48 | **28.5** | 48 | **28.5** | |
| Asian | 75 | 26 | **35** | 34 | **45** | 10 | **13** | 5 | **7** | |
| African | 3 | 2 | **67** | | | | | 1 | **33** | Rhine (1990) |
| European | 68 | 36 | **53** | | | | | 20 | **29** | |
| Indian | 3 | 2 | **67** | | | | | 1 | **33** | |
| Black (African) | 1398 | 627 | **45** | | | 190 | 14 | | | De Villiers (1968) |

**Table 5.1** continued.

| Trait | Inferior nasal margin | | | | | | | | | | | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ancestral group | | African | | | | Asian | | European | | | | |
| Trait form | | Guttered | | Incipient Guttering | | Straight/ Blurred | | Partial sill/ Shallow | | Sill/ Deep | | |
| | N | n | % | n | % | n | % | n | % | n | % | |
| **Black *(African)** | 234 | 93 | **40** | 34 | **15** | 12 | **5** | 52 | **22** | 43 | **18** | Current study |
| White (European) | 157 | 12 | **8** | 3 | **2** | 5 | **3** | 11 | **7** | 126 | **80** | |
| **Coloured*** | 122 | 34 | **28** | 21 | **17** | **5** | **4** | 39 | **32** | 23 | **19** | |
| African | 180 | 64 | **36** | 59 | **33** | 33 | **18** | 18 | **10** | 6 | **3** | Hefner (2003) |
| European | 184 | 1 | **0.5** | 6 | **3** | 41 | **22** | 76 | **41** | 60 | **33** | |
| Asian | 75 | 9 | **12** | 13 | **17** | 48 | **64** | 3 | **4** | 2 | **3** | |
| African | 3 | 1 | **33** | | | 1 | **33** | 1 | **33** | 0 | **0** | Rhine (1990) |
| European | 68 | 1 | **1** | | | 17 | **25** | 35 | **51** | 8 | **12** | |
| Indian | 3 | 0 | **0** | | | 3 | **100** | 0 | **0** | 0 | **0** | |

| Trait | Interorbital breadth | | | | | | | Reference |
|---|---|---|---|---|---|---|---|---|
| Ancestral group | | African | | Asian | | European | | |
| Trait form | | Wide | | Intermediate | | narrow | | |
| | N | n | % | n | % | n | % | |
| **Black *(African)** | 237 | 99 | **42** | 131 | **55** | 7 | **3** | Current study |
| White (European) | 158 | 19 | **12** | 81 | **51** | 58 | **37** | |
| **Coloured*** | 125 | 34 | **27** | 82 | **66** | 9 | **7** | |
| African | 180 | 101 | **56** | 60 | **33** | 19 | **11** | Hefner (2003) |
| European | 184 | 8 | **4** | 122 | **66** | 54 | **29** | |
| Asian | 75 | 5 | **7** | 39 | **62** | 31 | **41** | |

| Trait | Zygomatic projection | | | | | Reference |
|---|---|---|---|---|---|---|
| Ancestral group | | African/European | | Asian | | |
| Trait form | | Retreating | | Projecting | | |
| | N | n | % | n | % | |
| **Black *(African)** | 219 | 189 | **86** | 31 | **14** | Current study |
| White (European) | 149 | 135 | **91** | 14 | **9** | |
| **Coloured*** | 119 | 87 | **73** | 32 | **27** | |

**Table 5.1** continued.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| African | 3 | 0 | **0** | | | 3 | **100** | Rhine (1990) |
| European | 68 | 17 | **25** | | | 14 | **21** | |
| Asian (Indian) | 3 | 2 | **67** | | | 1 | **33** | |
| Trait | | | | Alveolar prognathism | | | | Reference |
| Ancestral group | | African | | | | Asian/European | | |
| Trait form | | Projecting<br>(Slight-moderate) | | | | Orthognathic (none) | | |
| | N | n | % | | | n | % | |
| **Black *(African)** | 187 | 106 | **57** | | | 81 | **43** | Current study |
| White (European) | 113 | 15 | **13** | | | 98 | **87** | |
| **Coloured*** | 86 | 33 | **38** | | | 53 | **62** | |
| African | 1 | 1 | **100** | | | 0 | **0** | Rhine (1990) |
| European | 68 | 21 | **31** | | | 12 | **18** | |
| Asian | 2 | 2 | **100** | | | 0 | **0** | |
| Trait | | | | Zygomatic suture shape | | | | Reference |
| Ancestral group | | African | | Asian | | European | | |
| Trait form | | Angled<br>(Curved) | | Smooth<br>(Angled) | | S-shaped<br>(Curved) | | |
| | N | n | % | n | % | n | % | |
| **Black* (African)** | 237 | 41 | **22** | 143 | **76** | 4 | **2** | Current study |
| White (European) | 185 | 65 | **49** | 65 | **49** | 1 | **2** | |
| **Coloured*** | 125 | 24 | **24** | 72 | **73** | 3 | **3** | |
| African | 156 | 9 | **6** | 57 | **37** | 90 | **57** | Hefner (2003) |
| European | 151 | 3 | **2** | 73 | **48** | 75 | **50** | |
| Asian | 63 | 4 | **7** | 21 | **33** | 38 | **60** | |
| African | 6 | 4 | **67** | 2 | **33** | | | Rhine (1990) |
| European | 68 | | | 15 | **22** | 49 | **72** | |
| Indian | 12 | 8 | **67** | 4 | **33** | | | |

**Table 5.1** continued.

| Trait | Transverse palatine suture shape | | | | | | | | | Reference |
|---|---|---|---|---|---|---|---|---|---|---|
| Ancestral group | | African | | Asian | | European | | | | |
| Trait form | | Anterior bulging | | Straight | | Posterior bulging | | Scalaris | | |
| | N | n | % | n | % | n | % | n | % | |
| **Black *(African)** | 196 | 15 | **8** | 32 | **16** | 50 | **26** | 99 | **50** | Current study |
| White (European) | 130 | 9 | **7** | 23 | **18** | 32 | **25** | 66 | **50** | |
| **Coloured*** | 93 | 9 | **10** | 17 | **18** | 22 | **24** | 45 | **48** | |
| African | 180 | 84 | **46** | 32 | **18** | 18 | **10** | 46 | **26** | Hefner (2003) |
| European | 184 | 44 | **24** | 57 | **31** | 19 | **10** | 64 | **39** | |
| Asian | 75 | 25 | **33** | 34 | **45** | 5 | **7** | 11 | **15** | |
| Trait | Malar tubercle | | | | | | | | | Reference |
| Ancestral group | | Afr/Eur | | Asian | | | | | | |
| Trait form | | Absent | | Incipient | | Trace | | Present | | |
| | N | n | % | n | % | n | % | n | % | |
| **Black *(African)** | 214 | 80 | **37** | 119 | **56** | 5 | **2** | 10 | **5** | Current study |
| White (European) | 139 | 111 | **80** | 25 | **18** | 0 | **0** | 3 | **2** | |
| **Coloured*** | 111 | 39 | **35** | 61 | **55** | 7 | **6** | 4 | **4** | |
| African | 180 | 87 | **48** | 51 | 28 | 26 | **14** | 16 | **9** | Hefner (2003) |
| European | 184 | 93 | **51** | 59 | 32 | 25 | **14** | 7 | **3** | |
| Asian | 75 | 32 | **43** | 25 | 33 | 10 | **13** | 8 | **11** | |
| African | 3 | | | | | | | 3 | **100** | Rhine (1990) |
| European | 68 | | | | | | | 27 | **40** | |
| Indian | 3 | | | | | | | 2 | **67** | |
| Trait | Palatine torus | | | | | | | | | Reference |
| Ancestral groups | | African/European | | | | Asian | | | | |
| Trait form | | Absent | | | | Present | | | | |
| | N | n | % | | | n | % | | | |
| **Black *(African)** | 230 | 170 | **74** | | | 60 | **26** | | | Current study |
| White (European) | 158 | 91 | **58** | | | 67 | **42** | | | |
| **Coloured*** | 122 | 84 | **69** | | | **37** | **30** | | | |
| African | | | | | | 0 | **0** | | | Rhine (1990) |

|  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|
| European |  |  |  | 10 | **15** |  |
| Asian |  |  |  | 0 | **0** |  |
| African | 56 | 0 | **0** | 0 | **0** | Berry and Berry (1967) |
| Indian (Amerindian) | 50 | 0 | **0** | 1 | **2** |  |

| Trait | Mandibular torus |  |  |  |  | Reference |
|---|---|---|---|---|---|---|
| Ancestral group |  | African/European |  | Asian |  |  |
| Trait form |  | Absent |  | Present |  |  |
|  | N | n | % | n | % |  |
| **Black *(African)** | 223 | 209 | **94** | 14 | **6** | Current study |
| White (European) | 156 | 137 | **88** | 19 | **12** |  |
| **Coloured*** | 107 | 101 | **94** | 6 | **6** |  |
| African | 3 | 3 | **100** | 0 | **0** | Rhine (1990) |
| European | 68 | 61 | **90** | 7 | **10** |  |
| Asian | 3 | 2 | **66** | 1 | **33** |  |
| Black South African (African) | 246 |  |  | 60 | **24** | Ihunwo and Phukubye (2006) |

| Trait | Incisor shovelling |  |  |  |  |  |  |  | Reference |
|---|---|---|---|---|---|---|---|---|---|
| Ancestral group | Shovelling (per tooth) (Asian) |  |  |  |  |  |  |  |  |
| Tooth | RUI 1 |  | LUI 1 |  | RUI 2 |  | LUI 2 |  |  |
|  | n | % | n | % | n | % | n | % |  |
| **Black *(African)** | 24 | **46** | 23 | **46** | 31 | **47** | 34 | **48** | Current study |
| White (European) | 9 | **22** | 11 | **29** | 13 | **32** | 12 | **28** |  |
| **Coloured*** | 26 | **62** | 24 | **63** | 33 | **69** | 30 | **54** |  |
|  | RLI 1 |  | LLI 1 |  | RLI 2 |  | LLI 2 |  |  |
|  | n | % | n | % | n | % | n | % |  |
| **Black * (African)** | **11** | **11** | **12** | **13** | **12** | **11** | **13** | **11** |  |
| White (European) | **2** | **2** | **2** | **2** | **2** | **2** | **2** | **2** |  |
| **Coloured** | **4** | **10** | **4** | **10** | **8** | **15** | **10** | **19** |  |

**Table 5.1** continued.

| | **N** | M/F | Shovelling (Asian)<br>Combined frequencies including trace, semi-shovelled and shovel-shaped incisors<br>(per individual) | | | | |
|---|---|---|---|---|---|---|---|
| | | | n | % | | | **Reference** |
| American black (African) | 618 | M | 281 | **45** | | | Hinkes (1990) |
| | 1000 | F | 442 | **44** | | | |
| American white (European) | 1000 | M | 335 | **34** | | | |
| | 1000 | F | 296 | **30** | | | |
| Chinese (Asian) | 1094 | M | 994 | **91** | | | |
| | 208 | F | 201 | **97** | | | |
| Trait | | | Shovelling (Asian) | | | | |
| | | | **n** | % | | | |
| African | 3 | | 0 | **0** | | | Rhine (1990) |
| European | 68 | | 11 | **16** | | | |
| Asian | 3 | | 3 | **100** | | | |
| Trait | Carabelli's cusp | | | | | | Reference |
| | Present (European) | | | | | | |
| | Upper right molar 1 | | | | Upper left molar 1 | | |
| | n | | | % | n | % | |
| **Black *(African)** | 14 | | | **8** | 12 | **7** | Current study |
| White (European) | 11 | | | **16** | 15 | **25** | |
| **Coloured*** | 5 | | | **6** | 8 | **11** | |
| African | | | | | | | Rhine (1990) |
| European | | | | | | | |
| Asian | | | | | | | |

1. South Africa: skeletal collections from UP, WITS, UCT, US and UFS

2. North America:Terry Collection, Maxwell museum, New Mexico, Washington D.C, USA

3. North America: Maxwell Museum, New Mexico, USA

# Chapter 6: Conclusion

The forensic anthropologist and the law enforcement official often employ discrete trait analysis on crania from unknown human remains in an attempt to explain the skeletal features of that person that are associated with a particular population group (Gill, 1998). The concept of biological human races was established more than a century ago, and is according to many scholars deeply rooted in racial discrimination (Montagu, 1964). Anthropologists originally formulated descriptions on morphological features in an attempt to construct skeletal profiles that could assist them in classifying North American population groups. At the outset, these scholars were of opinion that subtle differences within human crania could only be described morphologically and were not fit to be quantified.

The fact that discrete traits are visually determined, and require no expensive laboratory apparatus was some of the reasons why anthropologists chose to employ this method in the identification of human remains. Over the last few decades, researchers have become increasingly aware of the apparent advantages inherent in the visual assessment of discrete traits. However, it is in the apparent benefit of the visual evaluation that some of the most challenging problems arise when dealing with the morphological variability among groups. Experiential knowledge and a fundamental understanding of human variation play a determining role in the effectiveness with which forensic anthropologists attribute ancestral differences to various population groups.

This study focused on the evaluation of non-metric traits used to estimate ancestry on a South African skeletal sample. This project's main focus was to evaluate the frequency distribution of these discrete traits among three commonly designated South African groups and to evaluate their statistical relationship with other variables such as sex and age at death. In essence, the research focused on attributing these traits to ancestry. The results of this study have shown considerable overlap of trait frequencies as well as lower frequency ranges than what would be expected. This overlap causes an ambiguity that makes the attribution of ancestry one of the most difficult assessments to make during osteological analysis. The body of evidence considered in this study reveal that the whole concept and interpretation of ancestry prove to be a much more complex and controversial aspect to physical anthropological studies than any of the other aspects of the biological profile (İşcan and Steyn, 1999). The question as to whether this set of non-metric traits has shown an association with ancestry was confirmed through ordinal regression analyses. The majority of the variables have shown to be reliable; however, several contributing factors including standardization of definitions still hamper the efficacy of these traits.

Another problem with discrete trait analysis included the application and repeatability of the definition of the character states and the interpretation of the frequency distributions. As mentioned above, many anthropology researchers and students have accepted the distribution of these traits to be associated with human variation within these three traditional “race” groups. This typological approach did not offer any overlap among the groups, such that when certain traits were found in the wrong group, for example a wide nasal breath within a European person, it was attributed to admixture. The current anthropological perspective on race, or biological race, permits a more lenient explanation of population variation and implies that overlap of these traits are present within all population groups, but the degree of this overlap may vary to such an extent that it is possible to provide a probability of one person belonging to one group or another (Ousley et al., 2009). While these statistical analyses are beyond the scope of this study, the modern view of population variation serves as an explanation for what has been observed in the distribution of these traits. This does not suggest that one cannot determine ancestry, but only that ancestral determination of non-metric or metric data need to be based on statistical analyses (Ousley et al., 2009; Hefner, 2009). Further research in this area is planned, as this study has shown that the traits are, however loosely, associated with ancestry and that they are repeatable.

This study established some basic statistical information as to the general behaviour of these variables among three South African population groups. The next step would be to assess the correlation of these traits with each, other as well as their accuracy for use within a court of law.

# Chapter 7: References

Angel, J & Kelley, L 1990, 'Inversion of the posterior edge of the jaw ramus: new race trait', in GW Gill & S Rhine (eds), Skeletal attribution of race: methods for forensic anthropology, Maxwell Museum of Anthropological Papers No. 4, Albuquerque NM, University of New Mexico.

Axellson, G & Hedegaard, B 1985, 'Torus palatinus in Icelandic school children', *American Journal of Physical Anthropology*, vol. 67, pp. 105-112.

Banerjee, M, Capozzoli, M, McSweeny, Sinha, D 1999, 'Beyond kappa: a review of interrater agreement measures', *The Canadian Journal of Statistics*, vol. 27, pp. 3-23.

Barbujani, G, Rolo, M, Barrai, I, Cisternas, JP 1986, 'Torus palatinus: a segregation analysis', *Human Heredity*, vol. 35, pp. 317-325.

Bass, WM 1987, *Human osteology: a laboratory and field manual*, MK Trimble, (ed.), Missouri Archaeological Society, Columbia.

Bass, WM 1995, 'Race estimation', in *Human osteology: a laboratory field manual*, 4th edn, Missouri Archaeological Society, Columbia.

Berry, AC 1974b, 'The use of non-metrical variation of the cranium in the study of Scandinavian population movements', *American Journal of Physical Anthropology*, vol. 40, pp. 345-358.

Berry, AC 1975, 'Factors affecting the incidence of non metrical skeletal variants', *Journal of Anatomy*, vol. 120, pp. 519-535.

Berry, RJ 1963, 'Epigenetic polymorphism in wild populations of mus musculus', *Genetic Research*, vol. 4, pp.193-220.

Berry, RJ & Berry, AC 1967, 'Epigenetic variation in the human cranium', *Journal of Anatomy*, vol. 101, pp. 361-379.

Brace, CL, Hunt, KD 1990, 'A nonracial craniofacial perspective on human variation', *American Journal of Physical Anthropology*, vol. 82, pp. 341-360.

Brasili, P, Gualdi-Russo, E, Zaccagni, L 1989, 'Discontinuous traits of the skull variation on sex, age, laterality', *Anthropologischer Anzeiger*, vol. 47, pp. 239-250.

Brasili, P, Gualdi-Russo, E, Zaccangi, L 1999, 'Scoring of non-metric cranial traits: a population study', *Journal of Anatomy*, vol. 195, pp. 551-562.

Brothwell, DR 1958, 'The use of non-metrical characters of the skull in differentiating populations', Dt. Ges. Anthrop, vol. 6, pp. 103-109.

Brues, AM 1972, 'Models of race and cline', *American Journal of Physical Anthropology*, vol. 37, pp. 389-399.

Brues, AM 1990, 'The once and future diagnosis of race' in GW Gill & S Rhine (eds), *Skeletal attribution of race: methods for forensic anthropology,* Maxwell Museum of Anthropological Papers No. 4, Albuquerque NM, University of New Mexico.

Caspari, R 2003, 'From types to populations: a century of race, physical anthropology, and the American Anthropological Association', *American Anthropologist*, vol. 105, pp. 65-76.

Caspari, R 2009, '1918: Three perspectives on race and human evolution', *American Journal of Physical Anthropology*, vol. 139, pp. 5-15.

Corruccini, RS 1974, 'An examination of the meaning of cranial discrete traits for human skeletal biological studies', *American Journal of Physical Anthropology*, vol. 40, pp. 425-446.

Darwin, C 1871/1874, '*The descent of man'*, 2nd edn, London, John Murray.

Dayal, MR, Kegley, ADT, Štrkalj, G, Bidmos, MA, & Kuykendall, KL 2009, 'The history and composition of the Raymond A. Dart Collection of human skeletons at the University of the Witwatersrand, Johannesburg, South Africa', *American Journal of Physical Anthropology*, vol. 00, pp. 000-000.

De Villiers, H 1968, 'Introduction', in The *skull of the South Africa Negro: a biometrical and morphological study*, Johannesburg. Witwatersrand University press.

Dirkmaat, DC, Cabo, LL, Ousley, SD, & Symes, SA 2008, 'New perspectives in forensic anthropology', *Yearbook of Physical Anthropology*, vol. 51, pp. 33-52.

Drennan, MR 1929, 'Recent discoveries bearing on human history in Southern Africa', *The Journal of the Royal Anthropological institute of Great Britain and Ireland.*

Edgar, HJH 2005, 'Prediction of race using characteristics of dental morphology', *Journal of Forensic Science*, vol. 50, pp. 269-273.

Edgar, HJH, Hunley, KL 2009, 'Race reconciled?: how biological anthropologists view human variation', *American Journal of Physical Anthropology*, vol. 139, pp. 1-4.

Finnegan, M 1972, 'The use of non metric and forensic identification', Paper presented at the 29th annual meeting of the *American Academy of Forensic Sciences*, San Diego, California.

Finnegan, M, McGuire, SA 1979, 'Classification systems for discrete variables in forensic anthropology', *American Journal of Physical Anthropology*, vol. 51, pp. 547-554.

Finnegan, M, Marcsik, A 1980, 'Anomaly of pathology: the stafne defect as seen in archaeological materials and modern clinical practice', *Journal of Human Evolution*, vol. 9, no.1, pp. 19-31.

Finnegan, M, Rubison, RM 1984, 'Multivariate distances and multivariate classification systems using non-metric traits in biological studies', in GN Van Vark, & WW Howells, (eds), *Multivariate statistical methods in physical anthropology*, Reidel Publishing Company, Dordrecht Holland.

Galton, F 1892, '*Finger Prints*', Macmillan, London.

Giles, E, Elliot, O 1962, 'Race identification from cranial measurements', *Journal of Forensic Science*, vol. 7, pp. 147-157.

Gill, GW 1990, 'Introduction', in GW Gill & S Rhine (eds), *Skeletal attribution of race: methods for forensic anthropology*, Maxwell Museum of Anthropological Papers No. 4, Albuquerque NM, University of New Mexico,.

Gill, GW 1998, 'Cranio-facial criteria in the skeletal attribution of race', in KJ Reichs (ed), *Forensic osteology*, Charles C Thomas, Springfield IL, pp. 293-314.

Green, RF, Suchey, JM, & Gokhale, DV 1979, 'The statistical treatment of correlated bilateral traits in the analysis of cranial material', *American Journal of Physical Anthropology,* vol. 50, pp. 629-634.

Grunbaum, BW, Selvin, S, Pace, N, Black, DM 1978, 'Frequency distribution and discrimination probability of twelve protein genetic variants in human blood as functions of race, sex, and age', *Journal of Forensic Science*, vol. 23, pp. 577-587.

Grüneberg, H 1963, '*The pathology of development*', Oxford University press.

Hamel, EC 2002, 'Race, slavery and Islam in Maghribi Mediterranean thought: the question of the haratin in Morocco', *Journal of North African Studies*, vol. 7, pp. 29-52.

Hanihara, T, Ishida, H 2001b, 'Frequency variations of discrete cranial traits in major human populations: supernumerary ossicle variation (I)', *Journal of Anatomy*, vol. 198, pp. 689-706.

Hanihara, T, Ishida, H 2001d, 'Frequency variations of discrete cranial traits in major human populations: III, Hyperostotic variations', *Journal of Anatomy*, vol. 199, pp. 251-272.

Hanihara, T, Ishida, H 2001e, 'Frequency variations of discrete cranial traits in major human populations: IV, Vessel and nerve related variations', *Journal of Anatomy*, vol. 199, pp. 273-287.

Hauser, G, De Stefano, GF 1989, 'Introduction', in *Epigenetic variants of the human skull*, Stuttgart, Schweizerbart.

Hausman, AJ, Wilmsen, EN, 1985, 'Economic change and secular trends in the growth of San children', *Human Biology*, vol. 57, pp. 563-571.

Hefner, JT 2003, 'Assessing nonmetric cranial traits currently used in forensic determination of ancestry', Ma thesis, University of Florida.

Hefner, JT 2009, 'Cranial nonmetric variation and estimating ancestry', *American Journal of Physical Anthropology*, vol. 54, pp. 985-959.

Henneberg M, Van Den Berg, ER 1990, 'Test of socio-economic causation of secular trend: stature changes among favoured and oppressed South Africans are parallel', *American Journal of Physical Anthropology*, vol. 83, pp. 459-465.

Hertzog, KP 1968, 'Association between discontinuous cranial traits', *American Journal of Physical Anthropology*, vol. 29, pp. 379-403.

Hinkes, MJ 1990, 'Shovel shaped incisors in human identification', in GW Gill & S Rhine (eds), *Skeletal attribution of race: methods for forensic anthropology,* Maxwell Museum of Anthropological Papers No. 4, Albuquerque NM, University of New Mexico, pp. 21-51.

Howells, WW 1973a, '*Cranial variation in man: a study by multivariate analysis of patterns of difference among recent human populations*', Papers of the Peabody Museum, Harvard University.

Hunley, KL, Healy, ME, Long, JC 2009, 'The global pattern of gene identity variation reveals a history of long range migration, bottlenecks and local male exchange: implication for biological data', *American Journal of Physical Anthropology*, vol. 139, pp. 35-46.

Ihunwo, AO, Phukubye, P 2006, 'The frequency and anatomical features of torus mandibularis in a black South African population', *Journal of Comparative Human Biology*, vol. 57, pp, 253-262.

Israel, H 1973, 'Age factor and the pattern of change in craniofacial structures', *American Journal of Physical Anthropology*, vol. 39, pp. 111-128.

Irish, JD 1997, 'Characteristic high- and low- frequency dental traits in Sub-Saharan African populations', *American Journal of Physical Anthropology*, vol. 102, pp. 455-467.

İşcan, MY, Steyn, M 1999, 'Craniometric determination of population affinity in South Africans', *International Journal of Legal Medicine*, vol. 112, pp. 91-97.

Ishida, H, Dodo, Y 1997, 'Cranial variation in prehistoric human skeletal remains form the Marianas', *American Journal of Physical Anthropology*, vol. 104, pp. 399-410.

Katzen, MR 1969, 'White settlers and the origin of a new society', in *The Oxford history of South Africa*, vol. 1, M Wilson, & L Thomson, (eds), Oxford University Press, Oxford, Cape Town.

Kellock, WL, Parsons PA, 'Variations of minor non-metrical skeletal variants in Australian Aborigines', *American Journal of Physical Anthropology*, 1970a; 32:409-4211.

Kennedy, KAR 1995, 'But, professor, why teach race identification if races don't exist?' *Journal of Forensic Science*, vol. 40, pp. 797-800.

Klepinger, LL 2006, 'Deciphering ancestral background', in M Cartmill, & K Brown, K, (eds), *Fundamentals of forensic anthropology,* pp. 64-75.

Knip, AS 1910, 'The frequency of non-metrical measurements on the skeletal remains of Christian populations from two sites in Sudanese Nubia', *Proceedings, Koninklijke nederlandse akademie van wetenschappen*, pp 433-468.

Komar, DA, Grivas, C 2008, 'Manufactured populations: what do contemporary reference skeletal collections represent? A comparative study using the Maxwell Museum documented collection', *American Journal of Physical Anthropology*, vol. 137, pp. 224-233.

Krogman, WM, İşcan, MY 1986, 'Assessment of racial affinity', in *The human skeleton in forensic anthropology*, 2nd edn, Springfield IL, Charles C Thomas.

L'Abbé, EN, Loots, M, Meiring, JH 2005, 'The Pretoria Bone collection: a modern South African skeletal sample', *Journal of Comparative Biology*, vol. 56, pp. 197-205.

L'Abbé, EN, Steyn, M, & Loots, M 2008, 'Life expectancy of the 20th century Venda: a compilation of skeletal and cemetery data', *Homo: internationale Zeitschrift für die vergleichende Forschung am Menschen*, vol. 59, pp. 189-207.

Lahr, MM 1996, 'Reconstructing population histories', in GW Lasker, CGN Mascie-Taylor, (eds), *The evolution of modern human diversity: a study of cranial variation*, Cambridge, Cambridge University Press.

Landis, JR, Koch, GG 1977, 'The measurement of observer agreement for categorical data', *Biometrics*, vol. 33, pp. 159-174.

Laughlin, WS, Jørgensen, JB 1956, 'Isolate variation in Greenlandic Eskimo crania', *Acta Genetica et Statistica medica*, vol. 6, pp. 3-12.

Lewontin, RC 1972, 'The apportionment of human diversity', *Evolutionary Biology*, vol. 6, pp. 381-398.

Lieberman, L, & Jackson, FLC 1995, 'Race and Three Models of Human Origins', *American Anthropologist*, vol. 9, pp. 231-242.

Livingstone, FB 1972, 'Genetic drift and polygenic inheritance', *American Journal of Physical Anthropology*, vol. 37, pp. 117-126.

Long, JC, Li, J, & Healy, ME 2009, 'Human DNA sequences: more variation and less race', *American Journal of Physical Anthropology*, vol. 139, pp. 23-34.

Matthews, GP 1933, 'Mandibular and palatine tori, and their etiology', *Journal of Dental Research*, vol. 13, p. 245.

McCullagh, P 1980, ‘Regression Models for Ordinal Data’, *Journal of the Royal Statistical Society*. Series B (Methodological), vol. 42, pp. 109-142.

Molto, JE 1983, ‘*Biological relationships of Southern Ontario woodland peoples: the evidence of discontinuous cranial morphology*’, National Museum of Canada, vol. 117, pp. 396.

Montagu, A 1964, ‘*The Concept of race*’, New York: Free Press.

Montagu, A 1974, ‘The origin of the concept of race’, in A Montagu (ed), *Man’s most dangerous myth: the fallacy of race*, 5th edn, New York, Oxford University Press.

Morris, AG 2005, ‘The history of race and typology in South African physical anthropology’, in G Štrkalj, N Pather, & B Kramer,(eds), *Voyages in science: essays by South African anatomists in honour of Phillip V Tobias’s 80th birthday: Content solutions*.

Ossenberg, NS 1970, ‘The influence of artificial cranial deformation on discontinuous morphological traits’, *American Journal of Physical Anthropology*, vol. 33, pp. 357-372.

Ousley, S, & Jantz, RL 2002, ‘Social races and human populations; why forensic anthropologists are good at identifying races’, Program of the seventy-first annual meeting of the American Association of Physical Anthropologists, New York.

Ousley, S, Jantz, R, & Freid, D 2009, ‘Understanding race and human variation: why forensic anthropologists are good at identifying race’, *American Journal of Physical Anthropology*, vol. 139, pp. 68-76.

Parr, NML 2002, ‘*Determination of ancestry from discrete traits of the mandible*’, University of Florida at Gainsville, (MA-thesis).

Patriquin, ML, Steyn, M 2002, ‘Metric assessment of race from the pelvis in South Africans’, *Forensic Science International*, vol. 127, pp. 104-113.

Price, B, Cameron, N, & Tobias, PV 1987, 'A further search for a secular trend of adult body size in South African blacks: evidence from the femur and tibia', *Human Biology*, vol. 59, pp. 467-475.

Relethford JH 1994, 'Craniometric variation among modern human populations', *American Journal of Physical Anthropology*, vol. 95, pp. 53-62.

Rhine, S 1990, 'Non-metric skull racing', in GW Gill & S Rhine (eds), *Skeletal attribution of race: methods for forensic anthropology,* Maxwell Museum of Anthropological Papers No. 4, Albuquerque NM, University of New Mexico, pp. 9-20.

Rightmire, GP 1972, 'Cranial measurements and discrete traits compared in distance studies of African negro skulls', *Human Biology*, vol. 44, pp. 263-276.

Rosenberg, NA, Pritchard, JK, Weber, JL, Cann, HM, Kidd, KK, Zhivotovsky, LA, Feldman, MW 2002, 'Genetic structure of human populations', *Science*, vol. 298, pp. 2381-2385.

Rösing, FW 1984, 'Discreta of the human skeleton: a critical review', *Journal of Human Evolution*, vol. 13, pp. 319-323.

Russell, F 1900, 'Studies on cranial variation', *American Naturalist*, vol. 34, pp. 737-745.

Saunders, SR 1989, 'Nonmetric skeletal variation'. In MY İşcan, KAR Kennedy, (eds), *Reconstruction of life from the skeleton*, New York, Wiley-Liss.

Schoeman, K 2007, '*Early slavery at the Cape of Good Hope, 1652-1778*', Protea Boekhuis.

Schwartz, GT 1995, 'Taxonomic relevance of enamel cap shape in extant hominoids and Plio-Pleistocene hominids', *American Journal of Physical Anthropology Suppl*, vol. 20, pp. 193.

Sjøvold, T 1973, 'The occurrence of minor non metrical variants in the skeleton and their quantitative treatment for population comparisons', *Homo*, vol. 24, pp. 204-233.

Spencer, S, Rogers, L 1984, 'Measurements and observations of the skull', in *The human skull: its mechanics, measurements and variations*', Springfield IL, Charles C Thomas.

Statistics South Africa, 2009, 'Demographic and other assumptions', (Online), Available: http://www.statssa.gov.za/publications/p0302/p03022009.pdf.

Stewart, TD 1962, 'Anterior femoral curvature: its utility for race identification', *Human Biology*, vol. 34, pp. 49-62.

Stewart, TD 1979, 'Attribution of race', in *Essentials of forensic anthropology: especially as developed in the United States*', Springfield IL, Charles C Thomas.

Steyn, M, Smith, J 2007, 'Interpretation of ante-mortem stature estimates in South Africans', *Forensic Science International*, vol. 171, pp. 97-102.

Suchey, J 1975, 'Use of non metric skeletal traits in forensic cases', Paper presented at the 28th annual meeting of the *American Academy of Forensic Sciences*, Washington, DC.

Suzuki, M, & Sakai, T 1960, 'A familial study of torus palatinus and torus mandibularis', *American Journal of Physical Anthropology*, vol. 18, pp. 263-272.

Tal, H, & Tau, S 1983, 'Statistical survey of the human skulls in the Raymond Dart collection of skeletons', *South African Journal of Science*, vol. 79, pp. 215-217.

Thorne, A, Wolpoff, MH 1992, 'The multiregional evolution of humans', *Scientific America,*vol. 266, pp. 76-83.

Tobias, PV 1972, 'Recent human biological studies in southern Africa with special reference to Negros and Khoisan', *Transactions of the Royal Statistical Society of Africa*, vol. 40, pp. 109-183.

Tobias, PV 1975, 'Stature and secular trend among South African Negroes and San (Bushmen)', *South African Medical Journal Suppl*, vol.40, pp. 145-164.

Trinkaus, E 1978, ‘Bilateral asymmetry of human skeletal nonmetric traits’, *American Journal of Physical Anthropology*, vol. 49, pp. 315-318.

Viera, AJ, Garrett, JM 2005, ‘Understanding interobserver agreement: the kappa statistic’, *Family Medicine*, vol. 37, pp. 360-363.

Wolpoff M, Caspari R 1997, ‘Polygenism, racism, and the rise of anthropology’, in *Race and human evolution*, New York, Simon & Schuster.

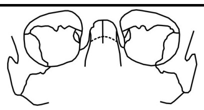
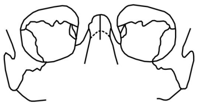
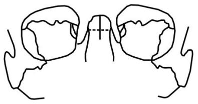
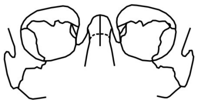
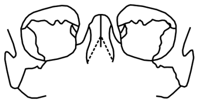
Woo, JK 1949b, ‘Direction and type of the transverse palatine suture and its relation to the form of the hard palate’, *American Journal of Physical Anthropology*, vol. 7, pp. 385-400.

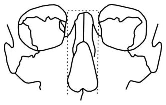
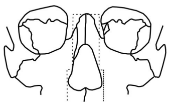
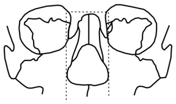
Woo, JK 1950, ‘The torus palatinus’, *American Journal of Physical Anthropology*, vol. 8, pp. 81-112.

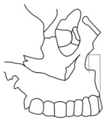
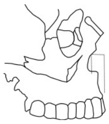
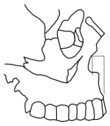
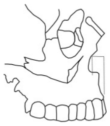
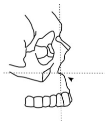
Wood-Jones, F 1930-1931a, ‘The nonmetrical morphological characters of the skull as criteria for racial diagnosis: general discussion of the morphological characters employed in racial diagnosis’, *Journal of Anatomy*, vol. 65, pp. 179-195.

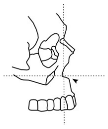
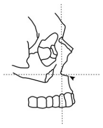
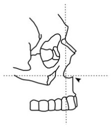
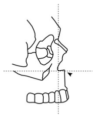
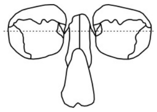
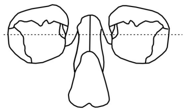
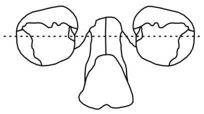
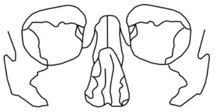
# **Appendix 1:** Scoring sheet for standard non-metric traits.

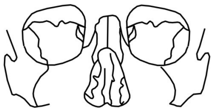
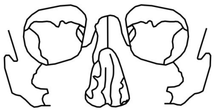
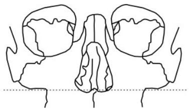
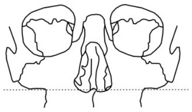
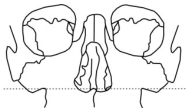
| | |
|---|---|
| Number | Date |
| Reference number | Location of specimen |
| Sex | Age |

| Nasal bone structure Score | Definition | Character state |
|---|---|---|
| 0 | Quonset hut (round): low, round & flat in profile. |  |
| 1 | Hut (oval): round & elongated sup-inf-projecting anteriorly from the side. |  |
| 2 | Tented (plateau): steep, broad & flat, ant-sup surface plateau. |  |
| 3 | Vaulted (semi-triangular): steep sided & narrow, ant-sup surface plateau. |  |
| 4 | Steepled (triangular): triangular in profile, sup-inf elongated, steep walls with no ant-sup surface plateau. |  |
| 5 | Unobservable | |
| Ancestry | European African | Asian |

| Nasal breadth Score | Definition | Character state |
|---|---|---|
| 1 | Long (narrow): teardrop shape when viewed anteriorly. |  |
| 2 | Rounded: bell-shaped. |  |
| 3 | Wide: constitutes a large portion of the face, with greatest lateral projection near the horizontal midline. |  |
| 5 | Unobservable | |

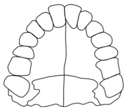
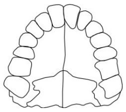
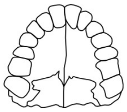
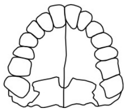
| Ancestry | European | African | Asian |
|---|---|---|---|
| Nasal overgrowth<br>Score | Definition | | Character state |
| 0 | Absent | |  |
| 1 | Present | |  |
| 5 | Unobservable | | |
| Ancestry | European | African | Asian |
| Anterior nasal spine<br>Score | Definition | | Character state |
| 0 | Short (rounded), minimal-to-no-projection of ans. | |  |
| 1 | Dull, not crossing imaginary line // to face. | |  |
| 2 | Medium, ans projects to prosthion, does not reach it & terminates in a sharp point. | |  |
| 3 | Long (sharp), terminates beyond prosthion, has sharp point. | |  |
| 5 | Unobservable | | |
| Ancestry | European | African | Asian |
| Inferior nasal margin<br>Score | Definition | | Character state |
| 0 | Guttered: gradual sloping of the nasal floor. Posteriorly to anteriorly. | |  |

| | | | |
|---|---|---|---|
| 1 | Incipient guttering: sloping commences more anteriorly. Proceeds similar to that of guttering, sloping less | |  |
| 2 | Straight: immediate transition from nasal floor to the maxilla, & absence of nasal sill | |  |
| 3 | Partial sill: weak but present vertical ridge of bone. | |  |
| 4 | Sill, when vertical ridge becomes pronounced | |  |
| 5 | Unobservable | | |
| Ancestry | European | African | Asian |
| Interorbital breadth Score | Definition | | Character state |
| 1 | Narrow | |  |
| 2 | Intermediate | |  |
| 3 | Wide | |  |
| 5 | Unobservable | | |
| Ancestry | European | African | Asian |
| Zygomatic suture shape Score | Definition | | Character state |
| 1 | Angled: greatest lateral projection of suture at or near the midline | |  |

| | | |
|---|---|---|
| 2 | Smooth: lateral projection of suture at inferior terminus. |  |
| 3 | S-shaped: characterised by a zig-zag appearance. |  |
| 5 | Unobservable | |
| Ancestry | European African | Asian |
| Zygomatic projection Score | Definition | Character state |
| 1 | Non-projecting: characterized by a face | |
| 2 | Projecting: unable to insert a pencil between the zygomatic bones and the pencil across the nasal aperture. | |
| 5 | Unobservable | |
| Ancestry | European African | Asian |
| Malar tubercle Score | Definition | Character state |
| 0 | Absent: no projection near the zygomaxillary suture | |
| 1 | Incipient: projection is noted, but does not cross the nasospinale plane. |  |
| 2 | Trace: a projection is noted but crosses nasospinale slightly. |  |
| 3 | Present: specimen breaking this plane to a great extent. |  |
| 5 | Unobservable | |

| Ancestry | European | African | Asian |
|---|---|---|---|
| Alveolar prognathism<br>Score | Definition | | Character state |
| 1 | Flat (orthognathic): face is not protruding in the area of dental region if pencil is lowered to chin. | | |
| 2 | Protruding (prognathic): face exhibits protrusion of the mouth region. | | |
| 5 | Unobservable | | |
| Ancestry | European | African | Asian |
| Mandibular/Palatine torus<br>Score | Definition | | Character state |
| 1 | Absent | | |
| 2 | Present | | |
| 5 | Unobservable | | |
| Ancestry | European | African | Asian |
| Incisor shovelling<br>Score | Definition | | Character state |
| 0 | Shovelled: lingual surface shows enamel rim with enclosed fossa being well developed. | | Right Upper Central<br>Left Upper Central<br>Right Upper Lateral<br>Left Upper Lateral<br>Right Lower Central<br>Left Lower Central<br>Right Lower Lateral<br>Left Lower Lateral |
| 1 | Semi-shovelled: distinct enamel ring, enclosed fossa is shallow. | | Right Upper Central<br>Left Upper Central<br>Right Upper Lateral<br>Left Upper Lateral<br>Right Lower Central |

| | | | |
|---|---|---|---|
| | | | Left Lower Central<br>Right Lower Lateral<br>Left Lower Lateral |
| 2 | Trace: distinct traces of a rim | | Right Upper Central<br>Left Upper Central<br>Right Upper Lateral<br>Left Upper Lateral<br>Right Lower Central<br>Left Lower Central<br>Right Lower Lateral<br>Left Lower Lateral |
| 3 | No shovelling: no perceptible trace of rim or fossa. | | Right Upper Central<br>Left Upper Central<br>Right Upper Lateral<br>Left Upper Lateral<br>Right Lower Central<br>Left Lower Central<br>Right Lower Lateral<br>Left Lower Lateral |
| 5 | Unobservable | | |
| Ancestry | European | African | Asian |
| Carabelli's cusp<br>Score | Definition | | Character state |
| 0 | Absent | | First Upper Right Molar<br>First Upper Left Molar |
| 1 | Present | | First Upper Right Molar<br>First Upper Left Molar |
| 5 | Unobservable | | |
| Ancestry | European | African | Asian |

| Transverse palatine suture shape Score | Definition | Character state |
|---|---|---|
| 0 | Straight (symmetrical): intersects palate perpendicular to median palatine suture, without deviating from the midline. |  |
| 1 | Anterior bulging at midline, symmetrical: Crosses median palatine, deviates anteriorly |  |
| 2 | Asymmetrical: deviates both anteriorly and Posteriorly, ant-post bulging scalaris. |  |
| 3 | Posterior bulging (symmetrical): crosses transverse palatine suture but deviates posteriorly at the midline, right and left halves |  |
| 5 | Unobservable | |
| Ancestry | European<br>African<br>Asian | |

# **APPENDIX 2:** Data for intra and interobserver error analysis

| Nasal bone structure<br>Observer 1 | Observer 2 | | | | | |
|---|---|---|---|---|---|---|
| Score | 0 | 1 | 2 | 5 | | Total |
| 0 | 15 | 0 | 0 | 0 | | 15 |
| 1 | 0 | 6 | 0 | 0 | | 6 |
| 2 | 0 | 0 | 1 | 0 | | 2 |
| 5 | 1 | 2 | 2 | 3 | | 8 |
| Total | 16 | 8 | 3 | 3 | | 30 |
| | $Chi^2$ | df | $Prob>chi^2$ | | | |
| Symmetry (asymptotic) | 5.00 | 3 | 0.1718 | | | |
| Marginal homogeneity | 5.00 | 3 | 0.1718 | | | |
| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
| | 83.33 | 35.00. | 0.7436 | 0.1130 | 6.58 | 0.0000 |
| Nasal bone structure<br>Observer 1 | Observer 3 | | | | | |
| Score | 0 | 1 | 2 | 5 | | Total |
| 0 | 13 | 0 | 2 | 0 | | 15 |
| 1 | 3 | 0 | 3 | 0 | | 6 |
| 2 | 0 | 0 | 1 | 0 | | 1 |
| 5 | 1 | 0 | 0 | 7 | | 8 |
| Total | 17 | 0 | 6 | 7 | | 30 |
| | $Chi^2$ | df | $Prob>chi^2$ | | | |
| Symmetry (asymptotic) | 9.00 | 4 | 0.0611 | | | |
| Marginal homogeneity | 8.14 | 3 | 0.0431 | | | |
| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
| | 70.00 | 35.22 | 0.5369 | 0.1060 | 5.07 | 0.0000 |

| Nasal breadth<br>Observer 1 | Observer 2 | | | | |
|---|---|---|---|---|---|
| Score | 0 | 1 | 2 | 5 | Total |
| 0 | 5 | 0 | 0 | 0 | 5 |
| 1 | 0 | 2 | 3 | 0 | 5 |
| 2 | 1 | 1 | 17 | 0 | 19 |
| 5 | 0 | 0 | 0 | 1 | 1 |
| Total | 6 | 3 | 20 | 1 | 30 |
| | $Chi^2$ | df | $Prob>chi^2$ | | |
| Symmetry (asymptotic) | 2.00 | 2 | 0.3679 | | |
| Marginal homogeneity | 2.00 | 3 | 0.5724 | | |

| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
|---|---|---|---|---|---|---|
| | 83.33 | 47.33 | 0.6835 | 0.1258 | 5.43 | 0.0000 |

| Nasal breadth<br>Observer 1 | Observer 3 | | | | |
|---|---|---|---|---|---|
| Score | 0 | 1 | 2 | 5 | Total |
| 0 | 5 | 0 | 0 | 0 | 5 |
| 1 | 0 | 5 | 0 | 0 | 5 |
| 2 | 4 | 5 | 10 | 0 | 19 |
| 5 | 0 | 0 | 0 | 1 | 1 |
| Total | 9 | 10 | 10 | 1 | 30 |
| | $Chi^2$ | df | $Prob>chi^2$ | | |
| Symmetry (asymptotic) | 9.00 | 2 | 0.0111 | | |
| Marginal homogeneity | 9.00 | 3 | 0.0293 | | |

| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
|---|---|---|---|---|---|---|
| | 70.00 | 31.78 | 0.5603 | 0.1082 | 5.18 | 0.0000 |

| Nasal overgrowth<br>Observer 1 | Observer 2 | | | |
|---|---|---|---|---|
| Score | 2 | 3 | 5 | Total |
| 2 | 13 | 2 | 0 | 15 |
| 3 | 0 | 5 | 1 | 6 |
| 5 | 0 | 2 | 7 | 9 |
| Total | 13 | 9 | 8 | 30 |

| | $Chi^2$ | df | $Prob>chi^2$ |
|---|---|---|---|
| Symmetry (asymptotic) | 2.33 | 2 | 0.3114 |
| Marginal homogeneity | 2.33 | 2 | 0.3114 |

| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
|---|---|---|---|---|---|---|
| | 83.33 | 35.67 | 0.7409 | 0.1289 | 5.75 | 0.0000 |

| Nasal overgrowth<br>Observer 1 | Observer 3 | | | |
|---|---|---|---|---|
| Score | 2 | 3 | 5 | Total |
| 2 | 12 | 1 | 2 | 15 |
| 3 | 1 | 3 | 2 | 6 |
| 5 | 0 | 0 | 9 | 9 |
| Total | 13 | 4 | 13 | 30 |

| | $Chi^2$ | df | $Prob>chi^2$ |
|---|---|---|---|
| Symmetry (asymptotic) | 4.00 | 3 | 0.2615 |
| Marginal homogeneity | 4.00 | 2 | 0.1353 |

| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
|---|---|---|---|---|---|---|
| | 80.00 | 37.33 | 0.6809 | 0.1323 | 5.15 | 0.0000 |

| Anterior nasal spine<br>Observer 1 | Observer 2 | | | | |
|---|---|---|---|---|---|
| Score | 0 | 1 | 2 | 5 | Total |
| 0 | 7 | 0 | 2 | 0 | 9 |
| 1 | 0 | 12 | 0 | 0 | 12 |

| | | | | | |
|---|---|---|---|---|---|
| 2 | 0 | 1 | 5 | 0 | 6 |
| 5 | 0 | 0 | 1 | 2 | 3 |
| Total | 7 | 13 | 8 | 2 | 30 |

| | Chi$^2$ | df | Prob>chi$^2$ |
|---|---|---|---|
| Symmetry (asymptotic) | 4.00 | 3 | 0.2615 |
| Marginal homogeneity | 4.00 | 3 | 0.2615 |

| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
|---|---|---|---|---|---|---|
| | 86.67 | 30.33 | 0.8086 | 0.1135 | 7.12 | 0.0000 |

| Anterior nasal spine<br>Observer 1 | Observer 3 | | | | |
|---|---|---|---|---|---|
| Score | 0 | 1 | 2 | 5 | Total |
| 0 | 5 | 2 | 2 | 0 | 9 |
| 1 | 0 | 12 | 0 | 0 | 12 |
| 2 | 0 | 5 | 1 | 0 | 6 |
| 5 | 0 | 0 | 0 | 3 | 3 |
| Total | 5 | 19 | 3 | 3 | 30 |

| | Chi$^2$ | df | Prob>chi$^2$ |
|---|---|---|---|
| Symmetry (asymptotic) | 9.00 | 3 | 0.0293 |
| Marginal homogeneity | 8.17 | 3 | 0.0427 |

| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
|---|---|---|---|---|---|---|
| | 70.00 | 33.33 | 0.5500 | 0.1065 | 5.16 | 0.0000 |

| Inferior nasal margin<br>Observer 1 | Observer 2 | | | | |
|---|---|---|---|---|---|
| Score | 0 | 1 | 2 | 5 | Total |
| 0 | 15 | 0 | 0 | 0 | 15 |
| 1 | 5 | 7 | 2 | 0 | 14 |
| 2 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 1 | 1 |
| Total | 20 | 7 | 2 | 1 | 30 |

| | $Chi^2$ | df | $Prob>chi^2$ |
|---|---|---|---|
| Symmetry (asymptotic) | 7.00 | 2 | 0.0302 |
| Marginal homogeneity | 7.00 | 3 | 0.0719 |

| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
|---|---|---|---|---|---|---|
| | 76.67 | 44.33 | 0.5808 | 0.1371 | 4.24 | 0.0000 |

| Inferior nasal margin<br>Observer 1 | Observer 3 | | | | |
|---|---|---|---|---|---|
| Score | 0 | 1 | 2 | 5 | Total |
| 0 | 14 | 0 | 1 | 0 | 15 |
| 1 | 3 | 9 | 2 | 0 | 14 |
| 2 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 01 | 1 | |
| Total | 17 | 9 | 3 | 1 | 30 |

| | $Chi^2$ | df | $Prob>chi^2$ |
|---|---|---|---|
| Symmetry (asymptotic) | 6.00 | 3 | 0.1116 |
| Marginal homogeneity | 5.45 | 3 | 0.1414 |

| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
|---|---|---|---|---|---|---|
| | 80.00 | 42.44 | 0.6525 | 0.1401 | 4.66 | 0.0000 |

| Interorbital breadth<br>Observer 1 | Observer 2 | | | |
|---|---|---|---|---|
| Score | 0 | 1 | 2 | Total |
| 0 | 4 | 0 | 1 | 5 |
| 1 | 0 | 7 | 7 | 14 |
| 2 | 1 | 0 | 10 | 11 |
| Total | 5 | 7 | 18 | 30 |

| | $Chi^2$ | df | $Prob>chi^2$ |
|---|---|---|---|
| Symmetry (asymptotic) | 7.00 | 2 | 0.0302 |
| Marginal homogeneity | 7.00 | 2 | 0.0302 |

| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
|---|---|---|---|---|---|---|
| | 70.00 | 35.67 | 0.5337 | 0.1223 | 4.36 | 0.0000 |

| Interorbital breadth Observer 1 | Observer 3 | | | |
|---|---|---|---|---|
| Score | 0 | 1 | 2 | Total |
| 0 | 5 | 0 | 0 | 5 |
| 1 | 0 | 8 | 6 | 14 |
| 2 | 3 | 2 | 6 | 11 |
| Total | 8 | 10 | 12 | 30 |

| | Chi$^2$ | df | Prob>chi$^2$ |
|---|---|---|---|
| Symmetry (asymptotic) | 5.00 | 2 | 0.0821 |
| Marginal homogeneity | 5.00 | 2 | 0.0821 |

| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
|---|---|---|---|---|---|---|
| | 63.33 | 34.67 | 0.4388 | 0.1283 | 3.42 | 0.0003 |

| Inferior nasal margin Observer 1 | Observer 2 | | | | | |
|---|---|---|---|---|---|---|
| Score | 1 | 2 | 3 | 5 | 6 | Total |
| 1 | 6 | 4 | 0 | 1 | 0 | 11 |
| 2 | 2 | 13 | 0 | 0 | 1 | 17 |
| 3 | 0 | 1 | 0 | 0 | 1 | 2 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 1 | 1 |
| Total | 8 | 18 | 0 | 1 | 3 | 30 |

| | Chi$^2$ | df | Prob>chi$^2$ |
|---|---|---|---|
| Symmetry (asymptotic) | 5.67 | 6 | 0.4615 |
| Marginal homogeneity | 5.33 | 5 | 0.3766 |

| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
|---|---|---|---|---|---|---|
| | 63.33 | 40.33 | 0.3855 | 0.1266 | 3.04 | 0.0012 |

| Inferior nasal margin Observer 1 | Observer 2 | | | | | |
|---|---|---|---|---|---|---|
| Score | 1 | 2 | 3 | 5 | 6 | Total |
| 1 | 1 | 8 | 0 | 2 | 0 | 11 |
| 2 | 0 | 14 | 0 | 2 | 0 | 16 |
| 3 | 0 | 1 | 0 | 0 | 1 | 2 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 1 | 0 | 0 | 0 | 1 |
| Total | 1 | 24 | 0 | 4 | 1 | 30 |

| | $\text{Chi}^2$ | df | $\text{Prob>chi}^2$ |
|---|---|---|---|
| Symmetry (asymptotic) | 15.00 | 6 | 0.0203 |
| Marginal homogeneity | 13.78 | 4 | 0.0080 |

| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
|---|---|---|---|---|---|---|
| | 50.00 | 44.00 | 0.1071 | 0.0797 | 1.34 | 0.0894 |

| Zygomatic projection Observer 1 | Observer 2 | | | |
|---|---|---|---|---|
| Score | 2 | 3 | 7 | Total |
| 2 | 2 | 0 | 0 | 2 |
| 3 | 0 | 24 | 0 | 24 |
| 7 | 2 | 2 | 0 | 4 |
| Total | 4 | 26 | 0 | 30 |

| | $\text{Chi}^2$ | df | $\text{Prob>chi}^2$ |
|---|---|---|---|
| Symmetry (asymptotic) | 4.00 | 2 | 0.1353 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Marginal homogeneity | 4.00 | 2 | 0.1353 | | | |
| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
| | 86.67 | 70.22 | 0.5522 | 0.1195 | 4.62 | 0.0000 |
| Zygomatic projection Observer 1 | Observer 3 | | | | | |
| Score | 2 | 3 | 7 | | Total | |
| 2 | 0 | 2 | 0 | | 2 | |
| 3 | 0 | 24 | 0 | | 24 | |
| 7 | 0 | 3 | 1 | | 4 | |
| Total | 0 | 29 | 1 | | 30 | |
| | Chi$^2$ | df | Prob>chi$^2$ | | | |
| Symmetry (asymptotic) | 5.00 | 2 | 0.0821 | | | |
| Marginal homogeneity | 5.00 | 2 | 0.0821 | | | |
| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
| | 83.33 | 77.78 | 0.2500 | 0.1031 | 2.42 | 0.0077 |
| Malar tubercle Observer 1 | Observer 2 | | | | | |
| Score | 0 | 6 | 7 | | Total | |
| 0 | 11 | 5 | 1 | | 17 | |
| 6 | 1 | 10 | 0 | | 11 | |
| 7 | 1 | 0 | 1 | | 2 | |
| Total | 13 | 15 | 2 | | 30 | |
| | Chi$^2$ | df | Prob>chi$^2$ | | | |
| Symmetry (asymptotic) | 2.67 | 2 | 0.2636 | | | |
| Marginal homogeneity | 2.67 | 2 | 0.2636 | | | |
| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
| | 73.33 | 34.33 | 0.5294 | 0.1498 | 3.53 | 0.0002 |

| Malar tubercle<br>Observer 1 | Observer 3 | | | | | |
|---|---|---|---|---|---|---|
| Score | 0 | 6 | 7 | Total | | |
| 0 | 11 | 6 | 0 | 17 | | |
| 6 | 0 | 11 | 0 | 11 | | |
| 7 | 0 | 2 | 0 | 2 | | |
| Total | 11 | 19 | 0 | 30 | | |
| | Chi$^2$ | df | Prob>chi$^2$ | | | |
| Symmetry (asymptotic) | 10.00 | 4 | 0.0404 | | | |
| Marginal homogeneity | 9.54 | 3 | 0.0229 | | | |
| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
| | 66.67 | 40.89 | 0.4361 | 0.1358 | 3.21 | 0.0007 |

| Alveolar prognathism<br>Observer 1 | Observer 2 | | | | | |
|---|---|---|---|---|---|---|
| Score | 1 | 4 | 5 | Total | | |
| 1 | 2 | 7 | 0 | 9 | | |
| 4 | 0 | 9 | 1 | 10 | | |
| 5 | 1 | 6 | 4 | 11 | | |
| Total | 3 | 22 | 5 | 30 | | |
| | Chi$^2$ | df | Prob>chi$^2$ | | | |
| Symmetry (asymptotic) | 11.57 | 3 | 0.0090 | | | |
| Marginal homogeneity | 10.29 | 2 | 0.0058 | | | |
| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
| | 50.00 | 33.56 | 0.2475 | 0.1038 | 2.38 | 0.0086 |

| Alveolar prognathism<br>Observer 1 | Observer 3 | | | |
|---|---|---|---|---|
| Score | 1 | 4 | 5 | Total |
| 1 | 9 | 0 | 0 | 9 |
| 4 | 4 | 6 | 0 | 10 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | 5 | 1 | 5 | 11 | | |
| Total | 18 | 7 | 5 | 30 | | |
| | Chi$^2$ | df | Prob>chi$^2$ | | | |
| Symmetry (asymptotic) | 10.00 | 3 | 0.0186 | | | |
| Marginal homogeneity | 9.31 | 2 | 0.0095 | | | |
| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
| | 66.67 | 31.89 | 0.5106 | 0.1143 | 4.47 | 0.0000 |
| Mandibular torus Observer 1 | Observer 2 | | | | | |
| Score | 2 | 3 | 5 | Total | | |
| 2 | 1 | 4 | 0 | 5 | | |
| 3 | 1 | 23 | 1 | 25 | | |
| 5 | 0 | 0 | 0 | 0 | | |
| Total | 2 | 27 | 1 | 30 | | |
| | Chi$^2$ | df | Prob>chi$^2$ | | | |
| Symmetry (asymptotic) | 2.80 | 2 | 0.2466 | | | |
| Marginal homogeneity | 2.80 | 2 | 0.2466 | | | |
| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
| | 80.00 | 76.11 | 0.1628 | 0.1486 | 1.10 | 0.1367 |
| Mandibular torus Observer 1 | Observer 3 | | | | | |
| Score | 2 | 3 | 5 | Total | | |
| 2 | 0 | 5 | 0 | 5 | | |
| 3 | 1 | 23 | 1 | 25 | | |
| 5 | 0 | 0 | 0 | 0 | | |
| Total | 1 | 28 | 1 | 30 | | |
| | Chi$^2$ | df | Prob>chi$^2$ | | | |
| Symmetry (asymptotic) | 3.67 | 2 | 0.1599 | | | |
| Marginal homogeneity | 3.67 | 2 | 0.1599 | | | |

| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
|---|---|---|---|---|---|---|
| | 76.67 | 78.33 | -0.0769 | 0.1243 | -0.62 | 0.7320 |

| Palatine torus Observer 1 | Observer 2 | | | |
|---|---|---|---|---|
| Score | 2 | 3 | 5 | Total |
| 2 | 0 | 18 | 0 | 18 |
| 3 | 0 | 10 | 0 | 10 |
| 5 | 0 | 1 | 1 | 2 |
| Total | 0 | 29 | 1 | 30 |

| | Chi$^2$ | df | Prob>chi$^2$ |
|---|---|---|---|
| Symmetry (asymptotic) | 19.00 | 2 | 0.0001 |
| Marginal homogeneity | 19.00 | 2 | 0.0001 |

| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
|---|---|---|---|---|---|---|
| | 36.67 | 32.44 | 0.0625 | 0.0278 | 2.25 | 0.0123 |

| Palatine torus Observer 1 | Observer 3 | | | |
|---|---|---|---|---|
| Score | 2 | 3 | 5 | Total |
| 2 | 3 | 15 | 0 | 18 |
| 3 | 0 | 10 | 0 | 10 |
| 5 | 0 | 2 | 0 | 2 |
| Total | 3 | 27 | 0 | 30 |

| | Chi$^2$ | df | Prob>chi$^2$ |
|---|---|---|---|
| Symmetry (asymptotic) | 17.00 | 2 | 0.0002 |
| Marginal homogeneity | 17.00 | 2 | 0.0002 |

| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
|---|---|---|---|---|---|---|
| | 43.33 | 36.00 | 0.1146 | 0.0795 | 1.44 | 0.0747 |

| Incisor shovelling | Observer 2 |
|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| Observer 1 | | | | | | |
| Score | 2 | 3 | 5 | 7 | | Total |
| 2 | 0 | 2 | 0 | 0 | | 2 |
| 3 | 0 | 14 | 1 | 0 | | 15 |
| 5 | 0 | 0 | 3 | 0 | | 3 |
| 7 | 0 | 4 | 0 | 6 | | 10 |
| Total | 0 | 20 | 0 | 6 | | 30 |
| | $Chi^2$ | df | $Prob>chi^2$ | | | |
| Symmetry (asymptotic) | 7.00 | 3 | 0.0719 | | | |
| Marginal homogeneity | 7.00 | 3 | 0.0719 | | | |
| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
| | 76.67 | 41.33 | 0.6023 | 0.1232 | 4.89 | 0.0000 |
| Incisor shovelling Observer 1 | Observer 3 | | | | | |
| Score | 2 | 3 | 5 | 7 | | Total |
| 2 | 1 | 0 | 1 | 0 | | 2 |
| 3 | 0 | 13 | 2 | 0 | | 15 |
| 5 | 0 | 0 | 3 | 0 | | 3 |
| 7 | 1 | 5 | 1 | 3 | | 10 |
| Total | 2 | 18 | 7 | 3 | | 30 |
| | $Chi^2$ | df | $Prob>chi^2$ | | | |
| Symmetry (asymptotic) | 10.00 | 5 | 0.0752 | | | |
| Marginal homogeneity | 9.34 | 3 | 0.0251 | | | |
| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
| | 66.67 | 36.11 | 0.4783 | 0.1064 | 4.49 | 0.0000 |
| Carabelli's cusp Observer 1 | Observer 2 | | | | | |
| Score | 0 | 5 | 6 | 7 | | Total |
| 0 | 0 | 0 | 3 | 0 | | 3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | 0 | 2 | 6 | 0 | | 8 |
| 6 | 0 | 1 | 15 | 0 | | 16 |
| 7 | 0 | 0 | 2 | 1 | | 3 |
| Total | 0 | 3 | 26 | 1 | | 30 |
| | $Chi^2$ | df | $Prob>chi^2$ | | | |
| Symmetry (asymptotic) | 8.57 | 3 | 0.0356 | | | |
| Marginal homogeneity | 8.57 | 3 | 0.0356 | | | |
| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
| | 60.00 | 49.22 | 0.2123 | 0.0999 | 2.13 | 0.0168 |
| Carabelli's cusp Observer 1 | Observer 3 | | | | | |
| Score | 0 | 5 | 6 | 7 | | Total |
| 0 | 3 | 0 | 0 | 0 | | 3 |
| 5 | 0 | 8 | 0 | 0 | | 8 |
| 6 | 1 | 3 | 11 | 1 | | 16 |
| 7 | 0 | 0 | 1 | 2 | | 3 |
| Total | 4 | 11 | 12 | 3 | | 30 |
| | $Chi^2$ | df | $Prob>chi^2$ | | | |
| Symmetry (asymptotic) | 4.00 | 3 | 0.2615 | | | |
| Marginal homogeneity | 4.00 | 3 | 0.2615 | | | |
| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
| | 80.00 | 33.44 | 0.6995 | 0.1164 | 6.01 | 0.0000 |
| Transverse palatine suture shape Observer 1 | Observer 2 | | | | | |
| Score | 0 | 1 | 2 | 5 | | Total |
| 0 | 4 | 0 | 0 | 2 | | 6 |
| 1 | 0 | 1 | 0 | 0 | | 1 |
| 2 | 0 | 0 | 2 | 1 | | 3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | 6 | 1 | 1 | 12 | 20 | |
| Total | 10 | 2 | 3 | 15 | 30 | |
| | $Chi^2$ | df | $Prob>chi^2$ | | | |
| Symmetry (asymptotic) | 3.00 | 3 | 0.3916 | | | |
| Marginal homogeneity | 3.00 | 3 | 0.3916 | | | |
| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
| | 63.33 | 41.22 | 0.3762 | 0.1225 | 3.07 | 0.0011 |
| Transverse palatine suture shape Observer 1 | Observer 3 | | | | | |
| Score | 0 | 1 | 2 | 5 | Total | |
| 0 | 2 | 2 | 0 | 2 | 6 | |
| 1 | 0 | 1 | 0 | 0 | 1 | |
| 2 | 0 | 0 | 3 | 0 | 3 | |
| 5 | 1 | 5 | 2 | 12 | 20 | |
| Total | 3 | 8 | 5 | 14 | 30 | |
| | $Chi^2$ | df | $Prob>chi^2$ | | | |
| Symmetry (asymptotic) | 9.33 | 4 | 0.0533 | | | |
| Marginal homogeneity | 9.23 | 3 | 0.0264 | | | |
| | Agreement % | Expected Agreement % | Kappa | Std. Err | Z | Prob>Z |
| | 16.00 | 35.67 | 0.3782 | 0.0976 | 3.88 | 0.0001 |